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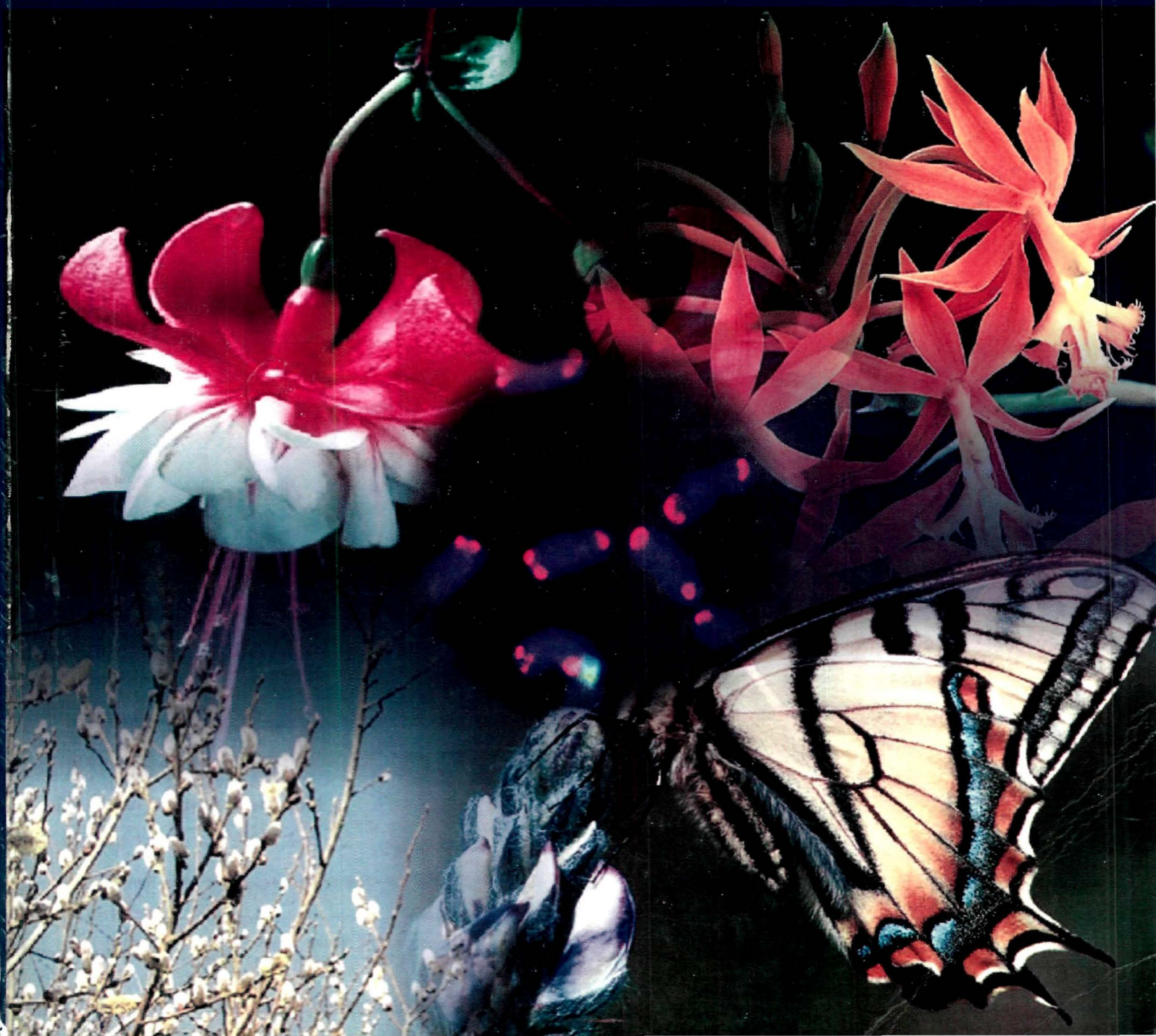

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STEM CELL RESEARCH : POTENTIAL FOR DIABETES THERAPY

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Abstract

Diabetes is a disease that affects millions and imposes a major burden on the health care system. Replacement of functional insulin-producing pancreatic beta cells, with pancreas or islet-cell transplants is considered the optimal treatment for diabetes mellitus. However, it is severely limited by the shortage of human organ donors. An effective cell-replacement strategy depends on the development of an abundant supply of beta cells and their protection from recurring immune destruction. Stem/progenitor cells, which can be expanded in tissue culture and induced to differentiate into multiple cell types, represent an attractive source for generation of cells with beta-cell properties. In addition to embryonic stem cells, several potential adult islet/beta-cell progenitors derived from pancreas, liver, and bone marrow, are being investigated for their ability to proliferate and differentiate into cells with glucose responsive insulin producing function. Stem cells hold great promise for the treatment of diabetes mellitus and scientists are trying to overcome specific obstacles so that this can become a reality.

Key Words : Diabetes mellitus, transplantation, stem cells, progenitor cells.

DIABETES MELLITUS

Diabetes mellitus, long considered a disease of minor significance to world health, is now taking its place as one of the main threats to human health. The past two decades have seen an explosive increase in the number of people diagnosed with diabetes worldwide. The problem has crept up with the global figure for people with diabetes set to double from the current estimate of 150 million to 333 million in 2025 (Habeck, 2003). Each year, diabetes affects more and more people and causes more deaths than AIDS and breast cancer combined. A WHO survey predicts a 195% increase in the number of diabetics in India, and at this estimated rate India would become the diabetic capital of the world by 2025 (King *et al*, 1998).

Diabetes mellitus is a debilitating condition that imposes an enormous burden on the healthcare system. It is actually a group of diseases characterized by abnormally high blood glucose levels. This hyperglycemia is a result of an absolute or relative deficiency of insulin. The excess glucose is responsible for most of the complications of diabetes, which include blindness, kidney failure, heart disease, stroke, neuropathy, and amputations.

Types of diabetes

There are two main forms of diabetes. Type 1 diabetes is due primarily to an auto-immune mediated destruction of pancreatic β-islets, resulting in absolute insulin deficiency. It typically affects children and young adults. People with type 1 diabetes must take exogenous insulin for survival in order to prevent the development of ketoacidosis. Type 2 diabetes is characterized by insulin resistance (reduced response to a given amount of insulin) and/or abnormal insulin secretion, either of which may predominate. It tends to affect older, sedentary and overweight individuals with a family history of diabetes. People with type 2 diabetes can often control their blood glucose concentrations through a combination of diet, exercise and oral medication. Type 2 diabetes often progresses to the point where only insulin therapy will help.

Treatment for diabetes

Long-term studies strongly suggest that tight control of blood glucose can prevent the development and retard the progression of chronic complications of diabetes mellitus. The Diabetes Control and Complications Research Trial Group (1993) has emphasized the importance of strict glycemic control in order to reduce ophthalmologic, neurological and renal complications of the disease. Though nutritional interventions and exercise greatly improve the diabetic condition, such measures usually require significant lifestyle modifications and a lot of self-control. Moreover, the oral hypoglycemic drugs compensate partially for metabolic derangements seen in diabetes and also show side-effects (Harrigan *et al*, 2001). As the disease progresses, the standard treatment beyond a certain point is, to try to control the glucose

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An invited article

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levels with insulin injections. Insulin therapy affords effective glycemic control, however its shortcomings such as ineffectiveness on oral administration, short shelf-life, hypoglycemia in event of excess dosage limit its usage (Zinman, 1989).

Pancreas transplantation, and more recently transplant of purified pancreatic islets, has offered the potential for independence from insulin injections. This helps to achieve a constant normoglycemic state and avoiding hypoglycemic episodes, a typical adverse effect of multiple daily insulin injections. In the United States approximately 1300 people with type 1 diabetes receive whole organ transplants each year, of which about 83% are successful. To prevent the body from rejecting the transplanted pancreas, patients must take powerful drugs that suppress the immune system for their entire lives, a regimen that makes them susceptible to a host of other diseases. Islet cell transplantation offers the advantage of being performed as a minimally invasive procedure, in which islets can be perfused percutaneously into the liver via the portal vein. As of June 2003, 705 pancreatic islet transplants worldwide have been reported to the International Islet Transplant Registry (ITR). Data analysis shows at 1 year after adult islet transplantation a patient survival rate of 97%, a functioning islet graft in 54% of the cases, whereas insulin independence was meanwhile achieved in 20% of the cases (Bretzel *et al*, 2004). However, using a novel protocol established by the Edmonton Center/Canada (Shapiro *et al*, 2000), the insulin independence rates have improved significantly reaching meanwhile a 50-80% level. However, the requirement for steroid immunosuppressant therapy to prevent rejection of the cells increases the metabolic demand on insulin-producing cells and eventually they may exhaust their capacity to produce insulin. Besides, the deleterious effect of steroids is greater for islet cell transplants than for whole-organ transplants.

One obstacle, however, is the fact that there is an inadequate supply of cadaveric human islets to implement this procedure on a widespread clinical basis. The scarcity of human tissue donors has focused interest in developing renewable sources of insulin-producing cells appropriate for engraftment. A promising source of transplantable islets in the future will come through the use of adult or embryonic stem cells. Advances in stem cell technology and transdifferentiation techniques have provided powerful tools to study pancreatic development, function and disease.

STEM CELLS

Stem cells hold great fascination for us-from both a theoretical and a practical viewpoint. These are unique cells with the capacity for self-renewal and the capability of forming at least one, and sometimes many, specialized cell types. Such stem cells are common in early embryos but as differentiation ensues and as growth promoting signals decline, embryonic cells lose these properties. By adulthood, the few remaining stem cells are dispersed and virtually invisible. Such stem cells are present in many tissues of adult animals and are important in tissue repair and homeostasis (Lodish *et al,* 2003). However, adult tissue derived stem cells are unipotent or multipotent i.e. capable of generating one or several cell types, respectively. Pluripotent stem cells are unique to embryonic tissue and can theoretically give rise to every cell type in the animal body. Hence, the main difference between embryo derived pluripotent stem cells and the multipotent stem cells from adult animals is in the number of types of differentiated cells that can be produced. This could be a reflection of the different origins of the cells (Donovan & Gearhart, 2001). All stem cells are derived from somatic cells except pluripotent stem cells that owe their origin to germ cells. Although reprogramming of somatic cell nuclei can endow them with totipotency and allow them to recapitulate development, however this is an impossibility in the normal life cycle.

Additionally, adult stem cells differ from embryo derived pluripotent stem cells in their inability to expand in culture without losing developmental potential. Hence it has been difficult to establish *in vitro* culture conditions for the indefinite expansion of these cells. A case in point are the adult haematopoietic stem cells that cannot be expanded in culture without losing developmental potential (Weismann, 2000). There are studies to suggest that it might be possible to establish conditions in which many adult multipotent stem cells can be grown indefinitely. It has recently been shown that the oligodendrocyte precursor cell, a type of multipotent stem cell can be grown in culture indefinitely (Tang *et al*, 2001). Nevertheless, constraints on the use of multipotent stem cells are imposed by problems associated with their expansion, differentiation and genetic manipulation.

The beta-cell mass in the adult pancreas possesses the ability to undergo limited regeneration following injury. Identifying the progenitor cells involved in this process and understanding the mechanisms leading to their maturation will open new avenues for the treatment of type 1 diabetes. However, despite steady advances in determining the molecular basis of early pancreatic development, the identification of pancreatic stem cells or beta-cell progenitors and the molecular mechanisms underlying beta-cell regeneration remain unclear.

Stem cells found in bone marrow and umbilical cord blood have been used extensively to repopulate the haematopoietic system and offer the possibility of autologous transplantation. Recent studies have suggested that these stem cells may also have a broader capacity to differentiate, possibly into beta-cells (Erfat, 2004).

DEVELOPMENT OF STEM CELL BASED THERAPIES FOR DIABETES

In developing a potential therapy for patients with diabetes, researchers hope to develop a system that meets several criteria. Ideally stem cells should be able to multiply in culture and reproduce themselves exactly. Stem cells should also be able to differentiate *in vivo* to produce the desired kind of cell (Hussain and Theise, 2004). For diabetes therapy, it is not clear whether it will be desirable to produce only beta cells or whether other types of pancreatic islet cells are also necessary. It is seen that in case of isolated beta-cells, as well as islet clusters with lower than normal amounts of non-beta cells, the release of insulin is not as responsive to glucose concentrations as that of intact clusters (Bosco *et al*, 1997; Soria *et al*, 1996). Therefore, many researchers believe that it will be preferable to develop a system in which stem or precursor cell types can be cultured to produce all the cells of the islet cluster in order to generate a population of cells that will be able to coordinate the release of the appropriate amount of insulin to the physiologically relevant concentrations of glucose in the blood.

Embryonic Stem Cells

Stem cells from embryonic sources, such as human embryonic stem and embryonic germ cells, have the ability to proliferate extensively in culture and have an inherent developmental plasticity that may make them a potentially unlimited source of cells that can sense glucose and produce mature insulin. Several groups of researchers are investigating the use of pluripotent embryonic stem cells which have the ability to differentiate into a variety of cell lineages *in vitro* and serve as sources of insulin-producing replacement tissue. Soria *et al* (2000) showed that insulin containing cells derived from embryonic stem cells, using a gene trap strategy, were able to normalize blood glucose in streptozotocin induced diabetic mice.

Embryonic stem cells can be induced to differentiate into insulin producing cells by manipulating culture conditions. Lumelsky and colleagues (2001) first obtained a highly enriched population of nestin positive stem cells from embryoid bodies and then stimulated them to differentiate to form islet like clusters resembling those found in pancreatic islets. Hori and coworkers (2002) reported that treatment of mouse embryonic stem cells with inhibitors of phosphoinositide kinase, an essential intracellular signaling regulator, produced cells that resemble beta-cells in several ways. Variations in embryonic stem cell culture conditions generate cells with properties of beta-cells (Kania *et al*, 2003; Kahan *et al*, 2003). Use of pax 4 or pdx-1 (transcription factors associated with beta cell lineage) along with modification of culture conditions promote differentiation towards insulin producing phenotypes. In addition to the work being done on rodent models, there are many reports of insulin production by human embryonic stem cells using different culture conditions (Assady *et al*, 2001; Segev *et al*, 2004).

However, it is important to ascertain that any insulin detected in culture media is being actively synthesized and secreted by the differentiated cells themselves. For instance, when Douglas Melton of Harvard University reproduced Lumelsky's experiment, he found that the cells had absorbed insulin from the culture medium rather than producing it themselves (Rajagopal *et al*, 2003). Hence, the need to discover markers for identification of truly functional islet cells. Besides, problems in control of differentiation and teratoma formation from embryonic stem cell derived insulin producing cells remain to be overcome. Ethical concerns about the use of embryonic stem cells need to be addressed, as these are typically isolated from tissue of discarded or aborted embryos. Rightly, ethical concern has been paramount in regulating research in the field of stem cells. This is difficult ethical territory with major complications involved, yet this is how almost every recent advance in reproductive technology began.

Adult Tissue as Source For Islet Cells

Tissue specific stem cells provide a neat way around the ethical maze. We know that new beta cells generated throughout adult life but the identity of adult pancreatic stem cells has been elusive (Holland *et al*, 2004). A promising source of islet progenitor cells lies in the cells that line the pancreatic ducts. Susan Bonner-Weir and her colleagues (2000) have reported that ductal cells isolated from adult human pancreatic tissue can be expanded in culture and then be directed to differentiate into glucose responsive islet tissue *in vitro*. They believe that it might be possible to do a biopsy and remove duct cells from a diabetic patient, proliferate cells in culture and give the patient back his own islets.

Some researchers question whether the ductal cells are indeed undergoing a dedifferentiation or whether a subset of stem like or islet progenitors present in pancreatic ducts

might proliferate and make it appear that ductal cells are dedifferentiating. Researchers at the University of Florida cultured pancreatic ductal epithelial cells from adult mice to yield islet-like structures. These cells on implantation into diabetic mice were able to reverse the diabetes (Peck *et al*, 2000). A population of nestin positive multipotential stem cells was discovered in both the adult pancreas islets and pancreatic ducts by Zulewski *et al* (2001). Depending upon the growth factors added, the cells can differentiate into pancreatic, endocrine, exocrine and hepatic phenotypes.

On the other hand, there are several studies, in rodents, to suggest that hematopoietic organs can also differentiate into functional pancreatic endocrine cells. Work done by two different groups of researchers leads us to believe that a bone marrow-derived cell type with pluripotential capacity can transdifferentiate (the ability of multipotential adult stem cells to cross lineage boundaries) into various phenotypes including pancreatic beta-cells (Ianus *et al*, 2003; Jiang *et al*, 2002). Hess and coworkers (2003) were able to show normalization of blood glucose and insulin levels in experimental diabetes and speculated that engraftment stimulated proliferation of local pancreatic progenitors.

Some groups believe that cell fusion could be one mechanism of apparent adaptation of bone marrow-derived cells. However, studies including the ones cited above, largely rule out cell fusion events as a mechanism for transdifferentiation.

Hepatic cells from rats (Yang *et al*,2002) and human fetuses have been differentiated *in vitro* into insulin secreting cells by culture methods and/or introduction of beta-cell specific genes and have reversed diabetes mellitus upon transplantation in rodent models (Zalzman *et al*, 2003).

Future Directions

As in every emerging field in biology, results of cell transplantation studies in animal models seem confusing. Before any kind of human islet cells can be used therapeutically, a renewable source of human stem cells needs to be developed. Embryonic as well as adult stem cells are potential sources and deserve exhaustive investigation until a therapeutically useful source of human islet cells is developed.

Then, there is the crucial issue pertaining to the standardization and establishment of reliable differentiation protocols. The considerable gaps in our knowledge regarding differentiation pathways of stem cells and the problems in control of differentiation and tumour formation from stem cell derived insulin producing cells need to be addressed and resolved.

Ultimately, type 1 diabetes may prove especially difficult to cure due to the destruction of cells because of autoimmunity. Effective stem cell based therapy then calls for overcoming this autoimmunity by immunosuppression. Evasion or escaping detection by the immune system by encapsulating or embedding the transplanted cells is another possibility. This end may also be achieved by genetic manipulation, in case of embryonic stem cells, which allows them to escape.

Safety Considerations

It is important that human disease treatment involving stem cell use must be both safe and effective. Three key safety issues are apparent. The first is whether cells can be derived that are histocompatible with every individual. Because of the great genetic diversity in human populations most types of transplantation have to overcome the problem of tissue rejection. Short term solutions are provided by immunosuppression and tolerance induction, however, genetic manipulation of stem cells might offer a better solution.

The second concern is regarding the ability of transplanted pluripotent stem cells to form tumours or differentiate inappropriately after transplantation. Hence the need for establishing techniques for homogeneous differentiation of human pluripotent stem cells and for their separation from stem cells.

A third safety issue is associated with infectious agents that could be present in stem cells. Ultimately, it may be necessary to establish standard conditions for establishing and growing human stem cells in defined, serum-free medium with purified recombinant growth factors and on extracellular matrices.

In *conclusion*, the ultimate goal of stem cell research is to replace or regenerate failing body parts and curing diseases that have so far defied drug-based treatment. There is still a long way to go, nevertheless, stem cell technology holds great promise for curative therapy for diabetes mellitus. The wide range of proposed cell sources and our increasingly clear picture of pancreatic development suggest that novel cellular therapies might one day compete with non-cellular glucose sensing and insulin delivery devices.

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CYANOBACTERIAL DIFFERENTIATION

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Abstract

The blue–green algae (cyanobacteria) have attracted considerable attention because of their unique position among prokaryotes. Despite their primitive cellular organization, the photosynthesis operating in these organisms is characteristic of higher plants. These algae possess a rare combination of oxygen evolving photosynthetic and oxygen sensitive nitrogen fixing systems. The process of nitrogen fixation is carried out by specialized cells known as heterocysts. Heterocysts contain an active nitrogenase and are differentiated at regular intervals in the algal filaments. Many morphological and physiological changes occur during differentiation of a heterocyst from a vegetative cell. Recently role of various genes involved in differentiation and pattern formation has been elucidated.

Key words: Blue-green algae, cyanobacteria, heterocyst, differentiation.

INTRODUCTION

Cyanobacteria can thrive with just water and light but show a greater degree of morphological and structural complexity than other groups of prokaryotes. Filamentous cyanobacteria present excellent examples of cellular differentiation, during which complete conversion of one cell type into another with distinct structure and function is achieved (Haselkorn, 1992; Wolk, 1996, 2000). Cellular differentiation is a very well organized process involving cell division, sensing environmental conditions, gene arrangements and different expression of genes (Wolk, 2000; Xu and Wolk, 2001). Cyanobacteria present a model experimental system for studies on developmental genetics and molecular biology due to their plant like photosynthesis and ability to fix atmospheric nitrogen.

Possible Origin of Heterocyst

Early atmosphere during biological evolution of cyanobacteria was anoxygenic. There were reducing conditions that provided ability to these organisms for fixing (reducing) nitrogen. As atmosphere turned increasingly oxygenic with passage of time, there was need for the cyanobacterial members to protect their nitrogenase enzyme from inactivation by oxygen and to fulfill their need for nitrogenous compounds. This possibly resulted in the formation of a versatile structure/ device called heterocyst. Heterocysts normally do not differentiate when sufficient nitrogenous substances are available to the organism. Fossils of heterocysts are known by the name *'Gunflintia'* (Tyagi, 1975).

As per geological records, cyanobacteria existed on earth for over 2.5 billion years (Schopf and Walter, 1982). Ancient cyanobacteria represented apparently the first photosynthetic organisms—with capability of utilizing water as the ultimate source of electrons for the generation of reductant in photosynthesis. The release of free oxygen during this process was one of the most significant events in the history of earth, as it changed the reducing atmosphere to an oxidizing one, thus enabling the development of the aerobic mode of heterotrophic metabolism in the living world. It is the most important mechanism for capturing solar energy to be converted to biomass. Oxygenic photosynthesis is the principal force in the cyclic transformation of carbon and oxygen and thus in the maintenance of the critical gaseous composition of the atmosphere (Fay, 1992).

The differentiated cells include heterocysts, akinetes (spores), and hormogonia with specialized functions of nitrogen fixation, perennation and motility respectively (Tyagi, 1975; Ahluwalia and Kumar, 1982; Haselkorn, 1992; Adams and Duggan, 1999). Among these, maximum attention at the molecular level or otherwise has been centered on the differentiation of heterocysts than the akinetes and hormogonia. Heterocyst development can be initiated on nutrient shift i.e. transforming the vegetative cells from a culture growing on nitrogenous compounds (nitrate/ammonia) and resuspending these, after washing with sterilized distilled water, in a medium free of combined nitrogen (Tyagi,

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This review is dedicated to the everlasting memory of my sincere student, Late Dr (Mrs) Manjit Kaur who later on became my colleague. Her contributions to Phycology in particular and Botany in general can never be forgotton.

1975). In most of the filamentous cyanobacteria, heterocyst is the only cell type (site) to develop within next 24 hours or so. These are the specialized cells differentiated in some cyanobacterial filaments at terminal, basal and intercalary positions. Changes associated with their differentiation make these cells the main site for active nitrogenase and hence nitrogen fixation (Haselkorn, 1980,1992; Wolk, 2000).

Cyanobacteria present a remarkable group of simple prokaryotic microorganisms having an oxygen evolving type of photosynthesis similar to higher plants. These are the organisms of choice for studies on heterocyst differentiation and nitrogen fixation because of their short and simple life cycle, easily manipulative nutritional requirements and presence of a versatile enzyme complex- nitrogenase. Differentiation results in distinctiveness in structure and function among cells of identical genetic make up. Differentiation of akinete and heterocyst from the vegetative cells offers an excellent system for developmental biologists and comprises the genera *Anabaena*, *Nostoc*, *Cylindrospermum*, *Scytonema*, *Calothrix* etc. (Tyagi and Ahluwalia, 1978; Thai and Wolk, 1990; Fay, 1992; Yoon and Golden, 1998; Kearns and Hunter, 2002). A small peptide encoded by the gene *patS* is reported to be expressed in proheterocysts and plays an important role in establishing the pattern of heterocysts (Yoon and Golden, 2001).

Structure

Heterocysts have three wall layers i.e. fibrous, homogenous and laminated, in addition to the existing wall layers of vegetative cells. Polar plugs or nodules are formed in the heterocysts at the junction of vegetative cell with the heterocyst. Thus 1-3 polar plugs per heterocyst can be there in different genera. These cells show high respiratory activity and are rich in enzyme glutamine synthetase. Granulation (characteristic of vegetative cells) disappears and synthesis of biliprotein containing antennae stops during differentiation of a heterocyst from a vegetative cell (van Gorkom and Donze, 1971; Ahluwalia and Kumar, 1982).

Heterocysts are deficient in ribulose 1,5 bisphosphate carboxylase, fixation of carbon dioxide, oxygen evolution (photo system II), manganese, plastoquinone and cytochrome b559 (Thomas, 1970). Cyanobacteria are able to fix atmospheric nitrogen into useful compounds to be taken up by the higher plants. Energy and reductant requirements for this fixation process are met with by photosynthesis occurring in vegetative cells of the filaments (Fay, 1992). Ultrastructural integrity of heterocysts after their isolation was also reported (Fay and Lang, 1971).

Heterocystous cyanobacteria in contrast to their primitive antecedents display remarkable evolutionary advances including differentiation, pattern formation, intercellular communications, physiological division of labour among cell types, developmentally regulated gene arrangements and gene expression, and a range of adaptive responses of survival value resulting in their faster distribution (Wolk, 2000).

Formation of Heterocysts

Heterocysts are differentiated when combined forms of nitrogen, like ammonium-nitrogen or nitrate-nitrogen, are in short supply or absent from the growth medium. Triggering factor is the increasing C: N ratio from 4.5 to 8.0 due to the depletion of N-reserve (Kulasooriya *et al*, 1972). The transformation into a heterocyst involves a range of structural and biochemical changes with mobilization of reserve products. Cytoplasmic membrane system gets re-organized with the replacement of peripheral thylakoids by new elaborate membranes (Giddings and Staehelin, 1978, 1979). There is degradation and synthesis of new proteins. A pore channel and a tubular neck are formed during differentiation. These differentiated cells are usually recognized by their round shape, pale colour, distinct (thick) three-layered outer envelope, polar (refractive) nodules and lack of cytoplasmic granulation.

During the process of heterocyst differentiation, large-sized (500μm diameter) cyanophycin granules appear in the cytoplasm and function in nitrogen turn over. These are distributed mainly in the periphery of the cells and consist of arginine-aspartic acid polypeptide and are produced by a ribosome-independent mechanism. Based on physiological and ultrastructural evidence, a post-maturation stage of heterocyst development was designated, during which accumulation of nitrogenase protein and the non-ribosomally synthesized polypeptide cyanophycin has been reported (Sherman *et al*, 2000). They suggested cyanophycin-containing polar plug as a key intermediate in the storage of fixed nitrogen in the heterocyst (Sherman *et al*, 2000). Number of microplasmodesmata get reduced to 50 between a vegetative cell – heterocyst junction, compared to 200 between vegetative cell – vegetative cell junction (Giddings and Staehelin, 1981). Inactivation/repression of nitrogenase by ammonia and oxygen points to a mechanism evolved by cyanobacteria to prevent wastage of energy and reductant in response to high cost of nitrogen

fixation (Fay, 1992). It is speculated that in the presence of ammonia or oxygen, the product of *nifL* gene inactivates the *nifA* protein (Haselkorn, 1986).

Heterocysts maintain a low intracellular level of oxygen to have an active nitrogenase through a thick envelope. This is composed of glycolipid and polysaccharide that retards the diffusion of atmospheric oxygen into the cell. Absence of oxygen producing photosystem II and proteolysis of phycobiliproteins during differentiation of heterocysts play an important role in keeping these anoxic. Enhanced rate of respiration also participates in scavenging residual oxygen (Wolk, 1994).

Pattern Formation

Heterocysts differentiate at semi-regular intervals showing a specific pattern in the vegetative filaments (unbranched or branched). In most of the free-living species of *Anabaena* and *Nostoc*, 5-10% of the vegetative cells differentiate into heterocysts whereas heterocyst frequency can be much higher (60%) in symbiotic algal forms (*Nostoc-Gunnera*) (Stewart *et al*, 1983). A significant information on pattern formation during heterocyst differentiation was provided initially through experiments involving simpler micromanipulations (Wilcox, 1970; Wilcox *et al*, 1973).

Heterocysts also regulate the pattern formation of akinetes in the algal filaments (Wolk, 1966; Ahluwalia and Kumar, 1982; Tyagi, 1975), cause fragmentation of the filaments and hence participate in multiplication (vegetative reproduction) and as an attachment organ in *Gloeotrichia*. Even today it is not possible to pinpoint a cell in the filament to be a potential heterocyst. The pattern of their distribution still remains elusive; hence these cells remain an enigma even today.

Heterocyst differentiation and gene rearrangements

In heterocystous cyanobacteria, two sites for gene rearrangements have been noticed in every chromosome during the differentiation of heterocysts (Golden *et al*, 1985; Golden, 1988; Haselkorn, 1992). These elements have sizes of 11 and 55 kb and each encodes a site-specific recombinase and catalyzes the excision of a non-replicating circular DNA molecule and fusion of distant parts of a gene in differentiating cells only. These rearrangements of genes occur after a series of signal transductions, gene activations and even morphological differentiations in response to environmental conditions (Golden *et al*, 1985, 1988; Haselkorn, 1992). Blocking of genome rearrangement and nitrogen fixation in *Anabaena* by inactivation of *xisA* gene has been reported (Golden and Wiest, 1988). Prasanna and Kaushik (1995) reported organization of *nif* gene in branched heterocystous cyanobacteria with respect to variation for *xisA* presence.

Molecular Studies

Many genes are involved in differentiation of heterocysts (Yoon and Golden, 1998; Wolk, 2000; Xu and Wolk, 2001). Few among these (*ntcA, hanA, hetR* and *hetF*) are known to be essential for the initiation of heterocyst development (Black *et al*, 1993; Buikema and Haselkorn, 1993; Wei *et al*, 1994; Khudyakov and Wolk, 1996; Wong and Meeks, 2001). Mutation among any of these genes results in Het$^-$ phenotype in *Anabaena* strain 7120. Some genes get activated on nutrient shift but do not participate in differentiation (*ntcA*) while some others get activated only on nutrient shift but regulate the differentiation of heterocysts as well (*hetR, patS*). Various categories of genes have also been reported for the morphological and metabolic maturation of heterocysts (*hetC, hepA*) (Wolk, 2000). Suppression of heterocyst differentiation in *Anabaena* PCC 7120 was shown through a cosmid carrying wild type genes encoding enzymes for fatty acid synthesis (Baucer *et al*, 1997). Zhou *et al* (1998) provided evidence that HetR protein is an unusual serine-type protease. Active site of HetR protease and its role in heterocyst differentiation was highlighted by Dong *et al* (2000). Stimulated formation of heterocysts in *Anabaena* sp. strain PCC 7120 was due to overexpression of *hetL* (Liu and Golden, 2002).

Nitrogen fixation

Heterocyst is the site of nitrogen fixation in cyanobacteria (Fay *et al*, 1968). These cells carry active nitrogenase for converting the atmospheric nitrogen to ammonia. Presence of a second nitrogenase in vegetative cells of a heterocystous cyanobacterium was also shown (Thiel *et al*, 1995). As this process is energy-expensive, studies on regulation of differentiation of these specialized cells are required for enhancing the biofertilizer potential of cyanobacteria. Natural regulation of heterocyst formation under conditions of combined nitrogen deficiency indicates the evolutionary wisdom of these organisms in not differentiating these cells, thus conserving resources. Among the many functions assigned to these cells having potential in biotechnology, nitrogen fixation is the major one, due to which the heterocyst has remained in prominence as a developmental and biofertilizer system (Bisen, 2003). Heterocystous algae are, therefore, inoculated in the paddy fields as an alternative or supplemental source of nitrogen (Vaishampayan *et al*, 2001). This inoculation can save a significant quantity of chemical nitrogen fertilizers.

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EMERGING ROLES OF NITRIC OXIDE IN PLANTS

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Abstract

Nitric oxide (NO) is known, since the past few years, as a bioactive molecule playing important role in a number of diverse activities of animals and plants. It is a small, highly diffusible molecule. It can rapidly pass through biological membranes thereby triggering various processes. The regulatory role of NO in plant development and plant interactions with microorganism, involving an interplay with other molecules like ethylene or reactive oxygen species (ROS), is discussed. It is implied to be an important defence molecule against stress and ROS, however further research is needed to understand conclusive physiological mechanism involved.

Key words: Development, Nitric oxide, Plant growth, Stress tolerance.

INTRODUCTION

The only gaseous signalling molecule in the living world for the last few decades has been the plant hormone ethylene. Another gaseous regulator nitric oxide (NO) was first identified in animal system as an endothelium derived relaxation factor, and later implicated in signal transduction pathways controlling neuro transmission, cell proliferation, platelet inhibition, programmed cell death, and host response to infection (Wink and Mitchell, 1998). The presence of nitrogen monoxide in plant has been known for some time (Leshem, 1996). Its regulatory role in plant biology during interactions with pathogenic micro-organisms was also reported by Delledonne *et al.*, (1998) and Durner *et al.*, (1998).

Chemistry of nitric oxide

Conceding to analogies with animal systems, it is automatically assumed that nitric oxide has physiological role in plants as well. Nitric oxide is a free radical lipophilic diatomic gas under atmospheric conditions. Its small stokes radius and neutral charge facilitates rapid membrane diffusion (Stamler *et al.*, 1992). The nitric oxide chemistry involves an interplay between three species differing in physical properties and chemical reactivity : nitrosonium cation (NO^+), nitric oxide radical (NO) and nitroxyl anion (NO^-). The most important chemical properties of NO is the existence of an unpaired electron allowing a high reactivity with O_2, super oxide (O_2^-), N derivatives and transition metals (Stamler *et al.*, 1992).

Origin of nitrogen oxide in plants

Although in animals, NO is generated by nitric oxide synthase, however, in bacteria, fungi and plants, the presence of NO, like the presence of reactive oxygen species (ROS), is associated with metabolism. Nitrification/ denitrification cycles generate NO as a by product of N_2O oxidation into the atmosphere. Plants not only react to the atmospheric or soil NO, but also emit fairly large amounts of NO (Durner and Klessig, 1999). The origin of NO production in plants is probably through the action of NAD (P) H^+ dependent nitrate or nitrite reducates (Yamasaki *et al.*, 1999). Thus various metabolic reactions are understood to be involved in generation and utilization of NO in plant bodies.

NO generation and methods of measurement

NO is an unstable molecule that is produced at very low concentrations. Therefore accurate and reproducible methods are required to detect NO (Beligni and Lamattina, 2001). It can, however, be measured either directly or indirectly. Direct methods involve chemi-luminiscence (Kikuchi *et al* 1993a,b) and electrochemical measurements (Malinski and Taha, 1992). Indirect methods depend on monitoring molecular species or a physiological effect, which reflects the presence of NO. They are oxyhemoglobin oxidation method (Kikuchi *et al.*, 1996), Griss reaction (Nims *et al.*, 1996) and utilization of fluorimetric probes (Misko *et al.*, 1993). Nitric oxide can also be detected as a free radical by electron paramagnetic resonance spectroscopy (Kozlovb *et al.*, 1996).

Physiological actions of NO in plants

Nitric oxide influences plant metabolism to great extent. The endogenously produced NO gas may be termed as a natural plant growth regulator and can be experimentally

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tested (Leshem, 1996). This can be accomplished by exogenous application of NO donors in a wide range of concentrations to a great variety of plant systems. As NO is a gas, it is mostly applied in the form of donor compounds that release NO into solution (Ramamurthi and Lewis, 1997). For this reason, the concentration of NO inside the plant tissues depends on the kinetics of release from the donor, the temperature and the reducing power (Ramamurthi and Lewis, 1997). Understandingly, the determination of NO concentration in tissue is not very easy and reliable, just similar to uncertainty about the physiological concentration of NO is animal system also. Exogenous application makes it difficult to determine whether the effects really have physiological implications. The effect of NO donor can be studied by using the compounds like sodium nitropruside and S-nitroso-N-acetylpenicillamine (Garcia Mata and Lamattina, 2001). The present review is an attempt to update nitric oxide's possible roles in plant's growth development and plant's stress conditions.

Growth and development

Relatively little is known about biological functions of NO in plants. It is probably a regulatory molecule during plant growth and resultant development (Gouvea *et al.*, 1997).

Sodium nitroprusside stimulated germination in *Paulowania tormentosa* seeds (Grubisic and Konjevic, 1990; Grubisic *et al.*, 1992). Dormant seeds of California-chaparral could germinate by smoke emitted from smoke treated sand or paper. The involvement of NO is suggested by the fact that an exposure to NO gas induced 100% germination in a manner similar to smoke (Keely and Fotheringham, 1997). Similarly, stimulation of light regulated germination was also demonstrated for lettuce seeds (Beligni and Lamattina, 1999).

In pea foliage, the response of NO was concentration dependent; low concentration producing an increase in rate of leaf expansion while at high concentration no promotive effects were seen (Leshem and Haramaty, 1996) suggesting a hormone type of role of NO in plant systems.

A lower concentration of NO induced elongation in maize roots (Gouvea *et al.*, 1997). A decrease in endogenous NO concentration appeared to be lower in mature fruits than in green fruits and in senescing flowers compared with fresh ones (Leshem *et al.*, 1998) suggesting its role with maturation and senescence.

Further Leshem *et al.*, (1998) supported the possibility of NO as a neutral, senescence delaying plant regulating agent, acting primarily by down-regulating ethylene emission. Its role in activation of transcription factors involved in gene expression was observed in maize root tip elongation (Ribeiro *et al*, 1999).

Biotic and abiotic stresses

Nitric oxide is a key signalling molecule in plants, mediating responses to various biotic and abiotic stresses (Delledonne *et al.*, 1998).

Biotic stress

Nitric oxide protected the chlorophyll in potato leaves that were infected with the pathogen (*Phytophthora infestans*). The effect was achieved with low NO concentrations (between 10 and 100 μm SNP) (Laxalt *et al.*, 1997). However, it was demonstrated that NO was not a effector molecule responsible in the killing of fungal elements by the host immunocytes, but its protective effect was related with plant defence mechanisms.

Plant pathogen interactions lead to a rapid and transient production of ROS (reactive oxygen species) called oxidative burst (Hammond-Kosack and Jones, 1996). These ROS have both signaling and toxic roles (Levine *et al.*, 1994).

It has been suggested that NO and ROS might be involved directly or indirectly through activation / repression of respective signalling pathways leading to gene expression and protein activity levels (Bolwell, 1999; Durner and Klessig, 1999).

No-donors and recombinant nitric oxide synthase were shown to modulate two tobacco pathogen-activated nitrogen activated protein kinases (Klessig *et al.*, 2001). This work clearly suggests the role of NO as a signaling molecule for protein synthesis and regulation.

Abiotic stresses

NO has been suggested as an anti stress molecule in plants as it reduces the amount of ROS generated under stress conditions. In potato foliage ROS were artificially generated by application of herbicides diquat and paraquat. NO was able to reduce chlorophyll loss, ion leakage, necrosis and defoliation produced by the herbicide. All these effects seem to originate from NO mediated reduction of the free amount of ROS (Beligni and Lamattina, 2000).

Nitric oxide can reduce the oxidative injury produced by drought on wheat seedlings and UV-B radiation on potato leaves, suggesting a putative role as an anti-stress molecule in plants by Garcia-Mata and Lamattina, (2001). They reported again in 2002 that NO induced stomatal

closure in faba beans. It was also indicated that ABA induced stomatal closure requires NO, as in *Arabidopsis* and pea (Garcia- Mata and Lamattina, 2002).

Thus, it has been recognized and established that NO has the ability to enhance plant fitness to withstand an environment constraints, however, it needs further experimentation to unravel the mechanism of action.

CONCLUSIONS

In recent years, much evidence has been accumulated in support of NO activity in plants. In both, animal and plant systems NO appears to take part either directly or indirectly. It is simple since NO is easily formed, highly diffusible as well as reactive.

NO is thought to have originated during initial periods of aerobic evolution, when NO producing cells were able to undergo denitrification or nitrification. It is believed to be the first antioxidant evolved during early life evolution (Feelisch and Martin, 1995). The study of NO in plants is fascinating and it plays role in many patho-physiological and developmental processes. However, more emphasis is required on chemical and molecular mechanisms of its action to be fully unravelled. The integration of NO functions with plant metabolism, growth and development and especially with plant hormones must be studied to achieve significant breakthrough. Furthermore new donor concentrations and time of application will have to be ascertained to envisage and understand the actual and fundamental mechanism of action of this small, simple but wonderful molecule.

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POLLUTION HAZARDS AS INFLUENCED BY SURFACE WATER (IRRIGATIONAL) QUALITY IN KALKA-KHARAR BELT (HARYANA-CHANDIGARH-PUNJAB)

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Abstract

Perceptible degradation in surface water quality has exacerbated salinity, sodicity, bicarbonate and alkalinity hazards from the discharge (BEI, +ve) to recharge (BEI, -ve) regime in Kalka-Kharar belt. Maximum impact on the irrigational water quality is noticed in the ponds, nalas, effluent drainage, low-flowing (clogged) canals/rivers and dug wells. Appreciable effects on groundwater quality is also found in the phreatic aquifer zone of the downstream tube wells. Loss in permeability, nature of ephemeral-influent rivers, imbalance in input-output of water in soils, uncontrolled seepages etc. could explain the phenomena in this Kandi belt.

Key Words: Pollution, pheratic aquifer zone, Kandi belt.

INTRODUCTION

The Kalka - Kharar belt under study constitutes a part of the Ghaggar River Basin, an extension of Indo-Gangetic Quaternary Basin. It comprises three distinct geological – geomorphologic units i.e., the Siwalik Hills, the Kandi belt and the alluvial plains. Sediments from the Siwaliks, on account of extensive denudation, are transported by about 140 ephemeral monsoon torrents (choes), which drain the catchments of about 20x56 Km^2 size. Steep sides, irregular and highly fragile catchment area effect the sediment transport and flow of water into the plains and beyond. Sediments of the Dagshai and Kasauli formations conformably overlie the Subathu Formation. The Subathus are exposed as a thin continuous belt in the entire eastern part of the Ghaggar basin. The hydraulic characteristics of these rocks are poor. The Siwaliks are exposed along the entire length of the hilly northeastern part. The overall permeability of the Siwaliks is poor even in case of majority of coarse clastics because of their clay content and compactness.

The hydraulic conditions in the area as per the UNDP (1985) data are well brought out pointing to low permeability of the aquifer material in the northeastern section of the Ghaggar canal, with seepage rate of about 0.180 m/day and calculated coefficient of permeability (i.e., 4.19 m/day). A thick sequence of about 604m of alluvium underlies the area occupying the longitudinal NW-SE belt known as the Kandi belt. Most streams with large catchment, outside snow-fed region, are influent and ephemeral in the upper reaches, intermittently influent (or effluent) in the middle reaches, and perennial and effluent in the lower reaches. Almost a similar condition in the upper reaches and catchment area is observed in the Ghaggar Basin.

FLOW REGIME

The surface water bodies like rivers, canals, lakes, reservoirs etc. play significant role in the groundwater flow system. The infiltration of surface water to groundwater usually occurs in recharge area. Base flow from groundwater to surface water bodies may occur in discharge area. In the discharge area (wherever the BEI is positive; Table–3), the hydraulic head increases with depth and net saturated flow is upward toward water table. The groundwater level is close to the ground surface, saturation being excess on the contributing area. At low run off, the usual feature in this study area (part of the Ghaggar Basin), the discharge area is only a small fraction of the total basin area. When the river discharges are high it increases to a much larger fraction of the basin. In the recharge (infiltration excess) area, the water table lies at considerable depth beneath thick unsaturated zone of varying thickness which separates it from the ground surface. The concept of recharge and discharge involves infiltration, nature of surface flow and the fact that almost all river water passed through the soil (Smith et al., 1987; Hillel, 1987, 1999; Falkenmark and Allard, 1991). Direct surface runoff is of little significance. Base Exchange Index

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(BEI=Cl–Na/Cl, ionic concentrations expressed in meq./l) determined in water samples has been broadly used to characterize the nature of recharge (BEI, -ve) and discharge (+ve BEI) area (Johnston, 1987a, 1987b, CGWB, and CPCB, 1999). In the present study BEI values have been used to identify the flow regime and their significance in relation to other parameters.

THE DATA

Chemical constituents affecting the suitability of water for irrigation are (i) total concentration of soluble salts (salinity) broadly related to the specific conductance (EC) of water, (ii) relative proportion of sodium to calcium and magnesium, (iii) relative proportion of bicarbonate to calcium and magnesium etc.. The following chemical parameters have been determined using the analytical data (UNDP, 1985; Rehal, 1993; Suman Bala, 1995; Indu Bala, 1995 and Prasad, 1994 ; 1997).

(1) Percent sodium (%Na) = (Na+K)100/ (Ca+Mg+Na+k) ionic concentrations expressed in meq/l., on which is based Wilcox classification (Wilcox, 1955), and expresses sodium hazard.

(2) Classification of irrigation water based on salinity hazard (~EC values) and the sodium absorption ratio (SAR)=Na/ $\sqrt{Ca+Mg}$ / 2; ionic concentrations expressed in meq./l as per the US Salinity Laboratory Staff (1954) i.e., sodium hazard.

(3) Residual sodium carbonate (RSC) = HCO_3 - (Ca+Mg), ionic concentrations expressed in meq/ l. The parameter is dependent on bicarbonate concentration. Bicarbonate hazard is caused by RSC or residual alkalinity in water when bicarbonate ions exceed the contents of alkaline earths in irrigation water (i.e. alkalinity).

(4) Doneen (1962) evolved modified criteria to classify irrigation water based on the solubility of salts and reactions occurring in the soil solution from cation exchange. He defined the term Permeability Index (PI) = Na + $\sqrt{HCO_3}$ X 100/ Ca + Mg + Na (ionic concentrations expressed in meq./l). PI rise is a function of rise in alkalinity and sodicity.

The present paper deals with changes in surface water quality, particularly irrigational, like sodicity/sodium hazard, alkalinity, bicarbonate hazard, salinity hazard and others in relation to permeability (PI) and BEI in the study area.

Table 1 : Location of Water Samples.

Sr. No.	Sample No.	Location of Water Samples
1	JR	Jhajhra Nadi, Kalka bridge
2	16R	Kaushalya Nadi, Isharnagar.
3	25	Confluence of Jhajhra and Kaushalya rivers
4	WGR13	Well in Ghaggar river, Bahorian village
5	32R	Confluence of Jhajhra, Kaushalya and Ghaggar rivers
6	14R	River Water, Pattan Village
7	SCR	Sukhna Choe river, Bapudham, Chandigarh
8	GR3(77)	Ghaggar river, near Chandigarh
9	GHG-1(86)	Ghaggar river, Mubarakpur
10	GHG-1(87)	Ghaggar river, Mubarakpur
11	GHG-2(86)	Ghaggar river, Pbi. University, Patiala
12	GHG-2(87)	Ghaggar river, Pbi. University, Patiala
13	L39	Sukhna Lake, near Cafetaria, Chandigarh
14	L40	Sukhna Lake, Chandigarh
15	CI21	Sirhind Canal Water
16	S9P	Daun village (Pond Water)
17	PI12	Sihon Majra (Pond Water)
18	PI16	Rangilpur (Pond Water)
19	S2	Nala Water, Mohali
20	S4RE	Patiali Ki Rao effluent
21	S18RE	Jainit Devi Ki Rao, Kiran Vanspati factory effluents,Khanpur.
22	EI6	Siswan Nadi effluents, Carboard Factory, Sialba Majri
23	EI3	Surya Jyoti Thermocol Factory effluents.
24	S7DW	Balungi Village (Dug Well water)
25	S10DW	Daun Village (Dug Well Water)
26	S3TW	Milk Plant, Mohali (Tubewell Water)
27	S17TW	Kharar (Tubewell Water)

The effect of surface water quality is also manifest in water samples of ponds, canals, lake, dug wells and tube wells during the period of about two decades. Right from the Jhajhra river through Kaushalya and Ghaggar rivers, besides hundreds of choes, nalas and dug wells to Kharar tubewell water (Sr. No. 27), a perceptible degradation is observed (Tables 1 and 2; Figs. 1 and 2). The data sources (of 1977, 1986-87, and 1990-1997 are from the investigations (to a large part) carried out at the Centre of Advanced Study in Geology, Panjab University, Chandigarh (UNDP, 1985 ; PPSB & CWP, 1989 ; Rehal, 1993; Suman Bala, 1995; Indu Bala, 1995; Prasad, 1994 and 1997).

The Jhajhra river water (Sr. No. 1) entering the study area below Kalka bridge is richer in %Na, SAR, salinity (EC), TDS, PI, alkalinity and bicarbonate values than that of the Kaushalya river (Sr. No. 2), confluence of Jhajhra and Kaushalya rivers (Sr. No. 3) and Ghaggar river (Sr. No. 4). There is loss of chloride (increase in sodium) content from Jhajhra (Sr. No. 1) to Jhajhra-Kaushalya confluence (Sr. No. 3), indicated by the BEI(+0.248) and (+0.071) values, respectively while Kaushalya (Sr. No. 2) and Ghaggar (Sr. No. 4) as also the confluence of the three rivers (Sr. No. 5) exhibit Na>Cl (expressed as –ve BEIs) from – 0.147 to – 3.891, respectively. The water sample from this confluence (Sr. No. 5) shows slightly lower values of %Na and SAR, higher alkalinity and PI values when compared with those observed in Jhajhra water (Sr. No. 1).

The 1987 data of water samples from Ghaggar river at

Table 2 : Chemical parameters of water Sample of the Study area.

Sr.No.	Sample No.	BEI	% NA	SAR	RSC meq/l	EC*	TDS mg/l	PI (%)	Alkalinity mg/l
1	JR	+0.248	42.70	2.12	+0.50	637	430	69.93	281
2	16R	-0.147	18.88	0.589	-0.32	304	200	56.97	171
3	25	+0.071	22.62	0.748	-0.22	404	256	56.85	195
4	WGR13	-0.147	13.51	0.478	-2.24	421	290	39.33	171
5	32R	-3.891	41.10	2.091	+1.14	500	330	70.61	323
6	14R	+0.368	7.96	0.259	-1.88	441	300	37.15	207
7	SCR	-0.276	36.60	1.829	+0.48	725	500	58.04	439
8	GR3(77)	-0.655	18.54	0.64	-0.63	490	286	54.38	240.42
9	GHG-1(86)	+0.118	4.05	0.126	-2.827	393	357	31.47	98
10	GHG-1(87)	+12.43	8.50	0.258	-2.071	500	313.5	55.84	108
11	GHG-2(86)	+0.542	15.56	0.482	+1.035	500	314	67.64	272
12	GHG-2(87)	+0.229	5.62	0.310	-12.593	760	476.5	12.31	56
13	L39	-1.294	22.79	0.644	-1.00	176	176	51.85	85
14	L40	-1.389	26.48	0.742	-0.40	176	176	63.93	134
15	CI21	-0.997	32.50	0.963	+0.19	145	96	79.43	146.4
16	S9P	-0.206	46.75	2.98	+11.40	1016	669	81.95	1085.80
17	PI12	+2.19	30.80	0.789	+4.52	301	199	83.21	402.60
18	PI16	-0.12	66.50	5.010	+2.79	498	329	89.53	390.40
19	S2	-0.617	28.03	0.78	+2.52	336	221	82.37	341.60
20	S4RE	-0.123	43.08	1.65	+6.40	538	353	101.31	573.40
21	S18RE	-0.646	68.56	5.54	+2.56	668	441	90.74	366
22	EI6	-5.235	39.40	5.670	+29.32	1742	1240	52.15	414.8
23	EI3	+0.809	22.70	0.855	+0.087	458	302	47.5	475.8
24	S7DW	-2.025	66.19	4.87	+8.68	743	489	103.43	719.8
25	S10DW	-0.725	55.68	5.06	+6.99	1326	879	73.26	1012.60
26	S3TW	-2.367	41.48	1.68	+2.88	356	235	89.64	353.8
27	S17TW	-2.367	42.28	1.69	+2.76	328	217	90.25	341.6

*** m mhos/cm at 25°C.**

Table 3 : Class and nature of water samples based on various parameters

Sr. No.	Sample No.	EC Salinity hazard	SAR Sodium hazard	% Na	RSC	PI	BE I Cl-Na	Nature of Sample Cl
1	JR	C_2	S_1	Permissible	Safe	I	+ Ve(D)	River
2	16R	C_2	S_1	Excellent	Safe(-ve)	II	- Ve(R)	River
3	25	C_2	S_1	Good	Safe(-ve)	II	+ Ve(D)	River
4	WGR13	C_2	S_1	Excellent	Safe(-ve)	I	- Ve(R)	Well in River
5	32R	C_2	S_1	Permissible	Safe	I	- Ve(R)	River
6	14R	C_2	S_1	Excellent	Safe(-ve)	I	+ Ve(D)	River
7	SCR	C_2	S_2	Good	Safe	I	- Ve(R)	Sukhna Choe (R) Chandigarh
8	GR3(77)	C_2	S_2	Excellent	Safe(-ve)	II	- Ve(R)	River
9	GHG-1(86)	C_2	S_1	Excellent	Safe(-ve)	I	+ Ve(D)	River
10	GHG-1(87)	C_2	S_1	Excellent	Safe(-ve)	II	+ Ve(D)	River
11	GHG-2(86)	C_2	S_1	Excellent	Safe	II	+ Ve(D)	River
12	GHG-2(87)	C_3	S_1	Excellent	Safe(-ve)	I	+ Ve(D)	River
13	L39	C_1	S_1	Good	Safe(-ve)	II	- Ve(R)	Lake (Sukhna)
14	L40	C_1	S_1	Good	Safe(-ve)	II	- Ve (R)	Lake (Sukhna)
15	CI21	C_1	S_1	Good	Safe	III	+ Ve(D)	Sirhind Canal
16	S9P	C_3	S_1	Permissible	Not Suitable	II	- Ve(R)	Pond
17	PI12	C_2	S_1	Good	Not Suitable	II	+ Ve(D)	Pond
18	PI16	C_2	S_1	Doubtful	Not Suitable	II	- Ve(R)	Pond
19	S2	C_2	S_1	Good	Marginal	II	- Ve(R)	Nala Water
20	S4RE	C_2	S_1	Permissible	Not suitable	III	- Ve(R)	River + effluent
21	S18RE	C_3	S_1	Doubtful	Not suitable	II	- Ve(R)	River + Effluent
22	EI6	C_3	S_1	Good	Not suitable	I	- Ve(R)	River + Effluent
23	EI3	C_2	S_1	Good	Safe	I	+ Ve(D)	Effluent
24	S7DW	C_2	S_1	Doubtful	Not suitable	III	- Ve(R)	Dug Well
25	S10DW	C_3	S_1	Permissible	Not suitable	I	- Ve(R)	Dug Well
26	S3TW	C_2	S_1	Permissible	Not suitable	III	- Ve(R)	Tube Well
27	S17TW	C_2	S_1	Permissible	Not suitable	III	- Ve(R)	Tube Well

Mubarakpur (Sr. Nos. 9 and 10) those (Sr. Nos. 11 and 12) from Patiala (PPSB & CWP, 1989) when compared with the 1977 data (UNDP, 1985) of the same river (Sr. No. 8), show appreciable change in water quality viz. all having Cl>Na (i.e., +ve BEI), loss in % Na and SAR, higher concentration of Ca+Mg over HCO_3 (except for 1986 sample from Patiala), more salinity and TDS but an over all decrease in alkalinity.

The water sample (1993 data) of Sukhna Choe (Sr. No. 7) in Chandiagrh shows more of %Na, higher values of SAR, bicarbonate, salinity (EC), TDS, alkalinity and slightly more Na>Cl (BEI, -ve) vis-à-vis the 1977 data (Sr. No. 8) of Ghaggar. The Sukhna Lake data (of 1993) show more BEI(-ve) values i.e. Na>Cl, more of % Na, higher SAR values, more concentration of Ca + Mg over HCO_3 (RSC), higher PI but less alkalinity and TDS content (Sr. Nos. 13 and 14). Ponding of water (in lakes, reservoirs, ponds etc.) causes appreciable change in its quality which is further substantiated in sequel. Higher values of % Na, SAR, HCO_3, EC (salinity), TDS, alkalinity, PI with Cl>Na (BEI+ve) and observed in the analysed water samples (1995 data) of ponds (Sr. Nos. 16, 17, 18) when compared with data for rivers (Sr. Nos. 1 to 12) and Sukhna Lake (Sr. Nos. 13 and 14) as evidenced by Figs. 1 and 2 (ref. Tables 1 and 2). The waters of these ponds are "not suitable" (ref. RSC), belong to C3S1 class (USSL classfication), class II (PI ; Doneen Classification) and have been graded as "good" to "doubutful" based on % Na values (Table No. 3).

Analysed water sample (1995 data) of Mohali Nala (Sr. No. 19), Patiali Ki Rao effluents (Sr. No. 20), Jainti Devi Ki Rao, Khanpur (Sr. No. 21), Siswan nadi (cardboard factory effluents ; Sr. No. 22) and Surya Jyoti Thermocol factory effluents (Sr. No. 23) exhibit maximum effects of

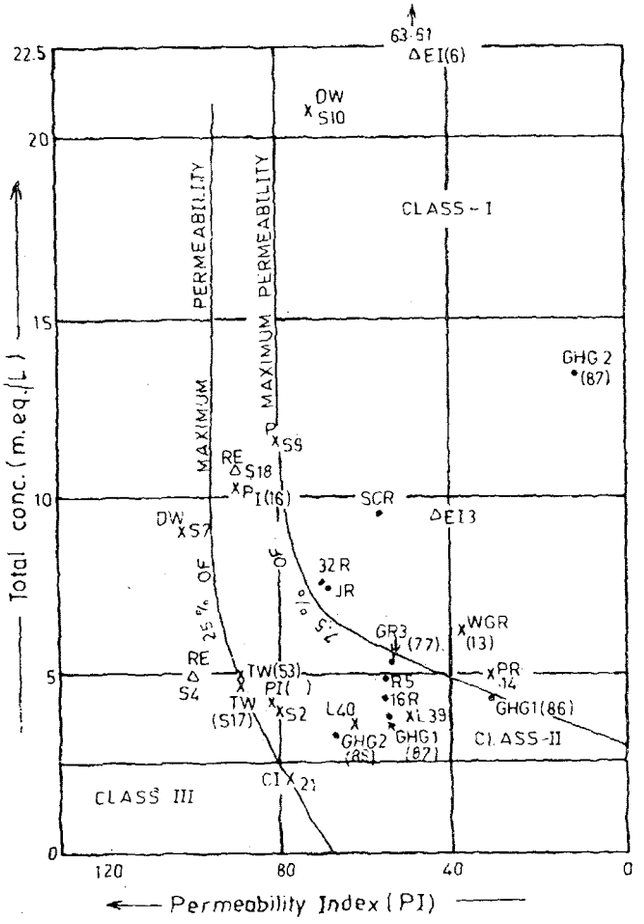

***Fig. 1** : Classification of irrigation Waters (after Doneen, 1964)*

pollution (Figs. 1 and 2). In comparison to the 1986 Ghaggar (Mubarakpur) data, 16 times increase in % Na *in Khanput (Sr. No. 21) and Rangilpur pond (Sr. No. 17)* water samples as also 40-fold rise in SAR values in them are evident. Maximum concentration of bicarbonate (RSC=+29.32), TDS (1240 mg/l) with the highest values of EC, SAR and lowest content of Cl and Na (BEI= -5.235), *with appreciable alkalinity are found in the water sample of* Siswan *nadi* (Sr. No. 22, Table 2). The water is brackish, *belonging to "C3S1 class" and not suitable"* class (RSC). These nala and rivers are stagnant and choked by effluents. The water sample of Sirhind canal (Sr. No. 15) water with less of choking and moderate flow belong to Class III (PI; Doneen classification), having *Cl>Na(BEI+ve), moderate alkalinity and* % Na (Tables 1 to 3; Figs. 1 and 2). The Patiali Ki Rao effluent water sample (Sr. No. 20) also belongs to class III of Doneen classification (Table 3).

Impact of surface water regime and quality is well reflected in the deterioration of groundwater quality. An increase in % Na up to 16 times (Sr. No. 24) in dugwell and 10 times in tube well waters (Sr. Nos. 26, 27), about 40 - fold in dugwell (Sr. No. 25) water and 13 - fold increase in SAR values of tubewell waters *are observed in the 1995 data* as against those in 1986 data (PPSB & CWP, 1989) water (*Tables 1, 2 and* 3). *High values of bicarbonate,* % Na, SAR, TDS and the highest salinity (EC), high alkalinity (1012.60 mg/l) which is about 18 times (Sr. No. 24) and 13 times (Sr. No. 25) more than the Ghaggar water (1986) data are noticed. The dugwell waters (Sr. Nos. 25 and 24) are classified, as C3S1 and C2S1, permissible and doubtful, belonging to class I and III, respectively, both are not suitable for irrigation (Table 3).

The mixed nature of water quality with much more salinization, alkalinity and sodium hazard in comparison to the tubewell waters (Sr. Nos. 26, 27) which belong to C2S1 (USSL class), permissible (%Na) but "not suitable" category (RSC based) and class III based on PI values (Doneen Classification) are brought out by the 1995 data presented in the work. Maximum salinity (EC = 1742) is observed in Siswan Nadi effluent (Sr. No. 22) with fairly high alkalinity, highest TDS (brackish water) and highest values for SAR, bicarbonate and Na > Cl nature. The pond water (Sr. No. 16) shows fairly high bicarbonate, salinity, TDS, PI values and the highest alkalinity (1085.80 mg/l) hazard followed by the next higher value (1012.60 mg/l) of alkalinity, TDS and salinity (EC=1326), SAR and Na>Cl, % Na, bicarbonate as well as the maximum PI (103.43) value in dugwell water (Sr. No. 24). Loss of permeability, increase in (Ca+Mg+Na) cations, observed in class III (Doneen, 1962) i.e. 25% of maximum permeability (Fig. 2) indicates the nature of solubility of salts and more cation exchange reactions. This loss in permeability is a function of increase in sodium and bicarbonate in the phreatic aquifer zone of the wells. The dug wells and tubewells show high negative BEI (characteristic of recharge area) and thus higher sodium concentration over chloride in these water bodies and soils.

CONCLUSIONS

It is very explicitly brought out by the data that in a decade or more, there has been perceptible deterioration in ground water and irrigation water quality in the study area, a part of the Ghaggar Basin. This increase in alkalinity, salinity, sodicity, sodium hazard and loss of permeability caused rise of water level, subsequently in large part of the basin, besides the pollution of water in the region. Excessive irrigation can exacerbate rather than alleviate the problem of soil salinity which is so acute in the region. Secondary process of alkalinization is another insidious companion to soil salinization. During the whole process, the cation

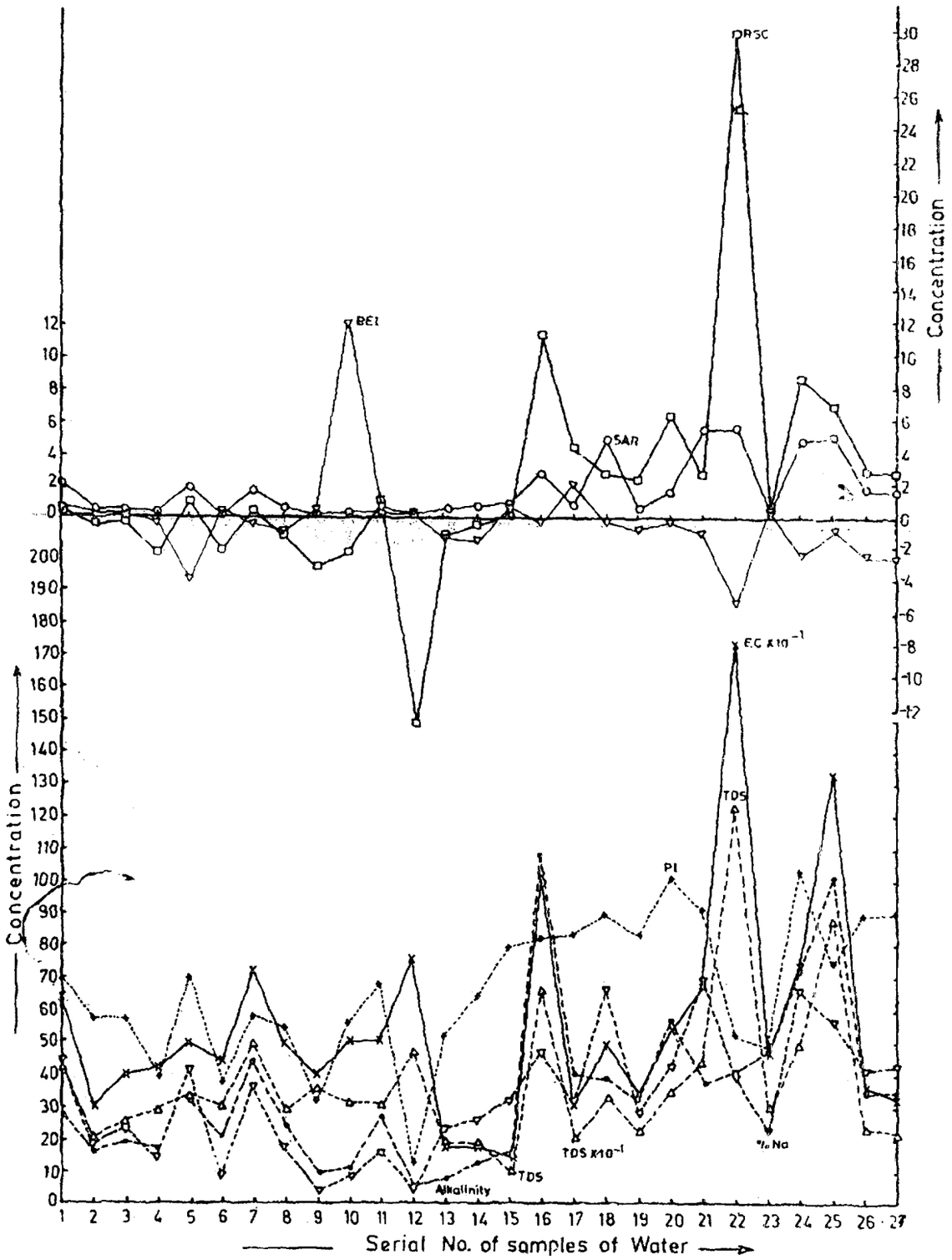

Fig. 2 : Plot of EC (x). Alkalinity (o), percent Na (▼), TDS (Λ) and PI (+) of Kalka to Ropar belt (Haryana and Punjab).

(EC in ms/m at 25°C. Alkalinity and TDS in mg/l; RSC in meq./L; BEI=Base Exchange Index; PI=Permeability index) [Data plotted TDS/10 and Alkalnity/10].

absorbing clay fraction of the soil becomes charged with sodium. The effect of sodium ion is to dispose the fine clay particles thereby causing the desirable crum structure to collapse. Soil pores are clogged by the dispersed clay particles thus increasing impermeability. This restricts water penetration and aeration particularly when the excess salts are leached away. Two phenomena are witnessed in salinization i.e. (a) disorganization of matrix of the soil, and (b) the deposition of soluble salts (Duchaufour, 1977). The water-level rise in an aquifer represents total response to processes of simultaneous drainage or discharge from and recharge to the aquifer. The simultaneous recharge and discharge is a function of the fluctuations in the groundwater level. The rates of recharge may decline subsequently and is time-dependent because of clogging of pore spaces or precipitation of salts (calcareous) related to water logging. It has been pointed out that as much as 40% of India's irrigated area is effected by salinization and alkalinity (CGWB, 1997).

The quality of drainage water (surface water) may be of immediate reuse for irrigation and in quite some cases the drainage effluent may be brackish or polluted and hence not suitable as is evident from the present study. It is evident that flow of water plays significant role in generating water quality. It is particularly so because water carries the dissolved substances as also the solvent effecting chemical reaction along its pathways. In this sense a river water sample is the water fraction mix caused by mobility and chemical activity. Dissolved ions causing salinization originate in various ways e.g. (a) carried by incoming waters, or (b) on account of leaching of detrital minerals, like feldspars, in the soil, or (c) because of weathering of nearby out crops of igneous rocks. Two hydrogeological factors like (i) evaporation flux being generally higher than water inflow causing imbalance in the input and output of water in soils (precipitation, surface or groundwater flow) and (ii) prevention of elimination of saline water because of insufficient drainage due to topographic location or caused by stratigraphic inclination of the subsoil water (cf. Fetter, 1993) could explain the salinization hazard downstream in the basin (under study). Salinization, alkalinization etc. normally occur in ascending order when capillary water brings up phreatic water as also when supersaturation of dissolved salt takes place through evaporation. Any shift in groundwater level may be a cause of soil salinization. The entire process of salinization, alkalinization, sodium hazard etc. in the study area may be explained by factors like low-lying (riverine) lands, clayey soil of lower permeability, slow drainage (ephemeral - influent), high sodium content, unlined earth channels which permit uncontrolled seepage and inappropriate soil management practices besides some other causes discussed in this work.

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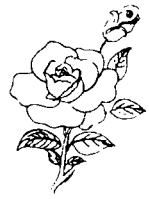

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MUSICAL ANALYSIS OF DNA SEQUENCES

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Abstract

DNA and music appear to be two things but poles apart. Our unique software provides a tool to reach out between two distinct disciplines of science and music to make a string of DNA sequences look like sound. The goal was to develop a sound, which captures as much as possible the sequence of DNA. It has been developed in order to analyze the DNA sequences in a proper and an efficient manner. It can also play a role in DNA steganography (the art of hiding data in DNA) as described in the text. The software has been developed in C++ language and can be procured on request at lalitmbharadwaj@hotmail.com.

Keywords : Sequence analysis, Musical, DNA software.

Just look at a sequence of DNA (a string of 4 letters A, G, C, T). How boring and irritating it looks? You quickly take your eye of it. Now imagine the DNA as music. You find it pleasant and start analyzing it. That is the idea for our current endeavor, which makes music from the fragments of DNA sequences. Unraveling the DNA helix with its bases lined up like the keys of a musical instrument with each key assigned a pleasant, self-discriminating musical note would be an achievement of the decade. Run your fingers along the keys to unravel the sequence along the DNA string. The sequence of bases in DNA has great importance as it decides the phenotype. Even in conducting laboratory experiments a DNA expert has to routinely analyze complex DNA sequence. Even a single base pair change affects the binding efficiency of the primers or similarly the DNA probes. Therefore, great care has to be taken.

The software has been developed to know correctly the sequence of bases in the DNA strings. The sequence of bases along a DNA string is of avid importance in biology and the precise sequence is necessary for any biological experiment to be conducted successfully. In DNA electronics for example, an area that aims to make electronic circuits out of DNA fragments; it is the sequence, which suggests whether DNA will act as an insulator, conductor or semiconductor. Short sequences may be quickly analyzed to design bioelectronic components, which may posses custom electrical characteristics.

Consider a sequence given below

ATGCCGATTACGATGCTAGCCGTA

Now using this sequence an experiment was to be conducted but due to human errors the sequence was read as

ATGCCGATTCAGATGCTAGCCGTA

And the results found were different thus ruining the experiment and efforts of the scientists involved. So there was a need to develop such software, which would reduce the margin of error in DNA sequence related experiments. This software is going to make the work of biologists much more interesting and fascinating, who have to analyze a number of sequences daily.

At CSIO, Chandigarh, this is an attempt to explore the endless possibilities that DNA offers in diminishing the conventional boundaries between various disciplines. In the earlier attempt unique software was developed which could give the DNA equivalent of any image, text, numeric or alphanumeric characters. Thus opening numerous possibilities for storing digital information in DNA (Bharadwaj *et al.*, 2002). The software can also be used for encoding and decoding of data in the form of DNA especially for steganography purposes. (DNA sequences upto a few hundred bases length scales could be got synthesized commercially and stored on suitable substrate like FTA cards (Millipore, Ireland) or polylysine coated plates; but larger sequences which may arise while encoding image files in DNA can not be practically synthesized in DNA). Such DNA encrypted files can be converted into music files using the present software and then transmitted over a particular FM band (radio waves) or using Internet. The decryption process will detect encrypted musical files and convert these into DNA sequences and then actual text or image file shall be generated using the DNA encryption/decryption software.

We know that people like music and can identify the

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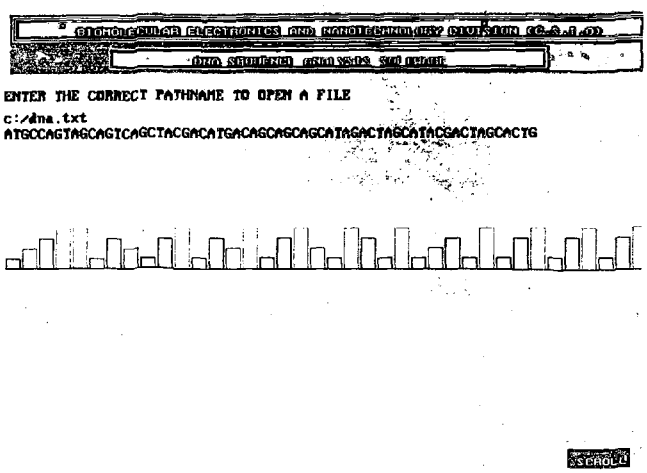

Fig. 1 : The input is taken from a file and after analyzing it the required output is given in the form of multimedia sound and a square waveform. The sound and the waveform will be produce according to the sequence of DNA string. For long sequence, scroll button may be pressed to go the next screen.

various musical tones much easily so multimedia contents are added in the software to make it more user friendly and a square wave graph is also formed in different colors on the computer screen suggesting which is A, T, G, C.

The program is made in C++, as it is basic and appropriate Language. The software reads the input (in the form of sequence) from the specified file and gives the output in the form of sound and square wave. A scroll button may be used to go to next screen if waveform cannot be displayed on single screen. Regarding the computer configuration we used standard P IV 1.6GHz, 256MB RAM, 40 GB hard disc drive. The user has to enter the name of the file having the DNA sequence along with pathname.

For creating professional music two things are important the tone and the pitch. If we take sequence of codon as a tone then some quantitative property of the corresponding amino acid such as atomic weight or pKa can decide about the pitch and its duration. Worldwide there have been a few attempts to assign musical tones to DNA sequences by assigning a tone to each codon (specific sequence of three adjacent bases on a strand of DNA or RNA that provides genetic code information for a particular amino acid). A group of Spanish scientists endeavor of what they claim to be audio version of the blueprint of life is now out as a 10 tune CD called "Genoma Music".

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A MULTIPLE THREE-DECISION PROCEDURE: EXPONENTIAL CASE

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Abstract

Let an observation from population or system π_i follow exponential distribution with probability density function (pdf), $f(x|\mu_i,\theta_i) = (1/\theta_i)\exp[-(x-\mu_i)/\theta_i]I_{[\mu_i,\infty]}(x)$ where μ_i ($-\infty<\mu_i<\infty$) is the location parameter, θ_i ($\theta_i>0$) is the scale parameter and $I_A(x)$ is the indicator function of event A, $i = 0,1,...,k$. The population $\pi_i(\pi_0)$ is called the treatment (control) population, $i = 1,...,k$. In this paper, a multiple three-decision procedure, based on equal sample sizes say n from the treatment populations and a sample of size n_0 (possibly different from n) from the control population, for two-sided comparisons of treatments better than the control ($\mu_i-\mu_0>0$) and the treatments worse than the control ($\mu_i-\mu_0<0$), on the lines of Bohrer (1979), Boher *et al.* (1981) and Liu (1997), is proposed such that for a given α ($0<\alpha<1$) the probability of no misclassification is at least $1-\alpha$ irrespective of the configuration of $\underline{\mu} = (\mu_0, \mu_1,..., \mu_k)'$. The constants necessary for the implementation of the proposed procedure have been provided. The scale version of the proposed procedure has also been discussed with application to normal probability distribution models.

Key words & phrases: Multiple three-decision procedure; Probability of misclassification; Type three-error; Statistical simulation.

INTRODUCTION

Let $\pi_0,\pi_1,...,\pi_k$ be (k+1) populations or systems such that an observation from population π_i follow exponential distribution with probability density function (pdf)

$$f(x|\mu_i,\theta_i) = (1/\theta_i)\exp[-(x-\mu_i)/\theta_i]I_{[\mu_i,\infty]}(x),$$

where μ_i ($-\infty<\mu_i<\infty$) is the location parameter, θ_i ($\theta_i>0$) is the scale parameter and $I_A(x) = 1$ (0) if $x \in (\notin) A$. The population $\pi_i(\pi_0)$ is called the treatment (control or standard) population, $i = 1,...,k$. Let $X_{i1},...., X_{in}$ be a random sample of size n from the treatment population π_i, $i = 1,...,k$ and $X_{01},...., X_{0n_0}$ be a random sample of size n_0 from the control population π_0. We assume that the random samples from the (k+1) populations are drawn independently. Let $Y_i = \min(X_{i1},...,X_{in})$, $S_i = \frac{1}{\nu_i}\sum_{j=1}^{n}(X_{ij}-Y_i)$, $\nu_i = n-1$, $i = 1,..., k$ and $S_0 = \left(\frac{1}{\nu_0}\sum_{j=1}^{n_0}(X_{0j}-Y_0)\right)$, where $Y_0 = \min(X_{01},..., X_{0n_0})$ and $\nu_0 = (n_0-1)$.

Let $\underline{\mu} = (\mu_0,\mu_1,....\mu_k)' \in R^{k+1}$ and $\underline{\theta} = (\theta_0,\theta_1,....\theta_k)' \in R^{k+1}$ where R^{k+1} is the (k+1) dimensional Euclidean space and R_+^{k+1} is its positive part. The treatment population π_i is called better than the control in terms of location (scale) parameter if $\mu_i - \mu_0 > 0 \left(\frac{\theta_i}{\theta_0} < 1\right)$ and is termed worse than the control if $\mu_i - \mu_0 < 0$, $\left(\frac{\theta_i}{\theta_0} > 1\right)$ $i = 1,...,k$. In this paper, we have proposed a multiple three-decision procedure to infer the treatment populations better and worse than the control, depending on the signs/deviations of parameter of the treatment populations from the parameter of control population, such that for a given value of α ($0<\alpha<1$) the probability of no misclassification is at least $1-\alpha$, irrespective of the true configuration of parameters. The location and scale cases have been dealt with separately.

In reliability and engineering the exponential distribution, used to model the life lengths of components, is as

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important as the normal distribution in agricultural and biological sciences. We call the location parameter of exponential distribution as guaranteed life and the scale parameter as the average life in addition to the guaranteed life. In medical sciences the location parameter is called latent period, i.e., the time elapsed between the first exposure to an agent and the appearance of its symptoms. A motivation to this problem is that suppose among several competing firms, supplying components under different brands having life length distributions as members of two parameter exponential distributions, there is a firm whose components have been accepted as standard components. In a healthy competition many firms will claim their components to be better than the control or standard. The proposed procedure will be useful to identify the firms better and worse than the control in such competitive markets.

Tong (1969) considered the problem of partitioning a set of normal populations by their locations with respect to control. Patel and Wyckoff (1990) used sample quasi ranges for classifying a set of k normal populations by their variances as better or worse than a control. Bohrer (1979) and Bohrer *et al.* (1981) proposed multiple three-decision procedures for two-sided comparisons of the treatments better and worse than the control with respect to location parameters under normal probability distribution models. Bohrer *et al.* (1981) also provided a method of computing exact critical points which satisfy the requirement that the probability of no misclassification is at least a specified value. Later, Liu (1997) gave extensive tables for these critical points to facilitate the applications of the procedure due to Bohrer *et al.* (1981). Misra *et al.* (2002) considered k ($k \geq 2$) members of a location-scale family with common scale parameter and proposed simultaneous confidence intervals for the distances from the worst and best populations, where the population associated with the largest (smallest) location parameter was labeled as the best (worst). From such simultaneous confidence intervals one can infer about the populations closer (farther) to (from) the best and the worst populations by identifying the relevant over-lapping (non-over-lapping) confidence intervals. The goal of the proposed procedure is to infer the treatments better and worse than the control rather than quantifying their deviations from the control through simultaneous confidence intervals proposed by Misra *et al.* (2002).

The proposed multiple three-decision procedure for two-sided comparisons of treatments better and worse than the control, with respect to location parameters, is given in Section 2. The computation of exact critical points, for the implementation of the procedure, is given in Section 3. The scale version of this problem along with its application to normal probability model is discussed in section 4. Throughout this paper we use the following notations:

$g_\nu(.)$: the pdf of the ratio of a gamma variate to its shape parameter ν with $G_\nu(.)$ as the corresponding cumulative distribution function (cdf); $\Delta_U(\underline{\mu},0) = \{i: \mu_i - \mu_0 > 0, i = 1,\ldots,k\}$; $\Delta_L(\underline{\mu},0) = \{i: \mu_i - \mu_0 < 0, i = 1,\ldots,k\}$; $\Omega_U(\underline{\theta},1) = \{i: \theta_i/\theta_0 > 1, i = 1,\ldots,k\}$; $\Omega_L(\underline{\theta},1) = \{i: \theta_i/\theta_0 < 1, i = 1,\ldots,k\}$; $b^+(b^-)$ means just greater (less) than b but not equal to b.

2. Procedure for the Location Case

Here we assume that $\theta_0 = \theta_1 = \ldots \theta_k = \theta$ (unknown). In this case an estimator of θ is $S = (\sum_{i=0}^{k} \nu_i S_i)/\nu$, where $\nu = k(n-1)+(n_0-1)$ and S/θ is distributed with pdf $g_\nu(.)$. Let $V_i = n(Y_i - \mu_i)/\theta$, i=1,...,k and $V_0 = n_0(Y_0 - \mu_0)/\theta$. Then $V_0, V_1, \ldots, V_k$ are independent and identically distributed (iid) exponential random variables with mean 1 and that $V_0, V_1, \ldots, V_k$, S are statistically independent. Now, for

any i between 1 and k define

$T_i = (Y_i - Y_0)/S(1/n+1/n_0)$.

A multiple three-decision procedure, say R_1, for the two-sided comparisons of the treatments with the control, in order to decide which treatments are better than the control and which are worse than the control, is as follows:

$$\begin{aligned} &\text{infer } \mu_i - \mu_0 > 0 && \text{if } T_i > c \\ &\text{infer } \mu_i - \mu_0 < 0 && \text{if } T_i < -c \qquad (2.1) \\ &\text{make no decision on sign of } (\mu_i - \mu_0) && \text{if } |T_i| \le c, \end{aligned}$$

where for a pre-specified small value of α ($0<\alpha<1$), the critical point c (c>0) is chosen such that

$$a(\underline{\mu}|R_1) = P[\text{no misclassification of any treatment}] \ge 1-\alpha \quad \text{for all } \underline{\mu} \in R^{k+1} \qquad (2.2)$$

Misclassification of treatment π_i, also called type-III error, means a decision that a positive $\mu_i-\mu_0$ is inferred as negative or, conversely, that a negative $\mu_i-\mu_0$ is inferred as positive. It may be noted that the probability requirement (2.2) controls type-III error of (2.1) at level α.

3. Computation of Critical Points

For the procedure (2.1), we have

$$a(\underline{\mu}|R_1) = P_{\underline{\mu}}\left[T_i \ge -c \text{ for all } i \in \Delta_U(\underline{\mu},0) \text{ and } T_j \le c \text{ for all } j \in \Delta_L(\underline{\mu},0)\right].$$

In order to compute the critical point c, satisfying (2.2), it is required to find a $\underline{\mu}^0 \in R^{k+1}$ which gives $a(\underline{\mu}|R_1) = \inf_{\underline{\mu}} a(\underline{\mu}|R_1)$. Such a vector $\underline{\mu}^0$ is referred to as the least favourable point. Now,

$$\begin{aligned} a(\underline{\mu}|R_1) &= P_{\underline{\mu}}\left[T_i \ge -c \text{ for all } i \in \Delta_U(\underline{\mu},0) \text{ and } T_j \le c \text{ for all } j \in \Delta_L(\underline{\mu},0)\right] \\ &= P_{\underline{\mu}}\left[Y_i - Y_0 \ge -cS(1/n+1/n_0) \text{ for all } i \in \Delta_U(\underline{\mu},0) \right. \\ &\quad \left. \text{and } Y_j - Y_0 \le cS(1/n+1/n_0) \text{ for all } j \in \Delta_L(\underline{\mu},0)\right] \\ &= P_{\underline{\mu}}\left[V_i \ge -cW(1+\lambda) + V_0\lambda - (n\delta_{i0})/\theta \text{ for all } i \in \Delta_U(\underline{\mu},0) \right. \\ &\quad \left. \text{and } V_j \le cW(1+\lambda) + V_0\lambda - (n\delta_{j0})/\theta \text{ for all } j \in \Delta_L(\underline{\mu},0)\right], \end{aligned}$$

where $\lambda = n/n_0$, $W = S/\theta$ and $\delta_{p0} = \mu_p - \mu_0$, $p = 1,\ldots,k$. Since $\delta_{i0} > 0$ for $i \in \Delta_U(\underline{\mu},0)$ and $\delta_{j0} < 0$ for $j \in \Delta_L(\underline{\mu},0)$, therefore

$$\begin{aligned} a(\underline{\mu}|R_1) \ge P[&V_i \ge -cW(1+\lambda) + V_0\lambda \text{ for all } i \in \Delta_U(\underline{\mu},0) \\ &\text{and } Y_j - Y_0 \le cW(1+\lambda) + V_0\lambda \text{ for all } j \in \Delta_L(\underline{\mu},0)\ ]. \end{aligned} \qquad (3.1)$$

The above discussion enables us to find a $\underline{\mu} \in R^{k+1}$ which minimizes $a(\underline{\mu}|R_1)$. This is given in the following theorem.

Theorem 1: Let m ($0 \le m \le k$) be the cardinality of set $\Delta_U(\underline{\mu},0)$ and $\underline{\mu}^0 = (0,0^+,\ldots,0^+,0^-,\ldots,0^-) \in R^{k+1}$, where the last $k-m$ components equal to 0^-, middle m components equal to 0^+. Then

$$\begin{aligned} \inf_{\underline{\mu}} a(\underline{\mu}|R_1) &= \inf_m a(\underline{\mu}^0|R_1) \\ &= \inf_m \sum_{j=0}^{k-m} \binom{k-m}{j} (-1)^j v^\nu [\{(jc(1+\lambda)+\nu)^\nu (1+j\lambda)\}^{-1} \\ &\quad - \{(jc(1+\lambda)+(1+j\lambda)c(1+1/\lambda)+\nu)^\nu (1+j\lambda)\}^{-1} \\ &\quad + \{(c(j-m)(1+\lambda)+((j+m)\lambda+1)c(1+1/\lambda)+\nu)^\nu \times \\ &\qquad (1+(j+m)\lambda)\}^{-1}]. \end{aligned} \qquad (3.2)$$

Proof: From (3.1), we have

$$\begin{aligned} \inf_{\underline{\mu}} a(\underline{\mu}|R_1) &= \inf_m a(\underline{\mu}^0|R_1) \\ &= \inf_m \int_0^\infty \int_0^\infty \{\prod_{i=1}^{m} P(V_i \ge -cw(1+\lambda) + y\lambda)\} \{\prod_{i=1}^{k-m} P(V_i \\ &\qquad \le cw(1+\lambda) + y\lambda)\} e^{-y} dy] g_\nu(w) dw. \end{aligned}$$

By breaking the range of inner integral at point $cw(1+\lambda^{-1})$ the expression (3.2) follows.

We could not find explicitly the value of m for which the expression (3.2) is minimum. However, we have computed the value of $c = c^{\alpha}_{k,\lambda,\nu}$ through numerical iteration process as explained in the following steps:

(1) For a particular feasible configuration of k, λ and ν the expression (3.2) is computed for $m = 0, 1, \ldots, k$ with some trial value of c. Then the value of m say m^* which minimizes (3.2) is noted.

(2) For $m = m^*$ the expression (3.2) equated to $1 - \alpha$ is solved for c numerically. Let this value of c be c^*.

(3) With $c = c^*$ and the feasible configuration of k, λ, ν

taken in step (1) we again compute expression (3.2) for $m = 0,1,\ldots,k$. If the minimum value of expression (3.2) re-occurs at $m = m^*$, then we take c^* as the required critical point c. Otherwise, the new minimizing value of m say m^*, observed in this step, is noted.

(4) With the new minimizing value m^* of m the steps (2) and (3) are again performed. This process is repeated until we get the required critical point c.

The critical points $c = c^{\alpha}_{k,\lambda,\nu}$ computed through numerical iteration process, as explained above, are given in Tables 1-6 for some choices of k, λ, ν and α.

Table 1 : Values of $c^{\alpha}_{k,\lambda,\nu}$ (λ = .5, α = .05)

ν\k→ ↓	1	2	3	4	5	6	7	8	9	10
10	1.971	2.561	2.924	3.190	3.400	3.575	3.724	3.855	3.972	4.077
11	1.947	2.523	2.877	3.135	3.339	3.508	3.653	3.780	3.892	3.994
12	1.927	2.492	2.838	3.090	3.289	3.454	3.594	3.718	3.827	3.926
13	1.911	2.466	2.805	3.052	3.247	3.408	3.546	3.666	3.773	3.869
14	1.897	2.444	2.778	3.020	3.211	3.369	3.504	3.622	3.727	3.821
15	1.885	2.425	2.754	2.993	3.181	3.336	3.469	3.585	3.688	3.780
16	1.874	2.409	2.734	2.969	3.154	3.308	3.438	3.552	3.653	3.744
17	1.865	2.395	2.716	2.948	3.131	3.282	3.411	3.524	3.623	3.713
18	1.857	2.382	2.700	2.930	3.111	3.260	3.388	3.499	3.597	3.686
19	1.850	2.371	2.686	2.914	3.093	3.241	3.366	3.476	3.574	3.661
20	1.844	2.361	2.673	2.899	3.077	3.223	3.348	3.456	3.553	3.639
30	1.804	2.298	2.595	2.809	2.976	3.113	3.230	3.332	3.422	3.503
50	1.772	2.250	2.535	2.738	2.898	3.028	3.139	3.236	3.321	3.398
70	1.759	2.229	2.509	2.709	2.865	2.993	3.101	3.195	3.279	3.353
90	1.752	2.218	2.495	2.693	2.847	2.973	3.080	3.173	3.255	3.329
110	1.747	2.211	2.486	2.682	2.835	2.961	3.067	3.159	3.240	3.313
120	1.746	2.208	2.483	2.679	2.831	2.956	3.062	3.154	3.235	3.308
∞	1.729	2.183	2.451	2.642	2.790	2.911	3.014	3.103	3.182	3.252

Table 2 : Values of $c^{\alpha}_{k,\lambda,\nu}$ (λ = .5, α = .01)

ν\k→ ↓	1	2	3	4	5	6	7	8	9	10
10	3.479	4.192	4.631	4.951	5.206	5.417	5.598	5.757	5.898	6.026
11	3.409	4.095	4.515	4.821	5.064	5.265	5.438	5.589	5.723	5.844
12	3.352	4.015	4.421	4.716	4.949	5.143	5.308	5.453	5.582	5.698
13	3.305	3.950	4.343	4.629	4.854	5.041	5.201	5.341	5.465	5.577
14	3.265	3.895	4.278	4.556	4.775	4.956	5.111	5.247	5.367	5.476
15	3.231	3.848	4.222	4.493	4.707	4.884	5.035	5.167	5.284	5.390
16	3.202	3.808	4.174	4.440	4.649	4.822	4.969	5.098	5.212	5.315
17	3.176	3.772	4.132	4.393	4.598	4.768	4.912	5.038	5.150	5.251
18	3.153	3.741	4.096	4.352	4.554	4.720	4.862	4.986	5.095	5.194
19	3.133	3.714	4.063	4.316	4.514	4.678	4.817	4.939	5.047	5.144
20	3.115	3.689	4.034	4.283	4.479	4.640	4.778	4.898	5.004	5.100
30	3.005	3.539	3.857	4.085	4.264	4.411	4.536	4.644	4.741	4.827
50	2.921	3.424	3.722	3.934	4.101	4.237	4.352	4.453	4.542	4.621
70	2.885	3.376	3.665	3.872	4.033	4.165	4.277	4.374	4.459	4.536
90	2.866	3.350	3.635	3.838	3.996	4.125	4.235	4.330	4.414	4.490
110	2.854	3.333	3.615	3.816	3.973	4.101	4.209	4.303	4.386	4.460
120	2.849	3.327	3.608	3.808	3.964	4.091	4.199	4.293	4.375	4.449
∞	2.806	3.268	3.539	3.731	3.881	4.003	4.106	4.196	4.275	4.345

Table 3 : Values of $c^{\alpha}_{k,\lambda,\nu}$ ($\lambda^{-1} = k^{1/2}$, α = .05)

ν\k→ ↓	1	2	3	4	5	6	7	8	9	10
10	1.295	2.145	2.735	3.190	3.562	3.877	4.150	4.392	4.608	4.805
11	1.281	2.115	2.691	3.135	3.497	3.803	4.069	4.304	4.514	4.704
12	1.269	2.090	2.655	3.090	3.444	3.743	4.002	4.231	4.436	4.622
13	1.260	2.069	2.625	3.052	3.399	3.693	3.947	4.171	4.372	4.553
14	1.251	2.052	2.600	3.020	3.362	3.650	3.900	4.120	4.317	4.495
15	1.244	2.037	2.578	2.993	3.330	3.614	3.860	4.076	4.270	4.445
16	1.238	2.024	2.559	2.969	3.302	3.582	3.825	4.038	4.229	4.402
17	1.233	2.012	2.543	2.948	3.277	3.555	3.794	4.005	4.194	4.364
18	1.228	2.002	2.528	2.930	3.256	3.530	3.767	3.976	4.162	4.331
19	1.224	1.993	2.515	2.914	3.237	3.508	3.743	3.950	4.135	4.301
20	1.220	1.985	2.504	2.899	3.220	3.489	3.722	3.927	4.110	4.275
30	1.197	1.935	2.432	2.809	3.113	3.369	3.589	3.782	3.955	4.110
50	1.178	1.895	2.376	2.738	3.031	3.275	3.486	3.670	3.835	3.983
70	1.170	1.879	2.352	2.709	2.996	3.236	3.442	3.623	3.784	3.929
90	1.166	1.870	2.339	2.693	2.977	3.214	3.418	3.597	3.756	3.900
110	1.163	1.864	2.331	2.682	2.965	3.201	3.403	3.581	3.739	3.881
120	1.162	1.862	2.328	2.679	2.960	3.196	3.398	3.575	3.732	3.874
∞	1.153	1.841	2.298	2.642	2.917	3.147	3.344	3.516	3.669	3.807

Table 4 : Values of $C^{\alpha}_{k,\lambda,\nu}$ ($\lambda^{-1} = k^{1/2}$, $\alpha = .01$)

ν\k→ ↓	1	2	3	4	5	6	7	8	9	10
10	2.394	3.561	4.350	4.951	5.440	5.851	6.207	6.521	6.801	7.055
11	2.349	3.480	4.242	4.821	5.290	5.685	6.027	6.327	6.596	6.838
12	2.313	3.415	4.154	4.716	5.170	5.551	5.881	6.171	6.429	6.663
13	2.282	3.361	4.082	4.629	5.070	5.441	5.760	6.042	6.292	6.519
14	2.257	3.315	4.022	4.556	4.987	5.348	5.660	5.933	6.178	6.398
15	2.235	3.277	3.970	4.493	4.915	5.269	5.574	5.841	6.080	6.295
16	2.216	3.243	3.925	4.440	4.854	5.201	5.500	5.762	5.996	6.207
17	2.199	3.214	3.886	4.393	4.801	5.142	5.436	5.693	5.923	6.130
18	2.185	3.188	3.852	4.352	4.754	5.090	5.379	5.633	5.859	6.062
19	2.172	3.165	3.822	4.316	4.712	5.044	5.329	5.579	5.802	6.003
20	2.160	3.145	3.795	4.283	4.675	5.003	5.285	5.532	5.751	5.949
30	2.089	3.020	3.629	4.085	4.449	4.753	5.013	5.241	5.443	5.625
50	2.035	2.925	3.504	3.934	4.278	4.563	4.808	5.021	5.210	5.380
70	2.012	2.885	3.451	3.872	4.207	4.485	4.723	4.930	5.114	5.279
90	1.999	2.863	3.423	3.838	4.168	4.442	4.676	4.880	5.061	5.224
110	1.991	2.849	3.405	3.816	4.144	4.415	4.647	4.849	5.028	5.189
120	1.988	2.844	3.398	3.808	4.135	4.405	4.636	4.837	5.016	5.176
∞	1.960	2.795	3.333	3.731	4.047	4.309	4.532	4.726	4.898	5.052

Table 5 : Values of $C^{\alpha}_{k,\lambda,\nu}$ ($\lambda = 1$, $\alpha = .05$)

ν\k→ ↓	1	2	3	4	5	6	7	8	9	10
10	1.295	1.745	2.011	2.204	2.357	2.483	2.591	2.686	2.770	2.846
11	1.281	1.720	1.980	2.168	2.316	2.439	2.544	2.635	2.717	2.791
12	1.269	1.700	1.954	2.138	2.283	2.402	2.505	2.594	2.673	2.745
13	1.260	1.683	1.933	2.113	2.255	2.372	2.472	2.559	2.637	2.707
14	1.251	1.669	1.915	2.092	2.231	2.346	2.444	2.530	2.606	2.675
15	1.244	1.657	1.899	2.074	2.211	2.324	2.421	2.505	2.580	2.648
16	1.238	1.646	1.886	2.058	2.193	2.305	2.400	2.483	2.557	2.624
17	1.233	1.637	1.874	2.044	2.178	2.288	2.382	2.464	2.537	2.603
18	1.228	1.629	1.863	2.032	2.164	2.273	2.366	2.448	2.520	2.585
19	1.224	1.622	1.854	2.021	2.152	2.260	2.352	2.433	2.504	2.568
20	1.220	1.615	1.846	2.012	2.141	2.249	2.340	2.419	2.490	2.554
30	1.197	1.575	1.794	1.952	2.075	2.176	2.262	2.337	2.403	2.463
50	1.178	1.543	1.755	1.905	2.023	2.119	2.201	2.273	2.336	2.392
70	1.170	1.530	1.738	1.886	2.001	2.096	2.176	2.246	2.307	2.363
90	1.166	1.523	1.729	1.875	1.989	2.083	2.162	2.231	2.292	2.346
110	1.163	1.518	1.723	1.868	1.982	2.074	2.153	2.222	2.282	2.336
120	1.162	1.516	1.721	1.866	1.979	2.071	2.150	2.218	2.278	2.332
∞	1.153	1.500	1.700	1.841	1.952	2.042	2.118	2.184	2.243	2.295

Table 6: Values of $c^{\alpha}_{k,\lambda,\nu}$ ($\lambda = 1$, $\alpha = .01$)

ν\k→ ↓	1	2	3	4	5	6	7	8	9	10
10	2.394	2.924	3.245	3.479	3.664	3.818	3.950	4.066	4.168	4.261
11	2.349	2.859	3.167	3.391	3.569	3.715	3.841	3.951	4.049	4.138
12	2.313	2.806	3.104	3.320	3.491	3.632	3.753	3.859	3.953	4.038
13	2.282	2.763	3.052	3.261	3.427	3.563	3.680	3.783	3.874	3.956
14	2.257	2.726	3.008	3.212	3.373	3.506	3.619	3.719	3.807	3.886
15	2.235	2.695	2.971	3.170	3.327	3.457	3.568	3.664	3.750	3.828
16	2.216	2.668	2.938	3.134	3.287	3.414	3.523	3.617	3.702	3.777
17	2.199	2.644	2.910	3.102	3.253	3.378	3.484	3.577	3.659	3.733
18	2.185	2.624	2.886	3.075	3.223	3.345	3.450	3.541	3.622	3.695
19	2.172	2.605	2.864	3.050	3.196	3.317	3.420	3.509	3.589	3.660
20	2.160	2.589	2.844	3.028	3.172	3.291	3.393	3.481	3.560	3.630
30	2.089	2.489	2.725	2.894	3.027	3.135	3.228	3.309	3.380	3.444
50	2.035	2.412	2.634	2.792	2.916	3.017	3.103	3.178	3.244	3.303
70	2.012	2.380	2.596	2.750	2.870	2.968	3.052	3.124	3.188	3.245
90	1.999	2.362	2.575	2.727	2.845	2.941	3.023	3.094	3.157	3.213
110	1.991	2.351	2.562	2.712	2.829	2.925	3.005	3.076	3.138	3.193
120	1.988	2.347	2.557	2.707	2.823	2.918	2.999	3.069	3.130	3.186
∞	1.960	2.308	2.511	2.655	2.767	2.858	2.935	3.002	3.062	3.114

We see that the values of the critical constants increase in k and decrease in ν. This behaviour of our constants is in agreement with the constants proposed by Liu (1997) for the normal setting. Moreover, for larger values of ν (approximate normality) the constants proposed here are close to the constants given by Liu (1997). If θ is known the value of critical points can be read from these Tables against $\nu = \infty$.

Remark: The termination of numerical iteration process is theoretically questionable. However, we have not encountered such difficulty, even once, while carrying out huge computation work during the preparation of Tables 1-6. Further, we expect the termination of iteration process at least asymptotically since for large sample sizes our critical values and the critical values computed by Liu (1997) under normal probability distribution models are very close.

3.1 Validity of Critical Points

The validity of critical points $c = c^{\alpha}_{k,\lambda,\nu}$ has been checked through statistical simulation as explained below:

Random samples of sizes n (n_0) were generated from each of the k treatment (control) populations with equal μ and θ values. Then procedure R_1 was applied to see the misclassification for nominal value of α (probability of misclassification) using critical constants $c = c^{\alpha}_{k,\lambda,\nu}$. This process is repeated 4×10^5 times by generating fresh random samples in each repetition. The proportion of misclassification, say, $\hat{\alpha}$ observed in 4×10^5 repetitions along with the relevant configurations are presented in Table-7.

Table 7: α using c = $c^{\alpha}_{k,\lambda,\nu}$ when $\mu_0 = \mu_1 = \ldots \mu_k = \mu$ =4, θ = 3 & α = .05

n	n_0	k	c	$\hat{\alpha}$
5	5	3	1.886	.0088
5	5	4	2.012	.0051
4	8	3	2.734	.0017
4	8	4	2.914	.0047

Form Table-7 we see that the proposed critical values are conservative, i.e., the actual levels of misclassification $\hat{\alpha}$ of the proposed critical points are less than the nominal level α.

In order to check the performance of the proposed procedure, the above simulation process was also carried out for few tight configurations of μs. Various configurations of treatment and control populations considered in the simulation along with the proportion of no-misclassification, say 1-, α observed among 4×10^5 repetitions of relevant set of configurations, are presented in Table-8.

Table 8: (1-$\hat{\alpha}$) with different μs using c = $c^{\alpha}_{k,\lambda,\nu}$ & α = .05

n	n_0	k	c	m	μ_0	μ_1	μ_2	μ_3	μ_4	θ	1-α
5	5	3	1.886	2	1	3	2	5	-	3	.9658
5	5	4	2.012	2	4	5	5.5	2	3	2	.9978
4	8	3	2.734	2	3	4	3.5	2	-	5	.9673
4	8	4	2.914	3	5	6	6.5	7	4.5	8	.9898

The simulated values of probability of no-misclassification 1-$\hat{\alpha}$, presented in Table-8, are greater than the corresponding nominal level 1-α = 95 for tight configurations of μs and small sample sizes. It is expected that our procedure will perform quite efficiently for large samples on the basis of small sample sizes results of Table-8 and the fact that for large sample sizes our critical points are close to those proposed by Liu (1997) under normal probability distribution models.

In the following Section we discuss the scale version of the above procedure, i.e., two-sided comparisons of treatments with the control in terms of the scale parameters.

4. Procedure for the Scale Case

Using the notations given in the introduction a multiple three-decision procedure, say R_2, for the two-sided comparisons of the treatments with the control in terms of the scale parameters, to decide which treatments are better and worse than the control is as follows:

$$\begin{cases} \text{infer } \theta_i/\theta_0 > 1 & \text{if } S_i/S_0 > t \\ \text{infer } \theta_i/\theta_0 < 1 & \text{if } S_i/S_0 < 1/t \\ \text{make no decision on the value of } \theta_i/\theta_0 & \text{if } 1/t \le S_i/S_0 \le t, \end{cases} \quad (4.1)$$

where for a given value α (0<α<1) the critical constant t (t>1) is chosen such that

$$a^*(\underline{\theta}|R_2) = P[\text{no misclassification of any treatment}] \ge 1-\alpha \quad \text{for all } \underline{\theta} \in R^{k+1}_{+}. \quad (4.2)$$

It can be seen that

$$a^*(\underline{\theta}, R_2) = P_{\underline{\theta}}\Big[W_i/W_0 \ge (1/t)(\theta_0/\theta_i) \text{ for all } i \in \Omega_U(\underline{\theta},1) \text{ and } W_j/W_0 \le t(\theta_0/\theta_j) \text{ for all } j \in \Omega_L(\underline{\theta},1)\Big]$$

$$\ge P\Big[W_i/W_0 \ge (1/t) \text{ for all } i \in \Omega_U(\underline{\theta},1) \text{ and } W_j/W_0 \le t \text{ for all } j \in \Omega_L(\underline{\theta},1)\Big],$$

since $\theta_0/\theta_i<1$ for all $i \in \Omega_U(\underline{\theta},1)$ and $\theta_0/\theta_j>1$ for all $j \in \Omega_L(\underline{\theta},1)$. Here $W_i(W_0) = S_i/\theta_i(S_0/\theta_0)$, $i = 1,\ldots,k$ are independent gamma variates divided by their shape parameters $\nu_i(\nu_0)$. If m is the cardinality of the set $\Omega_U(\underline{\theta},1)$ then, as discussed in Theorem 3.1, $a^*(\underline{\theta}|R_2)$ attains infimum at the least favourable point $\underline{\theta}^* = (1,1^+,\ldots,1^+,1^-,\ldots,1^-) \in R^{k+1}_{+}$, where the last k-m components are equal to 1^- and middle m components are equal to 1^+. It may be noted that our results for the least favourable point of the location as well as the scale parameter vectors are similar to those proved by Tong (1969), Bohrer *et al.* (1981), Giani and Strabburger (1994) and Liu (1997) in different contexts for the location parameters under normal probability distribution models. The infimum value of $a^*(\underline{\theta}|R_2)$ is

$$\inf_{\underline{\theta}} a^*(\underline{\theta}|R_2) = \inf_m a^*(\underline{\theta}^*|R_2)$$

$$= \inf_m \int_0^\infty \prod_{i=1}^{m} P[W_i \ge w/t] \prod_{i=1}^{k-m} P[W_i \le tw] g_{\nu_0}(w)dw$$

$$= \inf_m \int_0^\infty [1-G_{\nu_1}(w/t)]^m [G_{\nu_1}(wt)]^{k-m} g_{\nu_0}(w)dw, \quad (4.3)$$

where $\nu_1 = \nu_i = n-1, i = 1,...,k$ and $\nu_0 = n_0 - 1$. Now using the numerical iteration process, as explained in Section 3 for the location case, one can compute the critical points $t = t^{\alpha}_{k,\nu,\nu_0}$. We have written a general program to compute the critical points t but their values have been presented in Tables 9 and 10 for balanced case, i.e; $\nu_1 = \nu_0 = \nu$, to economise the space.

Table 9 : Values of $t = t^{\alpha}_{k,\nu,\nu_0}$, α = .05, $\nu_1 = \nu_0 = \nu$

ν\k→ ↓	1	2	3	4	5	6	7	8	9	10
10	2.127	2.467	2.657	2.793	2.901	2.989	3.065	3.133	3.194	3.248
11	2.050	2.360	2.532	2.654	2.750	2.829	2.897	2.958	3.012	3.061
12	1.986	2.272	2.428	2.539	2.627	2.698	2.761	2.815	2.864	2.908
13	1.931	2.196	2.341	2.443	2.523	2.588	2.646	2.696	2.740	2.780
14	1.884	2.132	2.266	2.361	2.434	2.495	2.549	2.595	2.635	2.672
15	1.842	2.075	2.201	2.290	2.358	2.415	2.465	2.507	2.545	2.579
16	1.806	2.026	2.144	2.227	2.291	2.345	2.391	2.431	2.466	2.498
17	1.773	1.982	2.094	2.172	2.233	2.283	2.327	2.364	2.397	2.426
18	1.744	1.943	2.049	2.123	2.180	2.229	2.270	2.305	2.336	2.363
19	1.718	1.908	2.009	2.079	2.133	2.179	2.218	2.252	2.281	2.307
20	1.694	1.876	1.972	2.040	2.091	2.135	2.172	2.204	2.232	2.256
30	1.535	1.667	1.735	1.782	1.820	1.850	1.875	1.897	1.916	1.933
50	1.392	1.483	1.529	1.561	1.586	1.606	1.623	1.637	1.650	1.661
70	1.322	1.395	1.431	1.456	1.476	1.491	1.504	1.515	1.525	1.533
90	1.279	1.341	1.371	1.392	1.409	1.422	1.432	1.442	1.450	1.457
110	1.249	1.303	1.330	1.349	1.363	1.374	1.384	1.392	1.399	1.405
120	1.237	1.289	1.314	1.332	1.345	1.356	1.365	1.372	1.379	1.385

Table 10 : Values of $t = t^{\alpha}_{k,\nu,\nu_0}$, α = .01, $\nu_1 = \nu_0 = \nu$

ν\k→ ↓	1	2	3	4	5	6	7	8	9	10
10	2.953	3.334	3.562	3.727	3.858	3.967	4.061	4.143	4.216	4.283
11	2.798	3.139	3.341	3.487	3.602	3.698	3.780	3.852	3.916	3.974
12	2.671	2.979	3.161	3.292	3.395	3.480	3.553	3.617	3.674	3.725
13	2.565	2.846	3.011	3.130	3.223	3.301	3.366	3.424	3.475	3.521
14	2.474	2.734	2.885	2.994	3.079	3.150	3.210	3.262	3.309	3.351
15	2.395	2.637	2.777	2.877	2.956	3.021	3.076	3.124	3.167	3.206
16	2.326	2.553	2.683	2.777	2.849	2.910	2.961	3.005	3.045	3.081
17	2.266	2.478	2.601	2.688	2.757	2.813	2.860	2.902	2.939	2.972
18	2.212	2.413	2.528	2.610	2.674	2.727	2.771	2.810	2.845	2.876
19	2.163	2.354	2.463	2.541	2.601	2.651	2.693	2.729	2.762	2.791
20	2.120	2.301	2.405	2.478	2.535	2.582	2.622	2.657	2.687	2.715
30	1.839	1.965	2.035	2.084	2.123	2.154	2.180	2.203	2.224	2.242
50	1.599	1.682	1.728	1.759	1.783	1.804	1.821	1.835	1.848	1.859
70	1.486	1.550	1.585	1.610	1.629	1.644	1.657	1.668	1.677	1.686
90	1.417	1.471	1.501	1.521	1.536	1.549	1.560	1.569	1.577	1.584
110	1.371	1.418	1.443	1.460	1.474	1.485	1.494	1.502	1.509	1.515
120	1.352	1.397	1.421	1.437	1.450	1.460	1.469	1.476	1.482	1.488

4.1 Application to Normal Probability Model

Let an observation from population π_i follow normal distribution with mean μ_i and variance σ_i^2, $i = 0,1,\ldots,k$. In this case $S_i = \sum_{j=1}^{n}\left(X_{ij} - \bar{X}_i\right)^2 \Big/ \nu_i$ $\left(S_0 = \sum_{j=1}^{n_0}\left(X_{ij} - \bar{X}_0\right)^2 \Big/ \nu_0\right)$ is an unbiased estimator of $\sigma_i^2\left(\sigma_0^2\right)$ where $\bar{X}_i = \sum_{j=1}^{n} X_{ij}/n$, $\bar{X}_0 = \sum_{j=1}^{n_0} X_{0j}/n_0$, ν_i=n-1, i= 1,...,k and $\nu_0 = n_0$-1. Here $(\nu_i S_i)/2\theta_i$ follows gamma distribution with shape parameter $\nu_i/2$, $i = 0,1,\ldots,k$. Now, the Critical points given in the Tables 9 & 10 under the exponential probability model with $\nu = n$-1 can also be used for the scale parameter case under normal probability model by taking $\nu = (n\text{-}1)/2$.

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MANAGING INFORMATION SECURITY – A GROWING CHALLENGE

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Abstract

The immense popularity of the Internet as a business medium, and organizations opening their internal networks to customers and partners, has changed the nature of computing environment significantly. While providing convenience, the systems are more vulnerable to security threats and managing information security is getting nightmarish by the day. This paper attempts to identify the myths about information security and shows a more appropriate management strategy for organizations to follow for enhancing security. A comprehensive analysis should be conducted to identify resources that need to be protected. The resources should be classified according to the sensitivity level of information. A cost-benefit analysis should be performed to determine the level of security precautions that should be taken. Since it is impossible to have perfect security, consideration should be given to contingency planning and recovery. If the security is compromised, the organization should be able to recover quickly to keep the business running and minimize damages. Information security in the light of IT Act 2000 of GOI has also been discussed.

Keywords : Computer Security, Network Security, Information Security, Data Backup, Data Recovery, Access Control, Audit Trail, Contingency Planning.

INTRODUCTION

Information security has managed to get a tremendous amount of attention in the past few years, even grabbing headlines in the mainstream media. Despite this attention, asking ten people what Information Security is will likely result in ten different answers. To some people, security is about keeping the bad guys out of their systems. To others, security is about elimination of all threats. To still others, security is about management of risk. Despite the presence of security in the mainstream consciousness, outside of the Information Security community, there still isn't much agreement about what exactly security means.

Information is an asset that, like other important business assets, has value to an organization and consequently needs to be suitably protected. Information security protects information from a wide range of threats in order to ensure business continuity, minimize business damage and maximize return on investments and business opportunities [1].

Information can exist in many forms. It can be printed or written on paper, stored electronically, transmitted by post or using electronic means, shown on films, or spoken in conversation. Whatever form the information takes, or means by which it is shared or stored, it should always be appropriately protected.

Information security [9] is characterized as the preservation of:

- **Confidentiality**
  Simply means that the information is known no more widely than necessary. If you tell some medical secret to your physician, there has been no breach of confidentiality, because the fact was needed by the physician to render the requested service. If, on the other hand, your physician then tells your secret to someone else not involved in your treatment, confidentiality would be breached.
- **Integrity**
  Is the assurance that the information is untainted. Note that this does not deal with the *accuracy* of the information--it strictly means that the information put into the computer is the same as the information that comes back later.
- **Availability**
  Means that when the information is needed, it is ready for use. To many, this might seem counter-intuitive. But consider, if an attacker wants to put your organization out of business, wouldn't the ability to deny you access to your own information for a long enough time do the trick?

Information security can be achieved by implementing a suitable set of controls, which could be policies, practices, procedures, organizational structures and software functions. These controls need to be established to ensure that the specific security objectives of the organization are met.

Information Security includes many security concepts (see Figure 1) such as

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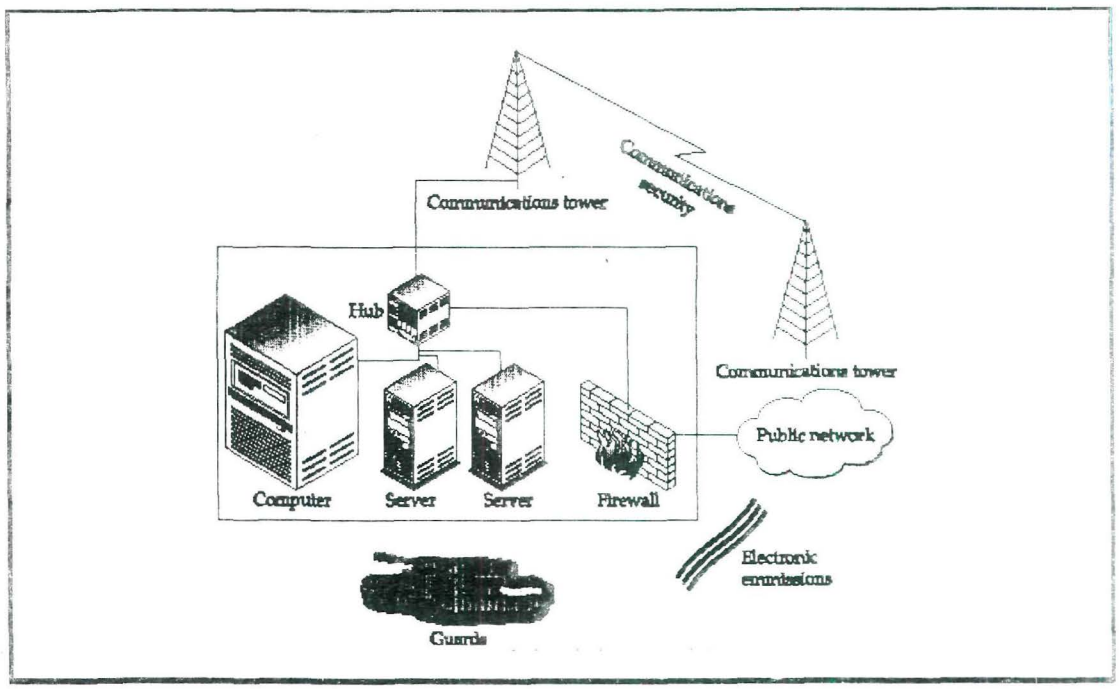

Fig. 1 : Information Security

- **Physical Security**
  This is necessary to protect physical assets like paper records and systems.

- **Communication Security**
  This is necessary to protect information in transit.

- **Emission Security**
  This is needed when the enemy has significant resources to read the electronic emissions from the computer systems.

- **Computer Security**
  This is necessary to control access on computer systems.

- **Network Security**
  This is needed to control the security of local area networks.

Managing Computer Security

Security has taken center stage in today's world with the increase in threat every year from attacks on computer systems. News events about computer related data errors, thefts, burglaries, fires, and sabotage dominate. The increased use of networked computers, including the Internet, Intranet, and the Extranet, has had a profound effect on computer security. The nature of the computing environment has changed significantly. The greatest advantage of remote access via networks is convenience. This convenience makes the system more vulnerable to loss. As the number of points from which the computer can be accessed increases, so does the threat of attack. More caution is clearly needed to counter such threats.

The first step in managing computer security is to identify the resources that need to be protected. For example, the resource to be protected might be CPU cycles or computer time. This is unlikely to be the objective of most attackers or hackers. Frequently, hackers are interested in obtaining access to private or confidential information. Sometimes, the organization may not even consider the information to be 'valuable' to anyone else and may not be willing to take security precautions. This is a serious mistake. Hackers often steal or destroy data or information simply because it is there. Other hackers may delete or destroy files in an attempt to cover their illegal activity. This leads to just one conclusion – A casual attitude towards computer security is never justified.

The second step in managing computer security is to determine against whom do you want to protect your system. The security needs of a military computer system are likely to be significantly different from the security needs of a corporation. Are you trying to protect your computer system from teenagers 'playing around', or corporate spies, or industrial espionage?

The third step in managing computer security is balancing the costs and benefits of various security safeguards. In other words, how much are you willing to spend on security? Clearly, it is prudent to spend more on protecting resources that are of greater value to the organization. The cost of security safeguards include not only the direct costs of the safeguards, such as equipment and installation costs, but also indirect costs such as employee morale and productivity. It is important to recognize that increasing security typically results in reduced convenience. For example, employees may resent the inconvenience that results from implementing security safeguards. Too much security can be just as detrimental as too little security; a balance must be maintained.

The last step in managing computer security is contingency planning. If security is violated, how do you recover? What are the data backup policies? What are legal consequences? What will be the financial impact? A risk analysis should be performed in planning computer security policies and financial support. Computer risks fall into one of three major categories: destruction, modification, and disclosure. Each of these may be further classified into intentional, unintentional and environmental attacks. The threat comes from computer criminals and disgruntled employees who intend to defraud, sabotage, and 'hack'. It also comes from computer users who are careless or negligent. Lastly, the threat comes from the environment; an organization must protect itself from disasters such as fire, flood, and earthquakes. An effective security plan must consider all three types of threats: intentional attacks, unintentional attacks, and environmental attacks. What is the organization's degree of risk exposure? Insurance policies should be taken out to cover such risks as theft, fraud, intentional destruction, and forgery. Business interruption insurance covers lost profits during downtime.

Computer System Failures

A Computer system can fail for several reasons, including:

- Operator mistakes
- User mistakes
- Malicious acts
- Hardware malfunction
- Software bugs
- Environmental factors, such as lightning, fire, earthquake, or power outage.

When discussing computer reliability, it is useful to distinguish between *errors, failures* and *faults* in a computer system. An error occurs when there is a deviation from expectations. Some errors are acceptable because they can be overcome, others are not. An unacceptable error is a failure. If the failure can have serious consequences, it is considered a critical failure. A fault is a condition that results in a failure.

System reliability is distinct from system security. Security is designed to protect against intentional misuse and does not consider malfunction. Improving one factor often enhances the other factor. Both factors need to be considered in managing risk.

Establishing a Security Policy

Every organization should have a security policy that defines the limits of acceptable behavior and the organization's response to violations of such behavior. Its purpose is to assign accountability and delegate authority across the organization. The security policy will naturally differ from organization to organization, based on its own unique needs. For example:

- There may be an edict barring the playing of computer games on corporate computers.
- There may be a policy against visiting adult web sites on the Internet using corporate Internet accounts or computers.
- Some organizations may wish to restrict the use of a specific protocol because it cannot be administered securely.
- Employees may be prohibited from taking copies of certain corporate data out of office premises.
- There may be a policy prohibiting use of pirated software.

The security policy should not only define acceptable behavior, but it should also contain the organization's response to violations. How will the violators be reprimanded? Will the organization reprimand violators inside the organization differently from violators outside the organization? What type of civil or criminal actions might be taken against violators?

The security policy should be a broad statement that guides individuals and departments in achieving certain goals. The specific actions needed to realize the goals are contained in supporting standards rather than in the policy document. The security policy should be concise and to the point, generally not exceeding ten pages. It should be easy to understand. Its focus should be on emphasizing the role of individuals and departments in achieving the objectives. It is not the purpose of the security policy to educate or train individuals. Such an objective is better served through training seminars.

The background for developing a security policy should be discussed. It should explain the purpose of security,

including why data integrity must be maintained. The importance of maintaining confidentiality and privacy of information resources should be emphasized. The continuous availability of information is important for the organization and any interruption can have serious financial consequences.

Employees should understand computer security is everyone's responsibility. The scope of the computer security policy should encompass all locations of the organization and all of its subsidiaries. Security is only as strong as its weakest link and therefore the same set of standards should be used throughout the organization. This means that the standards should be flexible enough so they can be used in a wide variety of circumstances and conditions, yet they should provide consistency and quality across the organization.

The security policies apply to all computer facilities and the data they contain, including standalone computers, Internet and Intranet sites, local area networks (LANs), and wide area networks (WANs). All forms of electronic communication, including email and fax and data transmissions are covered by the security policy. Other printed material, such as documentation and technical specifications, should be included in the security policy.

Computer security should be viewed as a means to an end and not an end itself. Computer security is an integral component of an organization's overall risk management strategy. The responsibilities of various departments and individuals should be identified in the security policy. The policy established should be evaluated on a periodic basis to incorporate changes in technology or circumstances. The authority for issuing and amending the security policy should rest with a committee such as the Information Technology Management Committee. This committee should be responsible for determining when circumstances justify departure from the policy; the committee should approve all exemptions and exceptions.

Active participation by individuals and departments is needed for a security policy to succeed. It is well established that individuals are more likely to accept the security policy if they have had input during its creation. The real benefit of participation is that employees or departments will make a positive contribution to the policy by imparting their knowledge. Senior management's support and cooperation is critical in implementing the policy.[8]

The relationship between the computer security policy and other corporate policies should be described. For example, the computer security policy should be used in conjunction with the firm's policies for:

- The internal control structure.
- Contingency plans, including business resumption planning.
- Privacy and confidentiality.
- Compliance with laws and regulations.

A process should be in place to ensure compliance with laws and regulations. Privacy and confidentiality issues have a serious effect on computer security. Increased governmental regulation should be expected in the future. The legal department should assist department heads in complying with laws and regulations.

The Computer Centre's and its security personnel's responsibilities should be defined in the security policy document. These responsibilities include:

- Ensuring that security personnel have the training and skill needed to perform duties required by the security
- Providing systems development methodology for security needs.
- Be responsible for all cryptographic methods and keys.
- Provide and manage virus detection software for networked and standalone computers.
- Be responsible for acquiring hardware or operating -systems that are not currently part of the organization's architecture.
- Authorizing the use of network, including the Internet and Intranet.
- Review, evaluate and approve all contracts with third parties concerning information systems.

For personal computer systems, additional precautions are needed and should be addressed in the security policy. Some points to consider include:

- All original data should be backed up on a periodic basis.
- Personal computers connected to a network may be a source of viruses; virus detection software should always be used, especially before copying data or programs on to the network.
- Confidentiality and privacy of data may be compromised.
- Certain types of confidential or important data should never be stored on a local hard drive; instead such data should be stored on the network, or on floppy or compact disks or

removable hard drive so that it may be removed and stored in a secure place.

- Standards should be established for remote access.
- Personal computers should not be directly connected to the Internet since the Internet is a source of virus infections and hackers may be able to gain access through it; Internet access should be only through the organization's Internet server, which is capable of protecting itself.

Physical Security and Data Security

Both physical and data security considerations are equally important. An effective security system will prevent a security breach. However, if in spite of proper protection, a system is successfully attacked, the system will create an audit trail to allow prompt investigation.

Unauthorized access to the computer facilities should be restricted and sensing and surveillance devices should be installed. Computer environment, including heating, cooling, dehumidifying, ventilating, lighting, and power should be protected. Appropriate care must be taken to protect the plant from harm, from accidents and disasters such as fire and floods. Adequate emergency lighting should be available for safe evacuation in case of fire or other disaster. Consideration must be given to loss or damage to computer equipment and peripherals. Media, such as disks, tapes, and output should be protected. User manuals for equipment and software must be protected to maintain continuity of proper operations. Surge protectors should be used to protect the computer system against power line disturbances. Finally, the organization must consider loss of or injury to its personnel.[6]

The layout of computer facilities is important in planning for computer security as well as achieving cost savings. As computers become smaller, they can be housed in smaller areas and this changes the way facilities are designed and planned. For example, it is no longer necessary to have raised floors in the computer room. If wiring is a concern, cables can generally be along the walls. If flooding is a concern, aluminum channels or I-beams can be used to raise components and cabinets. Placing the network equipment inside next to the processing equipment can save cabling costs. Smaller components may be stacked vertically to conserve floor space and reduce cable costs.

The computer facilities should be housed in a building's core area near wire distribution centers. Care should be taken to avoid a location where water or steam pipes cross either vertically or horizontally. The room should be sealed to keep out smoke and dust.

Only one *door* should be used for access into a secured area. The *door* should be self-closing and it should not have a hold-open feature. A combination or programmable lock may be sufficient. An alarm system should be installed. There should not be any direct access from public places.

Wires and Cables

With the increase in distributed computing, it is even more essential to protect the wiring system. Wires and cables are generally made of either copper or optical fiber. Fiber optics offers significant performance and security advantages. However, they cost more to install. Still, if considerable data needs to be transferred, the cost disadvantage of fiber optics rapidly diminishes.

Cables and wires are fragile. They can be easily damaged. It is not possible to repair damaged wires; they must be replaced. The electrical properties of cables may also be affected and the data may become unreliable. Alternate paths should always be provided for cables linking important or critical paths.

Fiber optics offers better security protection. It is relatively easy for someone to wire tap copper lines if they can obtain access anywhere along its length. Such wiretaps are very difficult to detect. In contrast, it is difficult and expensive to wire tap fiber optics. Moreover, normal operations are disturbed in a fiber optics tap and can therefore be detected more easily. Even with fiber optics, it is possible that a skilled individual with proper equipment can tap the system undetected. Fiber optics provides a deterrent, but should not be viewed as being perfectly secure. Of course, the best way to protect sensitive data is to use some type of encryption.

Fiber optics is not affected by electrical or magnetic interference. Copper wires have to be shielded with cabling and grounded metal conduits have to be provided. The ends of all fiber optic cables must be microscopically smooth. They have to be exactly aligned and positioned. This requires the use of expensive special equipment and highly trained personnel.

A knowledgeable and experienced individual should certify data wiring. Such an individual should:

- Perform a visual inspection.
- Check that each cable is connected correctly. Check that there are no crossed pairs.
- Use a reflectometer to detect if there are any constrictions, bad terminations, or external interference.

Purchase orders for any wiring should specify:

- Who will certify the wiring?
- What equipment will be used to test the wiring?
- What standards will be followed?

Destroying Data

Once data is no longer needed, it must be properly destroyed. Information on magnetic media is typically 'destroyed' by over-writing on it. While the information appears to have been destroyed, there are many subtle ties to consider. For example, if the new file is shorter than the old file, information may remain on the magnetic media beyond the new file's end-of-file marker. Any information beyond the end-of-file can be easily retrieved. A safe method is to overwrite the entire media. However, overwriting the entire media is time consuming and other methods, such as degaussing should be used. Degaussers are essentially bulk erasure devices and when used within their specification provide adequate protection. [9]

Formatting a disk does not safely destroy all information. It is important to note that magnetic media may retain a latent image of the preceding bit value after the write insertion of a new bit value. This occurs due to the inability to completely saturate the magnetization. While normal read/write operations are not affected by this limitation, it does pose a security threat and anyone with sophisticated equipment could exploit it.

For papers and other soft materials, such as microfiche and floppy disks, it is possible to shred them. Some shredders cut in straight lines or strips. Others offer crosscutting and particle producing. Some shredders disintegrate by repeatedly cutting and passing the material through a fine screen. Shredders may also grind the material and make pulp out of it.

Burning is still another way to destroy sensitive data that is no longer needed. As with shredding, burning means that the storage media can no longer be reused. Even when burning, one needs to exercise caution. It is possible, for example, to retrieve printed information using special techniques from intact paper ashes, even though the information may no longer be visible to the human eye.

Environmental Considerations

Computer facilities are susceptible to damage from environmental factors. Fire security is especially important and is discussed in detail in a separate section. Other important factors include heat, water, humidity, dust and power failure.

- ***Heat*** and high temperature can cause electronic components to fail. Air conditioning is generally essential for reliable operation. Simple precautions should be taken to ensure that air vents are not blocked and that the air is allowed to circulate freely. Backup power should be available for air conditioning if the computer system will be used even if the primary power fails.
- ***Water*** is an obvious enemy of computer hardware. Floods, rain, sprinkler system, burst pipes, etc. could do significant damage. Attention should be given to the design of routing water pipes and the location of the computer facilities. Instead of a traditional sprinkler system, consider using an alternate fire-extinguishing agent that will not damage the hardware.
- ***Humidity*** at either extreme is harmful to the hardware. High humidity is likely to lead to condensation that can corrode metal contacts or cause electrical shorts. Low humidity is likely to permit the buildup of static electricity. Computer facilities should either be housed on bare floors or floors covered with anti-static carpeting. Humidity should be continuously monitored and kept at acceptable levels.
- ***Dust***, dirt, and other foreign particles can ruin computer hardware. For example, dust can interfere with proper reading and writing on magnetic media. Personnel should not be permitted to eat or drink near the computer facilities. Air should be filtered and filters replaced at appropriate intervals.
- ***Power failure*** can render all equipment useless. Brownouts and blackouts are the most visible sign of power failure. However, voltage spikes are much more common and can cause serious damage. Lightning may produce spikes and such spikes may either damage equipment or randomly alter or destroy the data. A drop in line voltage can also lead to malfunction of computer equipment and peripherals. Voltage regulators and line conditioners should be used if electrical fluctuations occur. Use of uninterruptible power supplies should be considered.

Maintenance and Preventive Care

Facilities should be protected against adverse effects of the weather and other environmental factors. Regular maintenance can help prevent unexpected downtime.

Diagnostic programs should be run as part of regular maintenance. Maintenance logs should be kept. Scanning the logs can quickly identify recurring problems. The maintenance log should include, at a minimum, the following information:

- Description of equipment serviced.
- Organization identification number of equipment serviced.
- Date of service.
- Services performed, including the results of diagnostic tests.
- A note indicating whether the service was scheduled or unexpected.

Computer areas should be properly cleaned and dusted. Eating, drinking, and smoking should be prohibited in computer areas. Personnel should be trained in proper handling of computer equipment and peripherals. Personnel should be trained in proper handling of magnetic media and CD-ROMS. For example, magnetic media should not be placed on top of or near telephones, radios, and other electric equipment. Or, labels should be prepared prior to placing them on disk; many untrained personnel will affix the label to the disk and then write on the label using a ballpoint pen. [5]

Computers and peripheral equipment should be cleaned on a regular basis using cleaning products recommended by the manufacturer. Electrical equipment should never be sprayed directly with cleaning liquids. Keyboard surfaces should be cleaned with a damp cloth and vacuumed using special computer vacuums.

Magnetic media devices, especially the read/write heads and transport rollers, should be cleaned using commercially available cleaning products for such purpose. Dust, smoke, fingerprints, and grease can build up on recording surfaces and lead to crashes or permanent damage to the equipment and magnetic media. Printers may need to be cleaned to remove fibers, dust particles and lint. Simple precautions, such as using static-resistant dust covers protect the computer equipment and peripherals. Such covers should only be used when the equipment is not in use. Otherwise, the equipment may overheat and be damaged.

Water Alert Systems

Water alert systems should be installed in locations where water might damage computer equipment. Generally, water alert systems should be installed in the basement or in floors above the computer systems. Water sensing systems are especially useful in protecting electrical cables under the floor. Water sensors should be installed within suspended ceilings and inside water-cooled computer cabinets and process cooling equipment. The water sensors should activate an alarm as well as some type of a drainage pump.

Humidity Control

Humidity should be tightly controlled and maintained at an optimal level. When the air is too dry, static electricity is generated. When humidity is too high, generally at levels above 80% relative humidity, there may be problems with electric connections, as a process similar to electroplating starts to occur. Silver particles start to migrate from connectors on to copper circuits, thus destroying electrical efficiency. A similar process affects the gold particles used to bond chips to circuit boards. Generally, an optimal relative humidity level is about 40-60%.

Fire Protection

According to insurance companies, fire is the most frequent cause of damage to computer centers. No combustible material should be allowed in the computer room. This means special care should be taken in selecting office furniture. Waste receptacles of any kind should not be in the computer room. Instead, waste receptacles should be located nearby, just outside the computer room.

Fire detectors should be installed in appropriate locations and connected to an automatic fire alarm system. Fire detectors sense either changes in temperature or thermal combustion and its byproducts. Fire detectors may be actuated by smoke, heat, or flame.

Most computer room fires will be electrical, caused by overheating of wire insulation or other components. Smoke from an electrical fire may be toxic and it should be avoided in even small quantities. Generally, electrical fires cannot be extinguished till the heat source is eliminated.

A power panel with circuit breakers for the major pieces of equipment should be placed at an easily accessible location, preferably inside the computer room. The circuits should be clearly labeled so equipment can be shut down quickly in an emergency. Redundant devices should be on separate circuits. There should be one emergency switch to shut down everything in the event of a fire.

In the event of a major fire or explosion, the only concern should be the safety of human life. Computer equipment and wiring is likely to be destroyed by the intense heat. Backup copies of disks and data should always be kept at off-site locations. Not only will this help when attempting to recover from a fire, but it can also help during the fire

since the personnel will not attempt to save backup data by risking their lives.

In an electrical fire, it is essential that the power be shut off because a fire extinguishing system will only suppress the fire till power is stopped.

Water sprinkler systems are simple and a relatively inexpensive protection against fire. Most new buildings are required by code to have a sprinkler system. Accidental activation of the sprinkler system can cause substantial damage and it may take a long time before normal operations are resumed. In an electrical fire, water may even intensify the fire and cause greater damage. Sensors should be installed to cut off electrical power before sprinklers are turned on. It should be possible to activate sprinkler heads individually to prevent damage to a wide area. There should be a shut-off valve inside the computer room so that water can be shut off when it is no longer needed. This will minimize damage in the event of accidental activation.

Quick removal of smoke should be a priority. Special fans and blowers should automatically be activated by the smoke or fire alarm..

If computer equipment starts smoking, the first step should be to cut off the equipment's electrical power. This is frequently sufficient and the fire will probably extinguish by itself. If there are visible signs of fire, or if you can feel the heat, an appropriate fire extinguisher should be used. Carbon dioxide extinguishers are often recommended for microcomputer related fires. When using a carbon dioxide extinguisher, do not spray the extinguishing agent directly onto the glass surface of the CRT, since it will lead to a sudden drop in temperature and shatter the glass.

Personnel should be trained for fire emergency. Organization policy should state exactly what action should be taken in the event of a fire or smoke alarm. Personnel should be strictly forbidden from risking injury or loss of life to protect data or equipment.

The following steps can reduce the damage caused by fire, and in the process, reduce insurance premiums:

- Safes for storage of documents should have a minimum four-hour fire rating.
- Walls, floors, and ceilings of computer facilities should have a minimum two-hour fire rating.
- Fire alarm should ring simultaneously at the computer facility and the nearest fire department. In addition, the fire alarm signals should be located where prompt response is assured.
- Vaults used for storing backup tapes and records should be located in a separate building at a sufficient distance.
- Smoke and ionization detection systems should be installed throughout the ceiling of the computer facilities. Water detection systems should be installed under the floor of computer facilities.
- A fire extinguishing system should be installed throughout the computer facilities. Automatic sprinkler systems can be used in the supply and support areas. In case of destruction, there should be a disaster recovery plan.
- Building code and fire marshal regulations must be adhered to strictly.

Controlling Access

The purpose of access control is to ensure that only authorized users have access to a particular system and/or specific resources, and that access to and modification of a particular portion of data is limited to authorized individuals and programs.

The oldest method of restricting physical access is by using some type of lock. Security guards and security dogs are another way to restrict access in a wide variety of situations. The physical presence of guards and dogs serve as a deterrent. In the event of a problem, the guard is able to respond appropriately. Pre-employment screening and bonding are essential when hiring security guards.

Limitations with such methods are well known. Guards can become easily bored with the routine work and may not fulfill their duties as expected. It is easy for someone to forge identification and be let in by a guard. Another limitation of guards is that they may not be informed and, through procedural error, allow unauthorized individuals access to restricted areas.

Guard dogs are also very useful and act as deterrents. Dogs have excellent hearing and a keen sense of smell. Guard dogs can be trained to 'hold' intruders till security personnel arrive. One disadvantage of security dogs is that additional liability insurance must be purchased. Training and maintaining dogs is expensive. Finally, guard dogs generally cannot differentiate between authorized and unauthorized visitors.

Still, security is enhanced if guards and/or dogs patrol the facilities frequently and at random intervals. The use of guards and dogs contribute to psychological deterrence. It lets a potential attacker or intruder know that he might be caught. A determined attacker, of course, is unlikely to be deterred by psychological deterrents and security should always be supplemented through other means.

Something as simple as lights greatly enhances security. Lights improve the ability of security personnel to carry out surveillance. Lights also deter intruders from entering the facilities. Lights may be left on all the time, on timer control, on ambient control, activated by motion detectors, or manually operated.

Computer and terminal access control relates to who or what may have access to a certain service or system. Access control, essentially, is a form of authorization. A user's or service's privileges and rights dictate what services or objects (files, file systems, etc.) may be accessed. There are a number of ways to enforce access control by restricting or limiting access on various services or systems [2]. This may be done at various levels: at the Internet level (one can implement firewalls or application gateways), at the LAN level (one can use Novell Netware for user and file system access control), and also at the operating system level.

- **User-oriented access control:** An example of user access control on a time-sharing system is the user logon, which requires both a user identifier (ID) and a password. The system allows a user to log on only if that user's ID is known to the system and if the user knows the password associated by the system with that ID. This ID/password system is a notoriously unreliable method of user access control because users can forget their passwords and accidentally or intentionally reveal their passwords.

- **Data-oriented access control:** Following successful logon, the user is granted access to a host or set of hosts and applications. This is generally not sufficient for a system that includes sensitive data in its database. Through the user access control procedure, a user can be identified to the system. Each user can be associated with a profile that specifies permissible operations and file accesses. The operating system can then enforce rules based on the user profile.

  The database management system, however, must control access to specific records or even portions of records. For example, anyone in administration may be able to obtain a list of company personnel, but only selected individuals may have access to salary information. The issue is more than just one of the level of details. Whereas the operating system may grant a user permission to access a file or use an application following which there are no further security checks, the database management system must make a decision on each individual access attempt. That decision depends not only on the user's identity but also on the specific parts of the data being accessed, and even on the information already divulged to the user.

Within the organization, areas containing sensitive data should be accessible only to authorized personnel. Intrusion detection devices such as cameras and motion detectors should be used to monitor sensitive and high-risk areas against unauthorized individuals.

The hours to access 'key' microcomputer files should be limited. This prevents unauthorized access after normal working hours. Files should be expressed in terms of different levels of confidentiality and security such as top secret, confidential, internal use only, and unrestricted. Confidential information should not be displayed on the screen. To control access to sensitive data, there should be a mapping of access requirements to the system components. Access rights should be based on job function, and there should exist an appropriate segregation of duties. Temporary employees should be restricted to a specific project, activity, system, and time.

Hardware Security

Computer hardware has improved in reliability and speed tremendously. These technological advances have not always had a beneficial impact on computer security and data integrity. Most integrated circuit chips on hardware equipment appear to be inscrutable to a layperson. There are hundreds of thousands of transistors on a small semi-conductor. Still, it is possible for a bug to be planted into electronic equipment and it may be very difficult to detect. Several techniques may be used to seal the hardware against tampering.

Records should always be kept of hardware failure and computer down times. Regular maintenance should be performed on periodic intervals and records should be maintained. If computer equipment frequently requires servicing, personnel might be tempted to bypass controls and take shortcuts. The possibility of human errors therefore increases considerably. Records should be analyzed to determine if an unfavorable trend is observed for the downtime or if the equipment frequently requires unscheduled service.

Records should be kept of all computer equipment and peripherals. The hardware inventory logs should contain at least the following information:

- Description of the hardware
- Manufacturer's name
- Model number

- Serial number
- Company identification number
- Date of purchase
- Name, address and phone number of stores from where the item was purchased
- Date warranty expires
- The department or location where the hardware equipment will be used
- The name and title of responsible individual
- The department name
- The signature of the responsible individual or department head
- If the equipment is taken off premises, the date and time the equipment is checked out, and the date and time the equipment is returned, along with the signature of the authorized individual.

The hardware inventory logs should be stored in a secure location. A copy of the logs should also be stored in an off-site location. All hardware equipment should be etched or engraved with the company name, address, telephone number, manufacturer's serial number, and company's identification number. To prevent theft, locking devices should be used to secure computer equipment and peripherals to desktops, etc.

Software Security

Segregation of duties is essential in protecting computer programs during the development and modification stages. When software is developed and maintained internally, changes are frequently made to meet changing requirements. The source code is generally stored in the source library, while the compiled and executable version of the program is stored in the production library. The source library is under the control of the programmer, whereas the production library should be under the control of computer operations or a similar entity that does not have programming responsibilities. [10]

All programs and data files should have date and time stamps, including both production and test versions. Date and time stamps make it possible to determine the current version of the program in the event of an error or malfunction.

The transfer from test status to production status of programs should be accompanied by authorization by management. The quality assurance department should do a formal review before releasing the final production version.

Whenever modifications to a program are required, the reasons and requirement must be documented to prevent fraudulent modification. Requests for modification should include at least the following information:

- Description of change.
- Why is the change needed?
- How will the change benefit the department or organization?
- Name, title, and department of individual requesting the change.
- Approval of department head or another authorized individual.
- Date of request.
- Date of desired completion (time by which modifications should be made).

Once the Computer Centre receives the request to modify a program, it should determine:

- The priority of modification and the estimated date of completion.
- The cost to make the modifications and the charge to the user department.

The user department should be notified of the budgeted cost and the estimated completion time. The user department should approve the estimated completion time and budgeted cost.

A control sequence number should be assigned to the modification. Change requests should be tracked from the time they are initially submitted to the time the changes are completed. A programmer or analyst should be assigned the primary responsibility for making the changes. A determination should be made as to how the modified program will be tested. This generally requires the cooperation of the user department. Small changes or emergency modifications should be possible without going through the full formal control procedure. Such changes should be carefully monitored. At a minimum, the following information about the modification should be documented:

- Description of modification.
- Approval of the user department.
- Review of source code changes by a supervisor.

Password Security

Passwords are the way of identifying and authenticating users as they access the computer system. Generally, they provide verification that a user is who they say they are. A hacker is often able to guess the correct password because many individuals select words or strings of characters that have a logical association with the individual under attack. For example, individuals often select the following easily guessable words:

- Portion or variation of user account name
- Spouse's or girlfriend's/boyfriend's name
- Child's name
- Pet's name
- Bank account number
- Phone/Car number
- Own birthday, or a loved one's birthday
- Words like 'password' or 'code'
- Words found in any dictionary
- Pairing of short words found in any dictionary (such as *dogcat*)
- Dictionary words spelled backward (such as *rebmun*)
- Repeated character strings (such as *AAAABBBB* or *CCAATT*)
- Only number digits (such as *123456*)

The following measures can be taken to improve the security of the password scheme:

1. The number of possible password combinations should be large. An example of secure password is to include numbers of characters, such as a question mark or a percentage or a dollar sign in the password. This reduces the chances for the success of an outsider who either guesses the codes or uses a computer to make repetitive attempts under program control.
2. Operating system feature such as password aging should be enforced. Password aging is a feature that requires users to create new passwords every so often.
3. There should be automatic disconnection of the incoming line or logical link after a number of invalid attempts have been made. The usual limit is three to five attempts. This requires an attacker to hang up and redial after every few tries, increasing the time to perform a brute-force penetration (trying all possible combinations).
4. The operating system should log and report invalid sign-on attempts and other events with security implications. These could include an authorized person attempting to run sensitive application programs or using high-powered utility programs to copy or modify files.
5. The password file should be properly protected against unauthorized insertion of bogus user names and passwords by the hackers.
6. The passwords should always be kept in an encrypted format, Otherwise, it is easy for someone to scan for commands that are followed by passwords, such as logins, to capture passwords either from storage, or as they are being typed or routed in transit.

Authenticating an individual can be accomplished by using any combination of some thing you know, something you have, or something you are. Historically, passwords (something you know) have been used to prove the identity of an individual to a computer system. Over time, we have found out that relying on something you know is not the best way to authenticate an individual. Passwords can be guessed or the person may write it down and the password becomes known to others. To alleviate this problem, security has moved to the other authentication methods – something you have or something you are.

Smart cards can be used for authentication (they are something you have) and thus can reduce the risk the risk of someone guessing a password. However, if a smart card is stolen and if it is the sole from of authentication, the thief could masquerade as a legitimate user of the network or computer system.

Biometrics is yet another authentication mechanism (something you are) and thus they too can reduce the risk of someone guessing a password. As with other strong authentication methods, for biometrics to be effective, access to a system must be attempted through a correct entry path. If an attacker can find a way to circumvent the biometric system, there is no way for the biometric system to assist in the security of the system.

Audit Trail

Audit trails contain adequate information regarding any additions, deletions or modifications to the system. They provide evidence concerning transactions. An effective audit trail allows the data to be retrieved and certified. Audit trails will give information regarding the date and time of the transaction, who processed it, and at which terminal.

Computer-related risks affect the organization's internal control structure and thereby affect the organization's audibility. Electronic data interchange (EDI) systems are on-line systems where computers automatically perform transactions such as order processing and generating invoices. Although this can reduce costs, it can adversely affect organization's audibility because of the lessened audit trail.

To ensure the integrity of an EDI system, the following needs to be considered:

- **Controls over accuracy and completeness at the application level of an EDI system**

These controls include checks on performance to determine compliance with industry standards, checks on sequence numbering for transactions, reporting irregularities on a timely basis, verifying adequacy of audit trails, and checking of embedded headers and trailers at interchange, functional group and transaction set level.

- **Controls at the environmental level of an EDI system**
  These controls include reviewing quality assurance of vendor software, segregation of duties, ensuring that software is virus-free, procuring an audit report from the vendor's auditors, and evidence of testing.
- **Controls at the authorization level of an EDI system**
  These controls include operator identification code, operator profile, trading partner identifier, maintenance of user access variables, and regular changing of passwords.

Network Security

A computer network is simply a system of interconnected computers. When businesses send private information across the network, they place a high value on it getting to its destination intact and without being intercepted by someone other than the intended recipient. Individuals sending private communications obviously desire secure communications. Finally, connecting a system to a network can open the system itself up to attacks. If a system is compromised, the risk of data loss is high.

Network security [4] can be classified into two general classes:

- Methods used to secure data as it transits a network
- Methods which regulate what packets may transit the network

While both significantly affect the traffic going to and from a site, their objectives are quite different.

The following are various types of threats against networked computers and the protection mechanism against these threats [8]:

- **Denial-of-Service:** *DoS* (Denial-of-Service) attacks are probably the nastiest, and most difficult to address. These are the nastiest, because they're very easy to launch, difficult (sometimes impossible) to track, and it isn't easy to refuse the requests of the attacker, without also refusing legitimate requests for service.

  The premise of a DoS attack is simple: send more requests to the machine than it can handle. There are toolkits available in the underground community that make this a simple matter of running a program and telling it which host to blast with requests. The attacker's program simply makes a connection on some service port, perhaps forging the packet's header information that says where the packet came from, and then dropping the connection. If the host is able to answer 20 requests per second, and the attacker is sending 50 per second, obviously the host will be unable to service all of the attacker's requests, much less than any legitimate requests (hits on the web site running there, for example). Such attacks were fairly common in late 1996 and early 1997, but are now becoming less popular.

  Some things that can be done to reduce the risk of being stung by a denial of service attack include

  - Not running your visible-to-the-world servers at a level too close to capacity
  - Using packet filtering to prevent obviously forged packets from entering into your network address space.
  - Keeping up-to-date on security-related patches for your hosts' operating systems.

- **Unauthorized Access:** "Unauthorized access" is a very high-level term that can refer to a number of different sorts of attacks. The goal of these attacks is to access some resource that your machine should not provide the attacker. For example, a host might be a web server, and should provide anyone with requested web pages. However, that host should not provide command shell access without being sure that the person making such a request is someone who should get it, such as a local administrator.

- **Executing Commands Illicitly:** It's obviously undesirable for an unknown and un-trusted person to be able to execute commands on your server machines. There are two main classifications of the severity of this problem: normal user access, and administrator access. A normal user can do a number of things on a system (such as read files, mail them to other people, etc.) that an attacker should not be able to do. This might, then, be all the access that an attacker needs. On the other hand, an attacker might wish to make configuration changes to a host (perhaps changing its IP address, putting a start-up script in place to cause the machine to shut down every time it's started, or something

similar). In this case, the attacker will need to gain administrator privileges on the host.

From looking at the sorts of attacks that are common, we can divine a relatively short list of high-level practices that can help prevent security disasters, and to help control the damage in the event that preventative measures were unsuccessful in warding off an attack.

- **Hope we have backups:** This isn't just a good idea from a security point of view. Operational requirements should dictate the backup policy, and this should be closely coordinated with a disaster recovery plan, such that if an airplane crashes into your building one night, you'll be able to carry on your business from another location. Similarly, these can be useful in recovering your data in the event of an electronic disaster: a hardware failure, or a break-in that changes or otherwise damages your data.
- **Don't put data where it doesn't need to be**: Although this *should* go without saying, this doesn't occur to lots of folks. As a result, information that doesn't need to be accessible from the outside world sometimes is, and this can needlessly increase the severity of a break-in dramatically.
- **Avoid systems with single points of failure:** Any security system that can be broken by breaking through any one component isn't really very strong. In security, a degree of redundancy is good, and can help you protect your organization from a minor security breach becoming a catastrophe.
- **Stay current with relevant operating system patches:** Be sure that someone who knows what you've got is watching the vendors' security advisories. Exploiting old bugs is still one of the most common (and most effective!) means of breaking into systems.

A firewall is the point at which your private company network and a public network, such as the Internet, connect. A firewall system is a hardware/software configuration that sits at this perimeter, controlling access into and out of your company's network. While in theory firewalls allow only authorized communications between the internal and external networks, new ways are constantly being developed to compromise these systems. However, properly implemented they are very effective at keeping out unauthorized users and stopping unwanted activities on an internal network.

Firewall systems [6] protect and facilitate your network at a number of levels:

- They allow e-mail, and other applications such as ftp and remote login as desired, to take place while otherwise limiting access to the internal network.
- They provide an authorization mechanism, which provides a level of assurance that only specified users or applications, can gain access through the firewall.
- They typically provide a logging and alerting feature, which tracks designated usage and signals at specified events.
- They offer address translation, which masks the actual name and address of any machine communicating through the firewall. For example, all messages for anyone in the technical support department would have their address translated to technicalsupport@company.com, effectively hiding the name of an actual user and network address.
- They are adding new functionality, such as encryption and virtual private networks capabilities. Encryption is the coding, or scrambling, of data and keeps unintended users from reading the information. Virtual Private Networks employ encryption to provide secure transmissions over public networks such as the Internet.

Firewall systems can also be deployed within an enterprise network to compartmentalize different servers and networks, in effect controlling access within the network. For example, an enterprise may want to separate the accounting and payroll server from the rest of the network and only allow certain individuals to access the information.

Finally, you should consider that all firewall systems have some performance degradation. As a system is busy checking or re-routing data communications packets, they do not flow through the system as efficiently as they would if the system were not in place.

The Security Administrator

The size and needs of the organization will dictate the size of the security administration department. This department is responsible for the planning and execution of a computer security system. They supervise that the information system's data is reliable and accurate. The security administrator should possess a high level of

computer technical knowledge as well as having management skills and a general understanding of the organization's internal control structure.

A security administrator should interact with other departments to learn of the organization's changing needs and be able to maintain and update the security system efficiently. The security administrator is responsible for enacting and customizing policies and standards for the organization based on specific needs. Checks on performance and monitoring of staff should be done to ensure that these policies and standards are being complied with. In developing these policies and procedures, as well as the overall information computer security system, the security administrator must perform a risk assessment. [7]

Contingency Planning

Many man-made and natural disasters can strike an organization. A disaster may be defined as anything that will create a significant disruption in an organization's ongoing activities for a considerable period. Proper contingency planning can help minimize the loss of human life, data, and capital. Preparedness is the key to recovering from disaster.

The primary focus of computer security should always be to take preventive action, not corrective action. Nonetheless, it is impossible to prevent every security breach. It is virtually impossible to anticipate every problem and even if a problem can be anticipated, the cost/benefit criterion may not justify taking any preventive action. Sometimes the precautionary measures may prove to be ineffective because of human or other error. Productivity and efficiency may also be sacrificed if precautionary measures are taken too far.

Emergency procedures should be established for the each type of disaster that may occur. For each type of disaster, a determination should be made about the effect of the disaster on data processing and business operations. In other words, how long will the service be interrupted and at what level would the organization be able to operate?

Legal issues

Legal issues are important in considering computer security. An organization for violating legal requirements may incur substantial liability. Sometimes management may even be held personally liable.

Privacy and other personal rights may be violated due to lack of computer security. The public is very concerned about privacy and this is reflected in the ever-increasing legal requirements and regulations.

The Indian Parliament has passed legislation to protect private information. The Information Technology Act of 2000 (hereinafter referred to as 'the act') [3] is one major step in this direction. This act states that it aims at providing 'legal recognition for transactions carried out by means of electronic data interchange and other means of electronic communication, commonly referred to as "electronic commerce", which involve the use of alternatives to paper-based methods of communication and storage of information and aims at facilitating electronic filing of documents with the Government agencies'.

In addition, the Central Government has also notified two distinct kinds of Rules. These rules are The Information Technology (Certifying Authorities) Rules, 2000 and the Cyber Regulations Appellate Tribunal (Procedure) Rules, 2000.

The public is very concerned about information getting into the wrong hands, and is concerned when asked to provide sensitive information. To ensure that individual privacy is protected, the following needs to be considered:

- Classification of Information
- Accuracy
- Protection of sensitive Information.

Once the information is determined to be sensitive, it should be verified for accuracy before being put into a database. Such information should be afforded the necessary protection to keep it confidential and adequately protected.

The Information Technology (Certifying Authorities) Rules, 2000 detail various aspects and issues concerning to Certification Authorities for digital signatures. These rules specify the manner in which information has to be authenticated by means of digital signatures, the creation and verification of digital signatures, licensing of certification authorities and the terms of the proposed licenses to issue digital signatures. The said rules also stipulate security guidelines for certification authorities and maintenance of mandatory databases by the said certification authorities and the generation, issue, term and revocation of digital signature certificates. The said rules further mandate the audit of the operations of the Certification Authority and classify various kinds of information. The said Rules also have in Schedule II the Information Technology Security Guidelines, which mandate various guidelines for the implementation and management of Information Technology Security. The said Security Guidelines are a virtual Bible for all Certification Authorities for the security aspects of their operations.

The government has also specified the procedures relating to Cyber Regulations Appellate Tribunal in the notified Cyber Regulations Appellate Tribunal (Procedure) Rules, 2000. These rules specify how an application to the Cyber Regulations Appellate Tribunal has to be preferred along with relevant documents and application fee. It further stipulates how proceedings have to be conducted by the Tribunal. It has also elaborated on the powers of the Registrar of the Cyber Regulations Appellate Tribunal.

The government, by another notification of 17th October 2000, has also constituted the Cyber Regulation Advisory Committee. The committee shall advise the Central Government either generally as regards any rules or for any other purpose connected with the IT Act, 2000. The said committee shall also advise the Controller for Certifying Authorities in framing the regulations under this Act. It comprises, amongst others, the Minister of IT, various Secretaries of different Ministries, representatives from different trade bodies and technical bodies, director of the Central Bureau of Investigation, police chiefs from the states and the Controller of Certifying Authorities.

Email communications may be a source of claims of privacy violations. The organization should have a clearly stated policy about using computer systems for personal communications. For example, the organization may want to clearly state that the organization has the right to read all email communications. Courts have generally held that the employer has the right to view employee email; still it is prudent to have a written policy on this issue.

As per the Act, civil liability and criminal penalties may be imposed on any person who causes damage to a computer or computer system. The offender would be liable to pay compensation not exceeding Rs. 1 Crore (10 million) for gaining unauthorized access to a computer or computer system, damaging it, introducing a virus in the system, denying access to an authorized person or assisting any person in any of the above activities.

Moreover, any person who intentionally or knowingly tampers with computer source documents would be penalized with imprisonment up to three years or a fine of up to Rs. 2 lakhs or both. In simpler terminology, hacking is made punishable.

The Act also disallows the publishing and dissemination of obscene information and material. The introduction of this provision should curtail pornography over the net. Any person who disobeys this provision will be punishable with imprisonment of two years and a fine of Rs. 25,000 for the first conviction. In the event of a subsequent conviction, the imprisonment is five years and the fine doubles to Rs. 50,000.

Computer security related legal liability might be incurred in a variety of situations, ranging from programming errors to civil or criminal violations. An organization is expected to exercise due care and violation of the due care standard could result in liability. Consider a computer program that was originally designed properly, bug-free and operating effectively. However, due to lack of appropriate security, an attacker is able to place a logic bomb that causes the system to crash at a specified time in the future. The organization and its senior management may be held personally liable for any damages arising from the crash of the program. Such damages may include, for example, loss in market price of stock shares. Human life might also be affected if the program that crashed performed critical functions, such as a medical diagnosis system.

Consider another scenario where the attacker is able to modify the database of a construction company. Assume the database contains information about the strength of various types of steel that will be used to construct an office building. Engineers may rely upon the modified database and use steel that is not strong enough. The building eventually collapses and human life is lost. The liability that may result in such circumstances is likely to be astronomical, especially if it is proven that appropriate security could have prevented modification of the database.

The Act is only a first step in the amalgamation of the Internet into India's legal framework. There is still a long way to go before the Indian legal system integrates and accepts the Internet fully. Various important issues such as jurisdiction, intellectual property rights, extent of liability, etc. have yet to be addressed, although the Act and its rules and regulations are a first step in that direction.

While legislation will always be lacking behind as time and technology progress, the Parliament must ensure that it keeps amending the law and enacting new laws to keep pace with ever-changing standards. At the same time, Indian law must be compatible with international standards that are prescribed and that may be prescribed in the future. This is essential if we desire to effectively regulate this boundless world.

CONCLUSIONS

Information security is a mindset of examining the threats and vulnerabilities of an organization and managing these appropriately for the growth of today's business. In spite of the rising number of security breaches in recent years, far too many organizations have failed to take appropriate action. Establishing accountability, promoting awareness, protecting of assets, and other tactical steps are needed to combat attacks on information security. History has

shown that the security field has always been one step behind the genius minds of hackers. In order to keep the information safe and provide real privacy, the organizations will need to discover new and innovative ways to prevent hackers/crackers rather than alert a system that has already been contaminated. The future of Internet businesses lies in the hands of the agencies that provide Internet security. It is inevitable that the world will be a cyber-based community in the future in which Information Security will be a perpetual business.

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CRYPTOGRAPHIC TECHNIQUES

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Abstract

In this paper, some of the cryptographic techniques have been studied. We start with a brief description of the traditional cryptography also known as symmetric key method. The rest of the paper takes up public key cryptography first studied by Diffie-Hellman. Other cryptosystems using public key discussed here include ElGamal encryption and RSA. Some of the possible attacks on RSA are also discussed. Finally Kerberos method using public key is discussed.

Keywords : Decryption, digital signature, encryption, public key, symmetric key.

INTRODUCTION

Internet has wide range of applications varying from banking to electronic commerce and communication. Networks are generally not secure and anyone can listen or modify the message transferred over the internet. There are a number of situations where the information is confidential and an intruder can get information by monitoring the information circuit. Information transferred over the network must be protected against unauthorized access. One solution to this problem is to transfer the information in coded language. The art of secret writing is known as cryptography. Cryptography is a secure means of communication over insecure channel. The original message is known as plain text and the secret code is known as cipher text. The method of producing cipher text from plain text is known as encryption and reverse process is known as decryption.

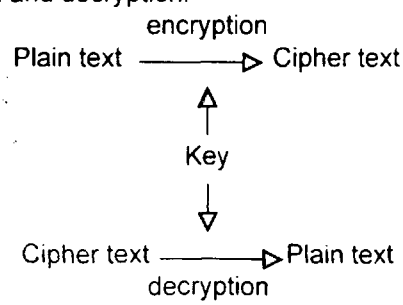
To decrypt a cipher text receiver must have some additional information known as decryption key. Since eavesdropper does not have decryption key he can not obtain plain text from cipher text. Sender also has a key for encryption known as encryption key.
Objectives of cryptography are:

- Confidentiality: Message is received only by the intended party.
- Integrity: To check whether data is modified during transmission either accidentally or deliberately.
- Authenticity: Verification of the origin of the data.

Julius Caesar's shift cipher was introduced more than 2000 years ago. According to Caesar's cipher each letter of the message is substituted by the letter which is three letters later in the alphabet. Hence A is replaced by D, B by E, Z by C and so on. A slight modification of Caesar's cipher was given in 1940's in Captain Midnight Code. According to this cipher instead of always using *3*, each letter of the message is replaced by the letter which is *n* letters later in the alphabet. The number *n* once chosen is kept fixed. The Caesar cipher is a particular case of Captain Midnight Code with $n = 3$. The next cryptographic system is Monoalphabetic cipher. According to this cipher there is an arbitrary mapping of one letter to another letter. The substitution of a letter by another letter in this system may not obey any system.

The Captain Midnight Code is very easy to break. One has only to get hold of sufficient number of cipher texts and see the repetition of letters. This can lead, by a judicious use of the language, to the value of *n* and then break the cipher. Since there are *26!* possible one to one mappings of alphabet, the Monoalphabetic cipher seems to be quite secure. However, methods exist which can break this cipher as well.

Traditional method of cryptography is called symmetric key cryptography. In this a single key is used for both encryption and decryption.



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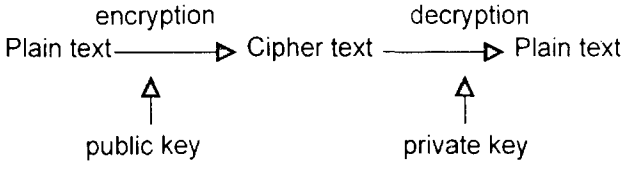
Both Captain Midnight Code and Monoalphabetic cipher are examples of symmetric key cryptography. For symmetric key cryptography both sender and receiver must share the secret key. Earlier this was done by sending keys in advance by some secure channel like private courier etc. Distribution of the initial secret key is one of the major drawback of symmetric key cryptography. Many times it may be the case that two parties/people have to communicate privately without any previous acquaintance. It is unrealistic to delay the communication long enough for the keys to be transmitted by some physical medium.

One solution to this problem is public key cryptography also known as asymmetric key cryptography. In asymmetric key cryptography each user has two keys – private key and public key. Private key is secret and known only to the person to whom it belongs and public key is made public. Private and public keys are such that a private key can not be guessed from its public key. A message encrypted with the public key of a person can only be decrypted with private key of the same person and vice-versa.



In public key cryptography if two persons A and B have to communicate, A sends a message encrypted with the public key of B and since only B knows his private key so only B can decrypt the message. Public key cryptography generally requires *10* times larger keys then conventional symmetric key cryptography to provide same level of security. Public key encryption/decryption computations are approximately *1000* times slower than symmetric key computations.

2. Diffie-Hellman Key Agreement

Diffie-Hellman (1976) gave the concept of public key cryptography. They invented the first practical solution to the key distribution problem based on public key cryptography. The Diffie-Hellman key agreement protocol allows two parties to establish a mutual secret key, even though they can only exchange message over a public channel. Suppose key is to be established between two persons/parties A and B. This protocol works as follows:

1. Let h be a sufficiently large prime and g be a primitive root *mod* h. Make g and h public.
2. A chooses a secret number x, $0 \le x \le h-2$, compute $c_1 = g^x \bmod h$ and sends c_1 to B.
3. B chooses another secret number y, $0 \le y \le h-2$, compute $c_2 = g^y \bmod h$ and sends c_2 to A.
4. A computes the shared key $k = c_2^x \bmod h = (g^y)^x \bmod h$.
5. B computes the shared key $k = c_1^y \bmod h = (g^x)^y \bmod h$.

Thus the secret key k is established between A and B.

Security of Diffie-Hellman Key Agreement

To get the key k one has to find x or y or $(g^x)^y \bmod h$ from $g^x \bmod h$ and $g^y \bmod h$. Let $c = g^x \bmod h$; $0 \le x \le h-2$. Then $x = \log_g c \bmod h$. Calculation of c from x requires at most $2 * \log_2 h$ multiplications (Diffie and Hellman, 1976). However to get x from c is much more difficult. Even using the best known algorithms, for certain carefully chosen values of h it requires $h^{1/4}$ operations (Diffie and Hellman, 1976). Suppose h is prime slightly less than 2^a. Then calculation of c from x requires at most $2 * \log_2 h < 2 * \log_2 2^a = 2a$ multiplications; while calculation of x from c requires $(2^a)^{1/2}$ operations. If a=*100* then computing c from x requires at most *200* multiplications and taking *logs mod* h requires 2^{50} operations i.e. 10^{15} (approximately).

The security of the Diffie-Hellman key agreement depends upon the difficulty of computing logarithms *mod h*. The Diffie-Hellman protocol, as it stands, does not provide authentication of the parties to each other.

3. ElGamal Encryption Algorithm

ElGamal encryption algorithm (ElGamal, 1985) is a slight modification of Diffie-Hellman key agreement. Suppose A has to encrypt a message m for B. Here the encryption proceeds as follows:

1. Let h be a large prime and g be a primitive root *mod* h. Make g and h public.
2. B chooses a secret number x, $0 \le x \le h-2$ and sends $g^x \bmod h$ to A.
3. A chooses another secret number y, $0 \le y = h-2$ and sends $g^y \bmod h$ to B. A also compute $(g^x)^y \bmod h$ and sends $m.(g^x)^y \bmod h$ to B.
4. B knows x, $g^y \bmod h$ and $m.(g^x)^y \bmod h$. B can compute $(g^y)^x \bmod h$. So B can get $m = m.(g^x)^y \bmod h / (g^y)^x \bmod h$.

The security of the system depends upon the Diffie-Hellman problem.

4. RSA

RSA (Rivest, Shamir and Adleman, 1978) is a public key cryptosystem invented in 1978. It is named after its inventors Ron Rivest, Adi Shamir and Leonard Adleman.

RSA cryptosystem is based on results from number theory and can be used for key generation, encryption, decryption and authentication (i.e. digital signatures). Before we describe these, we recall some elementary but basic results from number theory.

Let n be a positive integer. The set $Z_n = \{0, 1, 2, ..., n-1\}$ of non-negative integers $< n$ is a commutative ring with identity with addition and multiplication defined modulo n. Euler's $\emptyset(n)$ denotes the number of integers less than n which are relatively coprime to n. An integer e, $1 < e < n$, is invertible in Z_n if and only if e is relatively coprime to n. We have the following generalization of Euler-Fermat Theorem:

Proposition If n is a product of distinct primes then for any positive integer a, $a^{\emptyset(n)} = 1 \bmod n$.
The above proposition for n as a product of two primes is given in (Delfs and Knebl, 2002).

RSA Key Generation

RSA algorithm for public/private key generation works as follows:

1. Choose two large primes p and q and keep them secret.
2. Compute $n = pq$ and make n public.
3. Choose e, $1 < e < n$, such that e is relatively prime to $\emptyset(n) = (p-1)(q-1)$.
4. Find d such that $(ed - 1)$ is divisible by $(p-1)(q-1)$. Now (n, e) is the public key and (n, d) is the private key of any user A.

RSA Encryption

Suppose that a person A wants to send a secret message $m < n$ to B. A encrypts the message m with the public key (n, e) of B, computes $c = m^e \bmod n$ and sends c to B. Then B decrypts c with his private key (n, d) and computes $c^d \bmod n$ and gets the message m. This is made possible because $ed = 1 \bmod \emptyset(n)$ and the proposition above.
Observe that a message encrypted with the public key of a person can only be decrypted with the private key of the same person and vice-versa.

RSA Authentication

The RSA cryptosystem can also be used for digital signatures. Suppose that A wants to send a signed message to B. Let (n, e) and (n, d) be the public and private keys of A. Then A signs the message $m < n$ with his private key and computes $s = m^d \bmod n$. He then sends (m, s) as his signed message to B. Since B knows A's public key, he computes $s^e \bmod n$ and gets m. B is then sure that the message was sent by A. However, security of the message is not a consideration here.

A problem with this signature scheme is that if an intruder gets (m, s), he can replay it in future and can impersonate A. One solution to this problem is that for A's authentication to B, A has to sign a hash of the message sent by B and vice – versa. So it prevents **replay attack**.

Security of RSA System

The security of RSA cryptosystem depends on how difficult or easy it is to find the decrypting number d from the given public key (n, e). If the prime factors p, q of n are known, then $\emptyset(n) = (p-1)(q-1)$ is known. Extended version of Euclid's division algorithm can then be used to determine d such that $ed = 1 \bmod \emptyset(n)$. On the other hand, suppose that $\emptyset(n)$ is known.
Since

$\emptyset(n) = pq - (p + q) + 1 = n - (p + q) + 1$,
$p + q = n - \emptyset(n) + 1$ is known. Also
$(p-q)^2 = (p+q)^2 - 4pq = (p+q)^2 - 4n = (n - \emptyset(n) + 1)^2 - 4n$

showing that $p - q = \sqrt{(n - \emptyset(n) + 1)^2 - 4n}$ is determined. But then p and q are determined. Thus complexity of finding the decrypting number d of the RSA system is equivalent to the complexity of finding $\emptyset(n)$ which in turn is equivalent to the complexity of factorizing the modulus n. Several methods of finding prime factorization of large numbers are known. Among these, Trial division is the oldest and the least efficient method of factoring. This algorithm tries all prime numbers less than $sqrt(n)$. Exponent Factorization Method, Quadratic Sieve (QS), Multiple Polynomial Quadratic Sieve (MPQS), Number Field Sieve (NFS) are some other methods of factoring ((Burman, 2002), (infiNity)). Number Field Sieve is the most powerful factoring method at present and has been successfully used to factor both *140 bit* and *152 bit* RSA key(Burman, 2002).

Choice of key length in RSA is with the user. While short key length provides efficiency, longer key length provides extra security. Minimum recommended key length is *768 bits*. It is expected that *1024 bit* keys should be safe for immediate future and some consider *2048 bit* keys to be secure for decades.

4.1 Attacks against RSA

The Timing Attack

In RSA (Rivest, Shamir and Adleman, 1978) cryptosystem client B is required to compute $c^d \bmod n$, where (n, d) is the secret key of B. The modulus n and the message c are supposed to be known to the attacker and he intends to find the secret number d. This can sometimes be done by carefully measuring the amount of time required by

the private key operations. Paul Kocher (1996) described how different amounts of time required to process different inputs to cryptosystems is correlated with the secret key. The attack uses or depends upon the simple modular exponentiation algorithm that computes $c^d \bmod n$.

```
Let d =d0d1....dN-1 be the binary representation of d
Let c0 = 1
For k = 0 to N – 1
  If (dk = 1) then
    mk = ck.c mod n
  Else
    mk = ck
  Let ck+1 = mk2 mod n
End For
Return mN-1
```

The square and multiply algorithm given depends upon the procedure for obtaining binary representation of a number. The attacker proceeds by iteration. If in a loop operation of the algorithm a bit d_k of d is *1* then two operations are to be performed namely the multiplication $c_k.c \bmod n$ and then squaring $c_{k+1} = m_k^2 \bmod n$ while if d_k is *0* only the squaring operation is performed. Thus, if an attacker has the ways and means of keeping a track of the time taken in the loop operations, he can reasonably obtain the binary bits of d and, so, d itself.

Researchers have recovered the *512 bit* RSA decryption exponent in minutes using about *5000* timing measurements of modular exponentiation algorithm (Burman, 2002).

Prevention of Timing Attack

Kocher (1996) himself has suggested ways of preventing timing attack. One of these is to make all operations take exactly the same time. Another method is to make the time measurements quite inaccurate so that the attack becomes infeasible. However, both these methods are not very useful or practical.

Kocher (1996) has also suggested a much better solution for preventing this attack. Timing attack can be defeated by preventing the attacker from learning the base in modular exponentiation function. If the attacker does not know the base in modular exponentiation the corresponding timing information is of no use to him. This may be done as follows.

In case of RSA choose a random number r_j relatively coprime to n and compute $r_j = (r_i^{-1})^e \bmod n$. In the decrypting process before modular exponentiation multiply the base value c with $r_j \bmod n$. So, we need to compute $(r_j c)^d \bmod n$ in place of $c^d \bmod n$. Since $(r_j c)^d \bmod n = ((r_i^{-1})^e c)^d = (r_i^{-1})^{ed} c^d = r_i^{-1} c^d \bmod n$, the result is corrected by multiplying the decrypted value with $r_j \bmod n$ which gives $c^d \bmod n$.

Power Analysis Attack

Simple Power Analysis (SPA) is a technique that involves directly interpreting power consumption measurements collected during cryptographic operations. Power analysis attack (Burman, 2002) has been described by Kocher and is based on the fact that amount of current drawn by an electronic device depends upon the path followed by the current. A method for measuring the amount of current drawn has been described.

A computation execution which takes more time shall draw more current than a computation needing less time for its execution. Thus power analysis attack works on the same principle on which the time analysis attack works. In RSA modular exponentiation using square and multiply algorithm, if relevant bit of d is *1* then both modular multiplication and modular square are performed and if the relevant bit of d is *0* then only modular square is performed. Traces of current drawn during RSA secret key computation the beginning of each square or multiplication operation is indicated by a spike. Modular multiplication requires extra time or extra register load and so the width of the leading spike increases. Therefore in case of modular multiplication and modular square a wide spike is followed by a narrow spike. Thus by power analysis of RSA exponentiation computation a multiply and square operation can be distinguished from a square operation and, hence, the secret key d can be determined.

Prevention of Power Analysis Attack

Power analysis attack can be prevented if same computations are done for all bits of d. This can be achieved by avoiding conditional operations and conditional operations can be avoided in square and multiply algorithm as under:

```
Let d = d0d1....dN-1 be the binary representation of d
Let c0 = 1
For k = 0 to N – 1
  m1 = ck .c mod n
  m0 = ck
  m = mdk
  ck+1 = m2 mod n
End for
Return m
```

Here for either values of d_i both modular square and modular multiplication operations are performed. Hence power analysis does not render any help to attacker.

Fault Analysis Attack

Another attack was suggested by Demillo and Lipton in 1996 and Differential Fault Analysis by Biham and Shamir later the same year. On the lines of these two attacks Bao, Deng, Han, Jeng, Nagir and Narasimhalu (1996) suggested an attack to RSA on tamperproof devices.

All cryptographic computations are quickly done with digital hardware like PC, smartcard, cellular phone etc. It is assumed that by certain physical effects on tamperproof devices such as smartcard one can induce a fault at some random bit location in cryptographic computations which can compromise security of the system.

Suppose that RSA modulus $n = pq$ is a *768 bit* number. Let $c = m^e \bmod n$ be the cipher text corresponding to the plain text $m < n$. Let $d = d_0 d_1 \ldots d_{767}$ be the binary representation of the secret key d. Then

$$m = c^d \bmod n$$

$$= \left(c^{2^{767}}\right)^{d_0} \left(c^{2^{766}}\right)^{d_1} \ldots \left(c^{2^{767-i}}\right)^{d_i} \ldots \left(c^{2}\right)^{d_{766}} (c)^{d_{767}} \bmod n \quad (1)$$

$$= (c_{767})^{d_0} (c_{766})^{d_1} \ldots (c_{767-i})^{d_i} \ldots (c_1)^{d_{766}} (c_0)^{d_{767}} \bmod n$$

where $c_i = c^{2^i}$

Suppose that a one bit error is induced in the binary representation of d by changing a bit d_i from *1* to *0* or vice-versa. The attacker computes

$$m' = (c_{767})^{d_0} (c_{766})^{d_1} \ldots (c_{767-i})^{d'_i} \ldots (c_1)^{d_{766}} (c_0)^{d_{767}} \bmod n$$

The attacker chooses m arbitrarily, computes $c = m^e \bmod n$ and then computes m and m'. He can then compute

$$m / m' = (c_{767-i})^{d_i} / (c_{767-i})^{d'_i}$$

$$\left.\begin{array}{lll} = c_{767-i} & \text{if} & d_i = 1 \\ \text{or} & & \\ = 1/c_{767-i} & \text{if} & d_i = 0 \end{array}\right\} \quad (2)$$

By comparing the values of c_{767-i} and $1/c_{767-i}$ with (2) he can first determine i for which d_i is changed and can then determine the value of d_i. By repeating this process sufficiently many times, he can find all the bits of d and so the exponent d.

Suppose next that the attacker induces one bit error at c_{767-i} in c rather than in the key d. Then

$$m' = (c_{767})^{d_0} (c_{766})^{d_1} \ldots (c'_{767-i})^{d_i} \ldots (c_1)^{d_{766}} (c_0)^{d_{767}} \bmod n \quad (3)$$

and

$$m / m' = (c_{767-i})^{d_i} / (c'_{767-i})^{d_i} \quad (4)$$

Since bit error is introduced in c_{767-i} so this entry is actually present in (1) . Therefore d_i has got to be *1*. Suppose that the attacker has computed all possible $(c_{767-i}) / (c'_{767-i})$. He compares these values with the value in (4). Once a match is found, i is determined for which $d_i = 1$. By repeating the above procedure a sufficient number of times, the key d can be found.

Attack on Encryption and Signing with RSA (Delfs and Knebl, 2002)

In RSA cryptosystem if the same keys are used for encryption and digital signatures, the system is no longer secure. Let *(n, e)* and *(n, d)* be the public and private keys of A. Suppose B sends A an encrypted message $c = m^e \bmod n$. An attacker who can manage to get the cipher text message c encrypted by A's public key can receive the message $m = c^d \bmod n$ without knowing the private key d of A. For this purpose an attacker chooses a random number r, $0 < r < n$, r coprime to n and compute

$u = r^e \bmod n$

$v = r^{-1} \bmod n$

$w = u.c \bmod n$

The attacker sends w to A to get A's signature $w^d \bmod n$. On getting this the attacker computes $v.w^d \bmod n$ and gets $v.w^d \bmod n = r^{-1} u^d c^d = r^{-1} r^{ed} c^d \bmod n = c^d \bmod n = m$, the message received by A.

This attack is also called chosen cipher text attack against RSA and is possible because of any weakness of the RSA system but in the manner of implementation. To avoid such an attack different keys should be used for encryption and for digital signatures.

Common Modulus Attack (Delfs and Knebl, 2002)

Suppose two persons/users A, B of RSA have the same modulus n. Let (n, e_1) and (n, e_2) be the public keys of A and B respectively. The two exponents e_1 and e_2 are generally relatively prime. If a message $m < n$ is sent to both A and B encrypted with their public keys then the two cipher text messages are

$$c_1 = m^{e_1} \bmod n$$

$$c_2 = m^{e_2} \bmod n$$

An attacker can recover m from c_1, c_2, n, e_1, e_2. This is shown as follows.

If $gcd(c_1, n) = k > 1$, then k divides n and so $k = p$ or q. Therefore the cryptosystem breaks here. Suppose $(c_1, n) = 1$. Then we can find the inverse c_1^{-1} of c_1 *mod* n. Since e_1 and e_2 are relatively coprime, there exist integers r and s such that $re_1 + se_2 = 1$. Observe that r and s cannot be both positive or both negative. Assume that r is negative. Then

$$\left(c_1^{-1}\right)^{-r} c_2^{s} \bmod n = \left(m^{-e_1}\right)^{-r} \left(m^{e_2}\right)^{s} \bmod n = m^{re_1+se_2} \bmod n$$

To avoid this attack it is advised that while sending messages from one source to two or more clients no two moduli should be taken equal. Observe that the fault occurs not due to any weakness of the RSA system but in the manner it is implemented.

5. Kerberos

Kerberos ((Downnard, 2002/2003), (Kohl, 1991), (Neuman and Theodore, 1994), (Neuman, Wray, Medvinsky and Trostle), (Schneier, 2001), (Sirbu and Chuang, 1997)) was developed at Massachusetts Institute of Technology for project Athena in 1988. It is a trusted third party authentication protocol based on symmetric key cryptography.

To communicate with a particular server client first has to request a *TGT* (Ticket Granting Ticket) from the *AS* (Authentication Server) of *KDC* (Key Distribution Center). For this client has to prove his identity to *AS*. Using *TGT* client sends a request for service ticket to the *TGS* (Ticket Granting Server). Service ticket gives the client permission to send a request for the desired service to the server. A ticket is issued to the client for a single server and contains a valid time period and a key.

Abbreviations used in Kerberos protocol:

K_x - Secret key of X

$K_{x,y}$ – Key to be shared between X and Y during session

$\{M\}K$ – Message encrypted by key K

$A_{x,y}$ - Authenticator of X for Y

$T_{x,y}$ – X's ticket for Y

C – Client

S – Server

t_i – Time stamp

Kerberos protocol works as follows:

1. Client sends his identity and a request for *TGT* to *AS*.
2. *AS* responds by sending $\{k_{C,tgs}\}K_C$ and $\{T_{C,tgs}\}K_{tgs}$ to client, where $T_{C,tgs} = \{C, K_{C,tgs}, \textit{valid time period}\}$.
3. Client sends a request for desired server, his authenticator $\{A_{C,tgs}\}K_{C,tgs}$ and $\{T_{C,tgs}\}K_{tgs}$ to *TGS*, where $A_{C,tgs} = \{C, t_1\}$.
4. *TGS* verifies client's authenticator and sends $\{K_{C,S}\}K_{C,tgs}$ and $\{T_{C,S}\}K_S$ to client, where $T_{C,S} = \{C, K_{C,S}, \textit{valid time period}\}$.
5. Client sends the server his authenticator $\{A_{C,S}\}K_{C,S}$ and $\{T_{C,S}\}K_S$, where $A_{C,S} = \{C, t_2\}$.
6. Server verifies client's authenticator and if mutual authentication is requested by the client, server sends $\{t_2\}K_{C,S}$ to client.

Now the mutual authentication of client and server is complete. They can communicate in future using secret key they share.

Having a single *KDC* for the entire network is not feasible. If there is only one *KDC* it causes bottleneck problem and a single failure at *KDC* will make the entire system fail. To avoid such problems different principles are divided into different realms and each realm has one or more *KDC*. Any two *KDC* in the same realm are equivalent but two *KDC* in different realms have different databases. The two *KDC* in different realms share a secret key. When a client in one realm requests a server in a different realm it requires cross-realm authentication.

Limitations of Kerberos

In traditional Kerberos *KDC* maintain the secret key of all users. The security of Kerberos protocol depends upon the fact that *KDC* is trust worthy. If an attacker gains access to *KDC* database he can get the secret key of all the users and so the security of the system is violated. The recovery from such a compromise requires to re-establish the secret key with all the users which is very time consuming and costly task.

Kerberos using Public Keys

In traditional Kerberos system if the *KDC* is compromised

the entire security of the system breaks. But if public keys are used for encrypting *TGT* sent by *AS*, *KDC* has to maintain only the public keys of the users. Then getting an access to *KDC* database will not render any help to the attacker as modifying public keys in the infrastructure is quite difficult in contrast to reading secret keys.

PKINT (Public Key Cryptography for Initial Authentication)

In *PKINT* client sends his digital signature and a request for *TGT* to *AS*. *AS* verifies client's signature and sends a *TGT* and a session key $K_{C, tgs}$ encrypted with the public key of client. Client decrypts the session key using his private or secret key and proceeds with traditional symmetric key cryptography.

PKCROSS (Public Key Cryptography for Cross – Realm Authentication)

The specification describes how public key cryptography can be used for cross realm authentication. When a client request a service in different realm, the communication between the client and local *KDC* takes place in traditional manner. *PKCROSS* is used for authentication between local *KDC* and remote *KDC* with local *KDC* acting as a client. When remote *KDC* issues a *PKCROSS* ticket to local *KDC*, local *KDC* issues a *TGT* for remote realm to client.

PKDA (Public Key based Kerberos for Distributed Authentication)

PKDA was invented by Marvin A. Sirbu and John Chung–I Chuang. This protocol eliminates the need for *KDC* altogether. *PKDA* avoids the risk of *KDC* compromise as in traditional Kerberos and also eliminates the bottle neck problem that occurs at *KDC*, there being no *KDC*.

Additional abbreviations used in this protocol are:

P_X – Public key of X

P_X^{-1} – Private key of X

K_{temp} – Temporary key

X-cert – X's certificate

The protocol works as follows:

1. Client sends a request to server for his public key certificate. Client retrieves server's public key from the certificate sent by the server.
2. Client sends S, $(t_1, K_{temp}, A_{C, S})P_S$ to server, where $A_{C, S} = C$, *C-cert*, $(K_{temp}, S, P_S, t_1)P_C^{-1}$. Key K_{temp} is the key used by the server to encrypt the response.
3. Server responds with $T_{C, S}$, $\{C, S, K_{C, S}, t_1\}K_{temp}$, where $T_{C, S} = S, \{K_{C, S}, C, t_1\}K_S$
4. Client sends an application service request $T_{C, S}$, $\{C, t_2\}K_{C, S}$ to server.

Public key cryptography requires longer keys than secret key cryptography. Public keys generation and computations are much more time consuming than symmetric key computations. Therefore *PKCROSS* achieved better cross realm authentication than *PKDA* when a client has to communicate with two or more application servers in remote realm. *PKCROSS* uses public key cryptography only once between local and remote *KDC* and further communication proceeds with efficient secret key cryptography. *PKDA* sends long public key messages to multiple application servers.

6. Encryption for Future

The amount of information being communicated and stored electronically is vastly greater than every five years ago. As a result, the need for more effective information security tool is growing. Further improvement in encryption methods is desirable for faster and secure exchanges. Sooner or later, every cryptographic system has the potential to be successfully attacked, probably in a completely unexpected way and with unexpected consequences. In the face of great threat perceptions in view of the advancement in technology there is a greater need for looking for newer and more secure encryption techniques. A great deal of research is going on in this direction. The more advanced in technology, the greater is the vulnerability of encryption methods to attack.

The future of encryption lies squarely on inventing systems that not only protect users from known forms of attack "till to date" but also should provide security against all forms of attacks that the attackers might come up with in future.

CONCLUSIONS

Three public key cryptographic systems Diffie–Hellman, ElGamal encryption, RSA and public key extensions into Kerberos authentication protocol have been described. These methods have some drawbacks. Among the attacks described against RSA, power analysis attack seems to be the most powerful attack on modular

exponentiation. Public key cryptography at different stages of Kerberos improve its security and scalability. *PKDA* eliminates the need for *KDC* and hence avoids bottleneck problem. Computational requirements for public key cryptography are generally higher than secret key. Public key cryptography can improve security but at the cost of performance.

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CHARACTERIZATION OF SOME DIETARY FLAVONOIDS BY SPECTROPHOTOMETRY AND HPLC AND ASSAYS OF THEIR INHIBITORY POTENTIALS ON LIPID PEROXIDATION

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Abstract

Considering the antioxidant and anticarcinogenic potentials of flavonoids, experiments were performed to isolate and characterize them in routinely consumed fruits and vegetables employing U.V. spectrophotometry and HPLC. Seven out of nine flavonoid extracts inhibited lipid peroxidation (LPO) to varying degrees, but two were pro-oxidants and not antioxidants. The inhibitory potentials of the flavonoid extracts for lipid peroxidation (pro-carcinogenic) were further studied. Onions were found to contain the most potent inhibitor, quercetin-3-glucoside in high concentration, which inhibited lipid peroxidation substantially.

Key words: Flavonoids, Antioxidants, Lipid peroxidation.

Flavonoids are a group of water soluble phenolic compounds widely distributed in plants. They are benzo-gamma-pyrone derivatives and are responsible for the color of leaves, fruits and vegetables. The average daily consumption of these pigments by an adult human being is about 1 gm/day. They can scavenge free radicals, chelate Fe (III) and Cu (II) ions and act as antioxidants (Borek, 2001). Flavonols and flavanones are the most abundant subclasses (Cypriani *et al.*, 1993). They have several effects on the biological systems due to their antioxidant potentials (Middleton *et al.*, 2000; Machala *et al.*, 2001).

A judicious selection of fruits and vegetables for daily consumption by human beings can keep their bodies flushed with potent flavonoids for antioxidant effects against several ailments like cancer and myocardial infarction. Experiments were, therefore, performed to extract and characterize major flavonoids in routinely consumed fruits and vegetables.

Fresh fruits and vegetables namely *Malus pumila* (apple), *Capsicum annum* (capsicum), *Daucus carota* (carrot), *Cucumis sativus* (cucumber), *Vitis vinifera* (grapes), *Momordica incana* (bitter gourd), *Mangifera indica* (mango), *Brassica compestris (mustard)*, *Allium cepa* (onion), *Mentha spicata* (mint), *Spinacea oleracea* (spinach), *Lycopersicum esculentum* (tomato) were used for the preparation of the extracts of flavonoids. Extraction of flavonoids was done by the method of Swain (1976). To 1 gm of fruit/vegetable tissue, 5 ml of 80% methanol was added and the tissues were ground in a pestle and mortar. The extract was allowed to remain at room temperature for 10 minutes followed by filtration and storage in the refrigerator.

UV spectra of 0.1 ml of each of the flavonoid extract were recorded in the range of 200- 400 nm employing Elico SL159 UV spectrophotometer (Harborne, 1967). HPLC with ultraviolet detector was carried out according to the method of Ameer and Randy (1996). For analysis of freshly extracted flavonoids from fruits and vegetables, the mobile phase operated at a flow rate of 1.0 ml/min and initially consisted of water/methanol/acetonitrile/glacial acetic acid (64:30:5.6:0.4). From 20 to 43 minutes after sample injection, the mobile phase was linearly changed with the use of a solvent system controller (Waters Chromatography) to achieve a final mobile phase composition of water/methanol/acetonitrile/acetic acid (36.6:60:3.2:0.2). Sample volumes of 25 to 50 il were introduced by autosampler onto a C-18 reversed phase column (Zorbax ODS, 25 cm X 4.6 mm I.D.).Absorbance was measured at 280 nm by a fixed wavelength ultraviolet detector. Retention times were compared with standards to procure data for the peak identification.

Rat liver microsomes were prepared according to the method of Gupta and Dani (1979). Rats fed *ad libitum* were sacrificed by decapitation and their livers were perfused with normal saline. Protein concentrations in the microsomal preparations were estimated by the method of Lowry *et al.* (1951). Lipid peroxidation (LPO) in control and test samples was assayed in rat liver microsomes according to the method of Beuge and Aust (1978). For the assays of LPO in various extracts of flavonoids, 0.1 ml of the microsomal preparation containing 0.1 ml of Tris HCl buffer (150 mM), 0.1 ml of 1.5 mM ascorbate, 0.1 ml of ferrous sulphate (1mM) and 0.1 ml of flavonoid extract

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Table 1 : U.V. Spectral Data of the Extracts of Flavonoids

Source of extract	λ max (nm) in methanol	Compounds identified
Onion	254, 365	Quercetin 3-glucoside (Fl)[a]
Grape	290, 330	Naringenin (Fn)[b]
Mustard	220, 290, 330	Hesperidin (Fn)[b]
Apple	260, 370	Rhamnetin (Fl)[a]
Spinach	258, 319, 360	Kaempferol 5-deoxy (Fl)[a]
Mint	250, 319, 370	Robinetin (Fl)[a]
Bitter Gourd	260, 380	Tambuletin (Fl)[a]
Carrot	255, 350	Luteolin 7-glucoside
Tomato	215, 290, 330	Dihydrokaempferol (Fn)[b]
Mango	290, 315, 370	Fisetin (Fl)[a]
Cucumber	263, 382	Butein
Capsicum	260, 330	Genistein

a: Flavonol b: Flavanone

Table 2 : Retention Times of Flavonoids as Determined by HPLC

Source of extract	Retention time (min.)	Compounds identified
Onion	2.998	Quercetin 3-glucoside (Fl)[a]
Onion	4.77	(NI)[b]
Grapes	3.093	(NI)[b]
Grapes	12.750	Naringenin (Fn)[c]
Grapes	18.036	Hesperitin (Fn)[c]
Mustard	2.988	Possibly flavonol
Mustard	4.840	(NI)[b]
Mustard	6.014	Hesperidin (Fn)[c]
Mustard	12.889	Naringenin (Fn)[c]
Apple	3.401	Quercetin derivative (Fl)[a]
Apple	6.293	Hesperidin (Fn)[c]
Spinach	2.640	Kaempferol 5-deoxy (Fl)[a]
Mint	2.910	Robinetin (Fl)[a]
Bitter Gourd	2.685	Tambuletin (Fl)[a]

a: Flavonol b: Not identified c: Flavanone

were incubated at 37° C for 15 minutes after raising the volume in each tube to 1 ml by adding distilled water. No extract was added in the blank. After the incubation 1 ml of 10% tricarboxylic acid and 2 ml of 0.375% thiobarbituric acid were added to each tube and kept in a boiling water bath for 15 minutes. Absorbance in the supernatant of each tube was recorded at 532 nm after centrifuging the samples at 3000 g for 15 minutes. The results were expressed as nmol thiobarbituric acid reactive substances (TBARS)/mg protein.

UV spectral data of twelve flavonoid extracts from routinely consumed fruits and vegetables are presented in Table 1. Most of the compounds identified by this technique are either flavonols or flavanones. Table 2 depicts the retention times of major flavonoid peaks identified by HPLC. These data also corroborate the above observation that most of the flavonoids present in the seven extracts were flavonols or flavanones. Out of the twelve flavonoid extracts, only nine extracts showed any activity against LPO, while two extract had no effect on LPO. *In vitro*

Table 3 : In Vitro Effects of Flavonoids on Lipid Peroxidation in Rat Liver Microsomes

Source of extract (identified flavonoid)	Lipid Peroxidation (n mol TBARS/ mg protein)	Percentage inhibition(-)/ activation(+) of lipid peroxidation by each flavonoid extract
Control	1.20 ± 0.134	---
Carrot (luteolin 7-glucoside)	1.33 ± 0.129	+10.8%
Tomato (dihydrokaempferol)	1.16 ± 0.109	-3.3%
Mango (fisetin 3,7,3',4')	1.02 ± 0.133	-15%
Spinach (kaempferol 5-deoxy)	1.09 ± 0.09	-9.2%
Onion (quercetin 3-glucoside)	0.73 ± 0.144	-39.2%
Cucumber (butein)	1.38 ± 0.169	+15%
Mint (robinetin)	1.09 ± 0.057	-9.2%
Grapes (naringenin 5,7,4')	1.11 ± 0.133	-7.5%
Capsicum (genistein)	1.14 ± 0.104	-5%

All values are Mean ± S.D. of four observations

effects of nine extracts of flavonoids on LPO in rat liver microsomes are documented in Table 3. Seven out of nine extracts inhibited LPO whereas the other two were pro-oxidants. Quercetin 3- glucoside in the onion extract maximally inhibited LPO (39.2%), while others inhibited by varying degrees.

The protective effects of flavonoids against several diseases and ageing have been reported to be due to the free radical scavenging of active oxygens (hydroxyl and superoxide anions) and chelation of released iron (Machala *et al.*, 2001). Quercetin in association with lipophilic antioxidants (á-tocopherol) and ascorbic acid has been reported to inhibit oxidative modifications of LDL (Da Silva *et al.*, 2000). Dose dependent free radical scavenging effects of flavonoids have also been documented to inhibit xanthine oxidase (a pro-oxidative enzyme), spontaneous LPO and DNA cleavage (Russo *et al.*, 2000). Free radical scavenging activity of flavonoids has been reported due to the presence of hydroxyl groups at C4' or C3/C3' or due to a double bond between C2 and C3 (Burda and Oleszek, 2000). Quercetin inhibits the growth of malignant cells, induces apoptosis and arrests cell cycle (Choi *et al.*, 2001). Luteolin 7- glucoside in the carrot extract showed activation of LPO which was found to be due to electron delocalization by reduction of 2,3 double bond in the C-ring (Cao *et al.*, 1997). Butein in the cucumber extract also showed activation of LPO which was probably due to the open ring structure of butein. At higher doses few flavonoids may act as pro-oxidants and inhibit hormone metabolism (Skibola and Smith, 2000). Thorough studies have to be carried out on these flavonoids to suggest embargos and limitations for dietary consumption.

It can be concluded from these data that substantial consumption of those vegetables and fruits which contain sufficient concentrations of antioxidative flavonoids may be important for limiting the damaging oxidative reactions in cells to protect the consumers against diseases like cancer and myocardial infarction, which are known to be promoted by free radicals (Middleton *et al.*, 2000). Like water soluble vitamins, flushing of human body with antioxidative flavonoids may be very important, particularly during ageing when food consumption curtails.

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PRODUCTION OF C_{60} BY THE ARC IGNITION OF GRAPHITE

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Abstract

In this paper we report the production of C_{60} using the arc ignition of graphite. A set up was developed at Department of Physics, which uses an evacuated chamber having a free flow of He gas at desired pressures. This had also had a provision to bring two graphite rods through which large D.C current can be passed using a high current low voltage power supply. Provision for cooling the graphite rods by circulating cold water around, considering that the temperatures could rise up to 4000°C. The resultant carbon soot was purified and characterized by FTIR. The observed IR peeks confirmed the presence of Solid C_{60}. Thus we have at our disposal a set up for the production of C_{60} n of solid C_{60}.

Key Words: Nanomaterials, Fullerenes, C_{60}, FTIR.

Ever since the discovery of fullerenes [1] there has been a tremendous interest in these materials among the scientific community of chemists, physicist and material scientists. The fullerenes exhibit properties completely different from the earlier known forms of carbon [2,3]. By far the main interest in the fullerenes was due to a group of 60 carbon atoms (C_{60}). Quickly after the discovery of fullerenes a need for the production of their solids was seen as the next major step towards the growth of this field. It was only in 1990 that gram quantities of fullerenes were produced for the first time [4]. In the laboratory, the fullerenes, can be made from carbon rich vapors which are obtained in a variety of ways: resistive heating of carbon, laser ablation of carbon in He gas atmospheres, arc ignition of graphite, solar generators, inductive heating of graphite, synthesis by combustion and fullerene synthesis by pyrolysis. C_{60} has also been reported to occur naturally in some geological samples like shungite and fulgurite [5]. Of all the methods that produce C_{60} the ones that produce the highest yields are the arc ignition methods. Based on this we have designed an experimental set up to produce fullerenes in the laboratory. In this paper, we demonstrate this experimental technique and discuss the FTIR spectrum of the resultant purified soot.

In this method two carbon rods are mounted in such a manner so that their ends just touch. This system is then mounted inside a bell jar. The apparatus is then evacuated down to 1 Torr and then filled with He. A large electrical current is then passed through the rods, thereby generating a brilliant arc. When the arc is running, black soot like material is sputtered throughout the bell jar. The arc process produces high temperatures typically ~ 4000 K and a lot of heat is generated. After the rods have been consumed to the desired extent the apparatus is allowed to cool. When the apparatus cools down, the system is brought to atmospheric pressure and the bell jar is removed. The soot is then scraped out from its inside surface and analyzed for the presence of C_{60}. Testing is primarily done for C_{60} as this is the most abundant fullerene and thus easily detected using a simple technique viz. dissolution of soot in benzene giving us a red colour if C_{60} is present. The colour depends on the concentration and type of fullerenes in the sample.

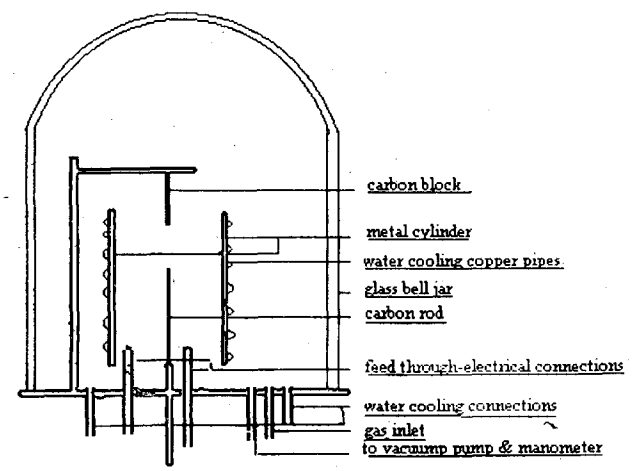

Fig. 1 : *The Schematic Diagram of the experimental set up*

The experimental set up for fullerene production requires the following components [6]; a vacuum pump, a glass

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bell jar, a mechanical set up for supporting the rods etc., a low voltage high current power supply and a He gas cylinder. The schematic diagram of the fullerene generator is as shown in Fig 1. The connections for water cooling, rod support, electrical terminals and gas inlet and outlet are fixed on a metallic base plate. The vacuum sealing was done with the help of rubber O-rings and vacuum grease. The bell jar is kept on the base plate. A large carbon block of diameter 10 mm is used as the negative terminal and the block holder is not movable. When arcing takes place the rod connected to the positive terminal gets consumed due to which the distance between the rod and the block increases thereby stopping the arcing process. To overcome this problem we devised a push and pull arrangement for the positive electrode with the help of which it could be moved without disturbing the vacuum. The rod arrangement is surrounded by an aluminum cylinder, which serves as a small collection chamber for the carbon soot. A narrow slit was also made in the vertical side of the cylinder. This helped us in setting up the arc when it had stopped. A few important points that should be considered are; the pressure of the He gas inside the chamber should be 100 Torr. An effective water cooling system should also be provided inside the chamber. In our set up we had wound copper coils around the aluminum cylinder. Cold water was then circulated through the coils to provide effective water cooling. For the experimental set up we require a low voltage, high current power supply. We can use either a.c or d.c supply. Using an a.c supply would burn both the carbon rods, whereas using a d.c supply would burn the rod attached with the positive terminal of the supply alone. In our experiments, we have used d.c power supply, providing us 100 Amp at 30 Volts. The rods used for the experiment should be of pure carbon. Impure carbon rods do not give good yields of fullerenes. The dimensions of the rods used were: diameter-5mm and length – 20 cm.

After collection the soot was collected for its fullerene content by dissolving it in Benzene which gave a deep red colour indicating the successful production of C_{60}. We have also performed the FTIR of our sample at RSIC, Panjab University, Chandigarh, to obtain an infra red spectrum which is shown in Fig 2. The relevant frequencies have been read from this Fig and presented in table 1, along with measurements from Menéndez et .al [7], who have tabulated several measured modes of C_{60}. The table shows only IR active modes.

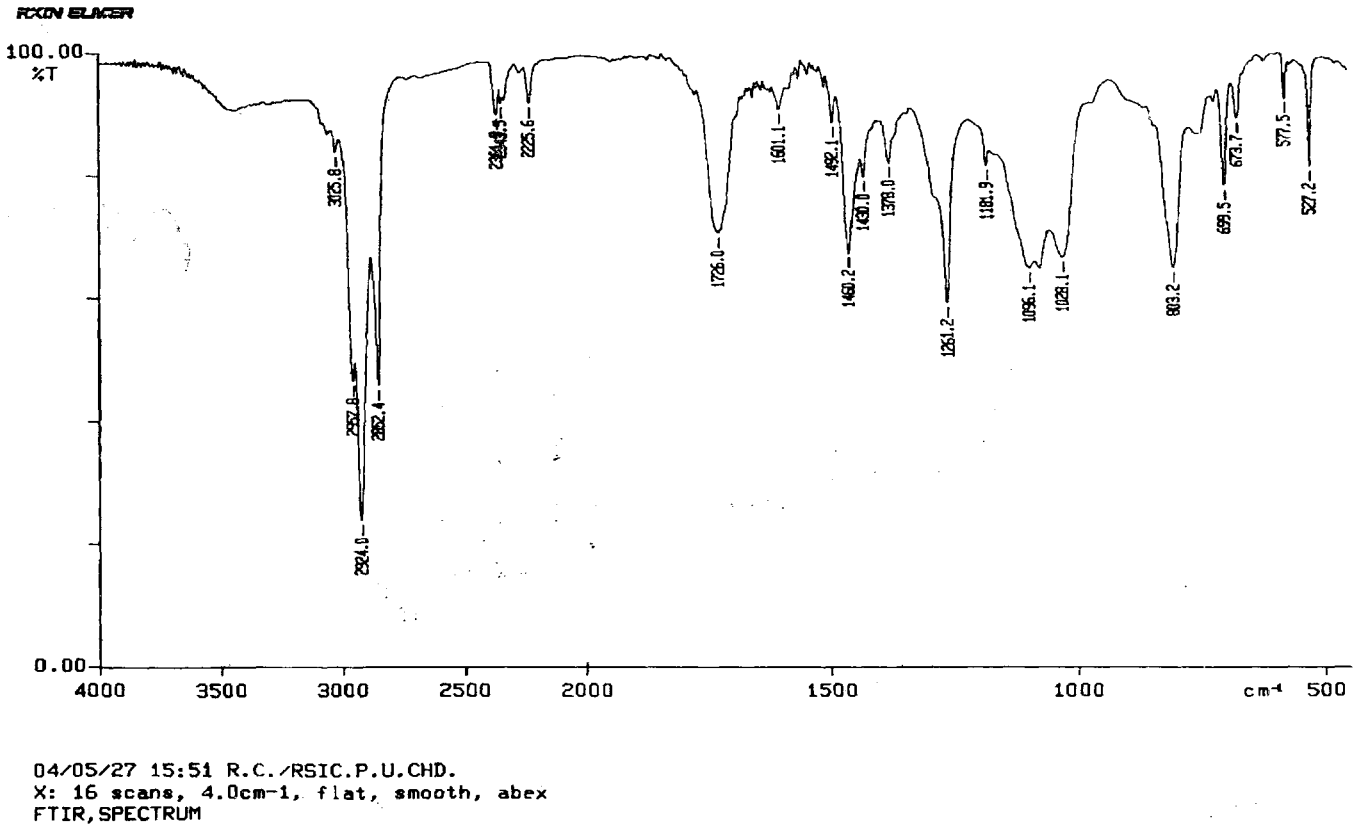

Fig 2 : FTIR Spectrum

Table 1 : IR active values of C_{60}

IR Active Mode Frequencies (cm^{-1})		
Mode	Menéndez et .al[7]	Present Results
T1u(1)	526	527.2
T1u(2)	575	577.5
T1u(3)	1182	1181.9
T1u(4)	1429	1430

In the early days of research, in the field of fullerenes, a major stumbling block was the availability of solid fullerenes. This was augmented by the 1990 successful experiment of Huffman and Krätschmer. Fullerenes are now even commercially available, but their cost is high making it difficult to acquire. Thus a need was thought to have our own experimental set up for fullerene production so that further research work in this very fascinating field does not suffer due to lack of solid fullerenes. Further experiments are still being conducted to obtain pure C_{60}.

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[7] Site: *http://www.public.asu.edu/~cosmen/C60_vibrations/mode_assignments.html*

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GENUS *KYLLINGA* ROTTB. (CYPERACEAE) IN UTTAR PRADESH, INDIA

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Abstract

The paper provides a detailed taxonomic account of 7 spp. of the genus Kyllinga Rottb. in Uttar Pradesh. Key to the species is also provided.

Keywords : Diversity, KYLLINGA, Uttar Pradesh.

INTRODUCTION

The state of Uttar Pradesh (after recent reorganisation) is situated between 77°-3' & 84°-39' N and 23°-52' & 30°-25' E. The area falls under Gangetic Plain and covers forested area of Tarai & Bhabhar tract, cultivated areas of Purvanchal, Rohilkhand Duabs and Bundelkhand. But the flora of the region is not yet published. Present study deals with the floristic diversity of the genus *Kyllinga* Rottb. in the state. The study is based on the field observations, scrutiny of literature (Uniyal *et al* 1997, Duthie 1929, Hooker 1893-94, Singh & Srivastava 2002) and herbarium specimens housed in CAL, LWG, DD, BSA, BSIP, MU (herbarium at Merrut University) GU, (herbarium at Gorakhpur University) DUTHIE (Allahabad University) herbaria. The species under the genus Kyllinga have been arranged alphabatically.

KYLLINGA Rottb.

Descr. *et* Icon. Nov. Pl. : 12. 1773, *nom. cons.*

LT.: *Kyllinga nemoralis* (J. R. & G. Forst.)Dandy ex Hutchinson & Dalziel (*Thryocephalon nemorale* J.R. & G. Forst) [=K *monocephala sensu* Rottboell, *non* Rottboell, 1773, *nom. illeg. (typ. cons.)*]

Notes : Koyama (1985) cites "*Kyllinga brevifolia* Rottboell" as the type species and Mabberley (1987) lists *Kyllinga* Rottb., as a congeneric synonym of *Cyperus* L.

Stems erect, simple, leafy below only, terminated by 1-3 sessile capitate spikes. Spikes ovoid or cylindric, dense, with numerous small compressed spikelets. Glumes 4-5, distichous, rhacheola disarticulating above the two lowest which are empty. Stamens 1-3, anterior; anthers linear-oblong, muticous or nearly so. Nut compressed laterally; style linear, base continuous with nut; branches 2, linear.

A genus of *ca.* 33 species distributed in hot and temperate regions except Europe; Seven species are found in India as well as U.P.

Key to the species in U.P.

1a. Inflorescence open, umbelliform with elongated rays.....*K.hyalina*

1b. Inflorescence congested in a head.....2

2a. Glumes winged on keels.....3

2b. Glumes not winged.....4

3a. Keel of glumes with a narrow spinulose crest .....*K. nemoralis*

3b. Keel of glumes with a broad hyaline incise-dentate erect .....*K.squamulata*

4a. Rhizomes not creeping.....*K.bulbosa*

4b. Rhizomes creeping 5

5a. Rhizomes slender, 1-3 mm thick. Stems triquetrous with flat sides. Leaves well developed. Stamens 1-3. Nuts yellowish-brown.....*K.brevifolia*

5b. Rhizomes stout, 3-4 mm thick. Stems sharply triquetrous with more or less concave sides. Leaves mostly reduced to sheaths. Sometimes upper with small blades; stamens 3. Nuts black.....6

6a. Stamens 3.....*K.melanosperna*

6b. Stamens 2.....*K.odorata*

Kyllinga brevifolia Rottb., Descr. *et* Icon. Pl. : 13. t. 4. f. 3. 1773; C.B. Clarke in Hook. *f.*, Fl. Brit. India 6 : 588. 1893; Koyama in Dassan., Rev. handb. Fl. Ceylon 5 : 248. 1985. *Cyperus brevifolius* (Rottb.) Hassk., Cat. Pl. Hort. Bogor : 24. 1844; Kern in Fl. Males. Ser. I. 7 : 656. 1974.

Type : India or. (probably Ceylon), *Koenig. s.n.* (*vide* Koyama, *l.c.*).

Perennial herbs. Rhizomes creeping, clothed with non-

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fibrous, brown scale-leaves. Stems rigidulous, triquetrous. Leaves sub-basal, shorter than or as long as stems, linear, acuminate, scabrid in upper part, 1-3 mm broad. Inflorescences capitate, terminal; spikes ovoid or globose, 5-10 mm across, subtended by 3-4 foliaceous bracts, bracts 2-5 cm long; spikelets strongly compressed, lanceolate or ovate-lanceolate, 2-3 mm long, usually with one flower; glumes 4-5, lowest empty; first glume elliptic-lanceolate, second ovate, third and fourth (floral) boat shaped, concave, sub-mucronate, keel green, sides scarious, 3-4-striate, 2 mm long; stamens usually 2, anthers linear; ovaries 1-celled; styles *ca* 1.5 mm long; stigmas 2. Nuts obovoid-ellipsoid, compressed, obtuse, yellow or pale brown, 0.25-0.3 cm long. *Fl. & Fr.* : May-Feb.

Habitat : Common in moist places, near streams, canal-banks, waste places, forest clearings.

Distribution : Tropical and warm temperate regions of the world.

Distribution in Uttar Pradesh : Agra, Aligarh, Allahabad, Azamgarh, Bahraich, Banda, Bulandshahar, Bijnor, Fatehpur, Ghazipur, Gonda, Gorakhpur, Kheri, Lucknow, Meerut, Pilibhit, Raibareli, Saharanpur, Sultanpur.

Representative specimens : Agra : Kitham, AKS, 525, (RBSCH). Aligarh : Nanau, *A.K. Singh,* 5140 (MU). Allahabad : University Campus, *B.K. Mishra,* 72 (DUTHIE); Akorha, *B.K. Mishra,* 512; Garwa, *B.K. Verma & R.P. Dube,* 582 (DUTHIE); *G. Panigrahi,* 11368 (BSA); Garwa, *G. Panigrahi,* 11368 (CAL!). Azamgarh : Mahrajganj, *S.N. Srivastava,* 14631 (GU); Bilariyaganj, *Chandra,* 4681 (GU). Bahraich : Bachkahi, *Chandra et al.,* 12265 (LWG!); Motipur, *O.P. Mishra,* 7720 (BSA). Banda : Manikpur, *B.K. Verma,* 5244 (DUTHIE). Bijnor : Kotwala, *Chandra* et al., 43822 (LWG!). Bulandshahar : Ambag, *Kaul* et al., 22929 (LWG); Canal Side, *L.K. Sharma,* 397 (MU). Fatehpur : Kishanpur, *S.K. Dixit,* 2234 (DUTHIE). Ghazipur : Bogana Tal, *S.D. Singh,* 12489 (GU). Gonda : Jarwa, *Chandra* et al., 25769 (GU!) (LWG). Gorakhpur : Ramghat Tal, *A.K. Srivastava,* 6893 (GU); Belandpur, *T.N. Srivastava,* 1413 (GU). Jaunpur : (cf. *S.K. Singh & Dixit* 1969). Kheri : Malani forest, *G. Saran* et al., 26389 (LWG!), Gola-Gokranath, *S. Saran* et al., 26514 (LWG!); Mailani, *C.L. Malhotra,* 50822 (CAL!). Lucknow : National Bot. Garden, *Shyamlal Kapoor,* 24018 (LWG!); NBG, *Ram Singh,* 4160 (LWG!); Itauja, *Kaul* et al., 23120 (LWG). Meerut : *s.l. S.K. Narwal,* 44564 (GU) (LWG!); Jani, *R.S. Saxena,* 532 (MU). Pilibhit : Gobal, *C.L. Malhotra,* 50822 (CAL!). Raibareli : Pokhani, *A. Singh* et al., 51504 (LWG!). Saharanpur : Bahadrabad, *A.K. Goel,* 108 (MU). Sultanpur : Golaghat, *Om Prakash,* 10179 (GU).

Kyllinga bulbosa P. Beauv., Fl. d'Oware & Benin. 1 : 11, t. 8, f. 1. 1804; Koyama in Dassan., Rev. Handb. Fl. Ceylon 5 : 245. 1985. *Kyllinga tenuifolia* Steud., Syn. Pl. Glum. 2 : 69. 1855; Fl. Hassan. : 638. 1976. Karthikeyan *et al.*, op. cit. : 61. 1989. [*Kyllinga triceps* Rottb., Descr. *et Icon.* Pl. : 14, t. 4, f. 6. 1773, *nom. superfl.*; C.B. Clarke in Hook. *f.*, Fl. Brit. India 6 : 587. 1893. *Cyperus triceps* Endl., Cat. Hort. Acad. Vindob. 1: 94. 1842. Mishra & Verma, Fl. Alld. 392. 1992.

Vern. Name: Nirbishi (Hindi).

Erect perennial herbs. Rhizomes short. Stems thickened at base, covered with fibrous leaf-sheaths. Leaves basal, shorter than or as long as stems, linear, flat or slightly conduplicate, 2-4 mm broad. Inflorescence capitate, consisting of 1-3, dense spikes, ovoid-oblong, pale, 4-8 mm across; bracts 3-4 upto 7 cm long; spikelets compressed, obliquely lanceolate or oblong, 1.5-2 mm long; glumes 4, hyaline, ovate-oblong; lowest 2 empty, third (floral) ovate or lanceolate, keel green, slightly excurrent, 3-4-veined, 1-1.5 mm long, fourth glume membranous empty; stamens 2, anthers oblong-linear; ovaries 1-celled; styles *ca* 1 mm long; stigmas 2. Nuts oblong-ellipsoid, obtuse, compressed, yellowish-brown, 1.5-2 mm long. *Fl. & Fr.* : July-April

Habitat: Common in moist grassy places, roadsides.

Note : Hara *et al.*, (1978) consider *Kyllinga triceps* Rottb., as the correct name but state "excluding the plate of Rheede and the relevant synonym". Rottb. *l.c.* included the validily described spices viz. *Scirpus tuberisus, N. Burm.* 1768; in its synonyms (= *Scirpus glomeratus* L.) thus *Kyllinga triceps* Rottb., is to rejected as *nom. illeg.* (Art. 63. 1. ICBN, 1988). While S. Hooper. (1976) considers *Kyllinga tenuifolia* Steud. (1840) as the correct name, Koyama (1985) accepts *Kyllinga bulbosa* Beauv. (1804) as correct; he however, does not refer to *Kyllinga tenuifolia* Steud. as a synonym of *Kyllinga bulbosa* Beauv. Karthikeyan *et al.*, (1989) violate the rule of priority without any comment. If *Kyllinga* Rottb. (1773) is merged in *Cyperus* L., the correct name for *Kyllinga bulbosa* P. Beauv., would be *Cyperus triceps* Endl. (1842), *non Cyperus bulbosus* Vahl.

Distribution : Paleotropics and subtropics.

Distribution in Uttar Pradesh: Agra, Aligarh, Allahabad, Azamgarh, Bijnor, Bulandshahar, Fatehpur, Ghazipur, Gorakhpur, Hamirpur, Jalaun, Kanpur, Lucknow, Mahoba, Meerut, Mirzapur, Moradabad, Muzzaffarnagar, Shahjahanapur, Sultanpur, Unnao.

Representative specimens : Agra : Agra College Campus, *Prof. Sinha.* 125709 (DD!); Poiyaghat, AKS, 770

(RBSCH). Aligarh : Chherut, *A.K. Singh,* 260A (MU). Allahabad : Handia, *B.K. Mishra,* 567 (DUTHIE!); Ramnathpur, *B.K. Mishra.* 598, Garwa, *B.K. Verma & R.P. Dube,* 511 (DUTHIE!). Azamgarh : Band Tal, *Kaul* et al., 54348 (LWG!); Madhuban, *S.N. Srivastava,* 14321 (GU); Atraulia, *Chandra,* 4690 (GU). Bijnor : Amangarh, *Chandra* et al., 44097 (LWG!). Bulandshahar : Khan Garden, *L. K. Sharma,* 881 (MU). Fatehpur : Naubasta, *S.K. Dixit,* 2280 (DUTHIE). Ghazipur : Gahmar, *S.D. Singh,* 13382 (GU). Gorakhpur : Madhaulia forest, *A.K. Srivastava,* 6948 (GU); Ramgarh Tal, *T.N. Srivastava,* 1441 (GU). Hamirpur : *s.l., Kumari Mukherjee,* 61460 (LWG!). Jalaun : Kotra, *G. Shukla,* 7421 (DUTHIE). Jaunpur : (cf. *S.K. Singh & Dixit* 1969). Kanpur : Botanic Garden, *Janki Prasad,* 2707 (LWG!). Lucknow : Banarasibag, *R.C. Bhardwaj,* 22603 (LWG!); *s.l., G.S. Puri,* 79 (DD!); *s.l., Ram Singh,* 34098 (LWG!); Near Carlton Hotel, *R.P. Patil,* 1220 (CAL). Mahoba : *s.l., Kumari Mukherjee,* 61460 (LWG!). Meerut : Hastinapur, *R.S. Saxena,* 1919 (MU); *s.l., N.P. Saxena,* (LWG-44490). Mirzapur : *s.l., O.P. Mishra,* 9943 (CAL); *s.l., U.C. Bhattacharya,* 17648 (CAL!); Chopan, *M.A. Rao,* 6184 (BSD). Moradabad : *s.l., Paliwal & Singh,* 118 (Hindu College Herb.). Muzaffarnagar : *s.l., R.C. Bhardwaj* (LWG-8442). Shahjahanpur : Badshahibagh, *A.K. Goel,* 856 (MU). Sultanpur : Amethi, *Om Prakash,* 10967 (GU). Unnao : *s.l., N.N. Sen* (LWG-3422).

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Soft annual herbs. Growing in small tufts. Roots purplish fibrous. Culms triquetrous, (3-) 6-20 cm tall, 0.5-1 mm wide, smooth throughout, soft. Leaves 2 or 3 to a culm, shorter than to slightly overtopping the culm; blades narrowly linear, (2-) 5-20 cm long, 1-3.5 mm wide, gradually acuminate, 3-costate, flattish, soft, thinly herbaceous; sheaths 1-5 cm long, pale-stramineous and tinged with light brown or red-brown-striate. Anthela simple, open and lax or more or less congested into a head-like cluster, 2-7 cm long and as wide; bracts 3-6, patent, most of them suppressing the anthela, the longest 10-25 cm long; rays 2 to 6, patent, slender, up to 6, patent, slender, up to 6 cm long; spikes subloosely bearing 5 to 20 spikelets, the rachis glabrous, 4-winged, the internodes 2-3 mm long. Spikelets eventually spreading, ovate to elliptic, strongly flattened, subacute, 4-8 mm long, 2-3 mm wide, 7- to 10-flowered, pale greenish; rachilla flexuous, jointed at base above the prophyll, the internodes c. 1 mm long, widely winged. Glumes ½-imbricated, ovate to ovate-oval, folded with an acute keel, 2-3 mm long, 2.25-2.5 mm wide, the green keel distinctly 3-nerved, serrulate-scabrous, the side hyaline pale or yellowish, strongly 3-nerved on each side, somewhat reticulate. Achenes elliptic to broadly elliptic, often asymmetric, bilaterally lenticular, 1.25-1.75 mm long, 1-1.25 mm wide, truncate or shallowly emarginate at apex, maturing brown to black-brown, puncticulate with isodiametrical epidermal cells; style 2.5-3 mm long, 2-cleft to ½ to 3/5 from apex. Stamens 2; anthers 0.5-1 mm long. *Fl. & Fr.* : Sept.-Nov.

Habitat : In wetlands.

Distribution : Tropical East Africa, Mascarena Is., India, Indo-China, Malaysia and Northern Australia.

Distribution in Uttar Pradesh : Basti.

Representative specimen: Basti: Saini, s.n. (GU)

Kyllinga melanosperma Nees in Wt., Contrib. Bot. India 91. 1834; Clarke in Hook. f., Fl. Brit. India 6 : 588. 1893. *Kyllinga bifolia* Miq., Fl. Ind. Bot. 3: 293, 1856; Verma & Mishra, Ind. Jor. For. Vol. 5(3), 226-238, 1982.

Perennials, 0.4-1.2 m high. Rhizomes short, thick, woody, creeping up to 5 cm long. Stems few to many, triquetrous above. Leaves much shorter than the stem. 3-5 mm broad. Inflorescence a solitary, terminal, greenish, ovoid or subglobose head, up to 1 cm long and 5-7 mm broad head; bracts 3-4, foliaceous, up to 15 cm or more long. Spikelets numerous, congested in the head, *ca* 3 mm long, usually bearing one, rarely 2 nuts. Glumes ovate, acute; keel green, excurrent, smooth; sides fuscous, 3-4 striate. Stamens often 3. Stigmas 2. Nuts ultimately black, obovoid-long, about 2/3 as long as glume. *Fl. & Fr.* : July-Dec.

Habitat : marshy banks of pools.

Distribution : South India and upper Gangetic Plains.

Distribution in Uttar Pradesh : Allahabad, Bahraich, Etawah.

Representative specimens : Allahabad : Garwa, *B.K. Mishra,* 731 (DUTHIE); University Campus, *B.K. Mishra,* 1389 (DUTHIE). Bahraich : Abdullaganj, *Rampher,* 16620

(LWG!). Etawa : *s.l., Kaul* et al., 24606 (LWG!).

Kyllinga nemoralis (J.R. & G. Forst.) Dandy *ex* Hutch., & Dalz., Fl. West Trop. Afr. 2 : 486 (in Key) & 487. 1936; Koyama in Dassan., Rev. Handb. Fl. Ceylon 5 : 249. 1985. [*Kyllinga monocephala sensu* Rottb., non Rottb., Descr. *et* Icon. Pl. : 13. t. 4. 1773, *nom. superfl.*; C.B. Clarke in Hook. *f.*, Fl. Brit. India 6 : 588. 1893. *Thryocephalon nemorale* J. R. & G. Forst., Char. Gen. Pl. : 130. 1776. *Cyperus kylingia* Endl., Cat. Hort. Acad. Vindob. 1 : 94. 1842; Kern in Fl. Males. Ser. I. 7 : 639. 1974. Type : Same as for *Kyllinga monocephala* Rottb., *nom superfl.*

Vern. Name : Nirbishi-Badamutha.

Erect herbs. Rhizomes creeping, stoloniferous, covered with brown scale-leaves. Stems rigidulous, triquetrous. Leaves basal, as long as or longer than stems, scabrid on margins in upper part, acuminate, 3-5 mm broad. Heads terminal, usually solitary, white globose-ovoid, 5-10 mm long, occasionally 1-3 smaller heads below the terminal one, subtended by 3-4, foliaceous bracts; spikelets obliquely ellipsoid-ovoid, strongly compressed, 3 mm long, usually with one flower; glumes 4, ovate, acuminate with reddish glands, lowest glume hyaline, keeled, 3-5-veined, 1-1.5 mm long, third glume (floral) 3 mm long, enclosing a bisexual flower; fourth glume enclosing a male or bisexual flower, sometimes barren; stamens 3, anthers linear; ovaries 1-celled; styles *ca* 1.5 mm long; stigmas 2. Nuts oblong-obovoid, compressed, yellowish-brown, *ca* 1.5 mm long. *Fl. & Fr.* : July-Mar.

Habitat : In grassy moist places. Common.

Distribution : Tropical and subtropical regions of the world.

Distribution in Uttar Pradesh : Aligarh, Allahabad, Azamgarh, Bahraich, Barelly, Bijnor, Bulandshahar, Etah, Faizabad, Fatehpur, Ghazipur, Gonda, Gorakhpur, Jaunpur, Kheri, Lucknow, Meerut, Mirzapur, Moradabad, Muzaffarnagar, Pilibhit, Raibareli, Saharanpur, Sultanpur.

Representative specimens : Aligarh : Chherut, *A.K. Singh,* 260 (MU). Allahabad : Alfred Park, *B.K. Mishra,* 533 (DUTHIE). Azamgarh : Dubari, *S.N. Srivastava,* 14379 (GU); Bada Pul, *Chandra,* 4691 (GU). Bahraich : Kakradari, *Chandra* et al, 12048 (LWG!); Kasang, *N. Gill.* 592 (CAL!); Motipur, *Harsukh,* 22862 (DD!). Bareilly : *s.l., R.B. Mathur,* 110924 (DD!). Bijnor : Jafrabad, *Chandra* et al., 43632 (LWG!). Bulandshahar : NREC-College, Khurja, *L.K. Sharma,* 439 (MU). Etah : Sakit, *T. Hussain & B. Dutt,* 10461 (LWG!). Faizabad : Safedabad, *J.A. Chowdhery,* 82641 (LWG!). Fatehpur : Kishanpur, *S.K. Dixit,* 2475 (DUTHIE). Ghazipur : Gahmar, *S.D. Singh.* 12281 (GU). Gonda : Birpur block, DFO, Gonda, 14/3528 (DD!). Gorakhpur : Lucchipur, *A.K. Srivastava,* 6980 (GU); Ramgarh Tal, *T.N. Srivastava,* 1439 (GU). Jaunpur : (cf. *S.K. Singh & Dixit* 1969); Mariyahoon, *J.N. Dwivedi,* 78 (T.D.C.). Kheri : Mailani, *C.L. Malhotra,* 23531 (CAL!). Lucknow : N.B.G., *Santa Devi,* 96554 (LWG!), NBG, *J.G. Srivastava,* 16970 (LWG!); Luck. University Campus, *G.S. Puri,* 78 (DD!); NBG, *Chunnoo,* 3531 (LWG!); Near Anausi acrodrum, *R.P. Patil,* 1702 (CAL). Meerut : Daural, *R.S. Saxena,* 746 (MU), Mirzapur : Dudhi, *O.P. Mishra,* 9910 (CAL!). Moradabad : *s.l., Paliwal & Singh,* 434 (Herb. Hindu College). Muzaffarnagar : *s.l., Tayal & Lalita,* 382 (DAV-College). Pilibhit : Danar Ghat, *C.L. Malhotra,* 50477 (CAL!). Raibareli : Inhaina Village, *Jamal Asraf Chowdhery,* 71815 (LWG!). Saharanpur : *s.l., s.n.* 41 (DD!); Badshahibag, *A.K. Goel,* 73 (MU). Sultanpur : Devarrh, *Om Prakash,* 10194 (GU).

Uses : Decoction of aromatic rhizomes used as a dieuretic, refrigerant, demulcent, tonic; also given in fevers and diabetes to relieve thirst. Rhizomes yield an essential oil used for the same purpose as the decoction. (cf. CSIR 1986).

Notes : Farr *et al.* (1979) considers for *Kyllinga monocephala* Rottb., *nom. superfl.* [=*Kylinga colorata* (L.) Druce (*Schoenus coloratus* L.)] as the correct name, but against item No. 462, Appendix III A (ICBN, 1988) *Kyllinga monocephala* Rottb., *nom. superfl.*, is shown as a taxonomic (=) synonym of *Kyllinga nemoralis*.

Kyllinga odorata Vahl, Enum. Pl. 2 : 382. 1806. *Cyperus sesquiflorus* (Torr.) Mattf. & Kukenthal, Pflanzenr. Heft 101 : 591-593, f. t E-J, 1936; Kern in Fl. Males (Ser. 1) 7(3) : 658, 1974. *Kyllinga sesquiflora* Torr. Ann. Lyc. N. York 3 : 287, 1836 var. *subtriceps* (Nees). Koyama, Quart. J. Taiwan Mus. 14 : 191, 1961; *Kyllinga cylindrica* Nees in Wight. Contr 91, 1834, incl. var. *subtriceps* Nees; Clarke in Hook. *f.*, Fl. Brit. Inida 6 : 588, 1893, excl. Specim. malacc; Murty & Singh in Proc. Nat. Inst. Sci. 27(B) 1 : 16, 1961. *Cyperus cylindricus* Champn. 1878; *Cyperus sesquiflorus* var. *cylindricus* Kuk., Pflanznr. 101 : 593, 1936; Bot. Jahrb. 70. 463, 1940; Kernin, Reinwardtia 3. 65, 1954. *Cyperus kernianus* Ohwi & Koyama, J. Jap. Bot. 30 : 126, 1955; Koyama. Act. Phytotax. Geobot. 16 : 55, t. 4. f. B-C, 1955; *Cyperus sequiflorus* ssp. *cylindricus* (Nees *ex* Wight) Koyama, Bot. Mag. Tokyo 83 : 187, 1970.

Perennial herbs. Rhizomes very short. Stems tufted, triquetrous, smooth, 10-30 x 0.1 mm. Leaves rigidulous, flat, gradually acuminate, scabrid on the margins in the upper part, 2-4 mm wide. Inflorescence capitate, whitish, finally straw-coloured, consisting of a terminal cylindrical head 10-12 x 4-5 mm. and 0-2 lateral, subglobose, sessile heads, much smaller than the terminal one. Inovl. Bracts

3-5, finally reflexed, upto 10 cm. Spikelets numerous, strongly compressed, though somewhat turgid, maturing 1 nut, 2-2.5 by 1-1.25, falling off as a whole; rachilla cylindric, disarticulating at the base. Glumes hyaline, 2-2.5 mm long broadly ovate, acute or apiculate, with smooth or hardly spinulose sharp keel, strongly 9-11-and 5-7-nerved. Stamens 2; stigmas 2. Nuts, biconvex, laterally compressed, obovate, or broadly obovate, obtuse, shortly apiculate, black, *ca* 1.5 x 1 mm. *Fl. & Fr.* : July-Sept.

Habitat : moist roadsides, wastelands, sandy loam or gravely subtratum.

Distribution : Trop. Africa, S.E. Asia, Sri Lanka and India to Yunan, Formosa and Malesia.

Distribution in Uttar Pradesh : Aligarh, Bulandshahar, Meerut.

Representative specimens : Aligarh : Chherut, *A.K. Singh,* 256 (MU). Bulandshahar : Canalside, Delhiroad, *L.K. Sharma,* 1605 (MU). Meerut : Hastinapur, *Murty & Singh,* 194 (MU).

Kyllinga squamulata, Vahl. Enum. Pl. 2 : 381. 1806. *Kyllingia metzii,* Steud. Syn. Pl. Cyp. 70. 1855. *Kyllinga monocephala,* Strachey Herb. Kumaon, 74 (*non* of Rottb.).

Plants sub-glabrous. Roots fibrous. Stems annual, tufted, 5-30 cm high. Leaves often longer than stem, *ca* 3.2 mm broad. Heads *ca* 4.3 cm in diam., green or brown; spikelets *ca* 3.2 mm long; spikes 1-3 ovoid; glumes scarcely acute its keel winged by a broad hyaline incise toothed crest. maturing 1. Nuts only, brown.*Fl. & Fr.* : Oct.-July.

Distribution : Tropical Africa, Asia.

Distribution in Uttar Pradesh : Bulandshahar. (Rare)

Representative specimens : Bulandshahar : Narora, *L.K. Sharma,* 1970 (MU).

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RESTRICTED HABITAT PREFERENCE IN KASHMIR HIMALAYAN MOSSES

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Abstract

In a survey of the habitat preference of mosses in Kashmir Himalaya, eight well defined habitats are recognized. Of the large number of studied bryophytes, 16 species of mosses show more or less a restricted habitat preference, while others show a wide range in their habitat colonization.

Keywords : Habitat preference, mosses, colonization

INTRODUCTION

The Kashmir Himalaya is situated between 35°.25' to 34°.55'N latitude and 73°.28' to 80°.30' E longitude. The valley of Kashmir, with its predominantly temperate climate and marked altitudinal zonation, is bound by lofty ranges of mountains on all sides. The Kashmir Himalaya, with alpine to subtropical climate and diverse habitats i.e., moist and dry soil, marshes, heaths, humus, streams, ponds and ditches, moist and dry rocks, mineralized substrata, tree trunks, bark, rotten/rotting wood etc., provide very favourable conditions for the growth of a rich bryophytic flora.

Despite that the moss flora of Kashmir has received some attention from moss taxonomists since the last century (*cf.* Vohra, 1969; Chopra, 1975; Qazi, 1985; Banday, 1997), no effort seems to have been made to study the moss vegetation of this area from an ecological angle. The present study, on the lines of some earlier ecological studies (Srinivasan, 1968; Pant, 1974; Parihar and Pant, 1975; Pant and Tewari, 1988; Bisht, 1989) on the mosses of Western Himalayas, provides an account of the habitat preferences of mosses of Kashmir Himalaya.

MATERIALS AND METHODS

The senior author, engaged in the exploration of mosses of the Kashmir Himalaya since 1990, visited several bryologically rich sites of this area and made extensive collections and field observations. The materials, brought to the laboratory at Srinagar, were later studied for their morphological and structural details to aid their identification and systematic placing. The field notes (habitat conditions, manner of growth) were taken at the spot. The voucher specimens are deposited in the herbarium of the Department of Botany, Kashmir University, Srinagar.

OBSERVATIONS AND RESULTS

In a study of the habitat preferences of mosses, the following eight well defined categories of habitats are recognized.

1. Calcifuges (well drained acidic soils)

Polytrichum juniperinum Hedw. On soil, in the crevices of rocks and on alpine meadows; Gulmarg, 2700m; Khilanmarg-Apharwat, 3500-4500m; Sheshnag, 3660m; Lidderwart, 3350m; *Vohra 580, 657, 676, 851, 883, 897.* On exposed hard soil in and near woods; Gulmarg, 2600m; *Banday 47 KASH,* and many other localities.

Pogonatum urnigerum (Hedw.) P. Beauv. On soil; Dachigam 1800m; Qazi 94. Mostly along streams forming large patches; Ahrabal, 2300m; *Raj 32.* On soil in woods, large patches; Gulmarg, 2800m; *Banday 48 KASH* and from many other localities of Kashmir Himalaya.

It has been observed that these two taxa, particularly *Polytrichum juniperinum* prefer well drained acidic habitat in numerous localities of Kashmir Himalaya. However, *Pogonatum urnigerum* usually prefers mild acidic situations. Earlier, these taxa were also considered as reliable indicators of acidic habitats (Watson, 1971; Crum, 1973).

2. Calcareous - basic soils

Aloina rigida (Hedw.) Limpr. In earthy crevices of a wall by roadside about the bridge; west of Sonamarg, 2500m; *Townsend T.87/360.*

Cratoneuron commutaum var. ***falcatum*** (Brid.) Moenk. Robust and stiff plants, often encrusted with lime, on wet calcareous soil in springs and streams; Thajiwas glacier, 3500m; Chandanwari-Sheshnag, 3000-3660m; *Vohra*

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929, 930, 949, 951, 829, 834.

C. filicinum (Hedw.) Spruc. On calcareous rocks and stones in streams; Gulmarg-Apharwat, 3000-4500m; Pahalgam, 2200m; Pahalgam-Sheshnag, 2200-3660m; Thajiwas, 3500m; *Vohra 599, 604, 632, 797, 806, 816, 867, 932, 937, 952.* On stream bank; Beerwah, 1800m; Arizal 1900m; *Banday 09 KASH, 22 KASH.*

In Europe, along with some other important mosses the two preceding species play an active role in rock building (Richards, 1932).

3. Exposed acidic rocks

Hedwigia ciliata (Hedw.) P. Beauv. Small or wide patches, glaucous-green, tufts very easily broken up when collected; on stones along streams well exposed to sun shine; Harwan, 1700m; *Koul & Dhar 155.* On rocks and stony walls; Harwan, 1700m; *Raj 155.* Dachigam, 1800m; *Singh 93.* On exposed stones; Arizal, 1900m; *Banday53 KASH.]*

4. Exposed basic rocks

Grimmia anodon B.S.G. Small cushions on dry rocks; Gulmarg, 2600m; *Banday 31 KASH.* A rare species in Kashmir Himalaya.

G. pulvinata (Hedw.) Sm. A low land moss on rocks and masonry wall tops, grows in cushions of dark green colour; Harwan, 1700m; *Kaul & Dhar 156.* On dry rocks; Hazratbal; *Raj 176.* On stones; University Campus, Hazarabal, 1600m; *Banday 139 KASH* and other places.

Schistidium apocarpum (Hedw.) B.S.G. Of very common occurrence on wall-tops, boulders facing westwards; Harwan, 1700m; *Kaul & Dhar 187.* Forming cushions on dry exposed rocks; Harwan, 1700m; *Raj 58.* Harwan, 1700m; *Qazi 13.* On bare rocks; Gulmarg, 2750m; *Banday 201 KASH.*

5. On rocks in running water

Fissidens grandifrons Brid. On partially or completely submerged clay banks, submerged patches; Harwan, 1700m; *Kaul & Dhar 194.* Common in moist places, often along stream banks; Harwan, 1700m; *Raj 194.* On rocks under waterfall; Dachigam, 1800m; *Banday 303 KASH.* On stone, submerged in running water; Chandanwari,3500m; *Vohra 828.*

6. Marshes-damp soil

Philonotis fontana (Hedw.) Brid. In alpine meadows near streams; Gulmarg,2700m; *Vohra 594.* On marshes, very common and abundant; Gulmarg, 270m; *Banday 344 KASH.* Pale green mats on damp soil; Arizal, 1990m; *Banday 40 KASH.*

One of the common mosses with still intact older brown gametophores of previous years.

7. On Bark

Neckera pennata Hedw. Yellowish green patches on the trunk of *Abies*; Dupather, 2100m; *Banday 88.* Gulmarg, 2700m; *Brotherus n-1124.*

Orthotrichum affine Brid. Common on trunks of *Platanus orientalis, Salix alba* and other deciduous tree species; Harwan, 1700m; *Raj 139.* Hazaratbal, 1600m; *Raj 145.* On bark of *Salix alba;* Beerwah, 1800m; *Banday 105 KASH.* On the bark of *Juglans regia;* Punichgund, 1600m; *Banday, 109 KASH.*

O.obtusifolium Brid. On the bark of the trunk of *Platanus orientalis*; Shalimar Gardens, 1600m; *Townsend T. 87/ 261.*

The above listed three taxa show a strict habitat preference for bark. However, there are many other species which grow on bark as well as on many other substrates.

8. On man made habitats

Tortula muralis Hedw. Small tufts, patches or hoary cushions, greyish when dry, green when moist; on mortar, concrete, basic rocks and walls, brick works, rarely on trees; Beerwah 1800m; *Banday 120 KASH* and on many other man made habitats.

Bryum argenteum Hedw. Uncommon in cliffs and crevices of moist rocks; Harwan, 1700m; *Kaul & Dhar 160.* Common on moist mud walls and roof tops in close tufts, less frequently in crevices of moist rocks; Hazaratbal, 1600m; *Kachroo 45.* Very common on road sides, cemented old exposed moist places and other man made habitats; Hazratbal, 1600m; *Banday 370 KASH.*

These preceding two taxa well adapted to urban and industrial areas in the Kashmir Himalaya, are considered to be tolerant to high level of sulphur dioxide pollution (toxiphilous) (Gilbert, 1969).

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STATUS OF GENETICALLY MODIFIED CROPS WITH SPECIAL REFERENCE TO INDIAN SCENARIO- A CRITICAL ASSESSMENT

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Abstract

This paper gives an insight into a modern biotechnology technique Genetic modification in the crop production, covering various aspects including the potential use of the technology over the past twenty years in the areas of agricultural biotechnology. This technology would likely to be at the forefront in solving the problems of food, feed and hunger of developing countries like India. A critical analysis has been done to differentiate between the benefits of this technology mainly in the reduction in use of pesticides and potential risks of the release of foreign genes into the soil thereby altering the soil micro flora. In the end, the efforts made by the Indian government in promoting this technology have been given.

Keywords : Genetic modification, Gene transfer, Bt Cotton, Pests, Phytoremediation.

INTRODUCTION

The traditional breeding of plants for expressing desired characteristics has been going on for a very long time in the history of the mankind. However, there are certain limitations associated with the use of traditional plant breeding, for e.g. it is almost impossible to transfer traits between different species. Secondly, during breeding large chunks of DNA segments are exchanged and could not be termed as exact science. Use of biotechnology offers solution to some of these issues. The history of such technology is given in Table 1.

Table 1: Historical Development of Plant Breeding till Genetic Modification of Crops

1694	Discovery of sexual reproduction in crops
1719	First recorded crop hybrid
1799	First report of cereal hybrid
1866	Mendel publishes his work with pea crosses
1876	Interspecific and intergeneric crossing
1900	Start of hybrid maize
1909	Protoplast fusion reported
1927	Mutation via X rays
1937	Polyploidization
1940	Single seed descent technique developed
1960	Embryo rescue defined
1970	Start of biotechnology
1983	First GM crop developed(Tobacco)
1990	First GM cereals

Source: Anonymous, 1998

Science of Genetic Modification

Genetic Modification is an advanced technology that alters the genetic makeup of living organisms such as animals, plants, or bacteria by any other species in a specific manner (no matter how unrelated these might be). Modern genetics offers an important additional source of genes for this purpose. The characteristics of an organism are determined by its *DNA (deoxyribonucleic acid)* that is the information-containing component of the chromosome, thereby, determining the characteristics of an organism. DNA provides the genetic code, which determines how the individual cells, and consequently the whole organism, will be constructed. This code is divided up into functional units called *genes*. The total characteristics of a plant (in case of food) will depend on which *genes* it has received from the parent plants and the interactions between the *genes* and environmental factors. The advent of modern techniques of genetic modification has enabled researchers to remove individual genes from one species and insert them into another, without the need for sexual compatibility. Once the new gene has been inserted into a plant, offspring that will contain copies of the new gene can be produced in the traditional manner. Once a potentially useful variety of *genetically modified* plant (hereafter called GM crops) has been produced in the laboratory, the next stage is to move to small-scale field trials to monitor how the crop performs in an agricultural situation.

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Benefits of GM Crops

The benefits of such technology have opened vast opportunities in the biotech field. From the point of view of developing countries; yield has been a major constraint. So GM crops offer tremendous potential in overcoming yield barriers. These crops also give better quality, tastier and newer products with a reduced maturation time to produce them. Various vaccines, antigens, enzymes etc can be produced using GM plants. Another upcoming usage of such crops lies in the process called *Phytoremediation*. i.e. to remove the heavy metals from the soil thereby increasing the quality of the soil. As far as industrial usage is concerned; it increases the biomass and fuel value of the crops, produces biodegradable plastics, adds desirable fragrance and flavour and reduces undesirable compounds. More details of the benefits are listed in Table 2.

Table 2: Some GM crops and their benefits

CROPS	GENE INSERTED	AIM
Chickpea Bean	alpha AI	To generate plants resistant to bruchids
Chickpea	*PGIP*	To generate plants resistant to fungal pathogens
Cotton	Bt. Cry gene(s)	To generate plants resistant to lepidopteran pests.
Potato	Bt. cry1A(b)	To generate plants resistant to lepidopteran pests
Potato	ACC synthase	To control fruit ripening
Tobacco	Bt. cry1A(b) and cry1C	To generate plants resistant to Helicoverpa armigera and Spodotera litura
Tobacco	Chitinase, glucanase and *RIP*	To generate plants resistant to fungal attack
Tobacco	*Bt. crylla5*	To generate plants resistant to *Spodoptera litura*
Rice	Bar	To generate herbicide-tolerant plants
Rice	Bt cry1A(b) Xa21	To develop plants resistant to lepidopteran pests, bacterial blight/disease
Rice	S-adenosylmethionine decarboxylase	To generate plants tolerant to stress
Rice	Pyruvate decarboxylase and alcohol dehydrogenase	To generate plants tolerant to flooding
Rice Pusa basmati	codA, cor47	Resistance against biotic and abiotic stresses
Rice	Xa-21, cry1A(b)	To generate plants resistant to lepidopteran pests and bacterial and fungal diseases
Rice	*Bt cry1A(b)*,	*chitinase* To generate plants resistant to lepidopteran pests
Rice	*Bt. cry1A(b)*, chitinase	To generate plants resistant to yellow stem borer
Rice	*Gm2*	To generate plants resistant to gall midge
Tomato	ACC synthase	To control fruit ripening
Tomato	Bt. cry1A(b)	To generate plants resistant to lepidopteran pests
Tomato	Ctx-B and Tcp antigens of Vibrio cholerae	Edible vaccine development
Brinjal	Chitinase, glucanase and thaumatin encoding genes	To generate plants resistant to diseases
Brinjal	Bt. cry1A(b)	To generate plants resistant to lepidopteran pests
Wheat	bar, HVA1, PIN2	Resistance against biotic and abiotic stresses
Cauliflower	*Bt. cry1A(b)*	To generate plants resistant to *Plutella scylostella*
Cabbage	*Bt. cry1A(b)*	To generate plants resistant to *P.scylostella*
Mustard/rapeseed	*Arabidopsis annexin* gene	To generate stress-tolerant plants
Mustard/rapeseed	*Choline dehydrogenase*	To generate abiotic stress-tolerant plants
Banana	ACC synthase	To control fruit ripening
Pigeon pea	*Protease inhibitor* and *lectin* genes	To generate plants resistant to bollworms and aphids

Source: Sharma et al., 2003

Risk assessment of genetically modified crops

GM crops are highly regulated by the Government of India as well as in other countries mainly due to perceived risks rather than actual risks. Therefore, it is mandatory for any developer of GM crops to undergo extensive biosafety analysis of these crops before the product could be commercialized .The risk assessment includes environmental safety, feed safety and several other studies including socio-economic studies. Some of the perceived risks are that the transfer of genes from GM crops to wild species either from the pollen grains or seeds etc. may result in GM species, which may be more harmful to the crop. Moreover, passing of genes from GM crops (meant for vaccines) to non-GM food crops may introduce vaccines in the food chain of humans. These crops also harm the ecosystem by removing the pests that are a good food for the predators thus destroying the food chain. The long use of such crops may increase the resistance of the pests, which may be dangerous to other spheres in our ecosystem. It is also feared that the persistence use of such crops may release the foreign genes (Bt toxins) into the soil that may harm the soil organisms thereby affecting the rate of decomposition and the whole nutrient cycling of the crop. However, till date no data is available to substantiate the above speculation.

Minimizing gene transfer

If the genes intended for Genetic modification are injected in the chloroplast of the crop, the problem of gene transfer can be solved to a great extent, as the pollen grains coming out will not contain any chloroplast. So, even if the pollen grains are transferred to other plants, gene transfer will not take place as chloroplast does not contain any genes.

Indian agricultural scenario

The Green revolution in India started in 1960's.The yields have increased due to improved crop variety and also due to the excessive use of agrochemical such as pesticides, herbicides, weedicides and insecticides etc. Due to the expensive nature of agrochemicals and their destructive effects on the environment along with the increased malnutrition, poverty, excessive population, loss of land to urbanization and other miscellaneous factors in India, the yield and quality of food grains was going down. Therefore, some efforts were required to raise the production of the food crops in India. So biotechnologists have come forward to help Indian farmers to adapt to genetic modification of crops a technology suited for rough conditions like drought, floods, scarce water supplies and natural resources.

GM research in India

The Government of India through the Department of Biotechnology (setup in 1986) has been taking initiatives in this field to solve the problem of food security in India. The Indian Council of Agricultural Research, Department of Science and Technology, Council of Scientific and Industrial Research, and certain other agencies are also active in promoting this area. Several experiments were started in the field in different locations using mustard, cotton, and tomato. Several Indian institutes and organizations are working in this area and are listed in Table 3. One of the experiments in cotton crop was carried out by using the technology provided by Monsanto, a US company to Maharashtra Seed Company (Mahyco) in 1997. Cry gene of *Bt*. *(Bacillus thuringiensis)* was added in cotton to reduce the risk of getting attacked by boll worms. This self-defense system against bollworms helped farmers manage these pests in an effective and integrated manner with minimum use of chemicals. Many field trials were carried out with *Bt cotton* (Qaim and Zilberman, 2003) in the late nineties in different states of India and it was proved that this technology significantly reduced pest damage and increased substantially the yield of the crops.

Table 3: Indian institutes working in genetic modification of crops

INSTITUTE	CROPS
Central Tobacco Research Institute, Rajamundry, A.P	Tobacco
Bose Institute, Kolkata, West Bengal	Rice
Tamilnadu Agricultural University, Coimbatore, Tamilnadu	Rice
University of Delhi, South Campus, New Delhi	Mustard,Rapeseed,Rice
National Botanical Research institute, Lucknow, U.P	Cotton
Central Potato Research Institute, Simla, H.P	Potato
Mahyco, Mumbai, Maharashtra	Cotton
Rallis India Ltd,Bangalore, Karnataka	Chilli

Future plans

The Indian government has been taking special initiatives in this area and have allocated huge resources into this technology in the 10th five year plan from 2002-2007.Special emphasis will be given on increasing the yield and stabilization of Rice, addition of more nutrients into cereals, scientific testing of various genetically modified crops. Various efforts will be made to prevent the pollen transfer to non-GM crops to avoid any untoward growth of GM weeds, to reduce any post harvest losses etc.

Conclusion and Challenges

Genetically-modified Crops have the potential to solve many of the India's hunger and malnutrition problems, and to help protect and preserve the environment by increasing yield and reducing reliance upon chemical pesticides and herbicides. Yet, there are many challenges ahead for government, especially in the areas of safety testing, regulation, international policy and food labelling. So, proper labelling procedures should be followed by the companies and the Public Sector Institutions involved in this venture and the rules and regulations so framed by the government be strictly adhered to. It is felt that genetic modification is the inevitable wave of the future and that we cannot afford to ignore a technology that has such enormous potential benefits. However, the government must focus on the unintended harm to human health and the environment as a result of use of such a technology.

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TAXONOMIC STUDIES ON INDIAN GELECHIIDAE I. REPORTING OF FIVE NEW SPECIES UNDER GENUS *DICHOMERIS* HÜBNER FROM NORTH INDIA (LEPIDOPTERA : GELECHIOIDEA)

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Abstract

Five new species of genus Dichomeris Hübner, namely sicasymmetria, kalesarensis, hansi, fuscodelta and bispotalis along with an already known species i.e. rasilella (Herrich-Shaffer) are described and illustrated in detail. New species groups are also proposed for the five new species owing to their different set of morphological and genitalic features from already known fifteen groups. Separate keys to the species groups have also been formulated on the basis of different morphological attributes including external genitalia. Prevalence of intra-specific variations observed in wing venation and sicae of rasilella have been commented upon.

Key words : Gelechiidae, *Dichomeris*, new species groups, five new species, intra-specific variations, North India.

INTRODUCTION

Dichomeris is one of the largest genera of family Gelechiidae with majority of its species recorded from Nearctic and Western Palaearctic regions (Park and Hodges, 1995). Out of 1000 species described from all over the world, more than 40 species are represented from South East Asia, including 25 from India (Gaede, 1937; Robinson *et al.*, 1994). Recently, Pathania and Rose (2003) described a new species *Dichomeris sicaellus* besides reporting two species viz., *D. acuminata* (Staudinger) and *D. rasilella* (Herrich-Shaffer) for the first time from India. Since erection of genus *Dichomeris*, 81 genera have been synonymised under it on the basis of characteristic morphological features of wing venation, shape of labial palpus and basal segment of antenna (Walshingham, 1892; Sattler, 1973; Zimmerman, 1978; Povolny, 1978; Hodges, 1986).

All the six species dealt here viz., *sicasymmetria* sp. nov., *kalesarensis* sp. nov., *hansi* sp. nov., *fuscodelta* sp. nov., *bispotalis* sp. nov. and *rasilella* (Herrich-Shaffer) have been described and illustrated in detail. The species *rasilella* has been re-described in this manuscript for making comparison with new species described here and already known diagnosis of this species Piskunov (1989).

Genus *Dichomeris* Hübner

Dichomeris Hübner, 1818. *Zutr. Samml. exot. Schmett.*, **1** : 25.

Type species: *Dichomeris ligulella* Hübner

Key to the species groups based on external characters of genus *Dichomeris* Hübner

1. Forewing with vein R_5 absent; upper side with four elongate fuscous spots..... ***rasilella*** **(Herrich-Shaffer) group**
- Forewing with vein R_5 present; upper side without elongate spots.....**2**

2. Forewing with vein R_3 connate with R_4+R_5..... ***sicasymmetria*** **group**
- Forewing with vein R_3 separate.....**3**

3. Forewing with ferruginous spots in discal cell. ..... ***kalesarensis*** **group**
- Forewing without ferruginous spots in discal cell.....**4**

4. Ground colour of forewing greyish-brown above, with a bean-shaped black spot in middle of wing one-third away from base. ..... ***hansi*** **group**
- Ground colour of forewing brownish-ochraceous above, without any spot in middle one-third from base. **5**

5. Alar expanse 12-13 mm; forewing with distinct fuscous streak in plical fold. ..... ***fuscodelta*** **group**

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- Alar expanse 9 mm; forewing without streak in plical fold..... ***bispotalis* group**

Key to the species groups based on external male genitalia of genus *Dichomeris* Hübner

1. Aedeagus ankylosed with sicae; lateral lobe of aedeagus triangular.....***bispotalis* group**
- Aedeagus free; lateral lobe of aedeagus not so, if present.....2
2. Sicae single lobed; aedeagus without lateral lobe.....***hansi* group**
- Sicae two lobed; aedeagus with lateral lobe.....3
3. Sicae separated at base; vinculum with lateral lobe present.....***kalesarensis* group**
- Sicae joined at base; vinculum without lateral lobes.....4
4. Sicae asymmetrical.....5
- Sicae symmetrical.....***fuscodelta* group**
5. Left lobe of sicae twice the length of right; lateral lobe of aedeagus restricted in its middle part, bearing denticles at distal end.....***sicasymmetria* group**
- Left lobe of sicae comparatively shorter than right; lateral lobe of aedeagus thorn-like, reaching up to its distal end.....***rasilella* group**

rasilella species group

Labial palpi with second segment thickened ventrally, also having dorsal scale tuft. Forewing with vein R_5 absent. Hindwing with $Sc+R_1$ joined to anterior margin of discal cell by an oblique bar one-fourth from of base. Male genitalia with culcitula exarched at distal end; vinculum without lateral lobes; sicae two lobed, asymmetrical; valvae slightly reaching beyond uncus. Aedeagus not ankylosed, with a thorn-like lateral lobe reaching up to distal end.

Remarks : As per key to species group by Park and Hodges (1995), *rasilella* group is reached only if condition of vinculum as almost straight or rounded is considered which in fact has been noticed actually in the only species under it i.e., *rasilella* (Herrich-Shaffer). However, citation of character of saccal region with a strong break in salient features of this species group by the aforementioned authors seems an inadvertent error and, therefore, not included in the diagnosis of this species group, thus re-characterising this group once again in the present studies.

Dichomeris rasilella (Herrich-Shaffer) (Phs. A-B; Pl. I, Figs. 1-8)

Anacampsis rasilella Herrich-Shaffer, 1855, *Schmett. Eur.*, **5:** 202.

Male : Head with vertex creamish-brown; frons light brown. Antenna with scape creamish-brown; flagellum concolourous near base and rest fuscous, annulated with brown. Labial palpi fuscous; second segment roughened above with creamish-white scales; third segment with apex comparatively lighter. Proboscis and maxillary palpi fuscous.

Thorax creamish-white. Forewing (Fig.1) oblong; costa slightly sinuate; apex pointed, somewhat produced; termen sinuate; tornus obtusely angulate. Ground colour creamish-white, speckled with fuscous above, more up to three-fourth from base, sparsely in rest; four elongated fuscous spots, with one of them located near base, two spots one-third away and another two-third away from base; a diffused spot on costa before apex and marginal fringe along termen fuscous. Underside light ochraceous, suffused with fuscous, more densely along basal one-third of costa, apex and termen. Discal cell about four-seventh of wing length; CuA_1 and CuA_2 moderately long stalked. Hindwing (Figs. 2 and 3) nearly as broad as forewing; costa slightly exarched medially; apex acute; tornus obtusely angulate. Ground colour light brown, with grey scales along costa and apex; cilia along inner margin three-fifth of wing width, creamish-white. Discal cell about half of wing length; $Sc+R_1$ joined to anterior margin of discal cell by an oblique bar one-fourth from base; M_2 closer to M_3 than M_1; veins M_3, CuA_1 connate or shortly stalked; CuA_2 from distal one-sixth of posterior margin of discal cell.

Abdomen light ochraceous dorsally, becoming darker distally, distal end dull ochraceous; ventral surface brown. Male genitalia (Figs.4-6) with uncus resembling tip of thumb distally, minutely setose; culcitula exarched distally; gnathos sickle-shaped, highly sclerotised, adorned with numerous microscopic setae at elbow joint-like bend; tegumen plus uncus much longer than vinculum, latter bifurcated at base, slightly bulged out laterally in distal half on each side and bearing setae; saccal region W-shaped; sicae two lobed, with common base, symmetrical and small, sparsely setose (Fig.7) or asymmetrical and long, foliaceous, profusely setose, with left one slightly shorter than right; valvae simple, slightly reaching beyond tip of uncus, narrow at base,

gradually broadened distally; costa arched; cucullus densely setose; base of valvae joining medially, each bearing clavate setose process. Aedeagus (Fig.8) extremely broad, narrowing in distal half, with a sclerotised ring-like zone one-third away from proximal end, marking point of attachment of a thorn-like lateral lobe outside aedeagus reaching up to distal end; entry to ductus ejaculatorius antero-lateral.

PLATE I

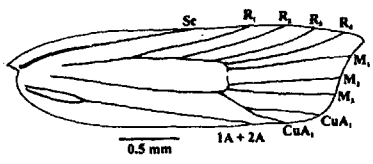


Fig. 1

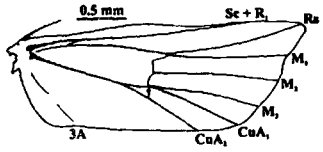


Fig. 2

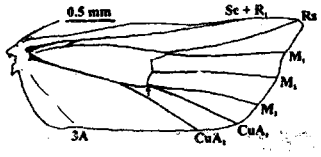


Fig. 3

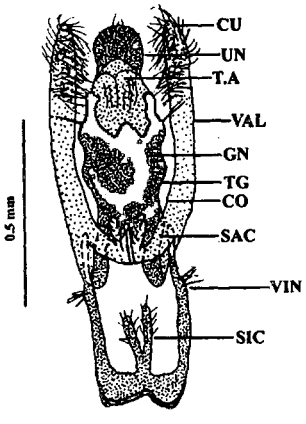


Fig. 4

Fig. 5

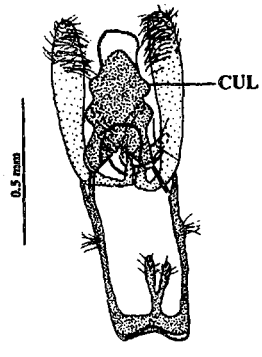


Fig. 6

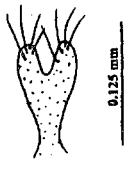


Fig. 7

Fig. 8

Dichomeris rasilella (Herrich-Shaffer): Figs. *(1), forewing; (2&3) hindwings showing variation in venation; (4) male genitalia (ventral view); (5) male genitalia (dorsal view); (6) male genitalia (lateral view); (7) sicae; (8) aedeagus.*

Alar expanse : Male : 15mm
Female : Not studied

Material examined: 1♂, 22.iii.2001; Naraingarh (Forest Rest House), Haryana. 1♂, 12.ix.2001; 1♂, 04.x.2001; Chandigarh. 1♂, 10.vi.2001;1♂, 15.viii.2001; 1♂, 19.viii.2001; 1♂, 18.viii. 2002; Sairighat (Forest Rest House), Himachal Pradesh. Collected by V.K.Walia and D. Wadhawan. (Type material in the Reference collection of Entomology Section, Zoology Department, Panjab University, Chandigarh.)

Flight period: March and June to October

Old distribution: Taiwan, Japan (Honshu, Kyushu), Korea, China, Russian Far-East, Europe, India (Srinagar, Kashmir) (Meyrick, 1928; Park and Hodges, 1995).

Larval host plant: *Artemisia princes* var. *orientalis* (Park and Hodges, 1995).

Remarks: This is the only known species under species group *rasilella* (Park and Hodges, 1995) and can be diagnosed due to absence of vein R_5 in forewing, presence of cubital pecten on hindwing and small-sized sicae in male genitalia. Pathania and Rose (2003) wrongly stated this species as new record from India. Whereas, Meyrick (1928) had raised a new genus *Gomphocrates* on the basis of a specimen of this species collected from Srinagar (Kashmir).

All the specimens of this species collected from Naraingarh (Haryana), Chandigarh (U.T.) and Sairighat (Himachal Pradesh) were noticed to possess creamish-white forewings densely suffused with fuscous in basal half, also marked with four fuscous spots in the centre as against described chocolate brown to grey ground colouration with four chocolate brown spots (Piskunov, 1989). In addition to this, intra-specific variations in the wing venation of hindwing and male genitalia were also noticed. Out of seven male specimens, hindwings of one of the specimens had veins M_3 and CuA_1 stalked, more minutely in another and connate in the remaining five specimens. Different workers while working on various groups of order Lepidoptera viz., Walia (2004) on Papilionoidea, Walia and Nisha (2003, 2004) on different subfamilies of Geometridae, Albretch and Kaila (1997) on Elachistidae (Gelechioidea) and Sotavalta (1964) on Arctidae have reported such type of variations.

Furthermore, out of three abdomens dissected for studying structure of male genitalia, one of the male genitalia astoundingly possessed symmetrical sicae, in contrast to asymmetrical in the other two. Such a falsification of entomological rule has also been reported in genera *Glossotrophia* Prout and *Scopula* Schrank of family Geometridae by Hausmann (1999).

sicasymmetria species group

Labial palpi with second segment roughened above towards apex. Forewing with vein R_3 connate with R_4+R_5. Hindwing with $Sc+R_1$ joined with anterior margin of discal cell by an oblique bar two-fifth from away base. Male genitalia with culcitula slightly convex distally; vinculum without lateral lobes; sicae with common base broad, bearing a pair of asymmetrical lobes, with left lobe twice the length of right; valva exceeding well beyond tip of uncus. Aedeagus not ankylosed; lateral lobe short and bearing denticles at distal end.

Remarks: Some of the salient features like presence of asymmetrical sicae, valva exceeding apex of uncus and vinculum almost straight reveal closeness of *rasilella* to the newly formed species group *sicasymmetria*. However, presence of vein R_5 in the forewing of latter distinctly separates it from the former species group.

Dichomeris sicasymmetria sp. nov. (Ph. C; Pl. II, Figs. 9-13)

Male: Head light brownish-grey; frons laterally fuscous. Antenna whitish-ochraceous, suffused with fuscous, about three-fourth of wing length, fasciculate, fasi-cae long. Labial palpi light ochraceous; second segment richly suffused with fuscous laterally on outerside, roughened above towards apex with whitish-ochraceous hair scales; third segment longer than second. Proboscis dull ochraceous; maxillary palpi fuscous.

Thorax greyish-brown. Forewing oblong (Fig.9); costa gently arched; apex acute, produced; termen slightly concave; tornus obtusely angulate. Ground colour greyish-brown above; costa whitish-yellow; three fuscous spots, one in plical fold at one-third away from base, another above and slightly ahead of it, third on discocellulars; a series of fuscous specks along termen; cilia along margin pale ochraceous. Underside greyish-fuscous; costa fuscous in basal one-fourth, rest whitish-yellow; wing between inner margin and plical fold creamish-white. Discal cell three-fifth of wing length; R_1 from beyond middle of anterior margin of discal cell; CuA_1 and CuA_2 short stalked. Hindwing (Fig.10) broader than forewing; costa straight except short slope in middle; apex acutely produced; termen sinuate; tornus obtusely angulate. Upper and underside grey,

enormously speckled with fuscous; costa whitish-ochraceous in basal half; cilia along inner margin two-third of wing width, pale grey. Discal cell about half of wing length; $Sc+R_1$ joined with anterior margin of discal cell by an oblique bar two-fifth from base; M_3 and CuA_1 moderately long stalked; CuA_2 from distal one-sixth of posterior margin of discal cell. Legs light ochraceous, suffused with greyish-fuscous; hind tibia light ochraceous hair scaled above. Male genitalia (Figs.11) with uncus U-like, beset with short setae; culcitula slightly excurved at distal end; gnathos sickle-shaped, apex pointed, recurved; tegumen and uncus longer than vinculum; vinculum bifurcated at base; saccal region curved; sicae with broad common base, giving out a pair of asymmetric lobes, left lobe double the length of right, narrower and pointed at distal end, latter blunt at

PLATE II

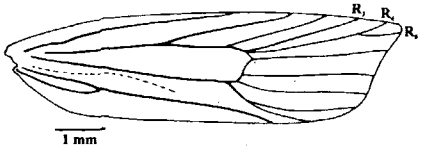


Fig. 9

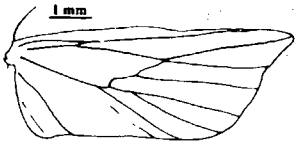


Fig. 10

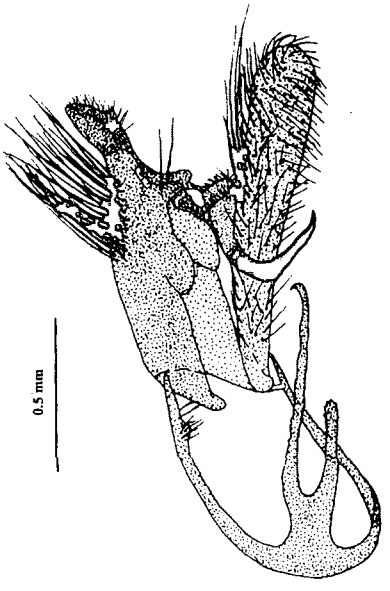


Fig. 11

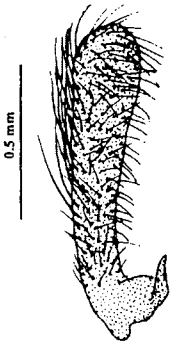


Fig. 12

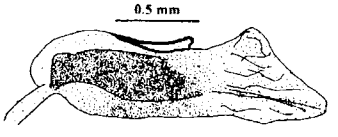


Fig. 13

***Dichomeris sicasymmetria* sp. nov.: Figs. (9)** forewing : (10) hindwing: (11) male genitalia (ventro-lateral view) (12) valva: (13) aedeagus;

apex; each valva (Fig.12) simple, narrow at base, gradually broadened distally, exceeding well beyond tip of uncus; costa arched at base; cucullus densely setose. Aedeagus (Fig.13) broad, with lateral lobe bearing short denticles at distal end; cornuti represented by numerous microscopic spines; ductus ejaculatorius opening laterally into aedeagus.

Alar expanse: Male : 18mm – 20mm
Female : Not studied

Material examined: Holotype : 1♂, 20.iv.2001; Kalesar (Forest Rest House), Haryana.

Paratypes : 1♂, 26.vii.2003; Subathu (Forest Rest House), Himachal Pradesh. 1♂, 17.viii.2002; Sairighat (Forest Rest House), Himachal Pradesh. Collected by V.K.Walia and D. Wadhawan. (Type material in the Reference collection of Entomology Section, Zoology Department, Panjab University, Chandigarh.)

Flight period: April, July and August

Type locality: Kalesar (Haryana)

Larval host plant: Unknown

Etymology: The new specific name *Dichomeris sicasymmetria* signifies the presence of asymmetrical sicae in the male genitalia.

Remarks: This new species is closely allied to *D. rasilella* (Herrich-Shaffer) of *rasilella* species group as both the species have asymmetrical sicae. However, these species differ in wing maculation and venation of forewing. Forewing in *rasilella* is characterized by absence of vein R_5 as against well-defined in *sicasymmetria* sp. nov.

kalesarensis species group

Labial palpi with second segment bearing expansible hair above. Forewing with vein R_3 free; R_4 and R_5 long stalked. Hindwing with $Sc+R_1$ joined by an oblique bar from middle of anterior margin of discal cell. Male genitalia with culcitula nearly straight at distal end; vinculum bearing a lateral lobe dilated at tip on each side at base; sicae paired, symmetrical, separated at base; valvae reaching well beyond tip of uncus. Aedeagus ankylosed; lateral lobe thorn-like, two-third of aedeagus. Female genitalia with corpus bursae possessing two unequal-sized sclerotised ridges; signum present.

Remarks: Although the newly formed species group *kalesarensis* shows similarities with *pyrroschista* group so far as symmetrical sicae separated at base and valvae exceeding tip of uncus is concerned, yet the presence of lateral lobes at the base of vinculum in *D. kalesarensis* only strengthen its raising to a status of separate group.

Dichomeris kalesarensis sp. nov. (Ph. D; Pl. III, Figs. 14-19)

Male: Head with vertex greyish-brown; frons concolourous, lateral margins black. Antenna about as long as forewing, ciliated; scape fuscous; flagellum dorsally dark brown with fuscous spots. Labial palpi with second segment thick, black on outerside, innerside dark grey with expansible whitish-ochraceous hair above; terminal segment dark fuscous above with basal half light ochraceous. Proboscis developed, dull ochraceous; maxillary palpi fuscous.

Thorax brown dorsally, with a median longitudinal ferruginous streak ending into a concolourous spot posteriorly. Forewing (Fig.14) oblong, narrow, broadened posteriorly; costa slightly bent inwards in middle; apex obtuse, produced; termen sinuate; tornus obtusely angulate. Ground colour greyish-light brown above, speckled with ferruginous and fuscous scales; a narrow pale ochraceous streak on costa from base to apex; a spot at base of costa black; longitudinal series of four ferruginous spots from near base to end of discal cell; two concolourous spots present, with one below first from base and another below third; a series of spots along costa from distal one-third to apex and along termen black; cilia along margin light brown, interrupted by tuft of pale ochraceous cilia from marginal spots. Discal cell about one-third of wing length, R_1 from beyond middle; CuA_1 and CuA_2 on a moderately long stalk. Hindwing (Fig.15) broader than forewing, trapezoidal; costa slopping downwards in middle otherwise straight; apex produced, tornus obtusely angulate. Ground colour on upper and underside fuscous, greyish-white along costa up to three-fifth away from base on upperside; cilia along inner margin about one-third of wing width, grey. Discal cell nearly half of wing length; anterior margin slightly exarched; $Sc+R_1$ joined by an oblique bar from middle of anterior margin of discal cell; Rs to apex; M_3 and CuA_1 on a moderately long stalk; CuA_2 from distal one-third of posterior margin of discal cell. Legs fuscous; tarsi of forelegs with whitish bands on joints, hind tibia fuscous hair scaled above; hind tarsi light ochraceous, densely irrorated with fuscous.

Abdomen fuscous; underside with a medial whitish-ochraceous band. Male genitalia (Figs.16 and 17) with

uncus U-shaped, bearing minute setae; culcitula nearly straight at distal end; gnathos expanded into rectangular setose structure and a pair of conical processes at base, tapering to a point; tegumen plus uncus nearly equal to vinculum, latter bifurcated at base and bearing a distally dilated, setose lateral lobe on each lateral side; sicae paired, symmetrical, long, separate at base, outer side of each beset with minute setae and inner side bearing comparatively minute spines; valvae simple, profusely setose, narrow at base, gradually broadened distally and exceeding well beyond tip of uncus; sacculus giving out narrowly digitate process beset with long setae, latter reaching up to base of uncus. Aedeagus (Fig.18) relatively broad posteriorly; cornutus represented by a highly sclerotised plate; lateral lobe thorn-like, two-third of

PLATE III

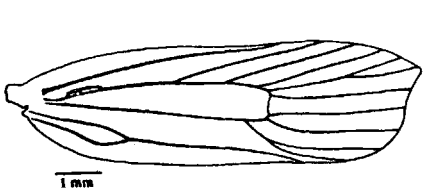


Fig. 14

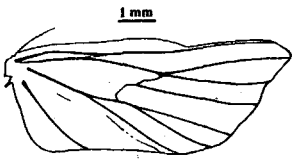


Fig. 15

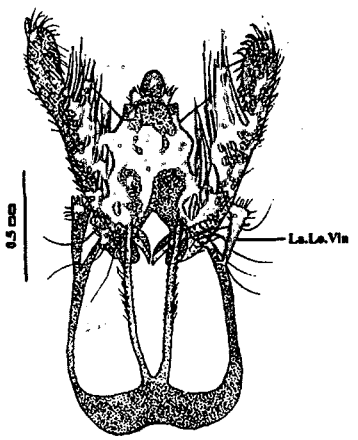


Fig. 16

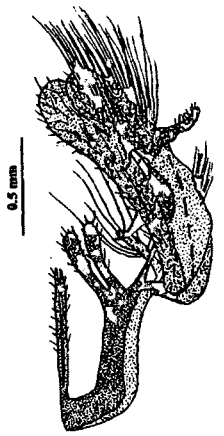


Fig. 17

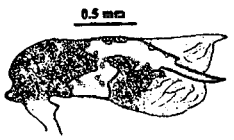


Fig. 18

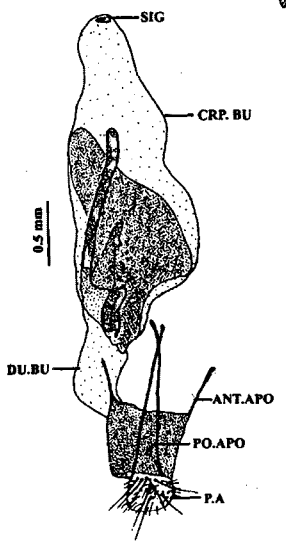


Fig. 19

Dichomeris kalesarensis sp. nov.: Figs. *(14) forewing; (15) hindwing: (16) male genitalia (ventral view): (17) male genitalia (lateral view): (18) aedeagus: (19) female genitalia.*

aedeagus; ductus ejaculatorius opening antero-laterally. Female genitalia (Fig.19) with corpus bursae large, membranous, possessing two unequal-sized sclerotised ridges; signum represented by a small, wavy margined, highly sclerotised plate at proximal end of corpus bursae; remaining part densely adorned with microscopic denticles; ductus bursae short membranous; anterior apophyses one-fourth of posterior, tips of both pairs dilated; papillae anales somewhat oval, adorned with setae of varying lengths.

Alar expanse: Male : 20mm – 21mm
Female : 20mm – 21mm

Material examined: Holotype: 1♂, 04.viii.2002; Kalesar (Forest Rest House), Haryana.

Paratypes: 2♂♂, 04.viii.2002; 6♀♀, 06.viii.2002; 12♂♂, 3♀♀, 07.viii.2002; 5♂♂, 2♀♀, 08.viii.2002; Kalesar (Forest Rest House), Haryana. 1♂, 2♀♀, 16.viii.2002; 1♂, 2♀♀, 17.viii. 2002; 3♂♂, 18.viii.2002; Sairighat (Forest Rest House), Himachal Pradesh. Collected by V.K.Walia and D. Wadhawan. (Type material in the Reference collection of Entomology Section, Zoology Department, Panjab University, Chandigarh.)

Flight period: August

Type locality: Kalesar (Haryana)

Larval host plant: Unknown

Etymology: The new species *Dichomeris kalesarensis* has been named after the type locality Kalesar in the state of Haryana because of its abundance.

Remarks: This species resembles *sandyctis* Meyrick of genus *Musurga* Meyrick now synonymised under *Dichomeris* so far as general body colouration, spots on forewing and paired sicae separated at base are concerned. However, the two species emphatically differ in venation of forewing and structure of male genitalia (Clarke, 1969). The closely allied species shows vein R_3 stalked with R_4 + R_5 in forewing, asymmetrical sicae and absence of lateral lobes of vinculum in contrast to vein R_3 free, symmetrical sicae and vinculum having lateral lobes in *D. kalesarensis* sp. nov.

hansi species group

Labial palpi with second segment not expanded at apex. Forewing with vein R_3 free; R_4 and R_5 stalked. Hindwing with $Sc+R_1$ joined by an oblique bar with anterior margin of discal cell two-fifth away from base. Male genitalia with culcitula broadly V-shaped at distal end; vinculum without lateral lobes; sicae single lobed, as long as valvae; valvae reaching well beyond uncus. Aedeagus not ankylosed, without lateral lobe.

Remarks: This species group resembles *hoplocrates* group as both of these have rounded uncus at distal end and single lobed sicae. However, leaden-blue metallic forewing in all the three species pertaining to the latter species group (Park and Hodges, 1995) clearly differentiates it and, therefore, necessitated proposing of new species group *hansi*.

Dichomeris hansi sp. nov. (Ph. E; Pl. IV, Figs. 20-24)

Male: Head greyish-brown scaled, tips of scales lighter. Antenna six-seventh of forewing length, fuscous; flagellum with transverse ochraceous bands below. Labial palpi with second segment fuscous on outerside, innerside ochraceous with fuscous suffusion at base, apex creamish-white; third segment longer than second, ochraceous, sparsely irrorated with fuscous. Proboscis ochraceous; maxillary palpi fuscous.

Thorax brown. Forewing oblong (Fig.20); costa arched; apex somewhat produced; tornus obtusely angulate. Ground colour greyish-brown above; costa yellowish-ochraceous; a large bean-shaped, black spot in middle at about one-third away from base; a spot at end of discal cell black; a small diffused triangular fuscous spot on costa at about two-third from base continuing as diffused streak up to inner margin, posteriorly margined by yellowish-ochraceous suffusion; a spot on apex and series of spots along termen fuscous; marginal fringe of cilia double, longer greyish-brown and shorter yellowish-ochraceous. Discal cell four-seventh of wing length; R_1 from beyond middle of anterior margin of discal cell; CuA_1 and CuA_2 on moderately long stalk. Hindwing (Fig.21) broader than forewing, costa exarched in middle; apex produced, acute; tornus obtusely angulate. Upper and undersides greyish-fuscous; cilia along inner margin about one-third of wing width, grey. Discal cell half of wing length; $Sc+R_1$ joined by an oblique bar with anterior margin of discal cell two-fifth from base of; M_3 and CuA_1 minutely stalked; CuA_2 from distal one-third of posterior margin of discal cell. Legs whitish-ochraceous, anterior two pairs suffused with fuscous; hind tibia roughly scaled throughout.

Abdomen greyish-brown above, whitish-ochraceous below. Male genitalia (Figs.22 and 23) with uncus U-shaped, minutely setose; culcitula broadly V-shaped at distal end; gnathos with lateral arms joining in middle, sickle-shaped, with a flat rectangular, minutely

spinose process at base; tegumen and uncus equal to vinculum in length, latter bifurcated at base, dilated and beset with setae; sicae single lobed, as long as valvae, moderately setose; valvae simple, narrow at base and abruptly broadened before middle, reaching well beyond uncus; costa slightly arched; cucullus densely setose; sacculus of each valva bearing very short and digitate setose process. Aedeagus (Fig.24) broad, lateral sides highly sclerotised, posterior end rounded, without lateral lobe; vesica adorned with numerous microscopic spines; ductus ejaculatorius opening antero-laterally.

Alar expanse: Male : 17mm
Female : Not studied

Material examined: Holotype : 1♂, 05.viii.2002; Morni (Forest Rest House), Haryana.

PLATE IV

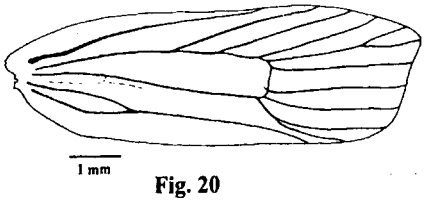


Fig. 20

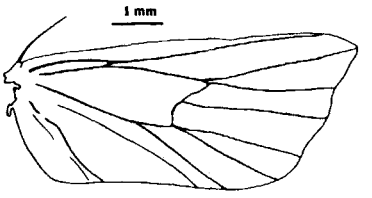


Fig. 21

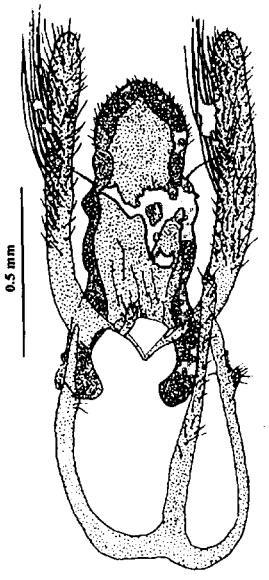


Fig. 22

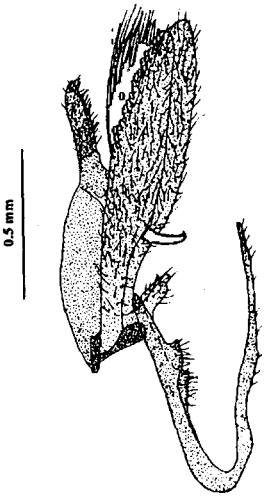


Fig. 23

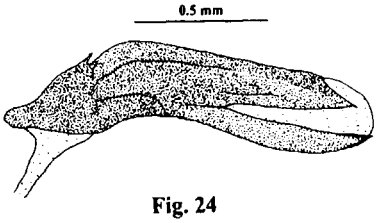


Fig. 24

***Dichomeris hansi sp. nov.*: Figs.** *(20) forewing: (21) hindwing: (22) male genitalia (ventral view): (23) male genitalia (lateral view): (24) aedeagus.*

Paratypes : 1♂, 20.ix. 2001; Kalka, Haryana. 2♂♂, 19.ix. 2002; Chandigarh. 1♂, 24.ix.2003;Sairighat (Forest Rest House), Himachal Pradesh. Collected by V.K.Walia and D. Wadhawan. (Type material in the Reference collection of Entomology Section,Zoology Department, Panjab University, Chandigarh).

Flight period: August and September

Type locality: Morni (Haryana)

Larval host plant: Unknown

Etymology: The name of new species pertains to a versatile entomologist Prof. Hans Raj Pajni of Panjab University, Chandigarh.

Remarks: A cursory look at the photograph of *Dichomeris loxospila* (Meyrick) belonging to *loxospila* species group (Park and Hodges, 1995) reveals position and shape of spots similar to those possessed by *D. hansi* sp. nov. However, single lobed sicae and absence of lateral lobes on aedeagus in *hansi* sp. nov. distinctly separates it from *D. loxospila* having paired sicae and aedeagus with complicated lateral lobes (Park and Hodges, 1995).

fuscodelta species group

Labial palpi with second segment not expanded above near apex. Forewing with vein R_3 free, R_4 and R_5 stalked. Hindwing with $Sc+R_1$ joined to anterior margin of discal cell by an oblique bar at one-fourth away from base. Male genitalia with culcitula U-shaped; vinculum without lateral lobes; sicae bilobed, lobes symmetrical, arising from common base measuring one-fourth of total length; valvae reaching beyond tip of uncus. Aedeagus not ankylosed; lateral lobe spine-like, arising from middle and reaching up to tip. Female genitalia with corpus bursae possessing sclerotised ridges of unequal size forming V-like structure; signum present.
Remarks: This newly erected species group *fuscodelta* is closely allied to *acuminata* group because of symmetrical sicae originating from common base and vinculum lacking lateral lobes. However, presence of well-developed scale tufts on ventral side of second segments of labial palpi, a pair of scale tufts on anepisternum in male (in some species), sicae fused with each other for more than one-third length and absence of lateral lobes in aedeagus of *acuminata* group sets it apart from *fuscodelta*.

Dichomeris fuscodelta sp. nov. (Ph. F-G; Pl. V, Figs. 25-30)

Male: Head with vertex pale brownish-ochraceous; frons fuscous. Antenna four-fifth of forewing; scape short, black; flagellum black dorsally, ochraceous ventrally. Labial palpi with second segment fuscous, grey above and at apex; third segment pale brownish-ochraceous with a longitudinal fuscous streak on inner side. Proboscis and maxillary palpi fuscous.

Thorax pale brownish-ochraceous; patagium tegula concolourous with a basal fuscous spot. Forewing (Fig.25) oblong; costa evenly arched; apex somewhat pointed; termen oblique; tornus inconspicuous. Ground colour pale brownish-ochraceous above; costa black at base; a distinct streak of black suffusion in plical fold from base to one-third away; a large fuscous spot on costa triangular, two-third away from base; a sub apical dark fuscous spot continuing anteriorly into a short and indistinct fuscous streak; cilia along margin ochraceous. Underside greyish-brown. Discal cell two-third of wing length; R_1 from beyond middle of anterior margin of discal cell; CuA_1 and CuA_2 on a short stalk stalked. Hindwing (Fig.26) with costa slopping downwards in middle, otherwise straight; apex somewhat pointed; termen sinuate; tornus obtusely angulate. Ground colour on upper and underside greyish-brown; cilia along inner margin two-fifth of wing length. Discal cell three-fifth of wing length; $Sc+R_1$ joined with anterior margin of discal cell by an oblique bar at one-fourth away from base; M_3 and CuA_1 short stalked; CuA_2 from distal one-fifth of posterior margin of discal cell. Legs fuscous; hind tibia pale brownish-ochraceous irrorated with fuscous, long pale brownish-ochraceous hair scaled above; hind tarsi dull fuscous, joints ringed with ochraceous.

Abdomen fuscous above; greyish-fuscous below. Male genitalia (Figs.27 and 28) with uncus and culcitula U-shaped, former beset with microscopic setae; gnathos bearing a long seta at its junction with tegumen; broad lateral arms joining a discoidal structure bearing microscopic spines in middle, giving out a sickle-shaped process; tegumen plus uncus longer than vinculum, latter bifid at base, with arm joining tegumen, bearing a globular, setose process near bifurcation; sicae bilobed, symmetrical, arising from common base measuring one-fourth of their total length, shorter than valvae, each process blunt at distal end, bearing a few minute setae; valva simple, narrow anteriorly, gradually broadened posteriorly; costa straight; cucullus rounded at distal end, reaching beyond tip of uncus; valvae joining medially, giving out a sparsely setose lobe-like processes at point of junction. Aedeagus (Fig.29) broad proximally, gradually narrows to a pointed tip; a spine-like lateral lobe on outside of aedeagus from near

PLATE V

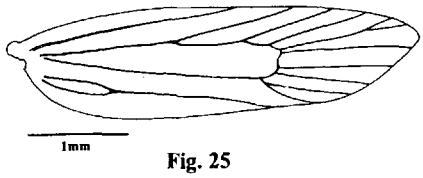


Fig. 25

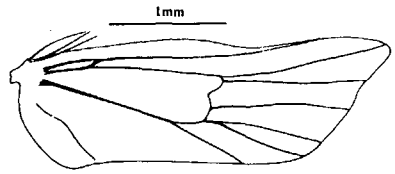


Fig. 26

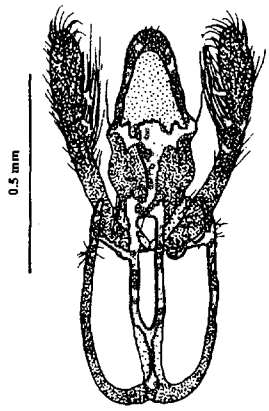


Fig. 27

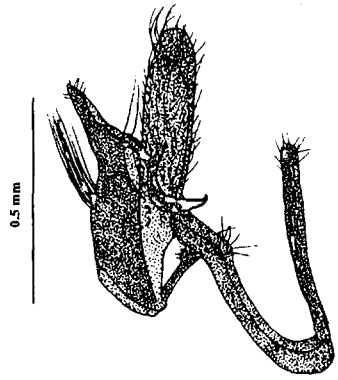


Fig. 28

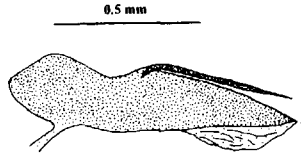


Fig. 29

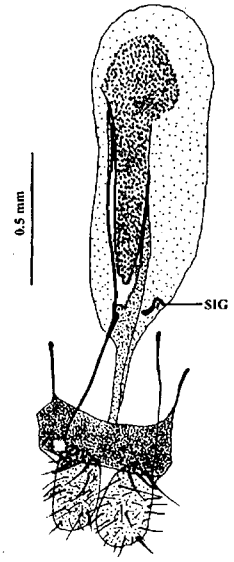


Fig. 30

Dichomeris fuscodelta sp. nov.: Figs. *(25) forewing: (26) hindwing; (27) male genitalia (ventral view): (28) male genitalia (lateral view); (29) aedeagus: (30) female genitalia.*

middle to tip; ductus ejaculatorius opening laterally. Female genitalia (Fig.30) with corpus bursae, oblong profusely denticulate, with sclerotised ridges of unequal size forming V-like structure; signum represented by irregular short denticulate plate near distal end; ductus bursae about one-third of corpus bursae; anterior apophyses one-third of posterior, apices of both pairs broad; papillae anales ovate, beset with setae of varying lengths.

Alar expanse: Male : 12mm – 13mm
Female : 12 mm – 13 mm

Material examined: Holotype : 1♂, 4.x.2001; Chandigarh.

Paratypes : 1♀, 12.vi.2000; 1♂, 16.vi.2001; 1♂, 1♀, 12.ix.2001; 1♀, 26.ix.2001; 1♂, 28.ix. 2001; : 2♂♂, 4.x.2001; Chandigarh. 1♂, 7.viii.2002; 1♂, 20.ix.2002; Kalesar (Forest

Rest House), Haryana. 1♀, 20.ix.2001; Kalka, Haryana. Collected by V.K.Walia and D. Wadhawan. (Type material in the Reference collection of Entomology Section, Zoology Department, Panjab University, Chandigarh.)

Flight period: June, September and October

Type locality: Chandigarh (U.T.).

Larval host plant: Unknown

Etymology: *Dichomeris fuscodelta* sp. nov. name highlights a triangular fuscous marking present on the costal margin of forewings.

Remarks: The present species does not resemble with any of the species of genus *Trichotaphe* Clemens identified after following key to the world genera of family Gelechiidae by Meyrick (1925). As this genus is currently synonymised under *Dichomeris,* therefore, it has been named *D. fuscodelta* sp. nov., a new addition to existing fauna.

bispotalis species group

Labial palpi with second segment expanded at apex above. Forewing with vein R_3 free; R_4 and R_5 stalked. Hindwing with $Sc+R_1$ joined to anterior margin of discal cell by an oblique bar one-third away from base. Male genitalia with culcitula U-like at distal end; vinculum without lateral lobe; sicae bilobed, symmetrical, arising from extremely short common base, nearly one-third of each valva; valvae reaching slightly beyond uncus. Aedeagus ankylosed with sicae; lateral lobe short, triangular, arising from its middle.

Remarks: The new species group seems close to *sparsellus* group (Park and Hodges, 1995) because of aedeagus ankylosed with sicae and uncus rounded at distal end. However, in *sparsellus* group, second segment of labial palpi has well developed scale tufts on ventral and dorsal sides, vinculum with a pair of membranous lobes arising from near base of valvae and latter greatly exceeding tip of uncus in contrast to presence of only dorsal tuft of scales on labial palpi, vinculum without membranous lobes and valvae slightly exceeding tip of uncus in *bispotalis* group.

Dichomeris bispotalis sp. nov. (Ph. H-I; Pl. VI, Figs. 31-35)

Male: Head pale brownish-ochraceous; lateral sides of frons fuscous. Antenna four-fifth of forewing; scape brown; flagellum with alternate fuscous and brown annulations. Labial palpi pale brownish-ochraceous; second segment fuscous, rough scaled, greyish above, expanded at apex. Proboscis and maxillary palpi pale brownish-ochraceous.

Thorax pale brownish-ochraceous. Forewing (Fig.31) oblong; costa arched, at base then straight; termen oblique; tornus inconspicuous. Ground colour pale brownish-ochraceous, base of costa fuscous; a wedge-shaped fuscous spot on costa at two-third away from base; subapical speck dark fuscous; cilia along margin concolorous to ground colour of forewing. Underside pale brownish-ochraceous. Discal cell three-fourth of wing length; R_1 from beyond middle of anterior margin of discal cell; CuA_1 and CuA_2 shortly stalked. Hindwing (Fig.32) with costa slopping downwards in middle otherwise straight; apex somewhat pointed, produced; termen oblique; tornus obtusely angulate. Ground colour pale greyish-ochraceous on upper and underside; cilia along inner margin equal to wing-width, pale greyish-ochraceous. Discal cell three-fourth of wing length; $Sc+R_1$ joined with anterior margin of discal cell by an oblique bar one-third away from base; M_3 and CuA_1 minutely stalked; CuA_2 from about distal one-fifth of posterior margin of discal cell. Legs ochraceous; hind tibia with concolourous hair scales above.

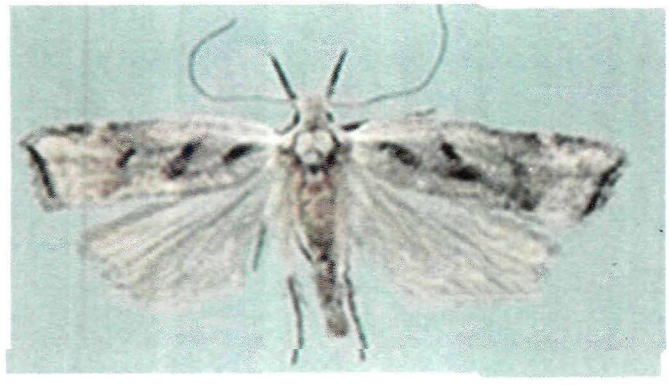
Abdomen dull brownish-ochraceous. Male genitalia (Figs.33-34) with tip of uncus thumb-like, beset with microscopic setae; culcitula U-like at distal end; gnathos with broad lateral arms joining medially disc-like structure, continuing into sickle-shaped process; tegumen and uncus longer than vinculum, latter bifurcated and broadened at base, its broadened part sparsely setose; sicae bilobed, symmetrical, with an extremely short common stalk, nearly one-third of valvae in length, each lobe broad anteriorly narrowed and slightly curved posteriorly, beset with a few microscopic setae at apex; saccal region W-shaped; valvae simple, narrow anteriorly, gradually broadened posteriorly, reaching slightly beyond uncus; costa arched; cucullus densely setose; sacculus of each valva joining in middle, possessing a very short and sparsely setose process. Aedeagus (Fig.35) ankylosed with sicae; lateral lobe short and triangular, arising from middle of its straighter side; vesica adorned with microscopic spines; ductus ejaculatorius opening laterally.

Alar expanse: Male : 9mm
Female : Not studied

Material examined:

Holotype : 1♂, 12.v.2003; Panchkula, Haryana.

Paratypes : 2♂♂, 12.v.2003; Panchkula, Haryana.



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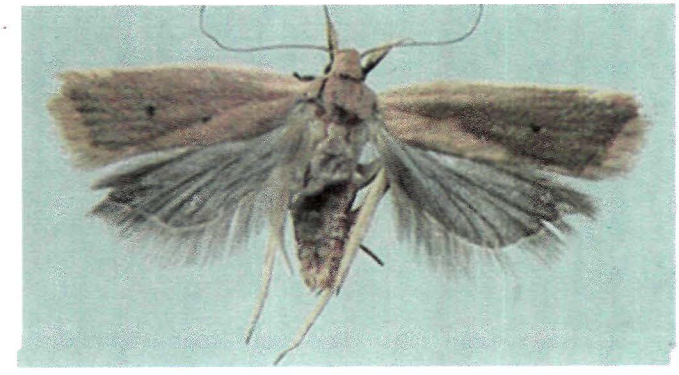

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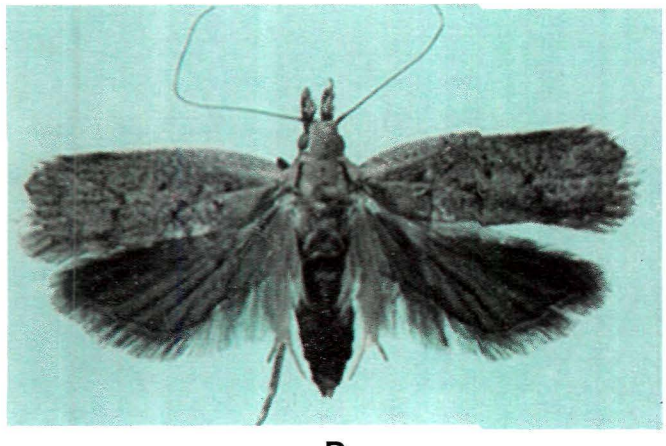

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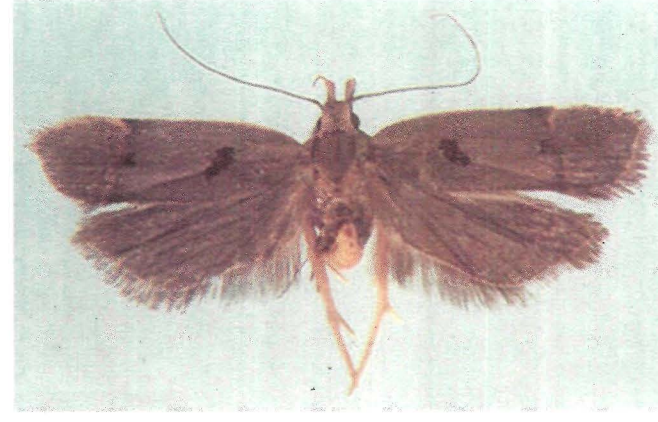

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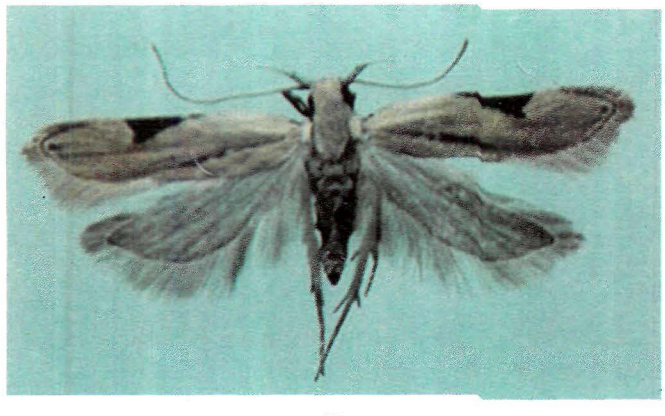

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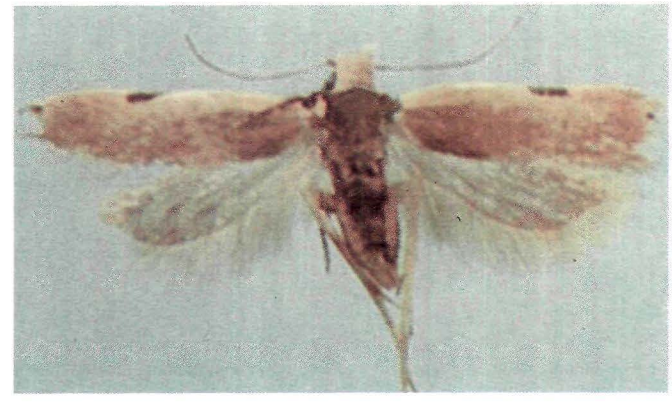
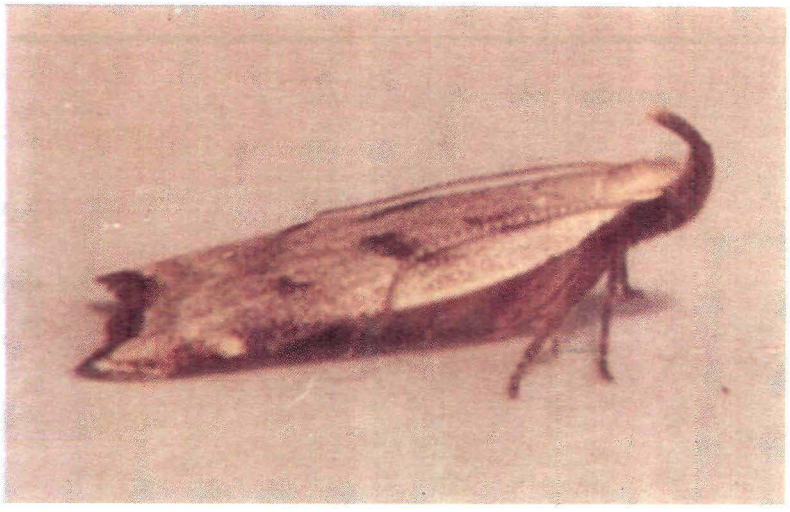


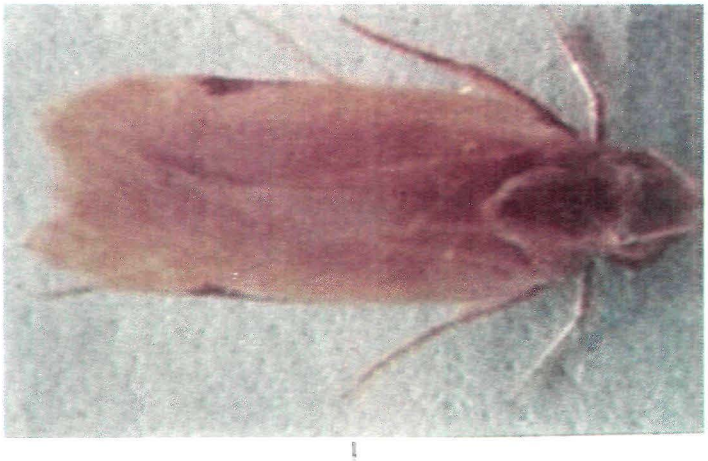
H

Dichomeris rasilella (Herrich-Shaffer) (Ph. B); *D. sicasymmetria* sp. nov. (Ph. C); *D. kalesarensis* sp. nov. (Ph. D); *D. hansi* sp. nov. (Ph. E); *D. fuscodelta* sp. nov. (Ph. F); *D. bispotalis* sp. nov. (Ph. H).
Ph. = *Photograph*.



A

G



I

Live photographs of Dichomeris rasilella (Herrich-Shaffer) (A); D. fuscodelta sp. nov. (G); D. bispotalis sp. nov. (I).

Collected by V.K.Walia and D. Wadhawan. (Type material in the Reference collection of Entomology Section, Zoology Department, Panjab University, Chandigarh.)

Flight period: May

Type-locality: Panchkula (Haryana)

Larval host plant: Unknown

Etymology: Presence of only two spots on forewings inspired naming of this species as *D. bispotalis* sp.nov.

Remarks : *Dichomeris bispotalis* sp. nov. resembles *D. fuscodelta* sp. nov. in ground colour and general pattern of forewing and paired symmetrical sicae arising from common base. However, present species possesses small-sized sicae on a short stalk, each broad at base and narrowing towards apex, aedeagus ankylosed with sicae and alar expanse measuring only 9mm as compared to sicae with common base measuring one-fourth of their total length, each of even width, aedeagus not ankylosed with sicae and alar expanse measuring 12-13 mm in *D. fuscodelta* sp. nov.

PLATE VI

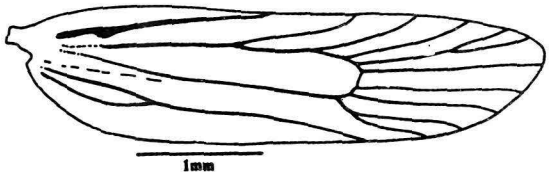


Fig. 31

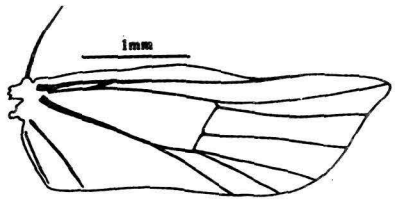


Fig. 32

Fig. 33

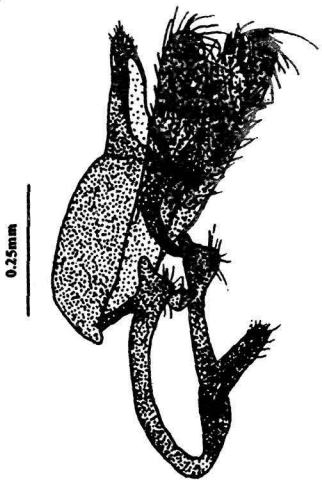


Fig. 34

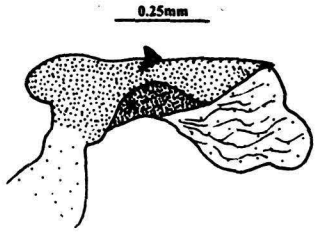


Fig. 35

Dichomeris bispotalis sp. nov.: ***Figs.****(31) forewing; (32) hindwing; (33) male genitalia (ventral view); (34) male genitalia (lateral view); (35) aedeagus.*

Field notes

Sitting posture of all the six investigated species was observed to be of same style. While resting on the substratum, the moths of this species make an angle by keeping the anterior end elevated on legs. The antennae are kept over the forewings with proximal half parallel to long axis of the body and distal half perpendicular to it as is revealed by three species *D. rasilella* (Herrich-Shaffer), (Ph.A) *D. fuscodelta* sp.nov. (Ph.G) and *D. bispotalis* sp.nov. (Ph.I).

DISCUSSION

Similarities in various genitalic structures viz., shape of uncus, gnathos, valvae, presence of culcitula and sicae in all the six species confirm not only their congeneric status but also establishes this group as a homogenous one.

Park and Hodges (1995) while dealing with 43 species of genus *Dichomeris* Hübner from Taiwan and Japan, formed 15 species groups, namely *harmonias*, *oceanais*, *acuminata*, *lushanae*, *lespedezae*, *picrocarpa*, *pyrroschista*, *microsphena*, *sparsellus*, *oxycarpa*, *rasilella*, *autometra*, *loxospila*, *hoplocrates* and *cymatodes*. In addition to this, separate keys were also formulated on the basis of morphological features and genitalic structures of both the sexes. After following key to the species groups based on morphological features, the investigated species and species groups arrived at were *kalesarensis* sp. nov. and *sicasymmetria* sp. nov. (species group *autometra*), *fuscodelta* sp. nov. and *bispotalis* sp. nov. (species group *cymatodes*), *hansi* sp. nov. (species group *loxospila*) and *rasilella* (Herrich-Shaffer) (species group *rasilella*). Whereas, on following key to species groups based on structure of male genitalia, same species ended up like *kalesarensis* sp. nov. (species group *pyrroschista*), *sicasymmetria* sp. nov. and *rasilella* (Herrich-Shaffer) (species group *rasilella*), *fuscodelta* sp. nov. (species group *acuminata*), *bispotalis* sp. nov. (species group *sparsellus*) and *hansi* sp. nov. (species group *hoplocrates*). Surprisingly, only one out of six species *i.e. rasilella* of the *rasilella* species group showed consistency in its species group status after following both the keys given by Park and Hodges (1995).

It is evident from the problems experienced while allocating appropriate species groups established so far that all the species known from the world cannot be accommodated within fifteen species groups prepared for forty three species. This surely necessitated establishing of more species groups with different combination of characters.

Results of placing any species compromisingly by ignoring salient features of available species groups can be very misleading for the future workers. Pathania and Rose (2003) identified one out of three species as *Dichomeris acuminata* (Staudinger) whose aedeagus showed one lateral lobe and kept it in species group *acuminata* without any comments despite the absence of lateral lobe, a well established character of this group (Park and Hodges, 1995). Therefore, to avoid these aforementioned anomalies encountered while following keys, formation of these five new species groups viz., *sicasymmetria*, *kalesarensis*, *hansi*, *fuscodelta* and *bispotalis* was an essential step to place species in right group.

Furthermore, Pathania and Rose (2003) have described the origin of two setose lobes, one on each side from the base of tegumen in all the three investigated species of *Dichomeris*. On the contrary, such setose lobes were found to originate from the base of valvae in the presently observed species. Similar structures were also noticed by Park (1994) and Park and Hodges (1995) arising from near base of valvae in various species of the aforementioned genus, to which these workers labelled as ventral free lobes.

ACKNOWLEDGEMENTS

The authors are sincerely thankful to the Ministry of Environment and Forests for sanctioning an All India Coordinated project on Taxonomy for research on Microlepidoptera (AICOPTAX) No. J-22018/58/99-CSC(BC). Authors are indebted to the Forest Department in the concerned states for rendering cooperation during the collection of material. We are also grateful to Prof. S. Chaudhary, Chairman, Department of Zoology, Panjab University, Chandigarh for providing necessary facilities and secretarial assistance.

Abbreviations used in figures : 1 A + 2 A = fused first and second anal veins; ANT. APO = anterior apophysis; CO = costa; CRP. BU = corpus bursae; Cu A_1 = first anterior cubital vein; Cu A_2 = second anterior cubital vein; CU = cucullus; CUL = culcitula; DU. BU = ductus bursae; Du. Ej = ductus ejaculatorius; GN = gnathos; La. Lo. Aed = lateral lobe of aedeagus; La. Lo. Vin = lateral lobe of vinculum; M_1 = first median vein; M_2 = second median vein; M_3 = third median vein; P. A = papilla analis; PO. APO = posterior apophysis; R_1 = first radial vein; R_2 = second radial vein; R_3 = third radial vein; R_4 = fourth radial vein; R_5 = fifth radial vein; Rs = Radial sector vein; SA = saccus; SAC = sacculus; Sc = subcosta; SIC = sicae; SIG = signum; TA = tuba analis; TG = tegumen; UN = uncus; VAL = valva; VIN = vinculum;

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VARIATIONS IN NUTRIENT AND NUTRITIONAL COMPONENTS OF JUVENILE BAMBOO SHOOTS

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Abstract

Juvenile bamboo shoots, a cheap source of nutrient rich food, have high content of amino acids, proteins, carbohydrates, fibre and minerals. There are great variations in their amounts among the species of Bambusa and Dendrocalamus presently analysed. The most significant variation was in the protein content which varied from 1.5 – 4.0g in Bambusa and and 1.0 – 3.0 g/100g fresh weight in Dendrocalamus, respectively. Looking at, these variations, the selection of genotypes having high nutritional components need to be made before they can be recommended as food.

Key words : juvenile bamboo shoots, health food, nutrients, genotypes.

INTRODUCTION

Bamboos, "the miracle-tree grasses" belong to the tribe Bambuseae, subfamily Bambusoideae of the family Poaceae. They comprise 110 genera and 1110-1140 species (Seethalakshmi and Kumar, 1998). They are the fastest growing plants, growing up to 40 cm a day. Majority of them are tall, erect, arborescent and woody, reaching up to 50 m in height and 40 –50 cm in diameter. However, some are dwarf, grass-like species. They have enormous utility for man from "cradle to coffin". Juvenile bamboo shoots have been projected as a new and promising health food. Several authors (Giri and Janmejay, 1992; Qiu, 1992; Richa and Sharma, 1998) have advocated the nutritive value of bamboo shoots which provide cheap source of nutrient rich food.

The present paper highlights the variations in nutrient and nutritional component of 5 species of *Bambusa* and 4 species of *Dendrocalamus*.

MATERIALS AND METHODS

The material for the present study was collected from the P.N. Mehra Botanical Garden, Panjab University, Chandigarh. The various species studied are: *Bambusa arundinacea, B. polymorpha, B. tulda, B. vulgaris* vars. *vulgaris,* and *wamin, Dendrocalamus calostachys, D. giganteus, D. membranaceus,* and *D. strictus*. Their shoots were harvested during rainy season (July-Oct.) at a stage when they were just emerging from the ground.

To study the various nutrients and minerals, freshly harvested, unprocessed shoots were peeled off with a sharp knife. These were then washed under tap water and used for estimation of amino acids (Lee and Takahashi, 1966), proteins (Lowry *et al.*, 1951), carbohydrates (Whistler, 1971), total fat (chloroform-methanol method), dietary fibre (Goering & Van Soest, 1970), sodium and potassium (by EEL Flame photometer), and heavy metals e.g. cobalt, copper, iron, manganese and zinc (by atomic absorption spectrophotometer). For various nutrients, the contents are given in g/100g fresh weight, mineral elements given as mg/100g fresh weight basis whereas the content of fibre is given in g/100g dry weight.

RESULTS AND DISCUSSION

Tables 1-4 show the nutrient and nutritional component of the various species and their comparison. A perusal of Table 4 reveals that there is a great variation in almost all the components analyzed except in the fat and lignin content whose range was 0.1-0.4 and 0.2 – 0.6 respectively in both the genera.

There is an enormous amount of variability in the amino acids (1.5-2.8), proteins (1.5 – 4.0) and carbohydrates (2.1-5.2) amongst species of *Bambusa* and amino acids (1.6-3.0), proteins (1.0-3.0) and carbohydrates (2.9-4.2) for *Dendrocalamus* species.

Likewise, there was a significant variation in the mineral elements in the species of the two genera. The ranges for these being Co=0.028-0.046, Cu=0.075-0.118, Fe=0.344-2.940, K=0.054-0.194, Mn=0.018-0.161, Na=0.027-0.088 and Zn=0.300-0.670, for species of *Bambusa* and Co=0.022-0.089, Cu=0.098-0.383, Fe=1.291-2.520, K=0.044-0.144, Mn=0.085-0.236, Na=0.059-0.092 and Zn=0.200-1.062 for those of *Dendrocalamus*. The content of cellulose, hemicellulose and total fibre ranges between 0.5-1.2, 0.3-1.0 and 0.2-

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MS Received November 13, 2003; Accepted April 23, 2004

Table 1 : Various nutrient content (g/100 g fresh wt) in the shoots of nine bamboo species

Sr. No.	Species	Amino acids	Proteins	Carbohydrates	Fats
1.	*Bambusa arundinacea*	2.8	3.8	5.2	0.4
2.	*B. polymorpha*	1.5	4.0	4.1	0.1
3.	*B. tulda*	2.1	2.0	2.3	0.3
4.	*B. vulgaris* var. *vulgaris*	2.3	2.5	2.1	02.
5.	*B. vulgaris* var. *wamin*	2.5	1.5	4.2	0.1
6.	*Dendrocalamus calostachys*	1.6	3.0	3.0	0.2
7.	*D. giganteus*	2.8	2.0	3.4	0.3
8.	*D. membranaceus*	2.0	2.0	2.9	0.4
9.	*D. strictus*	3.0	1.0	4.2	0.1

Table 2 : Mineral elements content (mg/100 g fresh wt) in the shoots of nine bamboo species.

Sr. No.	Species	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Manganese (Mn)	Potassium (K)	Sodium (Na)	Zinc (Zn)
1.	*Bambusa arundinacea*	0.028	0.076	0.344	0.018	0.110	0.034	0.525
2.	*B. polymorpha*	0.051	0.118	2.940	0.122	0.074	0.066	0.530
3.	*B. tulda*	0.032	0.110	0.630	0.089	0.194	0.027	0.425
4.	*B. vulgaris* var. *vulgaris*	0.031	0.075	1.594	0.161	0.054	0.054	0.300
5.	*B. vulgaris* var. *wamin*	0.046	0.085	1.674	0.123	0.066	0.088	0.670
6.	*Dendrocalamus calostachys*	0.034	0.098	1.578	0.106	0.107	0.074	0.200
7.	*D. giganteus*	0 089	0.383	2.520	0.236	0.144	0.092	1.060
8.	*D.membranaceus*	0.022	0.098	1.431	0.085	0.060	0.059	0.325
9.	*D. strictus*	0.030	0.118	1.291	0.131	0.044	0.074	1.022

Table 3 : Amount of fibre and its components (g/100 g fresh wt) present in the shoots of nine bamboo species

Sr. No.	Species	Total fibre	Cellulose	Hemicellulose	Lignin
1.	*Bambusa arundinacea*	0.8	1.2	1.0	0.6
2.	*B. polymorpha*	0.3	0.6	0.6	0.3
3.	*B. tulda*	0.2	0.7	0.7	0.2
4.	*B. vulgaris* var. *vulgaris*	0.6	0.5	0.3	0.4
5.	*B. vulgaris* var. *wamin*	0.4	0.9	0.7	0.2
6.	*Dendrocalamus calostachys*	0.4	0.8	0.7	0.3
7.	*D. giganteus*	0.4	1.0	1.2	0.6
8.	*D. membranaceus*	0.5	0.9	0.6	0.2
9.	*D. strictus*	0.3	0.5	0.4	0.2

Table 4 : Comparative amounts of various nutrients, mineral elements and fibre components of *Bambusa* and *Dendrocalamus*

Contents	*Bambusa*	*Dendrocalamus*
Nutrients	***g/100g fresh wt***	***g/100g fresh wt***
Amino acids	1.5 – 2.8	1.6 – 3.0
Proteins	1.5 – 4.0	1.0 – 3.0
Carbohydrates	2.1 – 5.2	2.9 – 4.2
Fats	0.1 – 0.4	0.1 – 0.4
Mineral elements	***mg/100g fresh wt***	***mg/100g fresh wt***
Cobalt (Co)	0.028 – 0.046	0.022 – 0.089
Copper (Cu)	0.075 – 0.118	0.098 – 0.383
Iron (Fe)	0.344 – 2.940	1.291 – 2.520
Potassium (K)	0.054 – 0.194	0.044 – 0.144
Manganese (Mn)	0.018 – 0.161	0.085 – 0.236
Sodium (Na)	0.027 – 0.088	0.059 – 0.092
Zinc (Zn)	0.300 – 0.670	0.200 – 1.062
Fibre	***g/100g dry wt***	***g/100g dry wt***
Total fibre	0.2 – 0.8	0.3 – 0.5
Cellulose	0.5 – 1.2	0.5 – 1.0

0.8 respectively in species of *Bambusa* and 0.5-1.0, 0.4-1.2 and 0.3-0.5 respectively in *Dendrocalamus* species. However, no significant variation was observed in the lignin components between the two genera.

The species of both the genera are hexaploids (2n=72) based on x=12 (Mehra and Sharma, 1975). With a high ploidy level, variation in the nutrient and nutritional components should have been low because polyploids represent an evolutionary dead end and hence infuse genetic conservation. However, this does not appear true in the bamboo species investigated presently. How and why have bamboos acquired, accumulated and retained high degree of genetic variability is not known, but once accumulated they seem to have preserved the variations very well by way of clonal propagation. Bamboos have long life periods with efficient methods of vegetative propagation. On account of infrequent flowering, bamboos have had considerably few generations and hence less opportunities in recombinational and structural chromosome alterations. Since the variation in the nutrient and nutritional components of bamboos is enormous, selection of bamboo clones with high amounts of amino acids, proteins, carbohydrates, fibre and micro-nutrients should be possible by intensive selection and clonal propagation of genotypes having high nutrient and nutritional components. As all these components are polygenetically controlled, their genetic parameters like genotypic coefficient of variation, heritability, genetic advance, and expected genetic advance also need to be determined before selection for better genotypes. Efficiency of absorption of nutrients though genotype-dependent, the availability of these macro/micro-nutrients in soil is their prime factor. Therefore, selection of genotypes with high nutritional contents *per* se would be more effective than selection of genotypes with high nutrient absorption.

Since malnutrition is prevalent in India, there is need for intensive selection, extensive cultivation and aggressive marketing of nutritionally rich bamboo shoots of various species of bamboos of our country.

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AMELIORATING EFFECTS OF ANTIOXIDANTS AGAINST DOXORUBICIN INDUCED GENOTOXICITY IN TESTIS OF MICE

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Abstract

An antitumor antibiotic, doxorubicin, is used for the treatment of a variety of the soft and solid human malignancies. During the present investigations, ameliorating effects of antioxidants, sesamol and garlic oil, have been tested against genotoxicity of doxorubicin by employing comet assay on the testis of mice (Mus musculus) of laca strain. Two different doses of sesamol and garlic oil were administered to mice for six consecutive days and then a dose of doxorubicin was given. The positive and negative controls were also run for comparison. The mice were tested for their genotoxicity after 24, 48 & 72 hours. Pretreatment with both the antioxidants reduced the sizes of the comets considerably. But the pretreatment of mice with the high dose of garlic oil reduced the mutagenicity of the drug to a considerable extent than sesamol pretreatment.

Key Words: Doxorubicin, sesamol, garlic oil, amelioration, comet assay.

INTRODUCTION

An antitumor antibiotic, doxorubicin, is used for the treatment of a variety of soft and solid human malignancies. Its usefulness is limited because of the production of free radicals. Its consumption produces large number of side effects on the body. It also shows mutagenic, genotoxic and carcinogenic effects as have been observed by chromosomal, micronucleus and comet assays. It intercalates between base pairs and disrupts DNA and RNA synthesis and interacts with mitochondrial membranes leading to cardiotoxicity (Kojima *et al.*, 1994; Awazu and Horie, 1997 and Jagetia and Aruna, 2000). Its bioreductive activation leads to the formation of hydroxyl radicals and hydrogen peroxide (Sinha *et al.*, 1989 and Kalyanaraman *et al.*, 1991) which cause decreased activities of endogenous antioxidant enzymes, induced apoptosis, congested heart failure, aging, infertility in males, reduced implants in females (Generoso *et al.*, 1989) and other mutagenic effects shown by chromosomal abnormalities or DNA damages in peripheral blood leukocytes (Teyssier *et al.*, 1989; Meistrich *et al.*, 1990; Klimova *et al.*, 1990; Aly *et al.*, 1999; Husseini *et al.*, 2000 and Kopjar *et al.*, 2002).

A large number of antioxidants like vitamin C and E and pretreatment with compounds like magnesium sulphate, glutamine, etc. have been tested on the experimental animals against the reduction of clastogenicity of doxorubicin (Al-Shabanah, 1998; Antunes and Takahashi, 1998 and Tavares *et al.*, 1998). Garlic and its organic allyl sulfur compounds by scavenging hydroxyl radicals and reactive oxygen species and also by acting in several other ways like blocking N-nitroso compound (NOC) formation, suppressing bioactivity of carcinogens, enhancing DNA repair, reducing cell proliferation and induction of apoptosis, have been reported to protect the individuals against cancer and tumors of a number of organs. It also reduces cholesterol, blood pressure, blood clotting and limits the free radical damages (Pan *et al.*, 1997; Brown, 1999; Amagase *et al.*, 2001; Milner, 2001a & b and Banerjee *et al.*, 2003). Sesamol is a phenolic compound responsible for high resistance. Its antimutagenic activity against reactive oxygen species mediated mutagenicity has been tested in TA 100 and TA 102 strains of *Salmonella typhimurium* (Kaur and Saini, 2001). During the present investigations, *in vivo* ameliorating effects of two antioxidants, sesamol and garlic oil, against the doxorubicin induced genotoxicity have been tested by employing comet assay in the testis of *Mus musculus* of laca strain.

MATERIALS AND METHODS

Males of *Mus musculus* of laca strain, weighing about 25 gms, were procured from the central animal house of Panjab University, Chandigarh. Doxorubicin RDF(R) (Doxorubicin hydrochloride) was procured from R.P.G. Life Sciences Ltd., Mumbai. A single dose of it (0.375mg/ 25 gm.b.wt.) (Al-Harbi, 1993) was administered intraperitoneally to mice (group IV). The mice were divided into 12 groups (Table 1), each having 5 mice. Sesamol, used as one of the antioxidants during the present investigations, is a phenolic compound extracted from the seeds of *Sesame indicum* and used as a domestic ayurvedic remedy. Two doses of it i.e., 0.1 mg/

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5 gm.b.wt. and 0.2 mg/25 gm.b.wt were given to mice for six consecutive days to two groups of mice (groups V & VI) and then followed by a single dose of doxorubicin (groups IX & X). To another two groups, two doses of garlic oil (another antioxidant) i.e. 0.5 ml of garlic oil diluted with olive oil 1:1 v/v (low dose) and 0.5 ml of garlic oil/25 gm.b.wt. (high dose) were administered daily for six consecutive days (groups VII & VIII) and then followed by a dose of doxorubicin (groups XI & XII). MNNG (N methyl-N'-nitro-N-nitrosoguanidine) was used as a positive control (group III). For negative control, distilled water (group I) and 0.5 ml/25 gm.b.wt. of olive oil (group II) were given to mice. The mice were dissected for their testes after 24, 48 and 72 hours of last treatment. The testes were transferred to chilled 1N saline and profused properly till all the traces of blood were removed. Then they were transferred to chilled homogenizing buffer (pH 7.5) (0.075 M NaCl and 0.024 M Na_2 EDTA). They were minced and homogenized at 2000-3000 rpm for 3-5 minutes. The homogenate was centrifuged at 1100-1300 × g for 10 minutes at O°C to obtain the cell suspension and the precipitate was resuspended in chilled homogenizing buffer at 1gm organ wt./ ml and allowed to settle for 1-2 minutes (Sasaki *et al.*; 1997). The pellet was used for studying the presence of DNA single strand breaks and alkali labile damages in individual cells, by employing the alkaline single cell gel electrophoresis assay (comet assay) of Singh *et al.* (1988). This assay can detect any nick produced by the clastogenic compound. The DNA is uncoiled and the fragments so produced move towards the anode at a rate inversely proportional to the size of the fragment during electrophoresis. Each cell with damaged DNA gives the appearance of a comet.

RESULTS AND DISCUSSION

Doxorubicin and MNNG treatment to mice caused hyperexcitability and hyperactivity. The bone marrow became brittle and alopecia was observed after 72 hrs of antibiotic treatment. Doxorubicin has been known to cause genotoxicity, clastogenicity and mutagenicity. It intercalates with DNA, affects DNA/RNA synthesis, causes single and double stranded breaks and sister chromatid exchanges. Excision of DNA is believed to be mediated either by the action of topoisomerase II or by the generation of free radicals. Doxorubicin first of all undergoes one electron reduction and produces doxorubicin semiquinone free radicals. It goes to the nucleus of the cell, gets reduced by flavoproteins, reacts with DNA and causes damage. Semiquinone free radical also reacts with oxygen to form superoxide anion radical ($O_2^{\cdot}$) which generates H_2O_2 and hydroxyl free radicals. These are highly destructive to the cells (Kalyanaraman *et al.*, 1991).

Sesamol is highly resistant and shows antimutagenic activity against oxygen species mediated mutagenicity in TA 100 and TA 102 strains of *Salmonella typhimurium* (Kaur and Saini,2001). Phytochemicals present in plant rich diets like garlic and its extracts, provide protection against reactive oxygen species induced damages in DNA, lipids and proteins (Gutteridge, 1993 and Borek, 1997& 2001).

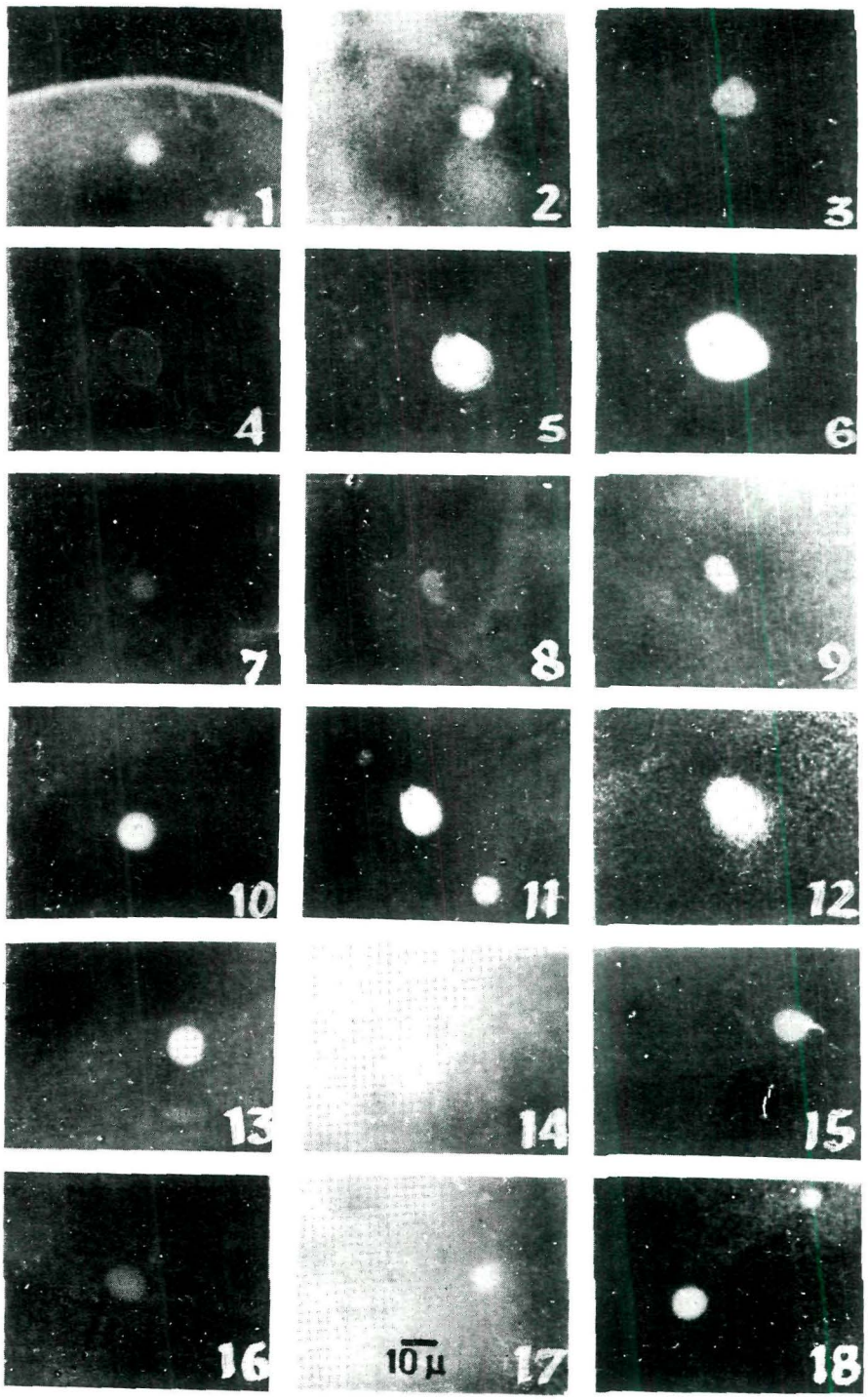
The comet assay has been employed for evaluating the protective role of sesamol and garlic oil against doxorubicin inducted DNA damages in the testis of mice. The results obtained have been tabulated in *Table* 1 and Plate1.

The perusal of the data indicates that low and high doses of sesamol (groups V and VI) and garlic oil (groups VII and VIII) produced almost the same percentage of cells with comets. The average tail lengths were low in sesamol treated groups than in the garlic treated groups. The percentage of cells with comets in the sesamol pretreated groups (groups IX and X) were almost the same as that of group IV (doxorubicin treated group) but the tail lengths were considerably reduced (depicting less damage to the DNA). The low dose of garlic oil pretreatment (group XI) reduced the cells with comets to half than the antibiotic treated ones (groups IV). However, the pretreatment of high dose of garlic oil in group XII seems to be the most effective one since the percentage of cells with comets were reduced to 1/4th-1/5th of the doxorubicin treated group IV. Even the average tail length depicting the damage to the DNA, was reduced to 1/3rd of the group IV treated individuals. Though the average tail lengths of comets in groups X and XII were the same but the percentage of cells with comets was on the higher side in sesamol high dose pretreated individuals.

These studies have revealed that both the antioxidants sesamol and garlic oil have acted as ameliorating agents against doxorubicin induced genotoxicity but garlic oil has more ameliorating efficacy than sesamol. Garlic and its diallyl disulfide components have already been reported as protective agents in kidney of hypertensive rats (Sharifi *et al.*, 2003 and Abdel-Wahhab & Aly, 2003), ameliorated gentamycin induced oxidative stress and nephropathy in rats (Podraza-Chaverri *et al., 2003)* and reduced inflammatory effects in humans (Keiss *et al.*, 2003). Thus garlic oil reduces the oxidative stress of doxorubicin in testis of mice more than sesamol.

Table 1: Effects of various treatments on percentage of cells with comets and frequency of their tail lengths in testis. For each treatment 5 animals were used and 50 cells were scanned

Group	Treatment	Dose mg/25gm b.wt. of mice	Hours of treatment	%age of cells with comets	Average tail length /cell (µm) mean ± SD
I	Distilled Water	0.5ml	24	-	-
	(negative control)		48	-	-
			72	-	-
II	Clive Oil	0.5 ml	24	2	0.01±0.001
	(negative control)		48	4	0.01±0.001
			72	8	0.02±0.001
III	MNNG	0.3mg	24	52	0.25±0.002
	(positive control)		48	78	0.43±0.003
			72	86	0.54±0.003
IV	Doxorubicin	0.375mg	24	20	0.10±0.010
			48	26	0.12±0.012
			72	34	0.15±0.013
V	Sesamol	0.1mg	24	2	0.01±0.001
	(low dose)		48	4	0.01±0.001
			72	4	0.01±0.001
VI	Sesamol	0.2mg.	24	2	0.01±0.001
	(high dose)		48	4	0.01±0.001
			72	6	0.01±0.001
VII	Garlic oil	0.5ml +	24	2	0.02±0.001
	(low dose)	0.5ml olive	48	4	0.02±0.001
		oil	72	8	0.04±0.003
VIII	Garlic oil	0.5ml	24	2	0.02±0.001
	(high. dose)		48	4	0.02±0.001
			72	8	0.04±0.001
IX	Sesamol	0.1mg	24	16	0.04±0.002
	(low dose)+	+	48	22	0.04±0.002
	Doxorubicin	0.375mg	72	32	0.05±0.002
X	Sesamol	0.2mg	24	20	0.03±0.001
	(high dose) +	+	48	24	0.04±0.001
	Doxorubicin	0.375mg	72	32	0.05±0.002
XI	Garlic	0.5ml +	24	10	0.04±0.004
	(low dose) +	0.5ml olive oil	48	14	0.06±0.005
	Doxorubicin	+0.375mg	72	16	0.09±0.005
XII	Garlic	0.5ml	24	4	0.03±0.001
	(high dose) +	+	48	6	0.04±0.001
	Doxorubicin	0.375mg	72	8	0.05±0.001



Comets produced in the testicular cells of the various treated groups.

Fig. 1. *Normal cell. 2. Garlic oil low dose for 72 hrs. 3. Garlic oil high dose for 72 hrs. 4 to 6. Effect of MNNG for 24, 48 & 72 hrs. Respectively. 7. Olive oil treatment for 72 hrs. 8. 0.1mg sesamol treatment for 72 hrs. 10 to 12. Doxorubicin treatment for 24, 48 and 72 hrs. respectively. 13. High dose of garlic oil pretreatment + doxorubicin for 48 hrs. 14. High dose of garlic oil pretreatment + doxorubicin for 72 hrs. 15. Low dose of garlic oil pretreatment.+ doxorubicin for 72 hrs. 16. High dose of sesamol pretreatment + doxorubicin for 24 hrs. 17. High dose of sesamol pretreatment + doxorubicin for 48 hrs. 18. Low dose of sesamol pretreatment + doxorubicin for 24 hrs.*

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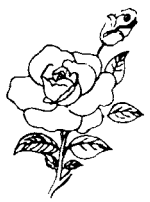

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POLLEN ANALYSIS OF THREE SPECIES OF *Dendrobium.* Sw. FROM MAHARASHTRA

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Abstract

Orchids have focused the attention of taxonomists, ecologists and biotechnologists and have also gained commercial importance in cut flower industry. Palynological study of three species of genus Dendrobium Sw. namely D. microbulbon A.Rich., D. mabalae Gammie and D. barbatulum Lindl. using SEM has been made. The monoporate pollens of Dendrobium microbulbon A.Rich. were observed to possess baculate ornamentation with bubble - like projections. Striate-rugulate excrescence is seen in D. mabalae Gammie. but monoporate pollens of Dendrobium barbatulum Lindl. possess reticulate ornamentation along with connate island formation. All these variations in the sculpturing of the three species of Dendrobium Sw. could be valuable tool in systematics and phylogeny of the genus.

Keywords: Dendrobium, baculate, striate-rugulate, reticulate, ornamentation.

INTRODUCTION

Orchids have attracted the attention of the taxonomists, ecologists, evolutionary botanists, agriculturists and biotechnologists. Orchids also gained much commercial importance as a cutflower industry. Such a fascinating group of flowering plants has been ignored for palynological study with scanning electron microscopy. SEM as well as TEM have become important parameters for inferring the interrelationship in systematics and phylogeny. Work on pollinia of orchids under SEM and TEM has been made by Chardard (1958, 1969, 1971); Heslop-Harrison (1966, 1968); Cocucci and Jenson (1969 in Yeung, 1987) and Vij *et al.* (2003). Keeping in view the very little work done on Indian orchids, present study on palynological work of the three species of the genus *Dendrobium* Sw. from western ghats was undertaken.

MATERIALS AND METHODS

The material was collected from different localities of western ghats. Pollen grains were studied under LM for their colour, shape, size, and ornamentation. The SEM study of pollen grains was conducted under electron microscope (Jeol 1200 ex model 1982) at the Laboratory of RSIC of Punjab University, Chandigarh.

After teasing the pollinia, pollen grains were collected and mounted on a double metallic stub with gold sputter coater for five minutes for coating the material. Material was then processed for scanning under electron microscope.

OBSERVATIONS

1. *Dendrobium microbulbon* A.Rich.

This interesting corticolous orchid differs from the other members in having crowded brownish pseudobulbs with radiating white patches in between nodes and covered with a network of fibres formed by decayed membranous sheaths. A stalk of receme having purplish brown white flowers is produced from the terminal portion of the pseudobulb. It was presently collected from Khandala.

Palynological Observations:

Under L.M:

Pollinia very small, waxy, linear, brownish, ovate. Pollen grains are very small and granular in appearance.

Under SEM:

Pollen grains are circular with bubble-like projections on exine surface (x, 5000) Pollens 6 μm in diameter, monoporate, sporoderm with baculate excrescence. Aperture region is marked by irregular cracks near the bubbles (x, 13000)

2. *Dendrobium mabalae* Gammie

This corticolous orchid has small, tufted, psuedobulbs 2-4 jointed, covered with a network of fibres and white coloured flowers born in recemes. Inflorescences are produced from the apex of the psuedobulb. It was collected from castle-rock near Goa.

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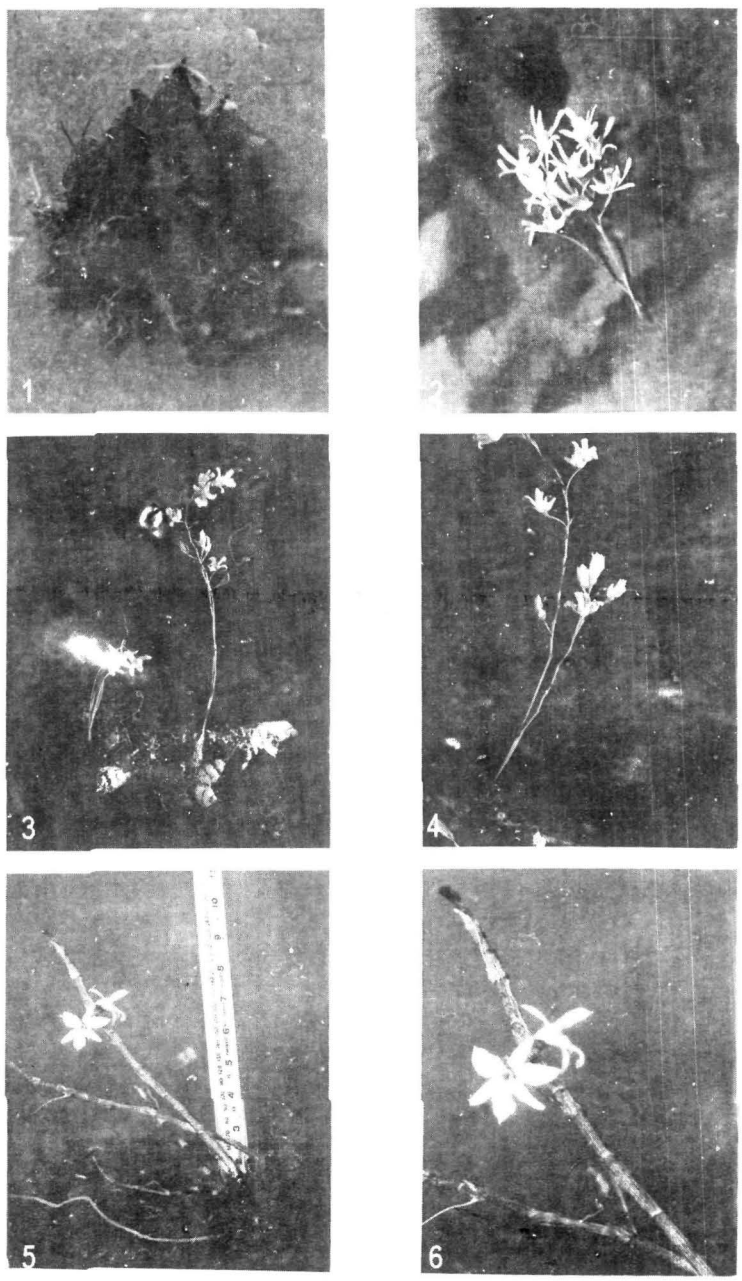
PLATE I



Dendrobium microbulbon **A.Rich** ***(Text Fig 1-2)***

1. *Habit of the plant.*
2. *Enlarged view of flowers.*

Dendrobium mabalae **Gammie.** ***(Text Fig. 3-4)***

3. *Habit of the plant.*
4. *Enlarged view of inflorescence.*

Dendrobium barbatulum **Lindl.** ***(Text Fig. 5-6)***

5. *Habit of the plant.*
6. *Enlarged view of a flower.*

PLATE - II

Dendrobium microbulbon **A.Rich.** ***(Text Fig. 1-2)***

1. *Entire plant with psuedobulbs 1-3 jointed and an inflorescence. (Enlarged three times)*
2. *Enlarged view of a flower. (Lateral side, enlarged ten times)*

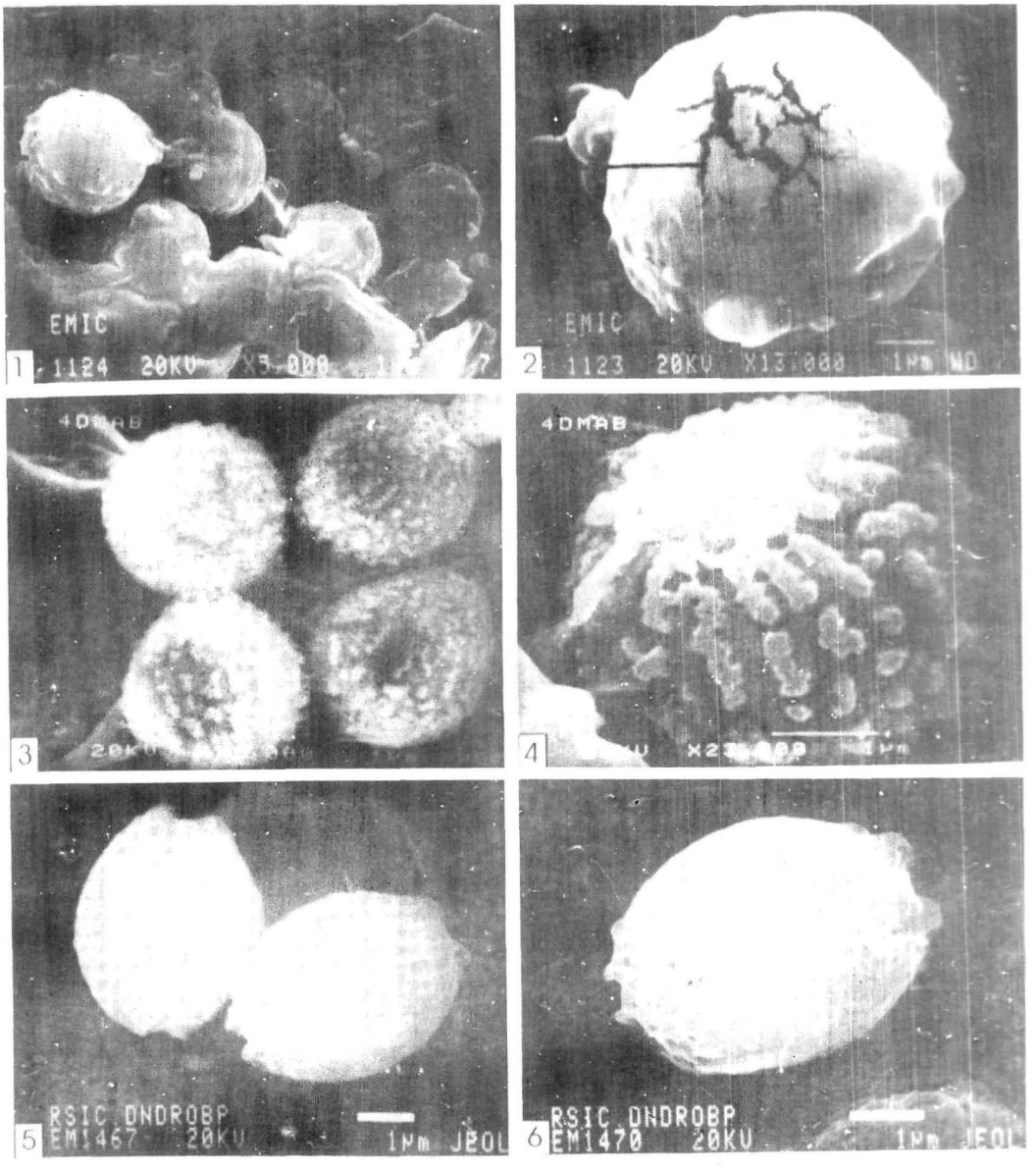
Dendrobium mabalae **Gammie** ***(Text Fig. 3-4)***

3. *Entire plant with ovoid, 2-4 jointed psuedobulbs and inflorescence. (Enlarged three times)*
4. *Enlarged view of a flower showing lip, fringed with thick white hairs. (Enlarged three times)*

Dendrobium barbatulum **Lindl.** ***(Text Fig. 5-7)***

5. *Entire plant with stem tapering towards apex and with terminal inflorescence. (Original size)*
6. *Enlarged view of a flower. (Lateral view, double size)*
7. *Enlarged view of a flower. (Front view, double size)*

PLATE III



Dendrobium microbulbon **A.Rich.** ***(Text Fig 1-2)***

1. *A group of circular pollen grains under SEM. (X, 5000).*
2. *Pollen grain with bubble like projections on the surface. Aperture region is marked by irregular cracks near the bubbles under SEM (X, 13,000).*

Dendrobium mabalae **Gammie.** ***(Text Fig. 3-4)***

3. *A group of pollen grains.(X, 11,000)*
4. *Enlarged view of a pollen-grain showing striate-rugulate wall, disrupted ring of annulus, under SEM. (X, 23,000).*

Dendrobium barbatulum **Lindl.** ***(Text Fig 5-6)***

5. *A group of pollen grains under SEM.*
6. *Enlarged view of a pollen grain in relation to reticulate wall, reticulate ornamentation is along with connate island formation and a thick margin fringed with reticulate surface behind.*

Ovate to obvate pollinia containing very small sized granular pollen grains.

Under SEM:

Pollen circular, 3.5 μm in diameter and monoporate. Pollen grains simple as well as compound. Sporoderm pattern is in the form of striate-rugulate excrescence. The ring of annulus is circular, disrupted and 1 μm in diameter (x, 23000).

3. *Dendrobium barbatulum* Lindl.

It is a corticulous orchid 25 to 30 cm in length, swollen at the base and tapering at the apex with whitish-pink coloured flowers arranged in lateral and terminal racemes. It was presently collected from Khandala.

Palynological Observations:

Under L.M:

Pollen grains were very small and oval in shape.

Under SEM:

Pollen grains monoporate, oval in shape, 4.6 μm in length and 3.8 μm in breadth. Sporoderm pattern-reticulate, excrescence long with connate island formations. Thick margin is fringed with reticulate surface behind.

DISCUSSION

Palynological study under SEM provides valuable clues for palynological aspects of taxonomical value. Palynological charactors such as location, shape and number of apertures, pollen size, and ornamentation of exine are important parameters in this context.

Pollen grains in all the three species of the genus *Dendrobium* Sw. are monoporate but they show slight variations in the structure of annulus ring and shape of apertures. Annulus ring is circular and disrupted in *Dendrobium mabalae* but indistinct in *D. microbulbon*, with bubble-like projections on the surface and with irregular cracks. In *D.barbatulum,* aperture is indistinct and with a fringed thick margin with reticulate ornamentation behind. The aperture is distal in most of the species of studied orchids.

The sporoderm pattern shows distinct baculate excrescence in *D.microbulbon* A.Rich., and striate rugulate in *D.mabalae* Gammie. Presence of dense type of striate-rugulate excrescence in *D. mabalae* Gammie showing it's primitiveness than that of *D.barbatulum.* Reticulate ornamentation in *D.barbatulum* Lindl. is long with the connate island formation. This feature is very remarkable in this taxon but the pollens of *D.microbulbon* A.Rich appears to be evolved due to the presence of sparce baculae in its pollen grains.

ACKNOWLEDGEMENTS

Thanks are due to Prof.S.P.Vij of Botany Department, Panjab University,Chandigarh, for necessary Laboratory facility for conducting this work. We also express our thanks to Dr.P.K.K Nair for identifying the palynological characters.

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TAXONOMIC STUDIES ON INDIAN GELECHIIDAE VII. TWO NEW SPECIES AND A NEW RECORD OF GENUS *STEGASTA* MEYRICK FROM INDIA(LEPIDOPTERA : GELECHIOIDEA)

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Abstract

Two new species of genus Stegasta Meyrick viz., S. pawani and S. valvulata are reported in detail. In addition, S. comissata Meyrick is being reported from India for the first time. Further, congeneric status of the three species has been delved in the light of similar basic wing maculation, external genitalic structures and sitting posture.

Key words : Gelechiidae, *Stegasta*, New species.

INTRODUCTION

Genus *Stegasta* of family Gelechiidae was erected by Meyrick (1904) on the basis of type species *S. variana* Meyrick from Queensland in Australia. Gaede (1937) reported fifteen species under the referred genus from all over the world but none from India. However, Diakonoff (1967) quoted India as one of the localities of *S. variana* in addition to other South-east Asian localities, on the basis of work of Fletcher (1921). Findings of the aforesaid workers have been corroborated by Pajni and Mehta (1986) in a report on Gelechiidae of Chandigarh. According to Robinson *et al.* (1995), *Stegasta* is represented by only twelve species, most of them from old and new world tropics as against only type-species from South-east Asia.

As a result of intensive and extensive surveys of various localities in the states of Himachal Pradesh, Haryana, Rajasthan, Gujarat and Union Territory of Chandigarh from May 2000 to October 2003, the authors collected 250 specimens of genus *Stegasta*. After performing multiple dissections and examining the genitalia of both sexes, the entire material was segregated into three species.

In the present communication, *S. valvulata* sp.nov. and *S. pawani* sp.nov. have been described in detail along with reporting of *S. comissata* for the first time from India. Generic characters of *Stegasta* and description of body colouration of *S. comissata* have already been given by Meyrick (1904, 1923), therefore, not reproduced in this paper.

SYSTEMATIC ACCOUNT

Genus *Stegasta* Meyrick

Stegasta Meyrick, E. 1904. *Proc. Linn. Soc.* N.S. Wales, **29** : 313.

Type-species : *Stegasta variana* Meyrick

Key to species of Genus *Stegasta* Meyrick

1.Forewing without a band along inner margin on dorsal side; male genitalia with each valva distinguished distally into strongly setose cucullus and taperingnaked valvula; juxta forming a U-like structure with a pair of foliaceous straight lobes; vesica of aedeagus adorned with four cornuti; female genitalia with each signum sharply bent to form sickle-like structure; papillae anales narrowly elongate. .....***valvulata* sp. nov.**

– Forewing with a band along inner margin on dorsal side; each valva in male genitalia with only cucullus present; juxta not forming a U-like structure distally; vesica adorned with three cornuti; female genitalia with each signum not sharply bent on tapering side; papillae anales broad. **2**

2.Forewing with brownish-orange band along inner margin suffused with grey;hair pencil on underside of costa greyish-black; male genitalia with sparsely setose narrow lateral processes of juxta not reaching beyond median part; vesica of aedeagus bearing one large and two small cornuti; female genitalia with signa robust and straight,short arm knobbed. .....***pawani* sp. nov.**

– Forewing with band on inner margin yellow; hair pencil along costa creamish-white on underside; male genitalia with juxta distinctly W-shaped, with large-

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sized lateral lobes reaching well beyond median part; vesica bearing two large and one small-sized cornutus; female genitalia with signa large sickle-shaped, shorter arm narrow and tapering. .....***comissata*** **Meyrick**

Stegasta valvulata sp. nov. (Ph. A; Pl.1, Figs. 1-8)

Male : Head with vertex adorned with broad fuscous scales black at tips; frons light greyish-fuscous, white along margins. Antenna five-sixths of forewing length; scape black, minutely white at apex; flagellum thick, comparatively thinner in female, blackish-fuscous with a few creamish-white rings. Labial palpi with second segment light grey, suffused with fuscous; third segment fuscous, marked by a broad creamish-white band at base, apex and in middle. Proboscis and maxillary palpi creamish-white.

Thorax blackish-fuscous, with a light yellow mesothoracic spot. Forewing (Fig.1) narrowly oblong; costa evenly arched; apex pointed; termen oblique; tornus inconspicuous. Ground colour blackish-fuscous above; three white spots on costa equidistantly placed, one towards apex largest; a broad yellowish-orange band on inner margin at one-fourth from base, becoming narrower and lighter towards costa, joining first white spot; U-shaped grey mark with anterior limb bordering the former band and posterior limb reaching second spot at costa, also bearing a black speck in middle; patch on inner margin before tornus dull orange; a diffused grey patch between third costal spot and tornus; cilia along margin pale grey irrorated with black scales. Underside dull fuscous; two white spots on costa, one in middle and another at three-fourth from base; whitish-ochraceous hair pencil along costa concealed beneath broad scales from costa. Discal cell about three-fifth of wing length; R_3 approximated to stalk of R_4 and R_5; M_2 connate with short stalk of M_3 and CuA_1. Hindwing (Fig.2) exarched medially, otherwise straight; apex acute, produced; tornus obtusely angulate. Ground colour above and below dark grey; cilia along inner margin as long as wing width, grey, paler towards base. Discal cell slightly more than half of wing length; $Sc+R_1$ joined to anterior margin of discal cell one-third away from base; Rs and M_1 moderately long stalked; M_3 and CuA_1 closely approximated at base; CuA_2 from distal three-seventh of posterior margin of discal cell. Legs fuscous, banded with light ochraceous, adorned with pale ochraceous hair scales above.

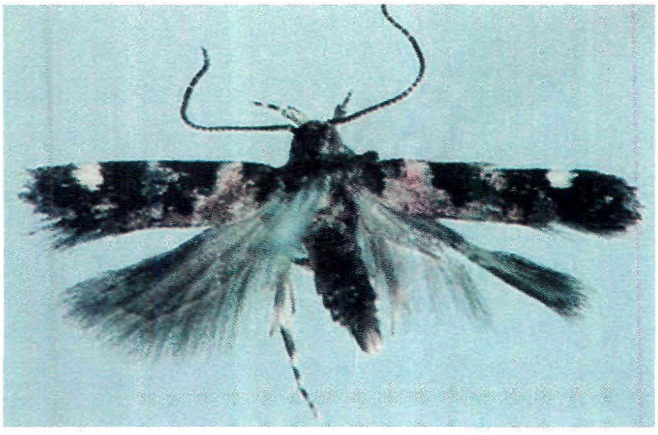
Abdomen fuscous; underside with two creamish-white bands, one in middle and another near distal end. Male genitalia (Fig.3-5) with uncus bifid, digitate, obtusely angled, both processes closely placed, blunt at tip; socii globular, nearly half of uncus, sparsely setose with a few very long setae; gnathos absent; tegumen V-shaped, each arm evenly broad along entire length, flat; vinculum narrow; saccus wanting; juxta broadly biconvex, uniformly sclerotised forming U-like structure distally, with a pair of more or less straight lateral foliaceous setose lobes; each valva (Fig.6) comparatively broader in basal one-third, narrow in middle, bifurcated distally into cucullus bearing backwardly directed strong setae, with a short spine at tip and a naked, comparatively shorter, pointed at tip valvula; costa arched; sacculus distinctly ovoid, minutely setose along ventral margin. Aedeagus (Fig.7) cylindrical, variable in width along its length; vesica adorned with four cornuti, largest among them sharply curved and pointed, another two much smaller, unequal-sized and a curved minutely dentate margin plate; ductus ejaculatorius opening laterally into aedeagus, terminating into an eye-like (?) sclerotised structure anteriorly. Female genitalia (Fig.8) with corpus bursae globular, membranous; a pair of identical, sickle-shaped, signa sharply bent before pointed tip; ductus bursae about twice of corpus bursae in length, sclerotised at distal end; appendix bursae somewhat spindle-like, narrowed into tubular form adjoining ductus bursae, ductus seminalis joining at its distal end; appendix bursae possessing triangular dentate-serrate plate, more sclerotised along distal margin; anterior apophyses one-fourth of posterior, comparatively broader; papillae anales narrowly elongate, beset with setae of varying lengths.

Alar expanse: Male : 9-10 mm
Female : 9-10 mm

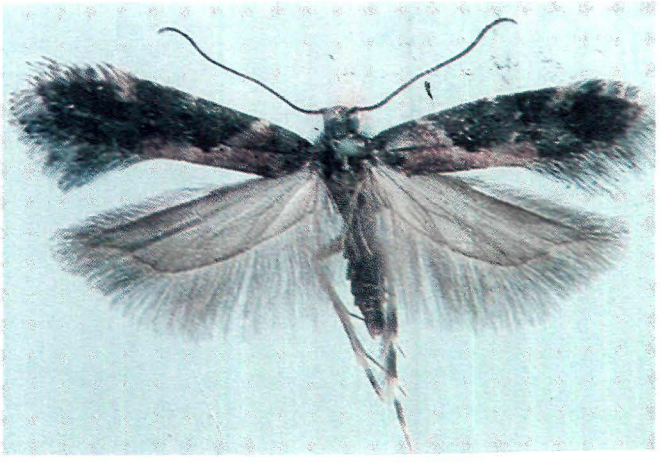
Material examined :

HOLOTYPE : Kotra (Forest Rest House), Rajasthan, INDIA; 1♂, 04.ix.2002 Collected by D. Wadhawan.

PARATYPES : Kotra (Forest Rest House), Rajasthan; 1♀, 28.iii. 2003; 1♀, 10.ix.2002; 1♂, 04.x.2002; 3♀♀, 09.ix.2002; 1♀, 10.ix.2002; 1♀,04.x.2002; 1♀, 29.viii.2003; 1♀, 1♂, 30.viii.2003;1♀, 28.viii.2003. Ranakpur, Rajasthan; 1♀, 05. ix.2002; 1♂, 31.viii.2003; 1♀, 01.ix.2003. Jharoal (Forest Rest House), Rajasthan; 1♀, 29.ix.2000; 1♂, 2♀♀, 30.ix.2000; 1♀, 02.x.2000; 1♂, 11.09.2002; 2♂♂, 1♀,12.ix.2002; 1♂, 09.x.2002; 1♀, 11.x.2002. Udaipur, Rajasthan; 1♂, 04.x.2000. Mount Abu, Rajasthan; 1♂,02.x.2000.



A



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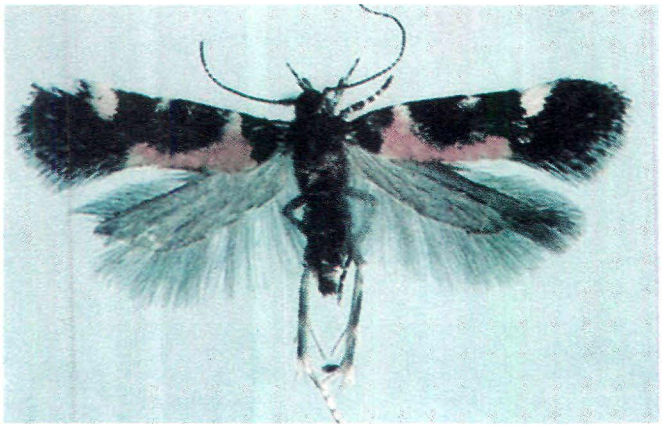

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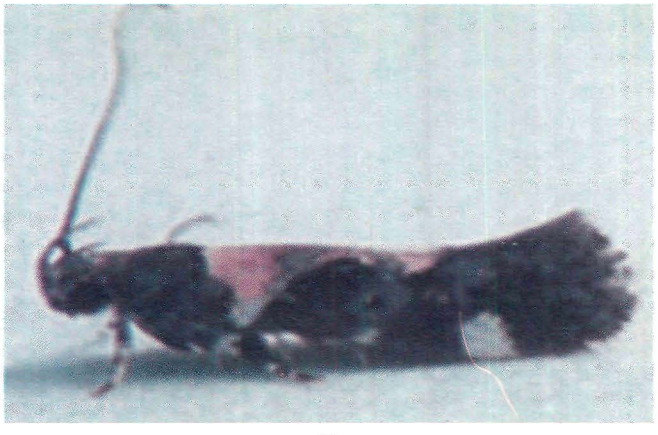

D

Photographs A-D : *(A) : Stegasta valvulata sp.nov.; (B) : Stegasta pawani sp.nov.; (C) and (D) : Stegasta comissata Meyrick.*

PLATE I

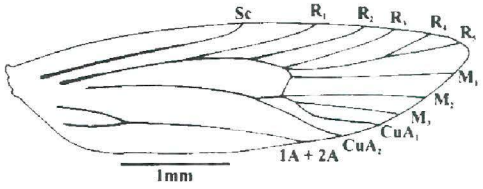

Fig. 1

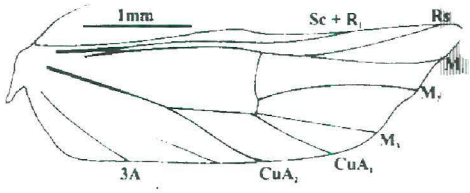

Fig. 2

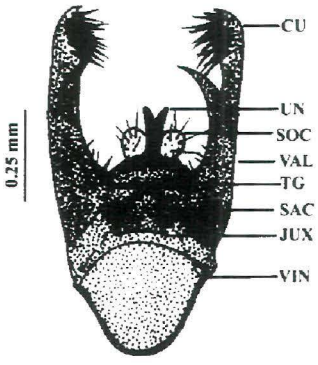

Fig. 3

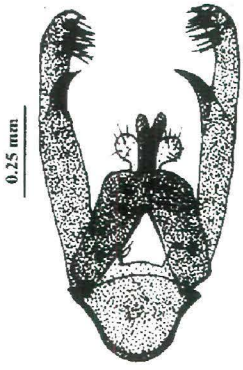

Fig. 4

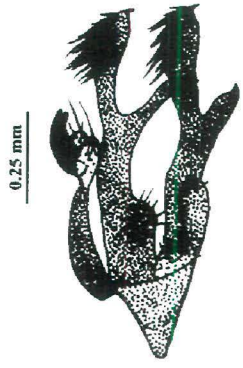

Fig. 5

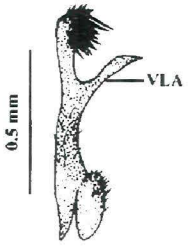

Fig. 6

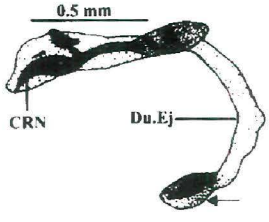

Fig. 7

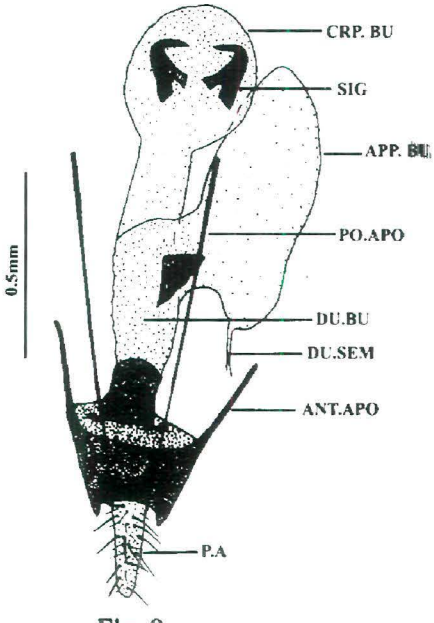

Fig. 8

Stegasta valvulata sp.nov.; Figs.(1) *forewing; (2) hindwing; (3-5) male genitalia; (3) ventral view; (4) dorsal view; (6) lateral view; (6) valva; (7) aedeagus; (8) female genitalia.*

Faridabad (Barkhal Lake), Haryana; 1♀, 01.x.2002; 1♀, 2♀♀, 02.x.2002. Kalesar (Forest Rest House), Haryana; 2♂♂, 2♀♀, 07.x.2001; 1♀, 07.viii.2002; 2♀♀, 07.x.2002. Sairighat (Forest Rest House), Himachal Pradesh; 1♂, 12.vi.2001, 1♂, 20.vii.2001, 1♀,26.ix.2001, 1♀, 28.ix.2001. Chandigarh; 1♂, 04.vi. 2003. Ambaji (Forest Rest House) Gujarat; 11♂♂, 14♀♀, 06.ix.2002; 4♂♂, 5♀♀,07.ix. 2002. Collected by V. K. Walia and D. Wadhawan.(Type material in the

Reference collection of Entomology Section, Zoology Department, Panjab University,Chandigarh.)

Flight period: March, June and August to October.

Larval host plant: Unknown

Etymology: The new species has been named *Stegasta valvulata* because of the presence of valvula.

Remarks: This species differs from *S. comissata* Meyrick in having poorly defined band along inner margin of the forewing in comparison to distinct in the closely allied species. In addition to this, presence of well defined valvula and four cornuti on vesica in aedeagus of *valvulata sp. nov.* clearly departs it from *comissata* which is without valvula and has three cornuti on vesica. Further, the sclerotised plate in ductus bursae and appendix bursae of female genitalia is conspicuously smaller in the new species as compared to much larger in the close ally. Out of 32 males and 47 female specimens of this species observed, only 23 males and 33 females possess a yellowish-white spot on mesothorax. Multiple dissections of genitalia of both the sexes with or without mesothoracic spot comprising of (3) males collected from Ambaji (Gujarat), Jharoal (Rajasthan) and Sairighat (Himachal Pradesh) and 2 females of Ambaji (Gujarat) and Ranakpur (Rajasthan) confirmed the conspecific status of the entire material.

Stegasta pawani sp. nov. (Ph. B; Pl. II, Figs. 9-15)

Male: Head with vertex adorned with broad grey scales, tips fuscous; vertex creamish-white. Antenna about five-sixths of forewing length, blackish-fuscous; flagellum with alternate segments in middle and few near tip grey. Labial palpi fuscous; second segment suffused with white scales, densely in basal two-thirds, sparsely in rest; third segment banded with creamish-white at base, in middle and at apex, with middle band broadest. Proboscis and maxillary palpi creamish-white.

Thorax blackish-fuscous, with a brown patch on mesothorax. Forewing (Fig.9) oblong, narrow, costa gently arched; apex acute; termen oblique; tornus inconspicuous. Ground colour blackish-fuscous above, suffused with grey; three white spots on costa, equidistant from each other, with central spot minutest and third from base largest and quadrate; a dull brownish-orange band suffused with grey along inner margin up to near tornus, with its proximal half gradually narrowing and joining first white spot on costa near base; an indistinct blackish-grey band between tornus and central white spot on costa, marked with black spot just below white spot on costal; another blackish-grey patch present between tornus and largest costal spot; an orangish and a white speck in middle of distal half of wing, with former after blackish-grey band and latter near apex along termen; cilia along margin grey, mixed with blackish-fuscous scales near base. Underside greyish-black, with traces of two distal white costal spots; a tuft of greyish-black hair pencil from base concealed beneath broad scales from costa. Discal cell three-fifths of wing length; M_3 and CuA_1 short stalked. Hindwing (Fig.10) slightly exarched medially, otherwise straight; apex acute, produced; tornus obtusely ungulate. Ground colour grey above and below; cilia along inner margin one and a half times of wing width, light grey. Discal cell more than half of wing length; $Sc+R_1$ joined by an oblique bar with anterior margin of discal cell one-fourth away from base; Rs, M_1 short stalked; M_3 and CuA_1 separate, CuA_2 from distal two-fifths of lower margin of discal cell. Legs blackish-fuscous, tarsi of all legs banded with white; hind tibia fuscous hair scaled above, with two white bands, one at base of each pair of spurs.

Abdomen blackish-fuscous; underside with a narrow grey band in proximal half and comparatively broader before distal end. Male genitalia (Fig.11 and 12) with uncus bifid, both halves closely placed, blunt at tip; socii globular, slightly bulged outwards in basal half, nearly half of uncus, sparsely setose with a few going well beyond tip of uncus; gnathos absent, tegumen broad V-shaped; vinculum narrow; saccus absent; juxta well-defined, its median part bluntly rounded, with shorter and sparsely setose process on each side; each valva (Fig.13) with costa somewhat straight; ventral margin of valva gently concave, bearing a spine-like projection ventro-laterally, slightly beyond two-thirds from base; cucullus beset with inwardly and anteriorly directed strong setae along with a short and stout spine at distal end. Aedeagus (Fig.14) cylindrical; vesica adorned with three cornuti, one of them strongly sclerotised and very large, a small sized pointed at distal end whereas other blunt and minutely dentate

PLATE II

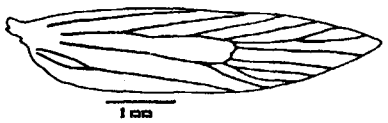

Fig. 9

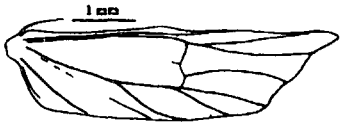

Fig. 10

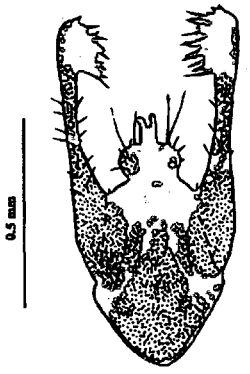

Fig. 11

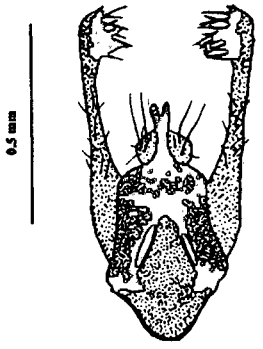

Fig. 12

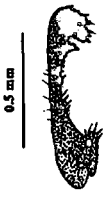

Fig. 13

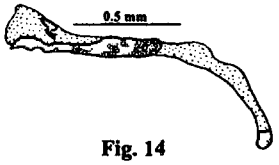

Fig. 14

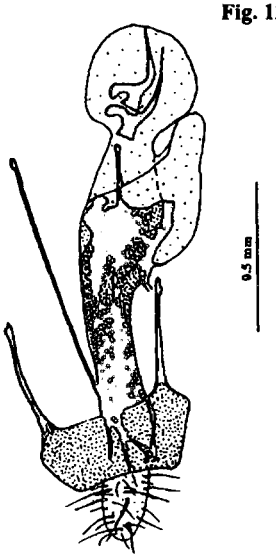

Fig. 15

Stegasta pawani sp.nov.; Figs.*(9) forewing; (10) hindwing; (11-12) male genitalia; (11) ventral view; (12) dorsal view; (13) valva; (14) aedeagus; (15) female genitalia.*

Material examined: Kalesar (Forest Rest House), Haryana INDIA; 3♀♀, 27.iii.2001; 1♂, 07.viii.2001; 1♂ 05.iv.2002; 1♀, 09.v.2002; 1♂, 1♀, 28.viii.2002; 1♀, 17.ix. 2002; 3♂♂, 19.ix.2002; 1♀, 20.ix.2002; 1♂, 1♀ 30.ix.2002; 1♂, 07.x.2001. Morni (Forest Rest House), Haryana; 1♀, 27.x.2000; 1♂, 30.x.2000; 1♀, 23.v.2001; 2♀♀, 25.iii.2001; 1♂, 04.viii.2002. Darpur (Forest Rest House), Haryana; 1♂, 26.iii.2001. Ranakpur, Rajasthan; 1♀, 27.x.2001; 1♂, 29.viii.2001; 3♂♂, 12.x.2002; 3♀♀, 13.x.2002; 4♂♂, 31.viii.2003; 4♂♂, 7♀♀, 01.ix.2003; 3♂♂, 5♀♀, 02.ix.2003. Mt. Abu (Forest Rest House), Rajasthan; 1♀, 06.x.2000; 2♂♂, 07.x.2000. Udaipur, Rajasthan 1♂, 26.viii.2001. Kotra (Forest Rest House), Rajasthan; 4♂♂, 09.ix.2002; 3♂♂, 10.ix.2002; 1♀, 05.x.2002; 3♂♂, 1♀, 28.viii.2003; 9♂♂, 3♀♀, 29.viii.2003; 15♂♂, 1♀, 30.viii.2003. Jharoal (Forest Rest House), Rajasthan; 1♂, 30.ix.2000; 1♂, 22.viii.2001; 3♂♂, 11.ix.2002; 2♂♂, 1♀, 12.ix.2002; 2♂♂, 9.x.2002; 1♂, 1♀, 11.ix.2002. Chandigarh; 1♂, 1♀, 11.v.2000; 1♀, 26.viii.2000; 1♀, 15.iii.2001; 1♀, 04.v.2001; 1♀, 16.vi.2001; 2♂♂, 17.vi.2001; 2♂♂, 19.ix.2001; 1♂, 20.ix.2001; 1♀, 27.ix.2001; 1♂, 29.ix.2001; 1♀, 03.vii.2002; 1♀, 26.vii.2002; 1♂, 02.x.2002; 2♂♂, 24.iii.2003; 2♀♀, 27.iv.2003; 1♀, 7.v.2003. Ambaji (Forest Rest House) Gujarat; 5♂♂, 6.ix.2002; 4♂♂, 1♀, 7.ix2002. Sairighat (Forest Rest House), Himachal Pradesh; 1♂, 16.x.2000; 1♀, 29.x.2000; 1♂, 7.iv.2001; 1♂, 18.viii.2001; 1♂,16.ix.2001; 1♂, 12.x.2001; 2♂♂, 13.x.2001; 2♂♂, 16.viii.2002; 1♀, 28.viii.2002; 1♀, 07.ix.2003. Subathu (Forest Rest House) Himachal Pradesh; 1♂, 28.ix.2001; 1♂, 28.viii.2002; 1♂, 29.ix.2002. Renuka, Himachal Pradesh; 1♂, 5.iv.2001. Collected by V.K.Walia and D. Wadhawan. (Type material in the Reference collection of Entomology Section, Zoology Department, Panjab University, Chandigarh.)

Flight period: March to October

Oid distribution: Brazil, Obidos, Santarema, Parintins and Manaos (Gaede, 1937; Clarke, 1969).

Larval host plant: Unknown

Remarks: This species is being reported from India for the first time. Besides availability of this species in abundance, it is wide spread as is revealed by the examined material. Colour pattern and structure of male genitalia as documented by Meyrick (1923) and Clarke (1969) respectively matches with the collected material. It has been noticed that out of 102 males and 52 females, 14 males and 10 females differed from the rest in having a creamish-white or yellowish-white spot on mesothorax. However, dissected out genitalia of specimens with or without spots of 7 males [collected from Kalesar (Haryana), Sairighat (Himachal Pradesh), Mt. Abu (Rajasthan) and Jharoal (Rajasthan)] and 4 females [from Kalesar (Haryana) and Sairighat (Himachal Pradesh)] did not show any variation in either sex, thus, confirming their conspecificity irrespective of topography and environmental conditions.

Field notes: All the three species of genus *Stegasta* treated taxonomically have been noticed to adopt a similar sitting posture (Ph. D) after landing on the substratum near source of light. Normally during quite and undisturbed conditions, the antennae are placed above the wings. However, disturbance of any kind, whether movement or vibrations in the cloth sheet due to wind velocity or enhancement in illumination due to reflectors for the purpose of photography, the moths instantly acquire an alert posture by raising their antennae somewhat perpendicular to the long axis of the body as revealed in the photograph.

DISCUSSION

All the three investigated species viz., *S. valvulata* sp. nov., *S. pawani* sp.nov. and *S. comissata* Meyrick, not only attain similar sitting posture but also have alike general body colouration. Not only that, they also resemble in shape of uncus, socii, tegumen, cucullus of valvae, three to four cornuti in the aedeagus of male genitalia and pair of identical signa in corpus bursae along with presence of appendix bursae possessing opening of ductus seminalis at distal end in the female genitalia of every observed species. These characters confirm their congeneric status and belonging to a homogenous group.

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ABBREVIATIONS

1 A + 2 A = fused first and second anal veins; 3 A = third

anal vein; ANT. APO = anterior apophysis; APX. BU = appendix bursae; CRN = cornuti; CRP. BU = corpus bursae; Cu A_1 = first anterior cubital vein; Cu A_2 = second anterior cubital vein; CU = cucullus; DU. BU = ductus bursae; Du. Ej = ductus ejaculatorius; DU. SEM = ductus seminalis; GP = genital plate; M_1 = first median vein; M_2 = second median vein; M_3 = third median vein; P. A = papilla analis; PO. APO = posterior apophysis; R_1 = first radial vein; R_2 = second radial vein; R_3 = third radial vein; R_4 = fourth radial vein; R_5 = fifth radial vein; Rs = radial sector; Sc = subcosta; SIG = signum; SL = sacculus; TG = tegumen; UN = uncus; VAL = valva; VIN = vinculum; VLA = valvula.

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ENDOSULFAN INDUCED CHANGES IN ALKALINE AND ACID PHOSPHATASE ACTIVITY IN LIVER AND MUSCLE OF *HETEROPNEUSTES FOSSILIS* (BLOCH)

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Abstract

Endosulfan induced alterations in the alkaline and acid phosphatase activities were studied in the liver and muscle in the catfish, Heteropneustes fossilis. The fish, exposed to different graded concentrations of endosulfan for 5 and 30 days revealed inhibition in the activity of alkaline phosphatase activity in both the tissues. Acid phosphatase activity increased in liver on exposure for 5 days but declined on prolonged exposure for 30 days. The muscle, acid phosphatase activity was inhibited both after 5 and 30 days of exposure.

Key Words : Endosulfan, liver, muscles, heteropneustes.

INTRODUCTION

Endosulfan is a broad spectrum cyclodiene insecticide with a wide application. It has short persistence in soil, hence, the excessive use of this pesticide may result in indirect entry in natural water bodies and damage to non-target organisms, particularly fish which are highly susceptible to very low concentration of endosulfan. Acid and alkaline phosphatases are the important enzymes associated with fish metabolism. According to Srivastava *et. al.* (1995), these enzymes are associated with the transport of metabolites, metabolism of phosphates, phosphor-protein, nucleotide, carbohydrate and synthesis of proteins. Alterations in acid and alkaline phosphatases have been reported in *Orechromis mossambicus* on exposure to heavy metals by James *et. al.* (1991) and in *Channa gachua* on exposure to endosulfan (Sharma, 1990). Considering the importance of acid and alkaline phosphatase, present investigation was carried out to study the activity of these enzymes in liver and muscle of *Heterpneustes fossilis* following endosulfan exposure for 5 and 30 days.

MATERIALS AND METHODS

Healthy live specimens of *Heteropneustes fossilis* (Bloch). were procured from the local catches and treated with 5% $KMnO_4$ solution for 5 minutes to check for any dermal infection. The fish (mean length 12.56cm ± 1.49mean weight 14.40 gm ± 1.42) were acclimatized to laboratory conditions for 7 days under ambient day length and water temperature ranging (25° to 28°C).

Thiodon 35EC (commercial name), was used for the present study. LC_{50}-96hr. value of endosulfan to *H. fossilis* was calculated to be 0.0101mg l^{-1} by graphic interpolation, more precisely calculated to be 0.0099 mg l^{-1} by employing probit analysis (Finney, 1980) assisted by software developed by National Institute of Occupational Health (NIOH), Ahmedabad. The toxicity tests were conducted at five different sub lethal concentrations viz. 0.001$^{mg\text{-}L}$, 0.002mg l^{-1}, 0.003mg l^{-1}, 0.004mg l^{-1} and 0.005mgl^{-1} for 5 and 30 days. A parallel control group of fish was maintained in chlorinated pesticide free tap water (pH - 7.2 to 7.4; Dissolved Oxygen – 6.5mg l^{-1} ± 0.50; Alkalinity – 154mg l^{-1} ± 10; Salinity – 0.155gm/kg). After stipulated period,(5 and 30 days) the fish were dissected to extirbate muscle and liver tissues. The tissues were weighed and 10% (w/v) pooled homogenates were prepared in ice cold solution of 0.25M sucrose solution prepared in 0.1M phosphate buffer, pH – 7.4. The activities of alkaline and acid phosphatase enzymes were estimated by methods suggested by Bergmeyer (1963), the protein content were estimated by Lowry's method given by Lees and Paxman (1972). All the data were tested for significance by student's t-test (Snedecor and Cochran, 1971).

RESULTS AND DISCUSSION

Alterations in the activities of acid and alkaline phosphatase enzymes following Endosulfan exposure are given in Tables 1 and 2. Acid and alkaline phosphatase activity was evaluated in all the 5 concentrations in liver

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Table 1 : Levels of acid phosphatase in muscle and liver of *Heteropneustes fossilis* exposed to different sublethal concentrations of endosulfan (5 and 30 days)

Exposure period (in days)	Tissue	Endosulfan concentration (mgL^{-1})					
		Control	0.001	0.002	0.003	0.004	0.005
5	Muscle	0.072 ± 0.0033	0.104 ± 0.0035***	0.055 ± 0.0042**	0.048 ± 0.0029**	0.047± 0.0026***	0.017 ± 0.0022***
			+ 44.44	– 23.61	– 33.33	– 34.72	– 76.38
	Liver	0.079 ± 0.0020	0.088 ± 0.0058*	0.084 ± 0.0035	0.081 ± 0.0032	0.085 ± 0.0020*	0.080 ± 0.0025
			+ 11.39	+6.32	+ 2.53	+ 7.59	+ 1.26
30	Muscle	0.071 ± 0.0049	0.030 ± 0.0085**	0.061 ± 0.0056	0.019 ± 0.0021***	0.026 ± 0.0059**	0.012 ± 0.0029***
			– 57.75	– 14.08	– 73.24	– 63.38	– 83.09
	Liver	0.072 ± 0.0087	0.061 ± 0.0034	0.048 ± 0.0017**	0.052 ± 0.0044	0.046 ± 0.0017**	0.038 ± 0.0021**
			– 15.27	– 33.33	– 27.77	– 36.11	– 47.22

Values expressed as µg PNP (P-nitrophenyl phosphate)/ mg protein /30 min; values are mean ± S.D. of 3 observations; (–) indicates percent inhibition; (+) indicates percent increase; level of significance *p<0.05; **p<0.01; ***p<0.001.

after 5 days of exposure. At lower concentration (0.001mg l^{-1}), the increase in activity was maximum and the enzyme was found to be very near to the control value at 0.005mg l^{-1} endosulfan concentration. Decline in the enzyme activity was observed in liver after 30 days of exposure. Inhibition in enzyme activity was found to be dose dependent. Acid phosphatase activity declined in muscle after 5 days as well as after30 days of exposure in all the concentrations except at the lower concentration i.e. 0.001mg l^{-1}. Endosulfan resulted in decrease in the alkaline phosphatase activity in both the tissues studied. Alkaline phosphatase activity in the liver showed a maximum decrease of 72.66% .

Endosulfan induced inhibition in the alkaline activity and increase in acid phosphatase activity in *H. fossilis* during the present investigations is in conformity with the study of Sharma (1990) in *Channa gachua* exposed to endosulfan; Shrivastava and Shrivastava (1998) in *Mus musculuss* exposed to carbaryl and Johal *et. al.* (2002) in *H. fossilis* exposed to fenvalerate. On the contrary, increase in the alkaline phosphatase activity and decrease in the acid phosphatase activity was observed in *Sarotherodon mossambicus* by Ruparelia *et. al.* (1984). Bulsu and Chakravarty (1987) observed significant inhibition in hepatic, alkaline and acid phosphatase activity in rats fed orally for 21 days on parathion, malathion and phosalone. Parthasarthi and Karuppasamy (1998) also reported decrease in acid and alkaline phosphatase activities in *Channa punctatus* exposed to fenvalerate.

Acid phosphatase is a lysosomal enzyme that is elevated due to pre-necrotic changes in tissues exposed to endosulfan. Acid phosphatase hydrolyses the ester linkage of phosphate esters and helps in the autolysis of cells after death. Marked inhibition in the acid phosphatase activity on chronic exposure occurs probably due to the accumulation of the toxicant beyond a tolerance limit in liver ,resulting in cellular damage and thereby causing impaired enzyme secretion and activity.

Alkaline phosphatase activity is known to play a role in glycogen metabolism and is capable of inactivating phosphorylase enzyme, thus promoting glycogen synthesis (Parthasarthi and Karuppasamy, 1998). According to Shaikila *et. al.* (1993), inhibition of alkaline phosphatase activity was due to the interaction of chemicals with cofactors and regulators. Endosulfan induced decline in the activity of alkaline phosphatase may be attributed to a decrease in the rate of

Table 2 : Levels of alkaline phosphatase in muscle and liver of *Heteropneustes fossilis* exposed to different sublethal concentrations of endosulfan (5 and 30 days)

Exposure period (in days)	Tissue	Endosulfan concentration (mgL^{-1})					
		Control	0.001	0.002	0.003	0.004	0.005
5	Muscle	0.082 ± 0.0045	0.080 ± 0.0072	0.086 ± 0.0018	0.070 ± 0.0035*	0.075 ± 0.0020	0.070 ± 0.0017*
			-2.40	+4.88	-14.63	-8.54	-14.63
	Liver	0.130 ± 0.0045	0.070 ± 0.0072***	0.071 ± 0.0018***	0.070 ± 0.0035***	0.062 ± 0.0020***	0.031 ± 0.0017***
			-46.15	-45.38	-46.15	-52.31	-55.38
30	Muscle	0.080 ± 0.0030	0.066 ± 0.0032***	0.035 ± 0.0034***	0.024 ± 0.0038***	0.030 ± 0.0027***	0.027 ± 0.0084***
			-17.50	-56.25	-70.00	-62.50	-66.25
	Liver	0.139 ± 0.0029	0.054 ± 0.0032***	0.082 ± 0.0034***	0.042 ± 0.0038***	0.038 ± 0.0027***	0.042 ± 0.0008***
			-61.15	-41.01	-69.78	-72.66	-69.78

Values expressed as µg PNP (p-nitrophenyl phosphate.) / mg protein /30 min; values are mean ± S.D. of 3 observations; (–) indicates percent inhibition; (+) indicates percent increase; level of significance *p<0.05; ***p<0.00

transphosphorylation. Severe acidosis may be the cause for inhibition in alkaline phosphatase activity in the tissues of treated fish. It is thus concluded that Endosulfan has toxic effect on the activities of acid and alkaline phosphatase enzymes in *H. fossilis*. Phosphatases are good indicators of stress conditions in biological systems (Verma *et. al.* 1980). Furthermore Endosulfan acts as a metabolic stressor that interferes with transphosphorylation and hence, impairs cell growth and proliferation.

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EPIPHYTIC MOSS DIVERSITY OF MT. ABU (RAJASTHAN)

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Abstract

The present study is aimed at enlisting the under-explored moss diversity of Mt. Abu, and understand the distribution of epiphytic mosses of this region. Diversity is comparatively rich at Mt. Abu due to high rainfall and high humidity. Twenty epiphytic mosses have been collected from various localities growing on different phorophytes. The study revealed that Mt. Abu has a great variety of bryophytes and is a 'hot spot' for them. It is a hill resort located at 72° 53' to 72° 75' East and 24° 31' to 24° 60' North with the total area of about 22 kms. X 1-8 kms.

Key words : Diversity, Epiphytic mosses, Mt. Abu, Rajasthan.

INTRODUCTION

Mount Abu is situated in the ranges of Aravallis in Sirohi district. It is a hill resort located at 72° 53' to 72° 75' east and 24° 31' to 24° 60' north with the total area of about 22 kms. X 1-8 kms. Its average height is about 4200' above MSL with its highest peak *Gurushikhar* being 5653' above MSL. Due to high rainfall and humidity it is the richest spot of bryophytes. Forest of study area is sub- tropical evergreen type. Average annual rainfall of Mt. Abu is 1033.91mm and had a mean annual temperature of 26°C maximum and 12.6°C minimum during the study period and percentage of relative humidity was the highest during the months of July and August, the average monthly mean values were 96.90% and 90.21 percent respectively.

MATERIALS AND METHODS

Most of the places were visited several times during different seasons of the year, especially following rains in the years 2001,2002 and 2003. Field notes were taken at the time of collection to observe habit, habitat, abundance and ecological conditions. Collection of mosses from various diverse habitats and localities along with appropriate samples of substrate were made during the period under study and brought to the laboratory in sealed polyethene bags. Mosses were air dried, pressed and stored in well-labeled standard size packets. For the description of genera, standard works by Bapna (1969), Chaudhary and Deora (1993), Chopra and Kumar (1981), Chopra (1975), Gangulee (1980)and Gangulee (1985) were consulted. Dry plant material was soaked in water for a few hours to 12 hours before studying. For morphological studies, material was dissected and observed under a binocular microscope. The specimens were identified and submitted in the Bryology Laboratory, Botany Department, College of Science, Mohan Lal Sukhadia University, Udaipur.

RESULTS

The following epiphytic mosses were identified.

Fissidentales, Fissidentaceae

***Fissidens bryoides* Hedw., in Sp. Musc. 153, 1801.**

Field notes: Plants growing on the bark of *Mangifera indica* Linn., *Phoenix sylvestris* Roxb., *Michelia champaca* Linn., *Eucalyptus obiqua* L' Herit.

Locality: Mt. Abu. Achleswar temple, alt. 1230 m, Delwara temple Mt. Abu, alt. 1125 m, Gaumukh Mt. Abu, alt. 1160 m, Mt. Abu city, alt. 1180 m.

Distribution: Western Himalayas (Ranikhet, Simla), South India (W. Ghats, Nilgiri, Coonoor), Rajasthan, Gujarat, Ceylon, Europe, Caucasus, Siberia, Japan, Taiwan, China, North and Central Africa, North and South America, Java, Philippines.

Pottiales, Pottiineae, Pottiaceae, Barbuloideae

***Hyophila comosa* Dix. et Varde in Arch. bot. 1:166, 1927**

Field notes: Plants growing on the bark of *Anogeissus latifolia* Wall *ex* Bedd.

Locality: Mt. Abu Sunset point, alt.1195 m.

Distribution : South India (Palni, Travancore). Rajasthan.

***Hyophila involuta* (Hook.) Jaeg., Ber. S. Gall. Naturw. Ges. 1871–72:356, 1873.**

Field notes: Plants growing on the bark of *Mangifera indica* Linn., *Phoenix sylvestris* Roxb., *Eucalyptus obiqua* L' Herit., *Anogeissus latifolia* Wall *ex* Bedd., *Dendrocalamus strictus* Nees, *Erythrina suberosa* Roxb.,

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Table 1 Distribution of epiphytic mosses of Mt. Abu in different regions of India

Species	Mt. Abu Himalayas	Western Himalayas	Eastern India	South India
1. *Fissidens bryoides* Hedw.	+	+	+	
2. *Hyophila comosa* Dix. et. Vard	+			+
3. *Hyophila involuta* (Hook.) Jaeg.	+	+	+	+
4. *Hyophila rosea* Williams	+	+		+
5. *Anomobryum auratum* (Mitt.) Jaeg.	+	+	+	+
6. *Brachymenium indicum* (Doz.et Molk.) Bosch et Lac.	+	+	+	+
7. *Brachymenium turgidum* Broth.ex Dix.	+			+
8. *Bryum argenteum* Hedw.	+	+		+
9. *Bryum capillare* L.ex Hedw.	+	+		+
10. *Bryum paradoxum* Schwaegr.	+	+		+
11. *Erpodium mangiferae* C. Muell.	+		+	+
12. *Fabronia minuta* Mitt.	+	+		
13. *Entodon prorepens* (Mitt.) Jaeg.	+	+	+	
14. *Entodon ovicarpus* Dix.	+		+	
15. *Entodon laetus* (Griff.) Jaeg.	+		+	
16. *Levierella fabroniacea* C. Muell.	+	+		
17. *Stereophyllum decorum*(Mitt.) Wijk. et Marg.	+	+	+	
18. *Stereophyllum setschwanicum* Broth.	+		+	
19. *Stereophyllum anceps* (Bosch et Lac.) Broth.	+		+	
20. *Wijkia tanytricha* (Mont.) Crum	+			+
	20	12	11	10

Morus alba Linn., *Cordia gharaf* (Forsk.) Ehrenb. et Asch.

Locality: Nakki lake Mt. Abu, alt. 1180 m, Gaumukh Mt. Abu, alt. 1160 m, Mt. Abu city, alt. 1180 m, Mt. Abu Giyan sarovar, alt. 1180 m, Mt. Abu way to Shiv Temple, alt. 1180 m.

Distribution: Cosmopolitan.

***Hyophila rosea* Williams in Bull. N.V. Bot. Card., 8: 341, 1941.**

Field notes : Plants growing on the bark of *Ficus bengalensis* Linn., *Anogeissus latifolia* Wall ex Bedd. *Syzygium cumini* (Linn.) Skeels., *Mangifera indica* Linn., *Nerium indicum* Mill., *Phoenix sylvestris* Roxb.

Locality: Mt. Abu Sunset point, alt. 1195m, Mt. Abu near Adhar Devi Temple, alt. 1125 m, near Delwara Temple, Mt. Abu, alt. 1125 m, Nakki lake, alt. 1180 m, near Swagat hotel, Mt. Abu, alt. 1180 m, Mt. Abu City, alt. 1180 m,

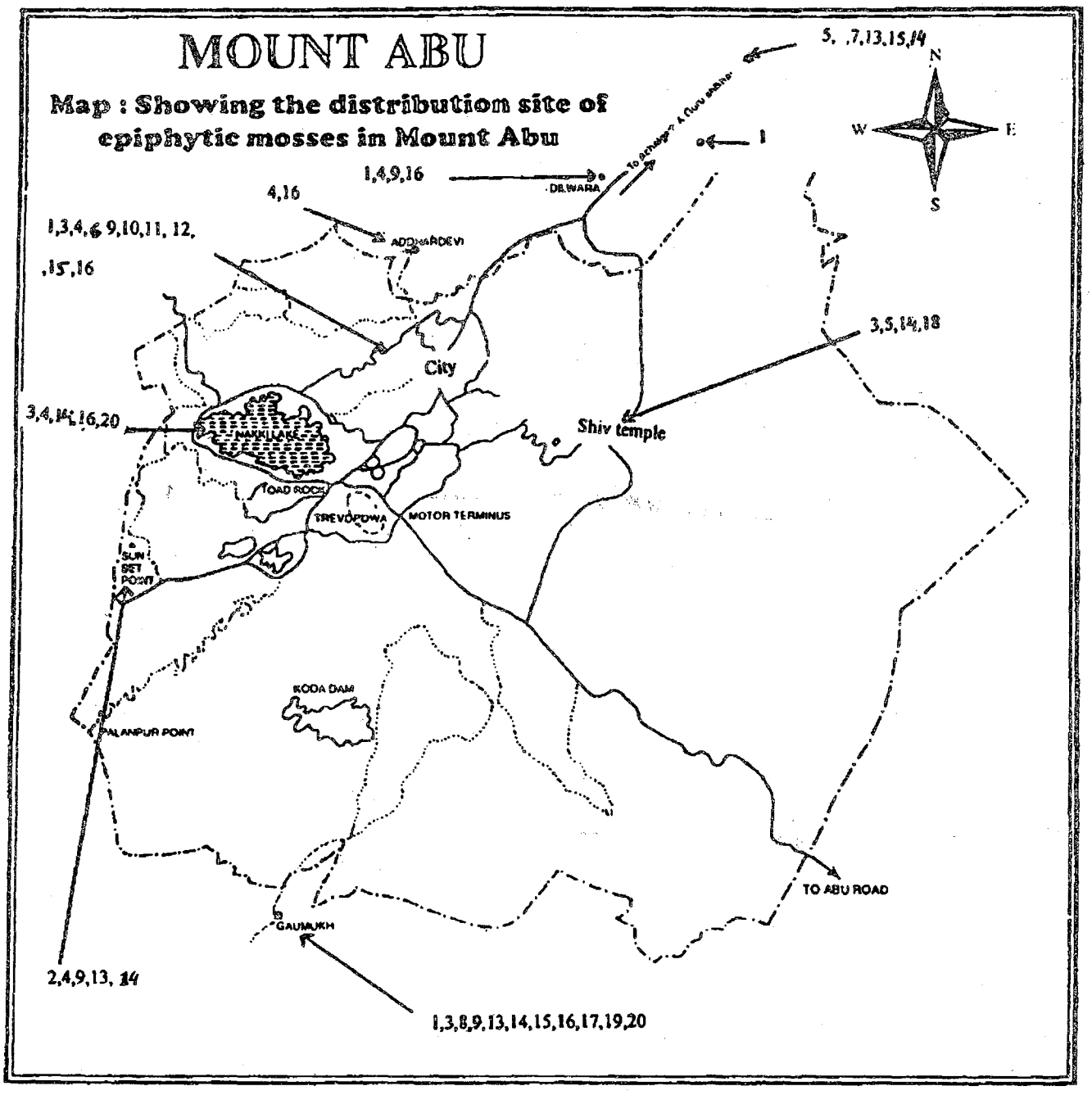
Distribution: Garhwal, Kumaon, Gujarat, Rajasthan, Philippines.

Eubryales, Bryineae, Bryaceae, Bryoideae

***Anomobryum auratum* (Mitt.) Jaeg. Ber. S. Gall. Naturw. Ges. 1873–74, 142, 1875.**

Field notes: Plants growing on the bark of *Phoenix sylvestris* Roxb., *Grevilea robusta* A. Cunn.

MAP. 1



The Numbers indicate the moss species mentioned in Table 1

Locality: Near Shiv Temple, Mt. Abu, alt. 1180m, Gurushikhar, Mt. Abu, alt. 1727 m.

Distribution: East Nepal, Sikkim, Darjeeling, Bhutan, Naga hills, Mussoorie, Ranikhet, Kashmir, Uttar Pradesh, Mahabaleshwar, Nilgiri, Palni hills, Rajasthan, Garhwal, Ceylon, Thailand, Philippines, China, Korea, Japan, Tanzania, Kenya, Madagaskar, North America, Australia, Pakistan, Formosa, New Guinea.

***Brachymenium indicum* (Doz. et Molk.) Bosch et Lac. in Bryol. Jav., 1:141 (1860)**

Field notes: Plants growing on the bark of *Eucalyptus obiqua* L' Herit.

Locality: Mt. Abu city, alt. 1180 m.

Distribution : South Bengal (Namkhana, Sundarban), Java, Amboina, Rajasthan, An Indomalesian species.

***Brachymenium turgidum* Broth.*ex* Dix. Rev. Bryol.35.94: 1908**

Field notes: Plants growing on *Eucalyptus globulus* Labill and *Grevillea* species and also on wall side and exposed rocks covered with soil.

Locality: Mt.Abu, Gurushikhar, alt. 1727m.

Distribution: Lingmala, Mahabaleshwar, Khandala (Western Ghats and South India)

***Bryum argenteum* Hedw. in Sp. Musc. 181, 1801. var. *lanatum* (P. Beauv.) Hamp. in Linnaea, 13:44, 1839**.

Field notes: Plants growing on the dead fallen stem joints of *Dendrocalamus strictus* Nees.

Locality: Gaumukh, Mt. Abu, alt 1160 m.

Distribution: Western Himalayas, Kashmir, South India, Rajasthan, Ceylon, Vietnam, Europe (Great Britain), Siberia, Korea, China, Japan, Philippines, Java, North, Central and South America, Hawaii, Australia, New Zealand.

***Bryum capillare* L. *ex* Hedw, in Sp. Musc. 182, 1801.**

Field notes: Plants growing on the bark of *Mangifera indica* Linn., *Phoenix sylvestris* Roxb., *Anogeissus latifolia* Wall *ex* Bedd., *Ficus bengalensis* Linn., *Eucalyptus obiqua* L' Herit.,

Locality: Mt. Abu city, alt. 1180 m., Gaumukh, Mt. Abu, alt. 1160 m, Delwara Temple, Mt. Abu, alt 1125 m, Sunset point, Mt. Abu, alt. 1195 m.

Distribution: Western Himalayas, Kashmir, South India, Rajasthan, Gujarat, Thailand, North Vietnam, China, Western Tibet, Taiwan, Korea, Japan, Siberia, Central Asia, Caucausr Europe, North and Central Africa, the whole of North and South America, Australia, New Zealand.

***Bryum paradoxum* Schwaegr. in Sp. Musc. Suppl. 3(1): 224 a, 1827.**

Field notes: Plants growing on the bark of *Phoenix sylvestris* Roxb.

Locality: Mt. Abu city, alt. 1180 m.

Distribution: East Nepal, Sikkim, Darjeeling, Bhutan, Khasia hills, Western Himalayas, Kashmir, Western Ghats, Rajasthan, Ceylon, China, Taiwan, Korea, Japan, Sakhalin.

Isobryales, Orthotrichineae,Erpodiaceae

***Erpodium mangiferae* C. Muell., Linnaea, 37:178, 1872**

Field notes: Plants growing on bark of *Phoenix sylvestris* Roxb.

Locality: Mt. Abu city, alt. 1180 m.

Distribution: North Bengal, Assam, Calcutta, Hoogli, Nadia, Birbhum, Midnapore, Orissa, Chhotanagpur, Northwest Himalaya, Uttar Pradesh (Saharanpur), Western Ghats, Palni, Rajasthan, Gujarat.

Hypnobryales, Leskeineae, Fabroniaceae

***Fabronia minuta* Mitt. in J. Linn. Soc. Bot. Suppl. 1:76, 1850.**

Field notes: Plants growing on the bark of *Phoenix sylvestris* Roxb.

Locality: Mt. Abu City, alt. 1180 m.

Distribution: Kulu, Kangra, Almora, Ranikhet, Rajasthan, Gujarat.

Hypnineae, Entodontaceae

***Entodon prorepens* (Mitt.) Jaeg. in Ber. S. Gall Naturw. Ges. 1876–77: 294 (1878)**

Field notes: Plants growing on the bark of *Mangifera indica* Linn.

Locality: Way to Gurushikhar, Mt. Abu, alt. 1727 m, Gaumukh, Mt. Abu, alt. 1160 m.

Distribution: Ranikhet, Nainital, Assam, Rajasthan, Gujarat, Nepal, Sikkim, Darjeeling, Bhutan, Khasia hills.

***Entodon ovicarpus* Dix. in J. Bomb. Nat. Hist. Soc., 39:789(1937).**

Field notes: Plants growing on the bark of *Anogesissus latifolia* Wall *ex* Bedd. *Grewia* species., *Jasminum auriculatum* Vahl., *Lantana camara* L., *Ficus bengalensis* Linn.

Locality: Mt. Abu, Near Shiv Temple, alt. 1180 m, Gurushikhar, alt. 1727 m, Nakki lake, alt. 1180 m, Gaumukh Mt. Abu, alt. 1160 m, Sunset point, Mt. Abu, alt. 1195 m.

Distribution: Arunachal, Gujarat, Rajasthan.

***Entodon laetus* (Griff.) Jaeg. in Ber. S. Gall. Naturw. Ges. 1876–77:295 (1878).**

Field notes: Plants growing on the bark of *Mangifera*

indica Linn.

Locality: Mt. Abu city, alt. 1180 m, Gaumukh Mt. Abu, alt. 1160 m.

Distribution: East Nepal, Darjeeling, Bhutan, Upper Assam, Khasia Hills, Gujarat, Rajasthan.

***Levierella fabroniacea* C. Muell. Bull. Soc. Bot. Ital. 1897: 73, 1897**

Field notes: Plants growing on the bark of *Mangifera indica* Linn., *Grewia* species, *Ficus bengalensis* Linn., *Eucalyptus obiqua* L' Herit. *Ficus glomerata* Roxb., *Phoenix sylvestris* Roxb., *Grevillea robusta* A. Cunn., *Cassia siamea* Lam., *Butea monosperma* (Lam.) Kuntze.

Locality: Mt. Abu City, alt. 1180 m, Peace park, Mt. Abu, alt. 1125 m, Nakki lake, Mt. Abu, alt. 1180 m, Delwara Temple Mt. Abu, alt. 1125 m, Gaumukh, Mt. Abu alt. 1160 m, near Adhar Devi, Mt. Abu, alt. 1150 m.

Distribution: East Nepal, Darjeeling, East Madhya Pradesh, Western Himalayas, Mussoorie, Ranikhet, Uttar Pradesh, Rajasthan, Western Ghats, Setschwan, Abyssinia, Transvaal (Africa).

Plagiotheciaceae, Stereophylloideae

***Stereophyllum decorum* (Mitt.) Wijk. et Marg. in Taxon, 9:52(1960).**

Field notes: Plants growing on the bark of *Anogeissus latifolia* Wall *ex* Bedd.

Locality: Gaumukh, Mt. Abu, alt. 1160 m.

Distribution: East Nepal, Kumaon, endemic in the Himalayas, Rajasthan, Gujarat.

***Stereophyllum setschwanicum* Broth. in Sitz. Ak. Wiss. Wien Math. Nat. Kl. Abt. 1, 133:581 (1924).**

Field notes: Plants growing on the bark of Erythrina *suberosa* Roxb.

Locality: Near Shiv Temple Mt. Abu, alt. 1180 m.

Distribution: East Nepal, Gujarat, Rajasthan, Darjeeling, Himalayas, China.

***Stereophyllum anceps* (Bosch et Lac.) Broth. in Nat Pfl, 1(3):898, 1907.**

Field notes: Plant growing on the bark of *Mangifera indica* Linn.

Locality: Gaumukh, Mt. Abu, alt. 1160 m.

Distribution: Chhotanagpur, Assam, Bangladesh, Kanara, Mahabaleshwar, Ceylon, Thailand, Vietnam, Java, Philipines, Rajasthan, Gujarat.

Sematophyllaceae, Heterophylloideae

***Wijkia tanytricha* (Mont.) Crum, The Bryologist, 74:174, 1971**

Field notes: Plants growing on the bark of *Mangifera indica* Linn., *Phoenix sylvestris* Roxb.

Locality: Gaumukh, Mt. Abu, alt. 1160 m., Nakki lake, Mt. Abu, alt. 1180 m.

Distribution: Darjeeling, Sikkim, Rajasthan, Java, Bhutan, New Guinea, Sumatra, Gujarat, Vietnam.

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ILL-EFFECTS OF DAMS ON THE FISH BIODIVERSITY IN HILLSTREAMS OF WESTERN HIMALAYAS

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Abstract

The Himalayas are the main watersheds in the Indo-Gangetic region, having numerous rivers, streams, lakes and reservoirs. The Western Himalayas face a serious water crisis on account of the low inflows, which are the least during the last fifteen years. This area may face a serious water crisis in the coming years. The presence of the dams like Tehri in the seismically active areas poses a great threat to the mankind. The dams, big or small, create a habitat unsuitable for the hillstream fishes leading to the decline in the endemic fish fauna. The classic example of habitat destruction leading to the decline in the fish fauna, being the Gobindsagar reservoir, where the catch of exotic silver carp, Hypophthalmichthys molitrix (Val.) has risen from a mere 2.00% in 1978 to 84.73% in the year 1997-98 at the expense of two indigenous carps namely Catla catla (Ham.) and Tor putitora (Ham.). This paper advocates the need for the provision of fish ladders in dams to facilitate auto stocking in the natural water bodies and also for upstream migration of the native fishes.

Key words : Hillstream, Dams, Fish, Anthropogenic activities.

INTRODUCTION

India is identified as a mega biodiversity country (McNeely *et. al.*, 1990) having two diversity hotspots, namely Western Ghats and Himalayas. Western Himalayas have been the perennial source of water by way of an excellent network of rivers and streams. The important rivers like Satluj, Ravi, Beas and the Ganges, have their origin within the radius of 150 Km in the Western Himalayas. According to Kottelet and Whitten (1997), India is one of the twelve countries having the richest freshwater diversity in the world.

The fishes of the Western Himalayan streams live under the harsh unstable environment. These now face a change, resulting from the activities of the humans, who share their limited world and are the successful competitors for water (Armantrout, 1998).

While the fishes may not seem important, still they are the key indicator of change with different fishes reflecting different environmental conditions (Moyle and Cech, 1988). The changes in aquatic system that cause the fish to decline and disappear are the changes that affect people as well. They may well serve a warning if they are declining/dying to those who should take care of what they may be doing to their own future.

The physical habitat altercation on account of dams and reservoirs (Li *et. al.*, 1987), siltation (Skelton, 1987) and introduction of exotic species (Johal *et. al.*, 1998) have chiefly been the factors responsible for the loss of fish biodiversity. In the present paper, the impact of large and small dams on fish diversity in the hillstreams of Western Himalayas has been discussed on the basis of the observations made during the period from Feb. 1998 to July 2001.

Topography

Geographically the Western Himalayas cover the states of Jammu and Kashmir (67.50%), Himachal Pradesh (17.00%)and Garhwal-Kumaun of Uttaranchal (15.50%) (Fig.1). The present study is based on the extensive icthyofaunal survey of the western Himalayan streams particularly in Himachal Pradesh and Garhwal regions.

Himachal Pradesh lies between river Ravi in the north-west and Tons-Yamuna in the south-east. It occupies an area of 55,673 sq. km. and lies between latitude 30° 22′ to 33° 10′ and longitude 70° 46′ to 79° 00′ E. Garhwal lies between latitude 29° 26′ to 31° 28′ N and longitude 77° 49′ to 80° 06′ E with a total area of about 30,000 sq. km.

These regions experience far more precipitation during the winter months as compared to the Eastern and the Central Himalayas where it is the summer precipitation, mostly in the form of rainfall.

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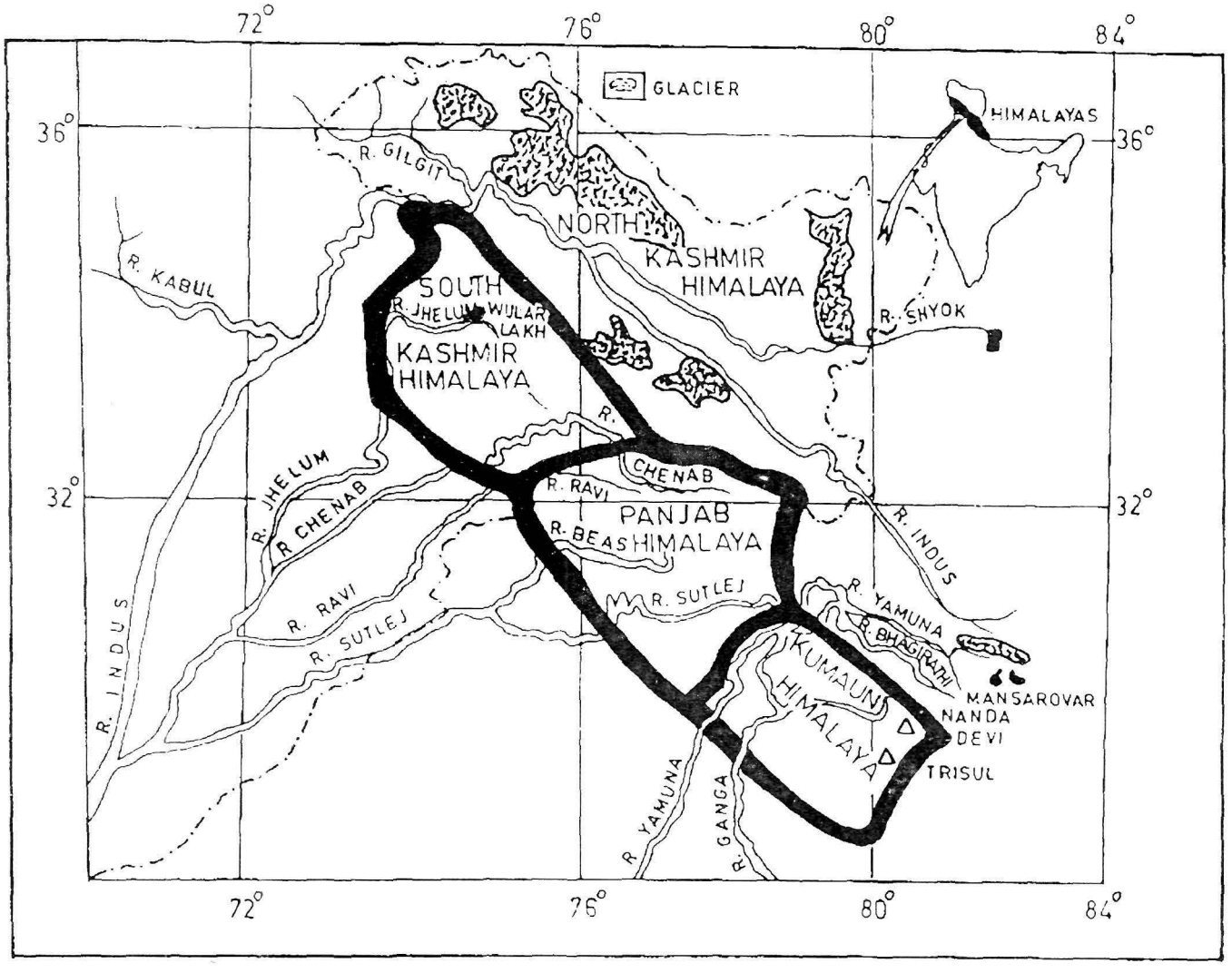

Fig. 1 : The bold lines in the map indicate the area of the present study.

MATERIALS AND METHODS

The present observations are based on the extensive icthyofaunal surveys conducted to study the ecology of hill streams of Western Himalayas under the collaborative programme between the U.S. Fish and Wildlife Service. Wasington, U.S.A. and the Department of Zoology, Panjab University, Chandigarh. The paper outlines the general observations and mainly the threats to the sensitive ecology of the Western Himalayas.

RESULTS AND DISCUSSION

Western Himalayas serves as a perennial source of water to the people of northern India. Under normal circumstances, the snowfall covers almost 75% of the areas in Western Himalayas. However, the satellite images of the Western Himalayas and the Mansarover Lake in Tibet by the Hyderabad based National Remote Sensing Agency has revealed that the catchment areas of the major rivers have received just 30% snowfall in the year 2000 and is the lowest ever recorded, which may be the further endorsement of the global warming. This has lead to reduced inflows, which has been the least during the last 15 years. It is on these inflows that the cropping pattern, drinking water availability, electricity generation etc. depend. This has resulted chiefly because of the reduced & erratic south-west monsoons and snowfall over the last couple of years due to the various anthropogenic activities.

Himachal Pradesh is a poor hill state and the only treasure it has is the vast network of rivers and streams. The states of Punjab, Haryana and part of U.P are dependent on the drinking water supply besides the hydro-electric requirements. The poor financial state has made the H.P

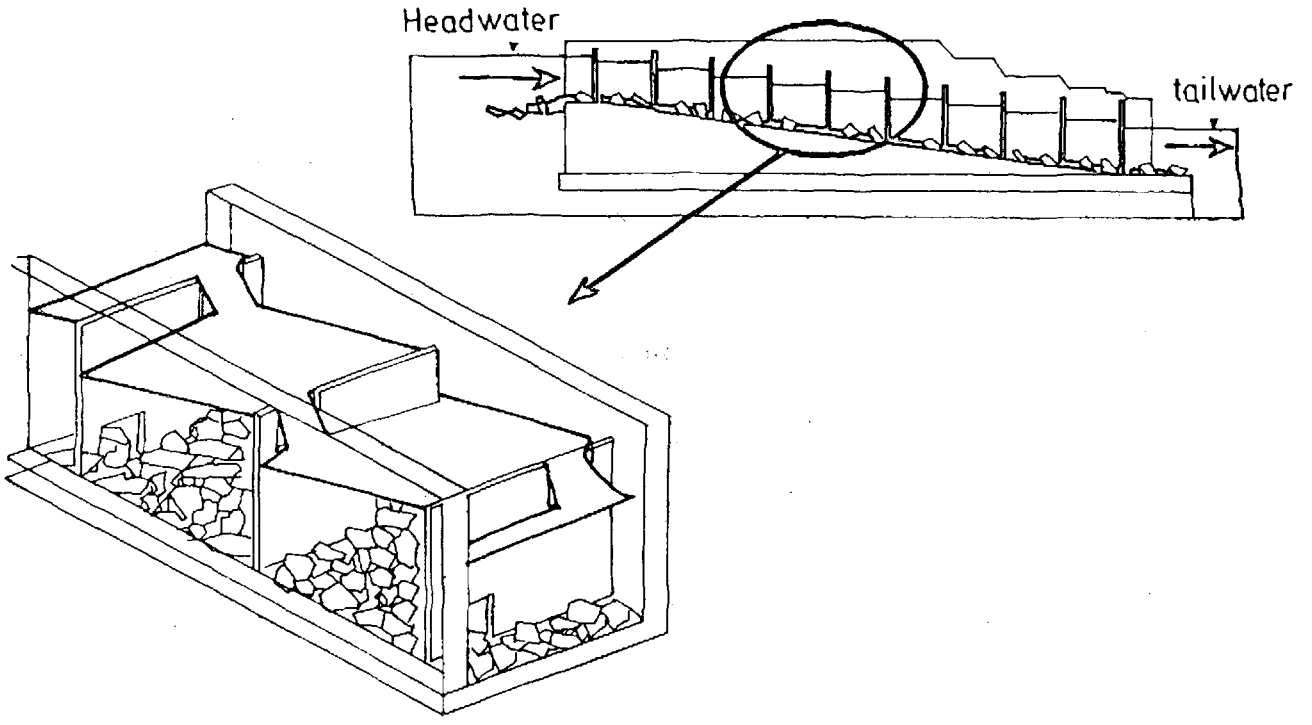

Fig. 1 : Conventional pool pass (longitudinal section and pool structure) showing different chambers and details of each chamber. In this type of pool pass, all the entry points are located diagonally opposite to each other and the base has plenty of sandstones, so that natural conditions can be provided.

government to harness the vast hydro-electric potential by way of making the small dams to generate the extra revenue for the state. These dams, no doubt are a earning revenue to the state government abut the bad impacts of these dams have largely been ignored.

Though a lot has long been debated about the good and bad impacts of big dams, very little attention has been paid to the small dams (up to 5 MW Capacity) in this region. During the last five years, more and more dams have come up in the hill state of Himachal Pradesh to augment the generation of hydro-electricity. During the year 1996-97, Memorandum of Understanding (MoU) for 64 projects with an average capacity of 71.4MW were signed out of which 30 projects have been given the technical clearance by the concerned agencies. During the second phase in the year 1999-2000, MoU for 24 projects with an aggregate capacity of 50.24 MW was signed and work is in progress on 5 projects. One project of capacity 100 KW was commissioned in Chamba area in January 2001.

All these dams have come up on the hill streams, which abode the hillstream fishes and these streams serve as a breeding ground for hillstream fishes like *Schizothorax richardsonii*, *Tor putitora*, *Crossocheilus latius diplocheilus*, *Garra gotyla gotyla*, *Glyptothorax garhwali*, and a host of other hillstream fishes. Completion of these dams has created reservoir like conditions resulting in the elimination of the breeding grounds of most of the native fishes. Their existence also obstructs the migration of the fishes leading to intermixing of different populations resulting in the genetic senility as well as genetically weaker population, which may result in the collapse of the capture fishery in the near future. Already the construction of the Pandoh dam in Himachal Pradesh has resulted in the reduction in the population of mahseers and schizothoracine fishes in the winter catches from 10.2-13.5% in 1964 to 0.5-1.0% in 1985-87 (Sehgal, 1988). The mahseer which used to migrate to the Jeuni stream in the pre-impoundment conditions can not move up now due to the deposition of debris (Sehgal, 1990) as a result of the appearance of reservoir like conditions. The study conducted by Natarajan and Sehgal (1982) points out that the mahseer stocks have been depleted by dams and weirs responsible for the prevention of most of the local fish migrations. Though the small dams do not have the ills of deforestation, migration, rehabilitation of the people, however these dams are doing no good to the population of the hillstream fishes.

Clean drinking water is what everybody needs, be it at

the cost of the fish because when it comes to humans vs. fish, it's the humans, who get the preference for obvious reasons. With the rapidly increasing population, the water is going to be scarcer and scarcer in near future. The excellent example being the capital of Himachal Pradesh, Simla, where summer residents feel the summer blues every year. The Government of Himachal Pradesh is looking for some foreign investments to implement its 64.81 crore lift water scheme from the river Giri-which is the breeding ground of one of the most important and endangered game fish of India

The construction of the Tehri dam over the tributaries of the river Ganges (1000MW-Stage-1) in the Garhwal Himalayas has raised many an eyebrows considering the seismic activity of the area. Serious doubts have been cast on its construction in one of the most unsuitable sites, keeping in view of the recent Gujarat earthquakes. It poses great human threat to the thousands of people living downstream.

Further concern has been expressed about the possible impacts of the Tehri dam on the water quality of the Ganges. The river Ganges has been the sacred river to the people over the ages and people feel that any attempt to tame the river Ganges shall lead to its deterioration. This is religious factor but is hard to overlook.

Another threat to the sensitive Himalayan ecology is by the Chinese ambitious plan to build the world's biggest hydro-electric project (38 million KW power stations) on the Yarlung Zangbo River in Tibet by creating a 15 Kilometer long tunnel in the Himalayas by nuclear explosions near Namche Barwa. The project which aims to divert the rain water for hundreds of Kilometer from the rainy north to the parched south is expected to start soon, when the three gorges dams will be completed. The nuclear explosions in the seismically active Himalayas may further aggravate the problem and it may also affect the inflows of the major rivers in India and it may quite well have an effect on the water quality too.

In Himalayas as in other parts of the world, several exotic species have been introduced overlooking the bad effects they have on the endemic fish fauna (Acheing, 1990; Elvira, 1990). The Gobindsagar is one of the important reservoirs in India, which came into existence with the construction of 225.56m high concrete gravity dam across the once turbulent river Satluj in 1963. Up to the year 1973, the dominant fishery of the reservoir comprised mainly of the Indian major carps: *Labeo dero*, *L.bata*, *L. rohita*, *L calbasu*, *Catla catla*, *Cirrhinus mrigla* and *Tor putitora* (Johal and Tandon, 1981). During 1981-82, *Labeo dero* was the dominant fish in this reservoir (38.47%), but the accidental introduction of the silver carp, *Hypophthalmichthys molitrix* from the Deoli fish farm in 1970 caused havoc in this reservoir. The emergence of the silver carp marked the beginning of the change in the catch structure with the fish establishing an overriding dominance over all the other species, percentage wise (Sugunan, 1995). Its catch rose from a mere 2% in 1978 to 84.73% in the year 1997-98 (Esmaeili and Johal, 2000). The data collected from 1981-1998 revealed that the catch of the Indian major carps have come down drastically. Though production wise silver carp is rated as "A" but it is rated "C" by the consumer preference due to poor shelf life and the low market value.

According to Kumar (1988), the exotic carps of Gobindsagar have increased at the rate of 8.2% in the last 14 years. Though the construction of the reservoir has created a source of fish for the people of northern India but the endemic fish fauna has been adversely affected.

Dams for generating electricity without the provision for the fish ladders have been constructed on several rivers in the past. The problem with the dams in India is that hardly any dam has the provision of the fish ladders, which can provide an upstream migration for the breeding of the fishes. There are some barrages especially at Ropar and Harike which have the provision of the fish ladders but these are used by poachers as fish traps. While constructing the fish passes at these barrages, the various aspects of breeding biology of the native fishes have not been studied. Besides this, the velocity of water current coupled with the substrate requirement for the spawning has not been taken into consideration. The dams without the provision of the fish ladders create a barrier to upstream and downstream fish migrations leading to the declining fish stocks (Riggs, 1990; Nehlsen *et. al.*, 1991; Esmaeili, 2002). The migratory obstructions have been recognized as the chief reason for the loss of the endemic fauna (Ros, 1981). In fact, the Fishery Biologists are hardly ever consulted while planning of these dams. So, ***"Dams are Engineer's delight but Ichthyologist's plight".***

It is not possible to construct the fish passes in the already existing large dams, but in case of the small dams, there is a possibility to have the fish passes called "Pool Pass". The principal of the pool pass consists in dividing up a channel leading from the headwater to the tailwater by installing cross-walls to form a succession of stepped pools. The discharge is usually passed through the openings in the cross-walls and the potential energy of the water is dissipated, step by step, in the pools (Fig. 2). The fish can migrate from one pool to the next pool through the openings in the cross-walls that are situated at the bottom. The migrating fish will encounter high flow

velocities only during their passage through the cross-walls, while the pools with their low flow velocities offer shelter and opportunities to rest. A rough bottom is a prerequisite to make pool passes negotiable for benthic fauna.

The adverse effects of the dams have recently been fortified with the report of the World Commission on Dams. A few of the major concerns are listed below:

1. Dams provide electricity, water, flood control and irrigation but they have wrecked havoc on people most of whom have very little say whether a dam should be built or not. The most recent example being the displacement of 10,000 villagers in China that were moved to make way for the three Gorges dams.
2. Dams have fragmented and transformed most of the World Rivers.
3. Dams have also affected the livelihood of many people who live in the downstream areas and rely on natural floodplain functions and fisheries.
4. Large dams have caused the loss of forests, wildlife habitats, species and aquatic biodiversity in both upstream and downstream areas.

   The Commission concluded that the true economic profitability of the large dam projects remains elusive, as the environmental and social causes of large dams were poorly accounted for in terms of economic terms.

CONCLUSIONS

1. Western Himalayas will face a serious water crisis in future. Already the inflows are the lowest for the last 15 years, so the alternating routes for harvesting rain water should be looked into.
2. The problem of exotic introductions to augment the fish production has been a world wide phenomenon but it has adversely affected the endemic fish fauna. It is desirable to study the past history of the exotic fish (es) before their introduction
3. China's dam project by creating a 15 Km long tunnel in the Himalayas by nuclear explosions, due to begin in 2009 needs a rethinking considering the seismic activity of the fragile Himalayas.
4. Though the impact of the large dams has long been debated in the International forums, small dams have invariably drawn little attention. Further studies should be undertaken to know their impacts for future strategies.
5. Fish ladders or fish passes should be an integral part of the dams irrespective of the size of the dams to facilitate the migration of the fishes.
6. Last but not the least; the Fishery Biologists should be consulted at every stage of planning of dams.

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INHIBITORY EFFECT OF *LANTANA CAMARA* EXTRACT ON REGENERATION OF *FUNARIA HYGROMETRICA* IN HALF KNOP'S LIQUID CULTURE MEDIUM

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Abstract

Lantana camara Linn.(family verbenaceae) is a wild luxuriantly growing pest plant which has enchroached upon large parts of pastures and forest area in tropical and subtropical parts of the world. It is one of the ten worst weeds of the world. Lantana is an aggressive invader of natural ecosystem. its leaf, stem, and root contain some harmful allelochemicals,which inhibited the germination and growth of funaria hygrometrica Hedw. Maximum regeneration was observed in control. Leaf extract was found to exhibit maximum inhibitory effect followed by stem and root extract.

Key Words : *Lantana, Funaria hygrometrica*, regeneration, Allelochemicals.

INTRODUCTION

Bryophytes are an important component of the vegetation in many region of the world. They are important tools for physiological and biochemical experiments. However,very little work has been done on allelopathic effects of *Lantana* on Bryophytes. Thirunavukkarasu *et al.*(2002), Studied the toxicity of *L.camara* leaves in calves. Juliani *et al.* (2002), evaluated the chemical composition of *Lantana xenica* essential oil and its antimicrobial activity. According to Rice (1979), allelopathy includes both inhibitory and stimulatory biochemical interactions among plants including fungi and microorganisms. Rice (1984) reviewed studies on allelopathy among terrestrial plants. Recently, Narwal and Tauro (1996) complied all the information available on field observation, methodology used in investigating allelopathy and its role in pest management.

Little attention has been paid on allelopathic effects of *Lantana* on Bryophytes. Spread of *Lantana* in the forest of Mt.Abu is adversely affecting survival of angiosperms in general and bryophytes in particular,affecting their spore germination and regeneration. Aqueous extract of root, stem and leaf inhibited regeneration in *Funaria*, where leaf extract is most potent in inhibitory action. The Autotoxic impact of crude volatile oil was observed from young leaves of *Lantana camara* on the parent plant itself. (Arora and Kohli, 1993). Aqueous leachate of *Lantana camara* was screened for allelopathic effect on water hyacinth *(Eichhornia crassipes)* growth (Saxena and Manjula, 2000). Antimicrobial activity was shown by the essential oil of *Lantana xenica* (Juliani *et al.*, 2002). Acute *Lantana camara* poisoning was described in Boer goat kid (Ide and Tutt, 1998).

The study revealed that the effect of *Lantana camara, is* obtained from various plant parts i.e.; root, stem and leaf. The percentage of regeneration increased, with increasing number of days, but with the increase in the concentration of *L.camara* extract,the percentage of regeneration decreased. However, the trend of maximum inhibition of regeneration was by leaf extract followed by stem and root respectively. In the present investigation the effect of allelochemicals secreted from different parts of *Lantana* i.e., root, stem and leaf on *Funaria hygrometrica* were studied.

MATERIALS AND METHODS

Fresh material of *Lantana camara* was collected from science college campus. Root, stem and leaves were separated from the plant, kept in an oven, dried at 80°C for 24 hours and chopped into small pieces. 10 grams of each was soaked in 100 ml of double distilled water for 24 hours and then filtered. Filtrate was autoclaved at 15 lb pressure for 15-20 minutes. Then the required concentration were prepared by addition of (HKM) culture medium in the extracts, while served as control.

In order to study the pattern of regeneration, leaves of *Funaria hygrometrica* were surface sterlized with 2% of calcium hypochlorite for 1-3 minutes and then 5-10 leaves was spread in the Petri dish containing whatman's filter paper no.1 moistened with half Knop's liquid culture medium and different concentrations viz 5%, 10%, 15%, 20%, 30%, 40%, 50% of root,stem and leaf extract of *Lantana*.These petri dishes were kept in different condition of day, night and diffused light.

For studying water relation leaf sample were obtained with a standard ¼ inch paper punch. The leaves were swabbed in distilled water and then blotted with a clean filter paper. A disc was punched from the leaf and then placed in a thermocouple psychrometer chamber (model

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Table 1 : Effects of different concentrations of leaf, stem and root extracts of *Lantana camara* on *Funaria hygrometrica* regeneration at different ages in half Knop's medium

Concentration (in %)	10th Day				20th Day				30th Day			
	LRE	LSE	LLE	Mean	LRE	LSE	LLE	Mean	LRE	LSE	LLE	Mean
Control	60.00	60.00	60.00	60.00	73.33	73.33	73.33	73.33	83.33	83.33	83.33	83.33
5%	43.66	33.33	26.34	34.44	66.66	66.66	60.00	64.44	73.33	66.66	63.35	67.78
10%	33.33	26.66	20.00	26.66	53.33	49.66	43.67	48.89	62.00	58.02	53.33	57.78
15%	26.66	13.33	13.33	17.77	46.66	40.00	26.66	37.77	52.31	41.00	40.00	44.44
20%	20.00	16.66	6.66	14.44	33.33	20.00	13.33	22.22	38.46	21.00	17.22	25.56
30%	6.67	10.00	0.00	5.56	10.01	6.66	3.33	6.67	20.00	5.22	4.77	10.00
40%	0.00	0.00	0.00	0.00	3.33	0.00	0.00	1.11	3.33	0.00	0.00	1.11
50%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0.00	1.11
Mean	23.79	20.00	15.79	19.86	35.83	32.04	27.54	31.80	42.01	34.40	32.75	36.39
SEm	0.466	0.466	0.466	0.269	0.609	0.609	0.609	0.351	0.71	0.71	0.71	0.41
CD 5%	1.326	1.326	1.326	0.7658	1.73	1.73	1.73	0.9991	2.02	2.02	2.02	1.166
CD 1%	1.77	1.77	1.77	1.022	2.309	2.30	2.309	1.333	2.696	2.696	2.696	1.556
Extra Medium												
Sem		0.165				0.215				0.251		
CD 5%		0.4689				0.6118				0.7141		
CD 1%		0.6258				0.8165				0.9531		

Mean Square of different days for regeneration

Source	d.f.	10th Day			20th Day			30th Day		
		SS	MS	F	SS	MS	F	SS	MS	F
A	2	7.52778	3.76389	5.766**	15.5278	7.76389	6.988**	12.1944	6.09722	4.208*
B	7	260.764	37.252	57.067**	521.542	74.506	67.055**	631.278	90.1825	59.570**
A X B	14	7.36111	0.525794	0.805	12.25	0.875	0.787	8.47222	0.605159	0.400
Error	48	31.3333	0.652778		53.3333	1.11111		72.6667	1.51389	

** = Significant at 1% level of significance

* = Significant at 5% level of significance LRE = *Lantana* root extract LSE = *Lantana* stem extract LLE = *Lantana* leaf extract

c-52 sample chamber, wescor) and equilibrated for 30 minutes. The water potential was read using a micro voltmeter (model HR-33 T dew point micro voltmeter, wescor). The tissue was frozen, thawed and equilibrated again in the thermocouple psychrometer chamber to determine osmotic potential. The water potential or osmotic potential was calculated as follows:

$$\text{Osmotic potential } \psi_p = \frac{\text{Reading}}{0.75\ \mu \text{ Volts bar}^{-1}}$$

To define conductivity, we take some soil sample of *Lantana* and *Funaria* and dried in oven. Conductivity or specific conductance is the measure of the water ability to conduct an electric current. Conductivity depends upon the number of ions or charged particles in the water. Conductivity meter is used to measure the ability of the water sample to conduct electricity. The specific conductance is measured by passing a current between two electrodes (1 cm apart) that are placed into a sample of water. The unit of measurement for conductivity is expressed in either microsiemens (μS/cm) or micromhos (umho/cm) which is the reciprocal of the unit of resistance, the ohm. Micro means that it is measured in millionths of a mho. Microsiemens and Micromhos are equivalent units.

RESULTS AND DISCUSSION

The leaf, stem and root extracts prepared in half Knop's liquid medium proved to be inhibitory for regeneration of *Funaria hygrometrica*. It is observed that all phases of regeneration are inhibited by the *Lantana* extract in which leaf extract is the most potent inhibitor followed by stem and root extract.(Table 1) Significant difference for regeneration in root,leaf and stem extract of *Lantana* was observed.

The regeneration was maximum in root extract followed by stem and leaf extract. The inhibition (%) over control was maximum for leaf extract (-100) at 20% aqueous extract concentration followed by stem extract (-100) at 30% concentration and (-100) at 40% aqueous concentration of root extract. The complete inhibition of regeneration was observed at concentration above 40. The results obtained show that the various extracts are inhibitory for the regeneration due to the presence of allelochemicals. Supplementing the extract with half knop's liquid culture medium increase the regeneration, which may be due to the presence of various nutrients in it as well as some antagonistic effect also. The spread of *Lantana* is a serious threat for the existing bryoflora of the subcontinent and measures should be taken well in time to check its further spread. We calculate osmotic potential of *Lantana* and *Funaria hygrometrica* and find that The osmotic potential of *Lantana* is 5.333 bar^{-1} and *Funaria* of *hygrometrica* water potential is 6.666 bar^{-1}.

The results were in conformity with Kothari and Chaudhary (2001), who studied the allelopathic effect of *L. camara* on regeneration of a liverwort *Asterella angusta,* They reported that the inhibition increased with increase in the concentration of leaf, stem and root of *Lantana*. Bhansali (2002) reported that extracts from leaf, stem and root of *L. camara* proved inhibitory for the regeneration of moss *Physcomitrium japonicum*. The probable reason may be the presence of higher concentration of allelochemicals in the glandular trichomes present on the leaf surface as compared to root and stem trichomes. The number of trichomes on leaf surface are also greater than stem and root.

We calculated the conductivity of *Lantana* and *Funaria* and found that the conductivity of *Lantana camara* (Soil) is 4.3 umhos/cm. and *Funaria hygrometrica* (Soil) is 3.9 umhos/cm. Conductivity determination are useful in aquatic studies because they provide an estimate of dissolved ionic matter in the water.

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MOSSES OF WESTERN HIMALAYA AND ADJACENT PLAINS - II

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Abstract

62 species included in 25 genera and 5 families of Dicranales are described and illustrated. Pleuridium tenue with long seta, as illustrated by Gangulee (1971), has been excluded from this genus. In order to facilitate determination of the various taxa, the keys are drawn mainly on the basis of vegetative characters. The taxonomic affinities of the pertinent taxa are indicated. The evolutionary trends witnessed in the Dicranales are also listed. The family Ditrichaceae, for reasons given in the text, has been treated after the Dicranaceae in departure to the earlier placing of this family.

Key Words : Taxonomic account, Key to taxa, Distribution, Chromosome number, Evolutionary considerations.

INTRODUCTION

Taxonomy, on which rest all other disciplines of biology, of all the plant groups is one of the on-going research projects of our department. The present study, which is in continuation to our earlier investigations on the moss flora of the Western Himalaya and adjacent plains (Chopra, 1975; Chopra and Kumar, 1981), provides an illustrated taxonomic account of the order *Dicranales*.

MATERIALS & METHODS

The material for this study were collected from the Western Himalaya and adjacent plains during 1960 to 2004 by the author himself or jointly with his students. Some earlier collections made by previous collectors and housed in various herbaria [British Museum Natural History, London (BM); Forest Research Institute, Dehra Dun (DD); Department of Botany, Panjab University, Chandigarh (PAN)] were also examined. The specimens, except where otherwise indicated, are located in the Panjab University herbarium (PAN). The field notes were taken at the time of collection. The cytological comments in the text are based on the chromosome number data compiled by Fritisch (1991) and subsequent publications on the subject. The materials were studied by the well known techniques being followed the world over. The citations for the taxa are as given in the Index Muscorum. (Wijk, Van Der, R., Margadant, W.D., Florschütz, W.D. 1959-1969) .The species are arranged alphabetically, and genra and families are arranged on presumed evolutionary considerations. All camera lucida drawings, except where otherwise stated, were drawn by the author himself at magnification indicated in the explanation to figures.

OBSERVATIONS AND RESULTS

Taxonomic treatment.

ORDER DICRANALES

Plants growing in dense tufts or cushions, rarely singly or in small patches. Stems simple or branched, mostly densely foliate. Leaves narrow-lanceolate or subulate, erect or secund; nerve often percurrent or excurrent, in transverse section mostly heterogeneous; alar cells not or differentiated; basal laminal cells mostly elongate, rectangular, upwards elongate or short-quadrate, mostly smooth. Setae mostly straight, long, rarely short. Capsules erect or curved to drooping. Peristome teeth 16, each cleft down to one-half to two-third of its length or deeply divided into two divisions, papillose above and vertically papillose-striate below or papillose throughout, sometimes smooth. Operculum conic-rostrate. Calyptra cucullate.

This large heterogeneous group exhibits a great diversity in gametophytic and sporophytic features. Sometimes, the morphological characteristics, at least in some taxa, are so over lapping, that they do not easily permit segregation into families or even genera. The problem is further compounded by convergent evolution which, as in several other groups of mosses, seems to have operated independently at different levels in this order as well.

Cytologically, the group appears to be less confusing. Majority of the investigated taxa show n = 13* or 14* or its multiples. The other chromosome numbers (n = 8, 10, 11, 12,15), recorded only in a few species of *Garckea*, *Trichodon*, *Seligeria*, *Paraleucobryum*, *Dicranum*, *Campylopus*, *Bruchia*, *Trematodon*, *Anisothecium* and *Dicranella*, could be of real existence. Nevertheless, it

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*These numbers are derived from an ancient chromosome numbers, n=7, which is still have preserved, of course only in a few dicranoid taxa.

also cannot be ruled out, that some of these reports may be the result of some errors in counting and/or misinterpretation of meiotic figures. It would be worthy of note, however, that the handling properties of the chromosomes in Dicranceae and Ditrichaceae are at complete variance with respect to each other.

From an evolutionary angle, it appears that narrow, increasingly cleft (down to one-half to two-third or deeply divided), papillose or papillose – striate peristome teeth versus broad-lanceolate, undivided and smooth peristome teeth; distinct apophysis versus indistinct apophysis; smooth versus ribbed capsules, homogeneous versus heterogeneous nerve, non-lamellate nerve back versus lamellate nerve back and differentiated alar cells versus alar cells lacking, found favour from the selection pressures which operated during the course of the evolution of this fascinating taxon, and also in its further divergence, as is witnessed in the present day taxa.

In our area, the order Dicranales is represented by 5 families, which are segregated as under.

Key to the West Himalayan families of Dicranales

a. Alar cells differentiated..... b
Alar cells not differentiated.....d

b. Capsules ovoid to obovoid with wide mouth; peristome teeth short and broad, smooth.....**1.*Seligeriaceae*** (*Blindia*)

Capsules broad-cylindric to cylindric, capsule mouth not wide; peristome teeth relatively longer and narrower, striate or papillose striate....c

c. Stems lacking central strand; capsules distinctly ribbed **2.*Rhabdoweisiaceae***

Stems with central strand; capsules smooth..... **3.*Dicranaceae*** (*Dicranum,Campylopus. Dicranodontium*)

d. Capsules with a markedly distinct apophysis..... **4.*Bruchiaceae***
Capsules without or with slightly distinct apophysis..... e

e. Nerve, in transverse section, homogeneous; peristome teeth mostly undivided, rarely partially split or perforate, smooth.....**1.*Seligeriaceae***

Nerve, in transverse section, heterogeneous; peristome teeth cleft deeply down to base or at least in the upper one-half, striate, papillose-striate or papillose.....f

f. Peristome teeth lanceolate, cleft down to one-half to two-third of their length, striate or papillose-striate..... **3.*Dicranaceae***

Peristome teeth narrow, deeply cleft into 32 filiform, papillose divisions..... **5.*Ditrichaceae***

1. FAMILY SELIGERIACEAE Schimp.

Plants small (except *Blindia*. B.S.G.), growing on sand stone or lime stone rocks. Stems simple or branched. Leaves mostly subulate from broadened base; nerve nearly filling the subula, percurrent, excurrent or ending below the apex, in transverse section homogeneous (except *Blindia*, sub-genus *Pseudodicranoweisia*); alar cells differentiated in *Blindia* only; basal laminal cells elongate, the median and the upper ones shorter. Setae straight or curved. Capsules exserted, ovoid to pyriform with wide mouth when empty, exannulate, urn stomatose. Peristome mostly present, deep-inserted, teeth 16, erect or recurved when dry, lanceolate, undivided, partially split or perforate, smooth. Operculum rostrate. Calyptra cucullate. Spores small.

The short, undivided, smooth peristome teeth are suggestive of the archaic nature of the family.

This family includes five genera, of which two (*Seligeria* Bruch. & Schimp., *Blindia* B.S.G.) are recorded from India. In our area, the family is represented only by one genus i.e. *Blindia*.

***Blindia* B.S.G., Bryol Eur. 11 : 17. 1846.**

Dioicous or autoicous. Plants light-green, brownish-green on drying, growing in dense tufts. Stems mostly branched. Leaves erecto-patent or secund, subulate from oblong base; margins toothed near apex or entire; nerve strong, filling the subula; alar cells differentiated, coloured, not reaching the nerve (at least in the West Himalayan taxa), basal laminal cells rectangular or very narrow- rectangular, thick-or thin-walled, upwards shorter or elongate. Setae short or long, straight or cygneous. Capsules exserted or immersed, erect to drooping, sub-globose or ovoid to obovoid, exannulate. Peristome teeth short and broad, lanceolate, irregularly perforate, smooth, sometimes wanting. Operculum with slanting beak. Calyptra cucullate.

Type: *Blindia acuta* (Hedw.) B.S.G.

This genus agrees with *Dicranum* Hedw. in showing well differentiated alar cells, but is readily distinguished from that taxon by the non-pitted walls of the basal laminal cells, the sub-globose or obvoid, exannulate capsules, and the short and broad, lanceolate, smooth peristome teeth.

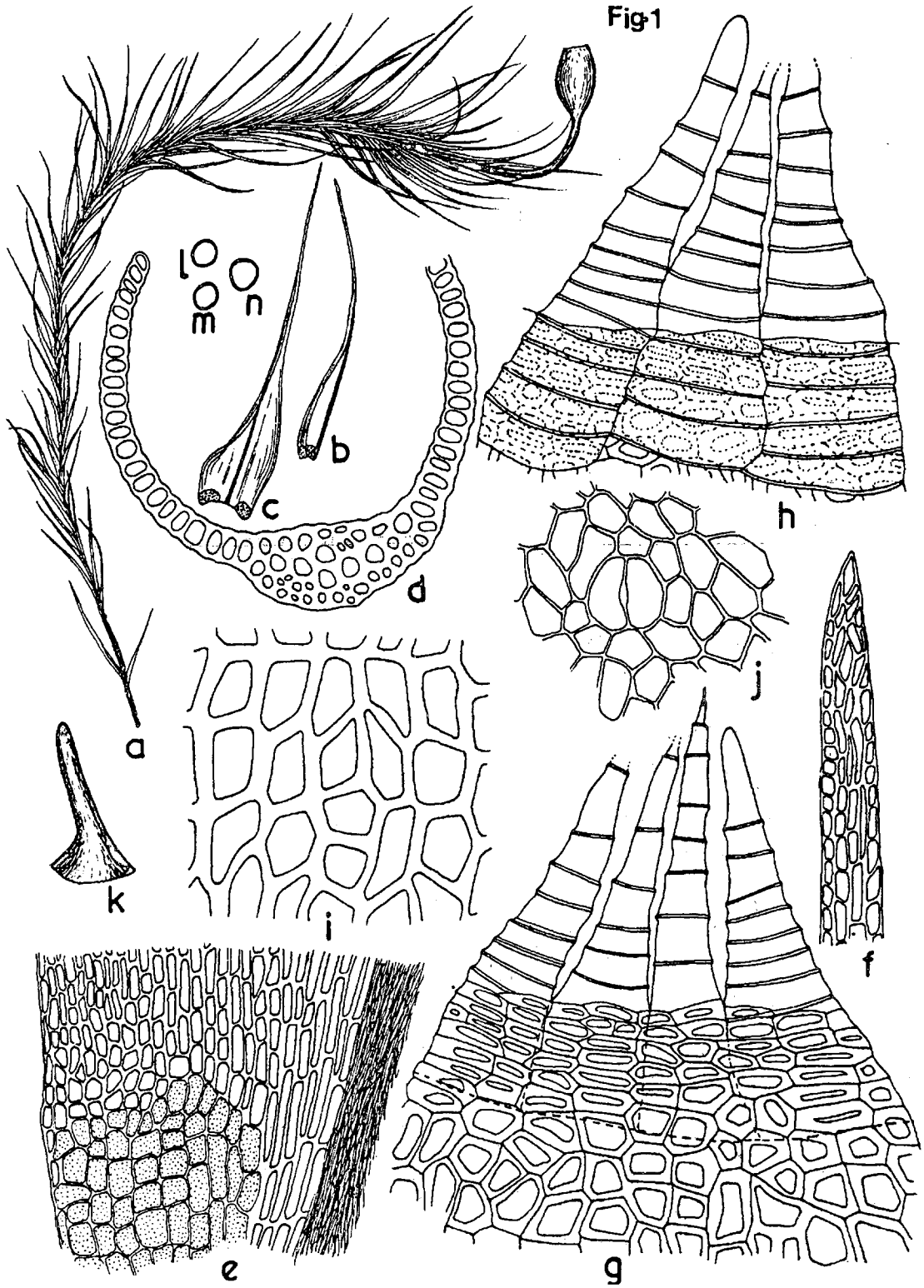

Fig. 1: Blindia campylopodioides Dix. et Badhw.
a. Plant x 10; b,c. Leaves x 20; d. T. S. leaf x 495; e, Alar cells and basal laminal cells x 495; f, Leaf apex x 495; g, h. Peristome x 495; i. Exothecial cells x 495; j. Stoma x 495; k. Operculum x 20; l,m,n. Spores x 495.

Cytologically, the genus is known from three species, of which two show n = 14. The third species i.e. *B. acuta* (Hedw.) B.S.G. occurs in two cytological forms i.e. n = 13 (G. Britain populations) and n = 14 (Ukrainian populations) which, probably, also explains its morpho-plasticity/ polymorphic nature. The remaining 29 species still remain cytologically unattended.

The genus Blindia B.S.G. contains 32 species, of which 4 are found in our area. Of these four, three are endemic in the Western Himalaya.

Key to the West Himalayan species of *Blindia* B.S.G.

a. Stems densely covered with rhizoids; leaves longly decurrent, 4.0-6.0 mm long; leaf margins toothed near apex..... **4.*B.sordida***

Stems without the rhizoidal covering; leaves hardly decurrent, 2.0-3.0 mm long; leaf margins entire throughout.....b

b. Nerve not filling the subula; upper laminal cells short-quadrate to sub-quadrate, 4-7 µm wide; setae cygneous..... **1.*B.campylopodioides***

Nerve nearly filling the subula; upper laminal cells elongate to rectangular, 12-16 x 4-5 µm; setae erect.....c

c. Leaves 0.2 mm wide at base, gradually narrowed to a setaceous point from a narrow-lanceolate basal portion; walls of basal laminal cells somewhat curved..... **3. *B.roerchii***

Leaves not less than 0.3 mm wide at base, suddenly narrowed to a subula from an ovate-lanceolate basal portion; walls of basal laminal cells straight..... **2. *B.himalayana***

1. *Blindia campylopodioides* Dix. *et* Badhw., Rec. Bot. Surv. India 12:68.1938.(Fig.1).

Plants light-green, growing in dense tufts. Stems 1.0 – 1.3 cm long, ascending, simple or branched. Leaves erecto-patent or slightly falcate, hardly altered on drying, 2.0 – 3.0 mm long and 0.3 – 0.4 mm wide at base, subulate from a convolute, oblong basal portion; margins recurved from middle upwards; nerve 30 – 40 µm wide at base, not filling the subula, in transverse section showing a few stereids; alar cells hyaline or reddish, 12 – 16 µm wide; basal laminal cells irregularly rectangular, 20 – 40 x 5 – 8 µm, the middle and the upper ones shorter, irregular, 4 – 7 x 3 – 4 µm, thin-walled. Setae cygneous, 2.8 – 3.0 mm long. Capsules ovate-globose, stomatose, stomata superficial; exothecial cells irregular, 12 – 30 x 12 – 16 µm, strongly incrassate. Peristome teeth 16, inserted below the mouth, upto 42 µm high, red below, pale above, united at bases. Operculum 0.5 mm long, obliquely rostrate. Spores 8 – 9 µm in diameter, psilate.

According to Dixon & Badhwar (1938), this species agrees with *Blindia japonica* except for its curved setae and deeply inserted peristome teeth.

Specimens examined: Himachal Pradesh: Khadrala, 2700 m, on rocks, September, 1977,*3013*; Dharmsala, 2,700m, on rocks, September, 1977, *3014*, *3102*; Dalhousie, Chamba, 2,500 m, on rocks, July, 1928, *388* (B.M.); Dalhousie, 2600 m, on rocks, October, 1917, *1403*.

Distribution: Himachal Pradesh. Endemic in the Western Himalaya.

Chromosome number : n = 13 + m (single population)

2. *Blindia himalayana* Dix. *et* Badhw., Rec. Bot. Surv. India 12 : 167. 1938. (Fig. 2)

Plants brownish-green, growing in dense tufts. Stems 1.0 – 1.5 cm long, ascending, branched. Leaves erecto-patent, hardly altered on drying, 2.0 – 2.5 mm long and 0.35 mm wide at base, suddenly narrowed into subula from ovate-lanceolate basal portion; apex sub-acute; margins entire; nerve slender, 40 – 52 µm wide at base, filling the subula and excurrent; alar cells well differentiated, reddish, in 5 – 7 rows, not reaching the nerve; sub-quadrate, 8 – 10 µm wide; basal laminal cells narrow-rectangular, 20 – 24 x 3 – 5 µm, walls straight, the middle ones 10 – 24 x 3 – 4 µm, the upper ones 12 – 16 x 4 – 5 µm. Sporophyte not seen.

This species seems very close to *Blindia acuta* B.S.G. The differences in leaf size and laminal cells size are only of degree. Earlier, Dixon & Badhwar (1938) have also made similar remarks "Similar to *B. acuta* B.S.G., but with smaller leaves, weaker nerve, shorter cells with much less incrassate walls". Fertile specimens need to be collected to ascertain its relationship with that taxon.

Specimen examined: Himachal Pradesh: Chamba, Khajar road, on rocks, July, 1928, *427*.

Distribution: Himachal Pradesh. Endemic in the Western Himalaya.

Chromosome number : Not known.

3. *Blindia roerichii** Williams, The Bryologist. 34 : 49 1931. (Fig. 3)

*Since I could not examine the material of this species, the description and figures are borrowed from William's publication (1931).

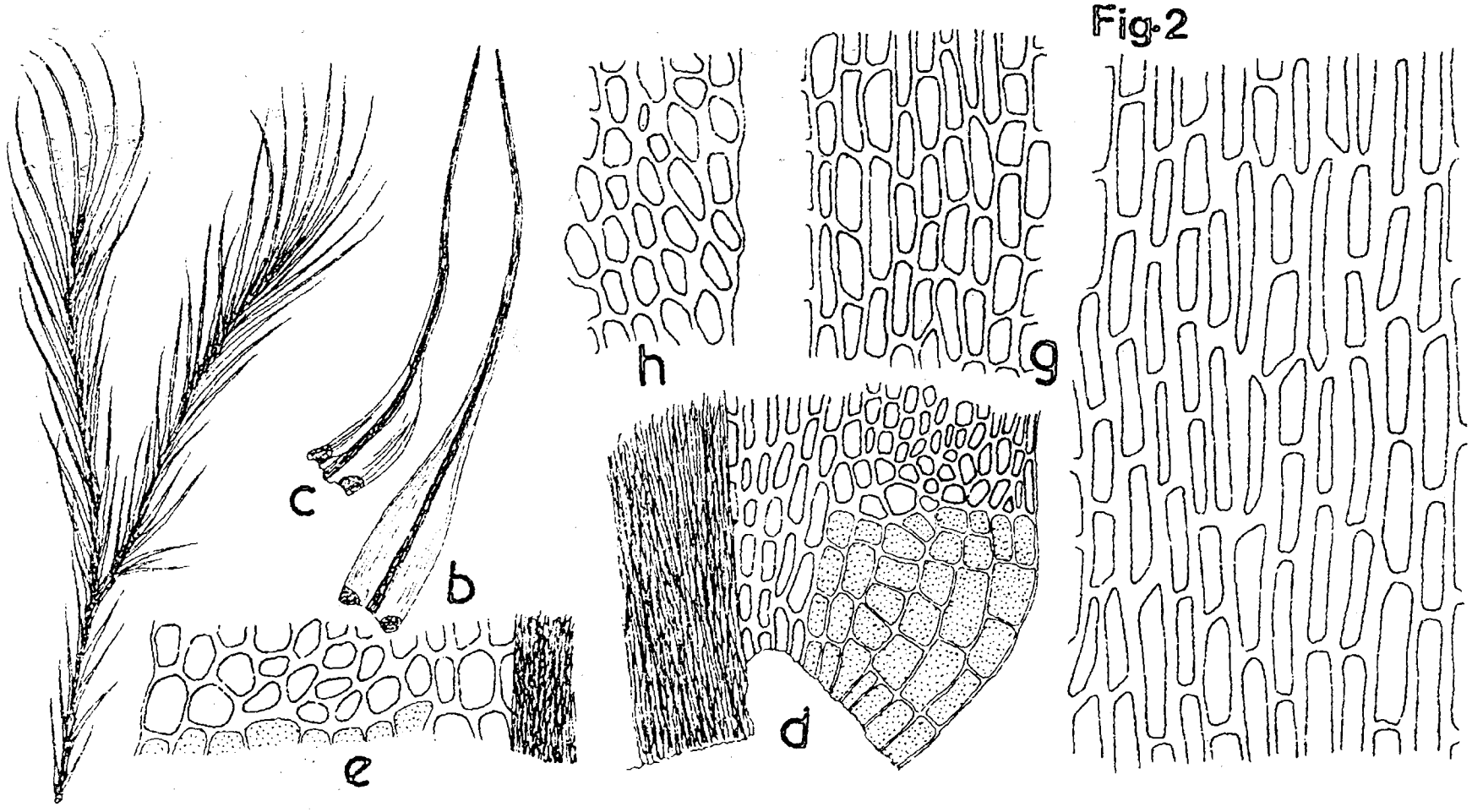

Fig. 2. Blindia himalayana Dix. et Badhw.
a. Plant x 6; b,c. Leaves x 20; d. Alar cells x 248; e. Cells immediately above the alar cells x 495; f. Basal laminal cells x 495; g. Median laminal cells x 495; h. Upper laminal cells x 495.

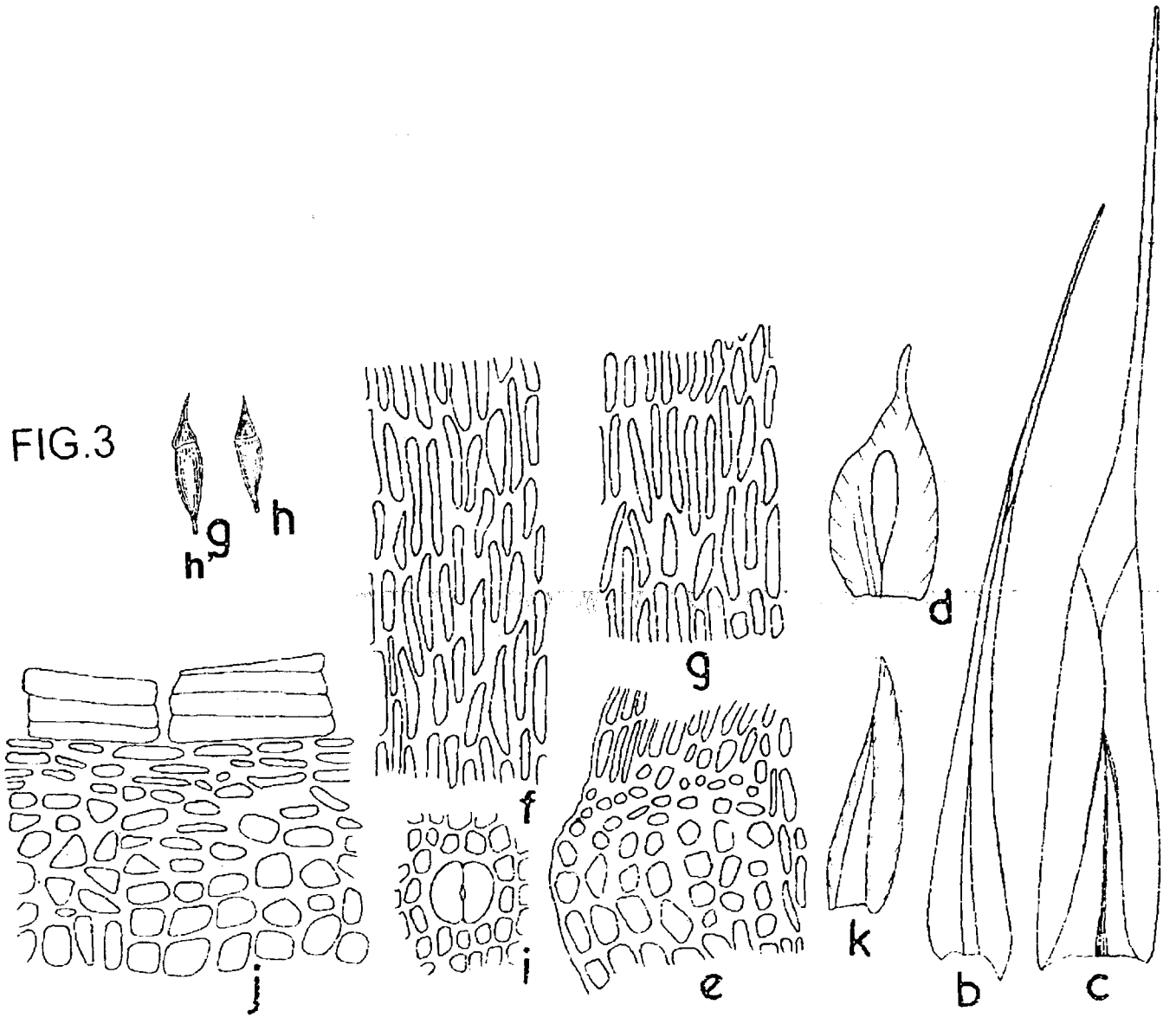

Fig. 3. Blindia roerichii Williams.
b,c. Leaves x 10; d. 25 e, Alar cells x 495; f, Basal laminal cells x 495; g, Median laminal cells x 495; h, h' Capsule with operculum x 20l Stoma x 495; j. Exothecial cells near capsule mouth and part of peristome teeth x 495; k, Calyptra x 20. (After Williams, 1931)

"Autoicous, the male flowers often clustered, 2 or 3 together, on short branchlets at apex of branch or almost sessile on stem just below the fruit, consisting of few antheridia and numerous filiform paraphyses, the inner perigonial leaves sometimes about as broad as high, without point or shortly pointed, with entire or slightly crenate margins, the outer leaves from a broadly ovate base rather gradually narrowed to an entire point as long or longer than basal part and more or less costate: plants growing in rather compact, brownish green tufts with branching stems up to 3 or 4 cm. high; stem-leaves only about 0.2 mm. wide and 3 mm. long, entire, nearly erect, from a lanceolate base gradually narrowed into a setaceous point; leaf-cells just above the base all with quite uniformly thickened, somewhat curving walls, up to 40μ long or more and about 4μ wide, the alar cells often forming a large, dark red cluster; perichaetial leaves erect, the inner about 4 mm long with broad, clasping base rather abruptly narrowed to a long setaceous point and costate about one-third way up; seta erect, mostly 7-8 mm. high; capsule erect, oblong to urn-shaped, without lid up to 1 mm. high, with an obliquely beaked lid of nearly equal

length, the exothecial cells about rim narrow and transversely elongate in 3 or 4 rows, those below more or less elongate, very irregular, with thickened walls; stomata 4 or 5 at very base of capsule; annulus none. Peristome (imperfect) of 16 teeth, smooth and red at base, sometimes pertuse along median line, divided to below the rim; spores smooth, 12μ in diameter; calyptra smooth, often slit two-thirds way up or more.

Type collected along stream at Kulu, Himalaya, *Number 270,* by Walter Koelz, June 30, 1930.

This species seemed to differ from all other members of the genus in being autoicous. Compared with *B.acuta*, it has leaves at base only about one half as wide with a much longer, setaceous point" (After Williams, 1931).

Distribution: Western Himalaya.

Chromosome Number: Not known.

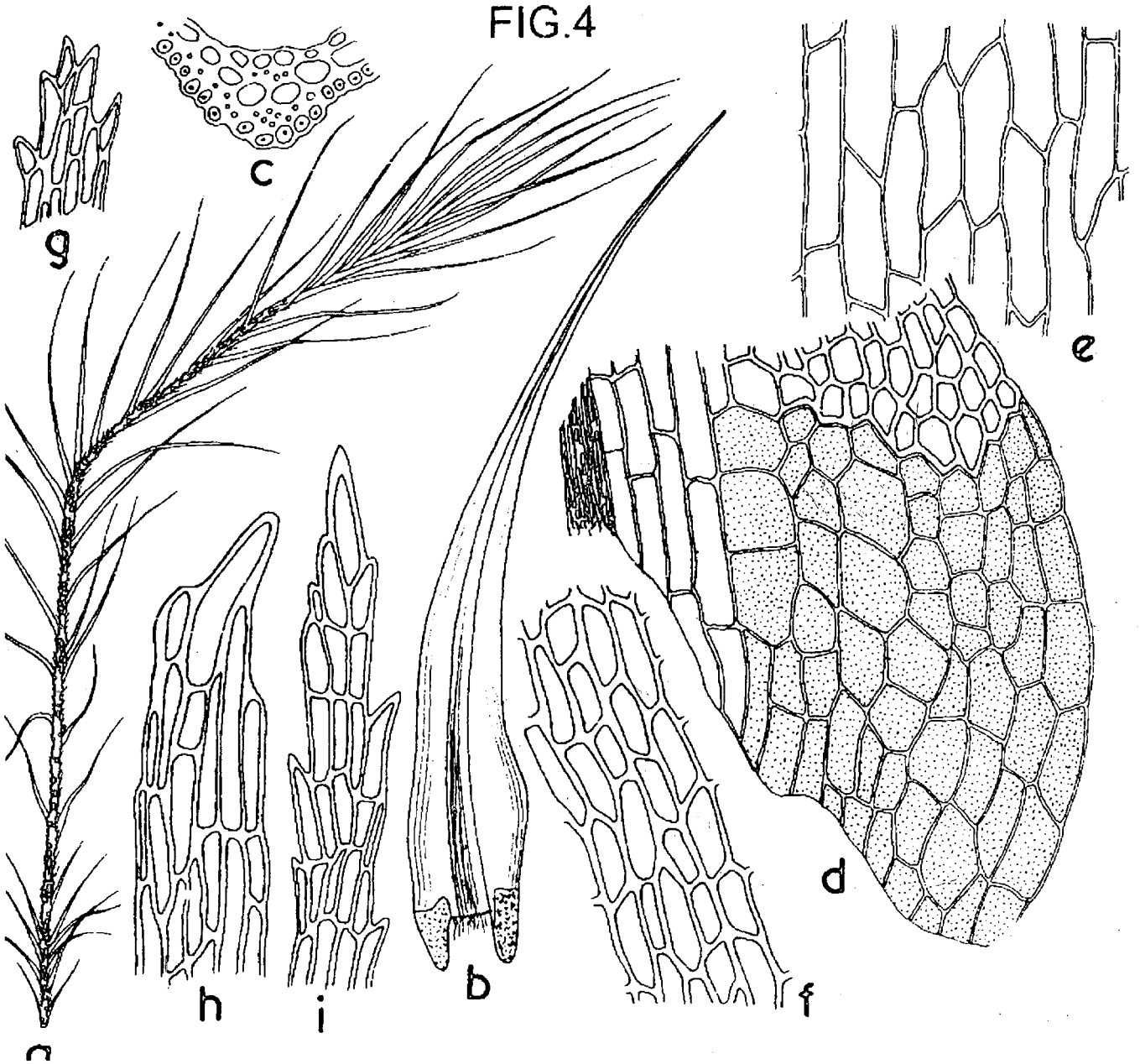

Fig. 4. Blindia sordida (Mitt.) C. Muell.
a. Plant x 12; b. Leaf x 25; c. T. S. leaf nerve x 610; d. Alar cells enlarged x 610; e. Basal laminal cells x 610; f. Median laminal cells x 610; g,h,i. Leaf apices x 610.

4. *Blindia sordida* (Mitt.) C. Muell., Bot. Ztg. Regensburg 22 : 349. 1864. (Fig.4)

Dicranum sordidum Wils. *ex* Mitt., J. Linn. Soc. Bot. Suppl. 1: 18. 1859.

Plants growing in dense tufts. Stems 2.0 – 2.5 cm long, simple or branched, covered with thick rhizoidal felt. Leaves erecto-patent, hardly altered on drying, 4.0 – 6.0 mm long and 0.5 mm wide at base, longly decurrent, gradually subulate from an oblong basal portion, subula ending in a spine; margins toothed near apex; nerve strong, with numerous rhizoids at base, in transverse section showing a median row of guide cells with a ventral stereidal band above and a dorsal stereidal band below; alar cells well differentiated, brown, polygonal, firm-walled, located in pockets formed by the decurrent lamina; basal laminal cells rectangular, 30-50 x 8-12 µm, the median ones narrow, elongate, often with oblique end walls, 12-24 x 4-6 µm, the upper ones short-rectangular, 10 -14 x 4 -5 µm. Sporophyte not observed.

The robust plants with thick rhizoidal felt covering the stem, and the relatively longer, decurrent leaves help distinction from other species of the genus.

Specimens examined: Sikkim (Ratong river side) 2,100 m, date of collection and substratum not given. Herb. Ind. Or. **7** (B.M.).

Distribution: Western Himalaya, Sikkim; Nepal.

Chromosome number: Not known.

2. FAMILY RHABDOWEISIACEAE

Plants growing in dense tufts or cushion-like tufts or cushions. Stems simple or branched, in transverse section without a central strand. Leaves crisped when dry, erecto-patent to spreading when moist, narrow-lanceolate to linear-lanceolate; nerve percurrent to excurrent or ending below the apex; upper laminal cells small, quadrate to sub-quadrate or rounded, smooth or papillose, rarely mamillose, the basal ones rectangular; alar cells absent or indistinct, rarely present. Setae long or short, straight or curved. Capsules erect or curved, ovoid to oblong-ovate or cylindric, mostly symmetric and non-strumose, rarely asymmetric and strumose; commonly 8-plicate when dry. Peristome teeth deeply inserted, undivided or split down to nearly one-half of their length, smooth to faintly papillose or longitudinally striate. Operculum with a long, slanting beak. Calyptra cucullate, smooth.

The family Rhabdoweisiaceae, chiefly characterized by stems without a central strand and capsules that are often ribbed, includes 11 genera, of which 8 are recorded from India. In our area, this family is represented by seven genera, which are segregated as under.

Key to the West Himalayan genera of Rhabdoweisiaceae

a. Alar cells absent or indistinct..... b
Alar cells present..... h

b. Laminal cells smooth..... c
Laminal cells papillose or mamillose..... f

c. Capsules ovoid or ovoid-conical to rounded-pyriform, distinctly 8 - striate..... d
Capsules oblong to cylindric, non-striate... e

d. Plants without marked zones of yearly growth; leaves not keeled; setae erect..... **1. *Rhabdoweisia***

Plants with distinct yearly zones of growth; leaves keeled; setae arcuate..... **4.*Oreas***

e. Capsules erect, symmetric, never strumose; peristome teeth undivided..... **2.*Dicranoweisia***
Capsules curved, asymmetric, distinctly strumose; peristome teeth split down to half of their length..... **6.*Oncophorus***

f. Leaves translucent, squarrose, 1.0-1.5 mm long; oblong-lanceolate to lingulate, apex broadly acute to rounded - obtuse; nerve ending below the apex; upper laminal cells conic - mammilose on both faces; peristome teeth cleft down to nearly one-half of their length..... **5.*Dichodontium***

Leaves opaque, erecto-patent, 3.0 – 3.5 mm long, narrow-lanceolate to linear - lanceolate, apex acute; nerve percurrent or excurrent; upper laminal cells papillose; peristome teeth undivided or absent..... g

g. Setae long; capsules exserted, non-striate, mouth not widened; peristome present, teeth undivided..... **3.*Oreoweisia***

Setae short; capsules scarcely exserted, 8 - striate, wide-mouthed; peristome absent..... **7.*Amphidium***

h. Leaf base not differentiated; leaf margins entire; upper laminal cells unistratose at margins; capsules erect, symmetric, never strumose; peristome teeth undivided..... **2.*Dicranoweisia***

Leaf base differentiated; leaf margins irregularly toothed at least near apex; upper laminal cells bistratose at margins; capsules curved, asymmetric, distinctly strumose; peristome teeth split down to one-half of their length..... **6.*Oncophorus***

1. *Rhabdoweisia Lindb. ex* Mild., Bryol. Siles. 48. 1869.

Autoicous. Plants growing in dense cushions. Stems without central strand. Leaves patent, crisped or curved on drying, linear-lanceolate, apex acute to obtuse; margins mostly plane; nerve narrow, ending in or below the apex; basal laminal cells elongate, rectangular, thin-walled, the upper ones quadrate to rounded-quadrate. Setae yellow to straw-yellow, straight. Capsules symmetrical, broadly oval, 8-striated, exannulate. Peristome teeth 16, undivided, smooth or faintly striate.

Type: *Rhabdoweisia fugax* (Hedw.) B.S.G.

This genus agrees with *Amphidium* in quadrate-rounded (but smooth) areolations and ovoid to rounded-pyriform, 8-striated, exannulate capsules, but differs in that the areolations in the latter genus are papillose (the papillae appear similar to those of the members of the family Orthotrichaceae), and the capsules are gymnostomous. *Rhabdoweisia* also agrees with *Oreas* in the rounded to rounded-quadrate, smooth laminal cells, and in that the peristome teeth are united at their bases. In some species of *Oreas* Brid., the peristome teeth are also undivided as in *Rhabdoweisia*. However, in the former genus, the teeth are vertically instead of obliquely striolate. It appears to the writer, that *Rhabdoweisia*, perhaps, is more in natural assemblage with *Oreas*, *Oreoweisia* and *Dicranoweisia* rather than with *Amphidium*.

Cytologically, this genus is known from three species [*Rhabdoweisia crenulata* (Mitt.) Jameson - n = 14 (13+m); *Rh. fugax* (Hedw.) B.S.G. n = 13 and *R. crispata*, n = 14, 13+m, 13]. It seems that in this genus the number n = 13 has evolved from n = 14 through reduction in the size of one of the chromosomes to qualify as m-chromosome, followed by the gradual loss of the m-chromosome from the complement. The estimation of n = 12 (Heitz, 1928) in some European population seems to be based on erroneous count.

Rhabdoweisia Lindb. differs from *Amphidium* Schimp. in that it lacks in n = 16, while the latter genus lacks in n = 14 and also lacks in m-chromosome as a part of its complement. The two genera, however, share n = 13 in some of their species. It agrees with *Oreas* in chromosome number (n = 13, 14), and in the possession of m-chromosome as a part of its fourteen chromosme complement.

Rhabdoweisia includes 5 species, of which 2 are found in India. In our area, this genus is represented by one species i.e. *R.crenulata* (Mitt.) James, which is nearly cosmopolitan in distribution.

Rhabdoweisia crenulata (Mitt.) James. Rev. Bryol. 17 : 6.1890. (Fig.5)

Didymodon crenulatus Mitt., Jour.Linn.Soc.Bot.Suppl. 1:23. 1859.

Oncophorus crenulatus (Mitt.) Braithw., Brit. Moss Fl. 1:300. 1887.

Rhabdoweisia denticulata Wils.*et* Mitt., Kew. J. Bot. 9:293. 1857. *nom.nud.hom. illeg.*

Rhabdoweisia sikkimensis Muell. *in* Par., Ind. Bryol. ed. 2, 4:142. 1905 *nom.nud.*

Plants small, growing in loose tufts. Stems with a reddish tinge, simple, in transverse section showing absence of central strand. Leaves patent, curled on drying, lower 1.5 - 2.0 mm, upwards to 3.2 mm long, lingulate without a differentiated basal portion, apex acute; margins crenulate down to half the leaf length; nerve ±75 µm wide, occupying nearly one-seventh of leaf base, ending 3-5 cells below apex; basal laminal cells hyaline, rectangular, to 80 x 22 µm, upward sub- quadrate, 12 - 15 x 10 -12 µm, Setae straight, twisted on drying, 4.8 mm long. Capsules erect, oval, 8-ribbed, 8.5 mm long and 0.5 mm in diameter. Peristome teeth entire, smooth or faintly oblique - striolate. Operculum conic-rostrate with an oblique beak. Spores spherical, 18 -22 µm, psilate.

Specimen examined: Uttaranchal : Nainital, Cheena Peak, 3000 m, on soil accumulated in rock crevices, October, 1971, *78K*.

Distribution: Uttaranchal, Darjeeling, Sikkim; China, Formosa, Europe, North and South Africa, North, South and Central America.

Chromosome number: n =14 (13+m - three populations)

2. *Dicranoweisia Lindb. ex* Mild., Bryol. Siles.48. 1869.

Blindia sect. *Dicranoweisia* (Mild.) C. Muell., Gen. Musc. Fr.246. 1900.

Plants growing in cushions. Male shoots bud-like, below the perichaetium. Leaves lanceolate-subulate; nerve percurrent; basal laminal cells elongate or rectangular, upwards shortly rectangular to quadrate, smooth or faintly papillose; alar cells enlarged and differentiated or indistinct. Capsules erect, cylindrical, smooth, never strumose. Peristome teeth entire or divided at apex,

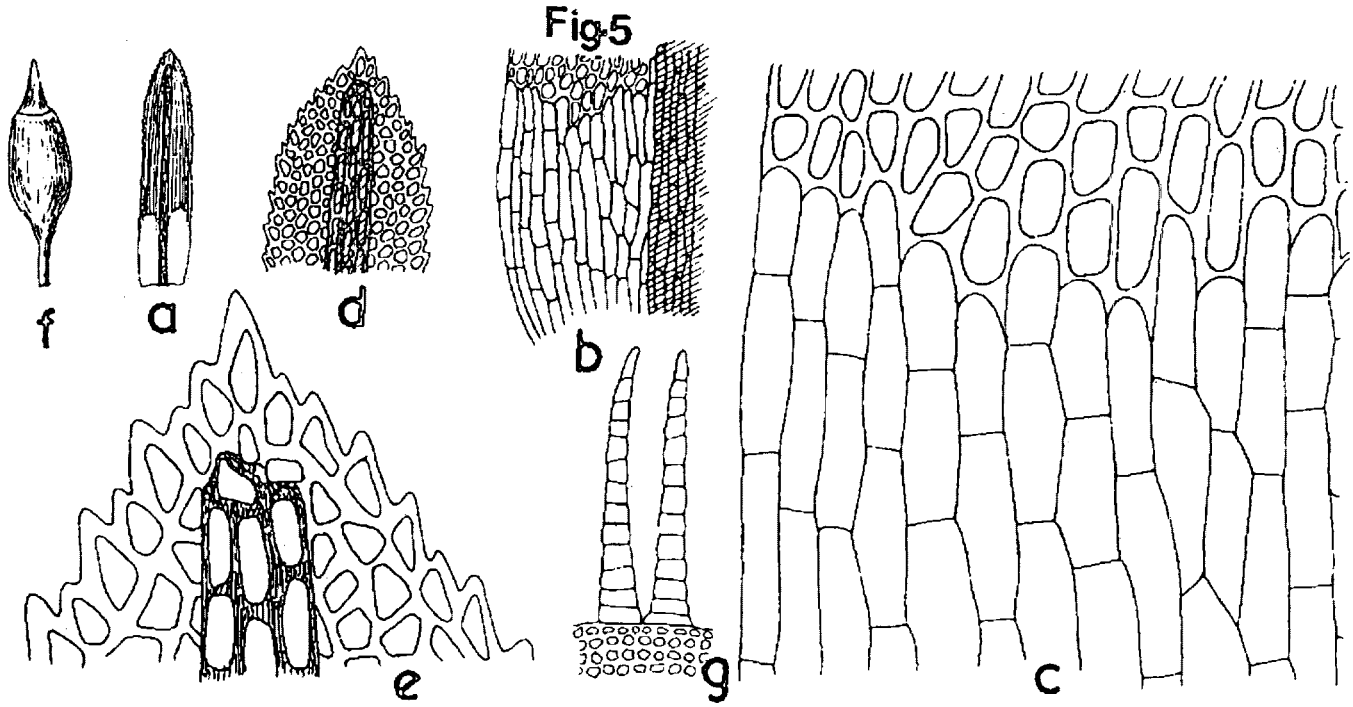

Fig. 5 : Rhabdoweisia crenulata (Mitt.) James.
a. Leaf x 19; b. Basal laminal cells x 200; c. Basal laminal cells enlarged x 495; d, Leaf apex x 495; e, Leaf apex enlarged x 495 g, Peristome x 248.

smooth or faintly papillose.

Lectotype: *Dicranoweisia crispula* (Hedw.) Mild.

As pointed out by Sainsbury (1955), this genus outwardly looks like *Weisia* of the Pottiales in appearance. It is, however, distinguished from the Pottiaceous mosses by its generally well defined alar cells and dicranoid peristome teeth.

Cytologically, this genus is known from five species, of which two [*Dicranoweisia antarctica* (C.Muell.) Kindb. - n = 13; *D.grimmiacea* (C.Muell.) Broth. - n = 13) appear to be cytologically conservative. The remaining three species (*D. brevifolia* Dix. - n = 13, 14; *D.cirrata* (Hedw.) Lindb. - n = 11, 12, 13, 14; *D.crispula* (Hedw.) Milde - n = 11 (single population), 14 (ten populations)] seem to have involved aneuploidy as a means for the evolution of their different cytotypes.

Dicranoweisia contains 26 species, of which 4 occur in India. In our area, this genus is represented by 2 species.

Key to the West Himalayan species of *Dicranoweisia* Lindb. *ex* Mild.

Leaf margins narrowly recurved; basal laminal cells rectangular (8 -12 µm wide), not or slightly thickened; alar cells not differentiated.....**1.*D.cirrata***

Leaf margins plane; basal laminal cells narrowly rectangular (4 – 6 µm wide), strongly incrassate; alar cells well differentiated.....**2.*D. crispula***

1. *Dicranoweisia cirrata* (Hedw.) Lindb.*in* Mild., Bryol. Siles. 49. 1869. (Fig.6)

Weisia cirrate Hedw., Spec.Musc. 69. 1801.

Plants light-green, growing in dense cushions. Male shoots with 3-4 perigonial bracts. Stems to 0.8 cm long, branched. Leaves cirrhate, spreading, crisped on drying, 1.6 – 2.0 mm long and 0.2 – 0.3 mm wide, lanceolate-subulate from widened base; margins narrowly recurved from middle upwards, tubular concave near apex, entire; nerve prominent, percurrent; basal laminal cells rectangular, to 32 x 8-9 µm (adjoining the nerve to 44 x 10-12 µm), thin-walled, the middle and the upper ones shortly rectangular to rounded-quadrate, 8-10 x 6-7 µm, in margins bistratose. Setae erect, 4.7-5.0 mm long. Capsules erect, broad-cylindric, 1.0 mm long and 0.5 mm in diameter, smooth, annulate. Peristome teeth smooth below, faintly papillose above. Spores brown, 11-16 µm, faintly asperate.

Specimens examined: Kashmir : Kamri Valley, 3000 m, on tree stumps, August, 1892, *12676, 12794, 12810*; Nittar Valley, August, 1892, *14246*; Uttaranchal : Didihat,

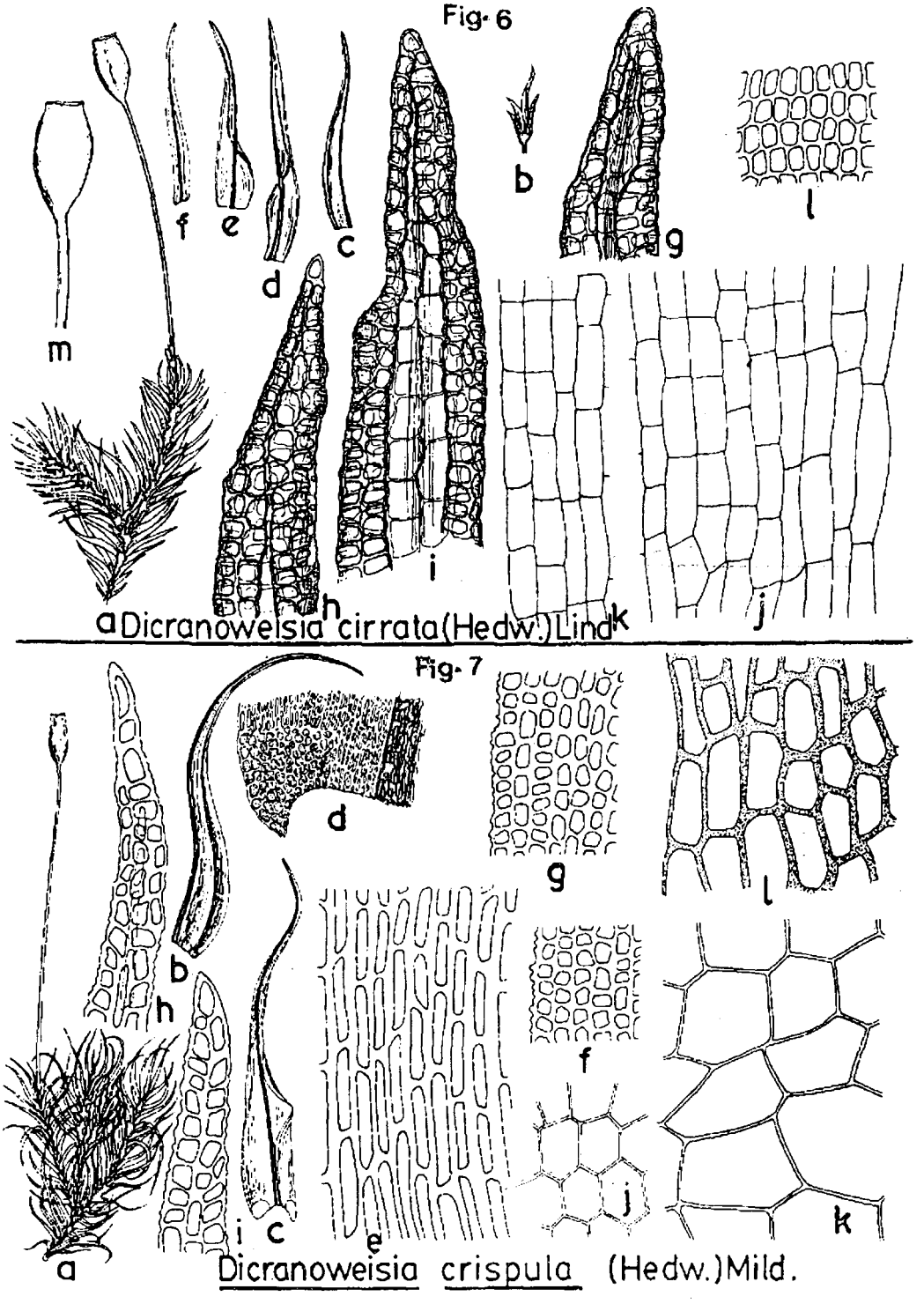

Fig. 6. Dicranoweisia cirrata (Hedw.) Lindb.
a. Plant x 10; b, Androecialbud x 19; c,d,e.f. Leaves x 19; g.h.i. Leaf apex x 495 j. Basal laminal cells x 495; k, Laminal cells at little above the base x 495; l. Upper laminal cells x 495; m. capsule x 19.

Fig. 7. : Dicranoweisia crispula (Hedw.) Mild.
a. Plant x 10; b,c. Leaves x 19; d. Leaf base showing alar cells x 495; e. Basal laminal cells x 495; f, Median laminal cells x 495; g. Upper laminal cells x 495; h,i. Leaf apex x 495; j. Exothecial cells x 248; k. Exothecial cells enlarged x 495; l. Alar cells enlarged x 495.

Ghurpatta, 1350 m, epiphyte, *3108*.

Distribution: Kashmir, Uttaranchal; Asia, Africa, Canaries, Madeira, Europe, North America. Nearly cosmopolitan.

Chromosome number : n=11*, 13.

2. *Dicranoweisia crispula* (Hedw.) Mild., Bryol. Siles. 48. 1869. (Fig.7)

Weisia crispula Hedw., Spec. Musc. 68. 1801.

Plants yellowish-green, growing in dense cushions. Stems to 2.1 cm long, branched once or twice. Leaves spreading, flexuose, upper sometimes secund, crisped on drying, 3.2 – 3.5 mm long and 0.6 mm wide, lanceolate-subulate from a widened basal portion; margins plane, entire; nerve percurrent; alar cells brown, enlarged, 14-20 µm wide; basal laminal cells narrow-rectangular, 20-44 x 4 - 6 µm (some cells to 66 µm long), strongly incrassate, the median and the upper ones short-rectangular to quadrate, 5 – 10 x 4 – 5 µm, incrassate. Setae straight, ± 1.0 cm long. Capsules erect, symmetrical, smooth, 2.0 mm long, cylindrical, exannulate; exothecial cells hexagonal, 27 – 40 µm wide, near the mouth shorter, 15 – 20 µm wide.

"Peristome reddish brown, teeth coarsely papillose above, irregularly point-striated below. Spores yellow-green, 10-15 µm, very finely papillose" (Nyholm, 1954).

Specimens examined: Kashmir : Nittar Valley, 3500 m, on rocks, August, 1892, *12816*; Aster Valley, 3700 m, August, 1892, *12830*; Hazara, Kagan Valley, 4500 m, August, 1896, *25016*. Himachal Pradesh : Narkanda, 3200 m, on rocks, August, 1975.*102K*; Dharmsala, 2400 m, on rocks, *2824*.

Distribution: Kashmir, Himachal Pradesh; Asia, Europe, North America, New Zealand.

Chromosome number =11*, 14.

This species agrees with *Dicranum* Hedw. in showing alar cells, but differs in the habit, the non-pitted basal laminal cells, and the ± undivided peristome teeth.

3.*Oreoweisia* (B.S.G.) De Not., Epil 1:489. 1869.

Weisia subgen. *Oreoweisia* B.S.G., Bryol Eur. 1:71. 1846 emend. Mild., Bryol. Siles. 53. 1869.

Plants yellowish-green, growing in close tufts. Stems branched, in transverse section triangular. Leaves erecto-patent, curled on drying, linear-lingulate or lanceolate-linear; margins mostly recurved at middle, plane upwards, serrulate at apex; nerve strong, ceasing below the apex, in transverse section showing a stereidal band below the median row of guide cells; basal laminal cells rectangular, thin-walled, smooth, the median and the upper ones obscure, rounded-quadrate, mamillose on both sides. Setae straight. Capsules erect or slightly inclined, oval to oval-cylindric, annulate. Peristome teeth red-brown to translucent, entire or irregularly divided, nearly smooth.

Lectotype: *Oreoweisia serrulata* (Funk.) De Not.

Cytologically, this genus is known from two species only i.e. *Oreoweisia bruntonii* (Sm.) Milde - n = 13, 14, 15; *O.laxifolia* (Hook. f.) Kindb. - n = 14 (13+m). The occurrence of n = 14 in both the species suggests, that this number may be more deep-seated than the other two numbers i.e. n = 13, 15.

Of the 18 species included in *Oreoweisia*, 8 are reported from South America. In India, this genus is represented by 2 species i.e. *O.brevidens Herz.*, and *O.laxifolia* (Hook.f.) Kindb., of which only the latter is found in our area.

Oreoweisia laxifolia (Hook. f.) Kindb., Enum. Bryin. Exot. 69. 188. (Fig.8)

Grimmia laxifolia Hook. f. Ic. Pl.*Rar.2.194B*. 1837.

Zygodon schmidii C. Muell., Bot. Zeit. 11: 60. 1853.

Didymodon laxifolius (Hook.f.) Mitt., J. Linn. Soc. Bot. Suppl. 1:23. 1859.

Weisia laxifolius (Hook.f.) Hamp. *In* Jaeg., Ber. S. Gall Naturw. Ges. 1877-1878: 370. 1880.

Oreoweisia schmidii (C.Muell.) Par., Ind. Bryol. 868. 1897.

Plants growing in dense tufts. Stems reddish-brown, 3.0 – 4.0 cm long, branched. Leaves erecto-patent, curled on drying, 3.0 – 3.5 mm long, linear-lingulate or oblong-lingulate, apex obtuse; margins serrulate from middle upwards with projecting cell ends; nerve strong, ceasing 4 – 7 cells below apex; basal laminal cells rectangular, 38 – 65 x 8 – 11 µm, thin-walled, upwards obscure, quadrate to oval-quadrate, 7-10 µm wide, incrassate, mamillose, at margins elongate, 11-13 µm long. Setae terminal, ±1.1 cm long, twisted on drying. Capsules reddish -brown, erect or very slightly inclined, ovate-cylindrical, 1.5 – 1.8 mm long and 0.6 – 0.7 mm in diameter; exothecial cells rectangular, 34 – 57 x 13 – 17 µm, incrassate, immediately below mouth short parenchymatous,10 - 17 x 10 – 11

*n=11 (Heitz, 1928) appears to be an erroneous report, since numerous populations of this species, from widely different geographic areas, have consistently shown n=13

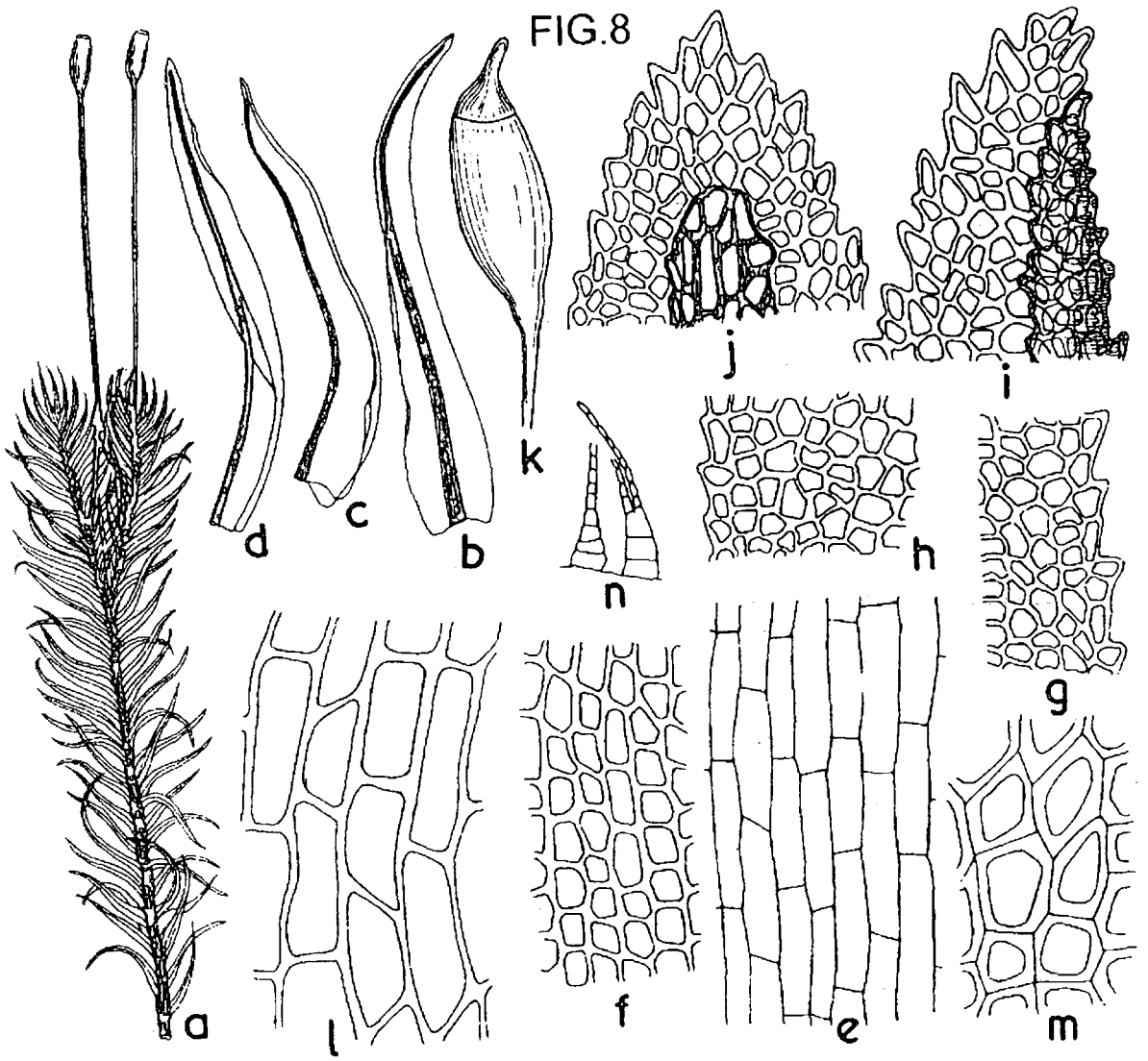

Fig. 8 : Oreoweisia laxifolia (Hook. F.) Kindb.
A Plant x 10; b,c,d. Leaves x 19; e. Basal laminal cells x 495; f. Median laminal cells x 248; g,h. Median laminal cells from leaf margin Inwards x 495; I,j. Leaf apex x 495; k. Capsule with operculum x 26; l. Exothecial cells x 495; m. Exothecial cells near capsule mouth x 248; n. Peristome x 248.

µm, strongly incrassate. Peristome teeth 0.25 mm high, deeply inserted, translucent, irregularly cleft, smooth. Operculum conic-rostrate, obliquely beaked. Spores brown, 18 – 22 µm, granulose.

Specimens examined: Himachal Pradesh : Narkanda, 2900 m, on base of tree trunk., September, 1976, *3110*; Kashmir : Musjid Valley, 3600-3700 m, on humus, July, 1891, *23673*; specimen no. *2057* from Sikkim.

Distribution: Kashmir, Himachal Pradesh, Uttaranchal, Darjeeling, Sikkim, Bhutan, N.E.F.A., Manipur, South India; Nepal, Yunnan, Japan.

Chromosome number : n =14 (13 + m)

4. *Oreas* Brid., Bryol. Univ. 1:380. 1826.

Monoicous. Plants growing in dense cushions, showing yearly zones of growth. Stems closely webbed with reddish-brown rhizoids, in transverse section triangular. Leaves erecto-patent, crisped on drying, carinate, lanceolate from a widened base; margins recurved at middle; nerve excurrent; basal laminal cells rectangular, the middle and the upper ones quadrate, smooth. Setae arcuate. Capsules furrowed on drying, ovoid-conical, short-necked, 8-striate. Peristome teeth 16, deep inserted, entire or irregularly cleft down to one-third to one-half portion, irregularly perforate, vertically striate. Operculum obliquely rostrate.

Lectotype: *Oreas martiana* (Hopp. *et.* Hornsch.) Brid.

The genus *Oreas* Brid., essentially found at high altitudes (3500-4200 m) in our area, is easily recognized by its closely webbed plants with well marked yearly zones of growth, arcuate setae and ovoid-conical, short-necked, 8-striated capsules. In the nature of the peristome, this genus appears to simulate *Oreoweisia*, but the gametophytic features in the two genera are quite unlike. Also in the latter taxon, the setae are straight and the capsules non-striate. It would be desirable to study the somatic chromosomes of the two genera to ascertain their cytological relationship. At any rate, the striated capsules and the entire peristome teeth vouch for the archaic nature of this taxon.

This genus is represented by a single species, *O.martiana*, (Hopp.et Hornsch.*in* Hornsch.) Brid. which is also recorded from our area.

Oreas martiana (Hopp. et Hornsch. *in* Hornsch.) Brid., Bryol. Univ. 1: 383.1826. (Fig.9)

Oncophorus martii Lindb., Utkast. Nat. Grupp. Eur. Bladmoss. 34. 1878. *nom. illeg. incl. spec. prior.*

Oncophorus martianus (Hopp. et Hornsch.) Lindb. *in* Par., Ind. Bryol. 866. 1897. *nom.invalid in synon.*

Oreas martii Kindb., Eur. N. Am. Bryin. 2 : 21. 1897. *nom. illeg.incl.spec.prior.*

Weisia martiana Hopp. & Hornsch. *in* Hook., Musci Exot. 2:104. *1819.*

Plants yellowish-green, growing in dense cushions felted by abundant reddish rhizoids. Stems 2.5 – 3.2 cm long with well marked yearly zones of growth innovating from just below the perichaetium. Leaves erecto-patent, crisped on drying, the lower ones 1.8 – 2.0 mm long and 0.35 mm wide, the middle and the upper ones 3.0 – 4.0 mm long, carinate, lanceolate from widened base; margins entire, slightly recurved at middle; nerve excurrent; basal laminal cells rectangular, ± 38 x 7 – 9 µm, the middle and the upper ones rounded-quadrate, 7 – 8 µm wide, smooth. Setae 4.0 mm long, arcuate. Capsules hanging, ovoid, short-necked, 8-striate, 0.9 mm long and 0.7 mm in diameter. Peristome teeth 16, teeth deep inserted, lanceolate, entire or irregularly cleft, vertically striate. Spores brown, spherical, 22-24 µm, sculptured granulose.

Specimens examined: Uttaranchal :Tehri Garhwal, Kidar Kanta,3600 m, on the stems of bushy roses, June, 1897, *23D*; Kashmir : Musjid Valley, 4000 m. substratum not indicated, July, 1983, *14375.*

Distribution: Kashmir, Uttaranchal, Sikkim; Central Alps, Japan, Alaska.

Chromosome number: Not known.

5. *Dichodontium* Schimp., Coroll. Bryol. Eur. 12. 1856.

Plants light-green, growing in loose tufts. Stems simple or branched. Leaves soft, squarrose, crisped on drying, lingulate or lanceolate; margins entire or serrulate; nerve strong, ending below the apex; laminal cells rounded-quadrate, mamillose, at base, towards the nerve, elongate. Capsules erect or sub-erect. Peristome teeth large, cleft, papillose.

Lectotype: *Dichodontium pellucidum* (Hedw.) Schimp.

The soft, squarrose leaves with rounded-quadrate, mamillose laminal cells and the nerve ending several cells below the apex help an easy distinction.

Cytologically, this genus is known from three taxa i.e. *Dichodontium olympicum* Ren. et Card. - n = 14; *D. pellucidum* (Hedw.) Schimp. - n = 14, 15; *D. pellucidum* var. *flavescens* (With.) Moore - n = 7. The available cytological data indicates that x = 7 is the base number from which other chromosome numbers are derived through euploidy; followed by aneuploid gain of one chromosome.

Dichodontium includes 7 species, of which only one i.e. *D.pellucidum* (Hedw.) Schimp.is recorded from our area.

Dichodontium pellucidum (Hedw.) Schimp., Coroll.Bryol. Eur. 12. 1856. (Fig.10)

Dicranum pellucidum Hedw., Spec. Musc. 142. 1801.

Plants light-green, growing in soft tufts. Stems to 5.0 cm long, simple or branched, laxly foliate. Leaves soft, squarrose, crisped on drying, 1.0 – 1.5 mm long and 0.45 – 0.5 mm wide at base, lingulate, apex acute; margins flat, serrulate; nerve prominent, ending 4 – 6 cells below the apex; basal laminal cells, towards the nerve, elongate, to 60 x 13 – 15 µm, towards margins and upwards rounded-quadrate, 10 -12 µm, mamillose. "Seta yellow; capsule curved or symmetrical, inclined or more seldom erect; exothecial cells with very thick longitudinal walls but thin transverse walls; peristome brown–red, with fine vertical point-striation, at apex yellowish and papillose, basal membrane 6-7 rows of cells. Spores 14-17 µm, yellow, slightly papillose". (Nyholm, 1954).

Specimens examined: Himachal Pradesh : Khadrala, Narkanda, 2500 m, along stream side, September, 1974, *3106, 42-S.*

Distribution: Himachal Pradesh; Pakistan, Europe, Madeira, Asia, North America.

Chromosome number : n = 14.

6.*Oncophorus* (Brid.) Brid., Bryol. Univ. I : 389. 1826.

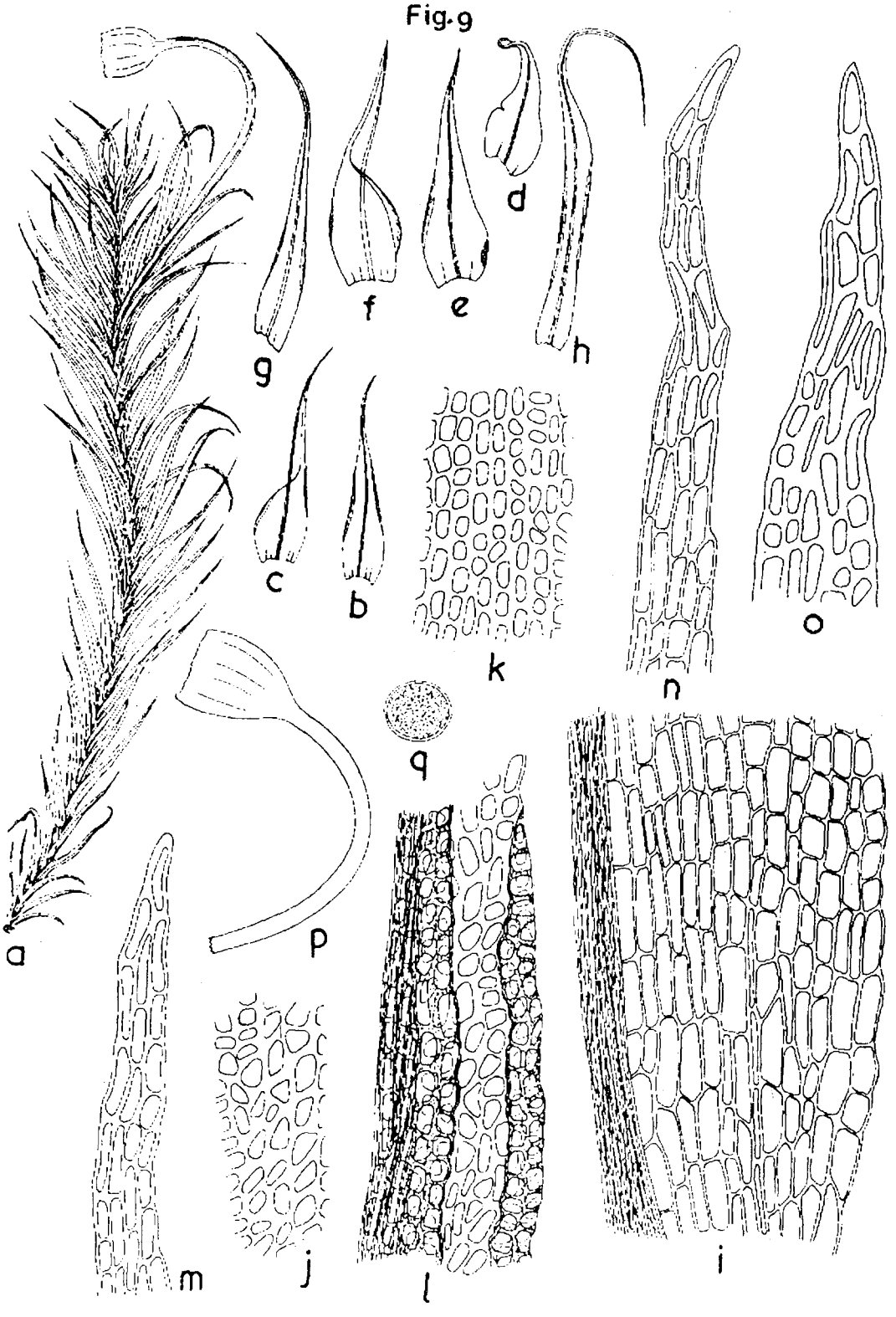

*Fig. 9 : **Oreas martiana (Hopp. et Hornsch.) Brid.***
a. Plant x 10; b.c.d.e.f.g.h. Leaves x 19; i. Basal laminal cells x 495; j.k. Median laminal cells x 495; m.n.o. Leaf apex x 495; p. Capsule with seta x 19; q. Spore x 495.

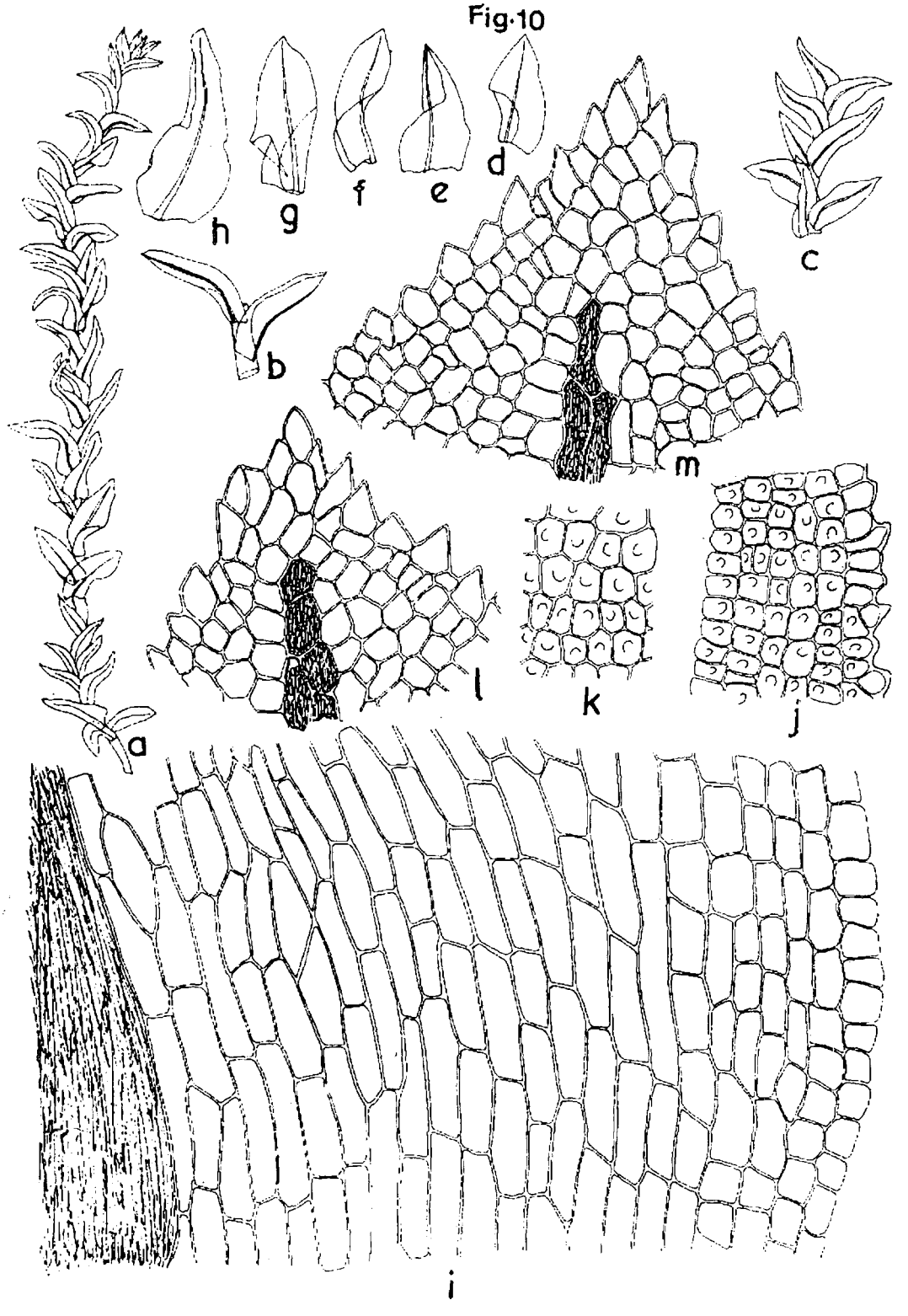

Fig. 10 : Dichodontium pellucidum (Hedw.) Schimp.

a. Plant x 19; b.c. Leaf arrangement x 19; d.e.f.g.h. Leaves x 26; i. Basal laminal cells x 495; j. Median laminal cells from margin inwards x 495; k. Median laminal cells x 495; l.m. Leaf apex x 495.

Dicranum sect. *Oncophorus* Brid., Mant. Musc. 53. 1819.

Dicranum sect. *Isocarpus* Mitt., J. Linn. Soc. Bot. 12:62.1869.

Autoicous. Plants growing in dense tufts. Male shoots bud-like with 3-5 perigonial bracts. Stems branched, densely foliate. Leaves erecto-patent to squarrose, crisped on drying, narrow-lanceolate to lanceolate-subulate from obovate, ovate-rectangular or oblong, erect sheathing basal portion; margins plane or recurved; nerve percurrent or excurrent; basal laminal cells rectangular, thin-walled, the upper ones small, quadrate. Setae straight. Capsules curved, asymmetrical, distinctly strumose, exannulate. Peristome teeth 16, deep inserted, cleft down to one-half portion, papillose-striate in the undivided portion and lightly papillose in the divided portion.

Lectotype: *Oncophorus virens* (Hedw.) Brid.

When fertile, this genus is easily distinguished from allied genera by its strumose capsule.

Cytologically, this genus is known from 4 species i.e. *Oncophorus crispifolius* (Mitt.) Lindb. - n = 14; *O. rauii* (Aust.) Grout - n = 14; *O. virens* (Hedw.) Brid, - n = 14; *O. wahlenbergii* Brid. - n = 14. The occurrence of n = 14 in all the widely separated populations of the so far investigated taxa of this genus is indicative of the cytological resistance of this genus to aneuploidy. The genus is further characteristized in that it lacks m-chromosome in its complement.

This genus includes 13 species, of which 7 are endemic in Asia. Two species occur in India, and the same are also recorded from our area.

Key to the West Himalayan species of *Oncophorus* (Brid.) Brid.

Leaves erecto-patent, suddenly narrowing into flexuose subula; leaf margins plane, entire or indistinctly serrulate towards apex; alar cells not or indistinctly differentiated..... **1.*O.virens***

Leaves squarrose, gradually narrowing into lanceolate, acute apex; leaf margins recurved at middle and serrate from middle upwards; alar cells differentiated..... **2.*O.wahlenbergii***

Oncophorus virens (Hedw.) Brid., Bryol. Univ. 1 : 390. 1826. (Fig.11)

Dicranum virens Hedw., Spec. Musc. 142. 1801.

Aongstroemia virens (Hedw.) C. Muell., Syn. 2:609. 1851.

Cynodontium virens (Hedw.) Schimp., Coroll. 12. 1856.

Leptodontium virens (Hedw.) Mitt., J. Linn. Soc. Bot. 11. 1859.

Diobelon virens (Hedw.) Hamp., Fl. Hercyn. 345. 1873.

Plants robust, yellowish-green, growing in dense tufts. Stems to 6.0 cm long, branched with reddish rhizoids between leaves in the lower half of the gametophores. Leaves squarrose, crisped when dry, 2.5 - 4.0 mm long and 0.5 mm wide, lanceolate from an ovate-rectangular, erect basal portion, gradually narrowed into an acute apex; margins narrowly recurved, irregularly serrate from middle upwards; nerve strong, percurrent; alar cells differentiated, pellucid, 12-15 µm wide; basal laminal cells rectangular, 37-60 x 6-9 µm, upwards quadrate to quadrate-rounded, 6-9 µm wide, towards the nerve shortly rectangular, 13 - 15 x 6 - 9 µm, towards margins (2 rows) transversally placed. Setae terminal, erect. Capsules 2.1 - 2.2 mm. long and 0.8 mm in diameter, cylindrical, asymmetrical, wide-mouthed, distinctly strumose, smooth. Spores spherical, 10 - 12 µm, asperately sculptured. Peristome teeth and operculum not observed.

Specimens examined: Kashmir : Nittar Valley, 3500 m, August, 1892, *12812*; Shatune Pass, 4500 m, July, 1892, *12786*; Burzil Valley, 3500 m, September, 1893, *14366*, Atosar Valley, 3500 m, July, 1892, *12852*; Himachal Pradesh : Lahaul, 3500 m, on soil gathered on rocks, date of collection not given, collector M.L. Bor, *1413*; Uttaranchal : Tehri-Garhwal, 3700 m, July, 1894, *15261, 15264*; Kumaon, 4500 m, August, 1894, *3753*; Hazara (Dara Kullu, Shinkiyari), June, 1899, *15926, 16268*.

Distribution: Kashmir, Himachal Pradesh, Uttaranchal; Central, North and Eastern Asia, Europe, N. Africa, N. America.

Chromosome number: n = 14.

Oncophorus wahlenbergii Brid., Bryol. Univ. 1: 400. 1826. (Fig.12)

Dicranum wahlenbergii (Brid.) Schultz, Syll. Pl. Nov. 2: 149. 1828.

Dicranum virens Hedw. var. *wahlenbergii* (Brid.) Hueb., Musc. Germ. 231. 1833.

Aongstroemia wahlenbergii (Brid.) C. Muell., Syn. 2: 610. 1851.

Cynodontium virens (Hedw.) Schimp. var. *wahlenbergii* (Brid.) Schimp., Bryol. Eur.Coroll. 12. 1856.

Fig. 11

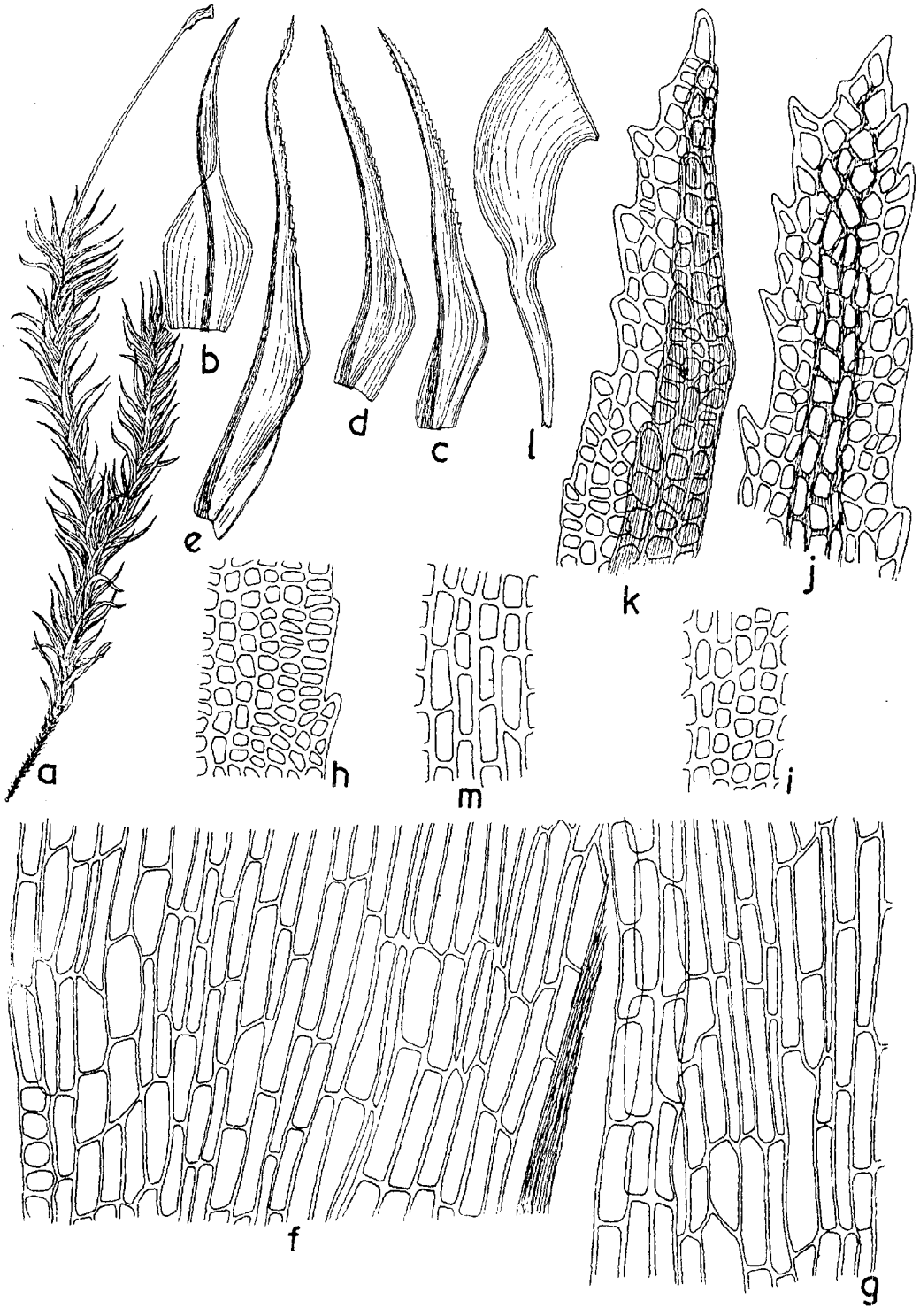

Fig. 11 : Oncophorus virens (Hedw.) Brid.
a. Plant x 10; b,c,d,e. Leaves x 26; f,g. Basal laminal cells x 495; h. Median laminal cells from margin inwards i.. Upper laminal cells x 495; j, k. Leaf apex x 495; l, Capsule x 24; m. Exothecial cells x 495.

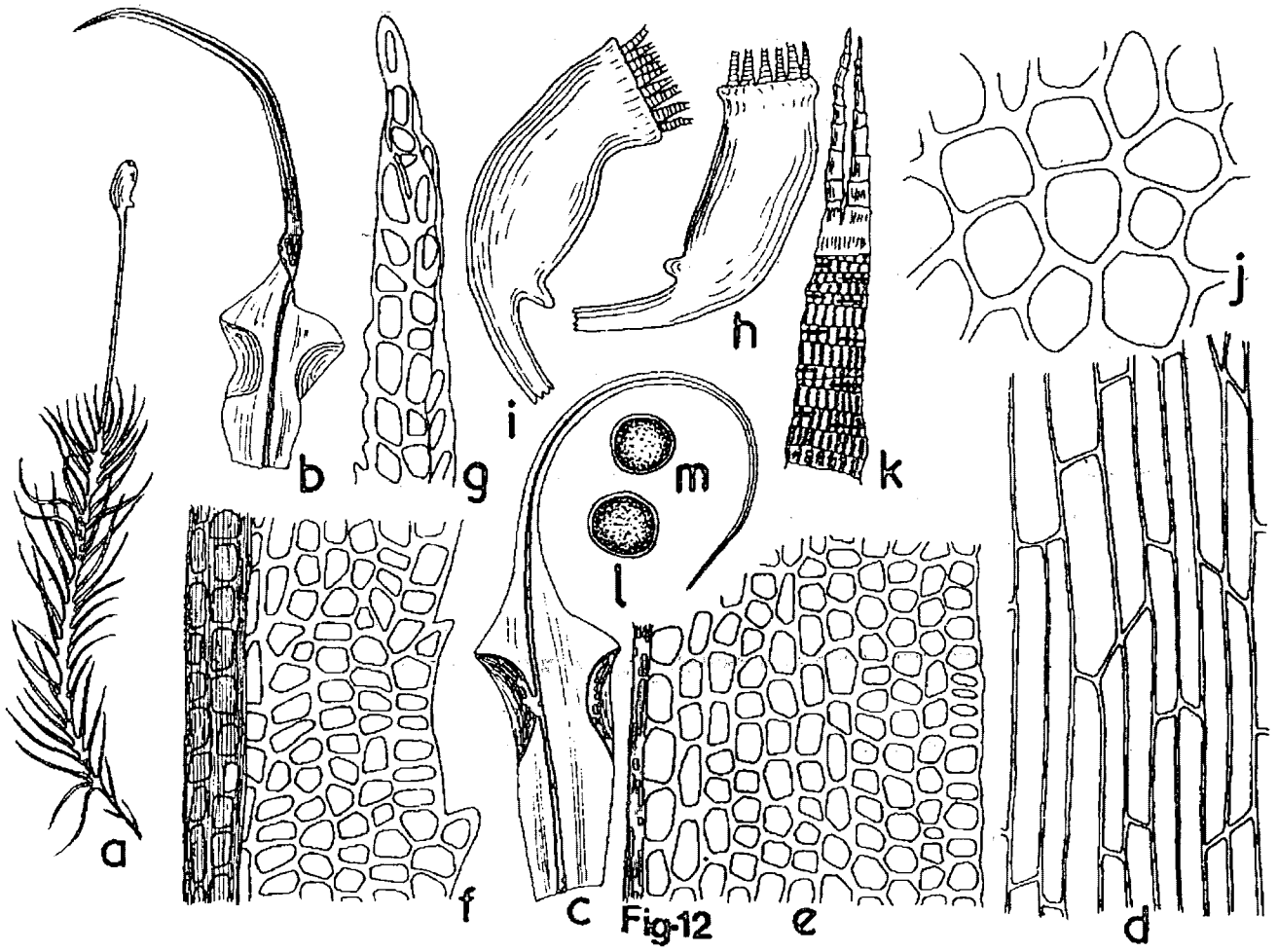

Fig. 12 : Oncophorus wahlenbergi Brid.
a. Plant x 10; b,c. Leaves x 26; d. Basal laminal cells x 495; e, Median laminal cells x 495; f, Upper laminal cells from margin inwards x 495; g, Leaf apex x 495; h, i. Capsules x 24; j, Exothecial cells x 495; k, Peristome tooth x 248; l,m. Spores x 495.

Leptotrichum wahlenbergii (Brid.)Mitt., J. Linn. Soc. Bot. Suppl. 1:12.1859.

Cynodontium wahlenbergii (Brid.) Hartm., Handb. Skand. Fl. Ed. 10, 2: 113. 1871.

Dicranella wahlenbergii (Brid.) Lindb., Acta Soc. Sci. fenn. 10. 243. 1872.

Cynodontium virens (Hedw.) Schimp. ssp. *wahlenbergii* (Brid.) Dix., Stud. Hand. Brit. Mosses 74. 1896.

Plants yellowish-green, growing in tufts. Stems 1.0 - 2.5 cm long, simple or branched. Leaves flexuose, spreading, crisped on drying. 5.0 - 6.0 mm long and 0.4 - 0.45 mm wide at base, linear-subulate from an obovate basal portion; margins plane, entire, towards apex slightly serrulate due to projecting cell ends; nerve strong, percurrent; alar cells not differentiated; basal laminal cells elongate, rectangular with oblique cross walls, 52-95 x 8-11 µm, thin-walled, the middle and the upper ones shortly rectangular to quadrate or quadrate-rounded, 7-10 µm wide, (some cells to 14 µm long), towards margins transversally placed, near apex elongate. Setae straight, 1.0 - 1.2 cm long. Capsules curved, oblong-cylindric, 1.3 - 1.5 mm long and 0.5 - 0.7 mm in diameter, distinctly strumose, smooth; exothecial cells polygonal to rounded, 18 - 25 µm wide, moderately thickened. Peristome teeth 16, 2.7 mm high, each cleft down to one-half, very faintly and sparsely papillose in the divided parts. Spores brown, spherical, 20 - 22 µm, asperately sculptured.

Specimens examined: Uttaranchal : Tehri-Garhwal, 3200 m, on soil gathered on rocks *16965, 16972.*

Specimen no. 1138 (BM) collected by J. Garrett and W. Lillie in August, 1924 from Kamri Pass as *O. gracillimus* is *O. wahlenbergii.*

Distribution: Kashmir, Uttaranchal, Sikkim; Nepal,

Japan, Korea, Siberia, Yunnan, Europe, Caucasus.

Chromosome number: n = 14.

7. *Amphidium* Schimp., Croll. Bryol. Eur. 39. 1856. *nom.cons.*

Plants small, growing in dense tufts or cushions, yellow-green. Stems unbranched. Leaves crisped when dry, linear-lanceolate, mostly recurved in the lower half, apex acute to acuminate; nerve percurrent; basal laminal cells hyaline, elongate-rectangular, thin-walled, the median and the upper ones hexagonal-round, incrassate, densely papillose. Setae short. Capsules scarcely exserted, pyriform, 8-striate, apophysis distinct. Annulus and peristome absent. Operculum with slanting beak. Calyptra cucullate, smooth.

Lectotype: *Amphidium lapponicum* (Hedw.) Schimp.

Cytologically, *Amphidium* Schimp. is known from three species, namely, *A. cyathicarpum* (Mont.) Broth. - n = 16; *A. lapponicum* (Hedw.) Schimp. - n = 13, 16; *A. mougeotii* (B.S.G.) Schimp. - n = 13. Interestingly, no other taxon in the family *Rhabdowesiaceae* has been found to possess a sixteen chromosome complement. Likewise, no other taxon in the family *Orthotrichaceae,* where *Amphidium* has been traditionally placed, is known to possess a thirteen chromosome complement. The occurrence of n = 13 along with n = 16 in one species of *Amphidium,* and n = 13 exclusively in another species of the same genus, seem to justify its inclusion in the family *Rhabdowesiaceae.*

Amphidium lapponicum (Hedw.) Schimp., Coroll. 39. 1856. (Fig.13)

Anictangium lapponicum Hedw., Spec. Musc. 40. 1801.

Plants green above, brownish below, growing in dense cushions. Stems simple, lacking central strand. Leaves contorted with twisted tips when dry, 17 – 2.2 mm long, linear-lanceolate; margins plane, entire; nerve thin, percurrent; basal laminal cells hyaline, rectangular 26 – 44 x 8 – 10 µm, the median and the upper ones obscure, hexagonal-round, 8 -12 µm, thickened at corners, densely papillose. Setae to 0.6 mm long. Capsules pyriform, 0.6 – 0.7 mm long and 0.6 mm in diameter, 8-ribbed when dry. Peristome lacking. Operculum obliquely beaked. Rest not observed.

When sterile, this species looks like *Zygodon* in appearance, but in the latter taxon the setae is elongate and peristome is present.

Specimen examined: Himachal Pradesh : Shimla, Narkanda, 2700 m, September, 1966, *2072.*

Distribution: Western Himalaya; Cosmopolitan.

Chromosome number: n = 13,16

3. FAMILY DICRANACEAE

Plants tall, robust, sometimes short or even minute and slender, mostly in dense tufts. Stems simple or branched, in transverse section often showing a central strand. Leaves narrow, long-lanceolate or subulate, usually falcate-secund, margins entire or serrulate; nerve narrow or wide, sub-percurrent to excurrent, in transverse section heterogeneous; alar cells not or strongly differentiated; basal laminal cells elongate with longitudinal walls sometimes porose-pitted, smooth, the upper ones short or elongate, pitted-porose or non-pitted. Setae mostly elongate, rarely short to very short, straight, sometimes flexuose when dry and cygneous when moist. Capsules ovate to cylindrical, exserted, erect or inclined, rarely immersed and cleistocarpous. Peristome teeth 16, each divided down to one-half to nearly two-third of its length into two or rarely three segments, papillose above and vertically striolate below. Operculum often differentiated, conic-rostrate with obiique beak. Calyptra large, mostly cucullate, smooth. Spores spherical, medium-sized, rarely large (± 25 µm or more), papillose.

The family Dicranaceae was divided into six sub-families (Brotherus, 1925). Subsequently, this treatment was followed by several authors in their manuals on the moss flora of their countries. However, recently (*cf.* Buck & Goffinet, 2000), two of these six sub-families, namely : Trematodontoideae (characterized by distinctly differentiated, generally long apophysis, lack of differentiated alar cells, and strongly ornamented spores) and Rhabdoweisoideae (characterized by stems without central strand, capsules ribbed and wide-mouthed), are treated as independent families *i.e.* Bruchiaceae and Rhabdoweisiaceae respectively. Of the remining 4 sub-families, Paraleucobryoideae characterized by distinctive nerve anatomy with median layer of small chlorocysts encircled dorsally and ventrally by large leucocysts, a feature shared only with the members of the family Leucobryaceae, is suggestive of its natural assemblage with these taxa of Leucobryaceae. This indeed tempts me to shift this taxon to the Leucobryales, and treat it as a sub-family of the family Leucobryaceae, but I have restrained from doing so because of its fancied affinity (which needs to be critically analyzed and carefully evaluated) with *Campylopus* and *Dicranum.*

The family Dicranaceae includes 49 genera (Buck &

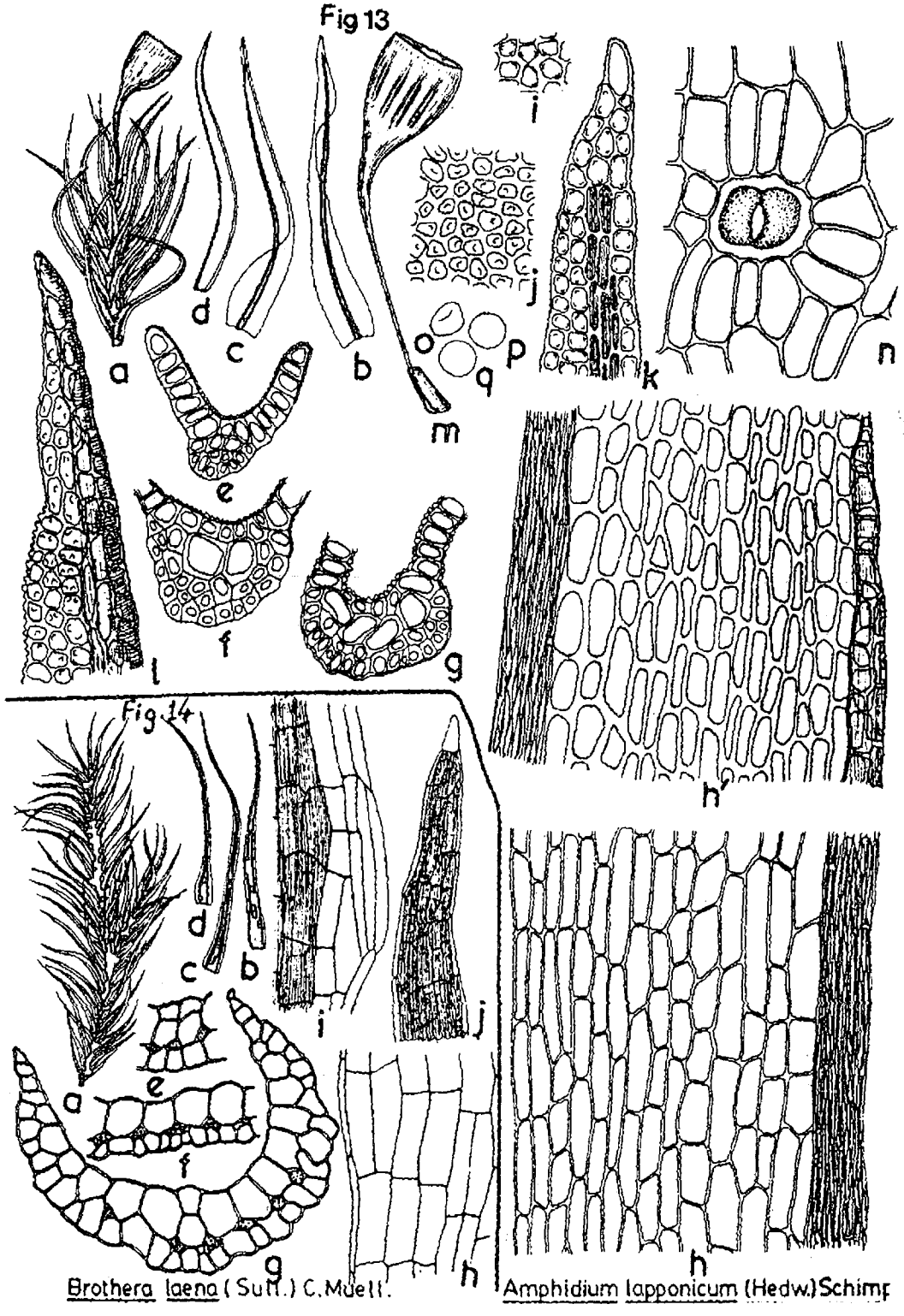

Fig. 13 : Amphidium Lapponicum Schimp.
a. Plant x 10; b,c,d. Leaves x 24; e,f,g. T.S. leaves x 495; h, basal laminal cells x 495; h, Basal laminal cells little above base x 495; i.j. Median laminal cells x 495; k,l. leaf apices x 495; m. Sporophyte x 20 n. Stoma x 495;. o,p.q Spores x 495.

Fig. 14 : Brothera leana (Sull.) C. Muell.
a. Plant x 10; b,c,d. Leaves x 16; e,f,g. T. S. Leaf nerve x 495; h. Basal laminal cells x 495; I. Laminal cells at mid leaf x 495; j. Leaf apex x 495.

Goffinet, 2000), most of which are distributed in the temperate zone. In India, the family is represented by 24 genera, of which 8 are recorded from our area.

Key to the West Himalayan genera of Dicranaceae

a. Nerve, when seen in transverse section, with a median row of chlorocysts sandwitched between large leucocysts dorsally and ventrally (Paraleucobryoideae).....b

Nerve, when seen in transverse section, without chlorocysts and leucocysts, mostly with a median row of guide cells, dorsal and ventral stereids, only dorsal stereids below the guide cells, or only stereids between the upper and the lower epidermis.....c

b. Stems always less than 1.0 cm. long., leaves 1.0-2.0 mm long; alar cells not differentiated; calyptra with frilled margins.....**1. *Brothera***

Stems not less than 2.0 cm long; leaves 3.0-8.0 mm long; alar cells strongly differentiated; calyptra entire-margined.....**2. *Paraleucobryum***

c. Leaves mostly secund; alar cells distinctly differentiated.....d

Leaves mostly not secund; alar cells not differentiated .....f

d. Nerve narrow, occupying much less than (at least never exceeding) one-third of the leaf base; basal laminal cells and some times the upper ones also pitted-porose.....**10. *Dicranum***

Nerve broad, occupying one-third to three-fourth of the leaf base; laminal cells never pitted-porose.....e

e. Leaves setaceous; basal laimnal cells elongate, polygonal or rectangular towards the nerve, narrowed towards margins to form a distinct border of elongate, linear cells; capsules smooth when dry; annulus not differentiated; peristome teeth divided down nearly to the base; calyptra base entire.....**4. *Dicranodontium***

Leaves elongate-subulate; basal laminal cells parenchymatous and similar from the nerve to the leaf margins; capsules mostly furrowed or striped when dry; annulus differentiated; peristome teeth divided down nearly to their half-length; calyptra fringed at base.....**3. *Campylopus***

f. Dry leaves helecoid-coiled.....**9. *Symblepharis***

Dry leaves erect-appressed or contorted to crisp, never helicoidly coiled.....g

g. Stems julaceous; leaves ovate to elliptical; laminal cells rhomboid to oval; peristome lacking.....**5.*Aongstroemia***

Stems not julaceous; leaves ovate-lanceolate to lanceolate, mostly subulate; laminal cells rectangular to linear; peristome present.....h

h. Nerve completely filling the entire subular part of the leaf; setae cygneous, at least when young, later strongly tortuous.....**8.*Campylopodium***

Nerve not completely filling the leaf apex or the entire subular part of the leaf; setae straight.....i

i. Leaves base not sheathing; peristome teeth united with each other in the lower half.....**6.*Anisothecium***

Leaves base sheathing; peristome teeth free, not united in the lower half also.....**7.*Dicranella***

Subfamily 1. Paraleucobryoideae

Plants olive-green or whitish-green. Sterns short or long, densely foliate. Leaves lanceolate-subulate, ± tubular in the subular part; nerve broad, filling or nearly filling the subula, in transverse section showing a median row of small chlorophyllose cells in between two rows of large hyaline cells; lamina reduced; alar cells absent or distinctly differentiated. Peristome teeth entire or each tooth cleft down to one-half of its length.

This subfamily agrees with the Leucobryales in the nerve structure, with *Dicranum* Hedw. or *Campylopus* Brid. of Dicranaceae in its habit, the broad nerve and the annulate capsules. Its chromosome number - n=12 [reported in *Paraleucobryum* (Limp.) Loesk. and *Brothera* C. Muell.] is also shared by some species of *Dicranum* and *Campylopus*.

In our country, this subfamily is represented by two genera, *(Paraleucobryum* and *Brothera)*, which are widely distributed in South India, the Eastern Himalaya and also in the Western Himalaya.

Key to the West Himalayan genera of *Paraleucobryoideae*

Plants with the habit of *Campylopus;* stems always less than 1.0 cm long; leaves 1.0-2.0 mm long; alar cells not differentiated; calyptra with frilled

margin.....**1. *Brothera***

Plants with the habit of *Dicranum*; stems not less than 2.0 cm long; leaves 3.0 – 8.0 mm long; alar cells distinctly differentiated; calyptra entire-margined .....**2. *Paraleucobryum***

1. *Brothera* C. Muell., Gen. Musc. Fr. 258. 1900.

Campylopus sect. *Leucocampylopus* Corr. *in* Unters. Veg. Vermehr. Laubm. 43. 1899.

Plants small, light-green with a whitish tinge, growing on tree trunks in small-sized cushions. Stems short, simple or branched, densely foliate. Leaves lanceolate-subulate, canaliculate in the upper part; nerve broad, ± excurrent, in transverse section 3-layered with a row of small, narrow chlorophyllose cells between two rows of large, hyaline cells; alar cells not differentiated; laminal cells hyaline, rectangular, the marginal row of differentiated linear cells. Setae cygneous, flexuose when dry. Capsules ovoid, annulate. Peristome teeth 16, entire or each cleft down to one-half of its length. Calyptra large, fringed at base.

Lectotype: *Brothera ankerkronae* C.Muell. *nom. nud.* = *B.leana* (Sull.) C. Muell.

In the field, this genus gives the appearance of *Campylopus,* but the whitish tinge of the plants help differentiation. It also differs from the latter genus in the structural organization of the nerve (guide cells and stereids absent) and in the lack of differentiated alar cells.

Cytologically, this small-sized genus is known from one species i.e. *Brothera leana* (Sull.) C.Muell. - n = 12. Although, the same chromosome number is also recorded in 6 species of *Campylopus* (with which this genus shares a similar appearance) and 12 species of *Dicranum,* yet the existing data is not permissive to conclude any direct plyletic relationship between these three taxa.

Brothera includes 2 species i.e *B.leana* (Sull.) C. Muell. and *B.himalayana* Broth. The former is distributed in Asia and America and the latter is endemic to the Western Himalaya.

Brothera leana (Sull.) C. Muell., Gen. Musc. Fr. 258. 1900. (Fig.14)

Leucophanes leanum Sull., Musc. Allegh. 41. 1846.

Campylopus leanus Sull. et Lesq., Musci. Bor. Am. 18.1856.

Syrrhopodon leanus Sull. ex Lesq. et Jam., Man. N. Am. Moss. 78. 1884. *nom. inval. in. synon. err.pro. Lecuophanes leanum.*

Brothera ankerkronae C.Muell. *in* Kindb., Enum. Bryin. Exot. 105. 1891. *nom. nud.*

Brothera japonica Broth. *in Par.,*Ind.Bryol.*155.1894* and *Broth.in* C.Muell., Gen.Musc. Fr. 259. 1900 *nom.nud.*

Plants whitish-green, growing in mats or cushions. Stems to 5.0 mm long, branched, densely foliate. Leaves erecto-patent, little altered on drying, 1.5-2.0 mm long and 0.15 mm wide at base, gradually narrowing from a convave, oblong basal portion into narrow canaliculate apical part; margins entire; nerve broad, occupying nearly 3/4 of the leaf base, shortly excurrent, in transverse section 3-layered, with the median layer of small chlorophyllose cells bounded on either surface by relatively larger hyaline cells (sometimes the nerve is 4-layered, 2 layers above a layer of small chlorophyllose cells and one layer below the chlorophyllose cells); lamina reduced, at base 3-6 cells wide, upwards only one cell wide, but persisting to the apex; basal laminal cells rectangular, 22-30 x 10-13 µm, (some cells to 41 µm long), hyaline, thin-walled, at margins one row of narrow (3 µm wide) linear cells, 20-34 x 3 µm. Sporophyte not observed.

This species, very common on the bark of *Quercus* and conifers, (particularly *Pinus*) has never been seen in fruiting in our area. Once familiar, it is very easily recognized by its general appearance.

Specimens examined: Kashmir : Pehlgam, 2600 m, on tree trunk, August, 1978, *109K*, Himachal Pradesh : Shimla on way to Glen, 2500 m, at the base of the trunk of *Quercus dilatata*, and *Pinus sylvestris,* November, 1977, *ICN;* Uttaranchal : Mussoorie, on way to Lal Tibba, 2500 m, tree trunk of *Cedrus deodara,* September, 1975, *107K;* very commonly found in Nainital.

Distribution: Kashmir, Himachal Pradesh, Uttaranchal, Darjeeling, Sikkim, South India; Yunnan, Upper Myanmar, Siberia, Manchuria, Korea, Japan, Phillippines, North and Central America.

Chromosome number: n = 12.

2. *Paraleucobryum* (Limp.) loesk., Allg. Bot. Zeitschr., 13: 167. 1907.

Dicranum subg. *Paraleucobryum Lindb. ex* Limpr., Laubm. Deutschl. 1: 373. 1886.

Dicranum sect. longifolia Hueb., Musc. Germ. 247. 1833.

Plants green, glossy or whitish-green. Leaves erecto-patent or falcate-secund, lanceolate-subulate; nerve broad, filling or nearly filling the whole leaf above the middle, in transverse section 3-4-layered, without guide

cells and without stereids; alar cells strongly differentiated, mostly brown and thick-walled, extending to the nerve; laminal cells rectangular, thin-walled. Setae long, twisted. Capsules erect or nearly so, oblong-cylindric, stomatose. Peristome teeth 16, each tooth cleft down to one-half of its length, obliquely or vertically striate. Operculum with long beak. Calyptra cucullate, base entire-margined.

Lectotype: *P. albicans* (Schwaegr.) Loesk.

Paraleucobryum (Limp.) Loesk. *agrees with Leucobryum* Hamp. in possessing a broad nerve, which fills or nearly fills the leaf above the middle, and is without guide cells and stereids, when seen in transverse section. It resembles *Dicranum* Hedw. in habit and also in the strongly differentiated alar cells. Further, the ridges of projecting cells at the back of the nerve, an archaic character (observed in *Paraleucobryum albicans* (Schwaeg.) Loesk.), is as well shared with some species of *Dicranum*. Additionally, the chromosome count (n = 12) in the European and American populations of *P. longifolium* is also in line with the chromosome number recorded in 9 species of *Dicranum* (Fritisch, 1991). The available data tend to indicate, that this genus may be a connecting link between *Leucobryum* and *Dicranum*, as also suggested by Grout (1937).

Cytologically, this genus is known from one species i.e. *Paraleucobryum longifolium* (Hedw.) Loeske - n = 12, 14. It differes from *Leucobryum* Hamp. [n = 6 (in 2 species), 11 (in 5 species)] in chromosome number and chromosome morphology. Its assemblage with *Brothera* C.Muell. seems natural even on cytological grounds.

Paraleucobryum includes eight species, of which only two are recorded from India and are also found in our area.

Key to the West Himalayan species of *Paraleucobryum* (Limp.) Loesk.

Nerve very broad, occupying nearly 3/4 - 5/6 of the leaf base, in transverse section showing a median row of chlorophyllose cells; lamina much reduced; alar cells brown, thick-walled.....**1.*P.enerve***

Nerve narrow, occupying nearly 1/4 -1/3 of the leaf base, in transverse section without a median row of chlorophyllose cells; lamina relatively much wider; alar cells hyaline, thin-walled.....**2.*P.himalayanum***

Paraleucobryum enerve (Thed.) Loesk., Hedwigia 47: 171. 1908. (Fig.15)

Dicranum enerve Thed. *in* Hartm., Handb. Skand. Fl. *ed. 5: 393.* 1849.

Dicranum albicans B.S.G., Bryol. Eur. 1:149. 1850. *nom. illeg. incl. spec. prior.*

Campylopus albescens Kindb. *in* Par., Ind. Bryol. Suppl. 88. 1900. *nom. inval. in.synon.err.pro. albicans.*

Campylopus albicans Kindb., Bih. K. Svensk. Vet. Ak. Handl. 7: 86. 1883. *nom. illeg. incl. spec. prior.*

Campylopus crassinervis Wils., Kew J. Bot., 9: 297. 1857. *nom. nud.*

Campylopus hallii Lesq., Misc., Publ. U.S. Geol. Geogr. Surv. 4:155. 1874.

Plants robust, whitish-green or light-green and glossy. Stems to 3.5 cm long, simple, densely foliate. Leaves erect-spreading or falcate, hardly altered on drying, the middle ones 4.0-5.0 mm long and 0.5 mm wide, the upper ones 6.5 – 8.0 mm long and 0.7 wide, lanceolate-subulate with a concave base; margins entire; nerve broad, occupying 3/4 - 5/6 of the leaf base, filling most of the subula above the middle, in transverse section 3-layered; lamina reduced, 6-8 cells wide on either side of the nerve at base, 1-2 cells wide near the apex; alar cells strongly differentiated, brown, quadrate, 10-16 µm wide, incrassate; basal laminal cells rectangular, to 50 x 12 µm, thin-walled. Sporophyte not observed.

Specimen examined: Kashmir (Dorma, above Pehlgam), 2500 m, July, 1925, *8063* (BM).

Distribution: Kashmir, Sikkim; Nepal, China, Formosa, Japan, Caucasus, Europe, North America.

Chromosome number: Not known.

Paraleucobryum himalayanum Dix., 150th. Anniv. Vol. R. bot. Gdn. Calcutta, 177. 1942. (Fig.16)

Plants in dense tufts. Stems 2.5 – 3.0 cm long, simple. Leaves erecto-patent, hardly altered on drying, to 4.2 mm long and 0.5 mm wide, lanceolate-subulate, tubular from middle above; margins entire; nerve occupying 1/4 -1/3 of the leaf base, in transverse section without the median row of chlorophyllose cells; alar cells hyaline, quadrate, 11-14 µm wide, thin-walled; basal laminal cells narrow-rectangular, some cells with oblique end walls, to 76 x 4-8 µm, the median ones relatively broader, at margins (1-2 rows) linear, to 68 x 4-7 µm, thin-walled, the upper ones short. Sporophyte not observed.

Specimen examined: Himachal Pradesh : Keylong, above Chamba, 2700 m, *2601* (BM).

Distribution: Himachal Pradesh. Endemic in the Western Himalaya.

Chromosome number: Not known.

As pointed out by Dixon (1942), this species shows the

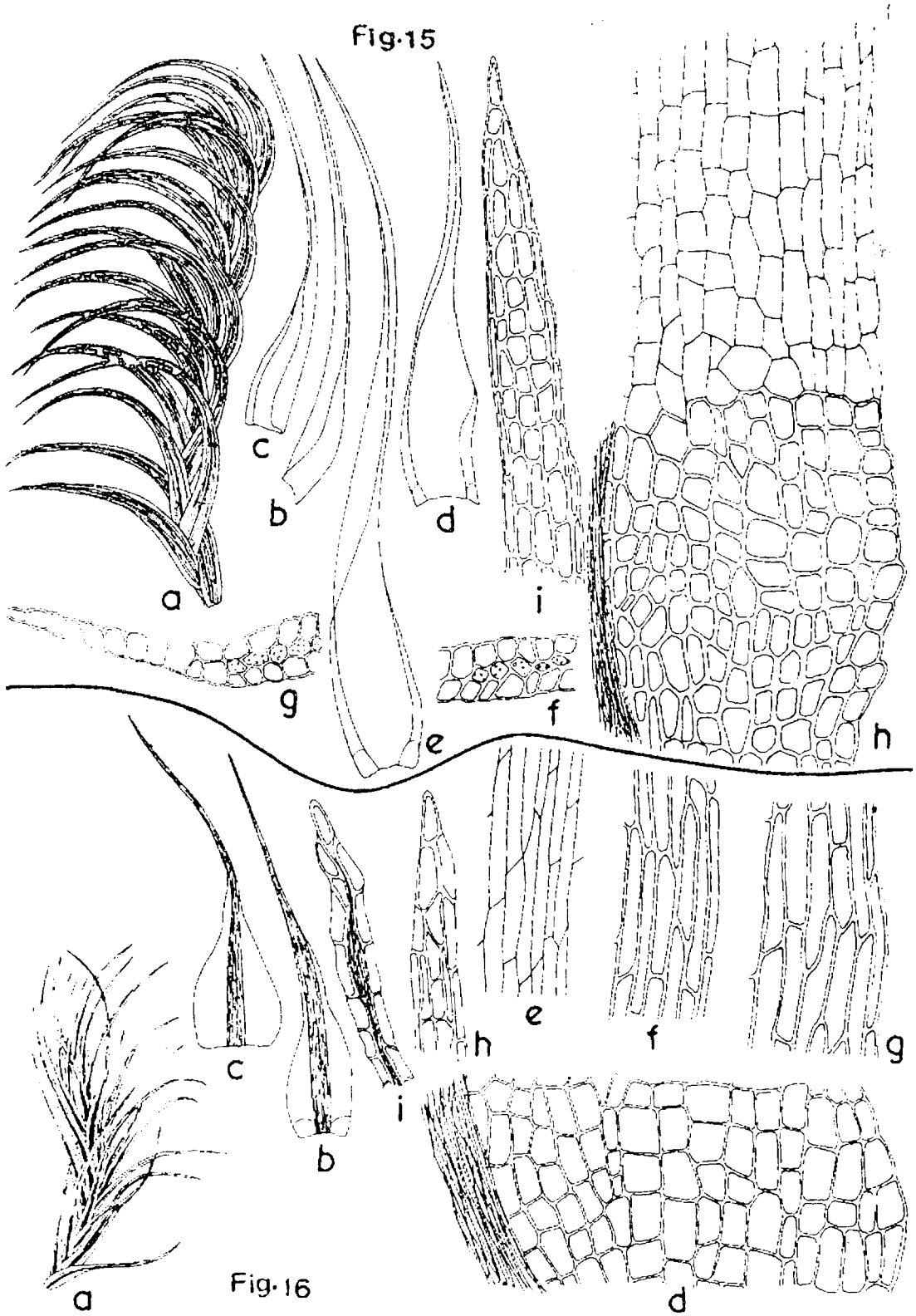

***Fig. 15 : Paraleucobryum enerve** (Thed.) Loesk.*
a. Part of Plant x 10; b,c,d,e. Leaves x 26; f.g. T. S. Leaf x 495; h. Laminal cells at leaf base x 495; I. Leaf apex x 495.

***Fig. 16 : Paraleucobryum himalayanum** Dix.*
a. A part of the Plant x 10; b,c. Leaves x 26; d. Basal laminal cells x 495; e. Cells little above base x 495; f.g. Median laminal cells x 495; h.i. Leaf apex x 495.

habit of *Dicranodontium*. The strongly differentiated, hyaline alar cells extending to the nerve, and 1-2 rows of linear cells at the leaf margins are quite in agreement with the same genus. However, the narrow nerve is unlike that of the leaf nerve of *Dicranodontium*. The laminal cells appear similar to *Leucobryum,* but the nerve structure is entirely different.

3.*Campylopus* Brid., Musc, Rec. Suppl. 4: 71. 1819.

Thysanomitrium Schwaegr., Sp. Musc. Supl. 2: 61: 1823.

Thysanomitrium Schwaegr., in Reinw. & Hornsch., Nova Acta Leop. Carol. 14 :706. 1829. nom. Illeg. orthogr. *pro.Thysanomitrium* Schwaegr.

Sphaerothecium Ham., Annls Sci. nat. Bot. Ser. 5,4: 361. 1865

Dioicous. Plants green to pale-green, growing in loose or dense tufts. Stems simple or branched, often with fragile buds or branches. Leaves erect, flexuose, falcate-secund, lanceolate or lanceolate-subulate, tubulose towards the apex; margins plane or incurved, entire or denticulate; nerve broad, occupying more than one-third of the leaf base, percurrent or excurrent; lamina narrow, unistratose; alar cells differentiated and often in auricles, hyaline or red to brown; basal laminal cells rectangular, often enlarged towards the nerve, upwards rhomboidal or quadrate to subrectangular. Setae short, erect or curved when moist. Capsules erect to inclined, cylindric or ovoid, sulcate when dry; annulus of 2-3 rows of cells; stomata absent. Peristome teeth 16, each cleft down to one-half of its total length, vertically striolate, papillose towards the tip. Operculum long rostrate. Calyptra cuculate, fringed at base.

Lectotype: *Campylopus flexuosus* (Hedw.) Brid.

This large genus of world wide distribution is in a state of taxonomic muddle. In our area, the members of this genus prefer acidic substrata, and are commonly found growing on bases of trees, on tree trunks, and branches, rocks and rock crevices and also on soil. The plants are mostly barren, and even when fertile, the sporophytic characters offer little assistance in distinguishing various species. The gametophytic features are highly variable. The structure of the nerve, on which is based the division of this genus into four subgenera (*Thysanomitrium, Palinocraspis, Eucampylopus, Pseudocampylopus*), is also not a very constant character. The length of the subula and the shape of the laminal cells are useful only within limits. The nature of the leaf margins, often employed in the preparation of present day keys to the regional species of this genus, appears to be an important character even with its pit falls here and there. However, the overall value of this character also needs to be checked through controled experimental studies with a large number of species from different geographic regions.

Cytologically, this genus is known from 13 species. Of the various discordant chromosome numbers (n = 10, 11, 12,13, 15,18) recorded in this genus, n = 12 (6 species) and n = 11 (4 species) are of most common occurrence. The existence of n = 10, 11, 12 in *Campylopus flexuosus* (Hedw.) Brid.; n = 11, 12 in *C. goughii* (Mitt.) Jaeg; - n = 10, 12 in *C.fragilis* (Brid.) B.S.G. is suggestive of the plasticity of the genotypes, resulting in the formation of several morphotypes, which in turn may be responsible for the taxonomic muddle in this large sized genus. Be as it may, the known cytological data do not seem to promise any aid in the delimitation of taxa of subgeneric or specific rank.

Campylopus contains over 600 species, of which nearly 57 are known to occur in our country. In our area, this genus is represented by 11 species, of which three *nom.nud.* species* i.e. *C.albovaginatus* and *C. barbuloides,* C. oedicaulis are endemic in the Western Himalaya.

Key to the West Himalayan species of *Campylopus* Brid.

a. Nerve in T.S. nearly homogeneous, without stereids (subgen.*Pseudocampylopus*).....b

Nerve in T.S. heterogeneous, with stereids.....c

b. Leaf tips flexuose on drying; nerve occupying nearly one-half of leaf base; alar cells rust-coloured, not bulging to give an auricle-like appearance.....**6.*C. goughii***

Leaf tips not flexuose on drying; nerve broad, occupying nearly two-third of leaf base; alar cells hyaline, bulging to give an auricle-like appearance.....**7.*C. gracilis***

c. Nerve in T.S. showing a dorsal and a ventral stereidal band (subgen. *Palinocraspis* and subgen. *Thysanomitrium*).....d

Nerve in T.S. showing only the dorsal stereidal band, ventral stereidal band absent (subgen. *Campylopus*).....e

d. Leaf base auriculate; nerve back distinctly lamellose, each lamella 3-4 cells high; alar cells inflated.....**10. *C. richardii***

Leaf base not auriculate; nerve back ridged

or wavy, never lamellose; alar cells not inflated.....**8. *C. laetus***

e. Leaf margins distinctly toothed towards apex.....f

Leaf margins entire throughout or faintly crenate.....h

f. Nerve back ridged.....**4.*C.ericoides***

Nerve back smooth.....g

g. Plants with numerous fragile buds among the comal leaves, fragile buds easily falling apart/separated just on touching the plants or even with wind currents; lamina contracted at base.....**5.*C. fragilis***

Plants without fragile buds among the comal leaves; lamina not contracted at base.....**3.*C. connivens***

h. Leaf base auriculate; median laminal cells oval to elongate-rhomboidal, 2-4 µm wide....***9.C.oedicaulis****

Leaf base not auriculate; median laminal cells rectangular to sub-rectangular, 5-8 µm wide.....i

i. Leaves erecto-patent with flexuose tip on drying .....**1.*C. albovaginatus****

Leaves erecto-patent, hardly altered on drying.....**2. *C. barbuloides****

1. *Campylopus albovaginatus* Broth.

Campylopus albovaginatus Broth. *in* Bruhel, Rec. Bot. Surv. India 13: 122. 1931. *nom. nud.* (Fig. 17)

Plants light-brown when dry, growing in loose tufts. Stems to 0.8 cm long, branched. Leaves erecto-patent, tips flexuose on drying, the lower ones 0.9 – 1.2 mm long, from middle upwards 2.5 – 3.0 mm long and 0.28 mm wide at base, lanceolate-subulate from a little widened basal portion; margins inflexed in the upper two-third portion; nerve 118 - 145 µm wide, occupying nearly one-half of the leaf base; alar cells mostly hyaline, quadrate to sub-rectangular, 10 – 10 µm wide, not or in very slightly differentiated auricles; 14 – 18 x 12 µm, at margins (2 rows) narrowly elongate, 18 – 30 x 4 µm, above irregularly rhomboidal, strongly incrassate, from middle upwards rhomboidal to rectangular with oblique cross walls, 12 – 18 x 5 – 8 µm. Sporophyte not observed.

Specimens examined: Uttaranchal : Mussoorie, Arnigadh gardens, 1835 m, on soil, June, 1900. Type : *4637* (BM), Himachal Pradesh : Shimla, Jakhoo hill, 2300 m, on forest floor, *2060*.

Distribution: Himachal Pradesh, Uttaranchal, endemic in the Western Himalaya.

Chromosome number: Not known.

2. *Campylopus barbuloides* Broth.

Campylopus barbuloides Broth. *in Bruehl., Rec. Bot. Surv. India. 13(1):123. 1931.nom.nud.* (Fig.18)

Plants growing in tufts. Stems to 1.3 cm long, densely foliate, branched. Leaves erecto-patent, hardly altered on drying, 2.4 – 3.0 mm long and 0.28 – 5.0 mm wide at base, oblong-lanceolate or ovate-lanceolate, canaliculate, subulate, denticulate near apex; margins inflexed down to two-third of leaf length; nerve occupying nearly one-half of the leaf base, in transverse section showing small-lumined cells (sub-stereids) below the guide cells; alar cells hyaline, nearly rectangular, 10 – 12 µm wide; basal laminal cells rectangular, to 40 x 10 – 12 µm, towards margins narrower, 5 – 8 µm wide, upwards rectangular to sub-rectangular, 14 – 22 x 6 – 8 µm, in the apical portion rhomboidal, 10 – 12 x 4 – 5 µm. Setae terminal, 0.8 – 1.0 cm long, cygneous. Capsules 1.4 mm long and 0.6 – 0.7 mm in diameter, ovate; exothecial cells rectangular, to 78 x 7 – 10 µm, strongly incrassate. Peristome dicranoid. Spores 12 – 15 µm.

Specimen examined: Uttaranchal : Mussoorie, Dhanolulti, 2100 m, on soil, 14 (BM).

Distribution: Endemic in the Western Himalaya.

Chromosome number: Not known.

3. *Campylopus connivens* Broth., Rec. Bot. Surv. India 13(1): 123. 1931. (Fig.19)

Plants light-green, in loose tufts. Stems to 1.0 cm long, mostly simple. Leaves erecto-patent, erect-appressed on drying, 3.5 – 5.0 mm long and 0.4 – 0.6 mm wide at base, lanceolate-subulate from an oblong basal portion; margins involute; nerve 0.26 – 0.30 mm wide, occupying nearly one-half to two-third of leaf base, in transverse section showing a row of guide cells with interrupted groups of sub-stereids below it; alar cells hyaline, not forming auricles, slightly inflated, rectangular to polygonal, to 16 µm wide; basal laminal cells rectangular, 40 – 70 x 7 – 11 µm, upwards narrower with oblique end walls, 4-6 µm wide, at margins sub-rectangular to rhomboid. Sporophyte not observed.

*I have described and illustrated these *nom.nud.* taxa, but refrained from establishing their validity by providing latin diagonosis, which must wait till a thorough study of all the species of this taxonomically mudled genus is made.

Fig. 17

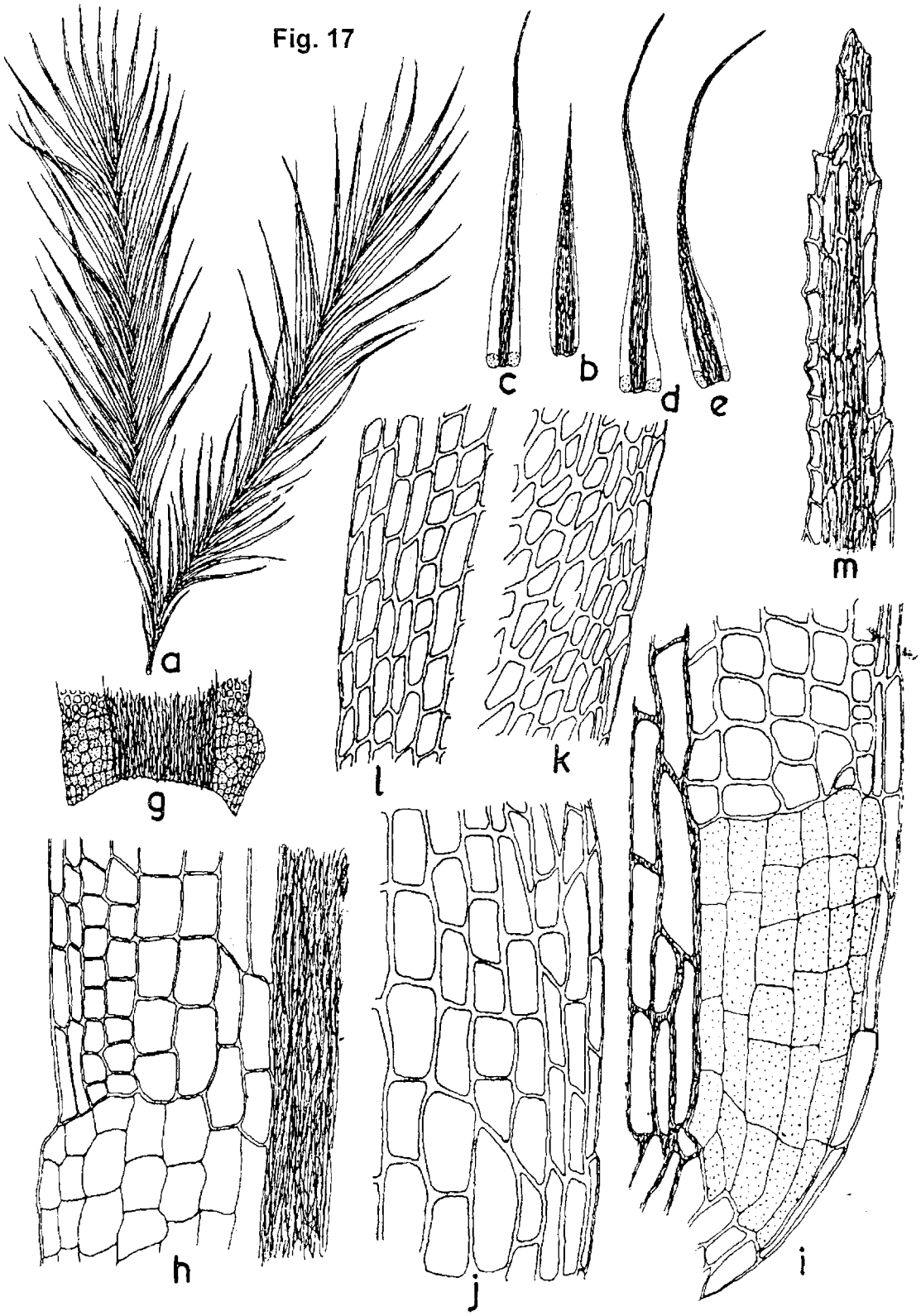

Fig. 17 : Campylopus albovaginatus Broth.
a. Plant x 10; b,c,d,e. Leaves x 26; g. Leaf base showing alar group x 248; h. Cells immediately above the alar cells x 495; k. Upper laminal cells x 495; l. Median laminal cells x 495 m. Leaf apex x 495.

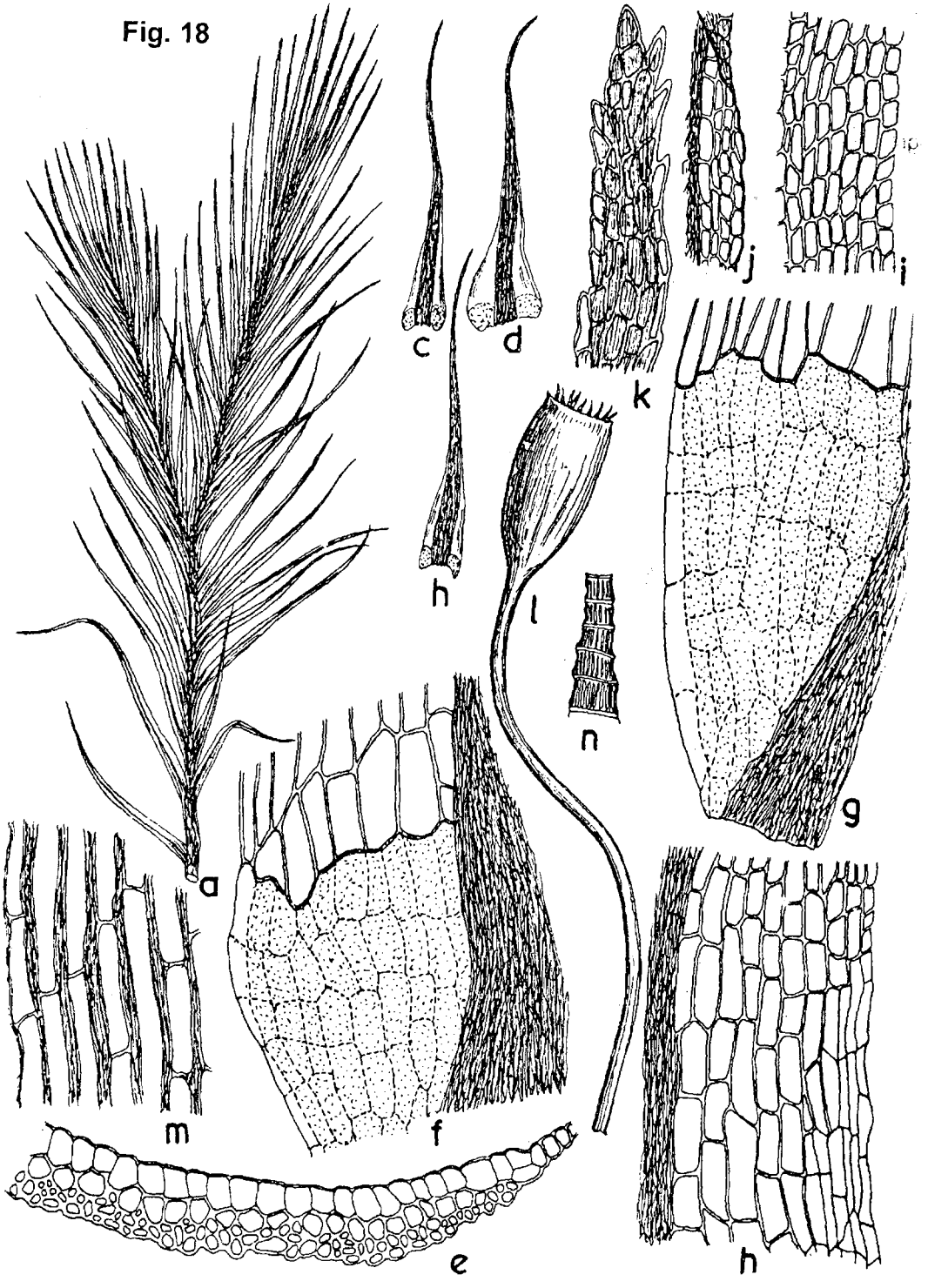

Fig. 18 : Campylopus barbuloides Broth.
a. Plant x 10; b.c.d. Leaves x 26; e. T. S. leaf x 495; f.g. Alar cells x 495; h. Median laminal cells x 495; j. Laminal cells at margins x 300; k. Leaf apex x 300.

Fig. 19

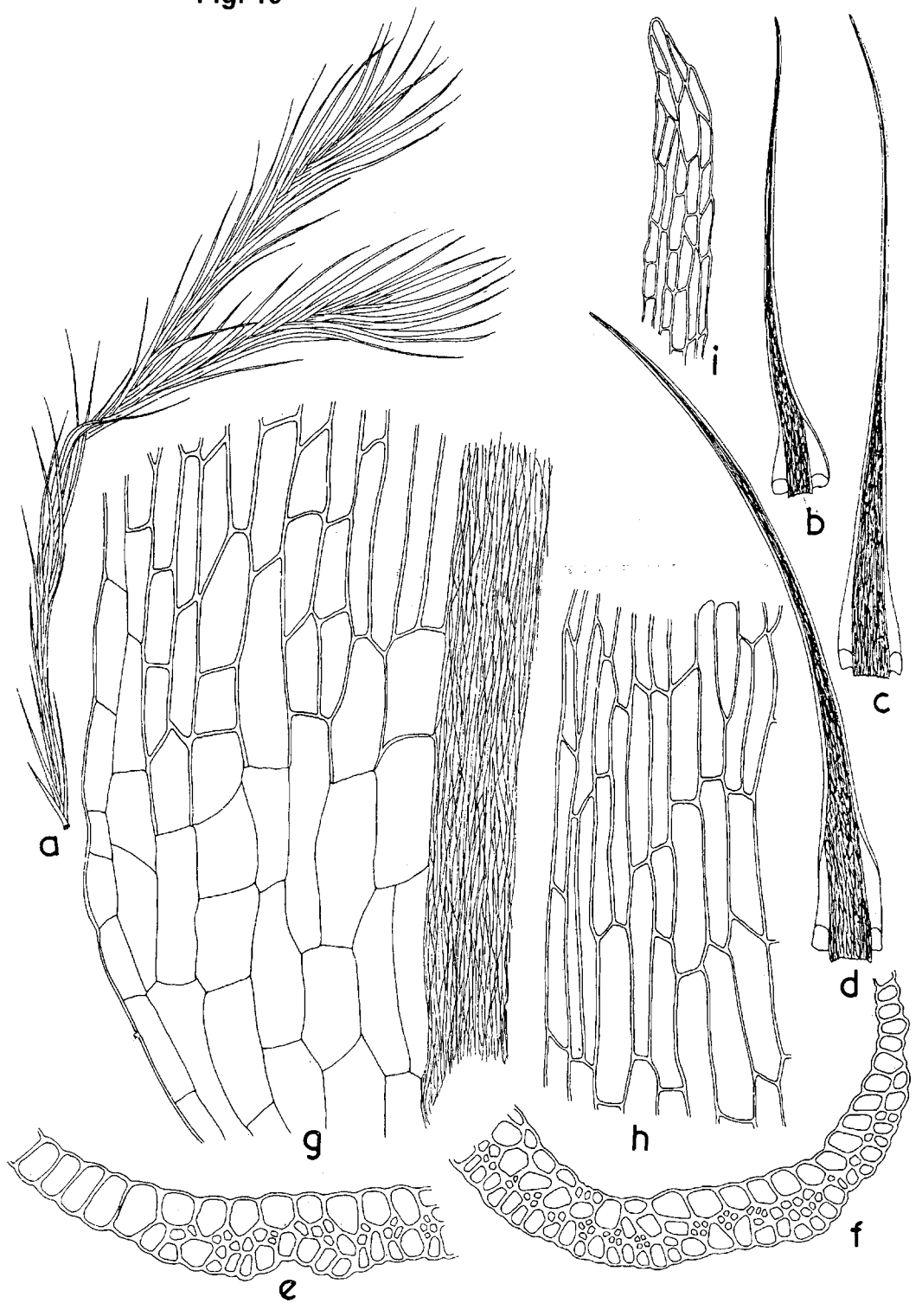

Fig. 19 : Campylopus connivens Broth.

a. Plant x 10. b. c.d. Leaves x 26. e.f. T. S. leaf x 495. g. Alar cells x 495. h. Basal laminal cells x 495. i. Leaf apex x 495.

Specimen examined: Himachal Pradesh : Shimla, 2100 m, on wet rocks, Bryotheca E. Levier, *15* (BM); Uttaranchal : Nainital, 2300 m, on wet soil gathered on rocks, *2249*.

Distribution: Himachal Pradesh, endemic to Western Himalaya.

Chromosome number: Not known.

4. *Campylopus ericoides* (Griff.) Jaeg., Ber. S. Gall. Naturw. Ges. 1870-71 : 424. 1872. (Fig.20)

Dicranum ericoides Griff., Calcutta Jour. Nat. Hist. 2: 499. 1842.

Plants light-green, growing in loose tufts. Stems to 2.0 cm long, simple, densely foliate. Leaves erecto-patent, little altered on drying, the lower ones 1.1 – 1.8 mm long, upwards 2.0 – 3.2 mm long and 0.3 – 0.4 mm wide, lanceolate, gradually narrowing into tubulose subula; margins inflexed in the upper half, serrulate in the apical part; nerve 125 – 132 µm wide, occupying nearly one-third of the leaf base, in transverse section wavy at back, stereids below the guide cells only; alar cells rust-coloured, not forming auricles, nearly sub-rectangular to quadrate, 15 – 20 µm; the median and the upper ones 16 – 25 x 5 – 8 µm, incrassate, at margins (1 row) rectangular with mostly oblique cross walls, 20 – 30 x 3 – 5 µm, thin-walled. Sporophyte not observed.

Specimen examined: Uttaranchal : Dewalsari, 2700 m, on the bases of the tree trunks, September, 1976, *1207F*.

Distribution: Uttaranchal, Darjeeling, Khasia Hills, Manipur; Nepal, Srilanka, Myanmar, Thailand, Vietnam, Java, Phillipines.

Chromosome number: Not known.

5. *Campylopus fragilis* (Brid.) B.S.G., Bryol. Eur. 1: 164. 1847. (Fig.21)

Dicranum fragile Brid., J.f. Bot., 1800 (2) : 296. 1801.

Dicranum funkii C. Muell., Syn. 1 : 392. 1848. *nom. illeg. Incl. spec. prior.*

Campylopus fragilis var. *pyriformis* (Schultz) Agst., *Ned.* Kraidk. Arch. 57: 332. 1950.

Campylopus flexuosus (Hedw.) Brid., var. pyriformis (Schultz) Dix., Stud. Handb. Brit. Mosses. 95. 1896.

Campylopus torfaceus B.S.G., Bryol. Eur. 1: 164. 1847.

Campylopus turfaceus Schimp., Syn. 704. 1806. *orthogr. pro C.torfaceus* B.S.G.

Dicranum pinetorum Griff., Calcutta. J. Nat. Hist. 2: 4976. 1842.

Dicranum pyriforme (Schultz) Brid., Bryol. Univ. 1: 469. 1826. Syn. 1: 399. 1848.

Plants yellowish-green, growing in tufts. Stems to 2.5 cm long, simple, matted with rhizoids in the basal part and with numerous fragile buds among the apical leaves. Leaves erecto-patent, little altered on drying, 2.4 – 6.0 mm long and 0.4 mm wide, lanceolate-subulate; margins involute upwards and serrulate below tip; nerve occupying nearly one-half of leaf base and nearly filling the subula with one row of laminal cells on either side, in transverse section showing dorsal stereidal band below the row of guide cells; alar cells transparent, irregularly rectangular, up to 13 µm wide, not in differentiated auricles; basal laminal cells rectangular, 18 – 46 x 6 – 11 µm, thin-walled with the marginal row of narrow-rectangular or elongate-rhomboidal cells, upwards rectangular to rhomboidal, 12 – 15 x 4 – 6 µm. Setae terminal, 4.5 mm long, cygneous when moist. Capsules 0.6 mm long and 0.4 mm in diameter, ovoid. Rest not observed.

The numerous fragile buds among the comal leaves, falling apart just at the touch of the plant at the time of collection, facilitate easy determination of the species.

Specimen examined: Himachal Pradesh : Dalhousie 2000 m, on bases of Pinus trees in exposed situations, July, 1974 104S; Khasya, Herb. Hook; Uttaranchal : Chopta, 3200 m, on rocks, November, 1987. 4034; Rambara, Kedarnath, 2590 m, on rocks, September, 1987, *5100*.

Distribution: Himachal Pradesh, Darjeeling, Khasia Hills; Siberia, Europe, North Africa.

Chromosome number: 10, ca.12.

6. *Campylopus goughii* (Mitt.) Jaeg., Ber. S. Gall naturw.Ges. 1870-71. 424. 1872. (Fig.22)

Campylopus compactus Wils., Kew J. Bot. 9: 297. 1857. *nom. nud.*

Dicranum goughii Mitt., J. Linn. Soc. Bot. Suppl. 1:17. 1859.

Plants dark-green, growing in dense tufts. Stems to 2.5 cm long; branched, tomentose. Leaves erecto-patent, leaf tip flexuose on drying, to 6.0 mm long and 0.4 – 0.6 mm wide at base, gradually lanceolate-subulate from a concave base, subula canaliculate, denticulate near apex; margins inflexed in the upper portion; nerve 185 – 260 µm wide, occupying nearly one-half of the leaf base, in transverse section homogeneous; alar cells rust-coloured, not forming auricles; broadly quadrate to polygonal,to 22 µm wide; basal laminal cells rectangular, to 50 x 7 – 10 µm, at margins narrower, 4-5 µm wide, upwards short,

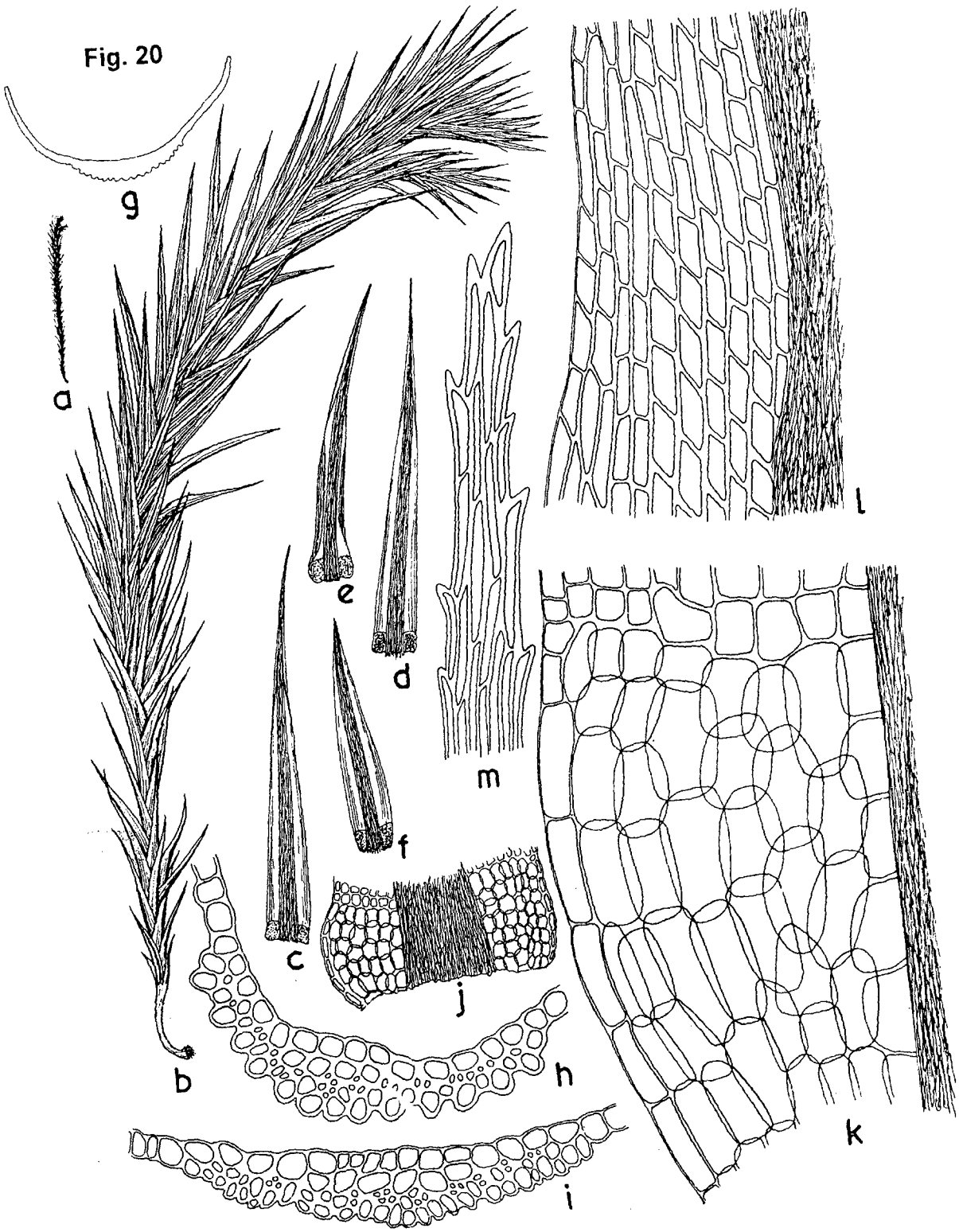

Fig. 20 : *Campylopus ericoides (Griff.) Jaeg.*
a. Plant x 3 b. Plant enlarged x 10; c.d.e,f. Leaves x 16; h,i. T. S. leaf x 495; j. Leaf base showing alar cells x 495. k. Alar cells enlarged x 495; i. Basal laminal cells x 495; m. Leaf apex x 495.

Fig. 21

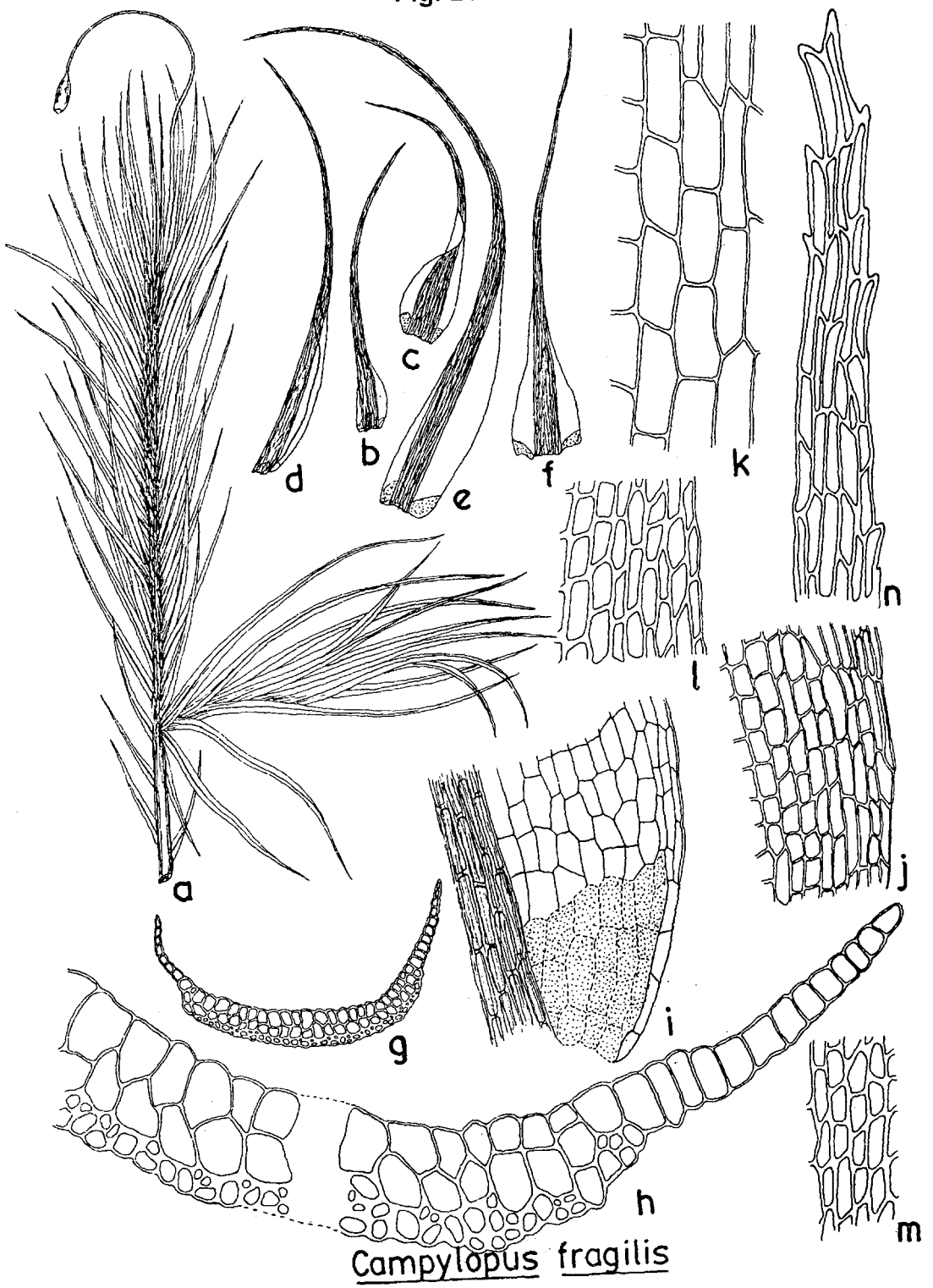

Fig. 21 : Campylopus fragilis (Brid.) B.S.G.
a. Plant x 10; b.c.d.e.f. Leaves x 26; g.h. T. S. Leaf x 495; i. Leaf Showing alar cells x 495; j. Laminal cells from margin inwards x 248; l. m. Median laminal cells x 495; n. Leaf apex x 495.

Fig. 22

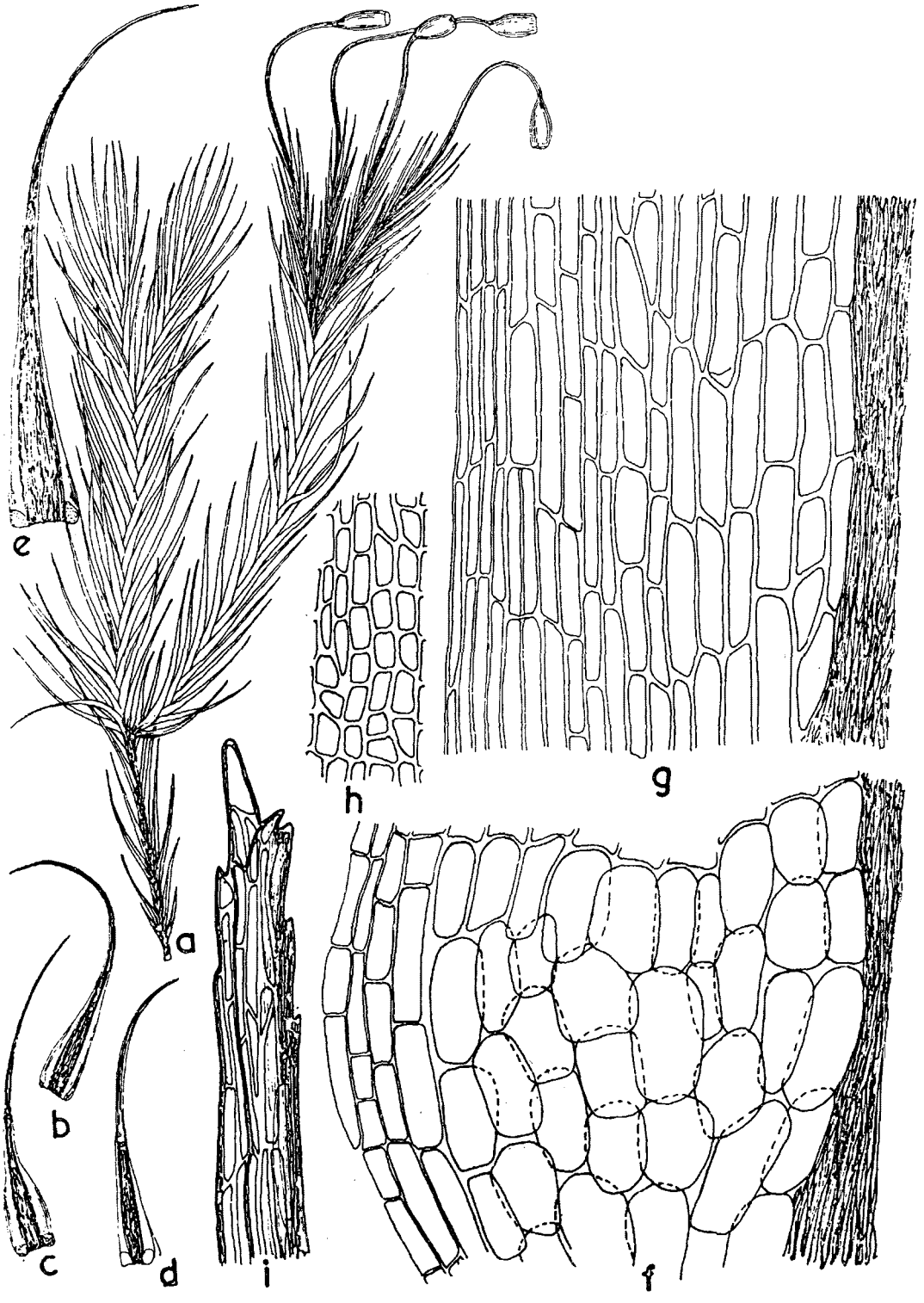

Fig. 22 : Campylopus goughii (Mitt.) Jaeg.

a. Plant x 10; b.c.d.e. Leaves x 26; f. Alar cells x 495; g. Basal laminal cells x 495; h. Median laminal cells x 495; i. Leaf apex x 495.

rhomoboidal, to 15 x 5 – 7 µm. Setae terminal, 4.0 – 6.0 mm long, cygneous when moist, straight when dry. Capsules reddish-brown, 1.4 mm long and 0.6 mm in diameter, ovate. Spores spherical, 12 - 15µm, asperately sculptured. Peristome, operculum, calyptra not observed.

Specimen examined: Himachal Pradesh : Shimla, Sanjoli road side, 1800 m, on rocks, September, 1966, *2059;* Uttaranchal : Didihat, Ghurpatta, 1350 m, on tree trunk, *3105.*

Distribution: Himachal Pradesh, Uttaranchal, Palni hills, Khasia hills, Darjeeling, Sikkim; Bhutan, Eastern Nepal; Srilanka.

Chromosome number: 11, ca.12

7. *Campylopus gracilis* (Mitt.) Jaeg., Ber. S. Gall. naturw. Ges. 1870-71 : 427. 1872. (Fig.23)

Dicranum gracile Mitt., J. Linn. Bot. Soc. Suppl. 1: 17. 1859.

Plants pale-green, growing in dense tufts. Stems to 1.7 – 3.0 cm long, branched. Leaves erecto-patent, hardly altered on drying, the lower ones to 1.0 mm long, upwards to 5.5 mm long and 0.5 mm wide at base, forming comal tuft at the stem tip, lanceolate-subulate from a widened basal part, subula canaliculate; margins inflexed, denticulate towards apex; nerve 0.25 - 0.27 mm wide, occupying up to two-third of the leaf base, nearly filling the subula above, lamina persisting only as a single row of elongate-rhomboidal to linear cells up to the leaf tip on either side of the nerve, in transverse section showing few narrow-lumined cells distributed between large-lumined ones below the row of guide cells, the upper epidermal cells distinctly larger than the cells of the lower epidermis, back faintly ridged; alar cells fragile, hyaline, forming auricles, irregularly rectangular to polygonal, to 15 µm wide; basal laminal cells irregularly rectangular, to 45 x 13 µm, thin-walled, in shoulders elongate-rhomboid to irregularly rectangular, 15 – 35 x 3 – 5 µm, the median ones rectangular to sub-rectangular, 7 – 16 x 6 – 8 µm, the upper ones narrower, rhomboidal, 13 – 15 x 3 – 4 µm. Sporophyte not observed.

Specimen examined: Himachal Pradesh : Shimla, Glen, 1800 m, on rocks, September, 1966, *2057; 2087;* Uttaranchal : Kumaon, 2200 m, February, 1898, *49* (BM), Nainital, 2300 m, on rocks, October, 1972, *2248.*

Distribution: Himachal Pradesh, Uttaranchal, Manipur, Darjeeling, Sikkim; Eastern Nepal, Myanmar, Thailand, China.

Chromosome number: n = 13

8. *Campyloplus laetus* (Mitt.) Jaeg., Ber. S. Gall. naturw. Ges. 1870-71 : 424. 1872. (Fig.24)

Dicranum laetum Mitt., J. Linn. Soc. Bot. Suppl. 1 : 19. 1859.

Plants light - green to yellowish-green, growing in dense tufts. Stems to 4.5 cm long, branched, radiculose in the basal portion. Leaves erecto-patent, erect-appressed on drying, to 5.0 mm long and 0.7 – 0.8 mm wide at base, lanceolate, gradually narrowing from an ovate, non-auriculate basal part into a tubulose subula; margins inflexed, denticulate in the apical part due to projecting cell ends; nerve 0.34 – 0.37 mm wide, occupying nearly one-half of the leaf base and nearly filling the subula above, in transverse section showing stereids above and below the median row of guide cells, back ridged; alar cells hyaline, not forming auricles, polygonal to hexagonal, 10 – 15 µm wide, thin-walled; basal laminal cells irregular, rectangular to elongate-rhomboidal, adjoining the nerve to 48 x 10 – 12 µm, towards margins narrower, at margins (2-3 rows) elongate, to 45 x 4 – 5 µm, the median and the upper ones rhomboidal to obliquely oval, to 18 x 4 – 6 µm, incrassate. Sporophyte not observed.

Specimen examined: Uttaranchal : Mussoorie, Lal Tibba, 2200 m, on rocks, September, 1976, *1104K;* Nainital, on soil gathered on rocks, August, 1977, *2822.*

Distribution: Uttaranchal, Darjeeling, Sikkim, Palni hills, Western Ghats; Eastern Nepal, Myanmar.

Chromosome number : n = 12 (11 + m)

9. *Campylopus oedicaulis* C.Muell.

Campylopus oedicaulis C.Muell. *in* Par., Ind. Bryol.Suppl. 95. 1900 *nom. nud.* (Fig.25)

Plants light-brown when dry, growing in loose tufts. Stems to 1.8 cm long, branched. Leaves erecto-patent, little altered on drying, the lower ones 2.0 – 3.0 long, from middle upwards 4.0 – 5.0 mm long and ±120 µm wide at base, oblong-lanceolate with bunch of rhizoids at base, gradually narrowed from widened basal portion, apex sub-acute; margins incurved, toothed in the apical part; nerve occupying nearly one-half to three-fifth of the leaf base, in transverse section showing a median row of guide cells with interrupted groups of stereids below; alar cells brown, in differentiated auricles; basal laminal cells irregularly rectangular, 12 – 45 x 7 – 12 µm, the median ones narrow-oval to elongate-rhomboidal, 12 – 15 x 2 – 4 µm, the upper ones relatively wider, rhomboidal. Sporophyte not observed.

Specimens examined: Uttaranchal :Nainital, 2300 m, on stones, October, 1970, *2250.*

Fig. 23

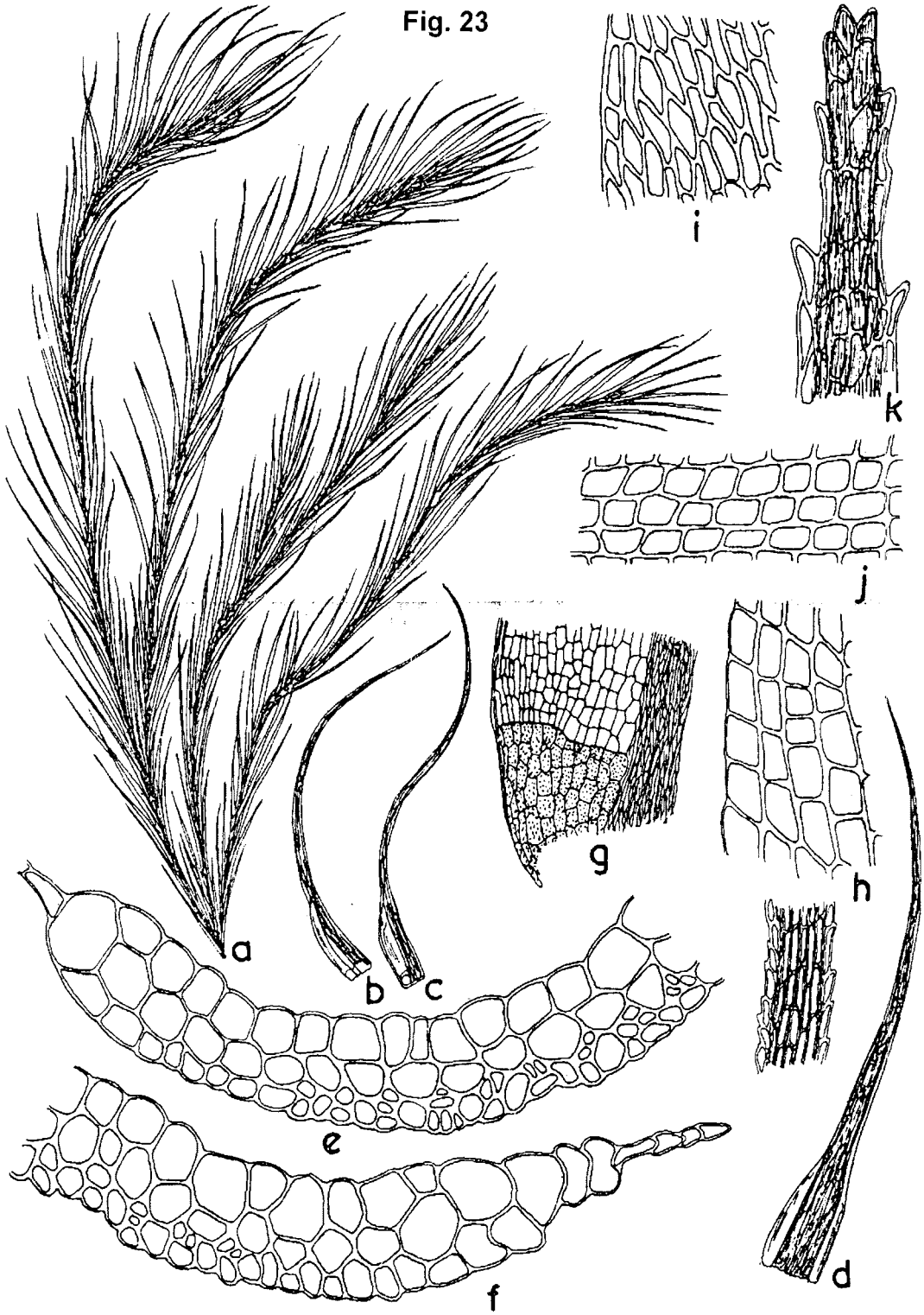

Fig. 23 : Campylopus gracilis (Mitt.) Jaeg.
a. Plant x 10; b.c.d. Leaves x 26; e.f. T. S. leaf x 495; g. Leaf base showing alar cells x 495; h. Basal laminal cells x 495; i. Upper laminal cells x 495; j. Median laminal cells x 495; k. Single row of laminal cells at margins in the apical part of leaf x 495.

Fig. 24

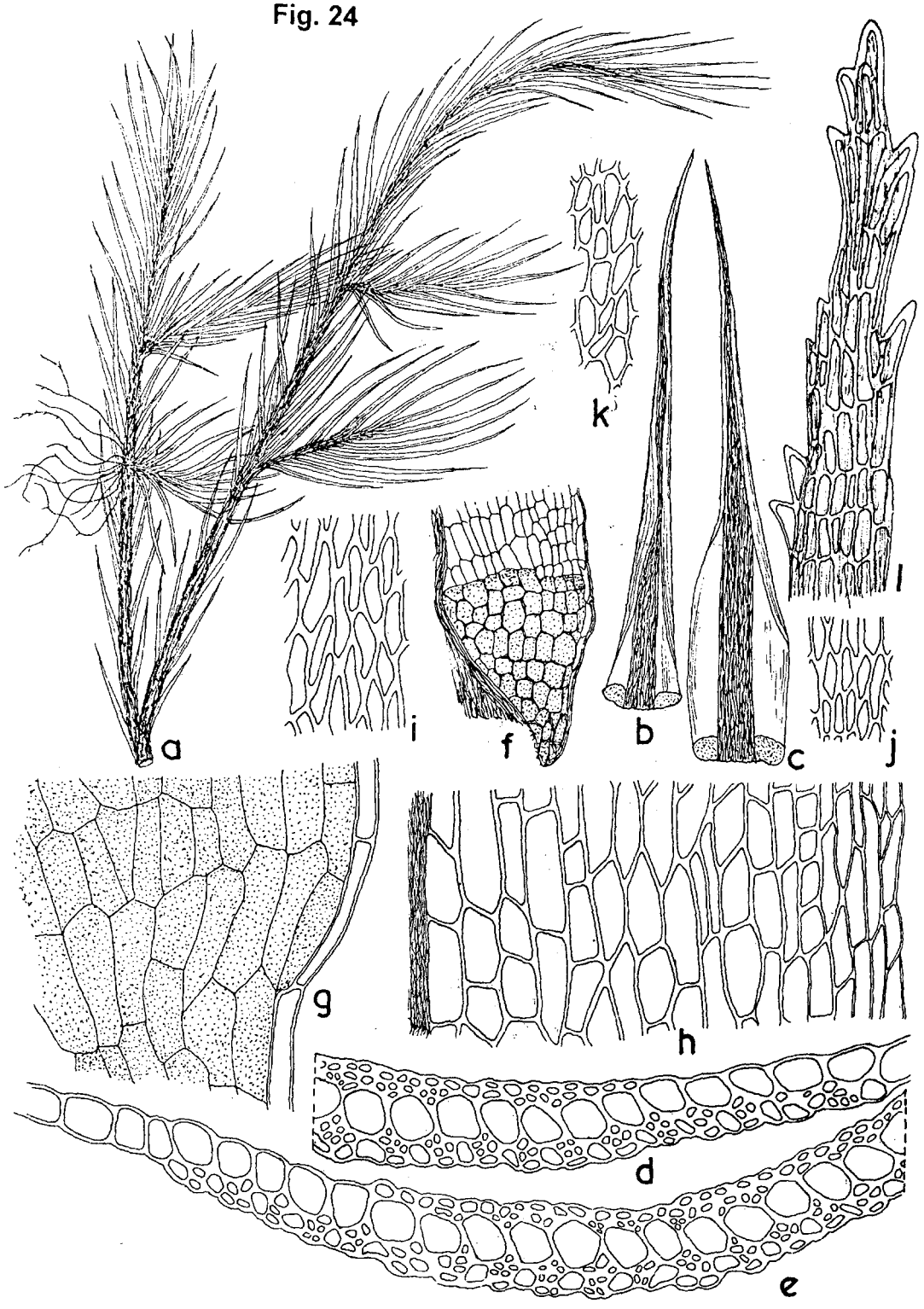

Fig. 24 : Campylopus laetus (Mitt.) Jaeg.

a. Plant x 10; b.c. Leaves x 26; d.e. T. S. leaf x 495; f. Leaf base showing alar cells x 248 g. Alar cells enlarged x 495. h. Basal laminal cells x 495; i.j. Median laminal cells x 495; k. Upper laminal cells x 495; l. Leaf apex x 495.

Fig. 25

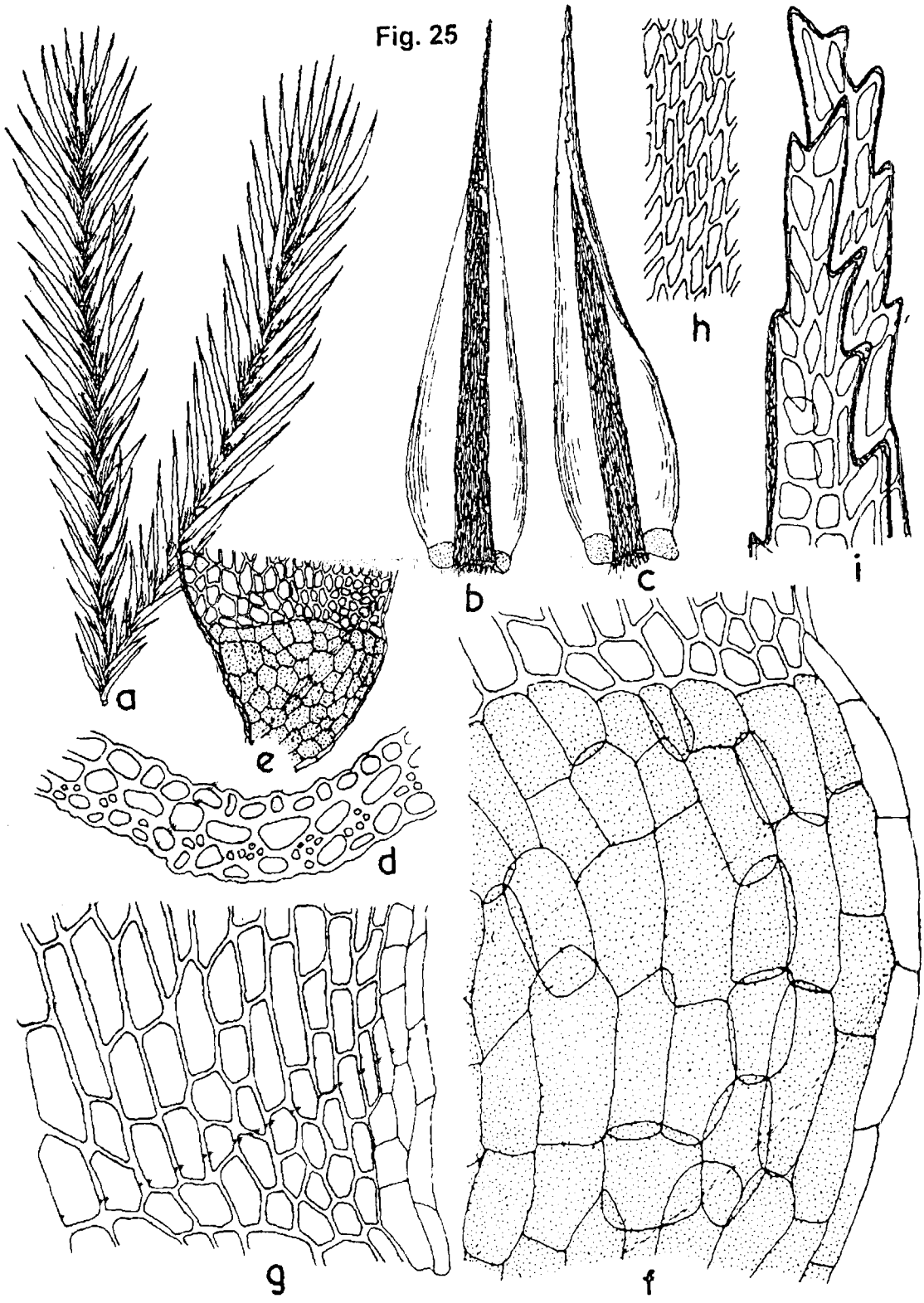

Fig. 25 : Campylopus Oedicaulis C. Muell.
a. Plant x 10. b.c. Leaves x 26. d. T. S. leaf narve x 495. e. Leaf base showing alr cells x 248. f. Alar cells enlarged x 495. g. Basal laminal cells x 495. h. Median laminal cells x 495. i. Leaf apex x 495.

Distribution: Western Himalaya.

Chromosome number: Not known

10.*Campylopus richardii* Brid., Mant. Musc. 73. 1819. (Fig. 26)

Campylopus exasperatus ((Nees *et* Blum.) Brid., Bryol. Univ. 1: 473.1826.

Campylopus nigrescens (Mitt.) Jaeg., Ber. S. Gall. Naturw. Ges. 1870-71 : 417. 1872. *hom.illeg.*

Campylopus umbellatus (Arnott) Par., Ind. Bryol. 264. 1894.

Dicranum nigrescens Mitt., Jour. Linn. Soc. Bot. Suppl. 1: 19. 1859.

Grimmia richardii (Brid.) Spreng., Syst. Veg. 4(1) : 154. 1827.

Pilopogon exasperatus (Nees et Blum.) Broth., Nat. Pfl. 1(3) : 336. 1901.

Pilopogon nigrescens (Mitt.) Broth., Nat. Pfl. 1(3) : 336. 1901

Pilopogeon richardii (Brid.) Broth., Nat. Pfl. 1(3): 336. 1901.

Thysanomitrion blumei (Doz. *et* Molk.) Card., Annuair. Cons. Jard. Bot. Geneve 15-16 : 161. 1912.

Thysanomitrion exasperatum (Nees et Blum.) Reinw. et Hornsch. Nov. Act. Ac. Leop. Car. 14(2) : 704. 1829.

Thysanomitrion nigrescens (Mitt.) P. Vard., Rev. Bryol. 49 : 40. 1922.

Thysanomitrion richardii (Brid.) Schwaegr., Spec. Musc. Suppl. 2(1) : 61. 1823.

Thysanomitrion umbellatum Schwaegr. *et* Gaud. *ex Arnott,* Mem. Soc. Linn. Paris 5: 263. 1827.

Trichostomum blumei Doz. et Molk., Ann. Sci. nat. Bot. Ser. 3, 2: 316. 1844.

Trichostomum exasperatum Nees *et* Blum., Nov. Act. Ac. Leop. Car. 11(1) : 134. 1823.

Trichostomum umbellatum (Arnott) Schwaegr. *in Gaud. in* Freyc., Voyag. Aut. Mond. Oranie Phys. 224. 1828.

Plants dark-green to pale-green, growing in dense tufts. Stems reddish, tomentose below, to 3.0 cm long, branched. Leaves erecto-patent, little altered on drying, the lower ones 2.5 – 3.2 mm long, upwards to 5.0 mm long and 0.4 – 0.6 mm wide, oblong-lanceolate from an auriculate base, apex long-acuminate or hair-pointed particularly in the perichactial leaves, hair-points hyaline, serrulate; margins inflexed in the upper part; nerve 0.2 – 0.3 mm wide, occupying nearly one-half of the leaf base, excurrent, in transverse section showing stereids above and below the median row of guide cells, back lamellose, lamellae up to 15, each 3-4 cells high; alar cells brown, inflated, in differentiated auricles, polygonal, to 25 µm wide; basal laminal cells, adjoining the nerve (3-4 rows), rectangular with oblique cross walls, to 38 x 12 – 15 µm, towards margins elongate-rhomboidal to obliquely oval, 17 – 22 x 5 – 8 µm, upwards progressively narrower, rhomboidal to obliquely oval, 10 – 18 x 2 – 5 µm, strongly incrassate. Sporophyte not seen.

This species is distinguished from other West Himalayan species of *Campylopus* Brid. by the hair-pointed leaves and the densely lamellose nerve back.

Specimen examined: Uttaranchal : Mussoorie, Nag Tibba, 3300 m, on rocks, September, 1976, *2007*; Pandukeswar, 1850 m, on rocks, November, 1987. *4035.*

Distribution: Uttaranchal, Darjeeling, Nilgiri and Palni Hills, Sikkim; Srilanka, Myanmar, Sumatra to Celebes, Borneo, Newguinea, Phillipines, China, Japan, Hawai. Ann. 2 – 6 and Oc.

Chromosome number: n = 11

4. *Dicranodontium* B.S.G., Bryol. Eur. 1: 159. 1847.

Plants pale-green, growing in dense silky tufts. Stems simple or branched, tomentose. Leaves deciduous, falcate-secund, setaceous from lanceolate basal part with or without widened auricles, upwards tubular-concave; nerve broad, filling the subula, in transverse section showing a median row of guide cells, a ventral - and a dorsal – stereidal band; alar cells fragile, hyaline, red – or rust-coloured, mostly inflated; basal laminal cells rectangular, broader towards the nerve, narrower towards margins forming a distinct border, upwards linear, incrassate. Setae at first cygneous, later erect or tortuous. Capsules erect, symmetric, oblong to ovoid-cylindric, exannulate; stomata absent. Peristome teeth 16, each tooth inserted below the mouth, divided nearly to the base, mostly vertically striate below and papillose above. Calyptra cucullate, entire.

Lectotype: *Dicranodontium longirostre* (Web. et Mohr) B.S.G. (= *D. denudatum* (Brid.) Britt.)

This genus agrees with *Dicranum* in habit and in the entire nature of the calyptra. It differs from the latter genus in its wider nerve, the bordered leaf margins, and the non-pitted-porose laminal cell walls. It resembles *Campylopus* in the deciduous nature of the leaves, the broad nerve and the shape of the capsules. The laminal cells, however,

Fig. 26

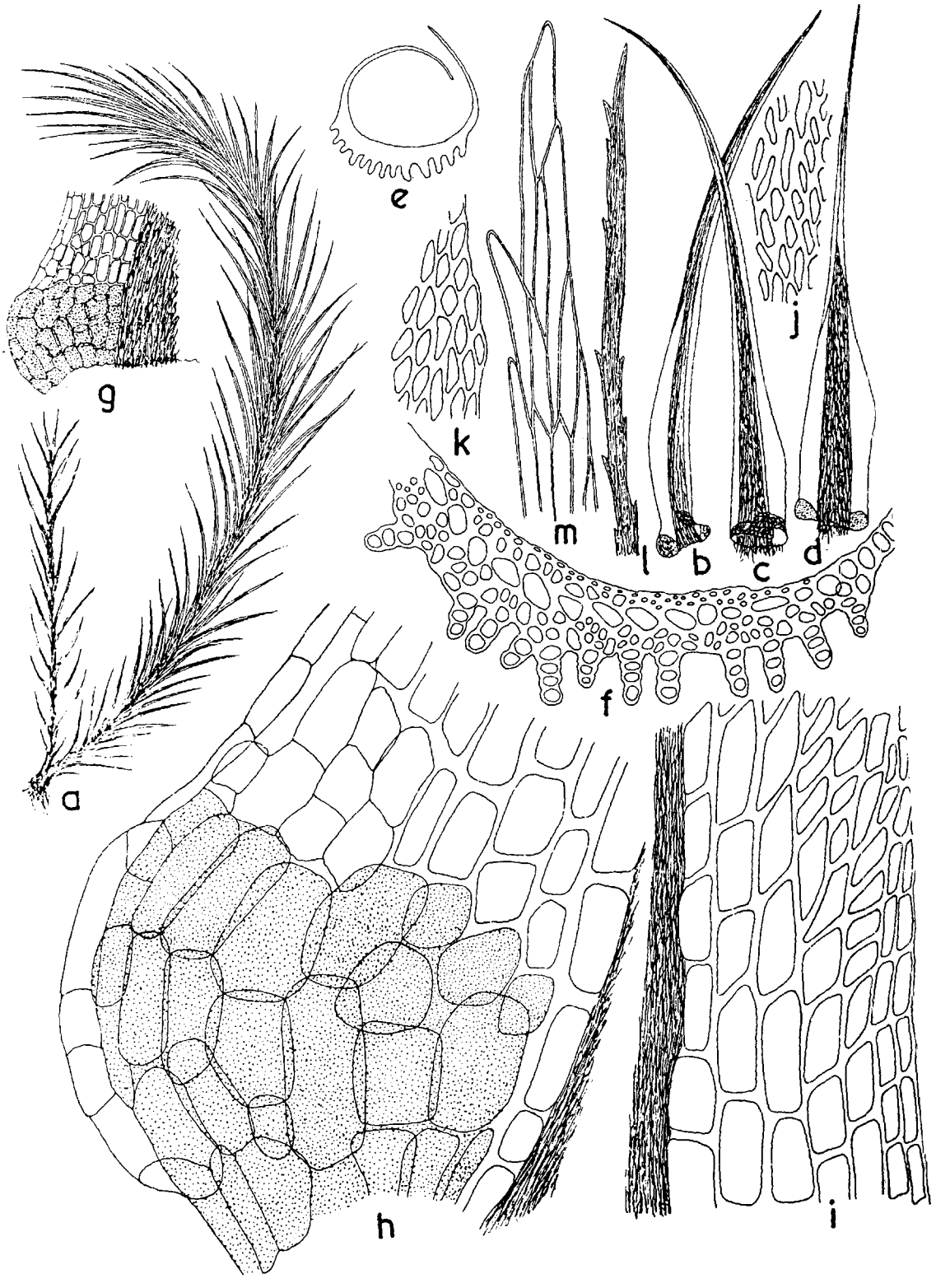

Fig. 26 : Campylopus richardii Brid.
a. Plant x 10. b.c.d. Leaves x 26. e. T. S. leaf x 495. f. T. S. leaf nerve enlarged x 495. g. Leaf base showing alar group x 248. h. Alar cells enlarged x 495. i. Basal laminal cells x 495. j. Median laminal cells x 495. k. Upper laminal cells x 495.

are linear in *Dicranodontium*, but rhomboid to short-rectangular in *Campylopus*. The peristome in *Dicranodontium* is more highly evolved than that of the other two genera.

Cytologicaly, this genus is known from one species only i.e. *Dicranodontium denudatum* (Brid.) Britt. *ex* Williams - n = 11, 11-12, 13 (12+m). This data is insufficient to comment on its cytological relationship with *Campylopus* Brid. and *Dicranum* Hedw., with which it shows similarity in some morphological characters.

Dicranodontium contains 39 species with maximum concentration in Asia. In our country, this genus is represented by 13 species (including 3 with manuscript names), of which only 4 are found in our area.

Key to the West Himalayan species of *Dicranodontium* B.S.G.

a. Leaf margins entire throughout...**1. *D. attenuatum***

Leaf margins serrulate, at least in the apical part.....b

b. Alar cells in differentiated auricles...**3.*D.denudatum***

Alar cells not in differentiated auricles.....c

c. Leaves to 11.0 – 15.0 mm long;leaf margins (at base) bordered by 8-10 rows of linear, strongly incrassate cells.....**4.*D.didictyon***

Leaves to 7.0 mm long; leaf margins (at base) bordered by 3-4 rows of thin-walled cells.....**2.*D.caespitosum***

1.*Dicranodontium attenuatum* (Mitt.) Wils. *ex* Jaeg., Ber. S. Gall. naturw. Ges. 1877-78. 380. 1880. (Fig.27)

Dicranum attenuatum Mitt., J. Linn. Soc. Bot. Suppl. 1:22. 1859.

Plants pale-green, yellowish-brown when dry, growing in tufts. Stems 2.0 – 2.5 cm long, mostly simple. Leaves erecto-patent, the lower ones 3.0 – 5.0 mm long, upwards 8.0 – 9.0 mm long and 0.5 mm wide, in comal tufts at apex, lanceolate-subulate with a broadly oblong basal part narrowed into canaliculate subula; margins entire; nerve occupying three-fourth of the leaf base, completely filling the subula above, excurrent into a short tooth at apex, in transverse section, showing a median row of guide cells, a dorsal – and a ventral – stereidal band; alar cells hyaline or rust-coloured, relatively fewer, inflated, polygonal, 8-9 µm wide, not in differentiated auricles; basal laminal cells, adjoining the nerve, to 32 x 12 µm, at half way towards margins rectangular, 25 -28 x 10 µm, incrassate, at margins (5-6 rows) narrow-rectangular to rhomboidal, 3-5 µm wide, thin-walled and forming a distinct border, the median ones sub-rectangular to quadrate. Setae flexuose when moist, 1.2 -1.25 cm long. Capsules ovoid-elliptic, 0.6 mm in diameter. Rest not observed.

This species is easily distinguished from other West Himalayan species of this genus by the erecto-patent leaves, the entire leaf margins, and the relatively fewer alar cells.

Specimens examined: Himachal Pradesh : Khadrala, 3400 m, on rocks, September, 1971, *1284*; Sikkim (Lachen), 3300 m, Herb. Or Hook. filet. Thoms *78b* (BM).

Distribution: Himachal Pradesh, Uttaranchal, Darjeeling, Sikkim; Bhutan. Endemic in the Himalaya.

Chromosome number: Not known.

2. *Dicranodontium caespitosum* (Mitt.) Par., Ind. Bryol. 337. 1896. (Fig. 28)

Plants yellowish-brown (dry), growing in dense tufts. Stems 1.5 – 2.0 cm. long, simple or branched. Leaves falcate-secund, little altered on drying, to 6.0 mm long and 0.5 mm wide, lanceolate-subulate from a widened, auriculed basal part; margins serrate in the apical part; nerve 0.33 mm wide at base, occupying nearly two-third of the leaf base and completely filling the subula; alar cells brown, fragile, inflated, polygonal, to 12 µm wide; basal laminal cells rectangular, to 37 x 10 µm, the median ones narrower, 30 – 37 x 5 – 8 µm, the marginal ones (3 – 5 rows) linear to narrow-rectangular with oblique cross walls forming a distinct border. Sporophyte not observed.

Specimen examined: Assam : Shillong, 1600 m, November, 1912, Herb. H.N. Dixon, 5 (BM).

Distribution: Western Himalaya, Assam, Darjeeling, Sikkim; Eastern Nepal, Yunan.

Chromosome number: Not known.

3. Dicranodontium denudatum (Brid.) Britt. *in* Williams, N. Am. Fl. 15: 151. 1913. (Fig. 29)

Dicranum denudatum Brid., Spec. Musc. 1 : 184. 1806.

Plants pale-green, in dense tufts. Stems 3.0 - 3.5 cm long, branched, radiculose in the basal part and also at base of the leaves. Leaves deciduous, falcate, 6.0-8.0 mm long and 0.5 cm wide, linear-lanceolate from an oblong basal part, gradually narrowing into a setaceous-tubulose point; margins serrulate in the apical part; nerve strong, occupying one-third to one-half of leaf base, excurrent; alar cells in widened auricles, hyaline, inflated, 10-13 µm

Fig. 27

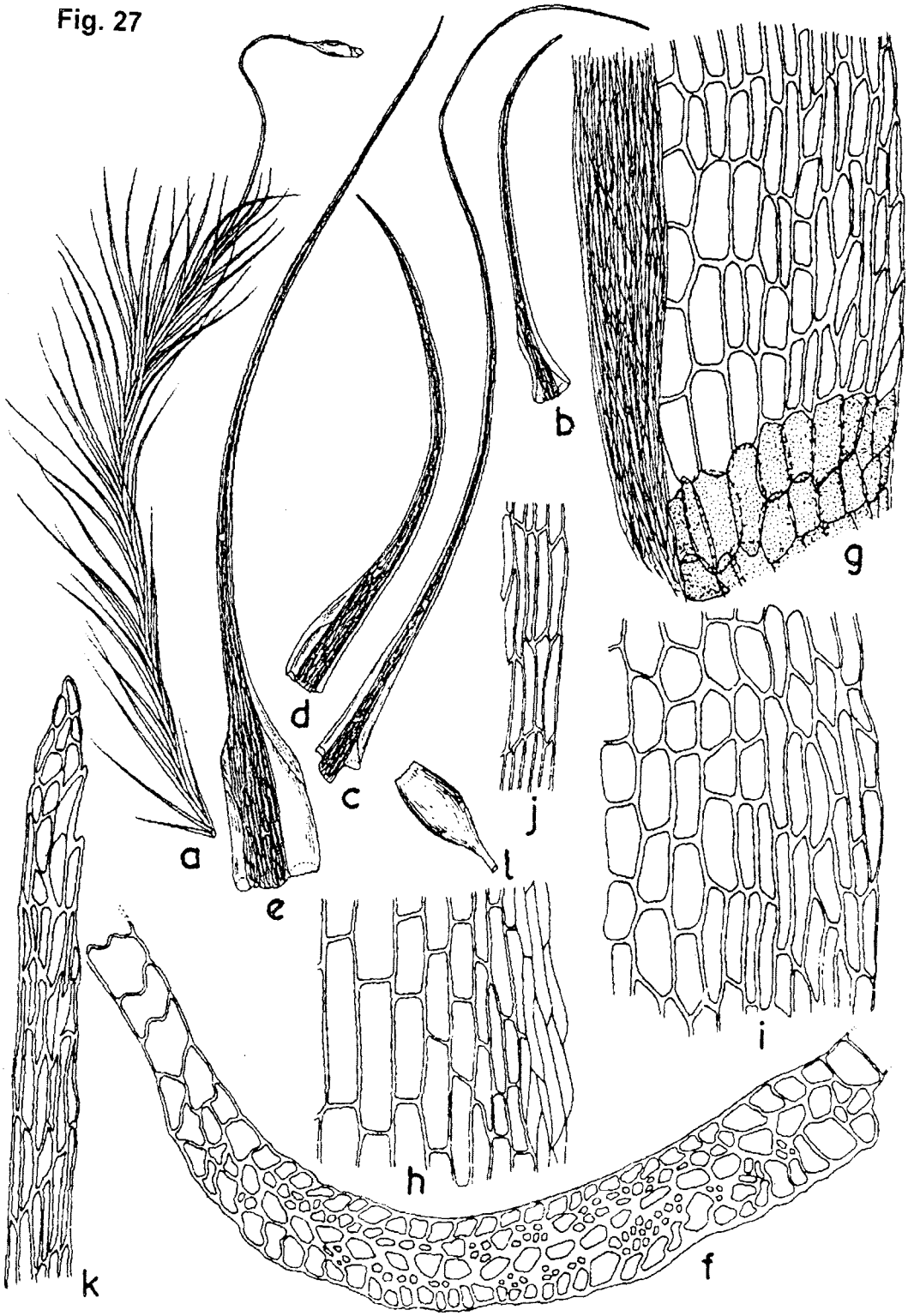

Fig. 27 : Dicranodontium attenuatum (Mitt.)
a. Plant x 6; b.c.d.e. Leaves x 19; f. T. S. Leaf x 475; g. Leaf base showing alar cells x 475; h. Basal laminal cells x 475; i. Median laminal cells x 475; j. Upper laminal cells x 475; k. Leaf apex x 475.

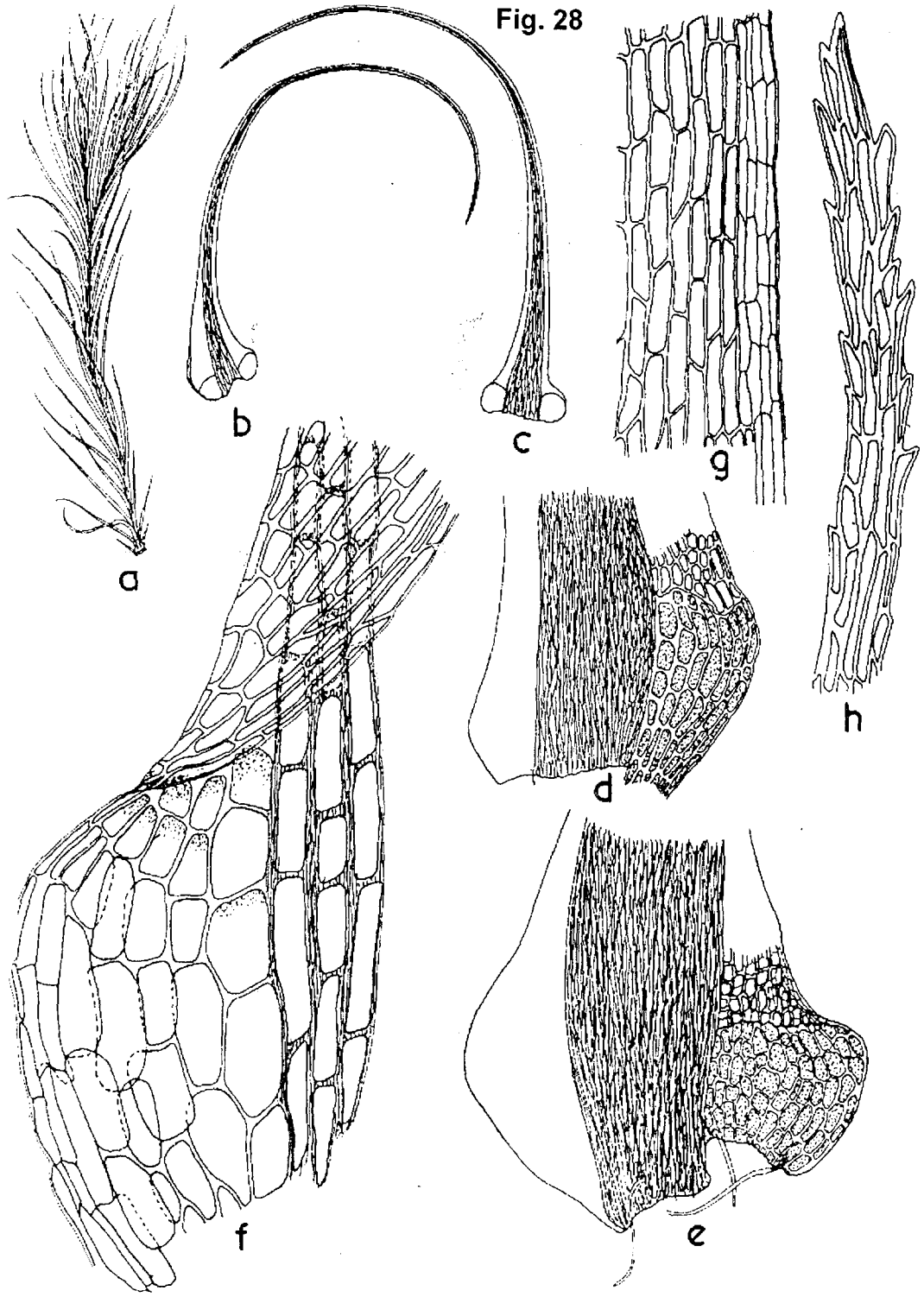

Fig. 28 : Dicranodontium denudatum (Mitt.) Par.
a. Plant x 6; b,c. Leaves x 20; d,e. Leaf base showing alar cells x 248; f. Leaf base enlarged x; g. Median laminal cells x 510; h, Leaf apex x 510.

Fig. 29

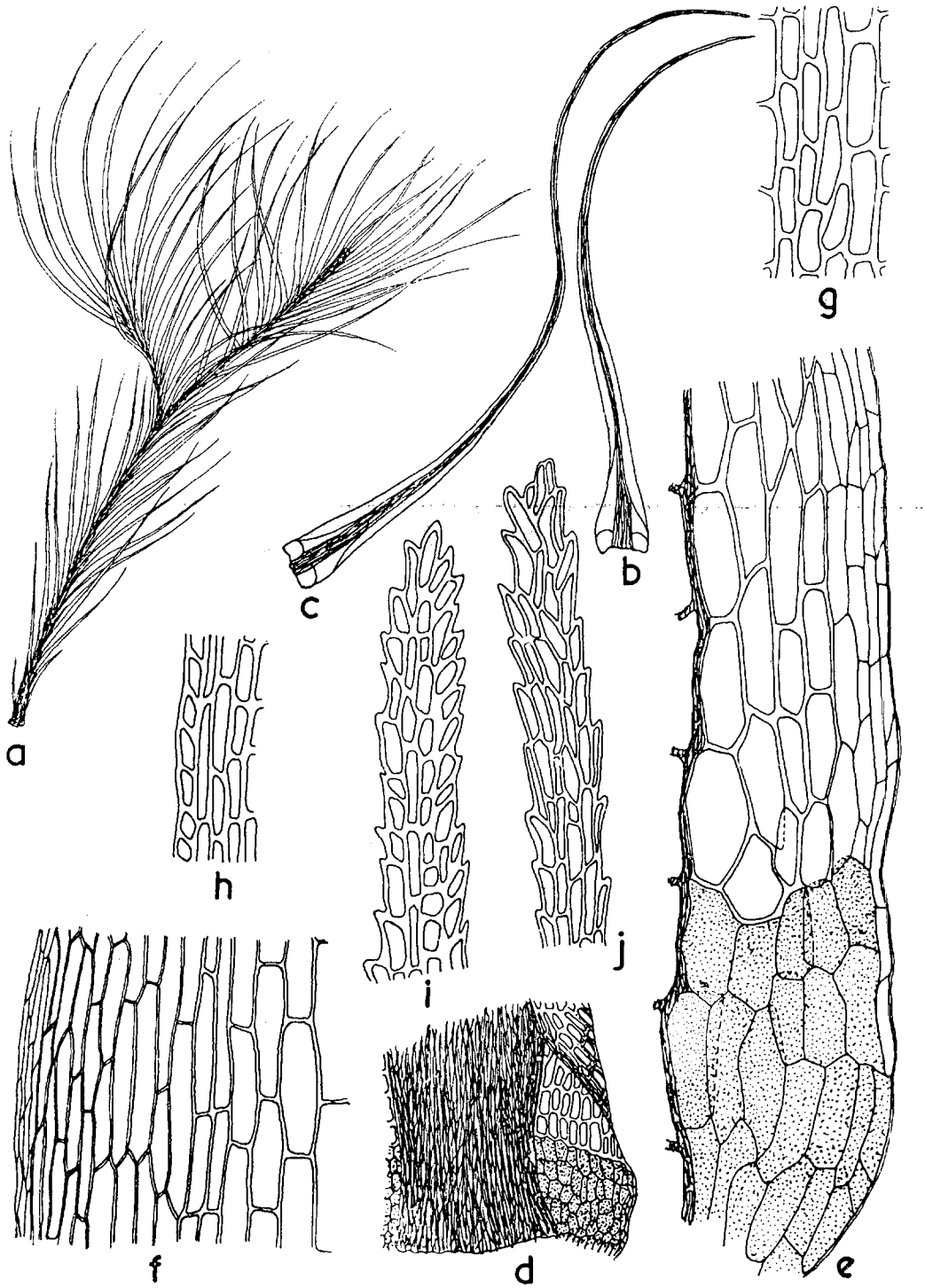

Fig. 29 : Dicranodontium caespitosum (Brid.) Brit.
a. Plant x 6; b,c. Leaves x 20; d. Leaf base showing alar cells x 248; e. Alar cells enlarged x 495; f. Basal laminal cells x 495; g,h. Median Laminal cells x 495; i,j. Leaf apex x 495.

wide; basal laminal cells rectangular to polygonal, to 43 x 5-7 μm, at margins (3-4 rows) elongate, linear, forming a border, the median ones rectangular, 22-28 x 6-8 μm, the upper ones shorter, 10-12 x 3-4 μm. Sporophyte not observed.

Specimens examined: Kashmir : Jaunsar, October, 1894, **22** (BM); Uttaranchal : Mussorie, 2200 m, on wet soil gathered on rocks, September, 1950, *200;* Himachal Pradesh : Dharmsala, 2170 m, on wet rocks, October, 1977, *2821.*

Distribution: Kashmir, Himachal Pradesh, Uttaranchal, Darjeeling, Sikkim; Eastern Nepal, China, Siberia, Japan, Europe, North America, Central America, South America.

Chromosome number: n = 11, 11-12, 13 (12 + m)

4. *Dicranodontium didictyon** (Mitt.) Jaeg., Ber. S. Gall. Naturw. Ges. 1877-78. 380.1880. (Fig.30)

Dicranum didictyon Mitt., J. Linn. Soc. Bot. Suppl. 1: 21. 1859.

Plants (dry) pale-green, in tufts. Stems 2.0-3.5 cm long, mostly simple. Leave falcate-secund, 1.1-1.3 cm long and 0.4 - 0.5 mm wide at base, lanceolate-subulate with a widened, slightly auriculate basal part; margins serrulate towards leaf tip; nerve ± 224 μm wide, occupying one-third to one-half of leaf base, excurrent, serrulate at back near apex; alar cells fragile, hyaline, inflated, 10 - 14 μm wide; basal laminal cells, adjoining the nerve, polygonal to rectangular, to 63 x 7-9 μm, towards margins narrow-rectangular to linear, to 42 x 3-4 μm, strongly incrassate, the median ones to 55 x 14-16 μm, the upper ones shorter, 8-12 x 3-4 μm. Sporophyte not observed.

Specimen examined: Myanmar, Nettoung, 2200 m, March, 68, *2877* Herb. Hampe.

Distribution: Western Himalaya, Darjeeling, Sikkim; Myanmar, Japan.

Chromosome number: Not known.

5.*Aongstsroemia* B.S.G., Bryol. Eur. 1:171.1846.

Plants small, yellowish whey dry. Stems simple, or branched, slender, julaceous. Leves small, appressed with the stem, ovate to ovate-oblong, apex acute, acuminate or rounded - obtuse, margins crenate due to projecting cell ends; nerve ceasing below or far below the apex; laminal cells rhomboidal to oval, thick-walled, smooth, towards base elongate, towards margins relatively shorter. Setae straight. Capsules erect, ovoid to cylindric. Peristome present or absent, when present, inserted below the mouth, mostly split, sometimes perforate.

Lectotype : *A. longipes* (Solms.) B.S.G.

Once familiar, the members of this genus are easily recognized by the slender, julaceous stems, bearing small leaves which, excepting their tip portion, are erect appressed to the stem.

This genus has not received any cytological attention so far.

Aongstroemia includes 15 species, of which only two i.e. *A.orientalis* Mitt.; *A.julacea* (Hook.) Mitt. are recorded from India. In our area, this genus is represented by only one species i.e. *A.orientalis* Mitt.

Aongstroemia orientalis Mitt., Trans. Linn. Soc.Bot.ser. 2,3 : 154. 1891. (Fig.31)

Anomobryum uncifolium Broth., Philipp.J. Sci. 5 : 146. 1909.

Plants yellowish-brown when dry. Stems mostly branched, 5.0 - 5.5 mm long, slender, julaceous. Leaves appressed to the stem, homomallus towards shoot apex, the middle ones 0.5 - 0.6 mm long and 0.3 mm broad, ovate, apex split, rounded-obtuse or obtuse; margins plane, crenate above due to projected cell ends; the upper ones (perichaetial) to ±2.1 mm long, subulate with a long, wide basal portion, subula nearly 1/3 of leaf length; nerve stout, 75 - 80 μm wide at base, ending below the leaf apex, in T.S. heterogeneous with stereids enclosed between the upper and the lower epidermis; basal laminal cells, beside the nerve, broad, sub-rectangular, towards margins (2 rows) shorter; the median ones rhomboidal to elongate, 8 - 12 x 3 - 5 μm. The upper one rhomboidal to oval, 8 - 10 x 3 - 5 μm, cells in the marginal row oval, obliquely placed, 5 - 8 x 3 - 5 μm, thick - walled. Setae apical, 1.0 cm long. Capsules slightly inclined, 1.6 mm long and 0.4 - 0.5 mm in diameter, cylindrical. Annulus and peristome lacking. Spores spherical 13 -17 μm asperately sculptur

Specimen examined: Western Himalaya (Milten's type bell 164, Herb. NY, U.S.A.).

Distribution : India (Himalaya); China, Burma, Taiwan, Japan, Philippines, Borneo, Central America.

Chromosome number : Not known.

6.*Anisothecium* Mitt.,J. Linn. Soc. Bot. 12 : 39. 1869.

Plants light-green to dark green, growing in tufts. Leaves squarrose to patent, lanceolate with wider basal portion or ovate-lanceolate; basal laminal cells wide-rectangular,

*Since the native material was not available, the description is based on the material from Myanmar.

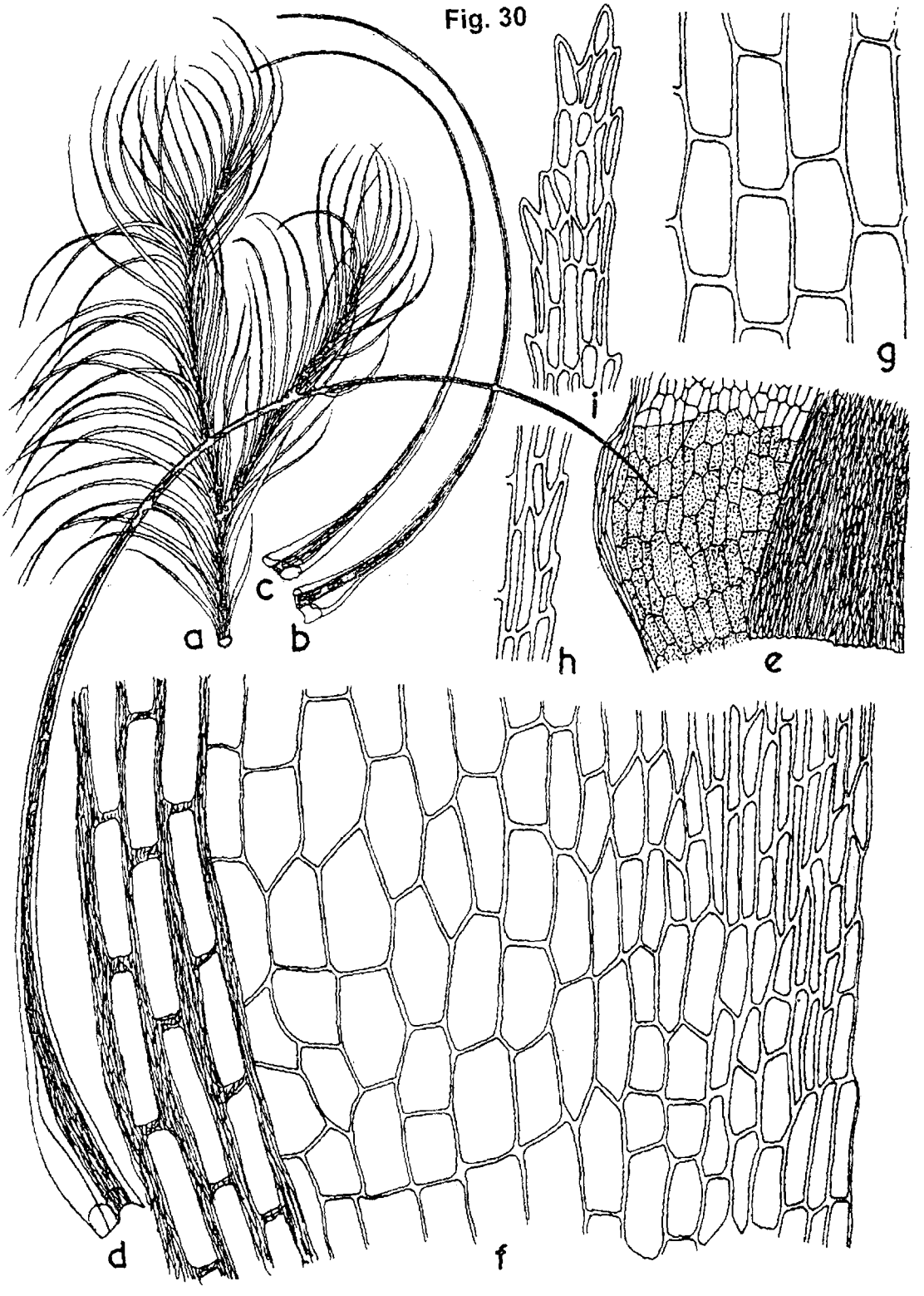

*Fig. 30 : **Dicranodontium didictyon (Mitt.) Jaeg.***
a. Plant x 6. b.c.d. Leaves x 20. e. Leaf base showing alar cells x 248. f. Basal laminal cells x 495. g. Basal laminal cells enlarged x 495. h. Median laminal cells at margins x 495. i. Leaf apex x 495.

Fig. 31

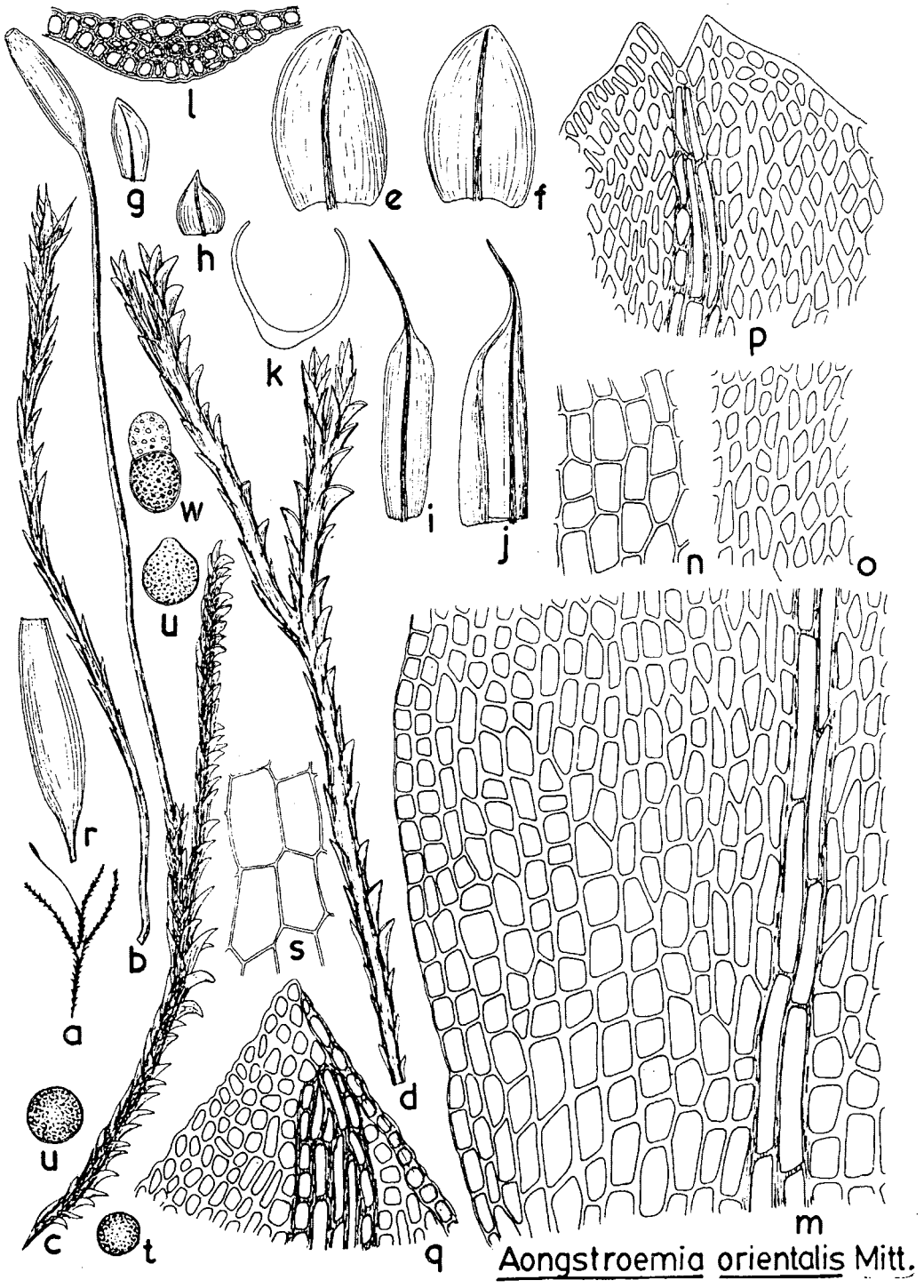

***Fig. 31. Aongstroemia orientalis* Mitt.**

a. Plant x ; b. Plant x 2 ; c,d. Plant with sporopohyte & Plants without sporophyte x 10; e,f. Middle leaves x 20; g,h. Basal leaves x 20 ; I,j. Perichaetial leaves x 20; k. outline of ; T.S. nerve x; T.S. nerve x 495; m. Basal laminal cells x 495 ; n x 495; o. Median laminal cells x 513 ; p,q cells in the apical part of the leaf x 495 ; r. Capsule x ?0 ; s. Exothecial cells x 495t, u. Spores x 495; v, w. germinating spores x.

Fig. 32

Fig. 32A

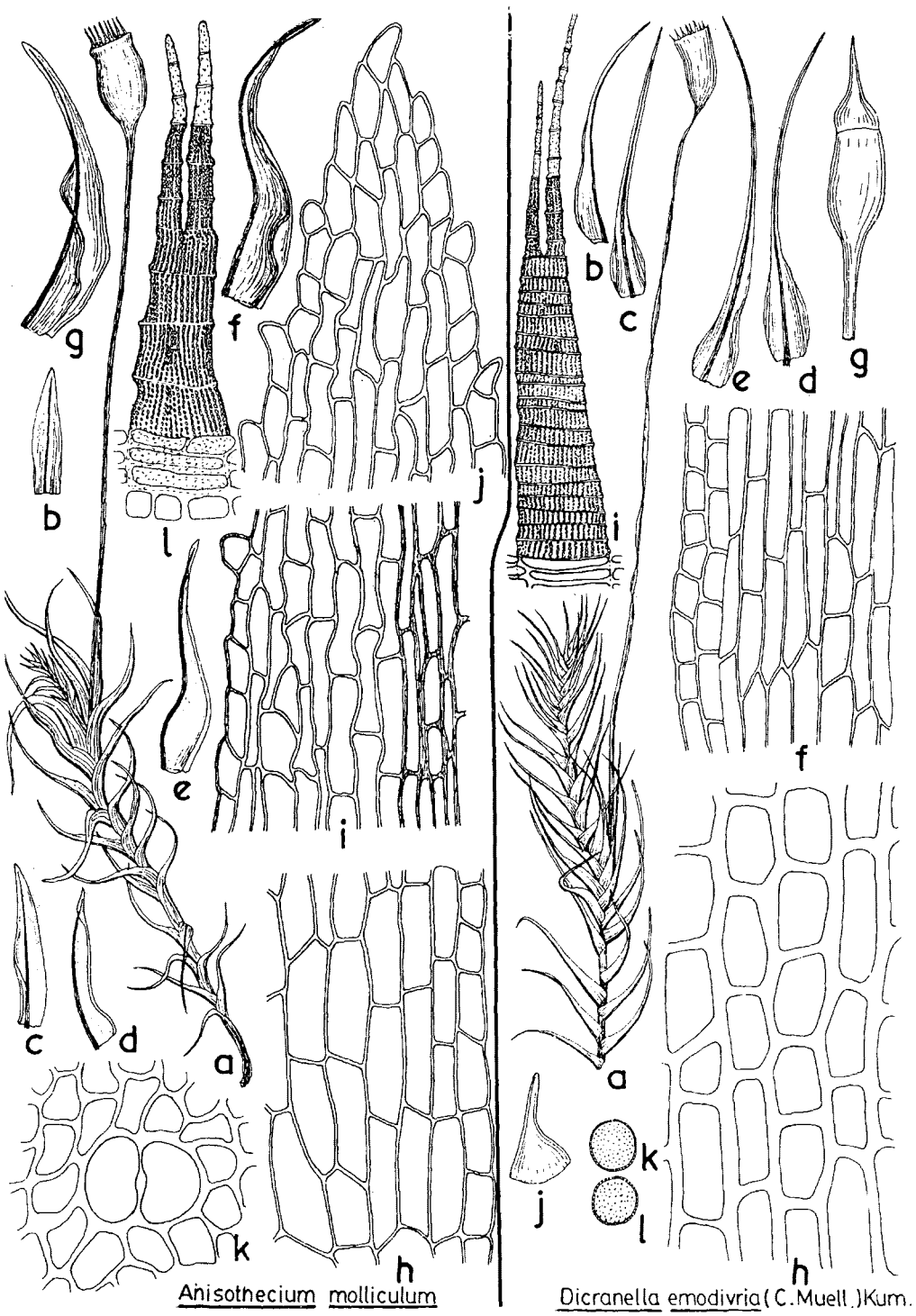

Fig 32. Anisothecium molliculum (Mitt.) Broth. – a Plant x10; b,c,d. Lower leaves x 19; e,f,g. Middle and upper leaves x 19; h. Basal laminal cells x 475; i, Median laminal cells x 475; J. cells in the apical part of the leaf x 475 k.Stoma x 475; l. Peristome tooth x 225.

Fig. 32A. Dicranella emodivaria C.Muell. *nom.* nud. a. Plant x 10; b. Lower leaf x 19; c,d,e. Middle and upper leaves x 19; f. Basal laminal cells x 475; g. Capsule with operculum x 19; h. Exothecial cells x 475; i. Peristome tooth x 225; k,l. Spores x 475.

thin-walled, the median and the upper ones narrow - rectangular. Setae terminal, red. Capsules erect, symmetrical, cylindrical. Peristome teeth dicranate. Operculum conic-rostrate.

Cytologically, this genus is known from 8 species. Of the several chromosome numbers (n = 7, 10,13,14,15,26) recorded in this genus, n = 14 (in 30 populations in 5 species), is the commonest. The other chromosome numbers [n = 15 (4 populations in 4 species); n = 13 (one population each in two species); n = 10 (two populations in one species); n = 7 (one population each in two species); n = 26 (one population in one species)] are recorded in a few taxa only. Interestingly, only Russian populations of two taxa [*A. schreberianum* (Hedw.) Dix.; *A. varium* (Hedw.) Mitt.] are observed to have conserved an original and ancient chromosome number (n = 7), which is considered as a base number for the evolution of other chromosome numbers found in the *Dicranales*.

Anisothecium is represented by 45 species, of which three are found in India. In our area, the genus is represented by two species only.

Key to the West Himalayan Species of *Anisothecium* B.S.G.

Leaves ovate-lanceolate; leaf margins distinctly serate down to one-half of the leaf length; nerve ending below the apex..... **1.*A. molliculum***

Leaves subulate from a widened base; leaf margins entire or faintly toothed near tip only; nerve fillig the subula.....**2.*A.varium***

1. Anisothecium molliculum (Mitt.) Broth., Nat. Pfl. ed.2; 10 : 177. 1924. (Fig. 32)

Leptotrichum molliculum Mitt., Musc.Ind.Or. : 11. 1859.

Anisothecium patulum (Mitt.) Broth., Nat.Pfl. 11 : 525. 1925.

Dichodontium molliculum (Mitt.) Broth., Nat. Pfl. 1 (3) : 316. 1901.

Dichodontium patulum (Mitt.) Broth., Nat. Pfl. 1 (3) : 316. 1901.

Dicranella mollicula (Mitt.) Jaeg., Ber. S. Gall. Naturw. Ges. 1870-71 : 381. 1872.

Dicranella patula (Mitt.) Jaeg., Ber.S.Gall.Naturw.Ges. 1870-71 : 381. 1872.

Dicranum patulum Wils., Kew.J.Bot. 9 : 295. 1857.*nom.*nud.*cf* Gang., Mosses of Eastern India 1 (2) : 239.1971.

Plants light-green to dark-green, growing in tufts. Stems 0.8 to 1.2 cm long, simple or branched, in transverse section showing central strand. Leaves patent or squarrose, at least when dry, the lower ones 0.9 to 1.4 mm long and 0.5 to 0.6 mm wide at base, the upper ones to 2.4 mm long, ovate-lanceolate, apex acute; margins dentate due to projecting cell ends in the apical part of the leaf; nerve distinct, brown, 53 µm wide at base, ending below the apex, in T.S. heterogeneous; basal laminal cells (towards the nerve) large, rectangular, 25 - 37 x 10 - 12 µm, towards margins smaller, 1.8 - 22 x 5 - 8 µm; the median ones narrow-rectangular, to 31 x 6 - 8 µm, the upper ones 20 - 24 x 5 - 8 µm, in the marginal row still smaller with projecting ends to form dentations. Setae terminal, sometimes appearing lateral due to innovations in the subapical part of the stem, brownish-red, straight, 0.8 - 1.0 cm long. Capsules erect, oval to narrow-cylindrical, 1.3 mm long and 0.8 mm in diameter, stomata 5 – 7, restricted to base of the urn, pheneroporous. Peristome teeth lightly-reddish, 300 -330 µm long, erect, split down to half the length, united in their lower halves. Operculum conic-rostrate. Spores 13 - 15 µm, asperately sculptured.

This is one of the commonest mosses found in the Western Himalaya (endemic in the Himalaya). It descends down to ±1200 m altitude. It grows in wet and shady places on soil/soil gathered on rocks/stones. The characteristic plant habit, the squarrose to erecto-patent to patent leaves help ready recognition.

Specimens examined: Uttaranchal : Mussorie, 2200 m, on soil on the mountain side rocks, during September 1966-2003, *1394, 1493, 2175, 2715;* Himachal Pradesh : Shimla, on soil on the mountain side rocks, Sept., 1966, 1985, Sept., 2004, *2055, 3703, 3995a;* Narkanda, 2,800 m, on rocks, soil on mountains walls, Sept. 1985, *3703* and many other collections.

Distribution: Himachal Pradesh, Uttaranchal, Darjeeling, Sikkim.

Chromosome number: n = 14, 15.

2. Anisothecium varium (Hedw.) Mitt., J. Linn. Soc. Bot. 12 : 40. 1869. (Fig.32-B)

Dicranella varia (Hedw.) Schimp., Coroll. 1856.13.
Dicranum varium Hedw. Spec. Musc. 133. 1801.

Dioicous. Plants short to long, light-green to dark-green, reddish-brown on drying, often in short tufts. Stems often branched, sometimes simple, to 0.5 to 1.0 cm long, showing conducting strand in transverse section. Leaves falcate on drying 1.6 - 1.9 mm long and 0.26 - 0.29 mm wide, oblong-lanceolate, apex acute to acuminate;

Fig. 32B

Fig. 33

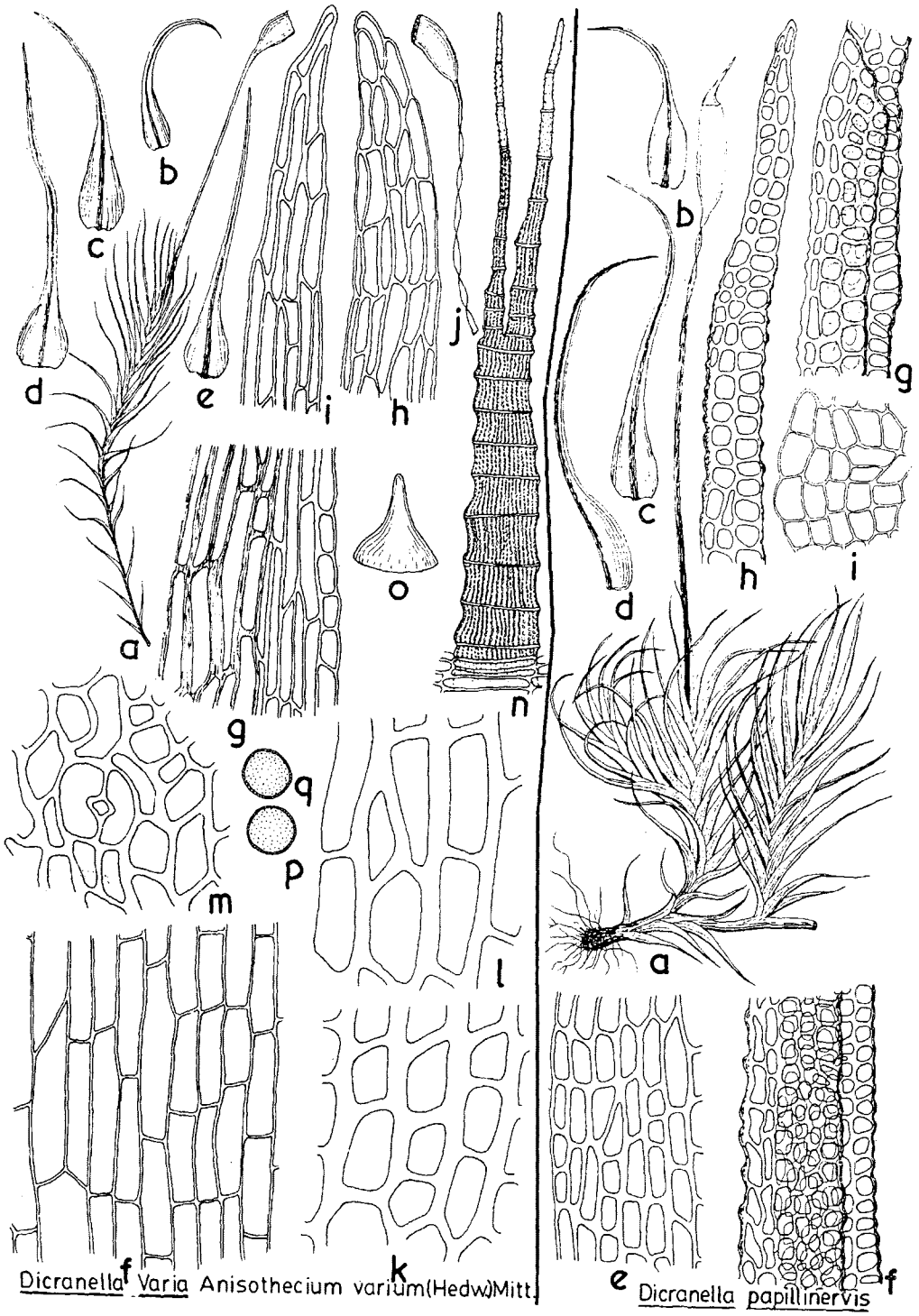

***Fig. 32B. Anisothecium varium* (Hedw.) Mitt.**
A Plant x 10; b. Lower leaf x19; c,d,e. Middle and upper leaves x 19; f. Basal laminal cells x 475; g. Laminal cells from the nerve to the margin x 475; h, i. Cells in the apical part of the leaf x 475; j. Capsule with seta x 10 ; k, l. Exothecial cells x 475; m. Stoma x 475; n. Peristome tooth x 225; O. operculum x 19 ; p,q. Spores x 475.

***Fig. 33 : Dicranella papillinervis* Dix.**
a. Plant x 10; b,c.d. Leaves x 19; e, Basal laminal cells x 475; f. Median laminal cells x 475; g,h. Leaf apex x 475; i. Exothecial cells x 475.

margins entire, near the apex crenate or coarsely dentate; nerve thin, 24 – 27 µm wide at base occupying nearly 1/8th of the leaf base and one half of the subular part, percurrent to sub-percurrent, in T.S. heterogeneous; basal laminal cells elongate – rectangular, 40 – 65 x 8 – 12 µm, the median ones 30 – 45 x 5 – 6 µm, thin-walled, the upper ones 25 – 30 x 3 – 4 µm, in the marginal row tending to be narrower, and linear and also projected to form crenulations or blunt, short-teeth. Setae 4.0 - 6.0 mm long, apical, sometimes appearing lateral due to innovations, slightly flexuose, twisted on drying. Capsules erect to sub-erect, 1.0 mm long and 0.50 mm in diameter. Stomata restricted to the basal part of the urn; exothecial cells irregular, 20 – 40 x 12 – 18 µm, strongly incrassate. Peristome teeth 16, orange to orange-brown, 280 - 320 µm long, split down to a little less than half of their length, vertically papillose-striate below, hyaline or faintly papillose above. Operculum conic, 0.65 mm long. Spores spherical, 12 – 15 µm, asperately sculptured.

This is a polymorphic species in respect of plant height, leaf length, leaf margins, length of the setae, shape and orientation of the capsule. I have examined several samples of *D.emodivaria* C. Muell. *in* Par.*nom.*nud. (Fig. 32A) and failed to find any qualitative feature to justify its separation from *A. varium*. It is observed, that in this taxon the plants are shorter, setae not twisted even on drying and the capsules are erect. These variations are found even in the same population of *A. varium*. Likewise, *D. viridissma*, also defies separation from *A.varium*. The only features, which can be advanced to separate it from the latter taxon are; its taller plants and slightly and coarsally dentate leaf margins near apex. These features, however, well fall within the range of variation seen in *A.varium*. Since the leaf shape, the laminal cells, the peristome characteristics are similar in *A.varium*, *D.viridissima* and *D. emodivaria*, there seems to be little justification in treating the latter two taxa as independent species. In my opinion, these two taxa can, at best, be given the status of formas i.e. *A. varia* forma *viridissima* and *A. varia forma emodivaria*.

At any rate, it does appear, at least, that *A. varium* possesses a great plasticity in its genotype that permits the evolution of several morphotypes, which cause confusion and encourage temptation to erect/create independent species in disregard to their similarity with *A.varium* in qualitative characters.

Specimen examined: Uttaranchal : Mussorrie, 2300 m, on soil mixedwith rubble, Sept., 1992, *24K, 25K;* Mussoorie, 2250 m, on soil mixed with rubble, Sept. 1957, *1494* (as *Dicranella emodivaria)*; Mussoorie, 2300 m, on soil mixed with rubble, Sept., 1957; August, 1969, *1496, 2176* (as *Dicranella viridissima)*.

Distribution : India (Himalaya), Japan, Korea, Russia, Europe, North America.

Chromosome number : n = 7, 14, 15.

7. *Dicranella* (C. Muell.) Schimp., Coroll. Bryol. Eur. 13. 1856.

Aongstroemia sect. Dicranella C. Muell., Syn.1: 430. 1848

Plants dark-to light-green, growing in short tufts. Stems simple or branched, densely foliate. Leaves erecto-patent, flexuose, falcate-secund, abruptly subulate from a sheathing base, or gradually linear-lanceolate from a non-sheathing base; margins entire or denticulate near apex; nerve strong, percurrent or excurrent, mostly filling the subula; alar cells absent; basal laminal cells elongate, rectangular, upwards sub-quadrate to narrowly rectangular. Setae straight. Capsules erect or inclined, oblong-cylindric to globose. Peristome teeth 16, each divided down to nearly one-half the length of the tooth into 2-3 papillose crurae, the undivided part vertically striate. Operculum conic or obliquely-rostrate. Calyptra cucullate.

Lectotype: *Dicranella grevilleana* (Brid.) Schimpr.

Dicranella is closely related to *Anisothecium*. Kindberg (1897) considered the latter taxon as a subgenus of *Dicranella*.

Cytologically, this genus is known from eight species, namely, *Dicranella cerviculata* (Hedw.) Schimp. - n = 13, 14, 15; *D. dietrichiae* ((C.Muell.) Jaeg. - n = 12; *D. emodi - varia* C.Muell. - n = 15 (14+m); *D. heteromalla* (Hedw.) Schimp. - n = 7(one population), 11 (one population), 13(11 populations), 14 (3 populations); *D. pacifica* Schof. - n = 15; *D. palustris* (Dicks.) Crundw. - n = 15; *D. subulata* (Hedw.) Schimp. - n = 13, 14, 14+m; *D. viridissima* C.Muell. - n = 16. The available data indicates, that this genus may be based on x = 7, with aneuploidy having played a major role in its evolution and speciation.

Dicranella includes 134 species, of which 9 are found in India. In our area, this genus is represented by 3 species, of which *D.papillinervis* Dix. is endemic to the Western Himalaya.

Key to the West Himalayan species of *Dicranella* (C.Muell.) Schimp.

a. Plants fasciculately branched; leaf margins recurved; nerve back papillose.....**3.*D. papillinervis***

Plants simple or branched through innovations; leaf margins plane; nerve back smooth.....b

b Leaves not flexuose when dry, to 2.5 mm long; peristome teeth spirally striate.....**4.*D.spiralis***

Leaves flexuose or falcate when dry 3.5 - 4.5 mm long; peristome teeth vertically striate.....c

c Leaves falcate or falcate-secund; margins denticulate at least near tip; basal laminal cells to 40 x 7 µm; setae1.3-1.4 cm. long; capsules inclined, asymmetric; spores 10-12 µm, asperately sculptured.....**2.*D. heteromalla***

Leaves erecto-patent; leaf margins entire; basal laminal cells to 80 x 8 - 12 µm; setae 0.7 cm long; capsules erect, symmetric; spores 18 - 20µm, sculptured granulose.....***1. D. divaricata***

1. *Dicranella divaricata* (Mitt.) Jaeg., Ber S. Gall. naturw. Ges., 1870-71; 376. 1872. (Fig.34)

Aongstroemia divaricata (Mitt.) C. Muell., Gen. Musc. Fr. 323. 1900.

Dicranella aciculate C.Muell. *in* Gang., Bull. Bot. Soc. Beng. 14: 19. 1960 *nom. nud. fid.* Nork. *in* Gang., l.c.

Dicranella madurensis Card. *in* P. Vard., Rev. Bryol. 49: 35. 1922 *nom. invalid in synon.*

Leptotrichum divaricatum Mitt., J. Linn. Soc. Bot. Suppl. 1:9.1959.

Dioicous. Plants light-green, growing in tufts. Stems 4.0 – 5.5 mm long, simple. Leaves erecto-patent to spreading, flexuose on drying, the lower ones 1.0 – 1.5 mm long, upwards to 4.0 mm long and 0.3 mm wide at base; lanceolate-subulate from an elliptic sheathing base; margins entire; nerve 52 µm wide, occupying one-fourth of the leaf base, filling most of the subula; basal laminal cells rectangular, to 80 x 8-12 µm, at shoulders 25-50 x 5-6 µm, upwards narrower. Setae straight, 7.0 mm long. Capsules nearly erect, oblong-cylindric, 1.25-1.3 mm long and 0.6 mm in diameter, smooth, furrowed on drying; exothecial cells irregular, elongate-rectangular to elongate-polygonal, 45-75 x 15-18 µm, strongly incrassate. Peristome teeth 16, 115-120 µm high, each cleft down to one-half of its total length, vertically papillose-striate below, striolate above except the hyaline tip. Spores spherical, 18-20 µm, sculptured granulose.

This taxon differs from other West Himalayan species of *Dicranella* in respect of its larger basal laminal cells, the shorter setae and the larger granulose spores.

Specimen examined: Uttaranchal : Mussoorie, Arnigadh, 1200-1800 m, month of collection not indicated, 1892, *228* (B.M.).

Distribution: Uttaranchal, Darjeeling, Khasia hills, Niligiri and Palni hills; Eastern Nepal.

Chromosome number: Not known.

2. *Dicranella heteromalla* (Hedw.) Schimp., Coroll. Bryol. Eur. 13. 1856. (Fig.34A)

Aongstroemia asperula Hamp. *in* C. Muell., Gen. Musc. Fr. 323. 1900. *nom. nud. fid.* Nork. *in* Gang. Mosses Eastern India 2: 257. 1971.

Aongstroemia heteromalla (Hedw.) C. Muell., Syn. 1: 432. 1848.

Cynodontium heteromallum (Hedw.) Mitt., J. Linn. Soc. Bot. 8: 16. 1864.

Dicranella asperula C.Muell. *in* Jaeg., Ber. S. Gall. naturw. Ges., 1877-1878: 374. 1880. *nom. nud.*

Dicranella roperi Dix. *in* Gang., Bull. Bot. Soc. Beng. 14: 18. 1960 *fid* Nork. *in* Gang., Mosses Eastern India 2: 257. 1971.

Dicranodontium heteromallum (Hedw.) Walth. *et Mol.*, Laubm. Oberfr. 98. 1868.

Dicranum heteromallum Hedw., Spec. Musc. 128. 1801.

Leptotrichum heteromallum (Hedw.) Mitt., J.Linn. Soc. Bot.Suppl. 1:11.1857.

Dioicous. Plants light-green to yellow-green, yellowish-brown on drying, growing in dense tufts. Stems 0.8-1.2 cm long, simple or branched through innovations, densely foliate. Leaves falcate-secund, crisped on drying, the lower ones 1.6 – 1.7 mm long, upwards 3.5 – 4.0 mm long and 0.3 mm wide, lanceolate-subulate, gradually narrowing from a widened, concave, sheathing base; margins serrate in the apical part; nerve 52 m wide, occupying nearly one-fourth of the width of leaf base, percurrent, filling most of the subula leaving a narrow, 1-2 cells wide lamina on either side; in transverse section heterogeneous; basal laminal cells rectangular, adjoining the nerve to 40 x 6-7 µm, towards margins 12-20 x 4-5 µm, the median and the upper ones shorter, quadrilateral with oblique horizontal walls, 12-15 x 4-6 µm. Setae straight, twisted on drying, 1.3-1.4 cm long. Capsules slightly inclined, furrowed on drying, 1.7 mm long and 0.6 mm in diameter, asymmetrical, oblong, exannulate; exothecial cells irregularly rectangular to polygonal, 40-45 x 16-20 µm. Peristome teeth 16, each cleft down to ± one-half of its total length, vertically papillose-striate. Operculum obliquely beaked. Spores spherical, 10-12 µm, asperately sculptured.

Specimens examined: Uttaranchal : Mussoorie, Jabar

Fig. 34A **Fig. 34**

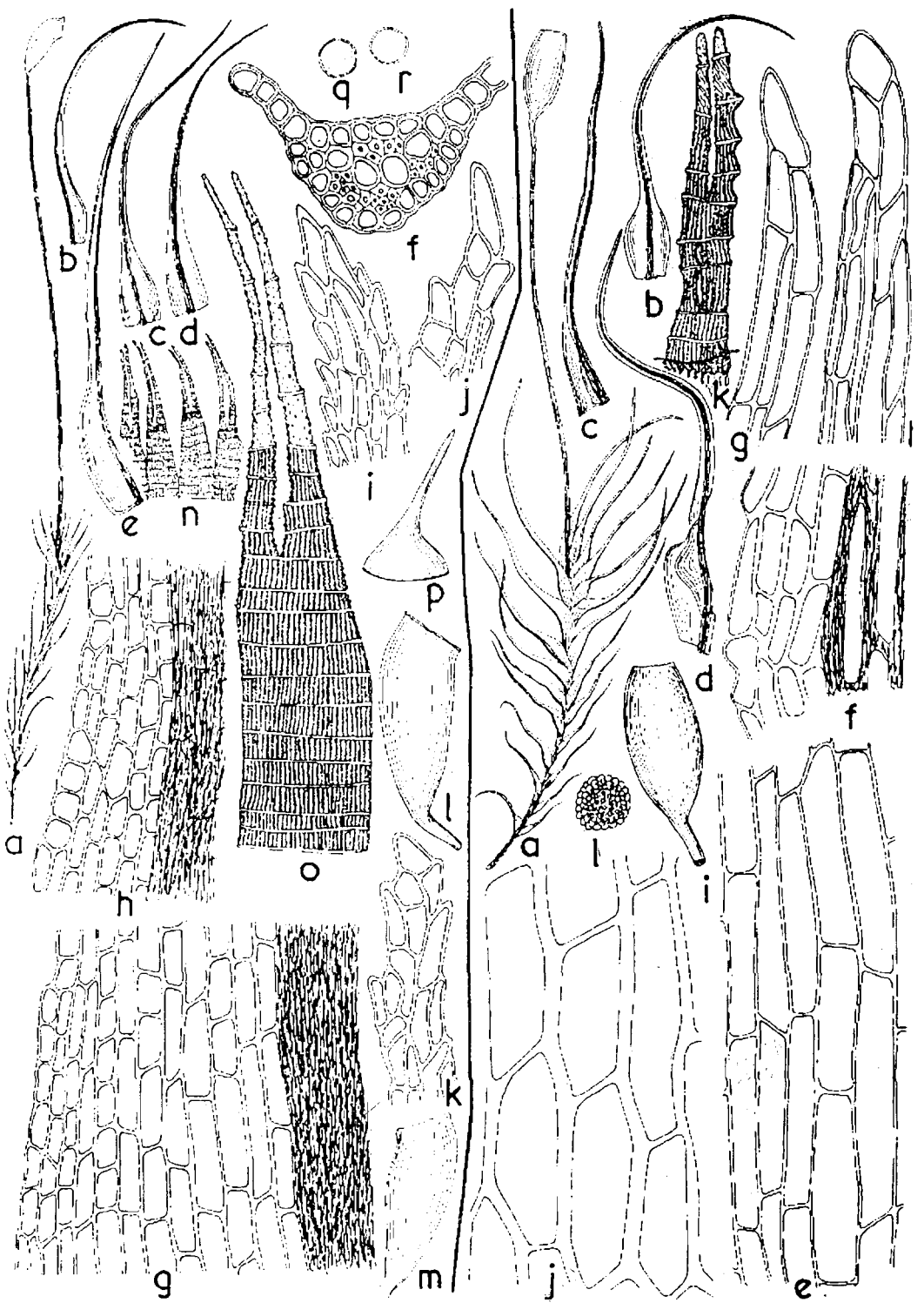

Fig. 34A. Dicranella heteromalla (Hedw.) schimp.
a. Plant x 10; b.c.d.e. Leaves x 19; f. T. S. Leaf x 475; g. Basal laminal cells x 475; h. Median laminal cells x 475; i.j.k. Leaf apex x 475; l. m. Capsule x 19; n. Peristome teeth x 120; O. Peristome tooth enlarged x 475; p. Operculum x 19; q r. Spores x 475.

Fig. 34 : Dicranella divaricata (Mitt.) Jaeg.
a. Plant x 10; b.c.d. Leaves x 19. E. Basal laminal cells x 475; f. Laminal cells at margins in mid leaf x 475; g.h. Leaf apex x 475; i. Capsule x 19; j. Exothecial cells x 475; k. Peristome tooth x 475.

Khet, 1950 m, on soil, September, 1958, *1492*; Himachal Pradesh : Shimla, on way to Glen, 2,000 m, on soil, September, 1978, *101K*; West Bengal : Darjeeling, 2100 m, August, 1958, *1492*; Sikkim : Tonglo, 2700m, Herb. Ind. Or. *67* (B.M.).

Distribution: Himachal Pradesh, Uttaranchal, Darjeeling, Sikkim, N.E.F.A., Assam; Bhutan, Nepal, Eastern Tibet, Central Asia, Amur, Korea, Japan, Europe, Caucasus, North and Central Africa, Am 1, 2, 3, 4. A nearly cosmopolitan species.

Chromosome number: n=7 (One population); n = 13 (13 populations); n = 14 (3 populations)

3. *Dicranella papillinervis* Dix., 150th Aniversary Vol. Royl. Bot.Gdn. Calcutta :179.1942. (Fig. 33)

Dioicous. Plants growing in dense cushions. Stems 3.0 – 4.0 mm long, fasciculately branched, densely foliate. Leaves erecto-patent, flexuose on drying, 3.0 – 5.0 mm long and 0.3 mm wide at base, lanceolate-subulate from a widened, oval-oblong or elliptic basal portion; margins recurved; nerve 53 µm wide, occupying nearly one-sixth of the leaf base, percurrent or excurrent, papillose at back; basal laminal cells rectangular, 10-28 x 4-6 µm, upwards short-quadrate, 6-8 µm wide. Setae straight, 0.9 mm long, twisted to the right. Capsules erect, furrowed on drying, 1.7 mm long and 0.5 mm in diameter, cylindrical. Operculum with a long slanting beak. Rest not observed.

This taxon is readily separated from the remaining West Himalayan species of *Dicranella* by its habit (growing in cushions), the manner of branching (fasciculate), and the nature of the nerve back (papillose). It agrees with *Distichium* B.S.G. in its papillose nerve back, the quadrate laminal cells (unusual of *Dicranella)* and the relatively longer operculum. A study of the peristome (not seen in the present specimen) is essential in order to ascertain the phyletic affinity of this interesting taxon.

Specimens examined: Kashmir : Lidar to Sind, 3000 m, September, 1931, *1404*.

Distribution: Endemic in the Kashmir Himalaya.

Chromosome number: Not known.

4. *Dicranella spiralis* (Mitt.) Jaeg., Ber. S.Gall. Naturw. Ges. 1877-78 : 374. 1880. (Fig.34B).

Aongstroemia spiralis (Mitt.) C. Muell., Gen.Musc. Fr. : 325. 1900.

Anisothecium spirale (Mitt.) Broth., Nat.Pfl. ed. 2, X : 177. 1924.

"Slender yellow-green plants. Stems up to 8 mm. high, usually forked below apex. Leaves erectopatent, laxer below, up to 2.5 mm. long, narrowing down from a wide semi-sheathing base into a subula entirely filled up by the excurrent costa above. Apex almost smooth-margined. Basal leaf cells narrow rectangular (up to 42 x 7 µ), narrower near apex. Costa brown, ± 50 µ wide in mature leaf, rather ill-defined at base. Seta red-brown, spirally flexuose when moist, straight but twisted when dry. Capsule red-brown, almost horizontal when moist, short cylindrical, symmetrical, ± 300 µ high, split to about two-thirds down, papillose specially at tip, showing spiral striations. Operculum long rostrate, bent to one side, shorter than capsule. Spores yellow, faintly papillose, 17 to 20 µ in diameter". (After Gang., 1971).

6.*Campylopodium* (C. Muell.) Besch., Annals. Sci. nat. Bot. Ser. 5, 18: 189. 1873.

Aongstroemia B.S.G. sect. *Campylopodium* C. Muell., Syn. 1:429. 1848.

Dioicous. Plants dark-green, growing in dense tufts. Leaves gradually or suddenly lanceolate-subulate from a widened and sheathing basal portion, tubular concave; nerve percurrent, in transverse section heterogeneous; laminal cells rectangular. Setae short or long, cygneous when young, later erect and tortuous. Capsules ellipsoid with a short neck, stomatose. Peristome teeth 16, each cleft down to one-half of its length, vertically papillose-striate. Operculum obliquely beaked. Calyptra cucullate.

Cytologically, *Campylopodium* (C. Muell.) Besch. is known only from *C.griffithii* (Mitt.) *ex* Broth. - n = 14 (13 + m). Interestingly, neither *Anisothecium* nor *Dicranella* (C. Muell.) Schimp., which are considered close to this genus, possess an m-chromosome in their fourteen or thirteen chromosome complements.

This genus contains 11 species, of which 3 are found in India. In our area, this taxon is represented by a single species.

Campylopodium griffithii (Mitt.) Mitt. *ex* Broth., Nat. Pfl. ed. 2, X : 183. 1924. (Fig.35)

Leptotrichum griffithii Mitt., J. Linn. Soc. Bot. Suppl. 1:9. 1859.

Dioicous. Plants dark-green, growing in dense tufts. Stems to 7.0 mm long, branched. Leaves erecto-patent to slightly falcate, contorted on drying, ± 2.5 mm long and 0.5 mm wide at base, lanceolate-subulate from a widened base, tubular concave in the upper portion; margins incurved, entire; nerve ± 80 µm wide, occupying nearly one-sixth of the leaf base, percurrent and mostly filling the subula, in transverse section showing a median row of guide cells and a ventral and a dorsal stereidal band respectively above and below the guide cells; basal

Fig. 34B

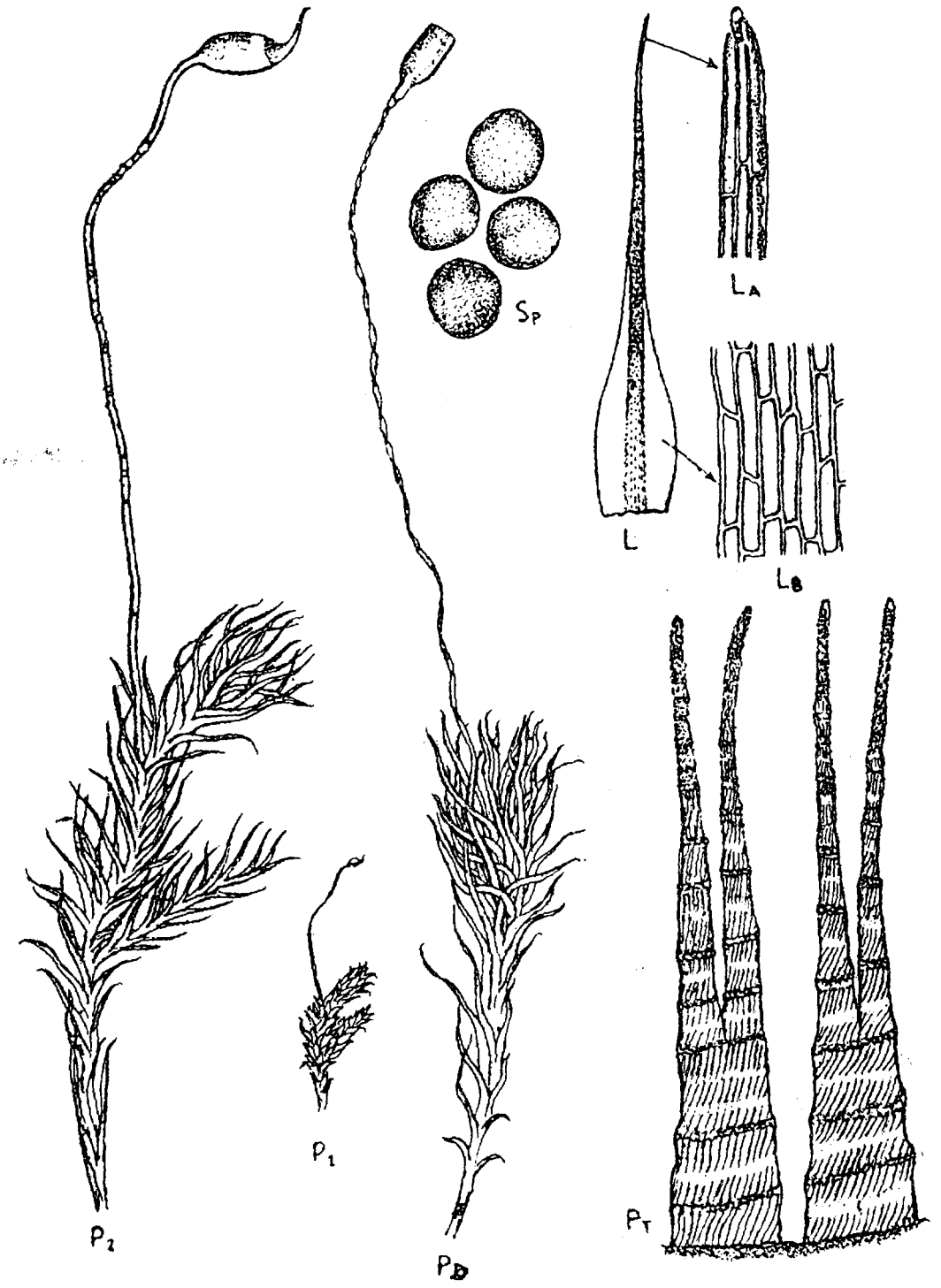

***Fig. 34B : Dicranella spiralis* (Mitt.) Jaeg.**
a. P_1 Normal plants x 2; P_2 Normal plant x 11; L. Leaf x 34; LA. Leaf apex x 450; LB-Basal cells of the leaf x 450; Pr. Peristome x 340. (After Gangulee, 1971)

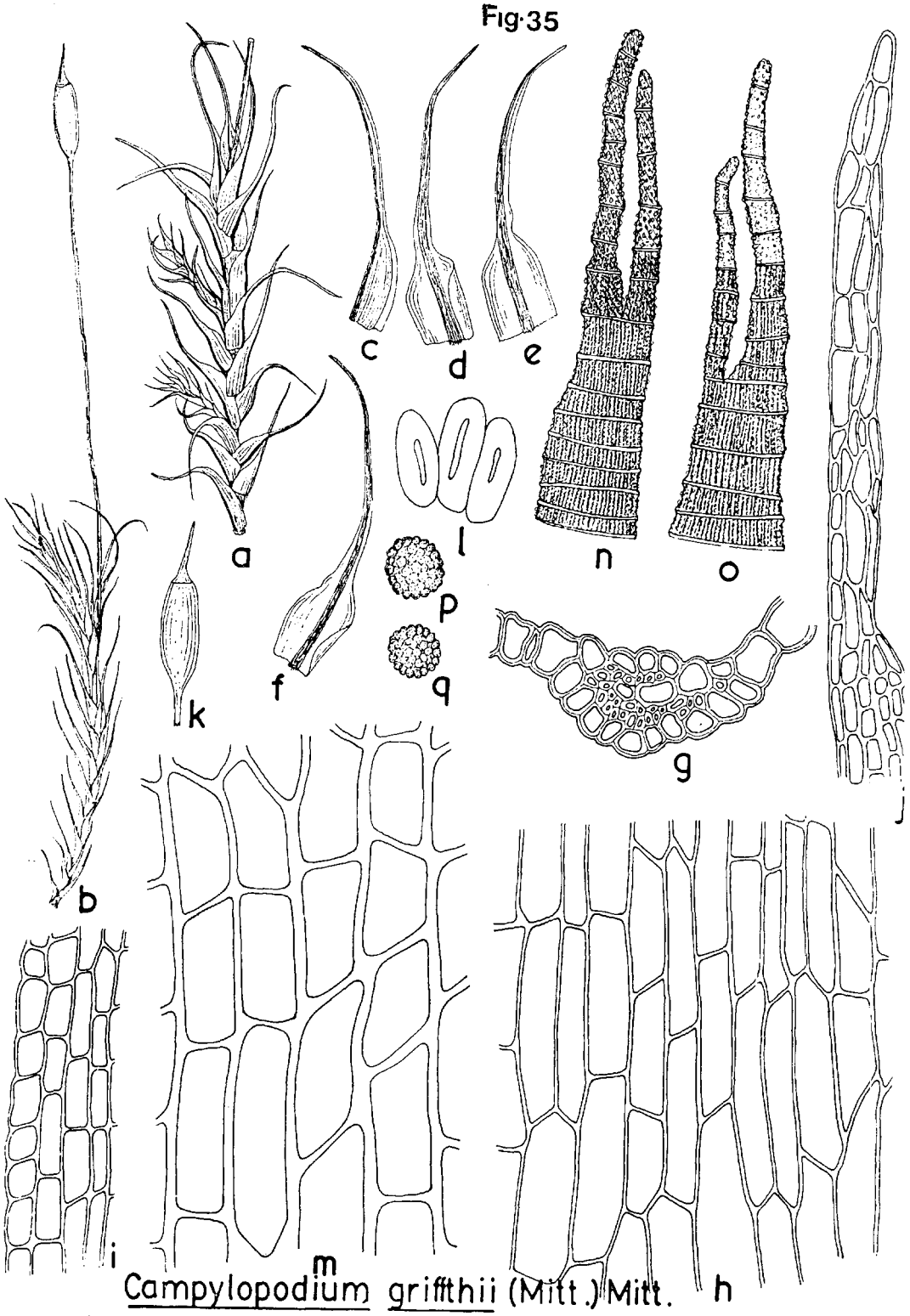

Fig. 35 : Campylopodium griffithii (Mitt.) Mitt. ex. Broth.
a. Plant enlarged x 19; b. Plant x 2; c,d,e,f. Leaves x 19; g. T. S. Leaf x 475; h. Basal laminal cell x 475; i. Median laminal cells x 475; j. Leaf apex x 475; k. Capsule with operculum x 19; l. Cells of the annulus x 475; m. Exothecial cells x 475; n,o. Peristome teeth x 475; p,q. Spores x 475.

laminal cells rectangular, sometimes with oblique end walls, to 70 x 8-12 µm, the median ones short-rectangular, 15- 22 x 5-8 µm, at margins 8 – 12 x 8 µm, towards apex narrower, 5-6 µm wide. Setae terminal, straight, 1.0 – 1.6 cm long. Capsules erect, 1.6 mm long and 0.6 – 0.7 mm in diameter, ellipsoid; exothecial cells rectangular or quadrilateral, 40-75 x 15-18 µm with strongly incrassate longitudinal and slightly thickened transverse walls. Peristome teeth 16, each cleft down to one-half of its length, vertically papillose-striate below and papillose above. Operculum 1.0 mm long, obliquely beaked. Spores spherical, 15-20 µm, sculptured granulose.

Specimen examined: Uttaranchal : Mussoorie – Jabar Khet, 2100 m, on rocks, September, 1956, *1387;* Nainital, 2150 m, on soil gathered on rocks, October, 1970, 2522; Himachal Pradesh : Dharmsala, 2200 m, on soil gathered on rocks, October, 1977, *2818*; Kerala :Anamallago, 900 m, on stones, *684*. (B.M.).

Distribution: Himachal Pradesh, Uttaranchal, Darjeeling, Khasia hills; Nepal.

Chromosome number: n=14 (13 + m).

7. *Symblepharis* Mont., Annls Sci. nat. Bot. Ser. 2, 8:252. 1837.

Plants robust, growing in dense tufts. Stems branched. Leaves spreading, helically coiled on drying, elongate-subulate, tubular from a widened, erect, sheathing basal portion; nerve narrow, percurrent or excurrent; alar cells not differentiated; basal laminal cells rectangular, hyaline, the median and the upper ones short, quadrate, thick-walled. Setae straight, apparently lateral due to innovations. Capsules ovoid-cylindric to cylindrical. Peristome teeth deep-inserted, cleft down to below the middle, papillose-striate. Operculum obliquely beaked.

Lectotype: *Symblepharis vaginata* (Hook.) Wijk & Marg.

The characteristically coiled leaves (when dry) in this genus enable an easy distinction from the rest of the genera of *Dicranaceae*.

Cytologically, this genus is known only from a single species i.e. *Symblepharis vaginata* (Hook.) Wijk *et* Marg. - n = 14 (13+m). The existing data is insufficient to comment on its cytological relationship with the other genera of *Dicranaceae*.

Symblepharis contains 12 species, of which 7 are found in Asia. In India, this genus is represented by 2 species, of which only S. *vaginata* (Hook.) Wijk & Marg. occurs in our area.

Symblepharis vaginata (Hook.) Wijk & Marg., Taxon 8: 75. 1959. (Fig.36)

S. dilatata Wils., Kew J. Bot. 4:293. 1857.

S. helicophylla Mont., Annls. Sci. nat. Bot. Ser.2 (8) : 253. 1837.

S. himalayana C. Muell., Gen. Musc. Fr. 315. 1900 *nom.*inval.

S.tenuis Schimp. *in* Salm., J. Linn.Soc. Bot. 33: 493. 1878 *nom. nud.*

S. kurzii Hamp. *in* Salm., J. Linn.Soc. Bot. 33: 493. 1898. *nom.nud.*

Dicranella himalayana Jaeg., Ber. S. Gall. naturw. Ges. 1870-1871 : 380. 1872.

Aongstroemia himalayana (Mitt.) Jaeg. *ex* Par., Ind. Bryol. 34. 1894. *nom inval.*

Leptotrichum himalayanum Mitt., J. Linn. Soc. Bot. Suppl. 1:12. 1859 *nom.illeg.*

Dichodontium hookeri Par., Ind. Bryol. 322. 1894. *nom.illeg.*

Plants yellowish-green, growing in loose tufts. Stems to 4.5 cm long, branched. Leaves spreading, falcate, helically coiled on drying, lanceolate-subulate from a wide, erect, clasping basal portion, channeled in the apical portion; margins entire; nerve narrow, 60 - 70 µm wide at base, percurrent; basal laminal cells rectangular, 34 - 57 x 10 - 60 µm, in the shoulders irregular, 8 - 37 x 5 - 8 µm, upwards nearly quadrate, 7 - 10 x 5 - 7µm, incrassate. Setae apparently terminal, 5.6 - 5.8 mm long. Capsules reddish-brown, erect, cylindrical, 1.5 - 2.0 mm long and 0.5 - 0.6 mm in diameter; exothecial cells irregular, 34 - 37 x 16 - 20 µm, strongly incrassate. Peristome teeth 16, tending to be in pairs, dicranate. Operculum conic-rostrate with an erect beak. Spores 16 - 18 µm, asperately sculptured.

Specimens examined: Himachal Pradesh : Narkanda, 3200 m , on the trunk of *Pinus wallichiana*, October, 1966, *2061*; Shimla, 2400 m, on soil gathered on rocks, August, 1961, *1865, 1866, 1867;* Uttaranchal : Mussoorie, 1800 m, on tree trunk, May, 1892, 621 (BM); Nainital, 2800 m, on the trunk of *Cedrus deodara,* October, 1970, *2254*; Tehri-Garhwal (Rikshin range), 3300 m, May, 1899, *16507*; Chopta, on decaying logs and soil gathered on rocks, 3620 m, September,1986; 3694.

Distribution: Uttaranchal, Darjeeling, Sikkim; Bhutan, Nepal, China, North and Central America.

Chromosome number: n = 14 (13 + m).

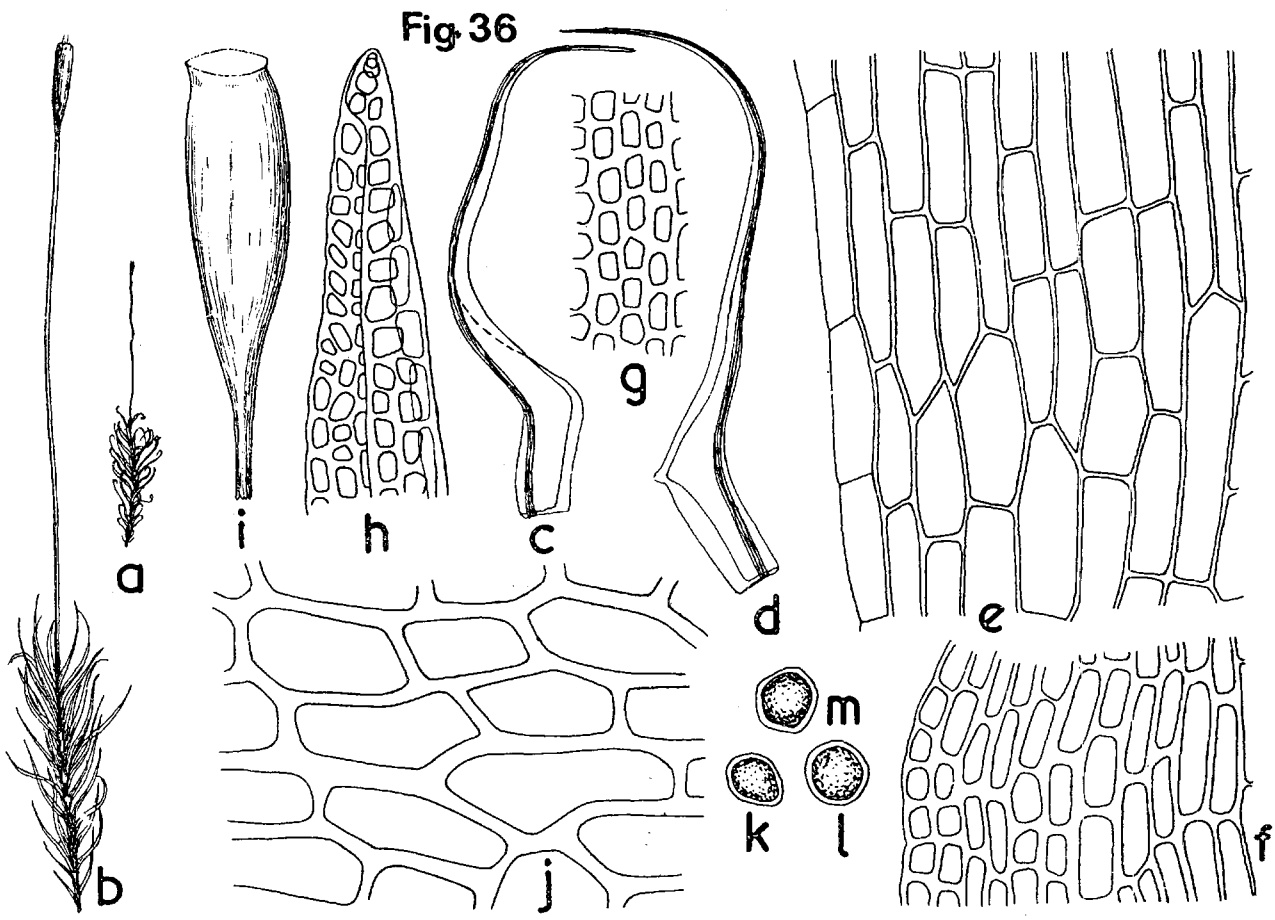

Fig. 36 : Symble pharis vaginata (Hook.) Wijk & Marg.
a. Dry plant x 4; b. Wet plant x 12; c,d,e,f,g,h. Leaves x 19; i. Basal laminal cells towards margin x 475; j. Basal laminal cells towards nerve x 475; k,l,m. Median laminal cells x 475; n. Leaf apex x 475; o.p.q. Capsule x 19; r. Exothecial cells x 475; s. Exothecial cells Enlarged x 475 t. Peristome tooth x 475; u,v.w. Spores x 475.

8. *Dicranum* Hedw., Spec. Musc. 126. 1801.

Dioicous. Plants robust, growing in loose or dense tufts. Stems densely radiculose upto considerable height, simple or branched. Leaves mostly falcato-secund, lanceolate-subulate from a widened sheathing base, often channelled or tubulose above; margins serrate or entire; nerve strong, excurrent, percurrent or ending below the apex, not or lamellose or ribbed at back, in transverse section showing stereidal band above and below the guide cells; alar cells strongly differentiated, mostly inflated, hyaline or coloured, not reaching the nerve; basal laminal cells elongate-rectangular, mostly porose, upwards similar or short, thin- or thick-walled, porose, or non-porose. Setae straight, long. Capsules erect or curved, symmetrical or asymmetrical, mostly cylindrical. Peristome teeth 16, each cleft down to one-half of its length, papillose-striate in the undivided part and faintly papillose towards the apical part of the divided portion. Operculum long-rostrate. Calyptra cucullate, entire at the base.

Lectotype: *Dicranum scoparium* Hedw.

The genus *Dicranum* Hedw. agrees with *Dicranoioma* (Ren.) Ren. in habit, but differs from the latter genus in its relatively broader nerve, unbordered leaves and the peristome teeth which are cleft only down to above the middle. The genus is easily recognized by the robust nature of the plants, the large, often coloured and inflated alar cells, and the generally porose walls, at least, of the basal cells. However, segregation into taxa of lower ranks is not easy. The characters provided by the nature of the leaf margins, the length and structural organization of the nerve, when seen in transverse section, the shape and relative size of the laminal cells and the porose or non-

porose nature of their walls proved helpful in the segregation of the species of *Dicranum* found in our area.

Cytologically, the genus *Dicranum* Hedw. is one of the most baffling taxon. The available cytological data seem to be of little value in defining the subgeneric delimitation and specific boundaries. Among an array of chromosome numbers (n = 7,8,9,10,11,12,13,14,15,23,24) distributed in eighteen species, that have been investigated so far, n = 12 is the most prevalent number (16 species) followed by n = 13 (7 species). It is of further interest to note that in this genus, there are still three species i.e. *D. fuscescens* Turn., *D. muehlenbeckii* B.S.G. and *D. spurium* Hedw., which have preserved an ancient chromosome number i.e. n = 7 (considered as one of the base number for the evolution of haplolepideous mosses) in some of their Russian and Ukaranian populations. The prepondrance of n = 12 in this genus raises a question "Could x = 6 be also one of the base numbers for the evolution of n = 12, 23, 24?" . The occurrence of intraspecific aneuploidy in *D. bonjeanii* De Not. (n = 11,12,13,14), *D. bergeri* Bland. *ex* Hoppe (n = 11,12,13), *D.fuscescens* Turn. (n = 7,8,9,10,11,12,24), *D. majus* Turn. (n = 11,12,13), *D. scopariun* Hedw. (n = 7,8,910,11,12,13) indicates that the genus *Dicranum,* during its evolution, may have experienced a cytological explosion, throwing a multitude of forms with deviant chromosome numbers, which are still preserved. Unfortunately, the plants/populations of the same species with different chromosome numbers have not been compared in respect of their morphological characteristics. It is thus not possible, even when highly desired, to know if alterations in chromosome numbers are/are not accompanied with any change in the morphology of the affected plants/populations. Further, discovery of taxa with n = 23 & n = 24 in this genus indicates the receptivity of its genome for the evolution of secondary polyploids/aneuploids.

Brotherus (1924), on the basis of the capsule and peristome characters, divided this 101 species-rich genus into three subgenera (*Crassidicranum, Eudicranum, Pseudochorisodontium).* Monkeymeyer (1927) treated this genus under three sections (*Dicrana-undulata, Dicrana-fragilifolia, Dicrana scoparia*). Sakuri (1952) studied Japanese species of *Dicranum,* and proposed its division into seven subgenera (*Undulati-Dicranum, Fragili-Dicranum, Elongati-Dicranum, Scopario-Dicranum, Falcati-Dicranum, Nippono-Dicranum* and *Pseudo-chorisodontium*). The first four of these subgenera, broadly agree with the sections proposed by Monkeymeyer. Nyholm (1954), on the basis of the nerve anatomy, divided *Dicranum* into four sections *(Dicrana scoparia, Dicrana spuria, Dicrana fuscescentia* and *Crassidicranum*). Takaki (1964) proposed its division into two subgenera (*Crassidicranum* and *Dicranum*). I have followed Takaki's (l.c.) treatment, which appears natural, at least, for the seven species that are found in our area.

I. Subg. *Crassidicranum* Limp. emend. Takaki, Jour. Hattori Bot. Lab. 27: 76. 1964.

Orthodicranum Loesk., Studien 85: 1910 *cf.* Takaki, l.c.

II. Subg. *Dicranum* (Hedw.) B.S.G., Bryol. Eur. 1:6. 1851. (fasc. 46-47 Consp. 1.(VIII).

Key to the West Himalayan species of *Dicranum* Hedw.

a. Alar cells unistratose (Subg. *Crassidicranum)*.....**5.*D. montanum***

Alar cells bistratose or multistratose (Subg.*Dicranum*).....b

b. Nerve back serrated-lamellose.....c

Nerve back smooth or ridged.....e

c. Leaves undulate.....**7.*D.undulatum***

Leaves without undulations.....d

d. Leaves mostly folded on the nerve; leaf tip loriform; nerve ending 2-3 cells below the apex; laminal cells, when seen in transverse section, transversally elongate with the external walls notched in the middle .....**4. *D.lorifolium***

Leaves not folded on the nerve; leaf tip not loriform; nerve percurrent or sub-percurrent; laminal cells, when seen in transverse section, vertically elongate with straight external walls.....**6.*D.scoparium***

e. Plants 5.0 - 7.0 cm long, fastigiately branched; leaf margins entire.....**2. *D.himalayanum***

Plants 2.5 - 3.5 cm long, sparsely branched; leaf margins serrulate..... f

f. Leaves subulate; external walls of laminal cells, in transverse section, notched in the middle..... **3.*D.Kashmirense***

Leaves with acute or obtuse apex; external walls of laminal cells, in transverse section, straight.....**1.*D.bonjeanii***

1.*Dicranum bonjeanii* De Not. *in* Lisa, Elenco Muschi Torino29. 1837. (Fig.37)

Dicranum palustre B.S.G., Bryol. Eur. 1: 143. 1847.(Fasc. 37-40; Monogr.29,31) *hom.illeg.*

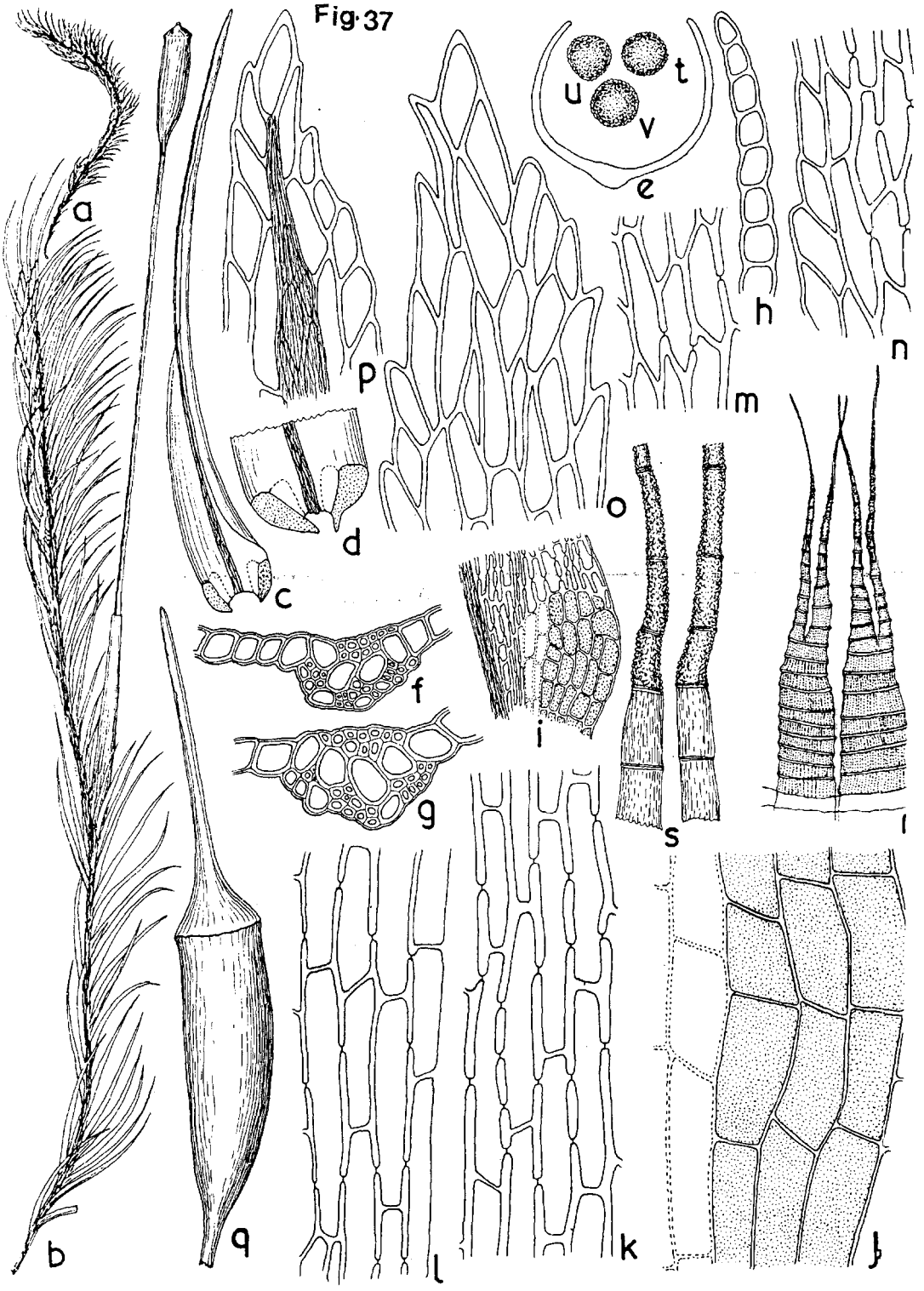

Fig. 37 : Dicranum bonjeanii De Not.

a. Dry plant x 2; b. Plant enlarged x 6; c, Leaf x 19; d. Basal part of the leaf x 50; e. T. S. leaf x 475; f.g. T. S. leaf enlarged x 475; h. Laminal cells in T. S. x 475 x 12; i. Leaf base showing alar cells x 200; j. Alar cells enlarged x 475; k,l. Basal laminal cells x 475; m,n. Median laminal cells x 475; o,p. Leaf apex x 475; q. Capsule with operculum x 19; r. Peristome teeth x 200; s. Upper part of peristome teeth enlarged x 475; t,u,v. Spores x 475.

Plants dark-green, growing in loose tufts. Stems to 3.5 cm long, sparsely branched, radiculose at base. Leaves erecto-patent, tips flexuose on drying, 5.0 - 6.0 mm long and 1.1 mm wide, oblong-lanceolate, gradually narrowing from a concave base, apex obtuse or acute; margins sub-entire near the tip, entire downwards; nerve prominent, 72 µm wide at base, percurrent, in transverse section showing a row of 2-4 guide cells between the ventral and the dorsal stereidal band in the upper part of the leaf, the lower stereidal band separated into 2-3 groups by 2 ridges on the back of the nerve; the external wall of lamina cells, in transverse section, straight; alar cells brown, rectangular to sub-quadrate or polygonal, enlarged, 18-27 µm wide; basal laminal cells rectangular, 60-98 x 10-12 µm, longitudinal walls porose, the median and the upper ones relatively shorter, ± 40 x 10-12 µm (some cells may be upto 58 µm), walls non-porose towards margins, near leaf apex rhomboidal, 18-24 µm. Setae straight, 1.8 cm long. Capsules slightly curved, 5.0 mm long and 1.6 mm in diameter, cylindrical. Peristome teeth 0.7 mm high, each tooth cleft down to one-half of its length, papillose-striate, faintly papillose near tip. Operculum 2.8 mm long, long-beaked. Spores brown, spherical, 18-20 µm, asperately sculptured.

Crum and Anderson (1981) considered this species as conspecific with *D. scoparium*. Undoubtedly, it agrees with *D.scoparium* in plant habit and leaf areolations. The laminal cells in both the species also show straight tangential walls, when seen in transverse section. However, the differences lie in the leaf margins (distinctly serrate in *D.scoparium*, sub-entire in *D.bonjeanii*), the nerve back, in transverse section, smooth or ridged in *D. bonjeanii*, serrated lamellose in *D. scoparium*) the median laminal cells (strongly incrassate and quadrate in *D. scoparium*, relatively much less thickened and rectangular in trasverse section in *D. bonjeanii)* and the capsule length (± 3.4 mm long in *D. scoparium*, ±2.5 mm long in *D. bonjeanii*).

Specimens examined: Himachal Pradesh : Shimla, Mashobra, 2,500 m, Herb. Ind.Or. 77 (BM), on soil, September, 1974, *43-S*; Kashmir : Gulmarg, 3300 m, on logs, August, 1978, *1129*.

Distribution: Kashmir, Himachal Pradesh; Sieberia, Caucasus, Europe, North America.

Chromosome number: n =11,12,13,14.

2. *Dicranum himalayanum* Mitt., J. Linn. Soc. Bot. Suppl. 1: 14. 1859. (Fig.38)

Plants dark-green, growing in dense tufts. Stems 5.0 - 7.0 cm long, fastigiately branched, densely foliate. Leaves patent, to 9.0 mm long and 1.2 mm wide at base, lanceolate, canaliculate in the upper narrower part; margins entire; nerve ± 11.0 µm wide at base, percurrent, smooth at back, in transverse section showing a ventral and a dorsal stereidal band separated by a median row of guide cells; alar cells coloured or hyaline, not forming auricles, 24-30 µm wide, in the marginal row 11-14 µm wide; basal laminal cells rectangular, 50-82 x 7-11 µm, longitudinal walls porose, strongly incrassate, the median and the upper ones smaller, 30-40 x 4-6 µm. Setae brown, straight or slightly curved, ± 2.2 cm long. Capsules reddish-brown, erect or slightly curved, 3.5 mm long and 1.4 mm in diameter, cylindrical, slightly contracted below the mouth; exothecial cells irregular, 34-52 x 14-23 µm, firm-walled, collenchymatous. Peristome teeth 16, each cleft down to one-half of its total length. Operculum conic-rostrate, 2.0 mm long, obliquely beaked. Spores brown, spherical, 20-25 µm, asperately sculptured.

The tall and robust plants, the fastigiately branched stems and the entire-margined leaves of this species facilitate its easy separation from *D. kashmirense*.

Specimens examined: Kashmir : Gulmarg, on way to Alpathar lake, 3,000 m, on rotting stumps, August, 1978, *1128*; Sikkim, 3500 m, substratum and date of collection not indicated, 1417, *2060* (BM).

Distribution: Kashmir, Darjeeling, Sikkim; Nepal.

Chromosome number: Not known.

3. *Dicranum kashmirense* Broth., Acta Soc. Sci. fenn. 24: 9. 1898. (Fig.39)

Plants dark-green, growing in loose tufts. Stems 2.5 - 3.5 cm long, sparingly branched. Leaves patent to falcato-secund, tips flexuose on drying, 3.4 - 4.7 mm long and 0.5 mm wide at base, lanceolate-subulate, canaliculate in the apical part; margins serrulate near the tip; nerve prominent, 70 µm wide at base, percurrent, in transverse section showing 3-4 guide cells, 2 stereidal bands and 2 week ridges at the nerve back; alar cells brown, fragile, enlarged, polygonal, 18-27 µm wide; basal laminal cells elongate-rectangular, 84-104 x 10-14 µm, incrassate, longitudinal walls porose, the upper ones irregular, elongate to elliptic, 50-70 x 10-12 µm, walls porose. Setae straight, twisted on drying, 1.2 - 2.0 cm long. Capsules reddish-brown, curved-cylindric, 2.3-2.4 mm long and 0.9 mm in diameter; exothecial cells irregular, 50-57 x 16-26 µm. Peristome teeth 16, each cleft down to one-half of its length, vertically striate-papillose in the undivided part, striate in the divided portions and papillose at tip. Operculum 2.0 mm long, conic-rostrate. Spores spherical, 16-22 µm, asperately sculptured.

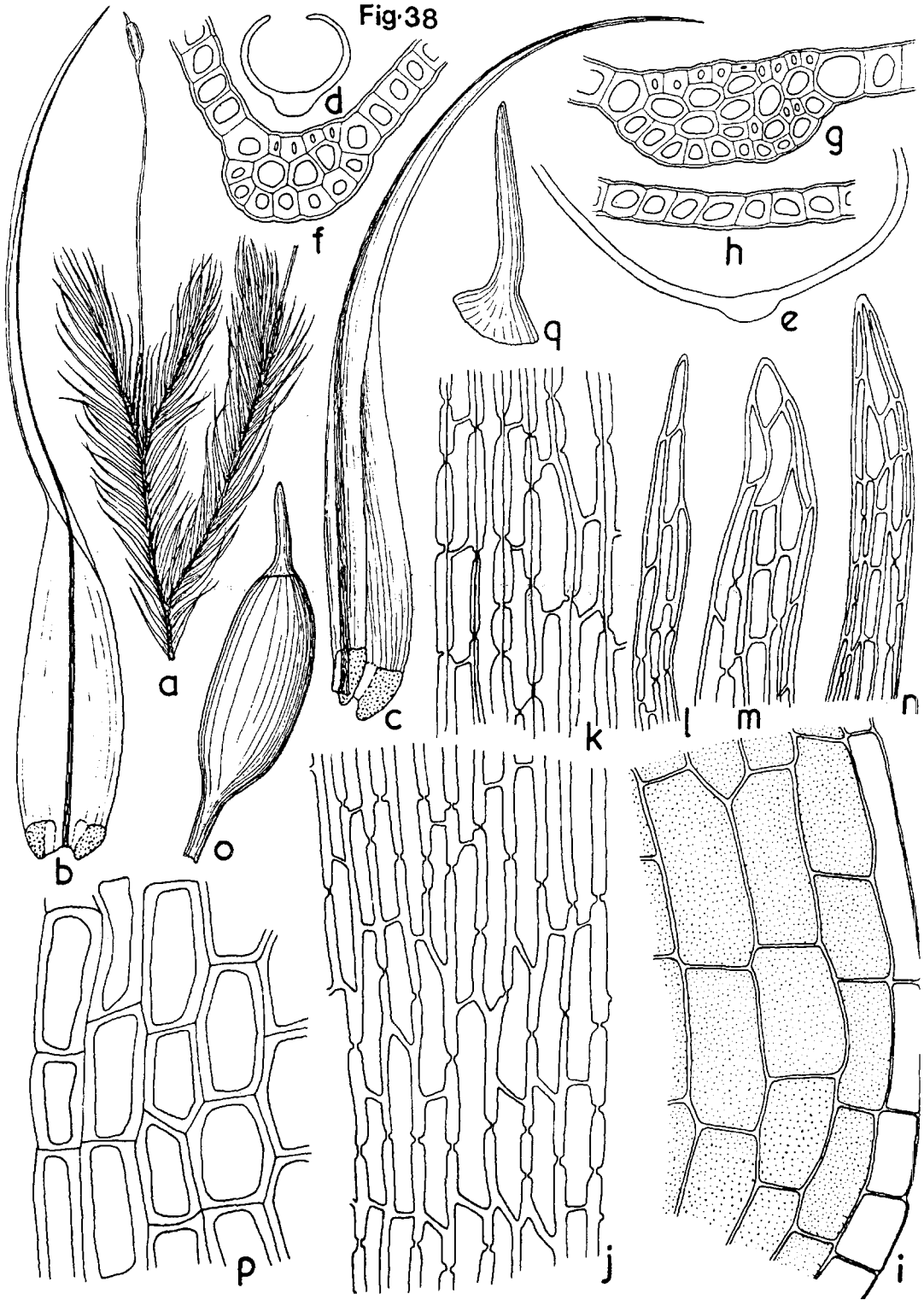

Fig. 38 : Dicranum himalayanum Mitt.

A Plant x 6; b.c. Leaves x 19; d.e. T. S. Leaf x 475; f.g. T. S. Leaf x 475; h. Laminal cells in T. S. x 475; I. Alar cells x 475; j. Basal laminal cells x 475; k. Median laminal cells x 475; l.m.n. Leaf apex x 475; o. Capsule with operculum x 19; p. Exothecial cells x 475; q. Operculum x 19.

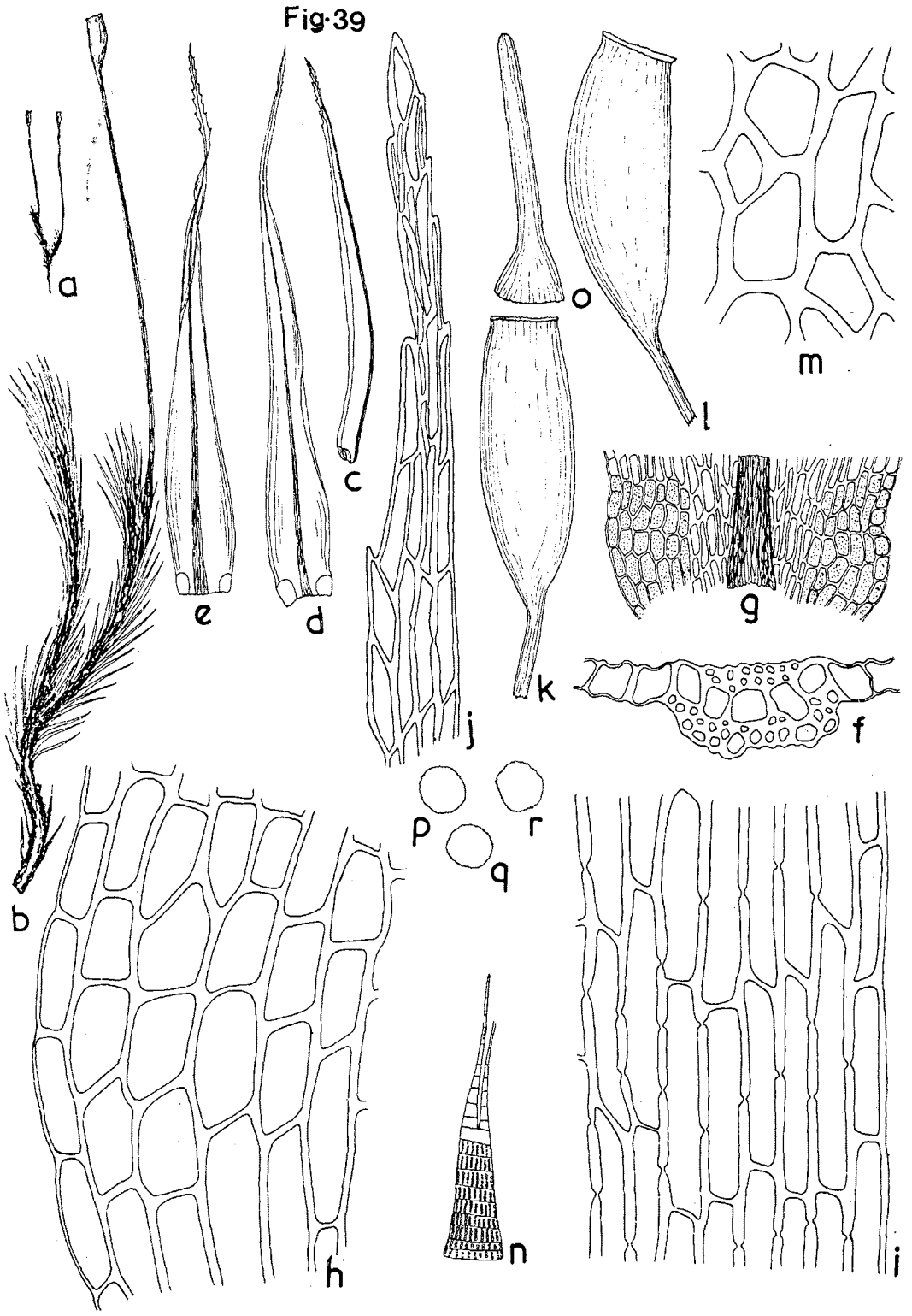

Fig. 39 : Dicranum kashmirense Broth.

a. Dry plant x 2; b. Wet plant enlarged x 12; c,d,e. Leaves x 19 f. T. S. Leaf x 475; g. Leaf base showing alar cells x 200; h. Alar cells enlarged x 475 i. Basal laminal cells x 475; j. Leaf apex x 475; k,l. Capsule x 19; m. Exothecial cells x 475; n. Peristome tooth x 248; o. Operculum x 19; p,q.r. Spores x 475.

This species is less robust, and more sparingly branched than the rest of the species recorded from our area. The subulate leaves, and the notched walls of the laminal cells, when seen in transverse section, help distinction from *D.bonjeanii* D.Not.

Sepcimens examined: Kashmir: Pehlgam, on way to Tulyan lake, 3,000 m, on logs, August, 1978, *1130*; Liddar Valley, 3500 m., Ist August, 1893, *14210*; Gulmarg, 3300 m, June 30, 1893 and September 13, 1932, *14283, 1420;* Muzarffarbad, July 27, 1894, *16492*; Gulmarg, 3000 m, on wet decaying logs, September, 1932, *1419, 1420;* Uttaranchal : Tehri-Garhwal, May, 1899, *12898, 15548, 15570, 16493.*

Distribution: Kashmir, Uttaranchal, N.E. F.A. Endemic in the Himalaya.

Chromosome number: Not known.

4. *Dicranum lorifolium* Mitt., J. Linn. Soc. Bot. Suppl. 1 : 15.1859. (Fig.40)

D.cristatum Wils., Kew J. Bot. 9:295. 1857. *nom. nud.*

Plants robust, yellowish-green, growing in loose tufts. Stems to 6.0 cm long, densely foliate, branched. Leaves falcate to falcato-secund, not much altered on drying, 0.8-1.5 cm long and 0.8 mm wide at base, lanceolate-subulate from widened, concave basal part, commonly folded on the nerve; margins serrate down to one-third portion; nerve 90-115 µm wide at base, ending 2-3 cells below the apex, in transverse section showing one stereidal band above and another one below the median row of guide cells, the lower stereidal band generally separated into 3 groups of highly thickened, very small-lumined cells, back lamellose, lameliae 4, each 1-2 cells high; alar cells brown, inflated, 27-34 µm wide; basal laminal cells rectangular, 54-82 x 10-20 µm, porose, the middle and the upper ones irregularly rhomboidal, 30-48 x 10-15 µm, strongly incrassate, in the apical part of the leaf non-porose. Setae straight, twisted on drying, 3.5 cm long. Capsules slightly curved, cylindrical, 4.8 mm long and 0.8-0.9mm in diameter. Peristome teeth not observed. Spores spherical, 18-24 µm, asperately sculptured.

Specimen examined: Assam : Cherapunji, September 1937, 1421 (BM).

Distribution: Kashmir, Assam. Darjeeling, Sikkim, Khasia Hills; Bhutan, Nepal.

Chromosome number: Not known.

5. *Dicranum montanum* Hedw., Spec. Musc. 143. 1801. (Fig.41)

Orthodicranum montanum (Hedw.) Loesk., Stud. Morph.Syst.Laubm.85. 1910.

Plants light-green, growing in small, compact tufts. Stems to 1.5 cm long, mostly branched, in transverse section rounded with central strand. Leaves falcate to falcato-secund, strongly crisped on drying, to 3.5 mm long and 0.4 mm wide, narrow-lanceolate from wide, nearly rectangular to oblong basal portion, canaliculate in the upper one-half to two-third portion, apex sub-acute; margins serrulate in the apical part; nerve 80 µm wide at base, percurrent or slightly excurrent, back serrulate in the apical part, in transverse section showing a median row of guide cells with feebly developed ventral stereidal band above and well developed dorsal stereidal band below; alar cells rust-coloured, unistratose, not reaching the nerve, inflated, quadrate, 15-18 µm wide; basal laminal cells rectangular, 35-60 x 7-10 µm, towards the nerve 20-35 x 5-8 µm , porose, upwards short, quadrate to irregularly-quadrate, 4-7 µm wide. Sporophyte not observed.

The plants-habit to grow in small, soft tufts, the strongly crisped leaves (when dry), the serrrulate leaf margins in the apical part, and the erect capsules help determination of this species.

Specimen examined: Kashmir : Gulmarg, 2700m, on humus and tree stumps, September, 1976, *1124.*

Distribution: Kashmir; China, Siberia, Caucasus, Europe, North America.
Chromosome number: n = 7,12 13,14.

6. *Dicranum scoparium* Hedw., Spec. Musc. 126. 1801. (Fig.42)

Bryum scoparium (Hedw.) L.ex Funck, Crypt. Gew. Fichtelgeb. 2: 237. 1802

Cecalyphum scoparium (Hedw.) P. Beauv., Prodr. 51. 1805.

Plants light-green, growing in loose tufts. Stems to 4.0 cm long, densely radiculose, branched. Leaves erecto-patent to slightly falcate, little altered on drying, 7.0 – 8.0 mm long and 1.1 mm wide, lanceolate from concave base, gradually narrowing into canaliculate subula; margins serrate down to one-fourth to two-third of the leaf length; nerve 120 -140 µm wide at base, nearly percurrent, in transverse section showing 3-4 guide cells, a ventral stereidal band, a dorsal stereidal band, up to 4 serrated ridges at back in the upper part of the nerve; alar cells brown, enlarged, 20-28 µm wide; basal laminal cells elongate-rectangular, 65-103 x 10-13 µm, lax, longitudinal walls porose, the median and the upper ones short-

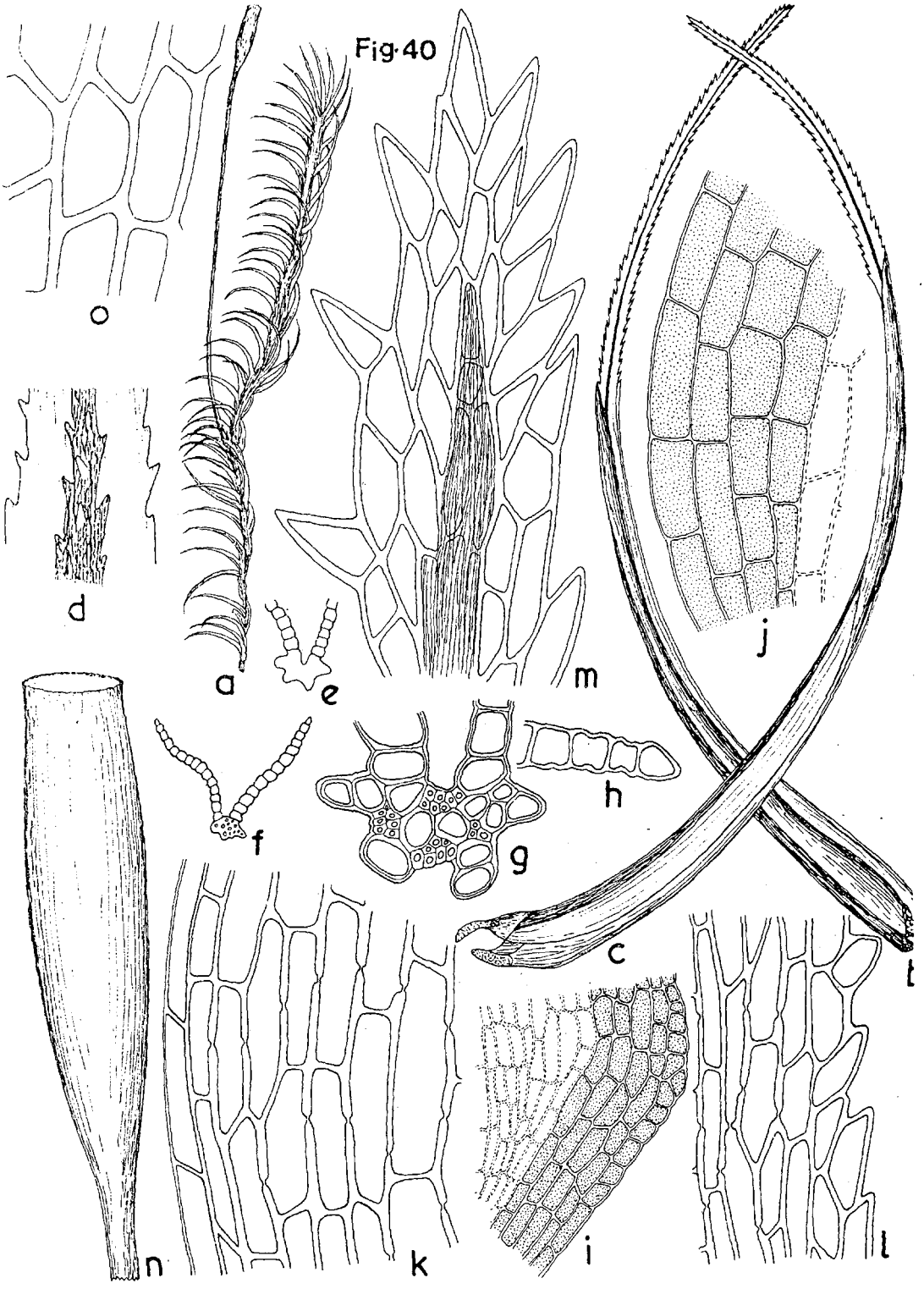

***Fig. 40** : Dicranum lorifolium Mitt.*
a. Plant x 6; b.c. Leaves x 19; d. Nerve back x 248; e f. T. S. leaf x 50; g. T. S. Leaf x 475; h. Laminal cells in T. S. x 475; i. Leaf base showing alar cells x 248; j. Alar cells enlarged x 475; k. Basal laminal cells x 475; l. Median laminal cells from margin inwards x 475; m. Leaf apex x 475; n. capsule x 19.

Fig. 41

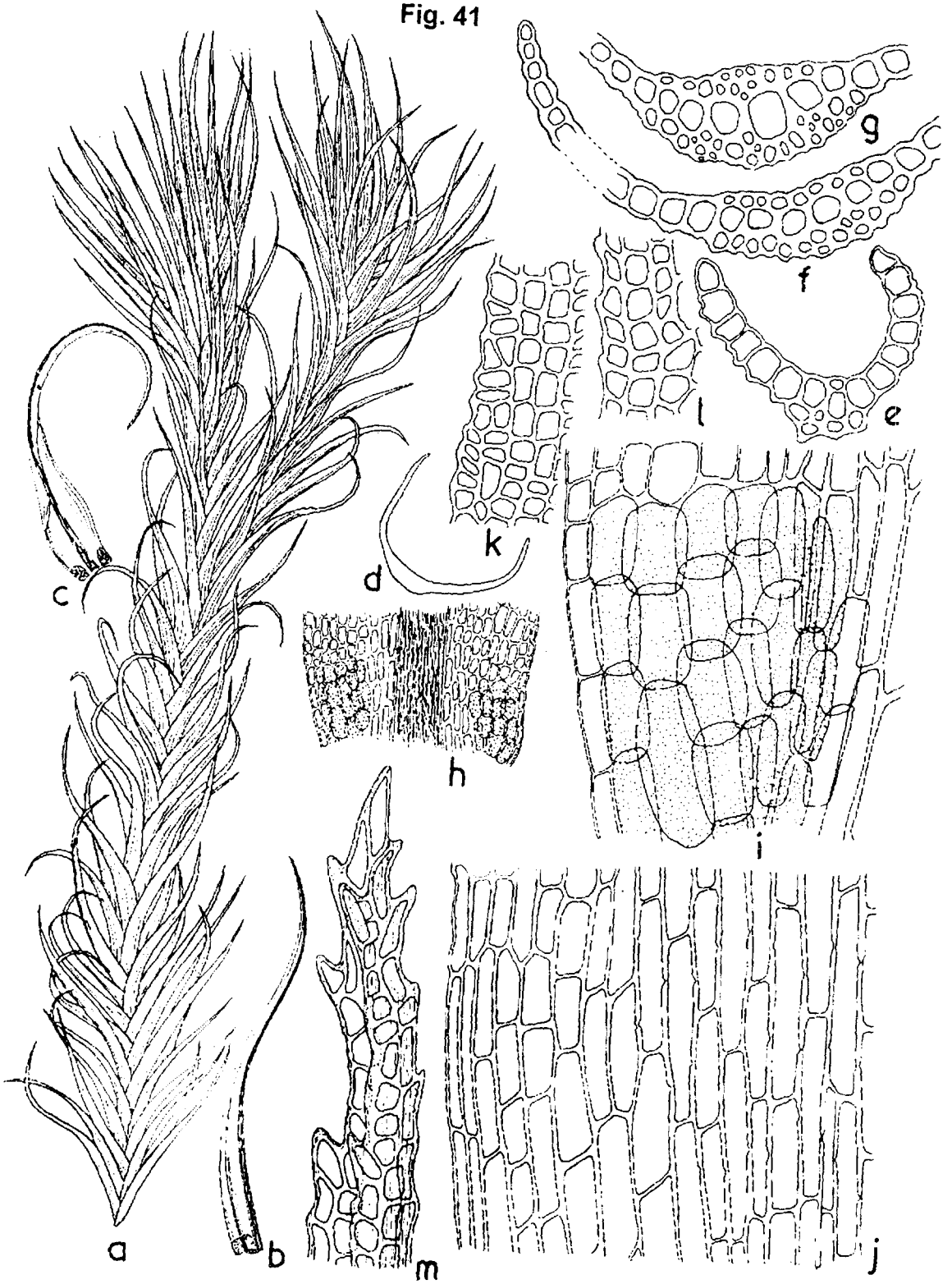

Fig. 41 : Dicranum montanum Hedw.

a. Plant x 6; b,c. Leaves x 19; d. T. S. Leaf x 475; e.f.g. T. S. Leaves; h. Leaf base showing alar cells x 248; i. Alar cells enlarged x 475. j Basal laminal cells x 475; k. Median laminal cells x 475; l. Upper laminal cells x 475; m. Leaf apex x 475.

Fig. 42

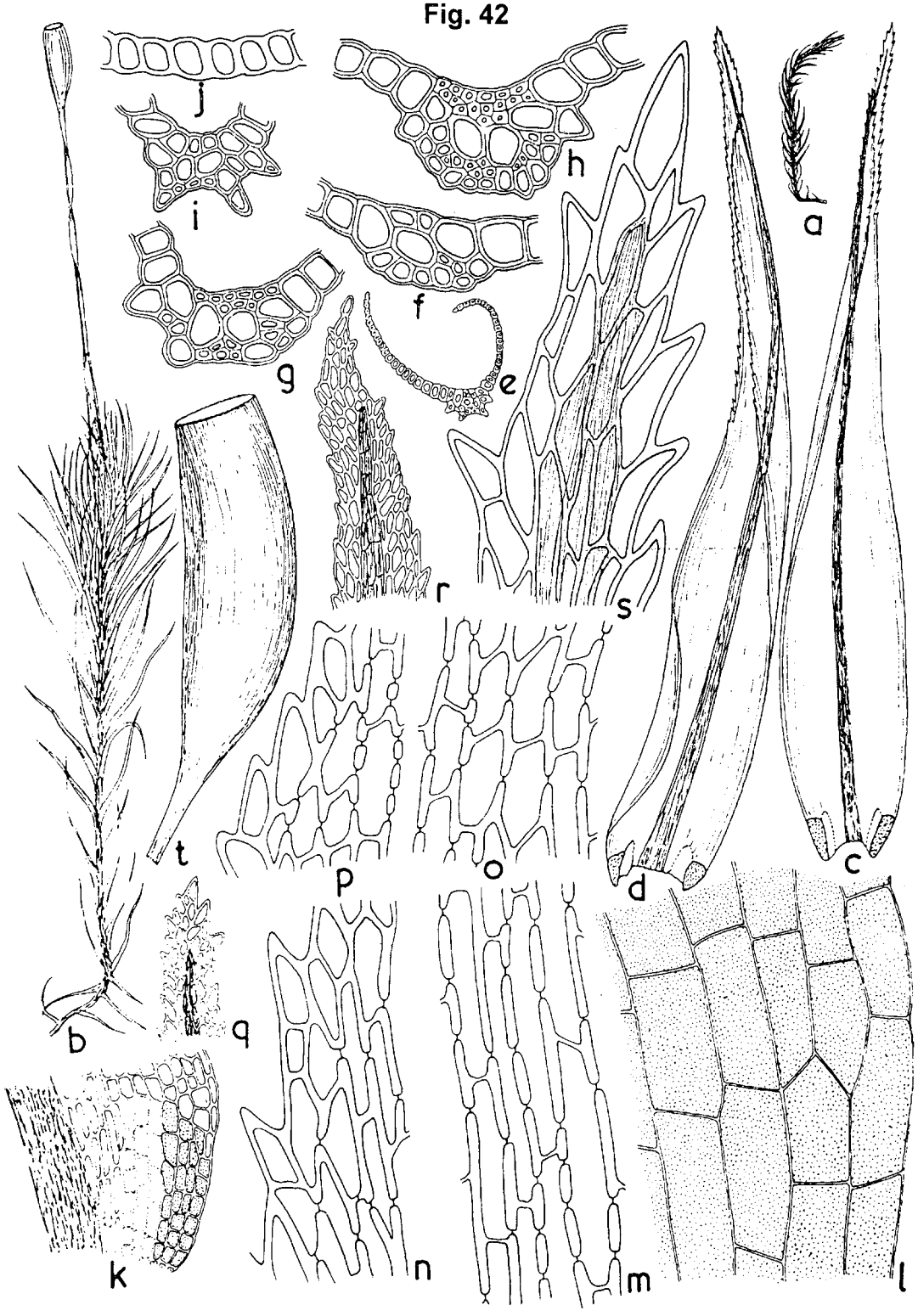

Fig. 42 : Dicranum scoparium Hedw.

A Dry plant x 2; b. Plant enlarged x 6; c,d. leaves x 19; e. T. S. leaf x 475; f,g,h,i. T. S. leaves at different portions x 475; j. Laminal cells in T. S. x 475; k. Leaf base showing alar cells x; l. Alar cells enlarged x 475; m. Basal laminal cells x 475; n. Basal laminal cells at margins x 475; o,p. Median laminal cells x 475; q,r. Leaf apex x 248; s. Leaf apex x 475.

rectangular or hexagonally elongate, 30-54 x 8-10 µm, strongly incrassate, in apex non-porose. Setae single, straight, 2.0 - 3.0 cm long. Capsules curved, arcuate-cylindric, 3.4 long and 0.8 mm in diameter, neck distinct, short. Peristome teeth 16, each cleft down to half of its length. Spores spherical, 18-22 µm, asperately sculptured.

Specimens examined: Uttaranchal : Chopta, 3200 m, on stones, November, 1987, *4037*, Himachal Pradesh : Narkanda, on way to Hatoo peak, 3500 m, on tree logs, September, *1467F*; Kashmir : Khilanmarg, 3500 m, on rotting tree stumps, August, 1976, *1127*; Kishinganga Valley, Gurais, 3000 m, August, 1893, *14326*: Liddar Valley, above Pehlgam, 3300 m, August, 1893, *14392*.

Distribution : Kashmir, Himachal Pradesh, Uttaranchal, Sikkim; Nepal, China, Korea, Japan, Europe, Caucasus, Amur, Azores, Madeira, Canaries, New-Zealand, Am 1, 2, 4. Nearly cosmopolitan.

Chromosome number: n = 11,12,13,14.

7. *Dicranum undulatum* Schrad. *ex* Brid., J. Bot. Schrader, 1800 (2) : 294.1801. (Fig.43)

D. bergeri Bland *in* Sturm, Deutschl. Fl.2 (6) :99.1809.

Cecallyphum undulatum (Brid.) P. Beauv., Prodr. 52. 1805.

Plants robust, dark-green, yellowish-brown on drying, growing in dense tufts. Stems to 12.0 cm long, densely radiculose, branched. Leaves erect-appressed, leaf tips curled on drying, distinctly undulate, to 1.1 cm long and 1.7 mm wide, lanceolate-subulate from a concave base; margins serrate down to two-third of the leaf length; nerve 117-144 µm wide at base, percurrent, in transverse section showing 3-4 guide cells, two stereidal bands, and at back, in the upper part of the leaf, two lamellae, each lamella 2-3 cells high, sometimes 2 slight ridges also seen on nerve back; alar cells brown, enlarged, 17-32 µm wide; basal laminal cells rectangular with sometimes oblique end walls, to 98 x 10-19 µm, porose, the upper ones irregular, elongate to rhomboidal, nearly as long as the basal cells, non-porose, incrassate. Setae single or upto four in a perichaetium, straight, apparently lateral due to innovations, 3.5 cm long. Capsules brown, slightly curved, cylindrical, 2.8 mm long and 1.0 mm in diameter, furrowed on drying. Peristome not observed. Spores brown, spherical, 12-18 µm, asperately sculptured.

The very robust plants, the strongly undulated leaves with coarsely serrate leaf margins help recognition of this species.

Specimens examined: Kashmir : Gulmarg, 3300 m, on stumps of conifers, August, 1976, *1125*; Uttaranchal : Chopta, Ukhimath, 3620 m, on soil gathered on rocks, September, 1986, *3695*; Tungnath, Chamoli, 3620 m, October, 1987, *5099*; Sikkim (Lachen), August, 1872, *35008, 35070, 35071*.

Distribution: Kashmir, Himachal Pradesh, Uttaranchal, Sikkim; Sieberia, Japan, Europe, North and Central America.

Chromosome number: n =10,11,12.13.

3. FAMILY BRUCHIACEAE Schimp.

Plants small, green or yellowish-green, growing singly or in wide cushions. Leaves mostly subulate from an obovate or oblong basal portion; margins plane or recurved, entire, sometimes toothed in the apical part; nerve sub-percurrent to excurrent, mostly heterogeneous; basal laminal cells enlarged, rectangular, upwards rectangular, sub-rectangular, rhomboid or quardrate. Setae very short or long, generally straight. Capsules ovoid or cylindric, generally curved, cleisto - or stego-carpous; apophysis distinct, short or long, strumose or non-strumose, stomatose; peristome teeth none or 16, divided nearly to the base. Spores distinctively sculptured.

The family Bruchiaceae includes five genera* (*Bruchia, Eobruchia* W.R. Buck, *Pringleela* Card., *Cladophascum* Sim, *Trematodon* Michx (*cf.* Buck & Goffinet, 2000), of which two (*Bruchia, Trematodon*) are recorded from India. In our area, Bruchiaceae is represented only by one genus i.e. *Trematodon*.

Key to the Genera

Setae short; capsules cleistocarpous..... ***Bruchia*****

Setae elongate; capsules stegocarpous..... ***Trematodon***

Trematodon* Michx., Fl. Bor. Am. 2: 289. 1803.**

Plants light-green to yellowish-green, commonly growing singly on bare soil. Stems short, mostly simple with a

*I find myself in complete agreement with Buck & Goffinet (2000) in assembling these five genera in the family *Bruchiaceae*. In respect of the treatment of this family, I agree with Takaki (1962) that Trematodontoideae (treated here as Bruchiaceae) is a connecting link between Dicranaceae and Ditrichaceae.

**Not recorded from the Western Himalaya so far.

*** The taxonomic account of this genus is after Kumar, S.S. (1985)

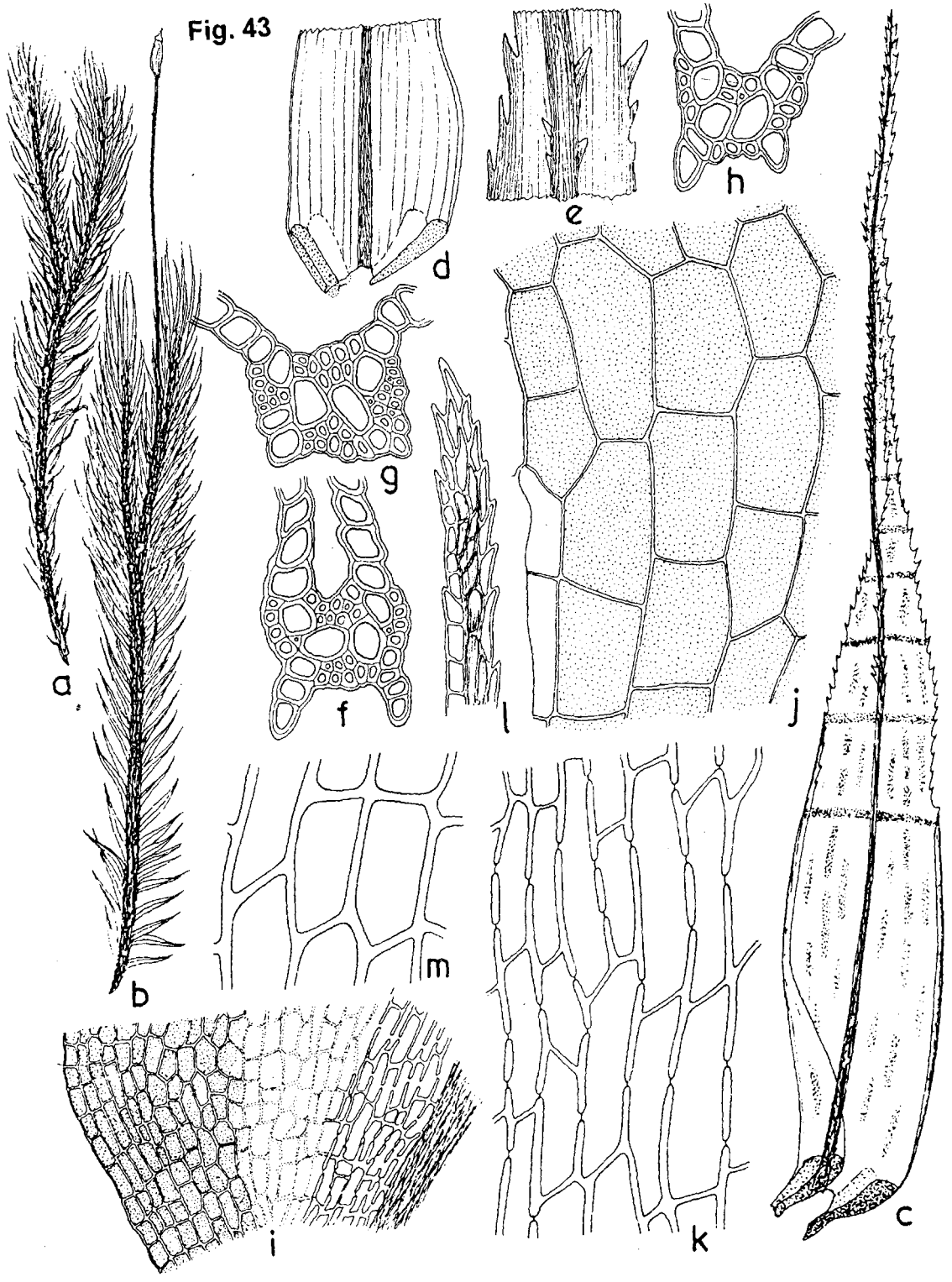

Fig. 43 : Dicranum undulatum Schrad. ex Brid.
a. Dry plant x 2; b. Wet plant x 6; c. Leaf x 19; d. Leaf base x248; e. Leaf margin and nerve back x 248; f,g,h. T. S. Leaf x 475; i. leaf base showing Alar cells x 248; j. Alar cells enlarged x 475; k. Basal laminal cells x 475; l. Leaf apex x 475; m. Median laminal cells x 300.

large central strand. Leaves lanceolate-subulate from broad, sheathing basal part; nerve sub-percurrent to excurrent; basal laminal cells rectangular to elongate-hexagonal, upwards short-rectangular, smooth; alar cells not differentiated. Setae long, flexuose on drying. Capsules cylindric, mostly ± curved; neck long, clavate, often strumose, stomatose throughout, stomata superficial. Peristome teeth 16, each tooth divided nearly to the base or entire or perforated, vertically striate, papillose in the upper part, sometimes absent. Operculum long, obliquely rostrate. Calyptra cucullate.

This genus displays some variability in respect of some sporophytic features, and sometimes extremes occur in the same tuft. Be as it may, it does appear that in this genus, the shorter capsular neck with struma at the base, the deeply cleft peristome teeth, and the large-sized spores with prominent sculpturing elements, are derived features.

Cytologically, this genus is known from 5 species i.e. *Trematodon ambiguus* (Hedw.) Hornsch. - n = 13+2 m; *T. brevicollis* Hornsch. - n = 11; *T. conformis* Mitt. - n = 13+m; *T. longicollis* Michx. - n = 14+m, 28, 28+2m; *T. subulosus* Griff. - n = 14+m. While this genus shares n = 14,15,28,30 with the allied genus *Bruchia,* it differes in that the latter taxon lacks in m-chromosome from being a part of the complement.

Trematodon Michx., includes 100 species (including 33 *nom. nud.* taxa) with their maximum concentration (27 endemic + 6 common elements) in Africa followed by America (22 endemic + 3 common elements) and Asia (18 endemic +.....? common elements). In our country, it is represented by 9 species, of which 4 are found in our area.

Key to the West Himalayan species of *Trematodon* Michx.

a. Leaves 1.0-1.1 mm long, acute; apophysis not strumose; spores 11-13 µm..... **4. *T. subulosus***

Leaves 3.0-6.0 mm long, subulate; apophysis strumose; spores 17-24 µm..... b

b. Plants not more than 2.0 mm tall; leaves 3.0 - 3.5 mm long.....**2. *T. conformis***

Plants more than 4.0 mm tall; leaves 4.0 - 6.0 mm long.....c

c. Stems 7.0-8.0 mm long; apophysis not less than twice the length of the urn.....**3. *T. longicollis***

Stems to 4.7 mm long; apophysis nearly as long as the urn.....**1. *T. capillifolius***

1. *Trematodon capillifolius* C. Muell. *ex* Roth., Aussereur. Laubm. 296. 1911. (Fig.44)

Plants yellowish-green, growing in wide patches or small cushions. Stems to 4.7 mm long, mostly branched at base, densely foliate. Leaves strongly curled when dry, spreading-flexuose when moist, 2.6 mm long, upwards to 5.0 mm long and 0.4-0.5 mm wide at base, capillaceous-subulate from a nearly ovate or oblong basal part, clasping at base; margins entire, or very faintly denticulate near apex; nerve sub-percurrent or percurrent, not filling the subula; basal laminal cells elongate-rectangular, to 74 x 10 µm, upwards rectangular to short-rectangular, 9-13 x 7-8 µm, larger towards the nerve. Setae yellow, straight, 1.8-2.0 cm long. Capsules curved, cylindric; urn 1.9 mm long and 0.74 mm in diameter; apophysis nearly as long as the urn, 2.0 mm long, strumose at base, stomatose throughout; exothecial cells elongate, 40-70 x 8-11 µm, strongly incrassate. Peristome teeth 0.33 mm long and 0.05 mm wide at base, irregularly perforate from nearly a little below the apex down to a little above the base, vertically striate below and papillose at apex. Spores spherical, 20-24 µm in diameter, coarsely sculptured.

The material illustrated as *T. capillifolius* in "Taxonomy of Indian mosses" (Chopra, 1975) on page 52, fig. 12 is actually *T. subulosus*.

This richly fruiting moss is very common in the Western Himalaya. It is one of the pioneers, which colonises on soil laid bare by land slides or by the humans. The capillaceous-subulate leaves, and the nearly equi-long apophysis and urn of the capsule help easy distinction.

Specimens examined: Uttaranchal : Mussoorie, on bare, calcareous soil, January 1892, and September, 1951, *423, 636, 637, 1490.* Himachal Pradesh : Shimla, on disturbed soil, October, 1966, 1977, *2054, 2063, 3017.*

Distribution: Western Himalaya.

Chromosome number: n = 15 (14 + m).

2. *Trematodon conformis* Mitt., J. Linn. Soc. Bot. Suppl. 1: 12. 1859. (Fig. 45)

T. indicus Mitt. *in* C. Muell., Gen. Musc. Frond. 310. 1900 *nom. nud. fid.* Dix. (on sheets) and Gang., Mosses of Eastern India 2: 227. 1971.

Plants yellowish-green, scattered singly. Stems 1.2-1.5 mm long, simple. Leaves curled when dry, flexuose when moist, 3.0-3.5 mm long and 0.35-0.37 mm wide, subulate-canaliculate with an ovate-rectangular basal part; margins dentate in the apical part; nerve brown, sub-percurrent; basal laminal cells irregular to rectangular, to 70 x 6-9 µm, from middle upwards sub-rectangular and then sub-

Fig. 44

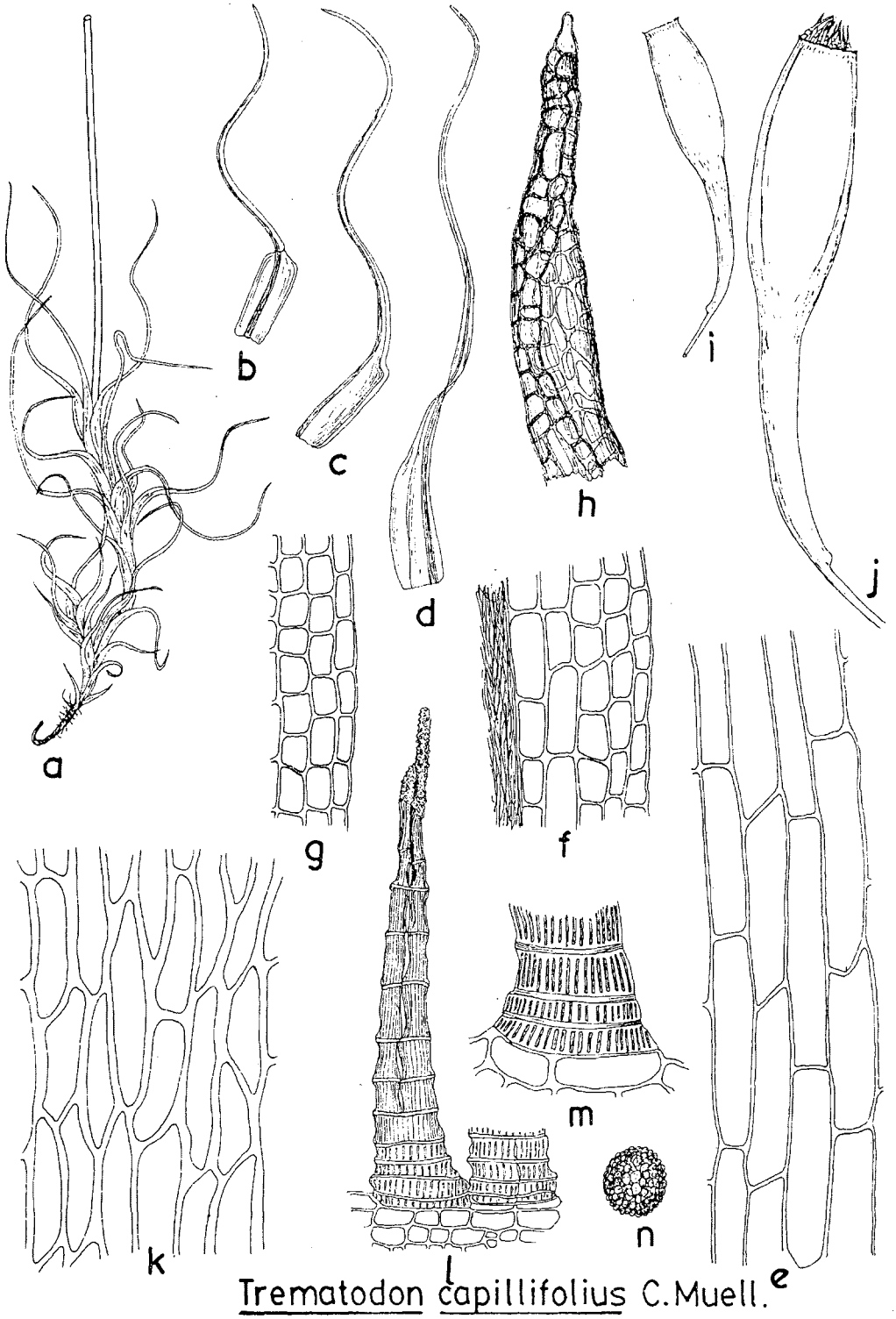

Fig. 44. Trematodon capillifolius C. Muell. ex. Roth.
a. Plant x 8; b,d. Leaves x 19; e. Basal cell x 475; f,g. Median laminal cells x 475; h. Leaf apex x 475; i. Capsule x 9; j. Capsule enlarged x 19; k. Exothecial cells x 475; l. Peristome teeth x 475; m. Peristome teeth at base x 475; n. Spore x 475.

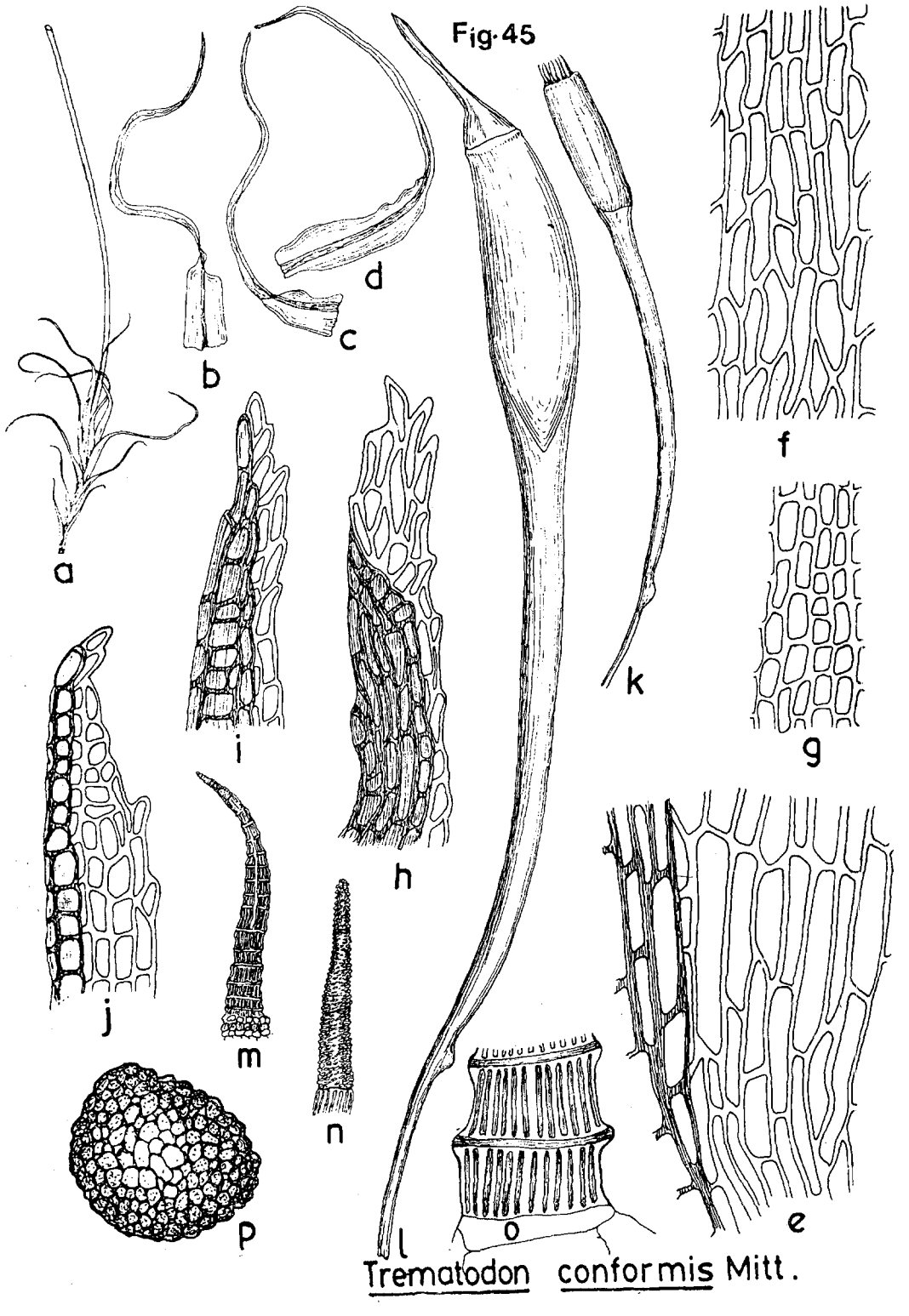

Fig. 45 : Trematodon conformis Mitt.

a. Plant x 6; b,d. Leaves x 19; e. Basal cells x 475; f. Exothecial cells x 475; h,j. Apices of leaves x 475; k. Capsule x 9; l. Capsule x 19; m,n. Peristome teeth x 475; o. Upper part of tooth x 475; Spore x 475.

Fig. 46

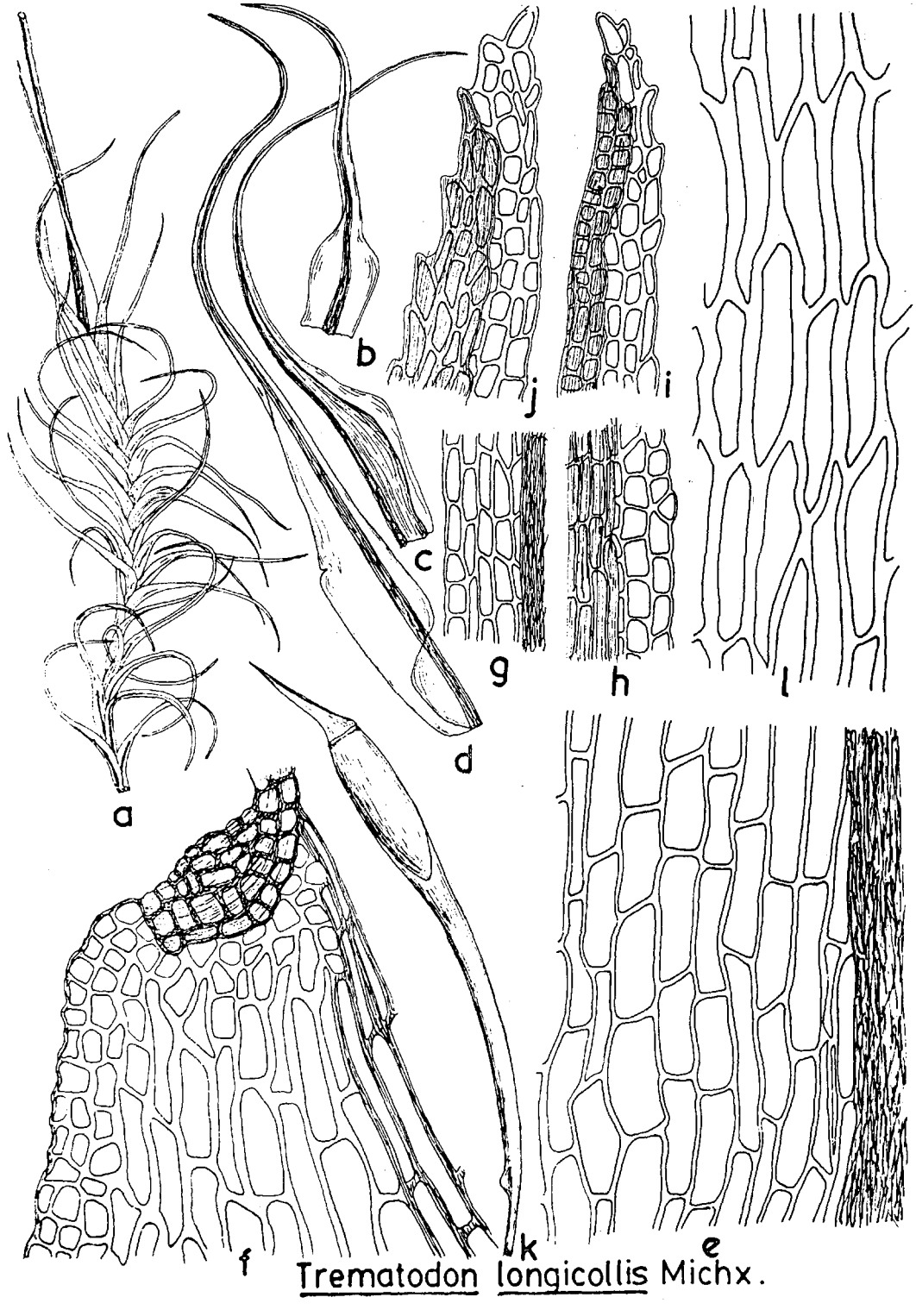

Fig. 46 : Trematodon longicollis Michx.
a. Plant x 8; b,c,d. Leaves x 19; e. Basal cells x 475 f. Cells at leaf shoulders x 475; g,h. Median laminal cells x 475; I,j. Apices of leaves x 475; k. Capsule x 9; i. Exothecial cells x 475.

quadrate, 7-12 x 5-6 µm. Setae erect, twisted when dry, 1.5 cm long. Capsules erect, sometimes slightly curved, cylindric; urn to 2.3 mm long and 0.74 mm in diameter; apophysis 5.0-6.0 mm long, strumose at base, stomatose throughout; exothecial cells elongate; annulus broad, of large, vertically elongate cells. Peristome teeth 16, irregularly split, joined at apex, vertically striate below and papillose at apex.

In my opinion, this taxon is only a haploid form of *T. longicollis*, from which it is differentiated only by quantitative characters i.e. the relatively shorter stems with smaller leaves, the smaller exothecial cells, and the shorter operculum.

Specimens examined: Himachal Pradesh : Jabli, 600 m, on moist, bare soil rich in rubble, September 1977, *3015.* India Orientalis, Jaeger Herbarium (BM).

Distribution: Western Himalaya, South India, N.E.F.A., Darjeeling, Sikkim; Bhutan, Nepal, Tonkin, Sumatra.

Chromosome number: n = 14 (13 + m).

3.*Trematodon* longicollis Michx., Fl. Bor. Am. 2: 289. 1803. (Fig.46)

T. ceylonensis C. Muell., Bot. Zeit. 22: 350. 1864 *cf.* Gang., Mosses of Eastern India 2: 231. 1971.

T. longicollis Wils. *et* Mitt. *in* C. Muell., l.c. *nom. nud. in synon. fid.* C.Muell., Bot. Zeit. 22: 350. 1864.

Plants yellowish-green, growing in widely-spaced patches. Stems 7.0-8.0 mm long, mostly simple, densely foliate. Leaves strongly curled when dry, spreading with flexuose tips when moist, 4.0-6.0 mm long and 0.4 mm wide at base, narrow to linear with an ovate or oblong basal part, clasping at base; margins incurved, entire except near tip; nerve sub-percurrent, not filling the linear limb; basal laminal cells rectangular, to 57 x 8-13 µm, at shoulders irregular, 7-10 x 5-6 µm, upwards rectangular to short-rectangular, 12-19 x 3-6 µm. Setae yellow, flexuose when dry, nearly straight when moist, 2.0 cm long. Capsules curved, cylindric; urn 2.5 mm long and 0.8-0.9 mm in diameter; apophysis nearly twice to thrice the length of the urn, 5.1 mm long, strumose at base, stomatose throughout; exothecial cells elongate, 58-70 x 9-12 µm, strongly incrassate. Operculum 1.9 mm long, long-rostrate, with an oblique beak. Rest not observed.

In our area, this species is found at relatively high altitude. The plants are mostly in loose tufts and grow on shady rocks and also on soil rich in rubble. The longer stems, and the very long apophysis (nearly twice to thrice the length of the urn), help easy separation from the remaining species of *Trematodon* Michx.

Specimens examined: Himachal Pradesh : Narkanda, 2700 m, on bare, calcareous soil, September, 1975, *3016;* Sikkim, 2100 m, Herb. Ind. Or. *49* (BM).

Distribution: Almost cosmopolitan.

Chromosome number: n = 14 + m, 28, 28 + 2m.

4.Trematodon subulosus Griff., Not. Pl. Asiat. II: 413. 1849. (Fig. 47)

Correction of *T. sabulosus* Griff., Calcutta J. Nat. Hist. 2: 493. 1842.

Plants yellowish-green, growing in scattered patches. Stems short, to 2.2 mm long, mostly simple, densely foliate. Leaves curled when dry, erecto-patent when moist, 1.0-1.1 mm long and 0.27 mm wide at base, ovate to oblong-lanceolate, apex acute; margins recurved, folded on the nerve in many leaves, entire except for 1 or 2 blunt teeth near apex; nerve sub-percurrent; basal laminal cells rectangular, 25-40 x 6-12 µm, a little above base irregular to polygonal, 20-30 x 8-10 µm, marginal row of relatively shorter cells, upwards rectangular, 13-20 x 8-10 µm. Setae yellow, nearly straight, 1.2 cm long. Capsules curved, cylindric; urn 1.8-2.4 mm long and 0.6-0.7 mm in diameter; neck nearly twice the length of the urn, 3.4-3.7 mm long, non-strumose at base, stomatose throughout; exothecial cells near the mouth of the capsule, 20-25 x 6-8 µm, incrassate, lower down to 32 x 4-7 µm, thin-walled. Operculum 1.1-1.3 mm long, long-rostrate, obliquely beaked. Immature spores (mature not observed) spherical, 12-13 µm in diameter, sculptured-papillose.

Specimens examined: Himachal Pradesh : Dharmpur, 1400 m, on soil, October 1976, *3018.* West Bengal : Darjeeling, February, 1957, 1489.

Distribution: Western Himalaya (low altitudes; also Punjab plains, Rajasthan), Assam; Bhutan.

Chromosome number: n = 15 (14 + m).

4. FAMILY DITRICHACEAE

Plants light-green, growing in tufts. Stems small, medium-sized or long, simple or branched. Leaves lanceolate or lanceolate-subulate from a broadened base; margins plane or recurved, entire or serrulate; nerve percurrent or excurrent, in transverse section showing a median row of guide cells with a few stereids above, a group of hydroids and a well developed stereidal band below; alar cells not differentiated. Setae mostly long, rarely short. Capsules exserted (immersed in *Pleuridium* and *Garckea*) erect or inclined, smooth or ribbed, annulate, rarely exannulate. Peristome single, teeth 16, each divided down to the base

Fig. 47

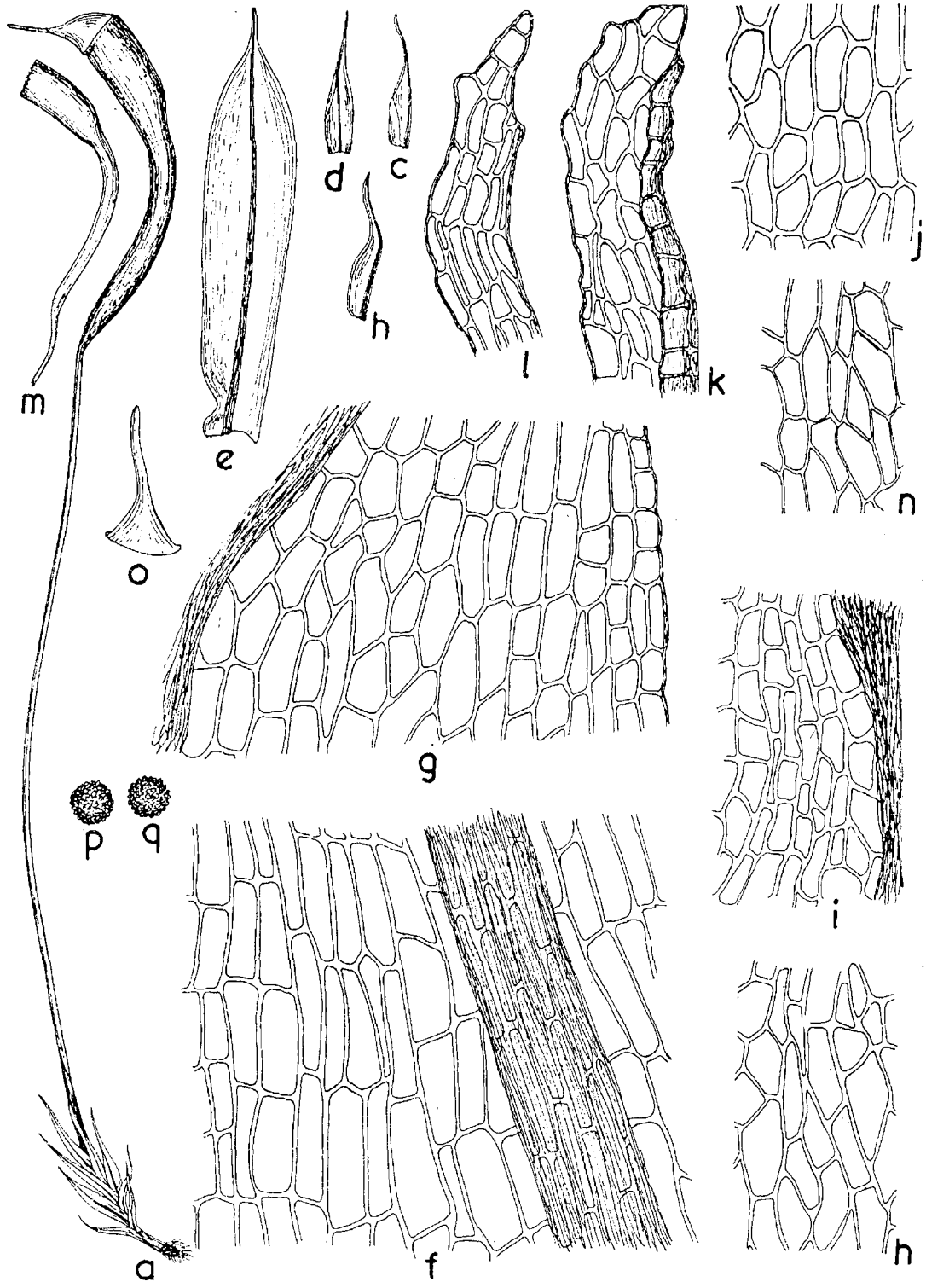

Fig. 47 : Trematodon subulosus Griff.

A. Fertile plant x 8; b,c,d. Leaves x 19; e. Leaf enlarged x 76; f. Basal cells x 475; g. Cells above the base x 475; h. Median cells x475; i. Upper cells x 475; j. Exothecial cells near capsule mouth x 400; k, l. Leaf apex x 475; m. Capsule x 9; n. Exothecial cells at capsule middle x 475; o. Oper culum x 19; p,q. Spores x 475.

into filiform, papillose crura, sometimes absent. Operculum conical to rostrate, rarely not differentiated. Calyptra cucullate.

Family Ditrichaceae comprises 24 genera, of which 8 are recorded from India. In our area, this family is represented by 6 genera.

Key to the West Himalayan genera of Ditrichaceae

a. Capsules immersed.....b

Capsules exserted.....c

b. Plants relatively taller and pencil-like in appearance; laminal cells (upwards) adjoining the nerve and at margins bistratose; nerve, in transverse section, rounded at the back and with a band of sub-stereids enclosed between the upper and the lower epidermis; peristome present; operculum differentiated.....**1. *Garckea***

Plant very small, never pencil-like in appearance; laminal cells unistratose all through, nerve, in transverse section, never rounded at the back, showing median row of guide cells with stereidal band above and below it; peristome absent; operculum not differentiated.....**2. *Pleuridium****

c. Leaves appearing to be distichous (particularly in the upper part of the plant); nerve back papillose; peristome teeth obliquely striolate.....**3.*Distichium***

Leaves not distichous; nerve back smooth; peristome teeth papillose, never obliquely striolate.....d

d. Leaves glaucous-green, covered on surface with blue-green filamentous or granular bloom .....**5. *Saelania***

Leaves neither glaucous nor with any bloom.....e

e. Leaves subulate; leaf margins plane, rarely incurved; upper laminal cells mostly narrow-rectangular; sporophyte mostly terminal; dry capsules smooth, non-strumose.....**4.*Ditrichum***

Leaves lanceolate from a broad basal portion; leaf margins recurved; upper laminal cells quadrate to quadrate-rounded; sporophyte often appearing lateral due to innovations; dry capsules furrowed, strumose.....**6.*Ceratodon***

1. *Garckea* C.Muell., Bot. Zeit.3: 865. 1845.**

Plants light-green, pencil-like in appearance, growing in loose tufts. Stems erect, slender, very thin, radiculose at base. Leaves appressed when dry, erecto-patent to erect-spreading when moist, narrow-lanceolate to lanceolate with widened basal portion, acuminate; nerve excurrent, percurrent or sub-percurrent, in transverse section rounded at the back and with sub-stereids enclosed between the upper and the lower epidermis; laminal cells narrow-rectangular to prosenchymatous. Setae short. Capsules immersed or emergent, short cylindric to oblong- cylindric; annulus revoluble, biseriate. Peristome teeth 16, inserted below the rim, irregularly cleft, perforate, papillose. Operculum conic-rostrate. Calyptra campanulate, covering operculum only.

Type: *Garckea phascoides* C. Muell. = *C. flexuosa* (Griff.) Marg. & Nork.

Garckea is represented by 4 species, of which *G. flexuosa* is widely distributed. It is rather interesting that the other three species are suspected to be variants of *G. flexuosa*. This, at least, indicates the wide range of morphological plasticity in the afore-mentioned species.

In our area, this genus is represented by *G. flexuosa* (Griff.) Marg. & Nork.

Garckea flexuosa (Griff.) Marg. & Nork., J. Bryol. 7 : 440. 1973 (Fig.48)

Garckea comosa Dozy & Molk., Ann. Sci. nat. Bot. Ser. 3,2 : 304.1844.

Garckea phascoides (Hook.) C. Muell., Bot Zeit. 3 : 865, 1845.

Grimmia flexuosa Griff., Calcutta. J. Nat. Hist. 2 : 492. 1842.

Dioicous. Plants light-green or yellowish-green, growing singly or in loose tufts. Stems 3.0-6.5 mm long, simple. leaves appressed with tips slightly twisted when dry, erect-appressed when moist, the lower ones 0.7-1.2 mm long, the middle ones 2.5-2,6 mm long and 0.2-0.3 mm wide at base, the perichaetial ones 2.8-3.0 mm long and 0.13 - 0.18 mm wide at base, narrow-lanceolate to lanceolate, narrowing from an oblong or ovate-oblong basal portion, acuminate; margins plane, rarely recurved above, entire; nerve distinct, 40-53 µm wide at base, excurrent, in transverse section rounded at back with a few to many sub-stereids above the lower epidermis; alar cells not differentiated; basal laminal cells narrow-rectangular to prosenchymatous, 38-88x3-8 µm, thin-walled, the middle

*Likely to be collected from our area and hence included in the Key to the Genera. I jointly with Mr. A.H. Norket of the British Musium of Natural History, London (when he was on a visit to India for the collection of mosses) did collect the material of *P. subulatum* from Dehra Dun during the winter months, but unfortunately, the collection was lost. Later attempts to find it from that locality with disturbed soil, bore no fruit. A borrowed illustration is given only to facilitate its recognition by the future investigators.

** The taxonomic account of this genus is after Kumar, S.S. (1978)

Fig. 48

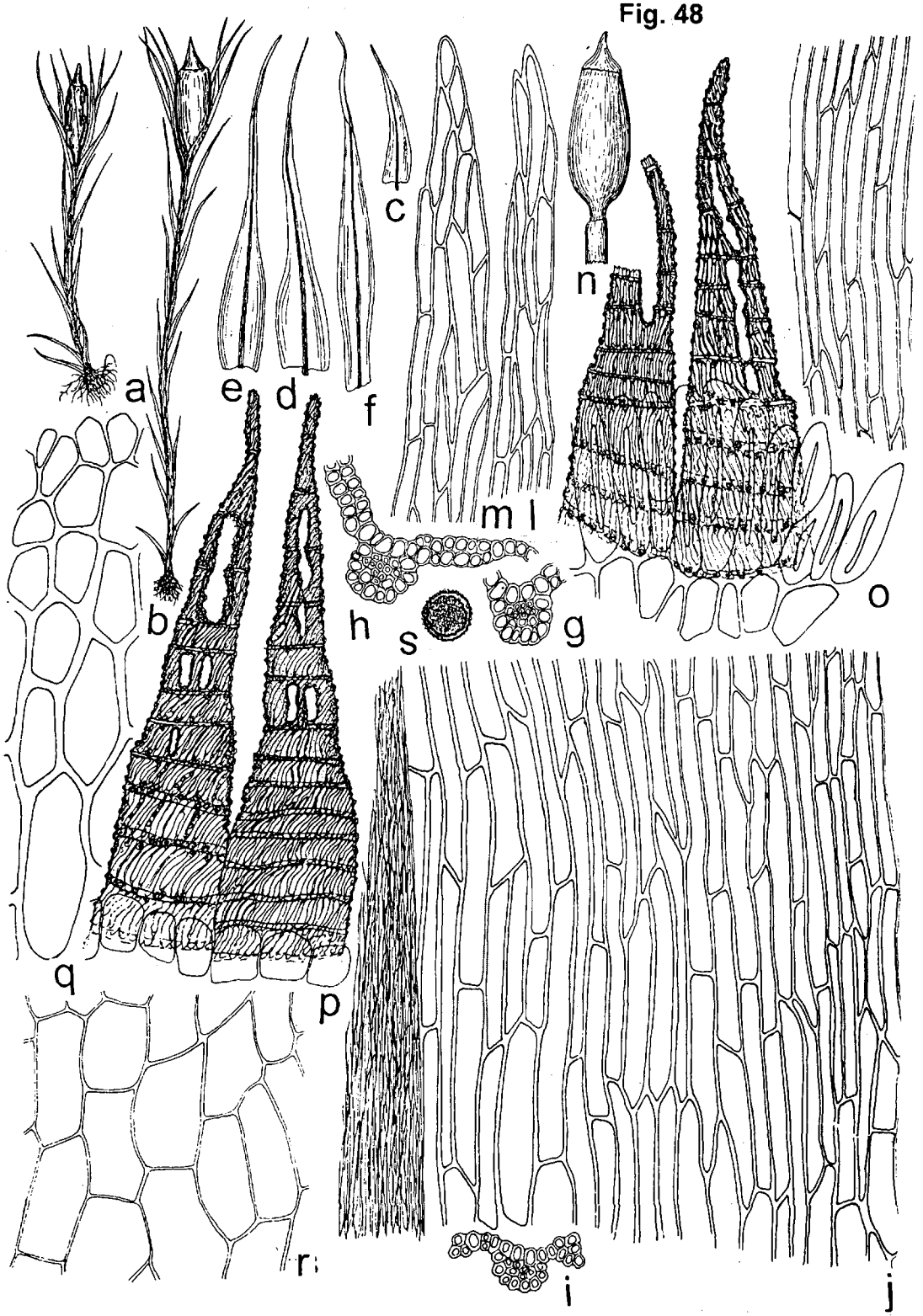

Fig. 48 : Garckea flexuosa (Griff.)n Marg & Nork.

a, b. Plants x 8; c. Lower leaf x 19; d,e. Middle Leaves x 19; f. Perichaetial leaf x 19; g,h,i. T.S. leaves x 248; j. Basal Cells of the leaf x 475; k. Median Laminal Cells x 475; l,m. Leaf cells at apices x 475; n. Capsule x 19; o,p. Peristome teeth x 475; q. Cells below capsule mouth x 475; r. Exothecial Cells x 475; s. Spore x 475.

ones to 80x3-5 µm, upwards bistratose at margins and also adjoining the nerve, 35-45x3-5 µm. Setae short, 0.4 mm long, vaginulate. Capsules immersed, 1.5 mm long and 0.5 mm in diameter, ovate - cylindric, annulate; exothecial cells immediately below the mouth (3-4 cells deep) elongate, incrassate, others irregular to oblong-hexagonal, 25-40x10-20 µm, thin-walled. Peristome teeth 16, inserted below the rim, + 180 µm long, reddish below , brown above, cleft, perforate, papillose. Operculum 0.4 mm long, conic-rostrate with scabrous tip . Calyptra small, campanulate, covering operculum only, surface papillose. Spores spherical, 16- 19 µm, asperately sculptured.

A comparison of the presently studied material with that described from Eastern India shows, that the West Himalayan population of this species is relatively taller (3.5- 6.5 mm vs 2.2 mm) , with longer leaves (upto 3.0 mm vs 2.0 mm) , longer capsules (1.5mm vs 1.0 mm) and smaller spores (16- 19 µm vs 20 - 26 µm).

In the field, this species is easily recognized by the pencil-like plant habit, the slender stems looking almost naked in the lower part because of small, distantly placed leaves, and the short cylindric capsules immersed in the perichaetial leaves. In our area, this taxon shows abundant fruiting.

Specimens examined: Uttaranchal : Mussoorie, on way to Maghra, 1600 m, on soil, September 1976, *K-701*; Himachal Pradesh : Dharamsala, near tea estate, 1650 m , on soil, August 1977, *3111, 3112.*

Distribution: Himachal Pradesh, Uttaranchal, Western India (Maharabaleshwar), Khasi Hills, West Bengal, South India; Nepal, Bhutan, China, Myanmar, Japan, Tonkin, Malaysia, Australia, Oceanic Islands, Madagaskar, Panama.

Chromosome number: n =12, 13, 13+m.

2. *Pleuridium* Rabenh. *nom. cons.*

Plants light-green, growing in loose or dense tufts. Stems very short, simple or branched through innovations. Leaves erect -spreading, lanceolate-subulate with broadened basal portion, concave; nerve broad, filling most of the subula; in transverse section showing a median row of guide cells between the ventral and the dorsal stereidal band; basal laminal cells rectangular to oblong-rhomboidal, upwards narrow-elongate-rectangular to linear. Setae very short. Capsules immersed, sub - globose, cleistocarpous, non-peristomate. Calyptra cucullate, smooth.

Lectotype: ***Pleuridium subulatum*** (Hedw.) Rabenh.

Sainsbury (1955) wrote, "These little mosses form more or less dense colonies in bare ground, and as they often fruit abundantly, and the capsules, although immersed, is fairly large and quite visible in the narrow perichaetial leaves, they are comparatively easy to find when fertile".

Morphologically, this phyletically interesting taxon is related to some other cleistocarpous taxa, notably *Bruchia* and *Archidium*. However, the lack of apophysis distinguishes it from *Bruchia*, and the small-sized, numerous spores help separation from *Archidium*.

Cytologically, *Pleuridium* Rabenh. is known from 5 species i.e. *P. acuminatum* Lindb. - n = 13, 26; *P.bolanderi* C.Muell.*ex* Jaeg. - n = 26; *P. palustre* (Bruch et Schimp.) B.S.G. - n = 7; *P. ravenelii* Aust. - n = 13; *P. subulatum*(Hedw.) Rabenh. - n = 13. Interestingly, n = 26 is recorded in the American populations only and n = 7 (the lowest chromosome number recorded in *Dicranales*) is found in the Russian material. It appears that polyploidy, in some manner, has conferred some selective advantage which enabled this genus to successfully colonize disturbed/ fast changing habitats.

The available cytological data indicates its similarity with *Archidium* [n = 13(4 species) and n = 26 (2 species)] rather than with *Bruchia* (n = 14, 15,16,28,30 with n = 14,15 being the most common). It is pertinent to mention here that in *Archidium*, as in *Pleuridium*, n = 26 is also recorded only in the American populations of the investigated taxa.

Pleuridium contains 32 species, of which *P.tenue* and *P.mussuriense* are recorded from the Western Himalaya. The gathering of the former species with long seta, illustrated by Gangulee (1971), can hardly find a place in this genus. The gathering of the latter species , according to Chopra (1975), is *Brothera leana*. Intensive collections from temporary and disturbed habitats are likely to result in the recollection of this opportunistic ephemeral taxon from our country.

3. *Distichium* B.S.G., Bryol. Eur. 2: 153. 1846. (Fasc. 29-30 Mon.1) *nom. cons.*

Cynotodium Hedw., Spec. Musc. 57. 1801. *nom. rejic.*

Plants growing in dense tufts. Stems simple or branched, tomentose. Leaves distichous, abruptly narrowed from a sheathing, oblong-oval basal portion into grooved subula; nerve broad, filling the upper part of the subula and excurrent, papillose at back in the subular part; basal laminal cells narrow, linear, upwards sub-quadrate to quadrate. Setae long, erect. Capsules erect or inclined, ovate-oblong, annulate, annulus of 2-3 rows of cells, deciduous. Peristome teeth 16, irregularly split or cracked, obliquely striolate. Operculum short, conic. Calyptra cucullate.

Lectotype: *Distichium capillaceum* (Hedw.) B.S.G.

In the field, this genus closely resembles *Ditrichum* Hampe in appearance. However, it is easily differentiated from the latter genus (particularly with the aid of a hand lens) by the distichous leaves, the papillose nerve back (in the subular part of the leaf), and the obliquely striolate peristome teeth.

Cytologically, this genus is known from 4 species i.e. *(Distichium austro-georgicum* C.Muell. - n = 14+m; *D. capillaceum* (Hedw.) B.S.G. - n = 7, 14, 28; *D. hagenii* Ryan - n = 42; *D. inclinatum* (Hedw.) B.S.G. - n = 13, 14. Unlike other genera of *Ditrichaceae* (where n = 13 is the most prevalent chromosome number), *Distichium* commonly possesses a fourteen chromosome complement. The number, n = 13 is recorded only in one population of *D. inclinatum*. The polyploid taxon and intraspecific polyploid populations in this genus, as in the other genera of *Ditrichaceae*, are also recorded from America only. It is interesting, that in this genus also an ancient, seven chromosome complement is still preserved in one population of *D.capillaceum,* when thirteen of its other populations consistently show n = 14 and two populations show n = 28.

The genus *Distichium* B.S.G. includes fifteen species with the largest concentration (9 species) in Asia (As. 2 and As. 3). In India, it is represented by two species, which are also recorded from our area, and interestingly found to occur at high altitude.

Key to the West Himalayan species of *Distichium* B.S.G.

Plants 0.7 – 1.5 cm tall; middle leaves 2.0 mm long; basal laminal cells 26 - 42 x 3 - 5 µm; capsules erect, symmetrical; spores relatively smaller, 12-15 µm.....**1.*D. capillaceum***

Plants 0.5 - 0.7 cm tall; middle leaves1.0 -1.6 mm long; basal laminal cells to 62 x 4-6 µm; capsules inclined, asymmetrical; spores relatively larger, 30 - 32 µm.....**2.*D. inclinatum***

1. ***Distichium capillaceum*** (Hedw.) B.S.G., Bryol. Eur. 2. 156. 1846. (Fig.49)

Ditrichum capillaceum (Hedw.) Watts *et* Whitel., Proc. Linn. Soc. N.S.W. Suppl. 27:35. 1902.

Didymodon cirrhifolius Harv. *in* Hook., Icon. Pl. Rar. 1 : 18.1836.

Leptotrichum capillaceum (Hedw.) Mitt., J. Linn. Soc. Bot. 4:67. 1859.

Cynontodium capillaceum Hedw., Spec. Musc. 57. 1801.

Trichostomum capillaceum (Hedw.). Sm., Engl. Bot. 16: 1152. 1803.

Didymodon capillaceus (Hedw.) Web. *et* Mohr, Ind. Mus. Pl. Cryt. 2. 1803.

Plants light-green to yellowish-green, growing in dense, silky tufts. Stems 0.7 to 1.5 cm long, simple or branched, tomentose at base. Leaves distichous, variousy curled when dry, erecto-patent to erect-spreading when moist, 2.0 mm long and 0.3 mm wide at base, suddenly narrowed into long subula from a sheathing, oblong-oval basal part; margins plane or incurved, serrulate at apex; nerve excurrent, filling most of the subula, papillose at back (at least in the subular part); basal laminal cells pellucid, linear or narrow-rectangular with somewhat oblique end walls, 26-42 x 3-5 µm, the median ones obliquely elliptical, 6-10 x 3-5 µm, in the subula sub-quadrate or rounded-quadrate, 4-5 µm wide. Setae erect, twisted when dry, 0.8 – 1.2 cm long. Capsules erect, symmetrical, 1.2–1.25 mm long and 0.5 mm in diameter, cylindric, smooth. Peristome teeth 16, 110–120 µm high, inserted below the rim, irregularly divided or cracked, obliquely striolate. Operculum 0.4 – 0.5 mm long, bluntly beaked. Spores spherical, 12-15 µm, asperately sculptured.

Specimens examined: Uttaranchal : Tehri-Garhwal, Kidarkanta, 3,000 – 3,600 m, on rocks, May 1879, *18D;*Mussoorie, Nag Tibba, 3,200 m, on rocks, September, 1975, K-*703, 704*. Himachal Pradesh: Khadrala, 2884m, on wet rocks, September, 1974, *45-S*; Chamba, Sural Valley, Chatwani forest and Pangi, 3,600m, 2,700m, 2,900m on rocks, July, 1899 September,1899, *15550, 15909* & *15910*; Manali, Rohtang Pass, 3980m, on rocks, September, 1988, K-*706*. Kashmir : Battistan, Shagarthang Valley, 2,400 – 3,300m, July, 1892, on rocks, *12732*; Nittar Valley, 2,700 m, on rocks, August, 1892, *12805* & *12817*; Pakistan : Hazara, Chapkro, Kagan & Muzaka Musalla, Shinkiari, 3,000 – 4,200m, on rocks, June, 1897, June, 1899, July,1899, 20.8.1899, *15415, 15496, 15912, 15913* & *16493*.

Distribution: Uttaranchal, Himachal Pradesh, Kashmir, South India, Sikkim; Cosmopolitan.

Chromosome number: n = 14, 28.

2. *Distichium inclinatum* (Hedw.) B.S.G., Bryol. Eur. 2: 193. 1846. (Fig. 50)

Cynontodium inclinatum Hedw., Spec. Musc. 58. 1801.

Cynodontium inclinatum (Hedw.) Brid., Spec. Musc. 1: 155. 1806.

Fig. 49

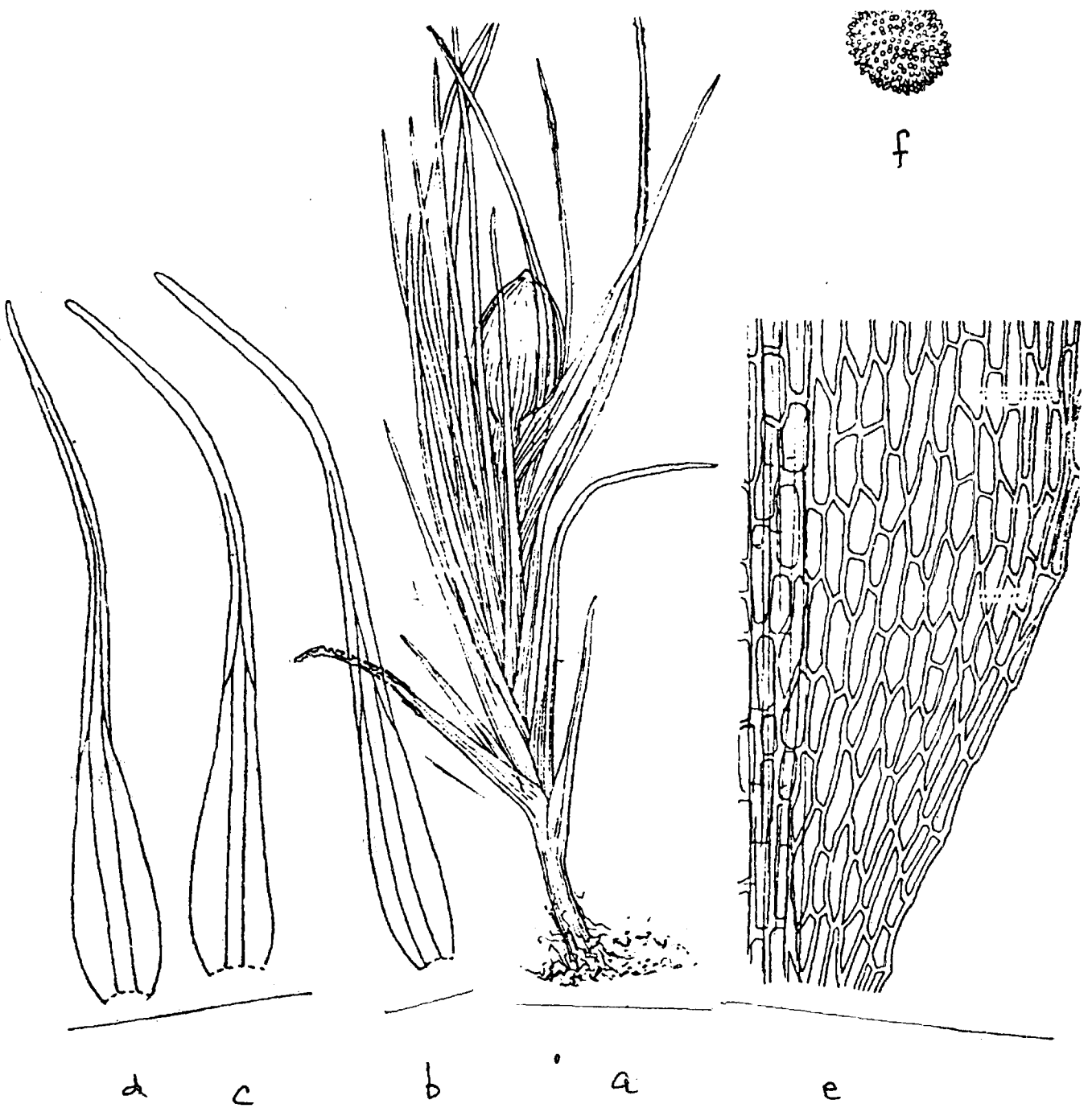

***Fig. 49 : Pleuridium subulatum* (Hedw.) Rabh.**
a. Plant x 40; b,c,d. Leaves x 50; f. Spore x 650; (After Crum and Anderson, 1981)

Cynodon inclinatus (Hedw.) Brid., Mant. Musc. 99. 1819.

Ceratodon inclinatus (Hedw.) Hub., Musc. Germ. 273. 1833.

Didymodon inclinatus (Hedw.) Web. et. Mohr., Ind. Musc. Pl. Crypt. 2. 1803.

Grimmia inclinata (Hedw.) Sm., Fl. Brit. 3: 1193. 1804.

Leptotrichum inclinatum (Hedw.) Mitt., J. Linn. Soc. Bot. Suppl. 1:10. 1859.

Swartzia inclinata (Hedw.) P. Beauv., Prodr. 90. 1819.

Plants dioicous, in light-green to yellowish-green, silky tufts. Stems 5.0 – 7.0 mm long, simple or branched, tomentose at base. Leaves erecto-patent to erect-spreading, curled on drying, 1.0 -1.6 mm long and 0.2 – 0.25 mm wide at base, suddenly narrowed into long subula from a sheathing, oblong-oval basal part; margins incurved, denticulate near tip; nerve excurrent, filling most of the subula, papillose at back, in transverse section showing a weekly developed ventral - and a strongly developed dorsal-stereidal band separated by a median row of guide cells; basal laminal cells pellucid, linear-oblong, to 62 x 4-6 µm, the median ones irregular, 6-12 x 3-5 µm, the upper ones quadrate, 4-6 µm wide. Setae straight, pale, 1.1 – 1.2 cm long. Capsules inclined, 1.1 – 1.2 mm long and 0.5 mm in diameter, asymmetrical, obovoid, stomata phaneroporus. Peristome teeth 16, inserted below the rim, each divided down nearly to the base, obliquely papillose-striolate. Operculum 0.3 – 0.4 mm long, conic, bluntly beaked. Spores spherical, 30-32 µm, asperately sculptured.

Specimens examined: Himachal Pradesh : Khadrala, 2884m, September, 1974, on rocks, *46-S*; Uttaranchal : Mussoorie, Nag Tibba, 3,200m, September, 1974, on rocks, K-*709*; Kashmir : Liddar Valley, Shishnag, 3,600 – 3,900m, July, 1893 and August, 1893, *13341, 14187*; Kamri Valley, 3,600m, August, 1892, on soil gathered on stones, *12796*; Sind Valley, near Battal, 3,000 – 3,300m, June, 1892, on rocks, *11633*.

Distribution: Kashmir, Himachal Pradesh, Uttaranchal, Sikkim; Europe, N.Africa, N. America.

Chromosome number: n = 13,14.

4. *Ditrichum* Hampe, Flora 50: 181. 1867. *nom.cons.*

Leptotrichum Hampe, Linnaea 20: 74. 1847. *hom. illeg.*

Plants light-green, growing in loose tufts. Stems mostly short, simple or branched, in transverse section showing a central strand. Leaves lanceolate to lanceolate-subulate from a widened base; margins mostly plane, rarely incurved or recurved; nerve sub-percurrent to excurrent, in transverse section showing a median row of guide cells between a weekly developed ventral stereidal group and a strongly developed dorsal stereidal band; alar cells not differentiated; basal laminal cells rectangular to oblong, upwards narrow, short-rectangular to sub-quadrate. Setae long, straight. Capsules erect or slightly inclined, cylindric, oblong-cylindric or ellipsoidal. Peristome teeth16, each tooth mostly cleft down to the base into two filiform,papillose divisions; basal membrane distinct. Operculum conic to short-rostrate. Calyptra cucullate, smooth.

The members of this genus are mostly found in dense or loose tufts on bare, clayey or sandy soil, along water streams, sides of the mountains, on rocks and occasionally on the base of tree trunks. The short, slender, mostly simple stems, the lanceolate-subulate leaves, the abundant sporophytes (except *D.flexicaule)* with long setae terminating in small, short -cylindric capsules, help easy recognition in the field.

This genus is closely related to *Pleuridium* Rabenh. as evidenced by their intergeneric crosses. The two genra, however, are morphologically quite distinct from each other.

Cytologically, *Ditrichum* Hampe is known from 14 species with thirteen chromosome complement being shared by 13 species. As in *Pleuridium* Rabenh., which is closely related to it, the polyploid taxa [*D.schimperi* (Lesq.) O.Kuntze and the intraspecific polyploid forms in *D. pallidum* (Hedw.) Hampe] are also recorded only from America.

Ditrichum includes 89 species,of which 11 are recorded from India. In our area, this genus is represented by 5 species.

Key to the West Himalayan species of *Ditrichum* Hampe

a. Plants tomentose, non-fruiting (in our area); stems 2.0-6.0 cm long, flexuose; leaves gradually narrowing into long subula from lanceolate, convolute basal portion; upper laminal cells short,sub-quadrate to quadrate-rounded.....**1.*D.flexicaule***

Plants not tomentose, abundantly fruiting; stems 0.1-1.2 cm long, non-flexuose; leaves narrowed into a subula from widened, nearly triangular, rectangular or oblong, non-convolute basal portion; upper laminal cells rectangular.....b

Fig. 50 Fig. 50A

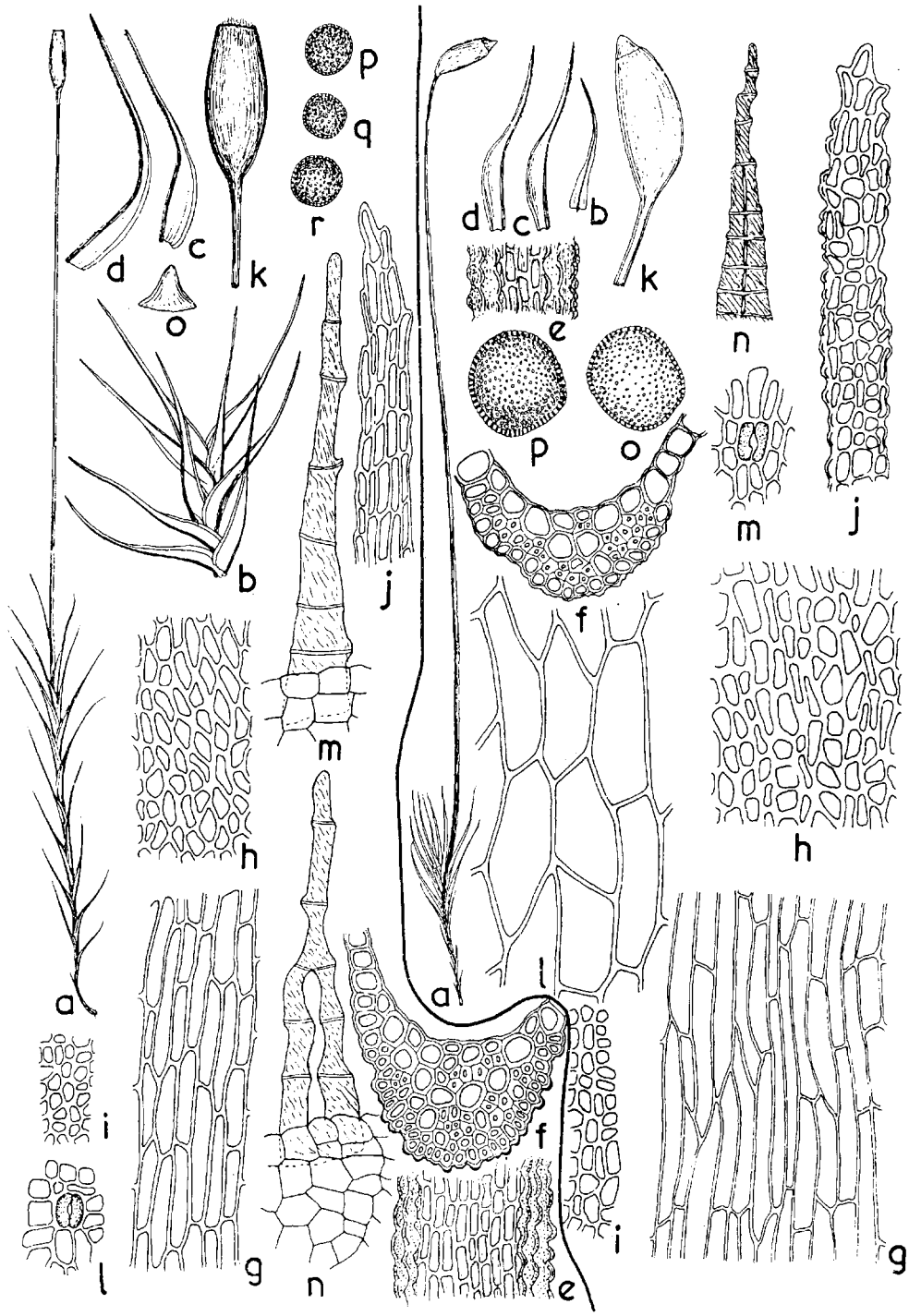

Fig. 50 : Distichium capillaceum (Hedw.) B. S. G.

a. Plant x 7; b. A part of the plant enlarged x 19; c,d. Leaves x 19; e. Nerve back x; f. T. S. leaf x 475; g. Basal laminal cells x 475; h. Median laminal cells x 475; i. Upper laminal cells x 475; j. Leaf apex x 475; k. Capsule x 19; l. Stoma x 225; m,n. Peristome teeth x 475; o. Operculum x 19; p,q,r. Sporesx 475.

Fig. 50A : Distichium inclinatum (Hedw.) B. S. G.

a. Plant x 7; b,c,d. Leaves x 19; e, Nerve back x 475; f. T. S. Leaf x 475; g. Basal laminal cells x 475; h. Median laminal cells x 475; i. Upper laminal cells x 475; j. Leaf apex x 475; k. Capsule with operculum x 19; l. Exothecial cells x 475; m. Stoma x 225; n. Peristome tooth x 225; o,p. Spores x 475.

b. Stems 1.0-2.0 mm long; leaves 1.2 -1.8 mm long, lanceolate to lanceolate-subulate from a triangular basal portion; leaf margins entire.....c

Stems 4.0 -12.0 mm long; leaves 2.8- 4.5 mm long, longly subulate with a broadened rectangular or oblong basal portion; leaf margins crenulate to denticulate.....d

c. Stems branched, and covered with a dense felt of rhizoids.....**3.*D. pusillum***

Stems simple, without the rhizoidal felt.....**4.*D. tortipes***

d. Leaves gradually narrowing from a widened basal portion; leaf margins recurved; setae 6.0-7.0 mm long; peristome segments linear, twisted...**5. *D. totuloides***

Leaves suddenly narrowing from a rectangular basal portion; leaf margins plane; setae 10.0-14.0 mm long; peristome segments erect, never twisted..... **2.*D. homomallum***

1.***Ditrichum flexicaule*** (Schwaegr.) Hampe, Flora 50: 182.1867. (Fig.51)

Cynodontium flexicaule Schwaegr., Spec. Musc. Suppl. 1: 113.1811.

Trichostomum flexicaule (Schwaeg.) B.S.G., Bryol.Eur. 2: 129. 1843 (Fasc.18-20 Mon. 15.11).

Plants growing in dense, shiny tufts, matted with rhizoids. Stems 2.0 – 6.0 cm long, simple or branched, slender, flexuose. Leaves erect-spreading, flexuose, slightly contorted on drying, narrow-lanceolate, long-subulate, 3.0 – 3.8 mm long and 0.33 mm wide in the basal portion; margins plane, denticulate in the apical portion of the subula; nerve concolourous, ± 80 mm wide at base, sub-percurrent to excurrent; basal laminal cells narrow-rectangular, 10 – 18 x 3 – 4 µm, at shoulders obliquely short-rhomboidal, the upper ones short, sub-quadrate to quardrate-rounded or irregular, 4 – 6 x 3 – 5 µm. Sporophytes not observed. "Setae red; Capsules ovoid to cylindrical; peristome highly and closely papillose, in the upper part colourless, towards the base reddish brown; basal membrane short. Spores 8 – 12 µm, yellow, smooth" (After Nyholm, 1954).

The figure of the peristome given by Nyholm (l.c.) shows that each tooth is cleft down to the basal membrane into two filiform segments which are joined at the nodes in the lower portion.

This taxon has never been observed in the fruiting condition in the Western Himalaya. Nevertheless, the gametophytic features *i.e.* the long flexuose, slender stems closely matted with rhizoids, the flexuose, long subulate leaves with convolute basal portion, and the yellowish-green plants growing on wet calcareous soil do help in the recognition of this species.

Specimens examined: Uttaranchal : Mussoorie, mossy fall, 1350 m, on damp calcareous soil, September, 1976. K-*176.*

Distribution: Uttaranchal, South India (Palni Hills); Nepal, Central Asia, Siberia, East China, Formosa, Japan, Caucasus, Europe, Algeria, Canary Islands, North America.

Chromosome number: n = 13,14.

2. *Ditrichum homomallum* (Hedw.) Hampe, Flora 50: 182. 1867. (Fig.52)

Ditrichum heteromallum (Hedw.) Britt., N. Amer.Fl.15: 64. 1913.

Didymodon homomallum Hedw., Spec. Musc. 105. 1801.

Trichostomum homomallum (Hedw.) B.S.G., Bryol. Eur. 2:130.1843

Weisia heteromalla Hedw., Spec. Musc. 71. 1801.

Plants yellowish-green, growing in tufts. Stems 1.0 – 1.2 cm long, simple or branched. Leaves erecto-patent to erect-spreading, erect-appressed with bent tips on drying, 3.0 – 4.5 mm long and 0.3 mm wide at base, lanceolate-subulate from widened, nearly rectangular to sub-rectangular base; margins plane, denticulate in the apical portion; nerve distinct, filling the subula, percurrent or excurrent; in transverse section showing a median row of guide cells with a weekly developed dorsal stereidal band below it, the cells of the upper and the lower epidermis relatively larger and distinct from the adjoining underlying cells; basal laminal cells rectangular, adjoining the nerve (3 – 5 rows) 25 – 48 x 7 – 8 µm, towards margins 8 –12 x 3 – 5 µm, upwards short, rectangular, 6 – 10 x 3 – 4 µm. Setae straight or slightly curved, 1.3 – 1.6 cm long. Capsules erect or nearly so, smooth, urn 1.6–1.9 mm long and 0.25 mm in diameter, cylindrical. Peristome teeth 16, each divided down to the base, remaining united at the nodes in the basal portion, densely papillose. Operculum conic-rostrate. Spores spherical, 9-12 µm, faintly asperately sculptured.

This species is differentiated from the preceding taxon by the relatively shorter, non-flexuose, closely leafy stems, the nearly rectangular, non- convolute basal portion of the leaves, and the relatively larger laminal cells.

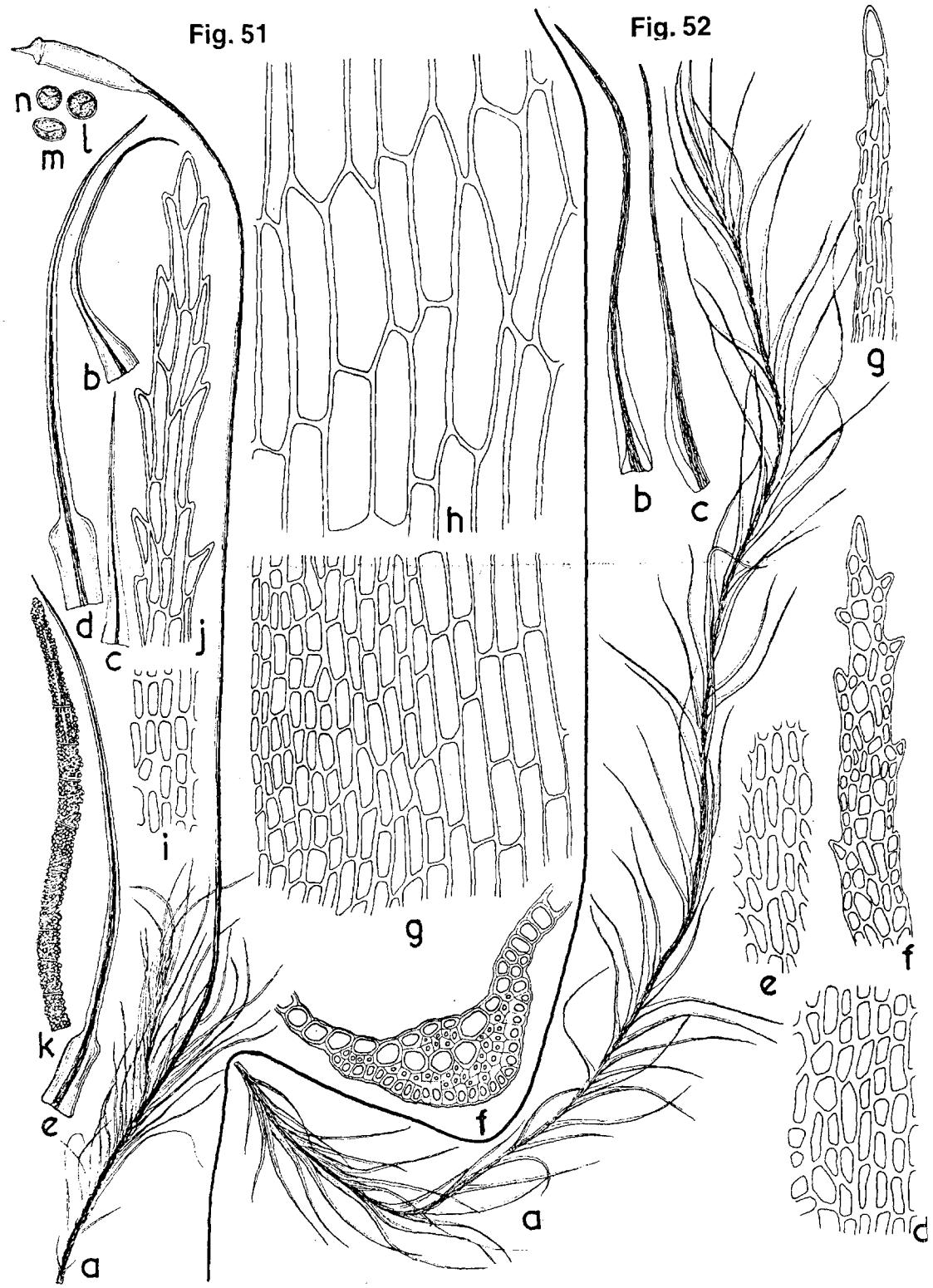

Fig. 51 : Dictrichum homonallum (Hedw.) Hampe.
a. Plant x 7; b,c,d.e. Leaves x 19; f. T. S. leaf x 475; g. Basal laminal cells x 225; h. Basal laminal cells enlarged x 475; i. Median laminal cells x 475; j. Leaf apex x 475; k. Part of peristome tooth showing markings x 475; l,m.n. Spores x 475.

Fig. 52 : Ditrichum flexicaule.
a. Plant x 7; a,c. Leaves x 19: d. Basal laminal cells x 475; e. Median laminal cells x 475; f,g. Leaf apex x 475.

Chromosome number : n =13, 13+m.

Specimens examined: Uttaranchal : Mussoorie, 2000 m, on soil, September, 1950, *199*;Mussoorie, 2000 m, on wet soil, September, 1976, *K-177;* Himachal Pradesh : Shimla, Mashobra, 2500 m, on damp soil, September, 1978, *K 178;* Dharmsala, on way to Triund, 2600 m, on soil, *3113;* Bhutan, 3000 m, Herb. Griffith, *91(BM).*

Distribution: Himachal Pradesh, Uttaranchal, Kurseong, N.E.F.A.; Bhutan, Japan, Europe, North America, South America, North Africa.

3. *Ditrichum pusillum* (Hedw.) Hampe, Flora 50: 182. 1867. (Fig.53)

Didymodon pusillus Hedw., Spec. Musc. 104. 1801.

Trichostomum tortile Schrad., Bot. Zeit. Regensburg 1: 74. 1802.

Leptotrichum tortile (Schrad.) Hampe *in* C.Muell., Syn. 1: 454. 1848.

Plants yellowish-green, growing in short, loose tufts. Stems 3.0 – 6.0 mm long, simple or branched, covered with a dense felt of rhizoids, in transverse section showing a central strand of hydroids and large cortical cells. Leaves erecto-patent, erect-appressed on drying, 1.2 – 1.3 mm long and 0.3 mm wide at base, lanceolate to lanceolate-subulate from nearly triangular base; recurved down to half the length; margins plane, entire; nerve 50 – 60 µm wide at base, percurrent or slightly excurrent, in transverse section showing few ventral stereids, a strongly developed dorsal stereidal band, a median row of guide cells and relatively larger, differentiated (from the underlying stereidal cells) cells of the upper and the lower epidermis; basal laminal cells irregularly rectangular, 6 – 13 X 4 – 7 µm, upwards narrow-elongate, 18 – 32 x 2 – 3 µm. Setae erect or slightly tortuous. Capsules 1.0 – 1.2 mm long and 0.2 mm in diameter, narrow-cylindric, symmetric, phaneroporous; exothecial cells irregular, 30-55 x 20-20 µm. Peristome teeth deeply cleft down to the basal membrane, papillose. Rest not observed.

This species differs from the preceding two species in its shorter stems, (3.0 – 6.0 mm, versus 10 – 60 mm), the erect-appressed (dry), smaller leaves (1.2 -1.3 mm, versus 3.0 – 4.5 mm) with nearly triangular basal portion, and the relatively longer and narrower upper laminal cells (18 – 32 X 2 – 3 um, versus 4–6 x 3–5 um or 6–10 X 3–4 µm).

Specimens examined: Uttaranchal : Mussoorie, 2300 m, on clay soil, September, 1952, *319, M238;* Nainital, Bhimtal, 1390 m, on clay soil along mountain, *3115;* Nepal (Wallanchoon), 3900 m, Herb. Musc. Wilson (BM).

Distribution: Uttaranchal, Darjeeling, Sikkim, Upper Assam; Nepal, Caucasus, Siberia, Europe, North Africa, North America.

Chromosome number: n = 13

4. *Ditrichum tortipes* (Mitt.) Kuntz., Rev.Gen.Pl.2: 835. 1891. (Fig.54)

Ditrichum longicurve Ren.*et* Card., Bull. Soc. R. Bot. Belg. 38: 10. 1900.

Leptotrichum tortipes Mitt., J.Linn. Soc. Bot. Suppl. 1: 10. 1859.

Plants yellowish -green, growing in tufts. Stems 3.4 – 4.0 mm long, mostly simple. Leaves 1.2 – 1.4 mm long and 0.27 – 0.30 mm wide at base, gradually narrowed into subula from broad base; margins plane; nerve strong, 50 – 60 µm wide at base, filling the subula; basal laminal cells rectangular, 8 – 14 x 5 – 7 µm, upwards narrow-elongate, adjoining the nerve longer, 21 – 27 x 2 – 3 µm (few cells are 11 – 13 X 2 – 3 um). Setae straight, 7.0 mm long. Capsules erect or very slightly inclined, 1.45 mm long and 0.5 mm in diameter, annulate. Peristome teeth tending to show one weak twist, each tooth cleft down into two filiform, papillose segments. Operculum conic , 0.5 mm long.

The presently examined material appears to agree with *D. pusillum* var. *tortile* and also with *D. tortuloides* in qualitative characters. In the latter taxon, however, the plants are taller, the leaves longer, the leaf margins distinctly denticulate, and the peristome teeth clearly twisted.

Specimens examined: Uttaranchal : Binsar, Almora, 2100 m. Sept. 1910, Herb. H.N.Dixon *29* (BM);

Distribution: Uttaranchal, Darjeeling, Sikkim, South India.

Chromosome number: n = 13

5. *Ditrichum tortuloides* Grout, The Bryologist 30 : 4.1927. (Fig.55)

Plants yellowish-brown when dry, gregarious. Stems 4.0 - 5.0 mm long, mostly simple. Leaves crisped when dry, erecto-patent when moist, 2.6 – 3.2 mm long and 0.3 – 0.5 mm wide at base, subulate, gradually narrowed from a lanceolate basal portion; margins reflexed at middle, serrate towards apex; nerve strong, 50-60 µm wide at base, percurrent; basal laminal cells rectangular with straight or slightly oblique end walls, 28 – 45 x 6 – 8 µm, the middle ones irregular, rectangular to sub-rectangular, 9 – 25 x 4 – 6 µm, upwards shorter. Setae straight, 6.0-7.5 mm long. Capsules slightly curved, cylindric, 1.1 mm long and 0.26-0.30 mm in diameter; annulus deciduous, consisting of one row of large cells. Operculum long-

Fig. 53

Fig. 54

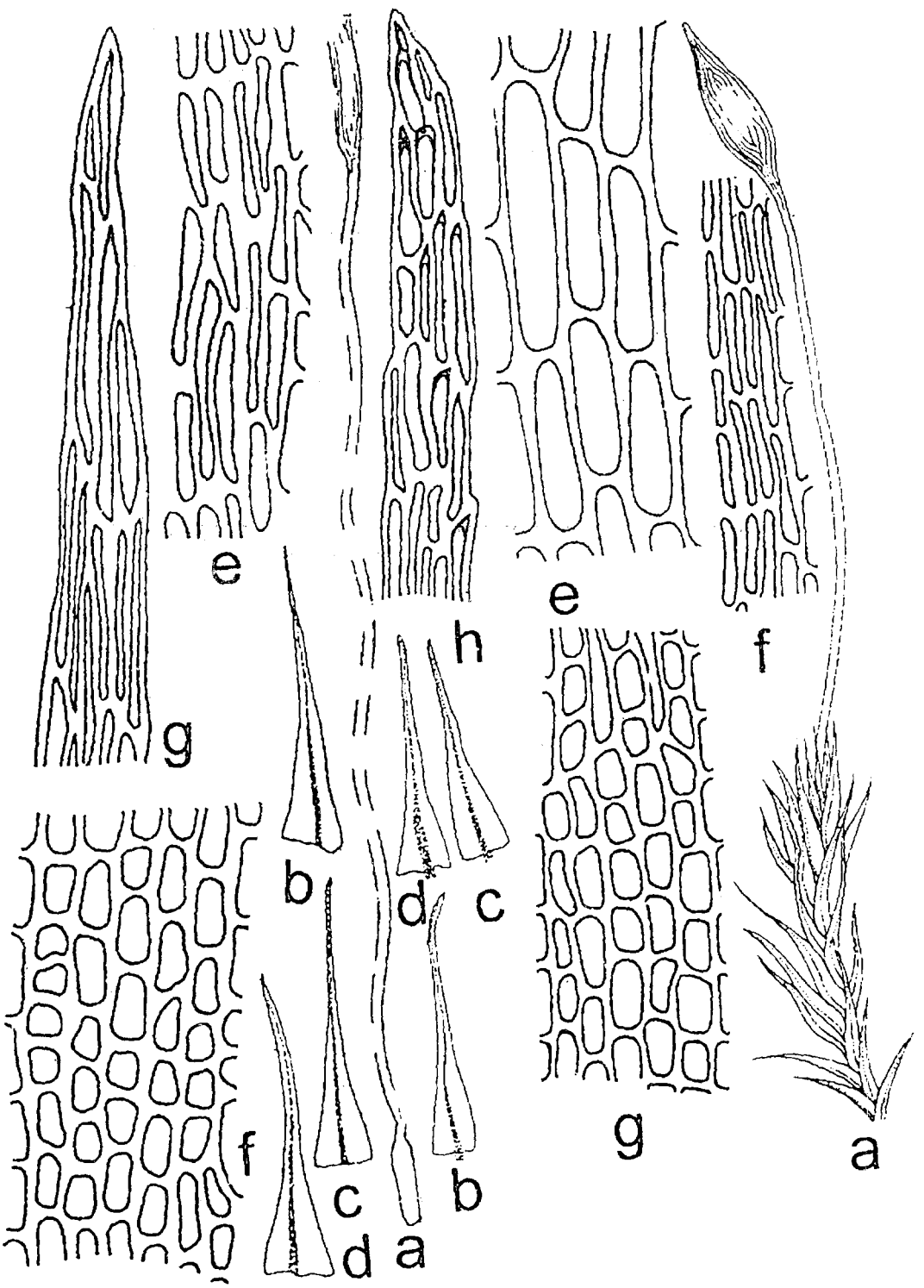

Fig. 53 : Ditrichum pusillum (Hedw.) Hampe.
a. Plant part x 7; b,c,d. Leaves x 19; e. Basal laminal cells x 475; f. Upper laminal cells x 475; g. Leaf apex x 475.

Fig. 54 : Ditrichum tortipes (Mitt.) Kuntz.
a. Plant x 7; b,c,d. Leaves x 19; e. Basal laminal cells x 475; f. Median laminal cells x 475; g. Upper cells x 475; h. Leaf apex x 475.

beaked, 0.6 mm long.

"Peristome teeth 16, fragile, apparently equal, linear segments twisted at least one turn, strongly papillose, reaching 0.5 mm in length from a low basal membrane, about 29 µm high" (After Grout, 1927).

According to Grout (1.c.), this species is closely related to *D.pusillum*, from which it is distinguished by its slender, papillose, tortuloid peristome teeth without any trabeculae or nodes.

Specimens examined: North America (Brook, New Fane, Vermont), 20.4.1927, on bare soil of old wood road, 89 (B.M.); Himachal Pradesh: Dharmsala, Tea Estate, 1500 m, on soil gathered on rocks, *3116*.

Distribution: Western Himalaya, Khasi and Jainti Hills; Europe, North America.

Chromosome number: n = 13, 13+m

5. *Saelania* Lindb; Utkast. Nat. Grupp. Eur. Bladmoss. 35. 1878.

Plants in dense tufts. Stems simple or branched. Leaves erect-spreading, slightly contorted on drying, commonly with a blue-green, bloomy covering on dorsal surface, linear–lanceolate, gradually acuminate; margins bluntly serrate in the upper part; nerve per-current or ex-current; alar cells not differentiated; laminal cells short-rectangular. Setae long. Capsules erect, oval to oblong-cylindric. Peristome teeth 16, each tooth irregularly divided to the base into two papillose crura. Operculum rostrate. Calyptra cucullate, smooth.

Type: *Saelania caesia* (P. Beauv.) Lindb.

Lindberg (1878) created this genus on the basis of the plant which had been previously placed in *Ditrichum* sample or *Trichostomum*. According to Grout (1936), it differs from the former genus in showing frequent innovations, blue-green filamentous bloomy covering on the dorsal surface of leaves, and the plane, distinctly serrate leaf margins. It is distinguished from the latter genus in its blue-green bloomy covering on the dorsal surface of the leaves, and the smooth laminal cells.

Dixon (1924) wrote, "Its affinity with *Ceratodon* Brid. is however, so obvious (though at the same time, it shows distinguishing characters of some importance) that its assignment to a separate genus near *Ceratodon* Brid. appears to be the most satisfactory arrangement". The linear-lanceolate, gradually acuminate leaves with the blue-green bloomy covering on the dorsal face, the plane leaf margins, and the broadly cylindric capsules, however, help separation from the closely related *Ceratodon* Brid. According to Braithwaite, it occupies an intermediate position between Tortulaceae and Dicranaceae.

Cytologically, *Saelania*, as in *Ceratodon* and *Ditrichum*, possess a thirteen chromosome complement. As in *Ceratodon,* this genus also lacks in polyploidy.

This monotypic genus is represented by *S. glaucescens*, which is also recorded from our area.

Saelania glaucescens (Hedw.) Broth., *ex.* Bom. & Broth., Herb. Musc. Fenn. ed.2, 2: 53. 1894. (Fig.56)

Trichostomum glaucescens Hedw., Spec. Musc. 112. 1801.

Plants glaucous-green, growing in dense tufts. Stems 1.0 – 1.5 cm long, branched through frequent innovations. Leaves erecto-patent to spreading, slightly contorted to hardly altered on drying, with blue-green bloomy covering on the dorsal face, the lower ones 0.5 – 0.7 mm long and 0.25 mm wide at base, the middle and the upper ones 1.76 – 2.5 mm long and 0.25 mm wide at base, linear-lanceolate, gradually acuminate; margins plane, upwards bluntly serrate; nerve strong, 75 - 80 µm wide at base, percurrent or shortly excurrent; in transverse section showing a median row of guide cells with the ventral stereidal band above and the dorsal stereidal band below it; basal laminal cells rectangular, 26 - 36 x 7 – 9 µm, the median ones rectangular, 9 – 15 x 5-6 µm, the upper ones sub-quadrate 8 – 10 x 6 – 8 µm. Setae twisted on drying, 8 -10 mm long. Capsules erect, indistinctly furrowed on drying, broad-cylindric, the urn 1.0 mm long and 0.8 mm in diameter; annulus of 2-3 rows of cells. Peristome teeth 16, each split down to the base into two papillose segments. Operculum conic-rostrate. Calyptra cucullate, smooth. Spores spherical, 12-15 µm, asperately sculptured.

Specimens examined: Kashmir: Sonmarg, 2700 m, on rocks, August 18, *1893, 14243*; Astor valley, 2700-3600 m, on soil gathered on rocks, August 14, 1892, *12826*

Distribution: Kashmir; cosmopolitan in temperate regions.

Chromosome number: n = 13.

6. *Ceratodon* Brid., Bryol. Univ. : 480. 1826.

Plants in loose or dense tufts, green, greenish-brown on drying. Stems simple or branched through innovations, in transverse section showing a central strand of hydroids. Leaves erecto-patent to erect-spreading, slightly curled on drying, ovate-lanceolate; margins recurved, entire or serrulate near apex; nerve strong, sub-percurrent, percurrent or excurrent; basal laminal cells short-

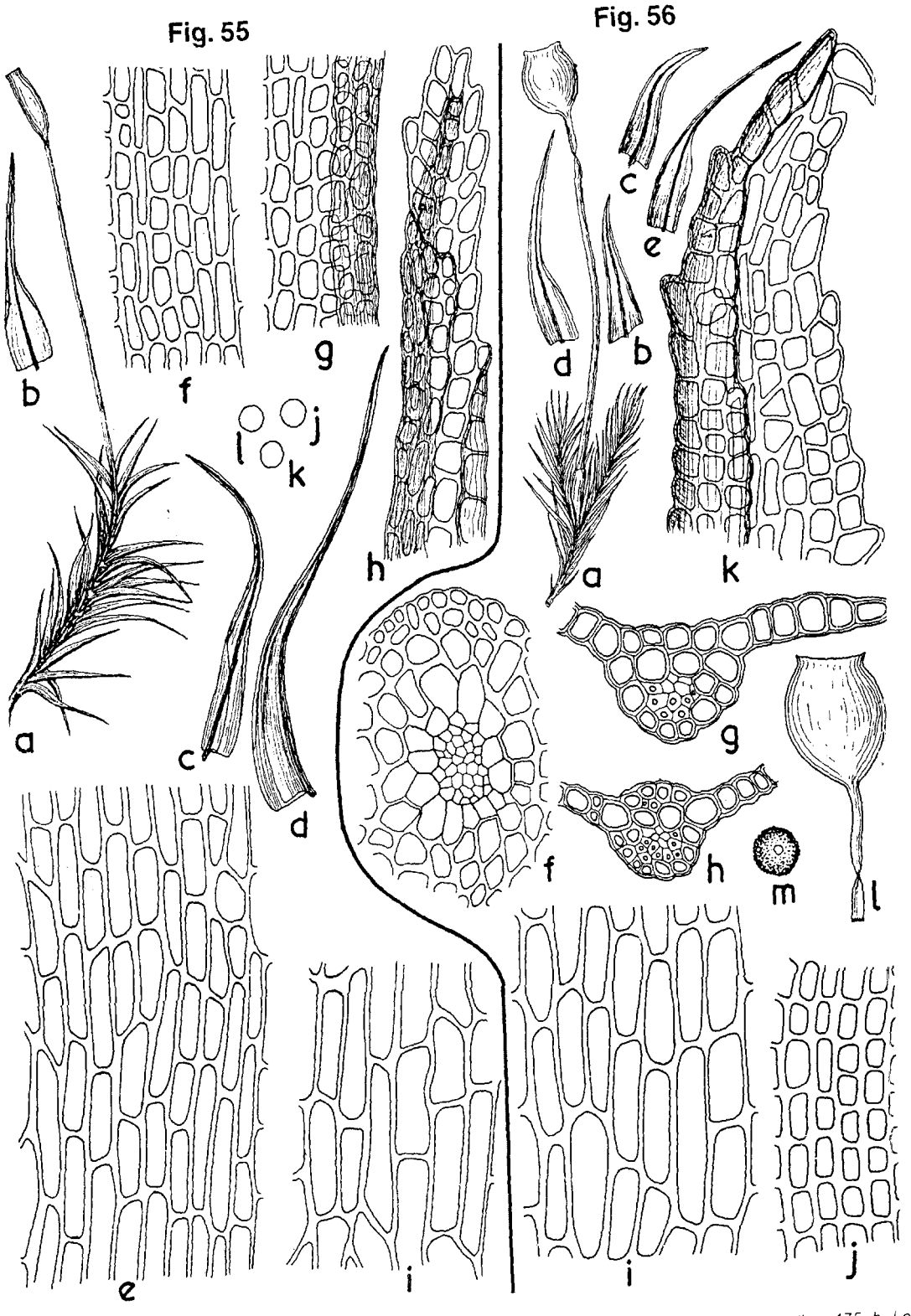

Fig. 55 : Ditrichum tortuloides Grout.
a. Plant x 7; b,c,d. Leaves x 19; e. Basal laminal cells x 475; f. Median laminal cells x 475; g. Upper laminal cells x 475; h. Leaf apex x 475; i. Exothecial cells x 475; j, k,l. Spores x 475

Fig. 56 : Saelania glaucescens (Hedw.) Bom. ex. Broth.
a. Plant x 7; b,c,d,e. Leaves x 19; f. T. S. stem x 475; g,h. T. S. leaf x 475; i. Basal laminal cells x 475; k. Median laminal cells x 475; k. Leaf apex x 475; l. Capsule with a part of seta x 19.

rectangular, upwards quadrate to quadrate-rounded, smooth. Setae long, straight. Capsules erect, inclined or horizontal, ribbed when dry, oblong-cylindric; annulus deciduous. Peristome teeth 16, each divided nearly to the base into filiform, papillose segments. Operculum conic. Calyptra cucullate.

The ovate-lanceolate leaves with recurved margins help separation from *Ditrichum* Hampe.

Cytologically, this genus is known from 3 species i.e. [*C. heterophyllus* Kindb., *C.purpureus* (Hedw.) Brid., *C. stenocarpus* B.S.G.]. with widely separated populations consistently showing n = 13. The genus does not seem to be amenable to secondary polyloidy.

Ceratodon includes 19 species, many of which are doubtfully distinct from *C. purpureus*(Hedw.) Brid. and *C.stenocarpus* B.S.G.. When sterile, even these two cosmopolitan species defy an easy separation from each other.

In our area, this genus is represented by two species, which descend to the foothills, at times.

Key to the West Himalayan species of Ceratodon Brid.

Capsules horizontal, asymmetrical, ovate-cylindrical, strumose at base.....**1.*C.purpureus***

Capsules erect, symmetrical, cylindrical, non-strumose.....**2.*C.stenocarpus***

1.*Ceratodon purpureus* (Hedw.) Brid., Bryol. Univ. 1:480.1826 (Fig.57)

Dicranum purpureus Hedw., Spec. Musc.136.1801.

Plants in dense tufts. Stems 0.8-1.0 cm long, branched through innovations. Leaves erect-spreading, appressed with tips curled on drying, 1.1-2.2 mm long and 0.5 mm wide at base, ovate-lanceolate, apex acute; margins recurved from base upwards to nearly the apex, crenulate near tip; nerve strong, percurrent or slightly excurrent, in transverse section heterogeneous; basal laminal cells short-rectangular, 10-22 X 5-7 um, the median ones short-rectangular to sub-quadrate, 5 -12 X 4-6 um, the upper ones quadrate or irregular, 5-7 um wide. Setae straight, twisted on drying, appearing lateral due to innovations, 1.1-1.8 cm long. Capsules inclined to horizontal, ovate-cylindrical, strumose at base, 1.6-1.7 mm long 0.5-0.6 mm in diameter, stomata superficial; annulus of 2-3 rows of cells. Peristome teeth reddish, each divided down to the base into filiform, papillose segments. Operculum conic, with a blunt curved beak, 0.42 mm long. Spores yellow, spherical, lightly sculptured asperate.

This species, descending to the foot hills in our area, is exceedingly variable. Sometimes, even in the same gathering, erect to horizontal, non - or indistinctly – strumose to strumose capsules are found. Experimental study is essential to decide the independent specific identity of these two species of *Ceratodon* Brid.

Specimens examined: Uttaranchal: Mussoorie, 2300 m, July 1957, ***29*** (BM); Kashmir: Gurais valley, 2400 m, on rocks, September 29, 1893, *14314*. Many other collections made from the Western Himalaya (Shimla, Dalhousie, Dharmsala, Chakrata) during 1973-2004.

Distribution: Western Himalaya, Eastern Himalaya, South India; Cosmopolitan.

Chromosome number: n = 13, 11.

2. *Ceratodon stenocarpus* B.S.G., Bryol. Eur.2:146.1846 (Fig.58)

Didymodon stenocarpus (B.S.G.) Mitt., J.Linn. Soc.Bot.Suppl.1:24.1859

Ceratodon purpureus (Hedw.) Brid.var.*stenocarpus* (B.S.G.)Dix., J.Bomb.Hist. Soc. 39: 773. 1937.

Dioicous. Stems 0.6-1.5 cm long, branched or rarely simple. Leaves erecto-patent to erect-spreading, erect-appressed or slightly crisped with tips twisted on drying, narrowly ovate-lanceolate, apex acute; margins recurved from base upwards to near the tip, slightly denticulate near apex; nerve strong, percurrent or excurrent, in transverse section showing a median row of guide cells with ventral stereidal band above and dorsal stereidal band below it; basal laminal cells rectangular, 16-26X6-8 um (few cells to 36 um long), the median ones short-rectangular to quadrate, 7-12X5-7 um, the upper ones quadrate, 6-8 um wide, incrassate. Setae yellow, straight or twisted, 1.1-1.8 cm long. Capsules 1.4-1.5 mm long, nearly erect, symmetrical, cylindric, non-strumose, phaneroporous; exothecial cells irregular, 40-47 x 25-28 µm, thin-walled. Peristome teeth 16, each divided down to the base into filiform, papillose segments. Operculum conic with a blunt curved beak. Spores spherical, 10-15 µm, asperately sculptured.

It is one of the commonest and richly fruiting mosses in our area. Once familiar, it can be easily recognized by its general appearance.

Specimens examined: Himachal Pradesh : Narkanda, on way to Hatoo peak, on rocks, *2466;* Solan, on rocks, *24715;* Uttaranchal: Mussoorie, Suakholi, 2400 m, on rocks, September, 2004; K-*2401*, Tehri-Garhwal, 3300-3600 m, on rocks, May 1894, *15252*; Kashmir : Gulmarg, 2400-2700 m, on rocks, June 6, 1892, August 8, 1892,

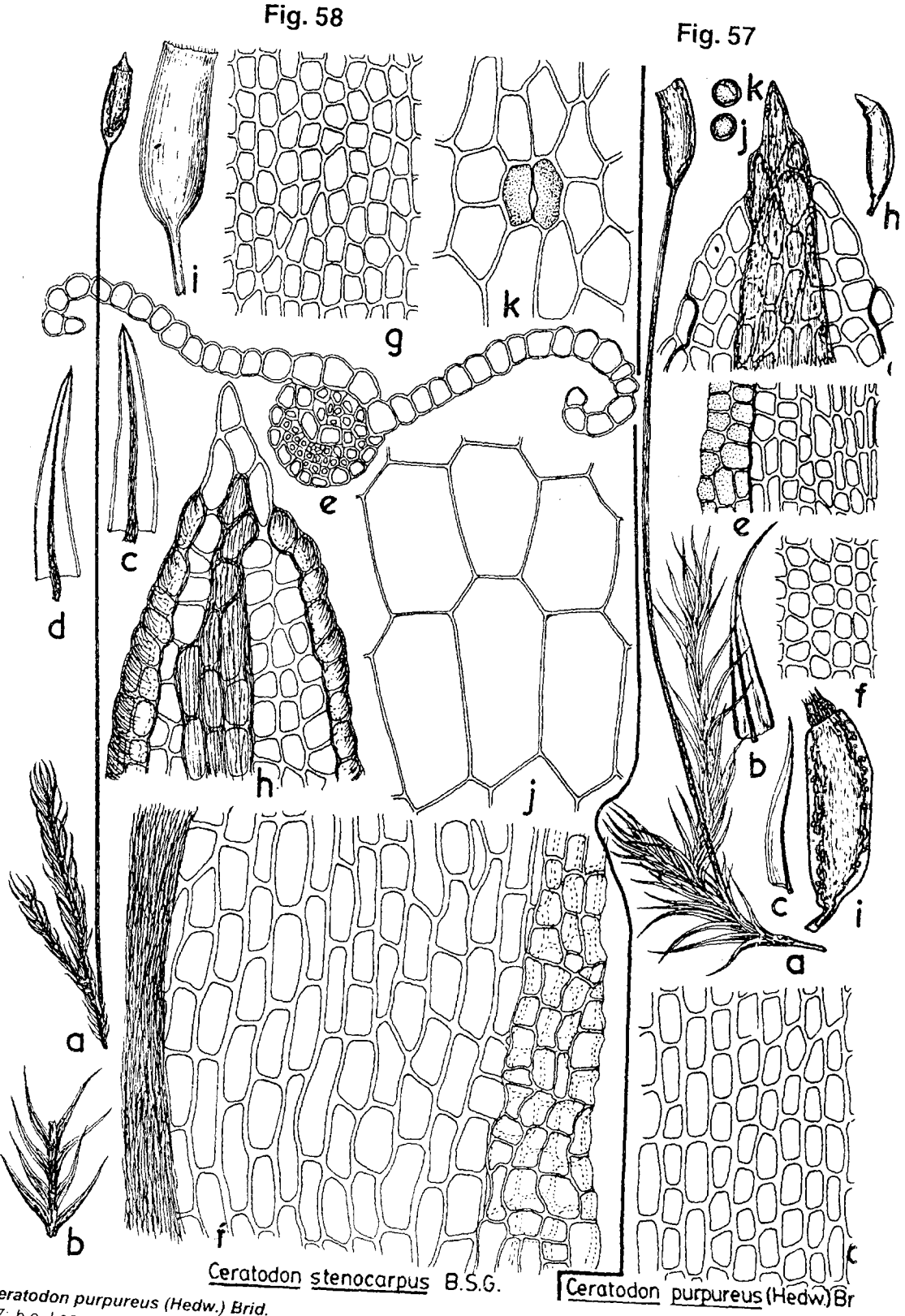

Fig. 57 : Ceratodon purpureus (Hedw.) Brid.

a. Plant x 7; b,c. Leaves x 19; d. Basal laminal cells x 475; e. Median laminal cells x 475; f. Upper laminal cells x 475; g. Leaf apex x 475; h. Capsule with operculum x 19; i. Capsule with peristome teeth x 19; j, k. Spores x 475.

Fig. 58 : Ceratodon stenocarpus B.S.G.

a. Plant x 7; b. A part of the plant enlarged x 19; c,d. Leaves x 19 e. T. S. Leaf x 475; f. Basal laminal cells x 475; g. Median Laminal cells x 475; h. Leaf apex x 475; i. Capsule x 19; j. Exothecial cells x 475; k. Stoma x 475.

August 31, 1892 and September 29, 1893, *11405, 12824, 12893, 12893, 12801, 14319*. Numerous other collections from the Western Himalaya made during 1974 to 2004.

Distribution: Himachal Pradesh, Uttaranchal, Sikkim, Khasi Hills; Bhutan, Nepal, Sri Lanka, Tropical Asia, Tropical Africa, South Europe, Mexico, Bolivia.

Chromosome number: n =13, 13+1 acc., 14, 15

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ABSTRACTS OF Ph.D. THESES AWARED BY THE PANJAB UNIVERSITY, CHANDIGARH, IN THE YEAR 2004

DEPARTMENT OF ANTHROPOLOGY

Name of the Candidate : Maninder Kaur **Supervisor : Indu Talwar**

A STUDY OF MORPHO-PHYSIOLOGICAL VARIATIONS AMONG PUNJABI RURAL – URBAN BRAHMIN FEMALES OF DISTRICT ROOPNAGAR, WITH SPECIAL REFERENCE TO SENESCENCE

The present study was conducted with a view to describing the morpho-physiological variation among Punjabi rural and urban Brahmin females, with special reference to senescence. There is a remarkable heterogeneity of rural and urban environment, so the present study explores that age related physical as well as physiological changes in two sub-groups of Brahmin population, with same broad genetic constitution but residing in different environmental setting. The cross-sectional sample consisted of 870 Brahmin females (rural =450, urban=420) ranging in age from 40 to 70 years, and residing in rural and urban area of Roopnagar district.

In all twenty four anthropometric measurements and three physiological parameters were taken on each individual. The anthropometric measurements included weight, height, sitting height, three facial measurements (morphological, facial height, bizymogomatic, breadth and bigonial breadth), six diameters (biacromial, bicristal, humerus bicondylar, wrist, femur bicondylar, ankle); Six circumferential measurements (upper arm, calf, chest, waist, abdomen, hip) and six skin folds (biceps, triceps, calf, subscapular, suprailiac and abdominal). The physiological parameters taken were blood pressure, grip strength and pulse rate. Three derived indices namely body mass index, ponderal index and waist/hip ratio were computed from the anthropometric measurements. To assess the association between anthropometric and physiological measurements age-wise and total correlations were calculated. To study the physique, all the females were rated in three components of somatotype following the Heath and Carter Anthropmetric method. Age at menarche of females was computed using recall method, while age at menopause was calculated using *status quo* as well as retrospective method.

Detailed analysis of the data reveal that all the anthropometric measurements show a decline in their mean values as the age progresses, but the onset and magnitude of decline varies among different measurements. Findings further demonstrate that urban Brahmin females are taller and heavier and have greater values for body mass index than their rural counterparts. Urban sample reveals greater mean values for sitting height, morphological facial height and bigonial breadth, while rural females show greater bizygomatic breadth than urban sample. Urban Brahmin females also showed greater mean values for biacromial breadth, bicristal breadth, humerus bicondylar diameter, and wrist diameter, whereas rural sample exhibits higher mean values for femur-bicondylar diameter and ankle diameter. All the circumferences (upper arm, calf, chest, waist, abdominal and hip) and skinfold thicknesses (biceps, triceps, calf, subscapular, suprailiac and abdominal) of urban Brahmin sample show greater development than their rural counterparts. Waist/hip ratio in rural as well as urban females increases as the age progresses, there by indicating centralized fat patterning among females in latter years.

Blood pressure (both systolic and diastolic) of urban Brahmin females show greater mean values than their rural counterparts. This may be attributed to differences in their eating habits and sedentary life style. In rural females the food is mostly from natural resources fresh and quite nourishing. While in urban areas the diet of people is mostly based on refined goods and poor in natural minerals. Urbanized people consum more of processed food, which is part of westernized diets extremely rich in fats, and hardly have any physical activity. These factors are responsible for obesity is urban women. Grip strength (both right and left hand) shows greater muscular strength in the upper limb of urban Brahmin females as compared to rural sample. Pulse rate reported a general increase in the mean values with the increasing age in rural as well as urban sample.

Somatotypes of rural and urban Brahmin females lie in mesomporphic endomorph sector at all ages and do not exhibit a change in component dominance as the age progresses. In both the samples, endomorphic component dominates throughout the age range under consideration followed by mesomorphic and ectomorphic components respectively.

Urban women experience menopause at a later age than their rural counterparts. Among rural sample mean and median age at menopause is 48.22± 2.47 years and 48.98 ±1.12 years respectively, while among urban sample it is 49.30±2.80 years and 50.12 ±1.15 years respectively. These findings therefore suggest that nutritional differences, less infections, better medical care, better awareness due to education is available to urban Brahmin females than their rural counterparts besides reproductive, socio-demographic and certain behavioural influences.

The present investigation suggests that changes in life style especially the increased physical activity in the elderly, and a well regulated diet containing essential nutrients can produce beneficial effects on muscle strength, endurance and general well being, Hence, this research has contributed to the better understanding of ageing process, so as to allow health care providers to make more informed and focused recommendations for active ageing of elderly females.

DEPARTMENT OF CHEMISTRY

(1) Name of the Candidate : Amarjit Kaur **Supervisors : S.V. Kessar and Paramjit Singh**

STUDIES IN GENERATION, REACTIVITY AND STEREOCHEMISTRY OF AZACARBANIONS

The present work describes enantioselective lithiation-substitution reactions of tertiary amines.

The Lewis acid complexation methodology for α-deprotonation of tertiary amines has been extended to aryl amines to change the existing DoM ranking of dialkylamino groups with respect to strong ortho activators. These results along with the relevant literature have been described in Chapter 2.

Chiral ligand mediated lithiation electrophile reactions of 1,2,3,4-tetrahydroisoquinoline carried out with a view to maximize enantioinduction and to unravel the mechanistic details are described in Chapter 3.

(2) Name of the candidate: Anand Gupta **Supervisor: Ramesh Kapoor**

SYNTHESIS AND STRUCTURAL CHARACTERIZATION OF ORGANOTIN(IV) CARBOXYLATES AND SULPHONATES

The chemistry of organotin(IV) derivatives is extensive with various geometries and coordination numbers. Higher coordination numbers can be generated either by inter-and/or intra-molecular interactions, especially in compounds where tin bonds to electronegative atoms, such as oxygen, nitrogen and sulphur. While extensive studies have been directed to elucidate the structures of organotin(IV) derivatives of monocarboxylic acids (R'COOH), only a limited number of investigations have been reported for organotin(IV) derivatives of dicarboxylic (HOOCR'COOH) and alkyl/arylsulphonic acids. The primary objective of the present work was aimed at isolating: i) discrete organotin(IV) derivatives by coordinating with strongly basic carboxylate ligands (carboxylic acids with high positive pk_a values); and ii) polymeric layered structures by employing weakly coordinating alkyl/arylsulphonate ligands and thus constructing a variety of supramolecular architectures in organotin(IV) chemistry.

The work presented in this thesis has been apportioned into three parts. The first chapter reviews primarily the structural diversity, exhibited by the organotin(IV) carboxylate and sulphonate derivatives. This chapter also briefly spells out the scope of the work presented in this dissertation.

The second chapter deals with the experiments carried out to prepare and purify the starting materials either by known literature methods or by improvised procedures, together with the preparation of hitherto unknown organotin(IV)

derivatives of arylmonocarboxylic acids, aryldicarboxylic acids and alkyl/arylsulphonic acids. The compounds were identified and characterized with melting points, elemental analyses, multinuclear (^1H, ^{13}C, ^{119}Sn) NMR, vibrational spectroscopy and X-Ray crystallography. The results have been discussed in three sections.

The first section deals with the preparation and characterization of diorganotin(IV) dicarboxylates, $[\{R_2Sn(OCOR')\}_2O]_2$ $R_2Sn(OCOR')_2$ [R = CH_3, *n*-C_4H_9; R' = $C_{10}H_7$, $C_{12}H_8NO_2$-*4* and $C_{12}H_8NO_2$-2] and (*n*-$C_4H_9)_2Sn(OCOR'OCO)$, (*n*-$C_4H_9)_2Sn(OCOR'COOH)_2$ [R' = $C_{12}H_8$, $C_{12}H_7NO_2$-*4*, $C_{12}H_6N_2O_4$-*4,4' and* $C_{12}H_6N_2O_4$-*4,6*']. These compounds were prepared by reacting R_2SnO (R = *n*-C_4H_9, CH_3) with the appropriate carboxylic acid in benzene in 1:1 or 1:2 mole ratios using Dean-Stark apparatus.

The 1:1 complexes $[\{R_2Sn(OCOR')\}_2O]_2$ [R =CH_3, *n*-C_4H_9; R' = $C_{10}H_7$, $C_{12}H_8NO_2$-*4* and $C_{12}H_8NO_2$-2] have been shown to adopt the usual dimeric structure containing distannoxane units with both types of exocyclic and endocyclic tin atoms acquiring six coordination. These observations are well supported by multinuclear (^1H, ^{13}C, ^{119}Sn) NMR, vibrational spectroscopy and are authenticated by X-ray crystal structure determination of $[\{(n\text{-}Bu_2Sn(OCOC_{10}H_7)\}_2O]_2$ and $[\{(n\text{-}Bu_2Sn(OCOC_{12}H_8NO_2\text{-}4')\}_2O]_2$. To a first approximation, the tin atoms appear to be pentacoordinated with distorted trigonal bipyramidal geometry. However, each type of tin atom is further subjected to a sixth weaker interaction and may be described as having a capped trigonal bipyramidal structure. The disubstituted organotion(IV) derivatives $R_2Sn(OCOR')_2$; [R = CH_3, *n*-C_4H_9; R' = $C_{10}H_7$, $C_{12}H_8NO_2$-*4* and $C_{12}H_8NO_2$-*2*] indicate the presence of anisobidentate carboxylate groups and non-linear C-Sn-C bonds in their IR spectra. From the chemical shift δ (^{119}Sn) and the coupling constant $|^1J|$ values the coordination number of the tin atom and the geometry of its coordination sphere have been suggested. These observations are well supported by single X-ray structure determination of *n*-$Bu_2Sn(OCOC_{10}H_7)_2$ and *n*-$Bu_2Sn(OCOC_{12}H_8NO_2$-*4'*$)_2$. These complexes show six coordinate tin in a distorted octahedral frame containing bidentate asymmetric chelating carboxylate groups with the *n*-Bu groups trans to each other. The geometry of these compounds is best described as a severely distorted octahedron. This structure determination has clearly established that these compounds prefer to adopt monomeric discrete structures rather than polymeric structures arising from bridging carboxylate groups. An interesting feature of the structures derived form *4'/2'*-nitro-2-biphenylcarboxylic acids is the non-coordination of the oxygen atom of the nitro group of the ligand as it is directed away from the tin atom. The nitro group does not make any close inter- or intramolecular contacts to tin in the crystal lattice. Diorganotin(IV) dicarboxylates in which the carboxylate residue contains a donor atom are known to acquire coordination numbers greater than six, but it appears that the presence of bulky diphenyl rings with free rotation around C-C probably bond takes the nitro group away from the neighbouring centers. Nucleophilic addition of naphthoate ion in compounds, (*n*-$C_4H_9)_2Sn(OCOC_{10}H_7$-*2*$)_2$ and $[(CH_3)_4N]^+[(CH_3)_2Sn(OCOC_{10}H_7$-*2*$)_3]^-$, respectively, integration of solution ^1H NMR spectra and elemental analysis established the 1:1 composition of the products and $\delta(^{119}Sn)$ NMR studies suggested the existence of seven coordinate tin species in solution.

It is surprising to note that very few reports exist in the literature on the chemistry of di-*n*-butyltin(IV) dicarboxylates derived from dicarboxylic acids even though multicarboxylate ligands possess several interesting characteristics. These compounds can adopt different coordination geometries because of their completely or partially deprotonated carboxylic groups leading to structures with higher dimensions. These compounds can be regarded not only as hydrogen-bond acceptors but also as hydrogen bond donors, depending upon the number of deprotonated carboxylic groups. Di-*n*-butyltin (IV) aryldicarboxylates (*n*-$C_4H_9)_2Sn(OCOR'OCO)$ and (*n*-$C_4H_9)_2Sn(OCOR'COOH)_2$ [R' = $C_{12}H_8$, $C_{12}H_7NO_2$-*4*, $C_{12}H_6N_2O_4$-*4,4'* and $C_{12}H_6N_2O_4$-*4,6*'] have been prepared and characterized through elemental analyses, multinuclear (^1H, ^{13}C, ^{119}Sn) NMR and IR spectroscopy. The narrow range of NMR shifts and IR stretching frequencies suggests a common solution and solid state structures for these compounds. We propose polymeric structure with 5-coordinated tin for 1:1 and six-coordinated monomeric structure for 1:2 derivatives.

The X-ray crystal structures of the following ligands, *i.e.*, *4'*- nitro-2- biphenylcarboxylic acid, 2'-nitro-2-biphenylcarboxylic acid, 4-nitro-2,2'- biphenyldicarboxylic acid, *4',4*-dinitro-2,2-biphenylcarboxylic acid and *4,6'*-dinitro-2,2'-biphenyldicarboxylic acid were also studied. These ligands exhibit interesting structural features. *4'*-nitro-2 biphenylcarboxylic acid forms a layered structure where no hydrogen-bonds link molecules along, or near the *bc* direction. These crystals are, therefore, expected to cleave readily parallel to a plane. Surprisingly, the nitro group does not take part in bonding. Structure of 2'-nitro-2-biphenylcarboxylic acid exhibits strong hydrogen-bonding between molecules to display three dimensional arrays. The intermolecular hydrogen-bonding between the oxygen atom of

nitro group and hydrogen atom of benzene ring propagates the layer along *ac* plane, whereas, the hydrogen-bonding between the two molecules through carboxylate groups propagates the chain along *ab* plane. The crystal packing in *4*-nitro-2,2'-biphenyldicarboxylic acid utilizes all the hydrogen-bonding possibilities of the carboxylic groups for lattice stabilization and due to almost orthogonal position of the phenyl rings generate corrugated sheets that run almost diagonal to *ac* plane. The arrangement of the dimmer unit are such that if repeated infinitely generates wedge shaped cavities. It is to be noted that the nitro groups in the molecule do not participate in the hydrogen bond network but are involved in two weak C-H...O interactions with the aromatic hydrogens. In the crystal lattice of *4,6'*-dinitro-2,2'-biphenyldicarboxylic acid the molecules related by a glide symmetry are infinitely hydrogen bonded thus generating a *zig-zag* array of molecules. Both the carboxylic groups pair up a dimers and only one set of parameters are needed to describe the entire array of hydrogen bonding. When they are stacked together herring-bone pattern is generated. The oxygen atoms of both the nitro groups do not take part in any hydrogen bonding. It is significant that molecules of *4,6'*-dinitro-2,2'-biphenyldicarboxylic acid incorporate a molecule of methanol during crystallization and act as a host for this small solvent guest. The crystal lattice is stabilized through a network of hydrogen bonds involving the carboxylic group of the host and hydroxyl group of the guest. The behaviour of both the carboxylic groups are very different in the hydrogen bonded molecular network stabilization, while the –COOH forms a cyclic dimer, the other ones are interlinked through the involvement of two methanol guest molecules. Thus both sides of the biphenyl moiety generate 8-membered and 12-membered rings. This pattern gets repeated infinitely thereby generating a "molecular staircase" propagating in [100] direction.

In the second section, synthesis and structural investigations of organotin(IV) picolinates have been discussed. The picolinates were prepared by the reaction between R_2SnO and the appropriate picolinic acid in 1:1 or 1:2 mole ratio. The compounds have been characterized by IR, multinuclear (^1H, ^{13}C, ^{119}Sn) NMR spectroscopy. The X-ray crystal structures of *n*-$Bu_2Sn(OCOC_5H_4N\text{-}2)_2$, $[\{Me_2Sn(OCOC_5H_4N\text{-}4)\}_2O]_2$, $Ph_3Sn(OCOC_5H_4N\text{-}4)$ and *n*-$Bu_2Sn(OCOC_5H_3N\text{-}2, 6\text{-}OCO)_2$ have been investigated. It was interesting to observe the involvement of the nitrogen atom in co-ordination to tin when the nitrogen is in the 2-position in the phenyl ring, while this was not observed when nitrogen is present at 4-position. The crystal structure determination of *n*-$Bu_2Sn(OCOC_5H_4N\text{-}2)_2$ shows the formation of polymeric chains. Pyridine-2-carboxylate chelates the tin atom via one oxygen atom and with the nitrogen of the pyridyl ring. The other oxygen atom of the carboxylate group goes to tin atom of the neighbouring molecule thus generating weak Sn...O interaction. Although the coordination number of tin in this compound is seven yet the best described geometry is distorted octahedral, as the O-atom is not considered to be in the coordination sphere of the tin atom. The crystal structure of $[\{Me_2Sn(OCOC_5H_4N\text{-}4)\}_2O]_2$ revealed the presence of two types of tin atoms. It has the usual tetraorganodicarboxylatostannoxane structure in which N-atom is not involved in any type of bonding as was observed in the structure of *n*-$Bu_2Sn(OCOC_5H_4N\text{-}2)_2$. However, intermolecular Sn-N bonding is observed in the X-ray structure of $Ph_3Sn(OCOC_5H_4N\text{-}4)$ and intramolecular Sn-N bonding is present in the structure of *n*-$Bu_2Sn(OCOC_5H_3N\text{-}2, 6\text{-}OCO)_2$.

The last section deals with sulphonate derivatives of organotin(IV) moiety. A number of alkyl/aryltin(IV) sulphonates, $R_2Sn(OSO_2R')_2$[R = CH_3, C_2H_5, *n*-C_3H_7, *n*-C_4H_9; R' = CF_3, CH_3, $CH_3C_6H_4$-*4*, $C_6H_2(CH_3)_3$-*2,4,6*] have been prepared and IR and solution (^1H, ^{13}C, ^{119}Sn) NMR spectra are reported. From the chemical shift, $\delta(^{119}Sn)$ and the coupling constants $^1J(^{13}C, ^{119}Sn)$ and $^2J(^1H, ^{119}Sn)$, the coordination of the tin atom and the geometry of its coordination sphere in solutions of these compounds is suggested. IR studies indicate that diorganotin(IV) sulphonates contain bridging SO_3X groups that yield polymeric structures with hexacoordination around tin and contain non-linear C-Sn-C bonds.

The X-ray crystal structures of $[(n\text{-}C_4H_9)_2Sn\{OSO_2C_6H_2CH_3\text{-}p\}_2].\ 2H_2O$, $[(n\text{-}C_4H_9)_2Sn\{\ \mu\text{-}OSO_2C_6H_2(CH_3)_3\}_2]$ and $[(n\text{-}C_4H_9)_2Sn\{(\mu\text{-}OH)(\mu\text{-}OSO_2C_6H_2(CH_3)_3)\}]_n$ have been investigated to delineate the coordination behaviour of the sulphonate group with tin(IV) to evaluate the metal-sulphonate bonding interactions. The X-ray crystal structure shows $[(n\text{-}C_4H_9)_2Sn\{OSO_2C_6H_2CH_3\text{-}p\}_2].\ 2H_2O$ to be monomeric six-coordinate tin containing unidentate paratoluenesulphonate groups, the other two positions are occupied by two water molecules. $[(n\text{-}C_4H_9)_2Sn\{\mu\text{-}OSO_2C_6H_2(CH_3)_3\}_2]$ is polymeric containing six-coordinate tin atoms. The structure exhibits highly symmetrical bridging bidentate mesitylenesulphonate groups and is made up of an infinite array of $(n\text{-}C_4H_9)_2SnO_4$ moieties. Compound $[(n\text{-}C_4H_9)_2Sn\{(\mu\text{-}OH)(\mu\text{-}OSO_2C_6H_2(CH_3)_3)\}]_n$ is a hydrolysed product of $[(n\text{-}C_4H_9)_2Sn\{\mu\text{-}OSO_2C_6H_2(CH_3)_3\}_2]$. Its structure is built of polymeric chains in which $[\{(n\text{-}C_4H_9)_2Sn\}_2(OH)_2]$ units are joined by bridging bidentate mesitylenesulphonate groups. The crystal

lattice is stabilized by a network of hydrogen bonds running through the sheets in which an oxygen atom of the sulphonate group and the hydroxyl group attached to tin participate in a symmetrical fashion.

Triorganotin(IV) paratoluenesulphonates, $R_3Sn(OSO_2R')$ [R = CH_3, C_2H_5, *n*-C_3H_7, *n*-C_4H_9; R' = $CH_3C_6H_4$-*4*] have been prepared by the reactions of R_3SnCl with $Ag^1(OSO_2C_6H_4CH_3$-*4*) in THF in 1:1 mole ratio. The IR and NMR spectral studies for these compounds suggest pentacoordination for tin with planar SnC_3 skeleton and bidentate bridging paratoluenesulphonate anionic groups.

The interactions between tin and the various suphonate groups are weak, since the distance between tin and the sulphonato oxygen has been observed to be longer, 2.20(3)-2.78(2) A than the normal Sn-O covalent bond distance of 2.13 A. We feel that the Sn-O (sulphonato) bonds reflect a relatively high degree of ionic character, consistent with the fact that these anions are weakly basis, being anions of strong acids. The earlier studies on diorganotin(IV) sulphonates and our present studies clearly demonstrate that these compounds preferably adopt polymeric sheet structures while their carboxylate analogues often exhibit monomeric chelating structure. This significant conclusion, that organotin(IV) sulphonates prefer polymeric sheet structures in the solid state, may provide the means to construct a variety of supramolecular architectures in organotin(IV) chemistry.

(3) Name of the Candidate : Monica Bhandari **Supervisor : G.L. Kad**

EXPERIMENTS TOWARDS THE PREPARATION OF ORGANIC COMPOUNDS UTILIZING UNCONVENTIONAL PROCEDURES

The work in thesis has been divided into 5 Chapters which utilizes unconventional methodologies for the synthesis of a few naturally occurring compounds. Novel methods for the protection and deprotection of aldehydes & ketones have also been reported. Brief overview of the work is as follows:

Chapter 1 deals with the synthesis of a few amides of the family piperacea by utilizing microwave-assisted aldol condensation of aldehydes with amides in presence of KF doped on neutral alumina as a base in the key step. The amides which have been synthesized are:-

5-(3',4'-methylenedioxyphenyl)pent-2(E), 4(E)dienopieridide(Piperine), 7(3',4'-ethylenedioxyphenyl)hept-2(E),4(E),6(E) trienopiperidide(Piperettine), 3-(3,4'5'-trimethoxyphenyl)prop-2(E)-enopiperidide(Piperlongumine), 5-(3',4'-methylenedioxyphenyl)pent-2(E)-4(E)-dienopyrrolidide (Piperylin), deca-2(E),4(E)-die nopyrrolidide dodeca-2(E),4(E)-dienamide, and N-cinnamoyl pyrrol.

Chapter 2 deals with the synthesis of 2-methylheptadecane, an insect pheromone isolated from Tiger moth and 4-hexanolide an Trogoderma species of desmestid beetles. These synthesis have been achieved through the use of indium in aqueous media for reaction between pyrazole amides with 3-bromopropene.

Chapter 3 makes use of clear & ecofriendly methodologies for preparation of oximes & deoximation reactions.

The synthesis of a new fatty acid 11-methylpentadecanoic acid utilizing zinc-copper couple conjugate addition of 1-iodo-8-methyl dodecane with methyl acrylate under ultrasonic conditions has been embodied in chapter 4 of the thesis.

Lastly, **Chapter 5** report microwave –assisted knoevenagel condensation of 10-formyl undecanoate, the component of pod husk of Terphrosia Purpurea. And also the synthesis of an important side chain component of the tropane alkaloide of various plant species, such as solanaceae, Erythoxylaceae, convolvulaceae etc. This component, that is 4-(3'4',5'-trimethoxyphenyl)but-3(E)-en-2-one has been synthesized via use of microwave heating & grinding in a mortar.

(4) Name of the candidate: Neena Garg **Supervisors: S.P. Narula and J.K. Puri**

PREPARATION AND CHARACTERISATION OF SOME HYPERVALENT SILICON COMPOUNDS

The past three decades have witnessed rich literature on the chemistry of hypervalent silicates. In recent years hypervalent silicon compounds have attracted a great deal of attention both for its intrinsic interest and possibility of discovering new materials and chemical reagents.

In the present dissertation, attempts have been made to develop new synthetic methods for the preparation of unknown anionic spirobicyclic pentacoordinated silicon(IV) compounds have O, N; N, S and O, O moiety in the structural framework and silicates having expanded ring system. The results are described in chapters 2 & 3.

Chapter-2

Section A: This section describes the synthesis and characterisation of anionic pentacoordinated silicate $[(C_7H_5O_2N)_2Si(C_6H_5)]^-[NHEt_3]^+$ having SiO_2N_2C type structural framework.

Section B: This section describes synthesis and characterisation of $[(C_6H_5NS)_2Si(C_6H_5)]^-[NHEt_3]^+$ incorporating N, S type ligand around silicon atom.

Section C: This section deals with the preparation and characterisation of anionic spirobicyclic pentacoordinated silicate $[(C_7H_4O_3)_2Si(C_6H_5)]^-[NHEt_3]^+$ with SiO_4C type skeleton.

Section D: This section ascribes the synthesis and characterisation of anionic $[(C_{14}H_{10}O_2)_2Si(C_6H_5)]^-[NHEt_3]^+$ with SiO_4C architecture having new five membered ring system.

Chapter-3: This chapter reveals the synthesis and characterisation of a new dianionic hexacoordinated silicate $[(C_4H_2O_4)_2\ Si(NCS)_2]^{2-}[BH^+]_2$ (where B=py, 3-mepy, 4-mepy) incorporating seven membered ring system around silicon atom.

(5) Name of the candidate: Seema Kanwar **Supervisor: S.D. Sharma**

INVESTIGATIONS TOWARDS THE STEREOCONTROLLED SYNTHESIS OF 2-AZETIDINONES AND THEIR BIOLOGICAL POTENTIAL

This dissertation includes the studies towards different variables and approaches involved in the synthesis and biological potential of 2-azetidinones commonly known as b-lactams. It consists of five chapters.

Chapter 1 includes the use of three remarkable reagents for the first time in the synthesis of 2-azetidinones via a variant of [2+2] cycloaddition. The new reagents used are ***(chloromethylene) dimethylammonium chloride, Lawesson's reagent*** and ***2, 2'-dibenzothiazolyl disulphide/triphenyl phosphine.***

Chapter 2 describe the cyclization of β–amino acids leading to β-lactam formation using the three reagents mentioned in Chapter 1. Their use was found remarkable in this ***intramolecular cyclodehydration*** reaction as well.

Chapter 3 *consists of two parts. The first part demonstrates the use of* $POCl_3$ and ***benzenesulphonyl chloride*** for formation of 3-phenylthio 2-azetidinones as precursors of 3-unsubstituted β-lactams. The second part discusses the construction of 4-memebered heterocycles involving C_3-C_4 bond formation leading to ***3-unsubstituted 4-heteryl β-lactams.***

Chapter 4 similarly consist of two parts–former deals with the formation of 2-azetidinones via the *ester* ***enolate–imine condensation reaction*** and the later describes the ***ring preparation of aziridines*** as well as their ring expansion reaction leading to β-lactam formation.

Chapter 5 describes in detail the method used for the determination of ***antimicrobial activities*** of some of the synthesized β-lactam compounds. This lead to the useful information regarding the structure-activity relationship which is embodied in this *Chapter*.

(6) Name of the Candidate : Soma Ghosh **Supervisor : Sanjay Trehan**

PREPARATION OF SOME NEW CHIRAL AMINES AND THEIR USE IN ASYMMETRIC SYNTHESIS

The past three decades have witnessed rich literature on the chemistry of hypervalent silicates. In recent years hypervalent silicon compounds have attracted a great deal of attention both for its intrinsic interest and possibility of discovering new materials and chemical reagents.

In the present dissertation, attempts have been made to develop new synthetic methods for the preparation of unknown anionic spirobicyclic pentacoordinated silicon(IV) compounds have O, N; N, S and O, O moiety in the structural framework and silicates having expanded ring system. The results are described in chapters 2 & 3.

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Chapter-3: This chapter reveals the synthesis and characterisation of a new dianionic hexacoordinated silicate $[(C_4H_2O_4)_2 Si(NCS)_2]^{2-}[BH^+]_2$ (where B=py, 3-mepy, 4-mepy) incorporating seven membered ring system around silicon atom.

(7) Name of the Candidate : Vikas **Supervisor : B.M. Deb**

TIME-INDEPENDENT AND TIME-DEPENDENT STUDIES OF QUANTUM MECHANICAL SYSTEMS

There has been a considerable need for a non-perturbative approach for studying atoms and molecules in intense/ superintense laser fields and/or magnetic fields, since perturbative approaches yield good results only for weak uniform fields. Moreover, for such quantum mechanical systems, an interesting and challenging task is to visualize the role of electron correlation. Various non-perturbative time-independent (TI) and time-dependent(TD) approaches have been developed from time to time. The present thesis studies a non-perturbative time-dependent quantum fluid dynamical density functional approach for large perturbations. This approach is simple and visual with appealing physical concepts

and computational economy. It solves only a single equation for a many-electron system. Chapter 1 of the thesis presents a review of the different time-independent and time-dependent non-perurbative approaches along with various experimental aspects of atoms in intense laser fields. Apparently counterintuitive phenomena in atom-laser interaction, e.g., multiphoton ionization (MPI), above-threshold ionization (ATI) and high-harmonic generation (HHG) in an intense laser field as well as the suppression of ionization in a superintense laser field are described in chapter 1.

Chapter 2 deals with a simple time-independent approach to study the correlation states (satellites) of atoms. The correlation states of atoms, particularly of charged ions, are difficult to compute accurately. Chapter 2 employs a simple density-functional formalism within a single determinantal approach along with Slater's sum rule, presents and discusses the results of Ar^{++} ($3s^2 3p^3 nl$) satellite states. Employing the Harbola-Sahni work-function-based potential for exchange, a Kohn-Sham-type differential equation was solved numerically. The effects of electron correlation energy functionals, namely, local Wigner and nonlocal Lee-Yang-Parr, both of which seem to deliver good results although for different correlation states, have been studied. This chapter reports about forty new correlation states for the first time.

Chapter 3 studies a non-perturbative quantum fluid dynamical density functional (TDQFDF) treatment of multiphoton processes of many-electron systems in intense laser fields, taking He atom as an example. The method is based on a hydrodynamical equation developed earlier in our laboratory through an amalgamation of time-dependent density functional theory and quantum fluid dynamics. Through the solution of a single hydrodynamical equation, He atom at 15 different laser intensities ranging from $5 \times 10^{12} Wcm^{-2}$ to $1 \times 10^{16} Wcm^{-2}$, at λ =1064nm, was studied for 100 femtoseconds(fs). The role of dynamical electron correlation in MPI, ATI and HHG was explored by employing local Wigner correlation energy density functional with the Ghos-Deb exchange functional. The exchange-only results differ significantly from the results including correlation, particularly for MPI. The high harmonics behaviour with pulse rise time as well as attosecond pulse generation were also studied. From this study of He atom in intense laser fields it was concluded that the TDQFDF approach employed here has considerable potential as a non- perturbative approach for investigating time-dependent processes involving multielectron atoms.

Therefore, chapter 4 of this thesis explored the potential of the TDQFDF approach for atoms with more than two electrons, e.g., Ne, Ar, Kr and Xe, in intense laser fields. It has been a challenge to theory to describe a plateau in ATI for any multielectron atom. Indeed, presently this is the test for any TD non-perturbative approach to be accepted for realistic systems since most of other phenomena like MPI and HHG have been understood to a large extent. In this chapter four noble gas atoms Ne, Ar, Kr and Xe were studied under an intense laser field of wavelength λ =1064 nm at five different intensities for a time duration of 100 fs. The TDQFDF approach successfully revealed the plateau in ATI of Ne, Ar, Kr and Xe together with the characteristic behaviour of HHG spectra and MPI. For ionization probabilities, the exchange-only results differ significantly from the exchange*correlation results. These two sets of results followed different paths of ionization although the end results of the ATI and HHG spectra do not differ greatly. There is strong need for developing better exchange*correlation energy functionals for large perturbative fields.

Following the success of the TDQFDF approach for many-electron atoms in intense laser fields as described in chapters 3 and 4, chapter 5 studies many-electron atoms in intense magnetic fields, as another strong perturbative field of study. It was already established in our laboratory that the TDQFDF approach, when carried out through the imaginary- time evolution technique (akin to quantum diffusion Monte Carlo method), yields accurate ground-state energies and densities for atomic and molecular systems. Employing this technique, chapter 5 calculates the electronic energies and densities of H, H^-, He, Ne and Ar atomic systems in intense magnetic fields of less than 10^{12}Gauss. Again, the local Wigner-type correlation and Ghosh-Deb local exchange functional were employed. In order to obtain the correct kinetic energy and atomic shell structure, a nonclassical correction term $T^{corr}[\rho]$ was added to Weizsacker's kinetic energy, following earlier works from our laboratory. The results for Ar atom and most of the results for Ne atom were reported for the first time. For H,H and He the present results gave satisfactory agreement with the best results reported in the literature. It was found that exchange effects dominate over correlation effects.

Chapter 6 extends the above study of atoms in static magnetic fields to He atom in a superintense pulsating magnetic field of order greater than 10^{12} Gauss. This is only a preliminary study for which the He atom was evolved nonrelativistically in real time under a magnetic pulse of peak intensity 4.7×10^{15} Gauss for about 30 fs. This pulse may represent the changing magnetic field during the final stages of stellar evolution from a white dwarf (~10^{12} Gauss) to a neutron star (>10^{12} Gauss). During the initial rise time of the pulse up to about 5 fs (<10^{12} Gauss), exchange and correlation energies

comparable to those in chapter 5 were obtained. The dynamics of the process were studied through electron density, current density and effective potential. In the present work, a current density functional and relativistic considerations were not taken into account. These would be necessary in future studies.

Overall, the present thesis was successful in applying the time-dependent quantum fluid dynamical density functional approach as an effective non-perturbative self-consistent and unified approach for studying both real-time and imaginary-time evolutions of quantum mechanical systems. It is worthwhile to note that no matter how many electrons are present in the system the method solves only one equation for obtaining the time-dependent single-particle densities, in contrast to other methods.

DEPARTMENT OF COMPUTER SCIENCE & APPLICATIONS

Name of the Candidate : M. Syamala Devi **Supervisor : Allam Appa Rao**

DESIGN OF A MULTIAGENT SYSTEM FOR CO-OPERATIVE DECISIONS AND MANAGEMENT

Decision-making is a major function of management. Quantitative models are normally used in the traditional computer techniques in support of decision-making. They, however, suffer in an environment of uncertain management decisions, which are crucial for real-life applications.

An agent is a self-contained computer program that can act robustly in unexpected situations and in its own environment. Such systems have a large number of applications in scheduling, manufacturing, control, diagnosis, and logistics. However, in a distributed environment, each agent has incomplete information and is restricted in its capabilities. Hence a multiagent system (MAS) which is needed. In a MAS, agents interact with other agents or with humans in pursuing their goals and executing their tasks.

Agent properties, their benefits and features of multiagent systems and their applications are briefly described in chapter 1. Work done so far in agent research is discussed in chapter 2. It includes agent theories, agent architectures, agent languages, and some existing agent systems developed so far. The agents include Letizia – an agent for web browsing, Julia – an entertainment agent and other agents. The protocol for agent communication KQML (knowledge query and manipulation language), which is becoming a standard, and the software and hardware requirements for using the protocol are also discussed in chapter 2.

Co-operative decision-making using multiagent systems offer acceptable decisions in many practical applications, which are very complex. In systems with decentralised co-ordination or co-operative systems, agents take autonomous local decisions and communicate with each other for co-operative global decisions. A case study of distributed decision support using multiagent system- road traffic control system is presented in chapter 2.

The thesis includes a detailed study of distributed application namely, real time operation of multiple reservoirs during severe storms. In this application, the possibility of applying multiagent technology to reservoir operation for flood control is explored. During the flood season operation of a reservoir is a difficult task. Further drawback is the delay and hesitation in taking decisions at different reporting stations located far away from head works. It is, therefore, attempted to develop a multiagent system for operation of a hypothetical case of a two-reservoir system. The system consists of two reservoirs R1 and R2 on two adjacent rivers, two basin areas and two flood prone areas. There are six agents in all, two at reservoir head works, two in the two catchment areas and two in the two flood prone areas. There is no single level state model for problem solving using multiagent systems. This may be visualised as a distributed state model with interaction depicted as a multipartite graph Need of the reservoir problem, description of the problem, and agent configuration in the reservoir system are included in chapter 3.

The system is modelled and agent configuration and functions of agents in the configuration are discussed. Mathematical formulations, based on Thomas Fiering, and ARMAX (2,4) models, Muskingum routing and other hydrological methods are discussed in chapter 4. Iterative algorithms are also developed for reservoir routing. Step method is used for reservoir routing during floods and ISD method is used for reservoir routing under normal circumstances.

A mathematical model is fitted for each agent. Co-operative decision making with multiple agents is fitted with a

distributed model. Two-way communication among distributed agents can be established using TCP /IP protocol. The agents in catchment and flood prone areas send processed local data to agents at reservoir head works. Inter communication between individual agents is also considered for cooperative decisions such as whether diversion is required or not, whether water is to be released or not, how much quantity is to be handled for the same. Thus chapter 5 contains interagent communication, state transition model, and co-operative decision making process for the two-reservoir system in the state model.

Programs are developed in programming language LISP and verified for available hydrological data. Implementation of interagent communication is also explored on windows platform using Java programming language. Chapter 6 contains algorithms and flowcharts, verification of programs, and implementation details.

Chapter 7 includes conclusions and directions for further research. Intelligent tasks are emphasised and advantages of this new technology to the reservoir problem are also highlighted. It may be concluded from the study carried out that modelling for the hypothetical case of multiagent system for reservoir operation during floods is more reliable, efficient and cost effective. As it can send appropriate and timely warnings, the downstream areas are protected from floods, and at the same time water in the reservoir is not lost for future uses. It may be emphasised that due to its many advantages, a multiagent system is suitable to study different models of co-operative decision making and can give elegant approach to handle similar problems in co-operative marketing, E-commerce etc. which are potentially in demand at present.

In the directions for further research and development, it is suggested that more complex hydrological methods can be used in addition to ARMAX (2,4) model and Muskingum models. KQML can be used for interagent communication. Multiagent system can be applied to any real water resources system. Instead of two-reservoir system, the study can be extended to the operation of more than two reservoirs as well as to the flood plain management.

DEPARTMENT OF MATHEMATICS

(1) Name of the Candidate : Amrit Pal Singh **Supervisor : Sudesh K. Khanduja**

A STUDY OF TAME AND DEFECTLESS EXTENSIONS OF HENSELIAN VALUED FIELDS

The research work carried out in the thesis has yielded some significant results regarding valued fields and their applications which are covered in five research papers, three of which have been published / accepted for publication in international journals. My work has generalized some well known results of Alexandru, Popescu, Zaharescu, Tverberg and Ota. I worked on five main problems in the present thesis, which are described below.

Let v be a Henselian valuation of arbitrary rank of a field K with value group G and $\overline{v}$ be its unique prolongation to a fixed algebraic closure $\overline{K}$ of K. Using saturated distinguished chains and the invariants related to an individual element α in $\overline{K} \setminus K$, namely $\omega_K(\alpha) = \max\{\overline{v}(\alpha - \alpha') \mid \alpha' \neq \alpha \text{ runs over } K - \text{conjugates of } \alpha\}$ and $\delta_K(\alpha) = \sup\{\overline{v}(\alpha - \beta) \mid \beta \in \overline{K}, [K(\beta : K) < [K(\alpha) : K]\}$, we have given several characterizations of finite tame extensions of valued fields. Further we have described a procedure for constructing a saturated distinguished chain for any α in $\overline{K} \setminus K$ when K (α) is a tame extension of a Henselian valued field (K,v) of arbitrary rank. Also we have determined explicitly some of the invariants associated with such a chain.

The results stated above constitute the main contents of the paper "On finite tame extensions of valued fields", accepted for publication in Communications in Algebra.

My second problem was to give a characterization of defectless extensions using saturated distinguished chains and

Cauchy pseudo nets. We say that a set $\{a_\lambda \mid \lambda \in \Lambda\}$, , of elements of a field K with a valuation v, where Λ is a well ordered set without last element, is a Cauchy pseudo net (with respect to the valuation v) if v $a_\rho - a_\sigma$) < v $a_\sigma - a_\tau$) for all $\rho < \sigma < \tau$ in Λ. It is already known that if $\{a_\lambda\}$ is a Cauchy pseudo net in a valued field (K,v), then for each ρ in Λ the set $\{v\ a_\rho - a_\sigma) \mid \sigma > \rho\}$ is a singleton set. A Cauchy pseudo net $\{a_\lambda \mid \lambda \in \Lambda\}$ of elements of (K,v) is said to have an element *a* as a pseudo limit if for each $\rho \in \Lambda$, one has v $a_\rho - a$) = v($a_\rho - a_\sigma$), $\sigma > \rho$.

We have proved that a valued field (K,v) has no proper immediate extension, i.e., it is maximally complete if and only if it has the property that whenever (L,w) is an extension of (K,v) such that the index of the value group of v in the value group of w is finite and the degree of the extension of the residue field of w over the residue field of v is finite, then L/K must be a finite extension and [L:K] is equal to the product of the degree of the extension of the residue field of w over the residue field of v and the index of the value group of v in the value group of w. We have also given a characterization of maximally complete fields using Cauchy pseudo nets which is different from that of Kaplansky and Fleischer.

These results constitute the main result of the paper entitled "Some characterizations of maximally complete fields" which has been accepted for publication in 'Trends in Theory of Rings and Modules', S.T. Rizvi and S.M.A. Zaidi (eds.), Anamaya Publishers, New Delhi 2004 .

My third problem was to extend a result of Tignol. Let (K,v) be a henselian valued field and $(K', v') \subseteq (\overline{K}, \overline{v})$ be a finite extension of (K,v). Since (K,v) is Henselian $v(Tr_{K'/K}(\alpha)) \geq v'(\alpha)$, where Tr stands for the trace. In 1990, Tignol proved that if (K',v')/(K,v) is a finite separable extension of degree any prime number, then the set $A_{K'/K}$ defined by $A_{K'/K} = \{v(Tr_{K'/K}(\alpha)) - v'(\alpha) / \alpha \in K', \alpha \neq 0\}$ has a minimum element provided (K',v')/(K,v) is a defectless extension. He also proved that the smallest element of $A_{K'/K}$ is zero in case (K',v')/(K,v) is a tame extension. In 2000, Khanduja proved that the above result of Tignol in fact holds for all finite tame extensions and showed that a finite separable extension (K',v') of a Henselian valued field (K,v) is tame if and only if zero is the minimum element of $A_{K'/K}$. In this thesis, we have proved that a finite separable extension (K', v') of a Henselian valued field (K, v) is defectless if and only if the set $\{v(Tr_{K'/K}(\alpha)) - v'(\alpha) / \alpha \in K', \alpha \neq 0\}$ has a smallest element.

In the course of proving this characterization of defectless valued fields, we have obtained some results, which are of independent interest as well. They are proved in the paper "On a Theorem of Tignol for Defectless extensions and its converse" which has been accepted for publication in Journal of Algebra.

Our next result is regarding an extension of a well known result of Ehrenfeucht proved in 1956, which states that a polynomial $f_1(x_1) + ... + f_n(x_n)$ with complex coefficients in the variables $x_1, ..., x_n$ is irreducible over the field of complex numbers provided the degrees of the polynomials $f_1(x_1), ..., f_n(x_n)$ have greatest common $f_1(x_1) + ... + f_n(x_n)$ belonging to $K[x_1, ..., x_n]$ is irreducible over any field K of characteristic zero in case the degree of each $f_i(x_i)$ is positive. He also proved that a bivariate polynomial $f_1(x_1) + f_2(x_2)$ is irreducible over a field of arbitrary characteristic provided the degrees of $f_1(x_1)$ and $f_2(x_2)$ are coprime. In 2002, using valuation theory, Bhatia and Khanduja extended the above result to more general bivariate polynomials. Clearly a polynomial F= $f_1(x_1) + ... + f_n(x_n)$ is reducible over a field K of characteristic $p \neq 0$ if F can be written as F= $(g_1(x_1))^p + ... + (g_n(x_n))^p + c[g_1(x_1) + ... + g_n(x_n)]$ where c is in K and each $g_i(x_i)$ is in $K[x_i]$. In 1966, Tverberg proved that the converse of the above fact holds for any algebraically closed field K of characteristic p>0, in the particular case when n=3. In 1982, Schinzel extended Tverberg's result by showing that this converse holds for any $n \geq 3$. We have given a proof of Schinzel's result which is shorter and entirely different from Schinzel's proof.

The paper containing the proof of this result entitled "An extension of the irreducibility criteria of Ehrenfeucht and Tverberg" has appeared in Communications in Algebra, **32** (2004), 579-588.

(2) Name of the candidate: Saurabh Bhatia **Supervisor: Sudesh K. Khanduja**

A STUDY OF IRREDUCIBLE POLYNOMIALS AND THEIR INVARIANTS OVER HENSELIAN VALUED FIELDS

The research work carried out in the thesis has yielded some significant results regarding valued fields and their applications which are covered in four research papers published/accepted for publication in international journals. My work has generalized some well known results of Alexandru, Popescu, Zaharescu, Panaitopol and Stefanescu. I worked on four main problems in the present thesis which are described below.

Let v be a henselian valuation of any rank of a field K with value group G and $\overline{v}$ be its unique prolongation to a fixed algebraic closure $\overline{K}$ of K. For an element α of $\overline{K} \setminus K$ which is separable over K, let $\omega_K(\alpha)$ denote the well known Krasner's constant given by $\max\{\overline{v}(\alpha-\alpha') \mid \alpha' \neq \alpha$ runs over K - conjugates of $\alpha\}$. In 1946, Krasner proved that if β belonging to $\overline{K}$ is such that $\overline{v}(\alpha-\beta) > \omega_K(\alpha)$, then $K(\alpha) \subseteq K(\beta)$. We have investigated whether $\omega_K(\alpha)$ is the smallest among all the elements λ of the divisible closure of G which have the property that whenever $\overline{v}(\alpha-\beta) > \lambda$, $\beta \in \overline{K}$ then $K(\alpha) \subseteq K(\beta)$. This problem was solved for rank one valuations by Khanduja in 1999. We have given an example to show that the answer to this question is "no" in general when rank $v>1$. It has been shown that the answer to the foregoing question is also in the affirmative when either (i) the characteristic of the residue field $R(K)$ of v is the same as that of K; or (ii) char $K=0$, char $R(K) = p > 0$ and the smallest convex subgroup[1] of the value group G of v containing $n(\omega_K(\alpha)-\lambda)$ for some positive integer n, *is not a* p - divisible group.

The above results constitute the main contents of the paper "A Characterization of Krasner's constant" which has appeared in Communications in Algebra 30(6) (2002), 2975-2991.

My second problem was to give a generalization of Eisenstein's and Ehrenfeucht's Irreducibility Criterion. In 1956, Ehrenfeucht proved that a polynomial $f_1(x_1)+\ldots+f_r(x_r)$ with complex coefficients in the variables $x_1,\ldots,x_r$ is irreducible over the field of complex numbers provided the degrees of the polynomials $f_1(x_1),\ldots,f_r(x_r)$ have the greatest common divisor 1. In 1964, Tverberg extended Ehrenfeucht's result by showing that when $r \geq 3$, then $f_1(x_1)+\ldots+f_r(x_r)$ belonging to $k[x_1,\ldots,x_r]$ is irreducible over a field k of characteristic zero if deg $f_i(x_i)$ is positive for each i. He also gave a simple proof for the irreducibility of a difference polynomial $f(x)-g(y)$ over any field k when the degree of f and g are coprime. In 1990, Angermüller gave a similar irreducibility criterion for a larger class of polynomials with coefficients in any field K, namely the class of generalized difference polynomials. Recall that a polynomial $P(x,y)$ is said to be a generalized difference polynomial (with respect to x) of the type (d,e) if $P(x,y) = cx^e + \sum_{i=1}^{e} P_i(y)x^{e-i}$, where $0 \neq c \in k, e \geq 1, d = \deg P_e(y) \geq 1$ and $\deg P_i(y) < di/e$ for $1 \leq i \leq e-1$.

We have studied irreducibility conditions for more general polynomials given by $F(x,y) = cx^e + \sum_{i=1}^{e} P_i(y)x^{e-i}, 0 \neq c \in k, e \geq 1$ such that there exists $t, 1 \leq t \leq e$ satisfying $\deg_y F(x,y) = \deg P_t(y) = d$ and $\deg P_i(y) < di/t$ for $i \neq t, 1 \leq i \leq e$.

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[1] A subgroup H of G is said to be convex if whenever $0 < g < h$, with h in H and g in G then $g \in H$.

Such a polynomial $F(x,y)$ will be referred to as a quasi-difference polynomial of the type (d,t) with respect to x. In 1990,L. Panaitopol and D. Stefanescu proved that a quasi- difference polynomial of the type (d,t) with d and t coprime is irreducible over $k\ (x)$. In this direction, we have gone further and given an irreducibility criterion for a quasi-difference polynomial of the type (d,t) with d and t not necessarily coprime, of which the criterion of Panaitopol and Stefanescu is a special case. Moreover our method of proof is new and uses the theory of liftings of polynomials is residually transcendental extensions.

The paper containing the proof of this criterion and its applications entitled "Difference polynomials and their generalizations" has appeared in Mathematika 48 (2001), 293-299.

My third problem is regarding lifting of polynomials which will be stated after introducing some notation. Let v be a henselian valuation of any rank of a field K and $\bar{v}$ be its unique prolongation to a fixed algebraic closure $\bar{K}$ of K having value group $\bar{G}$. For any subfield L of $\bar{K}$, let $R(L)$ denote the residue field of the valuation obtained by restricting $\bar{v}$ to L. Using the canonical homomorphism from the valuation ring of v onto its residue field $R(K)$ one can lift any monic irreducible polynomial with coefficients in $R(K)$ to yield a monic irreducible polynomial with coefficients in K. In an attempt to generalize this concept, Popescu and Zaharescu introduced the notion of lifting with respect to a (K,v)-minimal pair (a,δ) belonging to $\bar{K}\times\bar{G}$. As in the case of usual lifting, a given monic irreducible polynomial $Q(y)$ belonging to $R(K(\alpha))[y]$gives rise to several monic irreducible polynomials over K which are obtained by lifting with respect to a fixed (K,v) - minimal pair (α,δ). If F,F_1 are two such lifted polynomials with coefficients in K having roots θ,θ_1 respectively, then we have proved that $\bar{v}(K(\theta))=\bar{v}(K(\theta_1))$, $R(K(\theta))=R(K(\theta_1))$; in case (K,v) is a tame field, we have shown that $K(\theta)$ and $K(\theta_1)$ are indeed K - isomorphic.

The paper entitled "On extensions generated by roots of lifting polynomials" containing the proofs of the results mentioned in the above paragraph is to appear in Mathematika 49 (2002).

The last problem deals with limits of Cauchy sequences of elements algebraic over a complete valued field (K,v) of rank one. A well known result of Ostrowski asserts that the limit of a Cauchy sequence of elements of $\bar{K}$ does not always belong to $\bar{K}$ unless $\bar{K}$ is a finite extension of K. We have shown that when a Cauchy sequence $\{b_n\}$ of elements of $\bar{K}$ is such that the sequence $\{[K(b_n):K]\}$ of degrees of the extensions $K(b_n)/K$ does not tend to infinity as n approaches infinity, then $\{b_n\}$ has a limit in $\bar{K}$. We also give a characterization of those Cauchy sequences $\{b_n\}$ of elements of $\bar{K}$ whose limit is not $\bar{K}$ which generalizes a result of Alexandru, Popescu and Zaharescu.

The paper "On limits of sequence of algebraic elements over a complete field", containing the proofs of the above results has been accepted for publication in Algebra Colloquium.

(3) Name of the Candidate : Sukhvinder Kaur **Supervisor : Harinder Singh**

SOME PROBLEMS OF COUPLED AND GENERALIZED THERMOELASTICITY

The temperature changes produce stresses in continuous media. The source of stress is heat, hence the stresses generated by temperature field is called thermal stresses. If the material of the body in which they originates is elastic, these stresses are said to be thermoelastic. Today engineers and scientists to solve practical problems in structural and material design are using thermoelastic stress analysis. The aim of this thesis work is to study variation of temperature and variation of thermal stresses in a homogeneous isotropic elastic material considering some problems of coupled and generalized thermoelasticity.

In chapter1, introduction to thermoelasticity, its practical importance, coupled thermoelasicity, generalized thermoelasticity, thermal stresses, theory of elastic plates, thermal behaviour and thermal properties of materials, basic equations, boundary conditions effect of coupling and inertia terms and methods to solve the basis equations are discussed.

In chapter 2, considering importance of moving stress and temperature pulses in high speed machining we study the effects of temperature and stress (pressure) pulses traveling along across the surface of a thermo-elastic half-space. We consider a homogeneous, isotropic elastic half- space $y \geq 0$, which initially has temperature T_0 and is in stress free state. We study the development of temperature, displacement and stress assuming a two-dimensional temperature fields in the context of generalized theory of thermoelasticity. The variation in temperature field and stress field occurs owing to the action of external loadings (due to heating or cooling). Appropriate initial conditions and boundary conditions are introduced. The solutions are obtained for the variation in temperature field and stress field using method of Fourier expansion. Stainless steel is the material considered for the numerical calculations and results are shown graphically.

In chapter 3, variations in temperature and stresses in a horizontal heated plate are presented. We consider a homogeneous, isotropic elastic plate of thickness "H", initially has temperature T_0 and is in stress free state. The variation in temperature field and stress field occurs owing to the action of external loadings. The effects of both temperature and stress variation in a Plate are studied in the context of generalized theory of thermoelasticity. Appropriate initial conditions and boundary conditions are introduced. The solutions for the temperature and stress distribution are calculated. Stainless steel is the material considered for numerical calculations and the results are shown graphically.

When a thermo-elastic body is suddenly heated or cooled from out side, heat flow arises resulting in change in the temperature distribution in the body and development of stress field. In chapter 4, we study the development of these fields in each layer of a multi-layered plate using coupled thermo-elastic theory. Each layer of the medium is assumed to be of isotropic elastic thermally conducting homogeneous material. Perfect mechanical bonding at the interface between the different layers is assumed but there is finite contact resistance to the heat flow at the interface. After introducing appropriate initial and boundary conditions, the problem has been solved by using Laplace transform and theory of matrices. Temperature and stress distribution in the medium consisting Steel and Copper plates have been obtained and represented graphically.

The investigation of stress concentration around holes and notches of arbitrary shape in a given elastic medium is very important for modem engineering. Considering the importance of high stress concentration in chapter 5, we study temperature and thermal stresses in a hexagon region with an elliptic hole using elliptic co-ordinates. The solution for the temperature and thermal stress functions are obtained by five elementary functions method in plane themoelasticity of multiply- connected regions. Numerical calculations are obtained by the point-matching method for the thermal stress distribution of the hexagon with a central elliptical hole.

DEPARTMENT OF MICROBIOLOGY

Name of the Candidate : Harish Chander **Supervisors : Praveen Rishi and S. Majumdar**

EXPRESSION OF HEAT SHOCK AND ACID STRESS REGULATED OUTER MEMBRANE PROTEIN(S) IN *SALMONELLA ENTERICA* SEROVAR TYPHI AND THEIR INTERACTION WITH PHAGOCYTIC CELLS

Typhoid fever caused by *Salmonella enterica* serovar Typhi remains a common serious disease in the tropical developing countries, because of insanitary conditions and inadequate health facilities. The condition is further complicated due to upsurge of multi-drug resistant strains of *S. typhi*. Despite of tremendous research, the search for an effective vaccine against Salmonella is not over, because of adverse reactions, poor efficacy and the risk of reversion to virulent forms of existing vaccines as well as due to the lack of identification of protective moieties. This needs a better understanding of host-microbe interactions. Research on pathogenesis has focused on *Salmonella enterica* serovar Typhimurium infection in mice, and consequently, there is little information about *S. typhi* proteins and genes which may be involved in virulence or which are important in eliciting immune response.

Salmonella pathogen city is not only multifactorial but a multiphasic property also. As the infection proceeds from one anatomical site to another, the pathogen encounters environmental conditions, which are complex and diverse too. It is therefore, the interplay between the microorganism and the host, which decides the outcome of the disease. During the disease process, Salmonella encounters a variety of stress conditions which include alteration in temperature, pH, exposure to fatty acids and availability of oxygen as well as nutrients.

During the journey from external to the internal environment, enteric organisms are exposed to elevated temperature outside as well as inside the host. Pathogens adapt themselves to the changes in temperature by a phenomenon known as thermo tolerance attributed to heat shock proteins (HSPs). Although the function of HSPs as molecular chaperones in normal physiological processes was recognized much earlier evidence is now accumulating that these proteins are major antigens expressed by many pathogens like *Mycobacterum tuberculosis, Streptococcus pyogenes, Neisseria gonorrhoea, Campylobacter jejuni, Pseudomonas aeruginosa, Haemophilus, influenae, Halicobacter pylori, Escherichia coli, S. typhimurium* and *Chlamydia trachomatis*. The paucity of information on stress proteins of *S. typhi* is surprising, given the role of these proteins *in vivo* during *S. typhi* pathogenesis.

Following ingestion, enteric organisms are exposed to inorganic as well as organic acid stress in the gut. One of the most frequently encountered hostile conditions faced by *E. coli, Salmonella, Shigella flexneri*, while traveling through the GI tract include extremely low pH of the stomach. On exposure to relatively acidic conditions in the stomach, the acid tolerance response (ATR) has been found to control the expression of proteins, which serves as an adaptive mechanism for the survival of the organism under acid stress. Yet another stress encountered by *S. typhimurium* within the gut, is the presence of short chain fatty acids (SCFAs) like acetate, propionae and butyrate, which are produced as fermentation products by native intestinal microflora. The organic acids may provide stress to the pathogen as these can be present in gastro-intestinal ecosystem at high concentrations. A large number of polypeptide species was shown to be up-regulated and down-regulated during acid stress. Therefore, the molecular responses to these stress conditions involves the expression of a particular set of genes and eventually expression of protein, which may help the organism to overpower a particular stress conditions imposed by the host. However, the expression of the whole set of stress induced proteins and their relevance in the evolution of Salmonellosis, is yet to be defined. Thus keeping in mind the fact that this organism encounters different types of environmental stresses during the infection process, this study was designed to evaluate the expression of stress induced OMPs in *S. typhi* and to identify a common proteins (s), if any.

Further during interaction between microbe and the host, several microorganisms have been shown to induce apoptosis. Apoptosis and necrosis are two distinctly different forms of cell death. Necrotic death is usually the consequence of physical injury and does not involve the active participation of the cell. In contrast, apoptosis is the result of a highly regulated active processes, controlled by complex signal transduction pathways. Increasingly, this form of cell death has been shown to be important in infectious diseases. A number of microorganisms have been shown to induce

apoptosis in order to counteract host immune defence mechanisms or to host cell proliferation there by securing a niche for their replication. Several studies documented the role of bacteria and bacterial components (OMPs, LPS and HSPs) inducing apoptosis of the host cells. The significance of apoptosis in the establishment of infection by the microbe or its role as the host defence mechanism, and in therapeutics is yet to be explored.

Thus this study was aimed to evaluate the expression, purification of heat shock and acid (inorganic as well as organic) stress regulated outermembrane protein(s) of S. *typhi* and to evaluate their potential to induce apoptosis in mouse peritoneal macrophages. The bacterial strain *S. typhi* Ty2 was obtained from Central Research Institute (CRI), Kasauli, India. The strain was confirmed biochemical and serologically. In order to simulate the in-vivo situation, the organism was grown under the following stress conditions in the laboratory. For heat shock, bacteria were grown to 0.5 OD, and then the cells were shifted to 42°, 45° and 50°C for 30 minutes. For inorganic acid stress bacteria were grown in nutrient broth of pH 4.5 5.0 and 5.5 (pH adjusted with HCl), till the 00 reached 0.5. For organic acid stress, bacteria were grown in nutrient broth containing 2%. 4% and 6%of 100 mM SCFA stock till the OD reached 0.5. After growing the bacterial cells under the selected conditions outermembrane proteins were extracted and their protein profiles were analyzed.

A number of outer membrane proteins were found to be expressed under the selected conditions. But a 55kDa OMP was found with enhanced expression under all the above-mentioned stress conditions. This 55kDa OMP was present predominantly in the outer membrane fraction with a minor contamination in the inner membrane fraction of bacteria. To assess the expression of 55kDa protein during the natural course of infection, *in-vivo* immunogenecity was assessed using widal positive sera of typhoid patients. The presence of IgG antibodies was investigated in the sera of typhoid patients. 10 out of 12 Widal positive sera showed reactivity with 55-kDa stress induced OMP. Sera from healthy individuals failed to react with this stress induced outer membrane protein.

The phenotypic similarity of 55kDa protein under the three stress conditions was confirmed by eluting the proteins from separate gels. The proteins eluted from gels was pooled and run on the SDS-PAGE. The silver staining o the gel showed the single band been after extended electrophoresis. To relate the 55kDa protein immunologically which gels expressed under heat shock and acid stress conditions, antiserum against HSP molecule was raised. The anti-HSP-antibodies detected the acid (inorganic as well as organic) stress induced protein in Western blotting.

The stress-induced 55 kDa OMP was purified to homogeneity by HPLC and the purity was confirmed by silver staining of SDS-PAGE. The potential of *S. typhi* and 55 kDa protein to induce apoptosis in mouse peritoneal macrophages was assessed qualitatively as well as quantitatively. The internucleosomal cleavage of DNA of macrophages (hallmark of apoptosis) was observed on agarose gels after infection of macrophages with *S. typhi*. The same characteristic pattern of DNA ladder was also observed after interaction of macrophages with 55kDa protein. The apoptosis could also be visualized and quantified, different methods such as acridine orange staining, Hoechst-33342 staining, flowcytometric analysis using propidium iodide and Annexin V was done. Acridine orange and H-33342 staining revealed the induction of cell death by *S. typhi* and 55 kDa protein. Flowcytometric analysis using Propidium Iodide revealed hypo-diploid population because of induction of cell death by *S. typhi* and 55 kDa protein. Exposure of phosphatidylserine on the outer leaflet of the cells (Biochemical hallmark of apoptosis) could be seen by using Annexin V staining.

To delineate the underlying mechanism of apoptosis, the levels reactive nitrogen intermediates (RNI) and reactive oxygen species (ROS) were estimated. Significant difference was observed in the RNI levels of macrophages infected with *S. typhi* or stimulated with 55 kDa protein. The percentage inhibition of superoxide dismutase (SOD) activity was found to be higher in the macrophages infected with *S. typhi* or activated with 55 kDa protein, than the unactivated macrophages.

It is concluded from the study that 55 kDa protein, which gets expressed under some of the stress conditions seems to be a common protein on the basis of their expression molecular weight and their cross reactivity. This protein was found to have the potential to induce apoptosis in macrophages. The expression of this protein may help the organism to survive by causing apoptotic cell death of macrophages during the disease process and may play a role in down regulating the immune response. Detailed characterization of the stress induced OMP at the molecular level will provide a better understanding of the mechanism involved in the pathogenesis of this organism.

DEPARTMENT OF PHYSICS

(1) Name of the Candidate : Lalit Kumar Saini **Supervisors : Tankeshwar Kumar and R.K. Moudgil**

STRUCTURE AND DYNAMICS OF LOW DIMENSIONAL QUANTUM SYSTEMS

In this dissertation, we have presented a theoretical study of the ground-state behaviour of the (zero-temperature and zero-magnetic field) double quantum-well and the double quantum-wire systems, with particulars emphasis on the role of the dynamical character of many-body correlation effects. To this endeavour, we have employed the quantum/ dynamic version of Singwi, Tosi, Land, and Sjölander (qSTLS) approach.

In chapter 1, we have given a detailed description of low-dimensional (LD) electron systems, with particulars focus on the two-dimensional (2D) and one-dimensional (1D) electron systems. Motivation and the objectives of the present work are spelled out clearly.

In chapter 2, we have given the basic definitions of the dielectric response formulation, that are of direct relevance to the present work. The wave vector and frequency dependent linear density-density response function $\chi(q,\omega)$ is derived by applying the qSTLS approach to the bilayer system. The response function turns out to be in the form of a 2×2 matrix. This method provides us with a set of coupled integral equations, which are to be solved numerically in a self-consistent way for the response function. The relevant static and dynamic properties of the system can be deducted from the density response function.

In chapter 3, we have presented a study of the ground-state behaviour of the symmetric electron-electron and electron-hole bilayers by including dynamic correlation effects within the qSTLS theory. The static pair-correlation functions, the static and dynamic local-field correlation factors, the ground-state energy, and the dynamic excitation modes are calculated over a wide range of carrier density r_s and layer spacing d. The possibility of a phase transition into a density-modulated ground state is also investigated. Results for both the electron-electron and electron-hole bilayers are compared with those of the recent diffusion Monte Carlo (DMC) simulation studies. We find that the inclusion of the dynamical nature of correlations introduces quantitative as well as qualitative differences in the description of many-body properties as compared to static mean-field theories of the STLS type. The qSTLS predictions for the intra- and interlayer pair-correlation functions and the ground-state energy are found to be in overall better agreement with the DMC results. The growing oscillatory trends in the DMC intralayer correlation function with increasing r_s are accurately reproduced for $r_s \leq 10$ and $d/r_s a_0^* \geq 0.5$ – a feature that is completely missing in the STLS results. Another unique and important feature of the qSTLS theory is that, in both the electron-electron and electron-hole bilayer systems, it exhibits an instability towards a coupled Wigner crystal (WC) ground state, below a critical density and in the close proximity of the layers. Moreover, at densities higher than the critical density for the onset of WC phase, it indicates transition to a charge density wave (CDW) ground state. Our prediction of Wigner crystallization in these systems agrees qualitatively with the findings of the DMC calculation.

In chapter 4, we have explored the feasibility of the existence of a spin-polarization transition in the symmetric electron-electron and electron-hole bilayers. We accomplish this task by drawing a comparison between the ground-state energies of the unpolarized and fully polarized phases of the bilayer system. The ground-state energy calculation is performed by using the qSTLS theory. In addition, the numerical results are presented for the static density susceptibility and the static pair-correlation function over a wide range of carrier density r_s and layer spacing d. interestingly enough, a spin-polarization transition is found to take place in both the electron-electron and electron-hole bilayers from the unpolarized to the polarized liquid well before the unpolarized liquid could actually make transition to the WC ground state. The polarized electron-electron and electron hole bilayer systems too support the CDW and WC instabilities,

but the crossover density is now lowered in comparison with their respective unpolarized counterparts.

In chapter 5, the ground-state behaviour of the coupled electron-electron and electron-hole quantum wire systems is studied by including dynamic effects within the qSTLS theory. The numerical results are presented for the pair-correlation function, the ground-state energy, the static density susceptibility, and the static and dynamic local-field correction factors over a wide range of system parameters, viz., linear particle number density r_{sw}, wire size *b*, and interwire spacing *d*. The results reveal that the inclusion of the dynamical nature of particle correlations brings in quantitative as well as qualitative changes in the ground-state behaviour of both the electron-electron and electron-hole wire systems. In particular, it is found that these (dynamic) correlations can cause the (homogeneous) liquid phase, in these quantum wire systems to become unstable against a phase transition into a(n) (inhomogeneous) coupled Wigner crystal ground state at sufficiently low particle density and/or narrow wire size in the close approach of two wires. The interwire correlations are found to reduce the critical r_{sw} for the onset of Wigner crystallization with respect to an isolated quantum wire system, and at $b/a_0^* = 1$ the reduction in r_{sw} is about 15% and 4% in the electron-hole and electron-electron wire systems. Our prediction of Wigner crystallization for the electron-electron wire system agrees qualitatively with recent results of Tanatar *et al.* which they have obtained on the basis of an approximate density functional theory calculation.

(2) Name of the Candidate : Nitin Kumar Puri **Supervisor : I.M. Govil**

MEASUREMENTS OF X-RAY PRODUCTION CROSS-SECTION AND ANALYTICAL APPLICATIONS USING PIXE TECHNIQUE

The present thesis presents the work carried out in three parts. The first part concerns with the interaction of Carbon and Oxygen ions with rare earth elements, the second part deals with the applications of PIXE for the elemental analysis of archaeological and geological samples and third part includes the standardization and use of PIXE set-up at Chandigarh for medical, aerosol and forensic science samples.

The K and L X-ray production cross-sections were experimentally measured for rare earth nuclei namely Lanthanum (La), Cerium (Ce), Neodymium (Nd) and Samarium (Sm) with 35, 45, 50 MeV of carbon (C^{4+}) and 35, 50, 60 MeV of Oxygen (O^{5+}) ions. The L XRP cross-sections are compared with the theoritical predictions of existing FBA and ECPSSR theories. In case of C^{4+} ions, the ECPSSR gives a better agreement for higher masses Nd and Sm while for lower masses La and Ce, the FBA gives a better agreement. In case of O^{5+} ions, the measured L XRP cross-sections for all the target elements are in close agreement with the FBA predicted values as compared to ECPSSR theory. Inner shell vacancy production although studied for a long time, both experimentally and theoretically, is far from being completely understood. Apart from the intrinsic interest of ion-atom interactions the investigations of the basic ion-solid collision is necessary to understand the various phenomena associated with the penetration of ions through the solid matter. More extensive study and experiments are needed for better understanding of inner shell ionisation by heavy ions. This interest is due to the fact that inner shell ionisation cross-sections are required in different kinds of applications, e.g. calculations of stopping power, ion implantation, study of solids, plasmas and PIXE technique for trace element analysis of rare earth elements.

As part of the study of elemental analysis of ancient Indian coins, thirty-three punched marked coins (6^{th} century B.C.) and twenty-five coins belonging to medieval period (11^{th}-14^{th} century A.D) from India have been analysed using PIXE technique. The elements namely S, Ca, Fe, Ag, Cu, Ni, Pb were detected in most of the punch-marked coins while elements S, Ca, Fe, Cu, Ag, Sn, Pb were detected in 11^{th}-14^{th} century A.D. coins. Based on the elemental analysis different hypotheses put forward in the earlier literature was examined. The presence of Pb determined in medieval period coins does not rule out the utilization of local source of silver extracted from argentiferous galena containing lead instead of the Faranjal mines of Afghanistan as normally accepted. From

the consistent concentration of Ag in these coins despite the change of Kingdoms it is confirmed that beside the rulers the commercial communities had a great influence in the currency of medieval period.

This is the first attempt where reasonable number of ancient coins was analysed by modern non-destructive multi-elemental nuclear technique such as PIXE. Further study using multi-elemental technique (PIXE) for coins obtained from a large number of hoards of the individual rulers may throw further light on this complex subject. Elemental Analysis of more number of ancient Indian coins and pottery samples belonging to Harappan and other periods can provide alternative evidence about the trade and culture prevalent at different archaeological sites excavated in India.

Some geological samples are also analysed to find out the ratio of Rb to Sr (Rb/Sr) in these samples. These results are of importance for the chronology of the rocks and will provide more information for the selection of the rock and mineral samples for isotope study. The five samples were compared with results obtained by mass spectrometer. More number of geological samples from Himalayan region need to be analysed to establish this technique for precise information about the age and chronology of the rocks.

We have standardized the PIXE set-up for low energy X-ray spectroscopy at cyclotron laboratory, Chandigarh. Presently we analysed aerosol samples collected from industrial town Gobindgarh, Punjab, India; Gun Shot Residues (GSR) samples from Central Forensic Science Laboratory (CFSL), Chandigarh and bone species (normal, demineralized, deproteinized) from Department of Bio-Physics, Panjab University, Chandigarh. This facility is now fully operational and is being used for normal PIXE measurements.

(3) Name of the Candidate : Prem Singh **Supervisors : Devinder Mehta and K.P. Singh**

STUDY OF PHOTONATOM INTERACTION AND SUBSEQUENT PROCESSES IN THE X-RAY ENERGY REGION

The present thesis deals with the experimental study of the Rayleigh and Compton scattering of photons in the X-ray energy region, and the processes subsequent to photoionization. The investigations involve measurements of (i) the Rayleigh and Compton scattering cross-sections for the photons in the X-ray energy region, (ii) the resonant Raman scattering cross-sections and (iii) the L_i-subshell X-ray production cross-sections, Coster-Kronig (f_{ij}) and fluorescence (ω_i) yields. The measured Rayleigh cross-sections are compared with the theoretical (i) form-factor formalisms and (ii) S-matrix based calculations, and the Compton scattering cross-sections are compared with the Klein-Nishina cross-section incorporating the incoherent scattering function, to check their validity at low momentum transfer. The parameters related to the processes subsequent to the L_i-subshell ionization are compared with Krause's semi-empirical values and the theoretical relativistic Dirac-Hartee-Slater model based calculations, respectively.

In the present work annular- and point-source reflection geometry in the direct and secondary modes has been used. In the direct mode, the 59.536 keV γ-rays from ^{241}Am radioactive source have been used as the incident photons. In the secondary mode, the 59.536 keV γ-rays from the ^{241}Am radioactive source excite the K X-rays of secondary exciters, which are further used as the incident photons. The photons from the target were detected using the detection system consisting of an HPGe/Si(Li) detector (energy resolution ≈ 180 eV at 5.89 keV) coupled to a PC-based multichannel analyzer through a spectroscopy amplifier. The spectrum analysis, to evaluate area under the X-ray and Rayleigh-scatter peaks, was done using an indigenously developed computer code PEAKFIT. In this code a non-linear least-squares fitting routine involving fitting of multi-Gaussian function plus polynomial background is used. Correction due to absorption of the incident and emitted photons was estimated using the mass-attenuation coefficients, using the analytical expression involving μ and the angles of incidence and emission. The product of the incident photon intensity, detector efficiency and other geometrical factors was determined by measuring the $K\alpha$ X-ray yields from various thin elemental standard targets (thickness 100-300 $\mu g/cm^2$) excited by the incident photons and using the knowledge of $K\alpha$ X-ray fluorescence cross-sections.

Measurements of the Rayleigh and Compton scattering cross-sections for the 14.93 keV (Y $K\alpha$ X-rays) and 17.44 keV (Mo $K\alpha$ X-rays) photons for the elements with $6 \leq Z \leq 92$ and $1 \leq Z \leq 50$, respectively, were performed using the Ytterbium and Molybdenum annular foils along with ^{241}Am source in the secondary mode were used as photon sources. Measurements were performed at an angle of 141° under vacuum of ~ 10^{-2} Torr using the HPGe and Si(Li) detectors. Special care was taken to check interference due to Bragg diffraction from the target lattice in the Rayleigh scattering measurements and to determine the incident photon intensity and geometrical factors. For the 14.93 and 17.44 keV photon scattering, the modified form-factor values exhibit large deviations for the elements with electron binding energy in vicinity of the incident photon energy while a general agreement is observed for the other elements. These deviations are smoothed by incorporating the anomalous scattering factors (ASFs) to the MF values. Measured cross-sections for the 14.93 keV photons exhibit general agreement with the S-matrix values. Measured cross-sections for the 17.44 keV photons are on an average ~ 10% and ~ 7% lower than the MFASF and S-matrix values, respectively. Measured Compton scattering cross-sections for the 14.93 keV and 17.44 keV photons are found to be in general agreement, within experimental errors, with those calculated using the Klein-Nishina cross-section incorporating the non-relativistic Hartree-Fock incoherent scattering function (ISF).

Measurements of the Rayleigh and Compton scattering cross-sections, and *K-L* and *K-M* resonant Raman scattering (RRS) cross-sections, at the 59.536 keV photon energy, were performed at the 59° and 133° angles using the reflection mode geometrical arrangements involving the ^{241}Am radioisotope as photon source and planar HPGe and Si(Li) detectors. Theoretical Rayleigh scattering cross-sections based on the modified form-factors corrected for anomalous scattering factors (ASFs) and the S-matrix calculations are on an average ~ 15% and ~ 6% higher, respectively, than the measured cross-sections at the 133° angle and exhibit good agreement at the 59° angle. Larger deviations ~ 30% and ~ 20%, respectively, are observed at the 133° angle for the $_{64}$Gd, $_{66}$Dy, $_{67}$Ho and $_{70}$Yb elements having *K*-shell binding energy in vicinity of the incident photon energy. Measured Compton scattering cross-sections are in general agreement with those calculated using the Klein-Nishina cross-sections and the incoherent scattering function. Ratios of the *K-M* and *K-L* RRS cross-sections in Yb, Lu and Hf are found to be in general lower than that of the fluorescent *K-M* ($K\beta_{1,3,5}$) and *K-L* ($K\alpha$) X-ray transition probabilities.

Measurements of the L_i ($i = 1,2,3$)-subshell X-ray production (XRP) cross-sections, L_1-L_3 Coster-Kronig yield (f_{13}) and L_i ($i = 1,2,3$)-subshell fluorescence (ω_i) yields for the elements $_{77}$Ir, $_{78}$Pt, $_{81}$Tl and $_{83}$Bi at the 59.536 keV incident photon energy. The L_3-subshell XRP cross-sections for these elements have also been measured following selective ionization of the L_3-subshell by the Br/Rb/Sr/Y *K* X-ray photons. Measurements have been performed using the energy dispersive X-ray fluorescence (EDXRF) set-up both in the (i) direct mode and (ii) secondary mode together with the KBr/$RbNO_3$/$SrCO_3$/Y secondary exciters and an Si(Li) detector. In the direct mode, the 59.536 keV γ-rays from ^{241}Am radioactive source were used for target excitation. In the secondary mode, the 59.536 keV γ-rays from ^{241}Am radioactive source were used to excite the *K* X-rays of the secondary exciter, which further ionized the target *L* X-rays. Measured production cross-sections are compared with the theoretical ones evaluated using the most reliable theoretical values of the L_i ($i = 1,2,3$)-subshell photoionization cross-sections, Coster-Kronig transition probabilities, fluorescence yields and X-ray emission rates. The L_1-L_3 subshell Coster-Kronig (f_{13}) yield have been determined using the measured intensities of the $L\alpha$ X-rays emitted following photoionization in the L_i ($i = 1,2,3$)-subshells in different proportions by the 59.536 keV γ-rays and characteristic *K* X-rays from the Br/Rb/Sr/Y elements. The present measured f_{13} values for these elements are found to be substantially smaller than those based on the relativistic Dirac-Hartree-Slater (RDHS) model based calculations and agree well with the semi-empirical fitted values of Krause. In these measurements, the L_i ($i = 1,2,3$)-subshell fluorescence yields (ω_i) have been deduced using the measured XRP cross-sections and the L_i-subshell photoionization cross-sections based on the Hartree-Fock-Slater model calculations. Deduced ω_i values have been compared with the theoretical RDHS model based calculations and Krause's semi-empirical fitted values. Measured ω_1 values are found to be higher up to 50% than those based on the RDHS calculations, while the ω_2 and ω_3 values exhibit good agreement. The predicted jump in the RDHS based ω_1 values from $_{77}$Ir to $_{78}$Pt due to onset of the intense L_1-L_3 CK transition is not observed.

(4) Name of the Candidate : Ranber Singh **Supervisor : Satya Prakash**

DYNAMICS OF NANO-PARTICLES AND HYDROGENATED AMORPHOUS SILICON

This work deals with the theoretical study of dynamical properties of metallic nanocrystals ^{57}Fe, Ni and Ni_3Fe, semiconductor nanocrystals (Si and Ge) and hydrogenated amorphous silicon. The phenomenological study based upon the Born-von Karman model of interatomic force constants upto far distant nearest neighbours, vibrational density of states (VDOS), phonon dispersion relations and thermodynamic properties using calculated VDOS of ^{57}Fe, Ni and Ni_3Fe nanocrystals have been presented in chapters 2 and 3. It has been found that there is anisotropic stiffening in the interatomic force constants in the nanocrystals as compared to their bulk counterparts. This stiffening in turn leads to the shrinking in the interatomic distances and the enhancement in the VDOS at low and high phonon energies. The phonon dispersion relations in nanocrystals show an anomalous behaviour as compared to those of their bulk counterparts.

In nanocrystalline bcc ^{57}Fe, the average sound velocity calculations from the slope of VDOS at low energies showed that the nanophase ^{57}Fe consist of about 14 GPa pressure. The specific heat of nanophase is larger than that of bulk phase upto 110 K, however, at higher temperature it is smaller in nanophase. The calculated Debye temperature (Θ_D) at T=0 K is 384 K for nanophase ^{57}Fe, which nearly agrees with the experimental value of 345 K. The $\Theta_D(T)$ for nanophase is smaller than that for bulk phase below 110 K and has a sharp minimum at about 2.67 K. While in nanophase, the free energy is smaller; the vibrational entropy is larger than that of the bulk phase at all temperatures. The excessive free energy increases linearly with increase in temperature, whereas the excessive vibrational entropy increases sharply at low temperatures and becomes almost constant at higher temperatures (above 120 K).

In Ni_3Fe, the specific heat in the nanophase at low temperatures is nearly the same, but at higher temperatures (above 100 K) it is greater than that in its bulk counterpart. However, there occurs a peak at low temperatures in the excessive specific heat of nanophase fcc Ni compared to its bulk counterpart. This may be the signature of boson peak. The Θ_D of nanophase Ni_3Fe at absolute zero temperature is 512.8 K, which is more than that of 476 K of the bulk. While the vibrational entropies of nanophase Ni_3Fe and Ni are higher, the free energy is lower than those of their bulk counterparts at all temperatures. The difference of free energy of nanophase and bulk phase increases linearly with temperature at higher temperatures in both Ni_3Fe and Ni. The excessive entropy in nanophase Ni_3Fe increases sharply, however, it has a peak in nanophase Ni at low temperatures. At higher temperatures, it is constant in both nanophase Ni_3Fe and Ni.

A study of spherical semiconductor nanocrystals with the weighting function (average of sine and Gaussian functions), within the framework of phenomenological phonon confinement (PPC) model [Solid State Commun. 39, 625 (1981)], has been given in chapter 4. The results for the phonon confinement, Raman intensity peaks and Raman frequency shifts in spherical semiconductor nanocrystals are in good agreement with the microscopic calculations and experimental data. The main significance of the average weighting function is the physical justification of the spherical nanocrystals. A sine weighting function represents the spherical nanocrystal as a rigid sphere as if the vibrational amplitude reduces to zero at the boundary, whereas the microscopic calculations have shown otherwise that the silicon spherical nanocrystals are neither rigid spheres nor the spheres as if the vibrational amplitude decays in the Gaussian way. On the other hand, a spherical nanocrystal seems to be an average case in which the vibrational amplitude is well described by the function (which is average of sine and Gaussian functions) within the framework of PPC model. Therefore, it has been proposed that the average function should be used as a weighting function for the spherical nanocrystals, if the PPC model is being used to investigate their vibrational properties.

In chapter 5, a semiclassical approach applied to the dynamics of hydrogen in hydrogenated amorphous silicon (a-Si:H) showed that the local hydrogen concentration fluctuations-induced extra potential wells, if intense enough, lead to the localized electronic states in a-Si:H, which are metastable. The trapping of electrons and holes in these states leads to the electrical degradation of the material. These states also act as recombination centers for the photo generated carriers (electrons and holes) which in turn may excite a hydrogen atom from a nearby Si-H bond and break the weak (strained) Si-Si bond thereby apparently enhancing the hydrogen diffusion and increasing the light-induced dangling bonds. The critical temperature (T_c) at which the localized electronic state first becomes delocalized shows strong

dependence on both the average hydrogen concentration and the strength of induced potential well.

In chapter 6, a density functional based tight binding study of a-Si:H has been presented. Four samples of a-Si:H have been generated using MD simulations by quenching from the liquid state of silicon-hydrogen mixture and by hydrogenation of pure amorphous silicon samples. The a-Si:H samples generated from the liquid quench have more coordination defects as compared to the samples generated by hydrogenation of pure amorphous silicon structures. While the Si-Si and Si-H pair correlations are found independent of preparation procedure and initial conditions, the H-H pair correlations are dependent. Almost all the hydrogen atoms are bonded to silicon atoms as Si-H monohydrides existing as isolated Si-H bond or as the clusters of Si-H bonds. The distribution of hydrogen in all the samples is nonuniform and depends upon the preparation procedure and the initial structure from which the hydrogenated sample is generated. There also exist Si-H-Si bridge configurations in these samples.

In a-Si:H samples, there exists extra peaks at high frequencies as compared to pure amorphous silicon which are in reasonable agreement with the experimental results. The exact positions of these high frequency peaks are found dependent on the local environment, which changes from one sample to another. While the high frequency vibrational modes related to Si-Si bond vibrations are moderately localized in both pure and hydrogenated amorphous silicon samples, the vibrational modes related to Si-H bond vibrations in a-Si:H samples are highly localized. In a-Si:H samples, the free energy is larger while the entropy and specific heat are less than those of pure amorphous silicon sample at all the temperatures. There occurs the so-called 'boson peak' in all samples which is not found related to the coordination defects.

The electronic density of states shows a small energy gap at the Fermi level in all samples. The hydrogenation of pure amorphous silicon reduces the electronic gap states and increases the energy gap. The local electronic density of states at hydrogen atom sites in a-Si:H samples has no contribution in the band gap region.

(5) Name of the Candidate : Sangeeta **Supervisor : Manjit Kaur**

STUDY OF HADRONIC FINAL STATES IN HIGH ENERGY INTERACTIONS

The thesis describes various characteristics of hadronic final states in high energy hadron-hadron, hadron-nucleus and lepton-lepton interactions at high energies in the framework of some phenomenological models and statistical approaches. The characteristics of hadronic final states are studied to gain a better understanding of the underlying dynamics of multiparticle production.

The data from proton-Emulsion and pion-Emulsion interactions has been analysed by comparing with the predictions of two models FRITIOF and VENUS. Detailed inclusive studies have been undertaken at 50 GeV/c for pion-Emulsion interactions. The results obtained from this analysis support the Regge theory which assumes that cascading is a collective phenomenon. Thus the analysis gives an interesting comparison between the experimental data and the model predictions.

In the present work the main emphasis has been laid on the study of charged particle multiplicity distributions (MD) in hh, hA, and e+e- interactions. The study of MDs is important not only in full phase space but also in small rapidity windows due to intermittency phenomenon. The study of charged particle MDs can serve as a simple and basic tool to gain an insight into the multiparticle production process. We use three statistical approaches Negative Binomial distribution (NBD) , Multifractal NBD (MNBD) and parameterized NBD to study the MDs in hh, hA and e+e- interactions in full as well as restricted rapidity domains.Among all the approaches proposed so far to explain the MDs, NBD has been the most widely accepted and used as it explains the data satisfactorily except at higher energies as observed by DELPHI and ALEPH Collaborations in e+e- interactions and by UA5 collaboration in proton-antiproton interactions due to the appearance of shoulder structure and long multiplicity tail of the MD in full phase space and the multifractal behaviour of the MD in restricted rapidity windows.

The MNBD proposed by Chekanov et al., has been derived from nonlinear Markov Process explains the multifractal behaviour of MDs. It uses an additional free parameter 'g', which represents the strength of influence of the nonlinearity in the markov equation from which this distribution has benn derived. Using this approach we analyse the MDs in terms of their normalized bunching moments and compare with those obtained using NBD for various types of interactions. The results are also compares for NBD and MNBD in terms of chi-square/dof values and dependence of aggregation coefficient on the c.m. energy.

We analyse the MDs in lepton-lepton interactions at c.m. energy from 22 to 189 GeV in the framework of NBD, MNBD and parameterized NBD. The parametrized NBD, proposed by Giovannini et al., reproduces the MD from a weighted superposition of two NBD components, one arising due to two jet events and another due to multijet events. The weight factor used is the two-jet rate, which takes values corresponding to the jet resolution parameter as calculated using some jet finding algorithms. For present work we have used these values for JADE, DURHAM and CAMBRIDGE algorithms. The parameterized NBD incorporates the shoulder structure of MD very well.

For all these interactions discussed above the energy dependence of mean charged multiplicity <n> is described using four phenomenological approaches. And the results are extrapolated upto future linear collider for e+e- interactions at c.m. energy 500 GeV. Most of the results are published in research journals of international repute.

(6) Name of the Candidate : Sanjay Kumar Chamoli **Supervisor : I.M. Govil**

THE LIFETIME STUDIES OF THE EXCITED NUCLEAR STATES AT HIGH ANGULAR MOMENTUM IN THE MASS REGION A = 170 - 190

The nuclear shape studies in the mass region 170 - 190 has always attracted theoreticians and experimentalists due to a variety of structural phenomena exhibited by the nuclei in this region. This is the transitional region between the strongly prolate deformed rare earth nuclei and the spherical lead isotopes. The nuclear potential in this transitional region is soft, so these nuclei are expected to assume different shapes as a function of both the particle number and spin. The presence of highly deformation driving $\pi h_{9/2}$ and $\pi i_{13/2}$ intruder orbitals makes the shapes study in these nuclei rather more interesting. In the present work, a systematic study of level lifetimes is done for the nuclei in this mass region with Recoil Distance Lifetime Measurement Technique (RDM). For this purpose two isotopes of Rhenium (^{177,179}Re) and two isotopes of Thallium (^{187,189}Tl) were considered to see the effect of change of neutrons and protons on the level lifetimes of these nuclei. The experiment work was done at NSC, New Delhi and the data analysis was done at Panjab University, Chandigarh. The experimental results have been compared with the results obtained with two phenomenological nuclear models based on the mean field theory of nuclear potential i.e. the Cranked Hartree-Fock Bogoliubov (CHFB) and the microscopic Hartree- Fock model with total angular momentum projection technique.

The ^{177,179}Re and ^{187,189}Tl nuclei have been populated using the following reactions :

(i) ^{165}Ho(^{16}O, 4n)^{177}Re at 84 MeV beam energy.
(ii) ^{165}Ho(^{18}O, 4n)^{179}Re at 82 MeV beam energy.
(iii) ^{159}Tb(^{32}S, 4n)^{187}Tl at 154 MeV beam energy.
(iv) ^{165}Ho(^{28}Si, 4n)^{189}Tl at 138 MeV beam energy.

In the first two experiments the Ho target of thickness 800 μg/cm2 was used while the third experiment was performed with a Tb target of thickness 1.1 mg/cm^2 and the fourth experiment was done with Ho target of thickness 1.1 mg/cm^2. In all these experiments the Au stopper of thickness 8.0 mg/cm^2 was used. The data analysis is done with the computer program LIFETIME. The reduced transition probabilities B(E2) and the transition quadrupole moments Q_t for each γ-transition were deduced from the extracted level lifetimes using the rotational model.

In case of ^{177,179}Re isotopes the lifetime measurements have been done for the quasi-proton $\pi h_{9/2}[541]1/2^-$, $\pi d_{5/2}[402]5/2^+$ and $\pi h_{11/2}[514]9/2^-$ bands. The results indicate that in all the three bands the B(E2) values have almost constant behaviour with spin, indicating no major interaction of these bands with other bands of similar nature. This shows that the Re nuclei have stable nuclear structure corresponding to these configurations. This fact has been supported by the microscopic HF calculations done for all the three bands in these nuclei. Also for the $\pi h_{9/2}[541]1/2^-$ band, the TRS calculations show nearly constant quadrupole deformation as a function of rotational frequency, which is an indication of the stability of nuclear shape corresponding to this negative parity configuration. In both the Re nuclei studied, the average quadrupole deformation for the low K (= 1/2) $\pi h_{9/2}$ band is found to be higher than the other two high K (= 5/2) $\pi d_{5/2}$ and the $\pi h_{11/2}$ K (= 9/2) bands. In ^{177}Re nucleus the average value of deformation β_2 = 0.25, for the $\pi h_{9/2}$ band is found to be ~ 25 % higher than the $\pi d_{5/2}$ band (β_2 = 0.2) and ~ 14 % higher than that for the $\pi h_{11/2}$ band. In ^{179}Re nucleus the average quadrupole deformation β_2 = 0.25 for the $\pi h_{9/2}$ (low K) band is found to be ~ 16 % higher than the average quadrupole deformation β_2 = 0.22 for the $\pi d_{5/2}$ and $\pi h_{11/2}$ (high K) bands. The large value of quadrupole deformation of $\pi h_{9/2}$ band compared to the other bands in Re nuclei indicates the core polarization effect generated by the occupation of this high -j, low -K $\pi h_{9/2}$ band by the odd particle. The similar value of the average quadrupole deformation (β_2 = 0.25) for the ground state $\pi h_{9/2}$ band in ^{177}Re (N = 102) and ^{179}Re (N = 104) nuclei, indicates the saturation of nuclear deformation in the Re isotopes around the neutron mid shell of N = 104. The higher deformation of $\pi h_{9/2}[541]1/2^-$ compared to the $\pi d_{5/2}[402]5/2^+$ and $\pi h_{11/2}[514]9/2^-$ observed in the present work in ^{177,179}Re justifies the observed delay of ~ 70 keV in the band crossing frequency in this band relative to other bands in these nuclei.

In ^{187,189}Tl nuclei the lifetime measurements have been done for excited nuclear states in the negative parity $\pi h_{9/2}$ and the positive parity $\pi i_{13/2}$ bands. Since Tl (Z = 81) has its proton number close to the Z = 82 shell closure, therefore for both the bands the large changes in the values of the transition quadrupole moments are observed as a function of rotational frequency, indicating major structural changes taking place in these nuclei due to the change in the proton Fermi surface. In ^{187}Tl nucleus the low spin states of $\pi h_{9/2}$ and $\pi i_{13/2}$ bands are found to possess small oblate deformations of 0.12 and 0.08 respectively, but at high spins it changes to an average prolate quadrupole deformations of 0.22 and 0.26 respectively. These β_2 values are consistent with the values of deformations predicted for the oblate and the prolate sequences of these two bands by Lane et al.. It indicates that ^{187}Tl nucleus at low spins is slightly oblate but at high spins it attains a strongly deformed prolate structure corresponding to these configuration, reflecting the shape co-existence picture in this nucleus. The TRS calculations done for the negative parity $h_{9/2}$ and the positive parity $i_{13/2}$ bands in this nuclei also predict the shape co-existence picture for these two configurations. For, ^{189}Tl nucleus, the results of the lifetime measurements in $\pi h_{9/2}$ oblate ground state band show that the oblate quadrupole deformation for this band, β_2 = 0.08 remains almost constant with increase in spin. This indicates the stability of the ground state oblate structure of ^{189}Tl corresponding to this configuration. The non-observation of any change in the transition quadrupole moment with spin also rules out the existence of any prolate structure at high spins in this configuration. Thus the addition of two neutrons in ^{187}Tl nucleus (N = 106), the negative parity $h_{9/2}$ prolate structure at high excitation gets completely eliminated in ^{189}Tl. According to the calculations by Lane et al., this absence of prolate $h_{9/2}$ structure in Tl nuclei with mass A > 189 is predicted to be due to the reduction in its deformation with increasing mass number and hence less favourable at high spins in these nuclei. On the contrary, in the positive parity, $i_{13/2}$ band, major changes are observed in the quadrupole deformation with increasing spins along the band. In this configuration at low spins the nucleus remains in oblate form with very low deformation of β_2 = 0.04, but at high spins it attains a highly deformed prolate structure with average quadrupole deformation of β_2 = 0.29. So the prolate oblate shape co-existence is being confirmed by the measured deformation in ^{189}Tl for this configuration. The average value of β_2 ~ 0.29 for the prolate $\pi i_{13/2}$ configuration is much higher than the average value of β_2 ~ 0.23, possessed by the normal prolate bands of the nuclei in this mass region. This is the first observation of such a highly deformed prolate structure in Tl nuclei with deformation lying in between the normal (~ 0.23) and the super deformed (~ 0.45) structures. The TRS calculations, done for this positive parity $\pi i_{13/2}$ band in the two nuclei, show that instead of a sharp and well defined minimum, a spread in the potential energy surfaces is found at medium frequencies, which indicates the highly soft nature of the nuclear potential in this configuration. The large deformation at high spins of the $\pi i_{13/2}$ band can thus be interpreted as being due to the enhancement in the deformation driving property of this low K (1/2), prolate band in presence of the highly soft even - even nuclear core. The softness of the nuclear core is therefore responsible for the shape co-existence phenomena in the nuclei near the shell closure (Z = 82). As a result of the γ- softness, a smooth change of ground state shape is observed from purely prolate deformed structure in ^{177,179}Re to coexisting prolate-oblate shapes in ^{187,189}Tl and finally pure spherical shape in the lead nuclei.

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