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PRELIMINARY INVESTIGATIONS ON THE BIOLOGY AND CONTROL OF BEETELES DAMAGING STORED REEDS

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ABSTRACT

The damage potential of ***Dinoderus*** beetles (Bostrychidae) to stored bamboo, reed ***Ochlandra travancorica,*** one of the fibrous, raw materials for paper pulps and possible method for their control were investigated. The study included a general survey of insect damage of stored reed in Kerala, development of methods for rearing ***Dinoderus*** in the laboratory, experimental investigations on factors, influencing susceptibility of reed to ***Dinoderus,*** and evaluation of several chemicals under laboratory as well as field conditions for control of the borers. Observations were also made, incidentally, on fungal damage to stored reed-

Dinoder us spp. were the most important beetles damaging stored, read althouagh few other species, viz., ***Heterobostrychus aequalis(***Bostrychidae), ***Minthea rugicollis*** (Lyctidae) and ***Myocalandra exarata*** (Curculionidae), were also found on reed. Two species of ***Dinoderus*** were involved - ***D. minutus*** Fabr. and ***D. ocellaris*** Stehp.; the former was the most frequent and widespread, occurring also on manufactured reed articles. ***D. ocellaris*** was found in a mixed population with ***D. minutus.*** Subterranean termites were also found to cause damage.

The incidence of ***Dinoderus*** attack was highly unpredictable. No infestation occurred in small bundles of l- to 2-yr-old reed culms harvested at monthly intervals over an year and stored outdoors in the KFRl Campus at Peechi. In the KNP reed storage yard at Mevelloor and in some other places, active infestation was noticed on several occasions, but not consistently. No distinct seasonal pttern of infestation was evident during the period of study.

Both species of ***Dinoderus*** could be reared successfully in the iaboratory on dried tapioca chips, a new diet developed during this study. Continuous generation could be maintained on tapioca chips throughout the year and the insects required for experiments could be collected with ease. On tapioca ***D. minutus*** population increased upto 10-fold during a period of two months, a period sufficient for completion of one. generation. Other suitable diets containing wheat tlour were also developed.

Experimenls revealed that varietal differences, harvesting season and water transportation of reed did not influence susceptibility, but age of the culm at harvest and extent of drying after harvesting, did. Fully mature culm, about 5-yr old, was the most susceptible, while culm of flowered reed was immune. Culms of other ages were susceptible to varying degree, depending on the species of ***Dinoderus.*** The results suggested that while a threshold concentration of starch may be essential for development of the insect, other factors, possibly nonnutritive volatile chemicals, may elicit or promote infestation. Since reed harvested for pulping consists of an assorted group of culms of different ages, erratic occurrence of infestation may be expected.

Out of 11 insecticides tested by direct application to the beetles, all except three organochlorines - DDT, aldrin and chlordane - were effective. When five of these selected insecticides were screened by application to food surface, only HCH (BHC) and the synthetic pyrethroids, cypermethrin and permethrin, proved effective. In field experiments, monthly application of 0.5% HCH over the exposed surfaces of the stack did not ensure adequate protectlan, apparently, the frequency of application was not Sufficient.

Based on information gathered in this study on the biology and ecology of ***Dinoderus*** beetles, effectiveness of various insecticides, and economic and environmental considerations, a pest management strategy involving priority utilization of infested stock and minimal application of insecticide has been suggested. Regular storage of reed in the KNP yard started only in 1981 and there is risk of large-scale build-up of the beetle population in the yard over the years. It is therefore necessary to monitor the course of development of the ***Dinoderus*** population to make suitable modifications in the pest management strategy. fhree insect parasites and one insect predator of ***Dinoderus*** were recorded at Mevelloor in this study, but their role in regulation of the host population remains unknown at present.

Two types of fungi were found to grow on reed - ***Capnodium*** spp. (sooty mould) and ***Lenzites*** sp. Of these only the latter, a btown-rot fungus capable of degrading Cellulose, is of concern. In teed stored for periods longer than 4 to 6 months, deterioration caused by this fungus appeared to be more serious than that. caused by ***Dinoderus.*** Monthly spraying with boric acid - borax, which has both fungicidal and insecticidal action, gave partial control; more frequent applications may prove effective.

Further investigations are required to characterise the change in pulping quality and to quantify the loss in pulp yield in order to assess the economic advantage of controlling insect and fungal damage.

I. INTRODUCTION

The bamboo reed, *Ochlandra travancorica,* is an important long-fibred faw-material for pulp production in paper and rayon industries. The Kerala News-print Project (KNP) set uP at Mevelloor by the Hindustan Paper Corporation Ltd., (HPC), (a Govt. of India Undertaking), envisages utilization of nearly one lakh tonnes of reed (air dry) annually (Kale, 1976). Although some of it could be fed directly into the chipper, storage of large quantities of reed is inevitable for efficient operation of the pulp production system. In preliminary storage trials in the open mill yards at Meveltoor, Shri R. 8. Kale, the then Controller of Forests, HPC, and Shri Varkey Joseph, Forest Officer, KNP, noted problems of insect damage and referred the matter to the Kerala Forest Research Institute. Our preliminary investigations revealed that damage was caused by (1).termites and (2) bamboo borer, *Dinoderus* sp. We gave detailed recommendations to prevent termite damage by reatment of the storage yard with appropriate soil insecticide. Since little was known of *Dinoderus*-damage to reed, this study was undertaken, under a project sponsored by HPC, to make preliminary investigations on various aspects of the borer problem to provide necessary data base for developing control measures, if necessary.

Investigations were carried out more or less simultaneously on various aspects, as follows. (1) General observations were made on incidence of borers on reed and reed products at several places in Kerala to assess the damage potential. (2) Attempts were made to develop suitable methods for rearing *Dinoderus* spp. under laboratory conditions to obtain large number of insects for experimental studies. (3) Experiments were conducted to determine possible differences in susceptibility of reed harvested year–round from different areas during different seasons. (4) Several insesticides were tested by direct application under laboratory conditions against two species of *Dinoderus* by direct application and selected ones were further tested by application to food meterial. (5) A field trial was conducted in the HPC storage yard at Mevelloor to study the incidence of damage and to test the efficacy of chemicel sprays applied over the stack surface.

The report is organized into sections along the above lines of investigation. A critical review of literature pertaining to studies on *Dinoderus* spp. is given in the begining and a brief final section gives the conclusions and recommendations resulting from this study.

II REVIEW OF LITERATURE ON *DINODERUS* BORERS

Although not previously recorded as pests of stored reed, ***Dinoderus*** spp., small beetles measuring 2.5 to 4 mm in length, are notorious borers of felled' bamboo. Three species are known to attack bamboo—***D. brevis*** Horn., ***D. minutus*** Fabr. and ***D. ocellaris*** Steph. The biology and habits of the three species are similar and the beetles sometimes occur in mixed populations on the same lot of bamboo and are known collectively as 'Ghoon'. Their biology and habits have been studied in detail by Stebbing (1914), Beeson and Bhatia (1937) and Plank (1948). Beeson (1941) has summarised the early literature from India.

The adult beetles, both male and female, bore into felled bamboo, usually through cut ends, tunnel inside and mate. Each female lays about 20 eggs, according to Stebbing (1914) and about 110 eggs according to Plank (1948) singly, usually within the vessels of the fibrovascular bundles near the beetle tunnels. The larvae feed between the walls inside the culm, packing their tunnels with frass. The larval period may vary from 4 to 11 weeks under favourable conditions, depending on the species and the climate (Stebbing, 1914; Beeson and Bhatia, 1937). Pupation takes place in a cell at the end of the larval tunnel, the pupal period, lasting about four days. The immature beetle spends a variable period of time in further tunnelling and feeding before emerging through new or existing holes. Successive generations may occur on the same bamboo; heavy and repeated infestations converting it into a crumbling mass of material.

At Dehra Dun, three well-marked generations of the insect occur per year on the bamboo, ***Dendrocalamus strictus,*** as shown by records of rearing over several years (Beeson and Bhatia, 1937). The first and second generations starting in March and June, respectively, last about three months each, followed by the third generation which overwinters as larvae and produce adults in March, this generation lasting about six months. ***D.*** brevis and ***D. ocellaris*** were the commonest species at Dehra Dun, the former usually predominating. Five to seven generations, with some overlap, have been indicated for ***D. minutus*** which appears to be more common in warmer areas (Stebbing, 1914). According to Stebbing (1914p. 135), in Bengal, the first generation of ***D. minutus*** starts from the end of April and the fifth lasts to the end of October; nothing is mentioned about the status of the population during the period, November to March. Two to five overlapping generations have been suggested for ***D. minutus*** in Puerto Rico (Plank, 1948).

Most investigators have observed that bamboo culms cut at certain periods of the year are considerably less susceptible to ***Dinoderus*** than those cut at other periods. This 'safe' period, may be different for different parts of India (Stebbing, 1914; Beeson, 1941) but confusion exists in the literature with respect to the safe period even for the same locality. For example, Stebbing (1914 p. 142) reported that bamboo felled during the months of January, February and March were not attacked in 'South Malabar' (northern Kerala); Beeson 1941) recommended the cold season as the best time to fell bamboo in southern India and, Joseph (1958) recommended July and August, the period of least'starch content in ***Bambusa arundinacea,*** as best time for Kerala.

Attempts have been made to relate the seasonal differences in suceptibility to seasonal variations in starch content of the bamboo and it has been concluded that there is strong correlation between ths degree of susceptibility and the starch content (Beeson and Bhatia, 1937; Gardner, 1945: Plank and Hageman, 1951. Jossph; 1958; Mathur, 1961). In ***Dendrocalamus strictus,*** the average starch plus disaccharides content of the culms varied from 0 to 18 per cent of the dry weight (Beeson and Bhatia, 1937) and in ***Bambusa arundinacea*** the starch content varied from about 10 to 19 per cent (Joseph, 1958), during the year. Generally, the period in which the starch content was low was also the period of least susceptibility to the borer. Yet, there is usually considerable variation in the starch content from internode to internode within the same culm and between culms within the (Beeson and Bhatia, 1937 p. 244; Mathur, 1961). same clump. There is also significant variation in starch content between different species of bamboo and between different varieties of the same species (Plank, 1950). In ***Bambusa vulgaris*** which contains a comparatively high percentage of starch (yearly mean of about 20%) Viado and Ylagan (1957), in contast to ther findings cited above, found no correlation between susceptibility to ***D. minutus*** and starch or total sugar content. A critical study of the experimental data of various authors reveal that the oft-quoted correlation is seldom consistent. Beeson and Bhatia (1937 p. 251) had clearly recognized this and commented that the "contradictions and inconsistencies" of their experimental data are difficult to resolve and that their results only prove that starch and a water soluble substance, possibly a disaccharide, are essential for ***Dinoderus*** infestation and that neither of them alone is sufficient. They also concluded that the glucose content varied irregularly from 0 to 6.6 per cent and showed no correlation with borer attack. Some other authors have, however, been less critical in the interpretation of their data.

There was an earlier belief that susceptibility to borer infestation is high when bamboo is cut during the period of moonlit nights and vice versa, but there is no evidence to support this although there is appreciable fortnightly rhythm in the moisture content of bamboo culms in relation to the moon's phases (Beeson, 1941). Cut bamboo stacked under shade or cover is more severely attacked than those stacked in the open according to Stebbing (1914) but there is practically no difference between the two according to Beeson 1941,p. 671).

Methods of control recommended against ***Dinoderus*** borers may be classed .into 4 categories – (1) cuttjng the bamboo during a 'safe' period, (2) clump-curing (3) water seasoning and (4) treatment with preservative chemicals.

As discussed above, there is no dependable safe period for any region although many recommendations are available in the literature.

Clump-curing involves cutting the culms and leaving them at site with foliage to facilitate depletion of the starch and suagrs during the period of slow drying of the culm. Its effect has been studied by Gardner (1945), Plank (1950) and Mathur (1958, 1961). According and to Plank (1950) clump-curing resulted in up to 90 per cent control of infestation and the best results were obtained in moist hot weather when the culms could be kept alive for a month or more to facilitate starch depletion. Mathur (1958, 1961). however, found c1ump-curing ineffective. In a well designed experimental study with ***Dendrocalamus strictus*** (Mathur, 1961,) clump-curing up to 12 weeks did not lead to adequate starch depletion and did not prevent ***Dinoderus*** infestation. In fact, during the period of high starch content, culms in which leaves were removed immediately on cutting suffered much less attack than culms kept with leaves for clump-curing.

Water seasoning has been tested repeatedly by various investigators because it has been generally observed that bamboo floated in rivers are comparatively free from attack. It is assumed that this protection is due to leaching out of certain soluble substances, notably sugars. Unfortunately, the results of water-seasoning tests reported in the literature (Beeson and Bhatia, 1937; they also review previous tests); Atkinson, 1936; Plank, 1950; Roonwal *et a/.* 1966) are full of contradictions. Based on a critical assessment of the literature, we conclude that there is no sufficient proof of effectiveness of water treatmen as a preventive measure against ***Dinoderus*** attack although prolonged water treatment (2 to 3months) reduces susceptibility and keeps the material out of reach of the borers during the period of immersion.

Treatment with preservative chemicals has given more consistent protection. Stebbing (1914) reported that bamboo poles can be effectively protected against ***Dinoderus*** borers by immersing them in "common Rangoon oil" (crude petroleum) for 48 hours after they had been water-treated for five days and dried in shade for several days to facilitate absorption of the oil. Hocking (1942) suggested treatment with a mixture of equal parts of mineral oil and creosote. Treatment with preservative chemicals by dipping, brushing, by Boucherie process or by pressure process (Plank, 1950; Purushotham et al, 1953; Mathur, 1961; Jayanetti, 1975; Liese, 1980) have also been suggested. Based on experimental results, Plank (1950) suggested treatment of bamboo with 5% DDT in Kerosene or diesel oil, either by 10-min dip or by brushing. Chang *et a/ (*1979) found that bamboo infested with ***D. japonicus*** can be effectively protected by treatment with high pressure steam or soaking them for 8 hours in hot water or solutions containing aslow as 10 ppm trichlorphon or 3 ppm methamidophos.

These methods are either expensive, cumbersome or bring about chemical changes in the treated material and therefore not suitable for protection of material stored for pulping.

III. GENERAL OBSERVATIONS ON INSECTS DAMAGING STORED REED IN KERALA

Atleast two species of bamboo reeds are available in Kerala - ***Och/andra travancorica*** Gamble and ***O. scriptoria*** C.E.C. Fisher (O. ***reedi*** Benth. ex Gamble). The latter has a comparatively narrow culm and is not generally extracted for industrial use. ***C. travancorica*** is the most widely distributed and therefore the most used, particularly for pulp production, and accounts for most of the estimated annual production of 3 lakh tonnes of reed in Kerala. Unless otherwise specified, the term 'reed', as used in this report, refers to O. ***travancorica.*** Somewhat large variations in culm diameter and length are noticed among reeds obtained from different areas but no distinct varieties have so far been recognized. There is no published information on insects infesting stored reed, although ***Dinoderus minutus*** is known to attack stored bamboo in Kerala (Stebbing, 1914; Beeson, 1941; Joseph, 1958).

Methods

Monthly observations on pest incidence were made on reed stacked in the KNP storage yard at Mevelloor from August 1981 to September 1982. Large stocks of reed were being built up and stored in this yard since June 1981. Regular observations were also made on small bundles of reed stacked in KFRI campus at Peechi every month for 18 months from October 1981 to March 1982 (see section V). In addition to these regular Observations, stocks of reed and reed products were examined wherever possible. A few small stacks available in the KNP storage yard at Mevelloor were kept under observation since early 1977 when the present project was originally contemplated.

Observations and Discussion

THE INSECTS INVOLVED

Termites

Several species of subterranean termites were found to damage stored reed in most places. They gain entry into the stack from underground. Usually the feeding takes place inside the culm leaving the outer layer intact. Termite damage must be recognized as a major threat to stored reed. It can be prevented by stacking the reed bundles over raised parapets and treating the soil along'the sides of the parapet with the insecticide, aldrin, heptachlor or chlordane, recommendations for which were mads to the KNP before this project was taken up.

Beetles

In addition to ***Dinoderus*** spp., three other beetles of minor importance were found associated with reed. Brief details are given below:

Heterobostrychus aequalis Wat (Bostrychidae): Belonging to the same family as ***Dinoderus, H. aequalis*** is a dark brown elongate beetle, atleast twice as long as

Dinoderus (i.e. about 6 to 10 mm). The adult beetles were found in very small numbers in July 1981 at Mevelloor, boring through the cut ends of reed culms and making longitudinal galleries. No large population build up occurred, although some larvae were found established in reed. ***H. aequalis*** is a common borer in packing cases, tea chests, veneers, etc., and is known to infest several species of stored timber (Beeson, 1941; Mathew, 1982). It has an annual life cycle and is unlikely to acquire pest status in stored reed.

Minthea rugicollis Walker (Lyctidae): This small (2 to 3.5 mm long), flat, dark brown beetle covered with conspicuously crect thickened setae, is a common pest of several timber species in'plywood, match and packing case industries. It was found to bore into reed through cut ends and make irregular galleries. At Mevelloor the damage was negligible as large populations did not build up. It is unlikely to acquire pest status in stored reed.

Myocalandra exarata Boh (Curculionidae): Adults and larvae of this 'black weevil, about 15 mm in length, were found in small numbers in reed stored at Mevelloor. It is known to be a borer of green bamboo (Beeson, 1941) and is unlikely to become a serious pest in stored reed.

Dinoderus spp. (Bostrychidae): Of the three speceis of ***Dinoderus*** known to attack bamboo in India (Section 1). ***D. minutus*** was by far the most common, found in stacked reed as well as in reed products, throughout Kerala. While ***D. minutus*** was encountered every year during 1977 to 1983 in one place or another, ***D. ocellaris*** was found only in 1982. It was found at Mevelloor in June–July in stacked teed originating from Konni. The infestation was concentrated on comparatively fresh stacks of reed and both ***D. minutus*** and ***D. ocellaris*** occurred as a mixed population, with ***D. oce//aris*** dominating. The infestation was heavy and looked like an outbreak and adult beetles of both species could be seen boring on reeds along the sides of the stack. Dead beetles were seen in the accumulated dust.

D. ocellaris is distinguishable from ***D. minutus*** by its slightly larger site, (3 to 4 mm) reddish brown body colour and hemispherical pronotum. ***D. minutus*** (2.5 to 3.5 mm) has dark brown body colour and anteriorly narrowing pronotum. ***D. ocellaris*** is also more active ***D. oce//aris*** infested reed is usually more heavily damaged (Fig. 1), has bigger beetle holes and show conspicuous transverse tunnels (galleries made by adults for egg laying) on the inner culm surface.

General characteristics of Dinoderus infestation

The most striking feature of ***Dinoderus*** infestation brought out by observations over several years is that the incidence of infestation is highly unpredictable. Over the years, infestation was noticed practically in all months of the year, at one place or other, but not continuously in the same place. The most intense build up of population was noticed in May, June and July 1982, at Mevelloor. This was partly due to availability of large stocks of reed in the yard and involvement of both the species of ***Dinoderus.*** Incidence was apparently not related to season, but to some quality of reed. At times, when infestation did not occur in some localities it

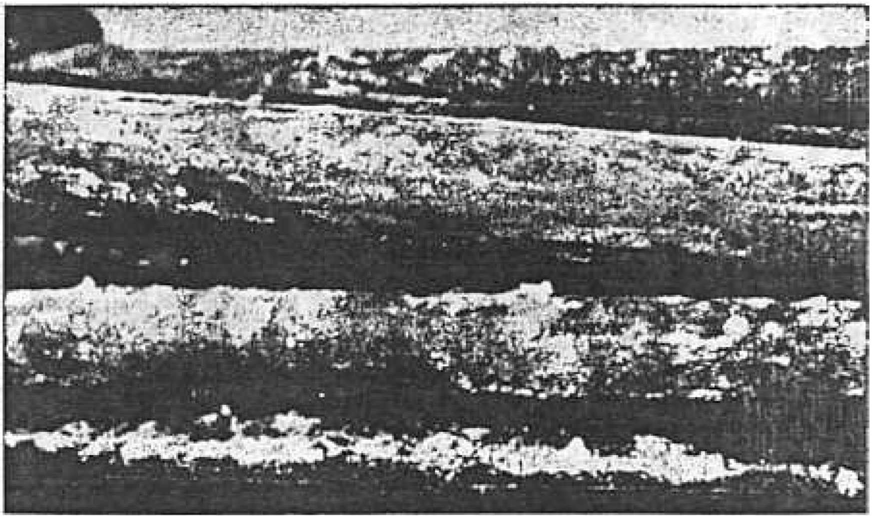

Fig. 1 **A bundle of reed *(Ochlandra travancorica)* infested by *Dinoderus ocellaris.* Note the borer holes and the accumulation of wood dust and frass pushed out by the beetles from their tunnels.**

occurred in other localities and in a given locality it occurred in some periods; but not all. For example, no infestation occurred in reed stacked at Nilambur during the period Feb. 1981 under another project (Gnanaharan *et al.,* 1982) although previous infestation have been noticed in the same yard.

Within a storage yard, often, infestation was confined to some of the stacks. Some of the infested stacks contained recently cut reed, but others had been stored for several months showing that freshness of the material was not the only criterion. The bottom ends of reeds were more heavily attacked than other portions. In heavy infestations, heaps of dust accumulated, particularly along the sides of the stacks. Most often, the intensity of infestation was greater towards the periphery of the stacks where the beetles entered the culms through the cut ends, (Fig.2) but declined sharply towards the interior. It was generally observed that infestations at particular sites declined in intensity and almos disappeared in about 2 to 3 months of first appearance, although this was not always the case.

Infestation of reed and bamboo occurs throughout Kerala It has been specifically recorded at Trivandrum, Mevelloor, Angamali, Trichur, Peechi Wadakkanchery, Chelakkara, Nilambur, Vythiri and Sultan's Battery.

Kinds of materials attacked by *Dinoderus*

In addition to stacked whole reed culms, finished products made of reed or bamboo were often damaged by *Dinoderus.* These included reed mats, stored in godowns (Angamali) and reed or bamboo baskets stored in retail shops and houses (Trivandrum, Pudukkad, Peechi, Trichur). Reed culms cut and stored at the site

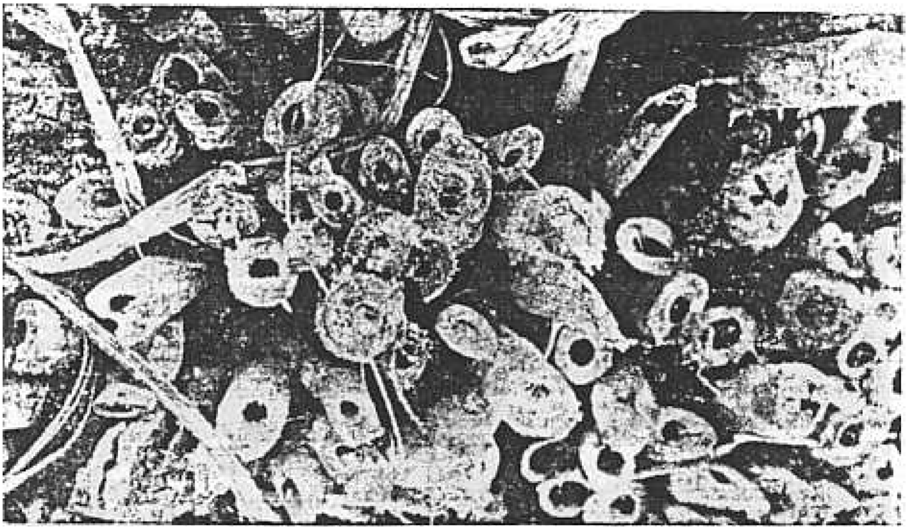

Fig. 2- **Edge of a reed stack, showing *Dinoderus* attack on the cut ends of one bundle of reed**

of extraction were not generally infested, although a few instances of light attack by ***D. minutus*** was observed in some places (Kollathirumedu, Sholayar). The exact period of storags of attacked bundles could not be determined accurately, but it was judged to be between 1 and 2 weeks. Split-bamboo roofing of an outdoor Orchidarium within the KFRI campus at Peechi was found heavily damaged by ***Dinoderus*** in January 1983 Bamboo or reed poles used in construction of field sheds were often found infested. All infestations recorded on finished products were caused by ***D. minutus.***

Natural enemies of *Dinoderus*

During thisstudy ***D.minutus*** was found to be attacked by atleast one predator and three parasites. These are listed in Table 1 along with other natural enemies reported from elsewhere.

Adults of ***Tillus notatus*** Klug (Cleridae), slim beetles measuring about 6mm. with orange. yellow and black coloured elytra are predaceous on the larvae of ***D. minutus*** and were recorded in small numbers at Mevelloor. ***Tribolium castaneum*** Herbst (Tenebrionidae), recorded as semipredaceous on ***D.minutus*** by Stebbing (1914) was found in good numbers (both adults and larvee) on ***Dinoderus*** infested reed at Mevelloor. This species known to breed on stored flour and other food commodities, may thrive on starch-rich ***Dinoderus*** - infested material. Its predatory habit could be incidental. In any case, it may exert some control on the development of ***Dinoderus*** populations.

Hectarthrum heros. another clerid beetle, reported as predator of ***D. minutus*** by Stebbing (1914) occurs in Kerala (Mathew, 1982), although not observed to predate on ***Dinoderus*** in this study.

All the three species of parasites (Table 1) were very common at Mevelloor. but their impact on the pest population is not known. They were also noticed in large laboratory cultures of ***Dinoderus*** maintained on reed. ***Spathius*** sp. and ***Cereocephala*** SP. have also been found to parasitize ***Sinoxvlon anale,*** another common bostrychid pest of stored timber in Kerala (Mathew, 1982).

Table **1.** ***Natural enemies of Dinoderus***

Parasite/ Predator	Family	Species	Country	Reference
Parasite	Braconidae	***Platyspathius dinoderi*** Gahan.	India	Present finding
		Spathius sp.	India	Present finding
		Spathius dinoderi	Phillippines	Gahan, 1925
		S.bisignatus Wlk.	India, Srilanka, Phillippines	Thompson, 1943
		Doryctes jarvus Mues.	Puerto Rico	Plank, 1948
	Pteromalidae	***Cercocephala*** sp.	India,	Present finding
		C. (Parasciatheras) sp.	Cuba	Bruner *et al.,* 1945
		C. ***(P.) dinoderi***	Phillippines	Gahan, 1925
		Proamotura aguila Girault	Puerto Rico	Plank, 1948
Predator,	Cleridae	***Tillus notatus*** Klug.	India	Present finding Stebbing, 1914 Beeson, 1941
		Hectarthrum heros (Fb.)	India	Stebbing, 1914
	Reduvidae	***Peregrinator biannulipes*** Montr.	Puerto Rico	Plank, 1948
	Ostomidae	***Tenebroides*** sp.	Puerto Rico	Plank, 1948
Semi-Predator or competitor	Tenebrionidae	***Tribolium castaneum*** Herbat.	India	Present finding Stebbing, 1914

IV. LABORATORY CULTURE OF DINODERUS MINUTUS

For investigations on various aspects of the biology and control of ***Dinoderus,*** it was necessary to maintain a laboratory culture of the insect to ensure its continuous availability. Probably because of variations in starch content, initial attempts to culture the beetle on reed were not always successful. In addition, it was difficult to extract large number of insects by dissecting the hard reed material when required. An alternative food medium was therefore desirable. Since infestation by ***Dinoderus*** borers are generally associated with a high starch content in the attacked material, dried chips of tapioca tuber, a cheap and readily available starch-rich material was tested as a possible culture medium. Tapioca stem and two wheat. flour-based diets were tested, in addition.

Materials and Methods

A nucleus culture of ***Dinoderus minutus*** was developed on infested reed. material ***(Ochlandra travancorica)*** collected in June 1980 from Chelakkara, Trichur District. Reed clums used for experiments reported in this section were of unknown age collected from Sholayar in March 1980. Clums stored in the laboratory were cut into small pieces and arranged in layers at the bottom of the rearing container to provide crevices, For initial experiments dry tapioca ***(Manihot esculenta)*** chips purchased locally were used. These chips were usually 2 to 3 cm thick and prepared by sun-drying. Since insecticide contamination was suspected in one of the market samples, for later experiments chips were prepared in the laboratory as follows. fresh tapioca was peeled and sliced into chips, about 2 cm thick, and dried at about 6O^{o}C for 48 hours in a hot air oven. The dry chips were stored. Tapioca stem was collected fresh and dried as above. Wheat flour cake was prepared by kneading the flour or flour-yeast mixture with water, spreading the dough into thin layer, about 0.5 mm, and drying as above.

The cultures were maintained at room temperature. Food material was placed in screw-capped plastic jars, 11 cm dia. x 14 cm height (Fig. 3) and infested with a known number of adults. For ventilation, the cap was provided with a 4 cm x 4 cm opening covered by plastic netting. The beetles were not sexed as there is no reliable method.

The suitability of various diets was compared by calculating the population multiplication index (PMI) which is the ratio betvveen the final and initial number of beetles within a specified period.

Results

The results of two preliminary experiments in which the insects were reared, on dried tapioca and reed are given in Table 2. In spite of initial tunnelling by the beetles in some pieces. no larvae developed on reed. In contrast, the beetles readily established themselves in tapioca chips and in 60 days the beetle population had multiplied over 4-fold (Table 2).

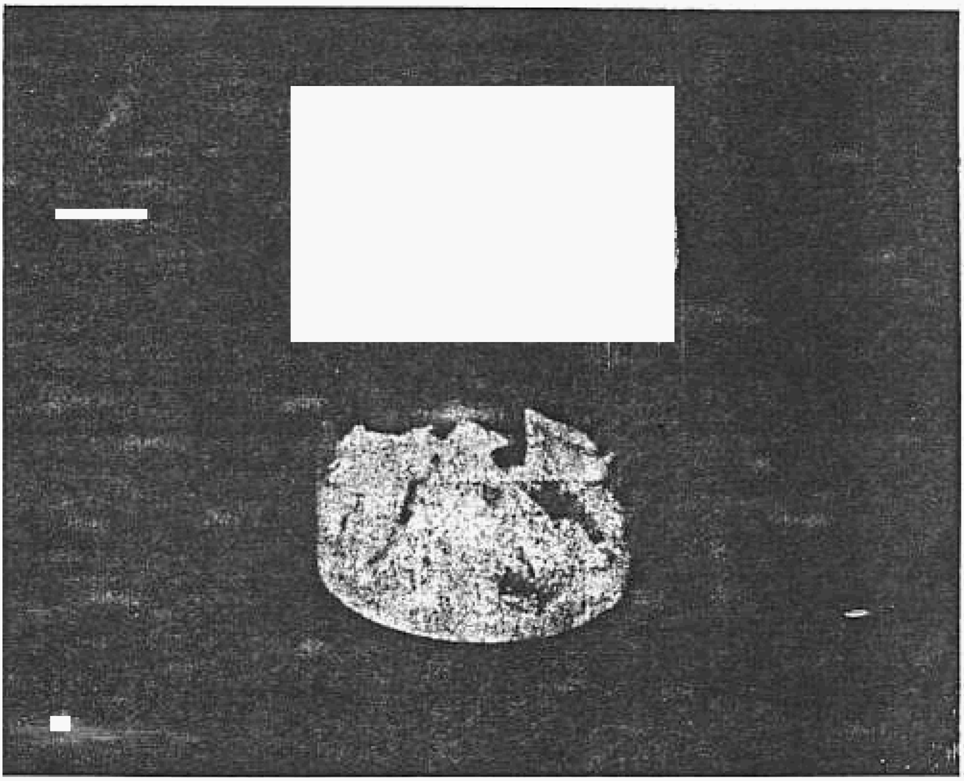

Fig 3. *Dinoderus* culture in plastic jars.

Table 2. Devolopment of ***Dinoderus minutus*** on dried tapioca and reed

Date of Expt.	Diet	No. of beetles placed on food (A)	No. of beetles found after 60 days (B)	Population Multi-plication Index (PMI) (B/A)
27 June 1980	Tapioca	75	332	4.4
	Reed	75	Nil	0
9 Sept. 1980	Tapioca	65	295	4.5
	Reed	65	Nil	0

To determine the time taken for development period of the insect from egg to adult on tapioca, three cultures were set up with 50 beetles each in 100 g tapioca and one culture each was examined after 30, 45 and 60 days. The results are given in Table 3. Forty two adults were found 30 days after setting up the culture. Some adults showed evidence of fresh emergence, but it is not clear how many were surviving parent beetles. Since atleast a few adults appeared by 30 days and since the pupal period is only 3–5 days (Plank, 1948), the developmental, period from egg to adult can be taken as about 30 days. A greater number of adults were produced in 45 days and the maximum in 60 days (Table 3). This is understandable as peak egg laying may occur many days after the beetles are placed in the food medium., In this experiment, the insect population multiplied about 10 -fold during the 60–day period.

Table 3 ***Number of insects found at the end of specified periods in three different cultures on dried tapioca started with 50 beetles each***

Developmental stage of the insect*	No. of insects found when examined after 30 days	45 days	60 days
Pupa	53	71	35
Adult	42	191	481
Total	95	262	516

*No. of larvae were not determined.

In another experiment, five diets, viz., reed, tapioca tuber, tapioca stem, wheat flour cake and wheat flour plus yeast cake containing yeast were tested simultaneously. This experiment was set up with a total of 750 beetles (originating from tapioca culture) with three replicates of 50 insects per diet A weighed quantity of 150 g of each diet was used per culture. The highest average increase in population, (PMI- 9.7) occurred (Table 4) in dry tapioca stem and wheat flour cake containing yeast which were followed by wheat flour cake and tapioca tuber with no increase in reed. The differences in PMI between diets which supported growth, however, were not significant, since there was considerable difference within replicates (up to 4 times in tapioca stem, for example). Much of this difference is probably attributable to differences in the sex ratio of the parent beetles. Tapoica tuber which gave a PMI of about 10 in some of the previous tests gave a PMI of only 3.2 in this set of experiments. The only possible conclusion from this experiment is that all the diets tested except reed were suitable for development of the insect. Further tests are required to establish their relative suitability.

Table 4. Development of *D. minutus* on various diets

Replication No.	No. of beetles found after 60 day interval (initial no. of adults-50)				
	Dry tapioca tuber	Dry tapioca stem	Wheat flour cake	Wheat flour +yeast cake	Reed
1	220	275	299	244	Nil
2	135	953	435	791	Nil
3	131	235	337	425	Nil
Mean	162	488	357	487	Nil
PMI	3.2	9.7	7.1	9.7	0

Experiment set up on 17 Jan. 1981

Starting February 1982 continuous cultures were maintained routinely in the laboratory on dried tapioca tuber, till May 1983. One or two cultures were set up every month, each with 100 beetles in about 100g of tapioca. The cultures were examined about 60 days later and the number of adults counted and recorded. These adults were utilized for various experiments. Figure 4 shows the PMI obtained

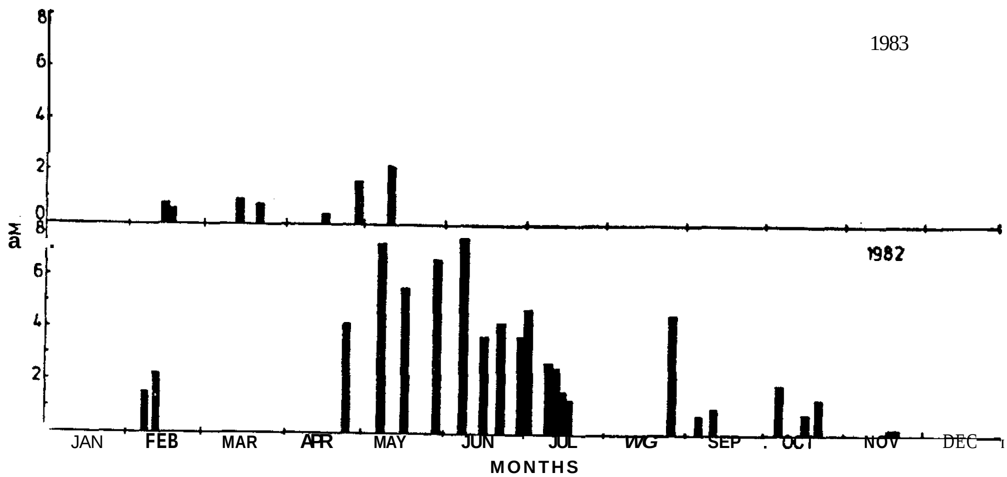

Fig. 4. Population multiplication index (PMI) obtained in routine laboratory cultures of *D. minutus* on dried tapioca uber from Feb. 1982 to May 1983. The PMI bar is plotted at culture midpoint, i. e. 30th day after setting up the culture.

in these cultures, It may be seen that the PMI ranged from 0.5 to 8. 5. Although, in general the PMI was low during the colder months, additional data are necessary to confirm this seasonal trend in view of the lower PMI recorded in April–May 1983 compared to the same period in 1982. Also, this trend is not borne out by the results of some other experiments (See the PMI obtained in the tapioca control. Table 5, Section V).

Discussion

The experiments have shown that ***Dinoderus minutus*** can be successfully maintained on dry tapioca chips. Over 10 successive generations of the beetles have been reared on this diet. There is no definite indication of loss of vigour of the population due to breeding on tapioca although the comparatively low rate of population increase noticed in April–May 1983 needs to be watched, Experiments are now in progress to check whether the decline in PMI was due to a possible change in the quality of dried tapioca. It appears that with occasional mixing of a few field-collected beetles to prevent loss of vigour due to inbreeding, cultures can be successfully maintained on tapioca continuously. ***D. ocellaris*** has also been bred successfully on dried tapioca (See Section V).

Other diets found suitable for development were dry tapioca stem and wheat flour cake with or without yeast. Dry tapioca stem is not always available and there could be variation in their quality depending on the plant variety and season of harvesting the stem. It is therefore not suitable for routine laboratory cultures. The wheat flour cake, particularly that containing yeast, may prove even better than tapioca in promoting growth and development, but further tests are necessary to evaluate its comparative performance. In practice, however, dry tapioca tuber may be more advantageous because it is cheap and is easy to prepare and store.

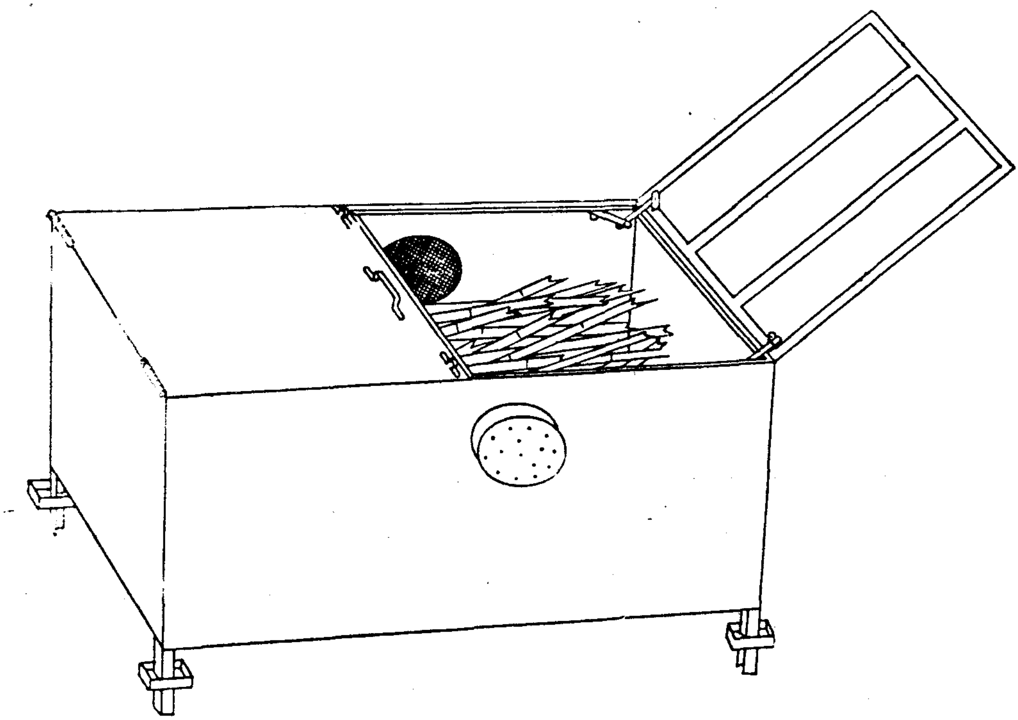

Fig. 5. Large tin container used for mass culture of *Dinoderus*

Reed supported growth of ***Dinoderus*** populations only in some instances. Apperently its suitability may vary depending on its starch content which in turn may depend on the season of harvesting and other unknown factors. It is therefore not a dependable material for laboratory culture of ***Dinoderus.***

For maintaining a stock culture of the beetles in the laboratory, however, reed may be used with advantage. We found it useful to build up a stock culture on naturally infested reed in a closed mild steel container, 180 cm x 90cmx90cm provided with a pair of hinged lids on top (Fig.5). Two sides are provided with ventilation holes covered with insect proof netting. Small quantities of mature freshly harvested reeds, dried for about two weeks at room temperature may be dumped in the container at intervals of 2 to 3 months. When required, beetles could be collected from infested reeds and placed in tapioca cultures for producing insects of desired developmental stage for experimental purposes.

V. INVESTIGATIONS ON FACTORS INFLUENCING SUSCEPTIBILITY OF REED TO *DINODERUS*

The erratic nature of ***Dinoderus*** infestation on reed has been noted earlier (Section 111). Differences in susceptibility may arise due to one or more of several reasons. Seasonal differences may occur as a result of seasonal variations in the starch content of reed. This has been shown in the case of bamboo, as discussed in Section II, but starch content may not be the only factor which determines susceptibility. Varietal differences is another possible factor although no distinct varieties of the commonly used reed, ***Ochlandra travancorica*** has been recognized (Section 111). In some localities, freshly cut reed bundles are transported by floating in river and this may also be suspected to confer immunity through leaching of some essential substances. In order to study the effect of these factors, reed cut at monthly intervals from five different localities were exposed to natural and artificial infestation by ***Dinoderus.*** Based on evaluation of these results, further experiments were carried out to study the effect of culm age, position of the test material within the culm, etc. Some of the laboratory tests were conducted with both ***D. minutus*** and ***D. ocellaris.***

Materials and Methods

Except where otherwise specified, reed used in all experiements reported here were obtained through the courtesy of the Kerala State Bamboo Corporation Limited. The Corporation extracts reeds from different areas and stores at various depots in and around Angamali from where monthly samplas from four localities, ***viz,*** Sholayar, Adimali, Pooyamkutty and Thalumkandam were collected. Reed from Pooyamkutty and Thalumkandam are transported part-way through water. Samplesw ere not available for some localities in some months for various reasons. Five culms representing each of the five localities were collected. The culms were 1 to 2 yr old as the Corporation selectively extracts culms of this age, which are better than older culms for making slivers for mat weaving Each culm, 4 to 5 m long, was cut into two and labelled individually. Of the 10 pieces from each locality, 8 were used for field tests and 2,for laboratory tests.

To study the effectof culm age and other related factors, reed harvested directly from clumps at Sholayar was used. Culms of different age were distinguished with the help of an expert reed cutter, based on their appearance and position in the clump.

Field tests

Field tests were carried out by exposing a bundle of reed each month, to natural infestation in an open field in the KFRl Campus. Each bundle consisted of eight smaller bundles containing samples of reed from each of the five localities. The bundle was placed on a wooden stand (Fig. 6) to protect the from subterranean termites. The bundles were superficially examined for signs of

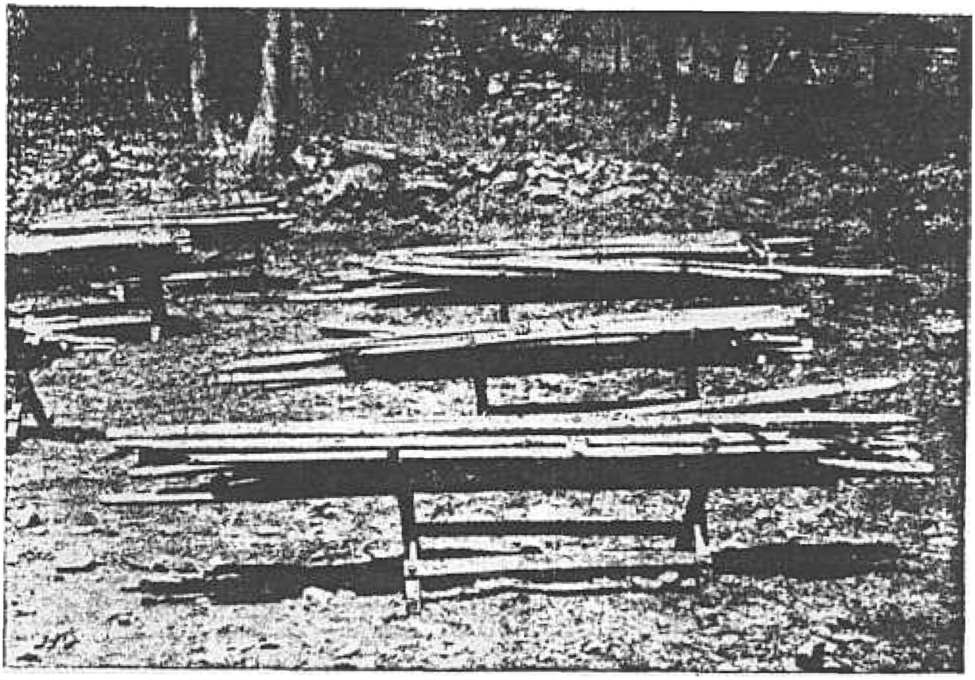

Fig. 6. A view of experimental reed bundles placed outdoors on wooden stands at KFRI campus to study natural infestation.

infestation at monthly intervals and final observations were made by untying the bundles.

Laboratory tests

In laboratory tests, reed samples were infested with a known number of adult beetles and the PMI determined by using the standard procedure (see Section IV). Representative pieces of the test sample were placed in an aluminium box, 14 cm × 7 cm × 6 cm, provided with a lid containing an opening 7.5 cm × 2.5 cm covered with fine wire mesh (Fig. 7). Segments of the reed culm were split longitudinally into 3 or 4 pieces and packed in the container. Fifty unsexed beetles, collected from tapioca culture (vide Section IV) were released into the container. For each test sample two replicate cultures were set up. Control cultures were set up simultaneously on tapioca chips. The containers were kept at room temperature (mean daily ambient temperature ranged from 26.1 to 29.7°C), inside a desiccator of 8 l air capacity, over a supersaturated solution of Mg $(NO3)_2$ 6 H_2O which maintained about 50 to 52 per cent R. H. (Winston and Bates, 1960). The desiccator was opened once every week to facilitate exchange of air. Other details of methods will be described along with the results.

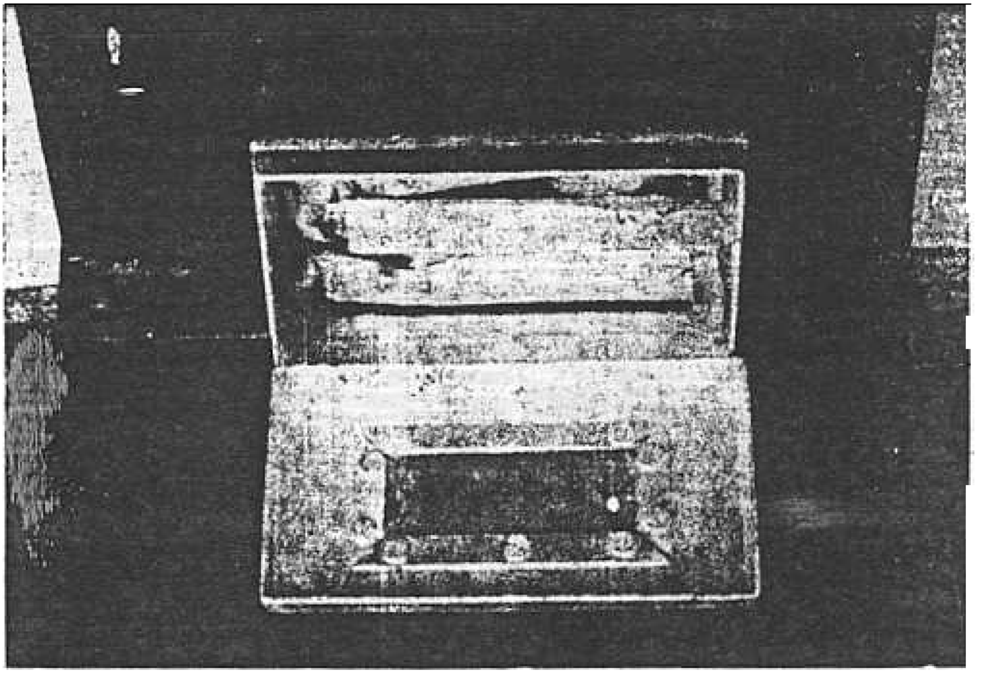

Fig. 7. Aluminium container usod for laboratory feeding tests. Tho lid is completely detachable and tight-fitting.

Results

Field tests

The field tests were run for 18 months with reed collected from October 1980 to March 1982. No borer infestation occured in any of the samples during the period. Final observations made on untied bundles confirmed absence of infestation. Reed stored for longer periods had black fungal growth on the outer surface; material stored up to 6 months generally retained the original yellow colour with sparse superficial fungal growth. As there was no incidence of borers no information could be obtained on seasonal or varietal differences in susceptibility.

Laboratory tests

The laboratory tests were run for 12 months with reed collected from December 1981 to November 1982. The results are given in Table 5. In the control cultures on tapioca, the PMI ranged from 1.5 to 6.8. There was no consistent seasonal trend. Such large variation in PMI in the same diet under similar conditions was not expected. It may possibly be due to variation in the sex ratio or condition of the founding population of beetles. Possible variations in the quality of the tapioca diet needs to be investigated. In general, very little population increase occurred on reed (Table 5). The highest PMI obtained was

Table 5. ***Development*** of ***Dinoderus minutus on reed harvested at monthly intervals from different localities***

Month of reed cutting (Dec. 1981 to Nov. 1982)	Population multiplication index				
	Tapioca control	Reed cut from			
		Sholayar	Admali.	Pooyamkutty	Thalumkandam
December	2.1	0.02	–	—	—
January	1.9	0	0	0	0
February	5.1	0	0	–	0
March	6.8	0.02	0.15	0.7	—
April	5.1	1.6	0	0	—
May	4.5	0	–	–	—
June	2.7	0.7	–	–	—
July	1.5	0.5	0	0	—
August	2.4	0.4	0.3	–	—
September	4.2	0.04	–	0.01	—
October	–	–	–	–	—
November	6.5	0	0	0	0

1.6 on reed collected from Sholayar in April 1982; in others it ranged from 0 to 0.7 It may be recalled here that a PMI of 0.5, for example, means that 50 offsprings were produced in a culture started with 100 beetles. The PMI was less than 1 in all samples except one, therefore reed must be considered a poor food meterial. Since the overall susceptibility to attack was low, no definite conclusion could be drawn on seasonal or varietal differences, although the results suggest that differences in susceptibility may not be attributable to seasonal or varietal differences in the quality of reed. As some larvae developed on reed obtained from Pooyamkutty, it can be concluded that water transportation does not confer immunity.

These results suggested that other unknown factors may be responsible for the erratic variations in susceptibility to infestation, Therefore further experiments were conducted to study the effect of (1) culm age and (2) position of the experi–mental meterial in the standing culm with respect to top and bottom. Variability in the period and conditions of storage of the cut culms was eliminated by harvesting the culms simultaneously. All these factors may be suspected to affect the content of strarch and/or other chemical constituents. Culms of five different ages (Table 6) as detetmined by their appearance and position within the clump were cut from Sholayar on 14 June 1982 and brought to the laboratory. Each culm was divided into two halves — bottom and top and two, representative samples of each half were taken. One was dried at room temperature for two weeks and the other in a hot air oven at 60^{0}C for 24 hrs following one week of room drying. Both samples were tested **2** weeks after cutting against both ***D. minutus*** and ***D. ocellaris.*** The .testing procedure was the same as described earlier except that the number of beetles used per container was 30 for ***D. minutus*** and 16, for ***D. ocellaris. D. ocellaris*** was obtained from infested field-collected reed kept in the laboratory. Control cultures were kept on tapioca.

Between the two species of ***Dinoderus*** there was marked difference in susceptibility (Table 6). With ***D. minutus,*** substantial infestation and population increase occurred only on 5-yr-old culm, in which the PMI ranged from 0.8 to 3.1 with an average of 1.6. This in comparison to an average PMI of 2.75 on tapioca, can ha considered a fairly good population increase. One–and two-year-old reed were generally unsuitable although a small number of larvae developed in some samples from the basal half of the culm. No development occurred in 6-month-old and flowered culm.

With ***D. ocel/aris,*** development occurred in culms of all ages except the flowered culm. Five year old culm was the most suitable, as in the case of ***D.minutus,*** with the PMI ranging between 4.8 and 25.9, with a mean of 9.4. Six-month- old culm was the least suitable, with others lying in between. In general, the basal portion of the culm appeared more suitable but the trend was not consistent. In general, ***D. ocellaris*** developed much better than ***D. minutus,*** both in reed and tapioca.

Between air–dried and oven–dried reed, the former promoted better growth in general, particularly in the case of ***D. ocellaris.*** Slight fungal growth was observed in some samples of room-dried reed, but not on oven-dried reed. There was no apparent correlation between fungal growth and susceptibility to ***Dinoderus***

Discussion

. The purpose of the experiments reported in this Section was to determine whether the observed variation in susceptibility of reed to ***Dinoderus*** infestation could be explained on the basis of any one of the factors studied, viz., cutting season, variety, water transportation, position of the reed segment within the culm, and manner of drying and moisture content. In addition to these reed qualities, another factor under test was the species of ***Dinoderus*** involved. The study has revealed that cutting season, reed variety and water transportation are not important, but age, position of the reed segment within the culm, manner of drying and moisture content of the reed, and the species of ***Dinoderus*** involved, are.

Table 6, *Effect of culm qualities on susceptibility to* Dinoderus

species of *Dinoderus*	Processing of reed	Population multiplication index										
			Reed									
		Topioca	6 month *old* culm		1 year old culm		2 year old culm		5 *year* old culm		Flowered culm	
			Base	Top	Ease	Top	Base	Top	Base	Top	Base	Top
minutus	Room dried	1.9	*0*	*0*	*0*	*0*	0.2	*0*	1.6	3.1	*0*	*0*
	oven *dried*	3-6	0	*0*	0.4	*0*	*0*	*0*	*0.8*	1	*0*	*0*
ocellaris	Room dried	8	*0*	*0.4*	12.8	1.8	0	4.9	25.9	0	0	0
	Oven dried .	7.1	*0*	0	0.1	2.8	*0.1*	*0*	*7.0*	*4.8*	*0*	*0*

The most decisive factors influencing susceptibility, as revealed by this study, are the culm age and the species of ***Dinoderus*** involved. Fully mature culm was the most susceptible to both the species while flowered culm was not attacked. Although less suitable than mature culm, ***D.ocellaris*** survived well in culms of all ages, except very young. On the other hand, ***D. minutus*** did not survive well in comparatively young culms although some beetles survived. ***D. minutus*** is the common species of ***Dinoderus*** found on reed in Kerala (Section III) and reed harvested for pulping consist of culms of all ages. This explains, together with the uncertainties of natural insect populations reaching a stock of reed to start the infestation, why infestations on reed are often patchy and unpredictable. Lack of natural infestation in the field tests reported here and the generally poor development of artificially infested ***D.minutus*** in the laboratory tests are due to the fact that comparatively young culms, 1-to 2-yr old; were used in these experiments. Incidentally, it may be noted that although 1-to-2yr old culms are selectively used by the Bamboo Corporation for mat making because they are more suitable for splitting into slivers, this practise fortuituously ehsured comparative feedom from borer attack of the manufactured products. This age group of reeds are, however, not completely free from attack, as our laboraary experiments show. Occasional attacks were also noticed in rolled reed mats stored in the Bamboo Corporation depots.

Lack of a clear cut seasonal difference in susceptibility was somewhat surprising in view of the claims of many authors that bamboo cut at certain seasons are not liable to attack by borers, although as discussed in Section II, no dependable safe period has been established for cutting bamboo in any region. Tests with fully mature reed culms would have brought 'out any possible seasonal trend more clearly, but it seems safe to conclude from the present data that there exists no 'safe period' for cutting reed; in Kerala.

The mechanism by which some factors bring about changes in the degree of Susceptibility may now be considered. A number of studies on bamboo, as discussed in Section II, have established a high correlation between starch-content and ***Dinoderus*** infestation, although at least one exception can be found (Viado and Ylagan, 1957) and several instances of inconsistency can be traced by a critical study of the data presented by many authors. With the present evidence, it would appear that a threshold concentration of starch is essential for successful establishment and survival of ***Dinoderus*** and that other factors, not yet fully understood, possibly volatile attractants, elicit - or promote natural infestation of bamboo and reed. 'Safe period' for cutting is probably a period of negligible starch content as many authors have claimed, but this may exist only for some species of bamboo as the starch content of other species may be above the threshold level even during the period of lowest starch content. Lack of correlatiqn between starch content and susceptibility may arise if the starch content is consistently above the threshold level as is perhaps the case in ***Bambusa vulgaris*** studied by Viado and Ylagan (1957) with a starch content of about 20%. during the yearly minimum. Cow intensity infestation of bamboo during the periods of high starch content, recorded by some authors when exposed to natural infestation outdoors may be due to the influence of other factors governing the abundance of natural populations of the beetles. Much of the confusion in the literature attempting to correlate the seasonal changes in susceptibility to starch content can be explained as follows. It is generally held ihat the starch content of bamboo is low during a certain period and moderate to high during other periods. Chemical determinations or semiquantitative histo-chemical observations generally confirm this, based on mean values. However, considerable variation is usually found in the starch, content between nodes of a particular culm, between culms of a particular clump, between different clumps, between different species of bamboos, etc. Such variations lead to variations in the susceptibility during natural exposure to infestation, leading to unexpected results. Starch stored in large quantities in the culms and rhizomes of bamboo is usually translocated and utilized rapidly for the uniquely rapid annual growth of new culms following the rains (Surendran, 1983). .This may perhaps lead to depletion of starch in some culms but not in others, depending on the physiological relationship between the newly developing culms and the older culms. Thus the starch content, and therefore the susceptibility, of various culms at'a given point of time become unpredictable.

The high susceptibility of mature culms of reed observed in this study appears to be due to high starch content. Similarly, the total resistance of flowered culm appears to be due to total depletion of the starch content. The greater suscept-ibility of the bottom portion of the reed culm could also be due to higher starch content. Poorer survival of the insect on oven-dried reed compared to air-dried reed may be attributed to lower moisture content rather than possible destruction of essential components as comparatively fresh stocks of reed were found more susceptible in field condition also (Sector VI).

Our results also suggest that D. ***ocel/aris*** prefers reed of comparatively higher moisture content while ***D. minutus*** thrives on reed of lower moisture content. This may be the reason for the wider occurrence of D. ***minutus*** on stored reed, particularly on manufactured articles. ***D. ocellaris*** however is, more active and is capable of developing on a wider age-group of reed culms. Its apparent preference for comparatively fresh reeds appears-to restrict its wider occurrence.

To conclude, fully mature culms are the most susceptible to borer. infestation and there is no safe period of cutting reed, except the period when it has flowered.

VI. CONTROL TRIALS

As discussed in Section II, traditional preservative treatments used against ***Dinoderus*** in bamboo cannot be used for protection of reed stored in large quantities for pulping. Clump-curing, suggested by some authors, have also proved ineffective in bamboo. In the present study, the effectiveness of several insecticides was evaluated. Eleven insecticides were tested by direct application against both the species of insects and selected ones were then tested by application to food surface. In addition, a few promising ones were tested in field experiments laid but in the KNP reed storage yard at Mevellor, where observations were made on the incidence of both insect and fungal damage.

Mateirials and Methods

Laboratory Experiments

Insects: Adults of both D. minutus and D. ***ocellaris*** were used for laboratory tests, ***D.minutus*** was obtained from tapioca cultures, and ***D. ocellaris*** from infested reed collected at Mevelloor and maintained in the laboratory for about 3 months.

Insecticides and screening methods: The inseticides tested were commercial formulations of five organochlorines, three organophosphates, one carbamate and two synthetic pyrethroids, details of which are given in Table 7. Initial screening was done by direct application under Potters' tower. Three concentrations of each insecticide were tested and three replicate tests were made using 20 beetles per teat. All insecticides were tested in water emulsions. Mortality was reaorded after 24 hr; moribundinsects were also counted as deed.

Dry tapioca stem was used as food (Section IV) to study the effeat of insecticide when,applied to food. Dry stems,.10 cm long, were dipped fur 30 sec. in the respective insecticide preparations, air-dried and placed in cylindrical glass jars. Three pieces of stems given the same treatment were placed in each jar and 20 beetles ***(D.minutus)*** were introduced. Water-dipped stems served as control. Mortality was recorded after 24 hr: where necessary, the stems were dissected to count the beetles.

Statistical methods: The significance of the difference in mortality between various insecticides was tested by analysis of variance (Panse and Sukhatme, 1978), taking each insecticide concentration separately. For these tests, the highly active synthetic pyrethroids were grouped, as in Table 7, with the other insecticides which were used at concentrations 10 times higher. Critical difference was calculated at 5 per cent level of significance.

Field Experiment

The field experiment was conducted in the KNP reed storage yard at Mevelloor. The effect of two chemicals viz,. HCH (BHC) and borax-boric acid applied at monthly intervals, was studied. Observations were also made on incidence of fungal infestation.

The experimental stacks were put up over low concrete parapets (Fig 8). Soil along the parapet had been earlier treated with aldrin to prevent damage from subterranean termites. Nine stacks, each 5mx 5m x 2m, were put by arranging bundles of freshly cut reed in a criss-cross manner, and three stacks were allotted, at random, to each treatment, including untreated control.

Fig. 8. An experimental reed stack at Mevelloor, being given monthly treatment. Note the concrete parapets and criss-cross stacking and reed bundles.

HCH was sprayed at 0.5% concentration of active ingredient (prepared from 50% wettable powder) and borax-boric acid at a concentration of 2% boric acid equivalent (BAE). The2% BAE solution was prepared by dissolving 200 g boric, acid and 300 g borax, both technical grade, in 20 litres of water containing 10 drops of a sticker-spreader. Twenty liters of the spray solution were sprayed over the exposed surfaces of the sfack using a rocker-sprayer giving an application rate of about 0.3 l m^2.

General observations on the incidence of insects and fungi were made at monthly intervals, by superficial examination of the stack. More detailed qualitative

Table 7. *Efficacy of various insecticides against Dinoderus minutus and D. ocellaris in laboratory tests*

Insecticide		*Dinoderus minutus*			*Dinoderus ocellaris*		
Chemical name	Trade name & formulation	%mortality at specified a. i.			%mortality at specified a. i.		
		0.1%	0.05%	0.25%	0.1%	0.5%	0.025%
Nil (Control)	—	0[c]	0[d]	0	0[d]	0[d]	0[g]
Organochlorines							
HCH	Lindane 20 EC[1]	100[a]	100[a]	80 [cde]	100[a]	100[a]	97[ab]
HCH	Hexidole 50 WP[2]	100[a]	100[a]	97[ab]	100[a]	97[a]	90[abcd]
Chlordane	Chlordane 20 EC[1]	100[a]	90[b]	77[cde]	100[a]	80[b]	73[e]
Aldrin	Aldrex 30 EC	100[a]	80[b]	83[abcd]	77[b]	43[c]	20[f]
DDT	DDT 25 EC[1]	73[b]	40[c]	33[f]	47[c]	7[d]	20[f]
Organophosphates							
Malathion	Cythion 50 E[2]	100[a]	100[a]	93[abc]	100[a]	100[a]	100[a]
Fenitrothion	Sumithion 50 E[2]	100[a]	100[a]	100[a]	100[a]	100[a]	93[abc]
Methyl parathion	Metacid 50[4]	100[a]	100[a]	97[ab]	100[a]	100[a]	80[cde]
Carbamate							
Carbaryl	Sevin 50 WP[5]	100[a]	100[a]	100[a]	100[a]	100[a]	100[a]
Sythetic Pyrethroids		0.01% (100 ppm)	0.005% (50 ppm)	0.0025% (25 ppm)	0.01% (100 ppm)	0.005% (50 ppm)	0.0025% (25 ppm)
Cypermethrin	Ripcord 10 EC[3]	100[a]	100[a]	100[a]	100[a]	100[a]	93[abc]
Permethrin	Permasect 25 EC[1]	100[a]	100[a]	100[a]	100[a]	100[a]	100[a]

1, Bharat Pulverising Mills Ltd.; 2, Rallis India Ltd.; 3, National Organic Chemical Industries Ltd.
4, Bayer (India) Ltd.; 5, Union Carbide India Ltd.

Within each column, mortality figures superscribed by the same letter do not differ significantly from one another at 5 per cent level of significance.

observations were made by dismantling one of the three replicated stacks after 9 months of storage, and the remaining two, after 18 months.

Results

Laboratory Experiments

Table 7 shows the results of laboratory tests in which the insects were directly exposed to insecticidal sprays. At 0.1%. the highest concentration tested, all insecticides except DDT and aldrin gave 100 per cent mortality of both species. At 0.05% chlordane also fell into the group of the less effective insecticides. Even at 0.025%, all the insecticides except the above three were sufficiently effective, giving over 80 per cent kill. The synthetic pyrethroids-cypermethrin and permethrin, were effective and comparable to the other effective insecticides at concentrations 10 times lower, the lowest effective concentration tested being 25 ppm (0.0025%). Thus the list of effective insecticides include cypermethrin and permethrin (synthetic pyrethroids); carbaryl (carbamate); malathion, fenitrothion and methyl parathion (organsposphates); and HCH (organochlorine). Of all the insecticides tested DDT was the least effective. ***D. ocellaris*** appeared to be more resistant than ***D. minutus*** to DDT and aldrin (Table 7).

Based on the criteria of high effectiveness in these tests, low cost and low mammalian toxicity, five insecticides were chosen for further tests by application to food medium. These were HCH, malathion, carberyl, cypermethrin and permethrin. When applied to the food medium at 0.1% concentration (Table 8), malathion proved ineffective, causing less than 50 per cent mortality. Carbaryl gave only about 87 per cent kill. The others, i. e. HCH, cypermethrin and permethrin proved highly effective.

Table 0. ***Effect*** of ***selected insecticides on Dinoderus minutus when applied to the food medium***

Insecticide: Chemical name	a. i. concn. (%)	No. of insects Per test	No. dead, mean of 3 replicates rounded off to the nearest integer .	Per cent mortality
Nil(Control)	—	20	0	0
HCH	0.1	20	20	100
Malathion	0.1	20	9	43
Carbaryl	0.1	20	17	86
Cypermethrin	0.01	20	20	100
Permethrin	0.01	20	20	100

Field Experiments

The incidence of ***Dinoderus*** infestation and other pertinent details, mainly appearance of fungal growth, are summarised in Table 9. Minor insect borers found have been mentioned in Section

During an observation period of about 19 months, no major build up of ***Dinoderus*** occurred in the experimetal stacks. A low level infestation of ***D. minutus*** occurred in a patch in one of the HCH treated stacks in January 1982, six months after the stacks were put up. It subsided without spreading to other parts of the stack. General absence of infestation was not due to absence of a population of ***Dinoderus*** in the area. When the experimental stacks were put up, large quantities of reed were already stored in the yard and fresh stocks were being regularly brought in. Low level infestation was already prevalent in some stacks. Infestation was noticed in some stacks in the yard in January, February, May and June-July 1982 with heavy population build-up from May to July. Most of these infestations were of D ***minutus,*** bat in June-July 1982 ***D. ocellaris*** was present in addition, and appeared to predominate. In general, infestation was more prevalent in comparatively fresh stocks of reed. The two parasites, ***Spathius*** sp. and ***Cercocephala*** sp. (Section 111) were abundant in the area during this period of pest abundance. Detailed examination of dismantled stack from each of the treatments in March 1982 and the remaining stacks in January 1983 confirmed that no borer infestation occurred in any of the stacks, except the one mentioned above.

The stacks suffered some damage from fungi. Beginning the second month, black fungal growth started appearing on the yellow surface of the read culms (Table 9). The intensity of fungal growth and surface coverage increased steadily, apparently favoured by the monsoon conditions, except in borax-boric acid treated stacks in which the reeds retained the original yellow colour, with patches of fungal growth. The fungi were identified as a mixture of sooty moulds, with ***capnodium walteri*** saee. and ***C. salicinum*** Mont. as the major species. These fungi usually grow superficially and do not cause degradation of cellulose. Their growth reached a peek by November - December 1981 and subsided during the following summer, although the black colour persisted, turning grey in course of time.

In December 1981, six months after the stacks were set up, white fruiting bodies of another fungus appeared. They were more numerous in control and HCH treated stacks and sparse on borax-boric acid treated stacks (Table 9). This fungus was identified as ***Lenzites*** sp. a brown-rot fungus capable of degrading cellulose. In stacks retained for longer periods, fresh fruiting bodies of ***Lenzites*** appeared again in June 1982. Fresh growth of ***Capnodium*** also occurred following the rains between June and September, rendering the reeds black. In borax-boric acid treated stacks, however, the reeds still retained the yellow colour with sparse growth of ***Capnodium;*** fruiting bodies of ***Lenzites*** were present, but fewer than in other stacks. When examined at the close of the experiment, borax-boric acid treated reed was yellow to grey in colour and appeared to have suffered deterioration than HCH treated and Control reeds which were grey to black in colour and were generally brittle and easy to crush, particularly the, younger clums. Attempts to quantify deterioration by determining changes in the density of reed were not succecsful because of sampling difficultes due to large variation within the stack.

Table 9. ***Incidence of insect and fungal infestation in outdoor reed stacks at***

Date of observation & storage period	Treatment		
	Nil	HCH	Borax–boric acid
6 Aug. 81 (2 months)	Moderate growth of the fungi ***Capnodium*** spp. giving a black coating on reed surface.	Sparse growth of ***Capnodiurn*** spp.	Sparse growth of ***Capnodium*** spp. making scattered black spots on low reed surface.
7 Sept. 81 (3 months)		Intensification of ***Capnodium*** growth, giving black coating	
6 Oct. 81 (4 months)			
7 Nov. 81 (5 months)	Fresh growth of ***Capnodium*** spp. following rains.	Fresh growth of ***Capnodium*** spp. following rains.	
7 Dec. 81 (6 months)	Exposed reeds black in colour. Large number of white fruiting bodies of the fungus, ***Lenzites*** sp.	Exposed reeds black in colour. Large number of white fruiting bodies of ***Lenzites*** sp.	Exposed reeds yellow, with scattered black spots. Small numbers of white fruiting bodies of ***Lenzites*** **sp.**
13 Jun. 82 (7 months)		***Dinoderus minutus*** infestation in a small patch in one of the stacks.	
6 Feb. 82 (8 months)		***Dinoderus*** infestation persisting.	
15 March 82 (9 months)	Reeds greyish black. One of the stacks dismantled	Reeds greyish black. One of the stacks dismantled	Reeds yellow. One of the stacks dismantled
8 June 82 (12 months)	Fresh fruiting bodies of ***Lenzites*** in moderate numbers	Fresh fruiting bodies of ***Lenzites*** in moderate numbers.	Fresh fruiting bodies of ***Lenzites*** in small numbers.
7 Sept. 82 (15 months)	Reeds grey to black	Reeds grey to black.	Reeds yellow to grey
15 Jan. 83 (19 months)	Reeds grey to black. Remaining stacks dismantled	Reeds grey to black. Remaining stacks dismantled	Reeds yellow to grey. Remaining stacks dismantled

Blank indicates no new reportable development.

DISCUSSION

The laboratory experiments have shown that out of the 11 insecticides tested, the most suitable for use against ***Dinoderus*** spp. are HCH (BHC) and the synthetic pyrethroids, cypermethrin and permethrin. Of these, only HCH was used in the field trial. It has the advantage of low cost and easy availability. Cypermethrin and permethrin are comparatively new insecticides and were not available when the field tests were laid out. Borax–boric acid was included in the field tests as it was known to be effective against insects and fungi (Findlay, 1967). and has no mammalian toxicity. It was not tested aginst ***Dinoderus*** by direct application as it is a stomach poison.

The field trial did not yield as much data as expected, on effectiveness of insecticides, becuase of very low infestation pressure. The incidence of a light infestation in one of the HCH-treated stacks shows that the treatment was not Sufficient. In view of its effectiveness in dip tests, it is clear that ineffectiveness of HCH in field trial was due to low frequency of application.. More frequent applications, perhaps weekly may be necessaryto get a prophylactic effect particularly during the monsoon season. Prophylactic effect is necessary because once the beetles establish themselves in the interior of the stack, insecticidal sprays cannot reach them. No conclusion can be drawn on the effectiveness of borax—boric acid under field conditions because the stacks were not under sufficient pest pressure.

The most notable result of the field trial is the observation that very little insect damage occurred in the experimental stack, but fungal damage was prevalent. ***Capnodium*** **sp.** apparently **do** not affect pulping quality as cellulose is not affected, but ***Lenzites*** sp. can cause deterioration. Since the fruiting bodies of ***Lenzites*** appeared in about ***6*** months of storage, the inf estation, and therefore cellulose depletion may have started earlier. Quantitative studies are required to assess the extent of damage, but considering the moderate to high density of ***Lenzites*** fruiting bodies on untreated and HCH treated stacks, some control measures against fungal infestation seems warranted for reed stored for longer periods. Monthly spray of Borax–boric acid gave some protection against ***Lenzites*** (also against ***Capnodium)*** and more frequent application may be expected to prevent establishment of ***Lenzites.***

Thus the present results suggest that frequent application of 0.5% HCH will be necessary for protection against ***Dinoderus*** and of 2% BAE solution for protection against fungi, particularly ***Lenzites.*** These two could probably be combined. The synthetic pyrethroids could probably replace HCH. Practical application of protective chemicals should, however, take into consideration the economics of chemical treatment and the envirorrmental impact. These will be discussed in the following Section.

VII CONCLUSIONS AND RECOMMENDATIONS

The main objectives of this study were to assess the damage potential of ***Dinoderus*** borers to stored reed and to investigate possibilities of controlling them. The study was intended to be of a preliminary nature with emphasis on gathering basic information on the biology and habits of the insect and commenced before large-scale storing of reed began at Mevelloor. Based on a general survey of ***Dinoderus*** infestation of reed, experimental investigations in the laboratory and limited field experiments and observation in the KNP reed storage yard at Mevelloor this study has brought out useful data on various aspects of deterioration of stored reed based on which the following conclusions and recommendations are made.

Damage potential

Damage to stored reed is caused by both insects and fungi.

Among the insects, subterranean termites and ***Dinoderus*** beetles are potentially capable of causing economic damage; a few other beetles found (Section 111) were of little importance. The termites gain entry into the stack through soil contact and can cause considerable destruction. Their attack can be prevented by stacking the reed over raised parapets and treating the soil along the sides of the parapet with the insecticide, aldrin, heptachlor or chlordane.

Dinoderus beetles, well known in India as bamboo borers, 'ghoon borers' or 'powder-post beetles' breed within the walls of the reed culm producing large quantity of wasteful dust. Two species of ***Dinoderos*** were involved, ***D. minutus*** and ***D. ocellaris, D. minotus,*** was the most common, occurring throughout Kerala in stored bamboo or reed and articles manufactured out of them. ***D. ocellaris,*** was noted at Mevelloor in June-July 1982 when it occurred as a mixed population with ***D. minutus.*** These beetles complete a generation in about two months and are capable of breeding continuously throughout the year in Kerala although in northern India the winter generation undergoes hibernation, Thus, theoretically, at least six overlapping generations of ***Dinoderus*** beetles could occur in Kerala.

Field observation revealed, however, that ***Dinoderus*** attack of stored reed was'sporadic and cannot be predicted with accuracy. A combination of several favourable conditions seems necessary for development of infestation. Experimental studies revealed that harvesting season, possible varietal differences and mode of transportation (by water or road) were not important factors affecting incidence of attack but maturity of the reed culm was. Fully mature clum about 5 yr old was the most susceptible to attack, while culms of flowered reed were totally immune. Younger culms except those bolow 1 yr were attacked to varying degree, particularly by ***D.ocellaris.*** Intensity of attack was not uniform as the stock consists of culms of all ages. Comparatively fresh stocks of read were more liable to attack, particularly by ***D. ocellaris.*** Rarely, some lots, of reed were found infested while awaiting transportation at the cutting sites, but generally, reed arriving at the storage site at Mevelloor were free of infestation.

The severity of infestaticn will depend upon the population build up of the beetles. Laboratory studies on artificial diets have shown that under favourable conditions, the beetle population can increase about 10-fold within one generation. Continuous availability of favourable conditions like stocking of large quantities of fresh reed on a regular basis, could lead to large population build up. The epidemic build up of ***Dinoderus*** population was noticed at Mevelloor in June-July 1982, about an year after regular storing of reed began. This build up subsided in about 2 months Three species of hymenopteran parasites were found during the period in moderate numbers but nothing is known of their role in suppressing the host population. With the projected annual utilization rate of nearly lakh tonnes (dry) of reed by the factory the reed storage yard at Mevelloor is likely to create a unique and ideal envinonment for multiplication of the ***Dindoderus*** population. Storage started only in 1981 and with every passing year, the beetle population is likely to build up, until an equilibrium state is reached in the new environment. It is quite likely that ***Dinoderus*** may become a persistent and menacing pest. The course of development needs to be watched. Observations already made in this study during the first year of storage are only of indicative value.

information is also required on the seriousness of the loss in pulp yield due to ***Dinoderus*** infestation. Accumulation of the dust resulting from beetle damage along the sides of the stack give an impression of serious economic loss, but quantitative estimate in terms of loss in pulp yield is necessary. It is possible that beetle attack, usually confined to a short distance from the exposed basal ends of the culm along the sides of the stack. give a false impression of serious loss.

Two types of fungi, were also found to grow **on** stored reed. One of them, the sooty mould, a mixture of several species of ***Capnodium.*** grow superficially on the reed culm during the monsoon season and leave a black colouration on the yellow surface Apparently they do not affect pulping quality as cellulose is not affected. The other fungus, ***Lenzites*** sp.. a brown rot fungus is capable of degrading cellulose and was found to produce fruiting bodies in about six months of storage. Apparently they continued to grow and produced furiting bodies again. Reed stored for about nine months and attacked by ***Lenzites*** were brittle and easy to crush, particularly the younger culms. Studies are needed to determine the effect of ***Lenzites*** infestation on pulping quality.

Deterioration caused by the cellulose-degrading fungus, ***Lenzites*** sp., appear to be more serious than deterioration caused by the insect borer. Fungal infection is more certain to occur, may effect all reed culms and persist, whereas ***Dinoderus*** attack was sporadic, affected only some stacks of reed and was transient.

Control

Two aspects must be considered here - the necessity to control and the methods of control, if control must be applied.

Let us consider the problem of fungal damage first. 4s discussed above, deterioration caused by ***Lenzites*** may he economically serious, but further studies are needed to establish this. This could be taken up by the research wing of HPC with expertise and facility available at factory site for pulp yield determination.

The present study was not concerned with fungal damage and the observations made were incidental. However, our results suggest that ***Lenzites*** damage may be reduced by fortnightly spraying of borax-boric acid (2% boric acid equivalent) over the stack surfaces. This chemical has no mammalian toxicity and is therefore environmentally safe for regular use. It also has insecticidal properties which may reduce damage by ***Dinoderus*** beetles. It is likely that control is necessary only for reed that must be stored for periods over four months.

With respect to the insect problem, again, the necessity to control infestation can be decided only on the basis of studies on loss in pulp yield. However, considering the fact that ***Dinoderus*** infestation is sporadic and may not occur in all the stacks at the same time, at least during the present level of population build up at the storage site, we sugggest the following strategy for management of the pest. Maintain a regular surveilance to discover incidence of infestation. As soon as infestation is noticed in the yard utilize the infested stack, on priority basis, for pulping. Simultaneously, give a prophylactic spray of 0.5% HCH (BHC) over the exposed surfaces of all stacks of reed in the yard. An application rate of about 0.3 l/m2, as used in this study. may be employed. Repeat the spraying at weekly intervals until the infested stock is completely utilized. And repeat the process if and when a new infestation occurs. The cost of insecticjde treatment is estimated at Rs.1230/-per application, for a stock of about 10,000 tons (12 stacks of 40m x 15m x 5m). The above figure includes Rs.510/- for purchase of insecticide and ,Rs.720/-for labour. Since one infested stack can be utilized normally in about a week, only one application of insecticide may be necessary per each incidence of infestation noticed. This procedure aims at destroying the existing population of beetles and not allowing new populations of build up. It may not become necessary to spray insecticide, once the presently existing population of beetles is destroyed. If repeated sprayings become necessary due to frequent build up of infestations due to some reason, use of the synthetic pyrethroids found effective in this study, viz.. Permethrin or Cypermethrin which are less hazardous enviromentally, although more expensive may be considered.

If for some reason or other, a proper pest management programme as suggested above is not practised, the reed storage yard at the KNP site is likely to become a large breeding site for the two species of ***Dinoderus*** beetles. Control will become mor difficult when a large population is built up because reservoire populations may establish themselves in other less preferred hosts such as miscellaneous timbers and small wood. It is also essential that regular surveilance of the development of ***Dinoderus*** population in the storage yard is maintained, by suitably trained or qualified personnel.

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