EVALUATION OF SELECTED SANKHUPUSHPAM (*Clitoria ternatea* L.) LINES FOR YIELD, ALKALOID CONTENT AND NODULATION

BY

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THESIS
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Dedicated

To

Amma, Daddy and Hari

DECLARATION

I hereby declare that this thesis entitled **"Evaluation of selected Sankhupushpam (*Clitoria ternatea* L.) lines for yield, alkaloid content and nodulation"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,

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CERTIFICATE

Certified that this thesis entitled **"Evaluation of selected Sankhupushpam (*Clitoria ternatea* L.) lines for yield, alkaloid content and nodulation"** is a record of research work done independently by Ms. Reshmi. C.R. (99-12-02) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Reshmi.C.R

Reshmi. C.R.

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LIST OF ABBREVIATIONS

m	Metre
cm	Centimetre
mm	Millimetre
g	Gram
kg	Kilogram
^0C	Degree Celsius
%	Per cent
ha^{-1}	Per hectare
day^{-1}	Per day
DAS	Days after sowing
LAI	Leaf area index
LAD	Leaf area duration
NAR	Net assimilation rate
CGR	Crop growth rate
RGR	Relative growth rate
AGR	Absolute growth rate
HI	Harvest index
CD	Critical difference
NS	Not significant
Fig.	Figure
No.	Number

Introduction

1. INTRODUCTION

The importance of plants as source of medicines is well known from time immemorial. Plants were first utilized as a source of food, shelter and clothing and later their medicinal properties were realised. Subsequently man started domesticating several plants including medicinal plants, for his day-to-day use. *Clitoria ternatea* L. (Butterfly pea) locally known as 'Sankhupushpam' is one such plant domesticated by man initially as an ornamental plant but later as a medicinal plant as well.

Clitoria ternatea is an evergreen perennial usually cultivated as an annual from seeds. This leguminous creeper is a common ornamental plant in Kerala homesteads. When trailed, it very well adorns hedges and walls. It also bears beautiful blue, white or pink flowers. The unique flower shape and attractive flower colours add to its ornamental value.

Almost all the parts of *Clitoria ternatea* are medicinally valuable. Its root is regarded as a good brain tonic and is an ingredient of 'Medhya rasayana' in Ayurveda. The root has diuretic and cathartic properties too. Root of white flowered plant is an antidote to snake bite and scorpion bite. Root bark is used as a demulscent, diuretic and laxative. Leaf paste is used in the palliative treatment of skin diseases. Flowers cure eye inflammation and uterine haemorrhage. Seeds possess antihelminthic, laxative and diuretic properties. The plant owes its medicinal properties to the resinous principles and tannins present in roots and the alkaloids present in seeds. Being a legume, it enriches soil fertility by nitrogen fixation. Moreover, the aerial portion serves as an excellent fodder for cattle.

A major lacuna which hinders the commercial cultivation of medicinal plants is the non-availability of authentic varieties. Nair (2000) screened the germplasm of *Clitoria ternatea* available at the College of Agriculture, Vellayani. The germplasm was evaluated for root yield, seed yield, biomass yield and alkaloid content under shade in a coconut garden as intercrop. In the present study, six superior lines evolved from the previous trial by Nair (2000) trial are further evaluated for yield, alkaloid content and 'nif' bacterial nodulation under two growth conditions namely in open condition as a pure crop and under shade as an intercrop in a coconut garden.

Review of Literature

2. REVIEW OF LITERATURE

Clitoria ternatea L. is a medicinally valuable climber, grown as an ornamental plant in the tropics. Randhawa and Mukhopadhyay (1986) consider India as the centre of origin of *Clitoria ternatea.* It belongs to the family, Fabaceae and subfamily, Papilionaceae. It has papilionaceous flowers, an infundibular calyx with persistent bracteoles, persistent stipules and stipels and stalked ovaries with a geniculate bearded style.

The genus *Clitoria* consists of about 60 species distributed mostly within the tropical belt, with a few species in temperate areas (Fantz, 1990).

The assemblage of genetic diversity offers enormous variability in plant breeding programmes for the development of new superior crop varieties with desired traits (Agrawal, 1998). Loss of variability is almost universal, and today there is widespread recognition of the need for conserving germplasm. In 1996, at the Department of Plantation Crops and Spices, College of Agriculture, Vellayani, thirteen herbaceous medicinal leguminous plants were collected, described and catalogued. Sunitha (1996) has conducted a performance evaluation trial of these plants in open as well under shade in a coconut garden. She identified three crops *viz., Mucuna pruriens, Clitoria ternatea* and *Indigofera tinctoria* as most promising in Kerala condition for large scale cultivation. Samuel (2000) collected various accessions of *Mucuna pruriens* from in and outside the country and evaluated them for seed yield, L-DOPA content and nitrogen fixing efficiency under shaded situations in a coconut garden. The genetic stock of *Clitoria ternatea* L. was evaluated for yield, alkaloid content and nitrogen fixing potential under shade in a coconut garden by Nair (2000). She has indicated the possibility of introducing *C. ternatea* as an intercrop in coconut garden.

Pilot studies conducted in *C. ternatea* at the College of Agriculture, Vellayani indicated the possibility of introducing *C. ternatea* as an intercrop in coconut garden (Nair, 2000). A few accessions which performed well under shaded condition in a coconut garden were identified. Six selected lines from this study were chosen for a comparative performance evaluation under shaded condition (in a coconut garden) and open condition.

The available literature on *Clitoria ternatea* relevant to the present study is reviewed in this chapter. Wherever relevant literature in *Clitoria* is not available, literature on similar aspects reported in other crops especially legumes is reviewed.

2.1 Crop production and management

Clitoria ternatea is a widespread legume having a pantropical distribution. It grows well in the tropics between 24^0N and 24^0 S. It grows from MSL to 1800 m altitude.

2.1.1 Soil and climate

Clitoria is a sun loving plant which thrives in any well-drained, moist garden soil. According to Chatterjee and Das (1989), it tolerates drought and salinity to some extent.

Clitoria ternatea L. cv. Milgarra is adapted to soil textures from loams to heavy clays and has been the most productive and persistent legume on cracking clayey soils in the seasonally dry tropics of northern Queens land (Hall, 1992).

2.1.2 Cultural practices

Clitoria ternatea is usually propagated by seeds. Seeds should be soaked 24 to 48 hours in water before sowing. Seeds are sown in rows taken at 30 cm spacing (Alencar and Guss, 1985). According to Singh *et al.* (1985) *Clitoria* recorded the highest dry matter yield at 25 cm row spacing. Nair (2000) reported transplanting of three week old seedlings of *C. ternatea* at a spacing of 60 x 60 cm. The possibility for vegetative propagation in *C. ternatea* was suggested by Sunitha (1996).

Chatterjee and Das (1989) suggested to raise *Clitoria* as a rainfed crop as it is drought tolerant. Singh *et al.* (1985) observed that *Panicum antidotale* is a good companion crop for *C. ternatea*.

2.1.3 Pests and diseases

Clitoria is reported to be tolerant to pests and diseases. However, there are a few reports on the occurrence of pests and diseases. It is reported as a host of root knot nematode (Alam, 1981; Ray and Das, 1985). Occurrence of blister beetle in *C. ternatea* was reported by Murugesan *et al.* (1997).

Bock *et al.* (1977) reported a tymo yellow vein virus infecting *Clitoria*. Tewari *et al.* (1981) identified *Clitoria* as a host of pea mosaic virus. Kar and

Das (1988) reported the occurrence of a fungus, *Pseudocercospora clitoriae* on *Clitoria ternatea* in India. A seed borne potyvirus was isolated from *C. ternatea* by Lima *et al.* (1993). Cowpea chlorotic mottle bromovirus (CCMV) could be isolated from *Clitoria ternatea* plants grown in experimental plots at the International Institute of Tropical Agriculture, Nigeria (Thottappilly *et al.*, 1993). A strain of cowpea aphid-borne mosaic virus caused systemic symptoms in *C. ternatea* (Sousa *et al.*, 1996).

Teleomorph of *Uredo goeldii* was reported to occur on *Clitoria fairchildiana* in Brazil (Ferreira *et al.*, 1999).

2.1.4 Harvest and yield

C. ternatea is a medicinally valuable crop. It is grown mainly for its roots and seeds. For biomass, it is harvested at two months after sowing and subsequent cuttings are taken year round (Katiyar *et al.*, 1970). The green yield and dry matter yield of *C. ternatea* were 24.3 t ha^{-1} and 5.4 t ha^{-1} respectively.

2.2 Growth and yield parameters

2.2.1 Biomass yield

The highest drymatter yield in *C. ternatea* (7.99 t ha^{-1}) was reported from three cuts at an interval of 70 days (Alencar and Guss, 1985). An above ground biomass of 4.9 - 9.1 t ha^{-1} from *Cajanus cajan* L, *Crotalaria juncea* L. and *C. ternatea* L. was reported by Ladha *et al.* (1996).

Clitoria ternatea yielded a biomass of 7.2 t ha^{-1} from a crop grown in open and 2.9 t ha^{-1} from a crop grown in shade (Sunitha, 1996).

2.2.2 Shoot growth parameters

Height of plant is one of the deciding factors contributing to increased crop yield especially in case of fodder crops where vegetative growth is more important. Variation in plant length within legumes is purely a function of the genetic make up (Bose, 1963).

According to Bhaskaran (1964) the rate of linear growth in *Rauvolfia serpentina* at pre-flowering, flowering and seed ripening stages was greater than at either seed setting or declining stage. The slow rate of growth during seed setting was attributed to the utilization of metabolic products for seed development. Veerupakshappa (1982) observed negative association of plant length with pod length and number of seeds per pod in cowpea.

In mothbean an increasing trend in plant length throughout the growth period was reported by Kulkarni and Karadge (1991). An increase in plant length may increase transpirational loss of water due to the increase in vegetative growth. This inturn may hinder reproductive growth and ultimately reduce the yield in leguminous crops (Anitha, 1989). A plant height of 3.7 m at three month stage was observed in vegetable cowpea by Jyothi (1995).

Variation in the number of leaves among the accessions may be attributed to the fact that it is purely a function of genetic make up and environmental conditions (Gardner *et al.*, 1988).

Bhaskaran (1964) reported an increasing trend in number of functional leaves till seed setting stage and thereafter their number decreased considerably for rest of the growth period in *Rauvolfia serpentina*. A similar trend in leaf number was reported by Kulkarni and Karadge (1991) in moth bean.

Decrease in the number of leaves during harvest stage in cowpea was reported by Jyothi (1995). It was attributed to leaf shedding during this stage. Nair (2000) reported similar trend in *Clitoria ternatea* from seed setting stage (150 DAS) to seed maturation stage (200 DAS). Frequent light irrigation produced highest number of leaves per plant in vegetable cowpea (Mini, 1997). Decrease in the number of leaves in *Clitoria ternatea* from seeding (150 DAS) to seed maturation (200 DAS) stage was reported by Nair (2000).

2.2.3 Root characters

A well developed root system is characteristic of increased yield in cowpea (Babalola, 1980). In soybean, root length and root girth exhibited an increasing trend upto seed setting stage and then declined (Barber, 1978). Similar trend was observed in *C. ternatea* by Nair (2000).

Anitha (1989) observed that greengram varieties with high root length and spread were low yielding due to increase of vegetative growth at the expense of reproductive growth.

2.2.4 Pod characters

Nair (1966) opined that variation in pod length of cowpea is due to characteristic genetic make up. In intercropping systems with coconut, groundnut, blackgram and greengram recorded a mean pod yield of 825 kg ha^{-1}, 225 kg ha^{-1} and 353 kg ha^{-1} respectively (Lourduraj *et al.*, 1992). *Mucuna pruriens* and *C. ternatea* when grown in open recorded per plant pod yield of 453 g and 398 g respectively on fresh weight basis. However under shaded condition in a coconut garden, the pod yield in *C. ternatea* was only 129 g per plant (Sunitha, 1996).

2.3 Physiological parameters

Photosynthetic efficiency and biomass production of crop plants are positively correlated with total leaf area of the plants (Russell, 1961). Increase in total leaf area results in higher leaf area index (LAI).

The optimum LAI depends not only on the arrangement of leaves within the canopy but also on the light intensity that the canopy receives. Growth will be slow in periods of low light intensity (Bleasdale, 1973).

Dhanram *et al.* (1971) observed that application of nitrogen increased the number of leaves, leaf area index and plant growth in cowpea plants. Ofroi and Sterm (1987) had also made similar observations in cowpea. According to Chatterjee and Das (1989), potassium increases leaf size, leaf weight, number and aperture size of stomata, net photosynthesis and efficiency of CO_2 assimilation in legumes.

Maggie (1989) observed that the LAI of cowpea increased at vegetative and flowering stage (0.85 and 1.50 respectively) and decreased at harvest stage (0.50), due to leaf shedding. Ilangovan *et al.* (1990) opined that larger leaf area index in senna (*Cassia angustifolia* Vahl.) with increased levels of nitrogen might be attributed to the positive influence of nitrogen on leaf area and the number of leaves produced.

Leaf area index (LAI) is the primary factor which determines the rate of dry matter production. It is found to lower during reproductive phase, as vegetative growth is reduced at this phase (Pearce and Mitchel, 1990). In cowpea, high level of nitrogen is found to significantly influence the LAI of cowpea (Geetha, 1999).

According to Haloi and Baldev (1986), NAR and RGR showed high values at initial growth stages compared to reproductive stage in cowpea. As the plant develops and number of leaves increases, more of them get shaded resulting in decrease of photosynthetic rate leading to lower NAR (Pearce and Mitchel, 1990). Downward drift of NAR with plant age was reported Gardner *et al.* (1988). In *Cicer arietinum*, high value of RGR at the initial growth stages was recorded by Haloi and Baldev (1986). Kulkarni and Karadge (1991) observed that in mothbean, RGR was highest during the seed maturation stage. Jyothi (1995) recorded the CGR of cowpea at 30 DAS, 45 DAS and 90 DAS as 0.6, 0.7 and 0.6 respectively. The decline in CGR is attributed to leaf shedding.

Harvest index (HI) varies among the legumes according to their genetic make up. It ranges from 0.30 to 0.65 in different genotypes of cowpea (Maggie, 1989). Dodwad *et al.* (1998) reported that HI was positively correlated with seed yield per plant.

2.4 Nodulation and nitrogen fixation

Leguminous crops have the capacity to fix atmospheric nitrogen in symbiotic association with the bacteria belonging to the genus *Rhizobium* which is often present in the root nodules (Thomas and Shantaram, 1984).

Lohnis (1925) reported that at least 80 to 120 pounds of nitrogen per acre could be added to the soil by growing legumes. According to Mirchandani and Khan (1953) the quantity of nitrogen fixed generally varies with each legume and ranges from 15 to 70 kg ha^{-1}.

Sen and Rao (1953) quantified nitrogen fixed by legumes in soil as 130 kg ha^{-1} annually. According to Russell (1961) it is difficult to estimate the actual amount of nitrogen fixed by leguminous crops in the field because of the difficulty in determining accurately the nitrogen content of soil as well as the amount of denitrification taking place during the growing season.

Cowpea is observed to fix about 201.8 kg ha^{-1} of nitrogen in the soil (Bose, 1963). The nitrogen contributions of legumes can be vital for maintaining soil productivity over long periods. A leguminous crop can add upto 500 kg of nitrogen to soil per hectare per year (NAS, 1979).

Bopaiah (1981) reported that cowpea could fix 198 kg nitrogen ha^{-1} when raised as pure crop. According to Rao (1988) cowpea could fix 74 - 240 kg ha^{-1} of nitrogen annually in tropical conditions.

Sanchez (1993) reported that generally *Mucuna* may fix nitrogen anywhere between 70 and 130 kg ha^{-1}. At Vellayani conditions, *Mucuna pruriens* enhanced soil nitrogen content by 60 kg ha^{-1} whereas *Clitoria ternatea* enhanced soil nitrogen by 70 kg ha^{-1} (Sunitha, 1996).

Greaves and Jones (1950) reported that by returning the legume crop to soil, the soil nitrogen content could be significantly enhanced. According to Russell (1961), legumes did not increase soil nitrogen content under all conditions. He observed that the nitrogen fixed is often transferred to the plant tops and seeds, and hence not much increase may be seen in the soil nitrogen. In case of legumes like peas, beans, soybeans and groundnut, even if their roots were often well nodulated, a large proportion of the nitrogen fixed was removed through seeds, straw and other harvested portions of the crop. However, the need for application of nitrogen was reduced when the crop was preceded by legumes (Saxena and Yadav, 1975; Lal *et al*., 1978; Faroda and Singh, 1983).

Inclusion of legumes in the cropping systems improved soil nitrogen status, thus reducing the need for applying nitrogen to succeeding crop (Palaniappan *et al*., 1976). According to Sen *et al*. (1980), leguminous plants contributed considerable amount of nitrogen through their root nodules and thus indirectly helped in the maintenance of soil fertility. Consequently, a boost in the yield of succeeding crop was obtained (Kushwah and Ali, 1988; Jadhav, 1989).

A marked response to the application of phosphorus on the nodulation and nitrogen fixation in legumes was reported by Sen and Rao (1953). Whyte and Trumble (1953) reported the importance of calcium for nutrition of the legume plant as well as nitrogen fixing bacteria.

Nodulation is poor in seasons characterized by short days or low light intensity. Similar effects were produced by shading. Both the infection of plants by nodule bacteria and the effectiveness of the nodulation in terms of nitrogen fixation improve usually as the supply of light increases (Whyte *et al.*, 1953).

According to Masefield (1955) and Pate (1958), nodulation of legumes was influenced by the flowering time of host. Nutman (1959) suggested that the total nodule activity with regard to nitrogen fixation was related to the number and size of nodules produced, persistence of nitrogen fixing bacteroid containing tissues in the nodules and specific activity of host tissues.

Russell (1961) stated that nodule production is associated with extensive root formation and that nodules of annual legumes tend to die out during active flowering and seed setting stages. According to Bose (1963), legumes with larger number of nodules fix higher amounts of soil nitrogen. The amount of nitrogen fixing is directly related to nodule size and their abundance (Sen and Bhaduri, 1971).

Clitoria belongs to a group of plants which nodulate effectively with a wide range of strains from different genera and species within a group (Date, 1977).

Humphreys (1978) reported that the efficiency of nitrogen fixation in legumes was assessed by comparing the relative plant nitrogen yield with nodule weight.

Growth and nitrogen fixation of soybean was reduced by a tall sorghum intercrop, whereas nitrogen fixation per plant was enhanced by a dwarf sorghum (Wahua and Miller, 1978) indicating that the reduction in yield and nitrogen fixation was partly caused by shading. Nodulation and nitrogen fixation of groundnut was greatly reduced when it was intercropped with maize, sorghum or millets (Nambiar *et al.*, 1983).

Nodulation is the main index of symbiotic nitrogen fixing efficiency in legumes (Venkataraman and Tilak, 1990). According to Chatterjee and Das (1989), the symbiotic effectiveness was more than 80 per cent in *Clitoria*. Higher amount of plant growth regulators such as indole acetic acid (IAA) and substances similar to cytokinin, gibberellic acid and abscisic acid were obtained from mature root nodules of *C. ternatea* when compared to roots. The level of tryptophan precursor of IAA was also higher in the nodules (Roy and Basu, 1992).

Sunitha (1996) reported that the number of root nodules in *C. ternatea* was significantly higher under open condition than under shade. It was 223.25 and 141.5 per cent respectively under open and shaded conditions. Nair (2000) reported that in *C. ternatea*, nodule numbers showed an increasing trend upto seed setting stage and at seed maturation, nodules were absent.

Nitrogen fixation causes the plant to grow faster and increases the need for nutrients and water (Liya *et al.*, 1998). Patra *et al.* (1999) reported that, as the groundnut plants grew older, the number and dry weight of nodules increased, but at later stages of growth the increase was at slower rate. Rajan (1999) recorded a range of 14.4 to 140.0 mg in nodule weight per plant, at 50 per cent flowering in green gram.

Nodule number, weight of nodules per plant and nodule leghaemoglobin content in ten cowpea cultivars were observed to be generally higher in pre-kharif season than in rabi season (Chattopadhyay *et al.*, 2000). High temperature and moisture deficiency were found to be the major causes of nodulation failure, affecting all stages of the symbiosis and limiting rhizobial growth and survival in soil (Hungria and Vargas, 2000).

2.5 Role of nutrients

Too much or too little carbohydrate in the legume may reduce nitrogen fixation (Whyte *et al.*, 1953). Khampare and Khanna (1972) reported that nodulation and nitrogen fixation is affected by the availability of plant nutrients. Sunitha (1996) observed that nutrient uptake in *C. ternatea* was higher under open condition than under shade. She opined that it may be due to better vegetative growth and higher dry matter production under open condition.

2.5.1 Nitrogen

According to Singh (1957), readily available soil nitrogen induced excessive vegetative growth. Mishra and Singh (1968) observed that in soybean, application of nitrogen at 60 kg ha^{-1} had little effect on root length or nodule number per plant. Tisdale and Nelson (1970) reported that excess quantity of nitrogen prolongs growth period and delays crop maturity.

Excess of nitrogen leads to retardation in nodulation (Punnoose and George, 1975; Singh *et al.*, 1999). In legumes, nitrogen uptake varied between 15 to 60 kg ha^{-1} (Mercy, 1981).

Selamat and Gardner (1985) observed that CGR and LAI of *Arachis hypogaea* increased with nitrogen application. LAI of fodder cowpea was maximum when 40 kg ha^{-1} of nitrogen was applied (Jena *et al.*, 1995).

Spacing and nitrogen levels in senna were found to have significant influence on plant height which showed an increasing trend with reduction in spacing and increasing levels of nitrogen. The number of branches also increased with the application of nitrogen (Ilangovan *et al.*, 1990).

Geetha (1999) reported that a starter dose of nitrogen was found to enhance the early growth and establishment of cowpea.

2.5.2 Phosphorus

Robert and Olsen (1944) reported that phosphorus has a beneficial effect on root growth, flowering, pod formation and seed setting in legumes. Tarila and Ormrod (1977) also reported similar observations. Garg *et al.* (1970) found an increase in the number of leaves in cowpea with an increase in the level of phosphorus.

Role of phosphorus in better root growth and nitrogen fixation in leguminous plants had been described by Tamhane *et al.* (1970). According to Tisdale and Nelson (1970), increased phosphorus uptake promotes root proliferation and subsequently root growth. Sinha (1971) reported that in gram (*Cicer arietinum*), phosphorus significantly increased the number and dry weight of nodules and the rate of nitrogen fixation.

In greengram, Panda (1972) observed an increase in plant height with increasing levels of phosphorus. Reddy (1975) also obtained similar results in greengram. Negative influence of phosphorus application on plant height was reported by Kesavan and Morachan (1973) in soybean.

In groundnut, phosphorus has got profound influence on the nodulation and the subsequent nitrogen fixation (Punnoose and George, 1975).

Cassman *et al.* (1980) opined that phosphorus capture by legumes was low as nodulating plants often possess poorly developed root system compared to non-nodulating plants. During the growth of legumes, uptake of phosphorus is in the range of 2.5 to 5.7 kg ha^{-1} (Mercy, 1981).

Arya and Kalra (1988) reported that in summer mung, pod yield, grain yield, dry matter and harvest index were found to increase with increasing levels of phosphorus from zero to 50 kg P_2O_5 ha^{-1}.

Addition of phosphorus to soil in which legumes are grown increases the nitrogen percentage in the tops of the legumes. It also increases the dry matter production. This is attributed to better root development, better nodulation and improved plant metabolism (Chatterjee and Das, 1989).

Improved dry weight of nodules and nitrogen accumulation in nodules by phosphatic fertilization was obtained in cowpea by Mali and Mali (1991).

According to Rajasree (1994), phosphorus influenced the growth and development of roots in legumes. A better root system was observed to enhance the rate of nitrogen fixation, which in turn increased the plant herbage yield. Mishra and Baboo (1999) reported that phosphorus enhances nitrogen fixation capacity of cowpea.

Zaurong and Munns (1980) reported that phosphorus deficiency caused stunting, delay in flowering and rusty appearance of leaflets in *Clitoria*. Acute deficiency of phosphorus can prevent nodulation in legumes (O' Hara *et al.*, 1988).

2.5.3 Potassium

Potassium increases plant height, leaf size, leaf weight, stomata number and their apertures, net photosynthesis and efficiency of CO_2 assimilation in legumes (Chatterjee and Das, 1989).

According to Yahiya (1996), grain legumes in general required high quantity of potassium for normal growth and development as well as for enhancing nodulation and nitrogen fixation.

In vegetable cowpea, potassium helps in effective use of irrigation water and in overcoming summer stress (Geetha, 1999).

2.6 Chemical constituents in *Clitoria ternatea*

Many legumes contain organic chemicals in sufficient quantity to be economically useful for many scientific, technical and commercial applications (Morris, 1999). Useful chemicals are present in various plant parts like seeds, roots, leaves and flowers.

2.6.1 Seeds

According to Chopra *et al.* (1949), seeds in powdered form constitute a more useful and safer medicine than roots. The seeds contain a toxic alkaloid (Burkill, 1935; Quisumbing, 1951) and an yellow fixed oil, gamma-sitosterol (Sinha, 1960a). Dymock *et al.* (1890) reported that seeds contain a bitter resinous principle and tannin.

Nadkarni (1927) observed that the testa of *Clitoria* seed is brittle and cotyledons are starch filled. By thin layer chromatography, Kulshrestha *et al.* (1968) detected the cersulfate positive compounds, adenosine, kaempferol-3-rhamnoglucoside, p-hydroxy cinnamic acid and ethyl-alpha- D-galactopyranoside in seeds.

Debnath *et al.* (1975) reported the presence of palmitic, stearic, oleic and linoleic acids in the seeds of blue and white varieties of *C. ternatea*. According to Joshi *et al.* (1981) the seeds of *C. ternatea* contained 10.2 per cent oil, 38.4 per cent crude protein and 44.8 per cent total sugars. The seed oil contained 18.5, 9.5, 51.4, 16.8 and 3.8 per cent palmitic, stearic, oleic, linoleic and linolenic acids respectively.

According to Mendoza *et al.* (1990), the seed protein content of *Clitoria ternatea*, *Mucuna pruriens*, *Canavalia ensiformis* and *C. gladiata* ranged from 28 to 30 per cent. Fat content in these species ranged from 1.2 to 3.7 per cent.

Clitoria ternatea also contains antifungal proteins and has been shown to be homologous to plant defensins (Osborn *et al.* 1995). Mathias *et al.* (1998) isolated alpha-O-beta-D- glycopyranosyl rotenoid from the methanolic extract of seeds of *Clitoria fairchildiana*.

2.6.2 Roots

Dymock *et al.* (1890) reported the presence of tannin in the root bark of *C. ternatea*. Kapoor (1990) reported the presence of starch, tannin and resin in root bark.

Lin *et al.* (1992) isolated a new rotenoid, 6-deoxyclitoriacetal from the ethanol extract of roots of *C. macrophylla*. *In vitro* tests showed that this compound possessed strong cytotoxic activity against cultured P-388 lymphocytic leukaemia cells. Clitoriacetal is a constituent of the Thai drug "Nantai-yuk".

A rotenoid glucoside, 6-deoxy clitoriacetal-11-O-beta-D-glucopyranoside has been reported from the roots of *Clitoria fairchildiana* by de Silva *et al.* (1998).

2.6.3 Leaves

An O-lactone compound called 'aparajitin' ($C_{26}H_{50}O_2$) was obtained from the alkaloid extract of dried leaves of *C. ternatea* by Tiwari and Gupta (1959). Sinha (1960b) reported the presence of an identical compound in *Clitoria mariana*. Aiyar *et al.* (1973) also reported the occurrence of aparajitin as well as β-sitosterol in the leaves of *Clitoria ternatea*.

2.6.4 Flowers

The use of flower pigments of *C. ternatea* as acid or alkali indicator was reported by Bose (1983). Acetone extract of the flower petals was blue which turned red in the presence of HCl and green in the presence of NaOH. Saito *et al.* (1985) isolated six blue acylated anthocyanins from the blue flowers. Terahara *et al.* (1996) reported the use of five anthocyanins-ternatins A_3, B_4, B_3, B_2 and D_2 from flowers of *Clitoria ternatea* as food colourants.

2.7 Economic importance of *Clitoria*

2.7.1 *Clitoria* as medicine

The root, stem and flowers of blue flowered variety are used for the treatment of snake bite and scorpion sting. Powdered seeds in combination with ginger powder has laxative action. The root of white flowered variety has got alexiteric and antihelminthic properties. It is used for treating tridosha (vata, pitta and kapha), leucoderma and intestinal burning sensation, pain and ulcers (Kirtikar and Basu, 1975).

In experimental rats, *Clitoria ternatea* had shown significant anxiolytic (Singh *et al*., 1977), tranquilizing and antidepressant activities (Singh *et al*., 1979). Root bark is diuretic and laxative (Chopra *et al*., 1980; Agarwal, 1997).

Pharmacognosy, pharmacology, clinical studies and phytochemistry of *Clitoria ternatea* were reviewed by Aulakh *et al.* (1988).

Clitoria ternatea has been considered as best "Medhya Rasayana" by Charak. The root, flower and sometimes the whole plant is used as medicine (Devadas, 1990). Antidiabetic activity of flowers when fed to rats was reported by Sharma and Majumdar (1990).

Home *et al.* (1992) reported that *C. ternatea* is effective for the management of *Alopecia areata* (loss of scalp hair) when included as a constituent in a hair oil.

In Thailand, *Clitoria macrophylla* is used in the treatment of skin diseases and for controlling pests (Lin *et al*., 1992).

The root of *Clitoria ternatea* is regarded as a good brain tonic in the indigenous system of medicine (Upadhye and Kumbhojkar, 1993). It is an ingredient of '*medhyarasayana*', which on administration improved behavioural impairments in mentally retarded people (Ajith, 1993). In children, the rasayana had enhanced intelligence quotient (IQ), haemoglobin content and digestive power (Jessy, 1995).

According to Agarwal (1997), root bark is used as poultice for swollen joints and as an emetic. Rao (1997) reported the use of *C. ternatea* in the palliative treatment of skin diseases.

The root extract of *C. ternatea* along with that of *Aristolochia indica* and *Rauvolfia serpentina* is used in snake bite (Kumar *et al.*, 1998). Antifungal property of *C. ternatea* was reported by Morris (1999). Taranalli and Cheeramkuzhy (2000) reported *C. ternatea* as brain tonic which improved memory and intelligence. Alcoholic extracts of aerial and root parts at 300 mg/kg body weight produced significant memory retention in rats.

2.7.2 *Clitoria* as fodder and food

Clitoria ternatea is considered as a pasture plant of some promise in Kenya. It is mostly used as cover and for green manure, but the leaves and pods are grazed by livestock (Whyte *et al.*, 1953). Katiyar *et al.* (1970) suggested it as a quality feed for sheep with digestibility of dry matter as high as 74 per cent.

The total digestible nutrients was 59.67 kg per 100 kg of drymatter of hay and nutritive ratio being 1:4:23 (Ramratan *et al.*, 1982). Barro and Ribeiro (1983) reported that *Clitoria* yielded 18 - 19 t ha^{-1} of hay annually.

Upadhyaya and Pachauri (1983) reported that the hay obtained from the aerial parts of *C. ternatea* yielded 97.6 per cent dry matter with 13 per cent crude protein. *C. ternatea* is one of the most persistent legumes for pasture establishment under favourable conditions (Wandera, 1984). According to Yadav (1984), the herbage of *C. ternatea* contained 21 per cent crude protein with 74.2 per cent digestibility. Hence, it could be utilized as a fodder for goats and cattle.

According to Adjei and Fianu (1985), leaf crude protein content of *C. ternatea* was 24 per cent and the yield was 26 t ha^{-1}. Pachauri and Patil (1985) reported that *Clitoria* had high protein content during first and second months of growth. Forage legumes formed an important part of rations of livestock as they are also rich in calcium, vitamin A, riboflavin, niacin and vitamin E. The *in vitro* protein digestibility (IVPD) of the raw mature seeds ranged from 70 to 78 per cent (Laurena *et al.*, 1991).

2.7.3 *Clitoria* as green manure and cover crop

Clitoria ternatea is a tall, slender climber often used as a soil cover and as green manure (Whyte *et al.*, 1953).

Thomas and Shantaram (1984) reported the possibility of growing leguminous cover crop as green manures in coconut basins.

Rehm and Espig (1991) reported *C. ternatea* as good ground cover plant. According to Peoples and Grey (1995), the mean nitrogen accumulation in leguminous cover crops is high, about 100 kg ha^{-1}.

2.7.4 *Clitoria* as a source of dye and fibre

Burkill (1935) suggested that the juice of leaves of *Clitoria* could be used to impart green colour to food.

The blue flowers of *C. ternatea* gave temporary colour to white cloth (Burkill, 1935) Blue flowers were boiled with rice to give it a bluish tinge (Uphof, 1968 and Abbiw, 1990) and to dye mats (Allen and Allen, 1981).

The use of flowers as colourants was also reported by Kunkel (1984) and Ambasta (1986). Abbiw (1990) reported that both seeds and corolla were used as litmus substitute. The flowers provide a blue food colouring for meals and drinks (Rehm and Espig, 1991).

Stem of *Clitoria lasciva* is the source of a fibre used by natives of Madagascar for making ropes (Uphof, 1968).

2.7.5 *Clitoria* as an ornamental plant

Clitoria ternatea is a common ornamental flowering garden plant in India and occurs as hedges all over tropical region from Himalayas to Sri Lanka (Agarwal, 1997).

The species of *Clitoria* cited as ornamentals include *Clitoria javitensis*, *Clitoria ternatea* (NAS, 1979), *C. mariana*, *C. fairchildiana* and *C. falcata* (Allen and Allen, 1981).

C. ternatea is the most widely cultivated ornamental in East Africa (Breyne, 1678). Cultivated species of ornamental value include double flowered forms namely *C. ternatea* var. pleniflora (Commelin, 1701), white - flowered forms namely *C. ternatea* var. *ternatea* f. *albiflora* (Tournefort, 1706) and *Clitoria heterophylla* (Curtis, 1820).

Petiver (1704) reported the cultivation of *C. mariana* for ornamental purpose in United States. *C. cajanifolia* is a subshrub species of *Clitoria* that is native to neo-tropics (Holland and Joachin, 1933).

2.8 Intercropping in coconut garden

The practice of intercropping in coconut garden is in vogue since ancient times. The major objectives in intercropping are to produce an additional crop without affecting too much the yield of base crop, to obtain higher economic returns, to optimize the use of natural resources including water and nutrients and to stabilize the yield of crop (Donald, 1963).

Several reports are available on the successful intercropping of medicinal plants in coconut gardens (Singh *et al.*, 1990 and Nair *et al.*, 1991). Jha and Gupta (1991) studied intercropping of medicinal plants with poplar and described their phenology.

Nair *et al.* (1991) by intercropped 13 medicinal and aromatic plants in a 12 year old coconut plantation and revealed the possibility of growing these plants as intercrops in 8-20 year old coconut plantation when no other intercrops are usually recommended. Shade did not adversely affect the growth of the plants studied.

2.9 Legumes as intercrop in coconut garden

Tremendous potentiality and possibility exist in intercropping promising legumes in coconut plantations. Legumes have the potential to transfer the excreted nitrogen to the associated non-legumes and hence play an important role in the intercropping system (Virtanen *et al.*, 1937 and Ruschel *et al.*, 1979).

Catedral and Lantican (1977) reported that artificial shade of 40 to 50 per cent caused an yield reduction of 30 per cent compared to that in full sunlight for soybeans and about 70 per cent for mungbeans.

According to Nair (1979), almost all tropical grain legumes are very sensitive to the partial shade existing in coconut gardens. Besides other intercrops such as tapioca, sweet potato, yams, colocasia, turmeric, ginger, banana etc., legumes also can be profitably cultivated as intercrops in coconut gardens (Bopaiah, 1981).

Sunitha (1996) reported that biomass yield of *Clitoria ternatea* in coconut shade was only 2.3 t ha^{-1}. Reduction in soybean yield and yield components due to different levels of shading was reported by Jegathambal and Karivaradaraaju (1999).

2.10 Residual effect of intercropping in soil

Intercropping systems involving legumes apart from giving additional income leave a significant amount of residual effect which could be made use of by the succeeding crop (Hegde and Pandey, 1992).

Ayyangar (1942) found that intercropped legume increased the available phosphorus, potassium and calcium in the soil.

Available phosphorus content of the soil increased with crop sequences inclusive of legumes (Sharma and Singh, 1970; Bindhu, 1999). White *et al.*, (1976) reported that total nitrogen content of the soil was increased by growing forage grasses. More nitrogen fixation was recorded in shade than in open areas by Skerman (1977).

The nodulated legumes contribute a good deal of the amount of nitrogen fixed in the soil (Bopaiah, 1981). A reduction in soil pH due to intercropping was recorded by Pillai (1985). He also noted a reduction in available nitrogen content of the soil whereas the phosphorus and potassium content of the soil were not affected much by intercropping.

Bavappa *et al.* (1986) reported that there was a build up of phosphorus and potassium nutrients in the coconut and arecanut based high intensity multispecies cropping system.

The net increase in inorganic nitrogen resulting from mineralization, after cultivation of *Mucuna* varied from 60 to 165 kg ha^{-1} (Flores, 1999).

2.11 Medicinal legumes as pure crop in open

Reports are very few on cultivation of medicinal legumes as pure crop. However, various aspects on the scientific cultivation of *Mucuna pruriens* was reported by Bammi and Rao (1982). Kapur and Atal (1982) had reported on the cultivation and utilization of senna in India. Senna is suited to drier tracts where coconut and other plantation crops do not perform well.

Agrotechnical studies on *Indigofera tinctoria* in experimental plots by Nair *et al.* (1990) revealed that the plant if cultivated in a scientific way, could provide 210 kg leaves from 10 cents of land.

The uptake of nitrogen, phosphorus and potassium was significantly higher under open condition in *Clitoria ternatea* (Sunitha, 1996). She also reported a higher biomass yield and nodule number under open conditions.

2.12 Performance of crops under shade and open conditions

According to Watson (1958), the amount of light energy intercepted by a crop is a major discriminant in crop production.

Soybean grown under 70 per cent shade grew much taller than those in the light (Allen, 1975). Tarila *et al.* (1977) reported that high intensity of light reduced plant height in cowpea. Positive influence of shade on plant height was reported in cassava (Ramanujam *et al.*, 1984; Sreekumari *et al.*, 1988), in broadbean (Xia, 1987) and in colocasia (Prameela, 1990). In ginger, plant height was found to increase with increase in shade intensity from zero to 75 per cent (Jayachandran *et al.*, 1991). In *Clitoria ternatea*, plant height at the time of harvest (180 DAS) under open and shade conditions were 420 cm and 309 cm respectively (Sunitha, 1996).

Blackman and Black (1959) suggested that reduction in plant length under shade may be due to the physiological and ecological influence, especially light, which limits growth of crops in mixtures. According to Anilkumar (1984) reduced plant height in crop mixtures may result from an unfavourable situation caused by the competition for water, nutrients and light.

Prabhakar *et al.* (1979) obtained higher leaf number in plots of cassava where no intercrop was raised. The leaf number decreased when grown under shade in coconut gardens (Sreekumari *et al*., 1988). Susan (1989) observed a decrease in the number of leaves with shading in ginger and turmeric. Sunitha (1996) reported higher number of leaves in *Clitoria ternatea* under open condition (582.1) when compared to shade condition (293). Leaf production in ginger under 20 per cent shade was found to be significantly superior compared to other higher levels of shade (Sreekala, 1999).

Bai (1981) reported that leaf area was not influenced by different intensities of shade in ginger, turmeric and coleus.

Root and bud growth are usually inhibited by low light intensities and this can lead to a reduction in assimilate flow to the root system (Nelson, 1964). Root length and number of lateral roots were more under open condition in *Clitoria ternatea* and *Atylosia scarabaeoides* (Sunitha, 1996). She also reported that root yield was significantly greater under open condition than under shade. The number and fresh weight of root nodules were significantly higher under open condition.

The maximum amount of dry matter production by a crop was strongly correlated with the amount of light intercepted by its foliage (Monteith, 1977). The biomass yield was significantly superior under shade condition in *Mucuna pruriens* and *Cassia mimosoides*. But in *Clitoria ternatea, Abrus precatorius*, *Crotalaria verrucosa* and *Atylosia scarabaeoides*, higher yield was obtained when they were grown under open condition (Sunitha, 1996).

Crop growth rate (CGR) of cassava grown under shade was reduced significantly when compared to those plants grown under normal light

(Ramanujam and Jose, 1984). Similar trend was observed in turmeric cultivars also.

Relative growth rate (RGR) showed a positive correlation with shade in rice (Jadhav, 1987).

Blackman and Wilson (1951), Newton (1963) and Coombe (1966) reported a positive correlation in crop plants between net assimilation rate (NAR) and irradiance. Ramanujam and Jose (1984) reported reduced NAR of cassava grown under shade compared to those plants grown under normal light. Ravisankar and Muthuswamy (1986) reported a significant negative correlation of NAR with light intensity in ginger raised in arecanut garden.

Sorenson (1984) observed higher leaf area ratio with higher shade intensity in winged bean. According to Babu (1993), leaf area duration (LAD) was lowest under open conditions in ginger plants.

Ancy (1992) observed a steady decrease in harvest index (HI) with increase in shade levels in ginger. The highest harvest index was observed in ginger under open condition (Susan, 1989).

The uptake of nutrients was greater under open condition in *Abrus precatorius*, *Clitoria ternatea*, *Atylosia scarabaeoides* and *Crotalaria verrucosa* than under shade (Sunitha, 1996). She added that there was no significant difference in the content of the chemically active principle in these species grown under both conditions of light.

2.13 Correlation studies

Positive association of plant height and yield was presented by Doss *et al.* (1974) in soybean. In blackgram, grain yield is positively correlated with harvest index (Kavitha, 1982). Significant positive correlation of seed yield with height of the plant, number of pods per plant and number of seeds per pod was reported in cowpea by Singh *et al.* (1982) and Jindal and Gupta (1984). Leaf area and biomass production was positively correlated in cowpea (Natarajaratnam *et al.*, 1984).

In cowpea, pod yield showed positive association with number of pods per plant (Sharma *et al.*, 1988; Sreekumar *et al.*, 1996; Resmi, 1998; Pournami, 2000; Vidya, 2000). Under partially shaded conditions, Abraham *et al.* (1992) reported a positive correlation of seed yield per plant with height, pods per plant and harvest index in blackgram. Pundhir *et al.* (1992) recorded significant positive correlation between pod length and seeds per pod in greengram.

A study conducted by Renganayaki and Sree Rengaswamy (1992) in cowpea revealed that seed yield per plant showed significant and positive association with total dry matter production, pod length and seeds per pod.

Naidu *et al.* (1994) reported significant association between clusters per plant and pods per plant whereas non significant positive association of pod length with seeds per pod was noticed. Sawant (1994) found that seed yield was significantly and positively associated with branches per plant, pods per plant, pod length, seeds per pod and harvest index in cowpea.

Tamilselvam and Vijendradas (1994) recorded significant positive correlation of seed yield per plant with plant height, branches per plant, clusters per plant pods per plant, pod length and seeds per pod in cowpea.

Naidu *et al.* (1996) concluded from their correlation studies in cowpea that seed yield per plant was significantly correlated with pods per plant and pod length, whereas seeds per pod showed non significant positive correlation with seed yield.

Samuel (2000) reported that a definite positive association can be made between plant length and shoot yield in *Mucuna pruriens*.

Materials and Methods

3. MATERIALS AND METHODS

The study entitled 'Evaluation of selected Sankhupushpam (*Clitoria ternatea* L.) lines for yield, alkaloid content and nodulation' was carried out at the Department of Plantation Crops and Spices, College of Agriculture, Vellayani from June to December 2000. The details of the materials used and the methods adopted during the course of research work are presented in this chapter.

3.1 Seed selection, characterization and germination studies

Seeds of six selected superior lines obtained from the preliminary genetic stock evaluation trial of *Clitoria ternatea* by Nair (2000) were collected for the study. The details of selected accessions are presented in Table 1.

Table 1. Details of *Clitoria ternatea* accessions selected for the study

Sl. No.	Accession No.	Primary source / place of collection	Flower colour and type
1	MP–73	Thiruvattar	White, single floret
2	MP–74	Vattiyoorkavu	Blue, single floret
3	MP–76	Vattiyoorkavu	White, single floret
4	MP–81	Vellayani	Blue, double floret
5	MP–83	Thirumala	Blue, single floret
6	MP–85	Thirumala	White, single floret

Observations such as hundred seed weight, seed colour, external appearance of seeds, germination percentage and days to 50 per cent germination were made on all the six accessions.

For recording hundred seed weight, 100 well filled seeds were physically counted and weighed in a digital electronic balance. Six such replications were made for each accession and the mean worked out. The colour and external characteristics of the seeds were noted by close observation using a hand lens (10x) during day time under sunlight.

Seeds were tested for viability as described below. Twenty seeds of each accession were surface sterilized using 0.1 per cent mercuric chloride for one minute and then washed thrice with distilled water. The seeds were then placed on moistened filter paper in petridishes. Seeds were considered to have germinated when the radicle emerged out of the seed coat. From the second day, seed germination count was taken and germination percentage of each accession was determined. The number of days taken for 50 per cent seed germination in each accession was also recorded.

3.2 Cultural trial of selected accessions as intercrop in coconut garden vis-à-vis as pure crop in open

3.2.1 Experimental site

Two sets of experiments were conducted for the study, one under open condition and the other under shaded condition in a nineteen year old coconut garden at the College of Agriculture, Vellayani. The location is situated at

Plate 1. Field view of the experimental plot

A. Crop in open condition

B. Crop under shade (as intercrop) in coconut garden

1

A

B

8^0 $5'$ North latitude, 77^0 $1'$ East latitude and at an altitude of 29 m above the mean sea level. The area enjoys a humid tropical climate. Soil of the experimental site is red loam belonging to Vellayani series.

3.2.2 Weather

Climatic parameters like temperature, relative humidity, rainfall and number of rainy days during the period of study are presented in Appendix I.

3.2.3 Experimental design and layout

The experiment was laid out in two randomised block designs with three replications separately for shade and open conditions. Forty-five plants of each accession were maintained in each plot at a spacing of 60 x 60 cm. Plot size was 5.4 x 3.0 m.

The land was thoroughly prepared by digging and powdered cowdung was incorporated at the rate of 3 kg m^{-2}. Seeds were sown in polythene covers filled with sand and watered daily. Seedlings were transplanted three weeks after sowing. Staking was done using casuarina poles one month after transplanting.

Destructive sampling was carried out for taking observations on the biometric traits at four growth stages, *viz.*, pre-flowering stage (45 DAS), flowering stage (90 DAS), seed formation stage (135 DAS) and seed maturation stage (180 DAS). Three plants per plot per replication were utilized for the periodic sampling. After taking biometric observations, samples were partitioned to stem, roots, leaves and pods for growth and yield analysis. The average of three plants per plot is taken for biometric observations, yield attributes and nodule characteristics.

3.2.4 Growth parameters

The following biometric observations were taken at four growth stages, *viz*., pre-flowering stage (45 DAS), flowering stage (90 DAS), seed formation stage (135 DAS) and seed maturation stage (180 DAS).

3.2.4.1 Plant length (cm)

Plants selected at random for periodical harvest and observation, were uprooted and plant length was measured from the collar region to the tip of the plant.

3.2.4.2 Number of leaves

Number of leaves in each observational plant were counted and recorded.

3.2.4.3 Leaf area (cm^2)

Ten leaves were taken at random from each sample plant. The leaf area of each was worked out by making use of graph paper. The mean value was worked out and recorded.

3.2.4.4 Number of pods per plant

Number of pods in each observational plant were counted and recorded.

3.2.4.5 Pod length (cm)

The length of ten pods selected at random from each observational plant was measured during the seed formation and seed maturation stages using a measuring scale. The mean value was worked out and recorded.

Plate 2. Variation in *Clitoria ternatea* accessions selected for evaluation: floral characters

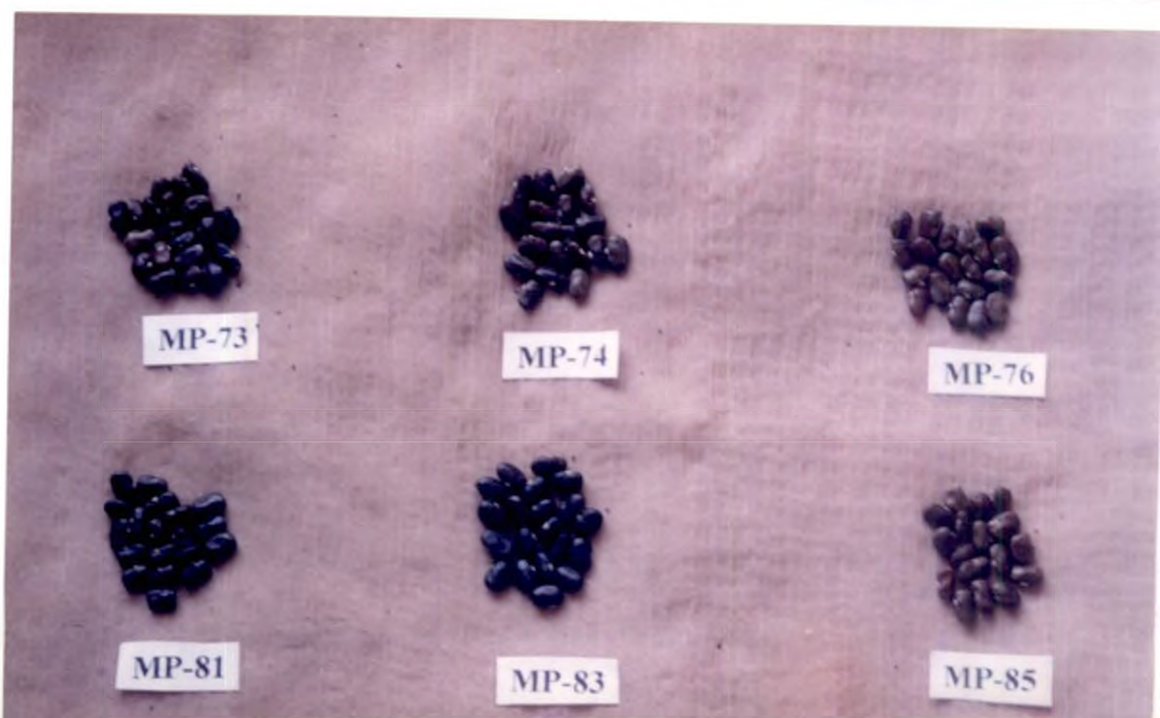
A. White flower (MP-73)

B. Blue double floret (MP-81)

C. Blue single floret (MP-74)

Plate 3. Variation in *Clitoria ternatea* accessions selected for evaluation: seed characters

2



3.2.4.6 Number of seeds per pod

Number of seeds in each pod of the observational plants were counted and the mean value was worked out.

3.2.4.7 Root length (cm)

Each sample plant was uprooted. The taproot and lateral roots were aligned together. Root length was measured from the collar region to the farthermost tip of the root system.

3.2.4.8 Root girth (cm)

Root girth at collar region was measured in each sample plant using a thread and measuring scale.

3.2.5 Yield attributes

3.2.5.1 Fresh and dry weight of leaves (g)

Fresh weight of leaves of each observational plant was taken separately using a Digiweigh (IPA scale) Model ITB 22/01 electronic balance. Leaf samples were then dried in a hot air oven at 60^0C for five days until consistent dry weights were obtained.

3.2.5.2 Fresh and dry weight of shoots (g)

Fresh weight of shoot portion of each observational plant was taken. The samples were then oven dried at 60^0 C until consistent dry weights were obtained.

3.2.5.3 Fresh and dry weight of roots (g)

Fresh and dry weight of the root portion of each observational plant were taken using a Digiweigh (IPA scale) Model ITB 22/01 electronic balance.

3.2.5.4 Fresh and dry weight of pods (g)

The pods from observational plants were collected and fresh weight was recorded. The pods were then dried in a hot air oven at 60^0C until consistent dry weights were obtained.

3.2.6 Root nodules

3.2.6.1 Number of effective root nodules

Total count of effective root nodules in each observational plant was recorded after detaching them from the root system.

3.2.6.2 Fresh and dry weight of root nodules (g)

Fresh weight of effective root nodules obtained from each observational plant was taken using a Sartorius analytic electronic balance. Root nodules were then dried in a hot air oven at 60^0C for three days until consistent dry weights were obtained.

3.2.7 Physiological parameters

3.2.7.1 Leaf area index (LAI)

Leaf area was measured using graph paper. The LAI was worked out based on the method suggested by William (1946).

$$\text{LAI} = \frac{\text{Total leaf area of the plant } (m^2)}{\text{Area of land covered by the plant } (m^2)}$$

Plate 4. Pods of *Clitoria ternatea* (MP-73)

Plate 5. Root nodules of *Clitoria ternatea* (MP-76) at 90 DAS in open condition


VIKAS
4


5

3.2.7.2 Leaf area duration (LAD) (days)

Leaf area duration was calculated using the formula given by Power *et al.* (1967).

$$LAD = \frac{(L_1 + L_2) \times (T_2 - T_1)}{2}$$

Where, L_1 : LAI at time T_1

L_2 : LAI at time T_2

$T_2 - T_1$: time interval in days

3.2.7.3 Net assimilation rate (NAR) (g m^{-2} day^{-1})

The method proposed by William (1946) was employed for calculating NAR on leaf dry weight basis.

$$NAR = \frac{(W_2 - W_1)\ (\log_e W_2 - \log_e W_1)}{(T_2 - T_1)\ \ (L_2 - L_1)}$$

where,

W_1, W_2 : dry weights of whole plant in g at time T_1 and T_2 respectively

L_1, L_2 : leaf area of the plant in m^2 at time T_1 and T_2 respectively

$T_2 - T_1$: time interval in days

3.2.7.4 Crop growth rate (CGR) (g m^{-2} day^{-1})

The CGR was worked out by using the formula of Watson (1958).

$$CGR = \frac{(W_2 - W_1)}{P\ (T_2 - T_1)}$$

where,

W_1, W_2 : whole plant dry weights in g at time T_1 and T_2 respectively

$T_2 - T_1$: time interval in days

P : ground area in m^2 on which W_1 and W_2 are estimated.

3.2.7.5 Absolute growth rate (AGR) (g day^{-1})

The AGR was determined using the formula given by Watson (1958).

$$AGR = \frac{(W_2 - W_1)}{(T_2 - T_1)}$$

where,

W_1, W_2 : plant dry weights in g at time T_1 and T_2 respectively

$T_2 - T_1$: time interval in days

3.2.7.6 Relative growth rate (RGR) (g day^{-1})

The RGR was determined by utilizing the formula given by William (1946).

$$RGR = \frac{\log_e W_2 - \log_e W_1}{T_2 - T_1}$$

Where,

W_1, W_2 : plant dry weights at time T_1 and T_2 respectively

$T_2 - T_1$: time interval in days

3.2.7.7 Harvest index (HI)

Harvest index was calculated in terms of pod yield and root yield. Harvest index (pod yield) was worked out from the data of pod yield and biological yield (total plant dry matter). Harvest index (root yield) was obtained from root yield and biological yield (total plant dry matter). Harvest index was calculated using the formula,

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.3 Phytochemical analysis

3.3.1 Soil NPK analysis before and after the experiment

Soil samples were drawn individually from every plot before the commencement of the experiment and after the harvest of the crop. Samples were taken at 0-15 cm depth, air-dried and passed through a 2 mm sieve.

The available nitrogen status was estimated using the alkaline potassium permanganate method (Subbiah and Asija, 1956) and expressed in kg ha^{-1}.

Bray's colourimetric method (Jackson, 1973) was used to estimate the available phosphorus.

The available potassium content was estimated using the ammonium acetate method given by Jackson (1973).

3.3.2 Nitrogen content of the plant (per cent)

Estimation of nitrogen content of plant samples collected from open and shaded conditions was carried out. The plant samples were oven dried for five days at 60^0C and ground to fine powder and subjected to diacid digestion. Nitrogen content of the plant was determined by modified Kjeldahl method (Piper, 1966).

3.3.3 Crude seed alkaloid content (per cent)

The crude alkaloid content of the seeds was estimated gravimetrically by solvent extraction of the powdered material (Sunitha, 1996).

3.3.3.1 Extraction of alkaloids

The powdered seed material was eluded with lime solution. The solution was filtered and the filtrate was taken in a separating funnel. About 80 ml of ether (organic solvent) was added to the filtrate. The solvent layer was retained in the funnel and was treated with dilute sulphuric acid (1 : 4 dilution) to get the alkaloid precipitated.

This was then filtered through a muslin cloth and was air dried. A light brown precipitate was obtained. It was dried until consistent weights were obtained.

3.3.4 Incidence of pests and diseases

Throughout the duration of the crop, periodical surveillance was conducted for detection of pests and diseases. However, no serious incidence was noticed.

3.4 Statistical analysis

3.4.1 Analysis of variance

Qualitative as well as quantitative traits of all the six accessions under trial were recorded. Analysis of variance as applied to randomised block design proposed by Cochran and Cox (1965) was used to find out whether there was significant difference among the accessions in respect of various traits. The significance was tested by F test (Snedecor and Cochran, 1967).

Pooled analysis as proposed by Panse and Sukhatme (1967) was carried out wherever possible after checking the error homogenity for yield and yield attributes and nodule characteristics to find out whether there was significant difference between shade and open conditions.

3.4.2 Correlation analysis

The phenotypic correlation coefficient between two characters X and Y was estimated as r_p (x, y).

$$r_p(x, y) = \frac{Cov_{(p)}(x,y)}{\sqrt{V_{(p)}x \times V_{(p)}y}}$$

Where $Cov_{(p)}$ (x,y) denote the phenotypic covariance between the characters X and Y estimated by taking the respective expected values of mean sum of products. $V_{(p)}x$ and $V_{(p)}y$ indicate the estimated phenotypic variances for X and Y respectively.

The genotypic correlation coefficient g_p (x, y) between the characters X and Y were estimated by using the genotypic variances and covariance between the two characters.

$$g_p(x, y) = \frac{Cov_{(g)}(x,y)}{\sqrt{V_{(g)}x \times V_{(g)}y}}$$

Where $Cov_{(g)}$ (x,y) denote the genotypic covariance between the characters X and Y. $V_{(g)}x$ and $V_{(g)}y$ indicate the estimated genotypic variances for X and Y respectively.

3.4.3 Selection index

The six accessions were discriminated based on sixteen selected important characters using the selection index developed by Smith (1937) and the discriminant function of Fisher (1936).

The selection index is described by the function, $I = b_1X_1 + b_2X_2 + \ldots b_k X_k$ where $X_1, X_2 \ldots X_k$ denote the mean values of the sixteen characters used in the study. The 'b' coefficients of the function were obtained by solving a set of simultaneous equations. These equations were derived by maximising the correlation between the genetic worth based on genotypic variance covariance matrix and phenotypic performance of the characters.

Based on the index I, index scores were calculated with respect to each accession and the accessions were ranked.

Results

4. RESULTS

The results of the study on 'Evaluation of selected Sankhupushpam (*Clitoria ternatea* L.) lines for yield, alkaloid content and nodulation' are presented in this chapter. Six lines found to be promising by Nair (2000) for cultivation under shade in a coconut garden were selected for further detailed study in the present experiment both under shade in a coconut garden and as a pure crop in open condition.

4.1 Seed selection, characterization and germination studies

Seeds of six superior lines of *Clitoria ternatea* identified in an earlier trial by Nair (2000) were collected. The accessions selected were MP-73, MP-74, MP-76, MP-81, MP-83 and MP-85.

Seeds of selected accessions were subjected to germination test. Observations such as hundred seed weight, seed colour, external appearance of seeds, germination percentage and days to fifty per cent germination were recorded for each accession. The details of seed characterization and germination studies are given in Table 2.

4.2 Cultural trial of selected accessions as intercrop in coconut garden and as pure crop in open

The selected accessions were raised in randomised block design with three replications each for shade as well as open condition. Observations were

Table 2. Seed characterization and germination studies of *Clitoria ternatea* accessions

Sl. No.	Accession No.	Seed colour and external appearance	100 seed weight (g)	Seed germination percentage	Number of days to 50 per cent germination
1.	MP – 73	Light brown and cylindrical	4.0	90	14
2.	MP – 74	Brown	5.5	75	19
3.	MP – 76	Light brown and cylindrical with hilum	6.0	70	21
4.	MP – 81	Dark brown with pure white hilum	5.5	70	21
5.	MP – 83	Dark brown and oval	4.0	85	18
6.	MP – 85	Light brown	5.0	82	17

made at four stages of growth *viz.*, pre-flowering stage (45 DAS), flowering stage (90 DAS), seed formation stage (135 DAS) and seed maturation stage (180 DAS).

4.2.1 Growth parameters

4.2.1.1 Plant length (Table 3)

At pre-flowering stage, no significant difference in plant height was noted among the accessions both under shade and open conditions.

At flowering stage also no significant difference could be noticed among the selected accessions under shade, but significant difference was noticed under open condition. Maximum plant length was recorded by MP-76 (142.91 cm) closely followed by MP-81 (140.20 cm). MP-76 (142.91 cm), MP-81 (140.20 cm) and MP-74 (134.06 cm) were statistically on par. The least plant length was recorded by MP-85 (127.56 cm).

At seed formation stage, there was significant difference among the accessions under both conditions. Maximum plant length under shade condition was recorded by MP-76 (157.56 cm). It was on par with MP-73 (155.22 cm) and MP-83 (145.11cm). The lowest plant length under shade condition at seed formation stage was recorded by MP-81 (126.34 cm). Under open condition, MP-81 (219.12 cm) recorded the maximum plant length. All the other accessions were on par. However, the least value for plant length was recorded by MP-85 (161.49 cm).

At the seed maturation stage, there was significant difference among the accessions under both conditions. Under shade condition, maximum plant length was recorded by MP-76 (191.56 cm). MP-74 (166 cm) recorded the least plant length under shade condition, and it significantly differed from all other accessions. Under open condition, MP-81 (257 cm) recorded the highest value for plant length. MP-76 (247.89 cm) was on par with MP-73 (242.66 cm). Least plant length was recorded by MP- 74 (227.78 cm).

The plant length was more in open condition than that in shaded condition at all the four stages and irrespective of the light condition, MP-76 showed superior performance.

4.2.1.2 Number of leaves per plant (Table 4)

At pre-flowering stage, there was significant difference among the accessions in number of leaves under shade condition. Maximum number of leaves was recorded by MP-81 (10.89) and MP-73 (10.89), closely followed by MP-85 (10.55). These were on par with MP-76 (9.22) and MP-83 (8.99) Lowest number of leaves was observed in MP-74 (5.33). Under open condition there was no significant difference among the accessions.

At flowering stage, number of leaves differed significantly among the six accessions under open condition, whereas no significant difference was observed under shade condition. Under open condition, maximum number of leaves was recorded by MP-76 (211. 89) followed by MP-81 (169.89). The lowest number of leaves was recorded by MP-74 (108.44), preceded by MP-83 (111.11).

Table 3. Growth parameters of *Clitoria ternatea* at four growth stages : plant length (cm)

Sl. No.	Accession No.	Pre-flowering (45 DAS)		Flowering (90 DAS)		Seed formation (135 DAS)		Seed maturation (180 DAS)	
		Shade	Open	Shade	Open	Shade	Open	Shade	Open
1.	MP – 73	64.01	72.22	89.28	129.81	155.22	168.51	174.00	242.66
2.	MP – 74	22.88	45.49	89.88	134.06	129.33	163.53	166.00	227.78
3.	MP – 76	60.52	80.37	93.91	142.91	157.56	171.58	191.56	247.89
4.	MP – 81	56.05	78.09	83.38	140.20	126.34	219.12	176.33	257.00
5.	MP – 83	37.15	62.23	75.50	130.73	145.11	165.88	178.45	234.45
6.	MP – 85	56.93	62.44	99.36	127.56	142.45	161.49	188.55	237.67
CD (0.05)	-	NS	NS	NS	10.26	14.51	18.25	6.63	5.71

Table 4. Growth parameters of *Clitoria ternatea* at four growth stages : number of leaves per plant

Sl. No.	Accession No.	Pre-flowering (45 DAS)		Flowering (90 DAS)		Seed formation (135 DAS)		Seed maturation (180 DAS)	
		Shade	Open	Shade	Open	Shade	Open	Shade	Open
1.	MP – 73	10.89	24.00	30.00	135.33	140.55	302.78	126.78	270.78
2.	MP – 74	5.33	14.33	19.78	108.44	130.56	284.33	93.89	248.44
3.	MP – 76	9.22	24.89	50.00	211.89	146.33	279.11	104.89	257.34
4.	MP – 81	10.89	22.78	32.99	169.89	88.44	308.89	79.22	267.67
5.	MP – 83	8.99	17.56	22.89	111.11	124.78	257.89	95.33	239.22
6.	MP – 85	10.55	26.56	54.22	144.89	125.78	243.33	96.78	223.67
CD (0.05)	-	3.25	NS	NS	13.80	14.57	31.41	12.83	8.77

NS – Not significant
DAS – Days after sowing

At seed formation stage, the number of leaves differed significantly among the six accessions under both shade and open conditions. Under shade, maximum number of leaves was recorded by MP-76 (146.33). It was on par with MP-73 (140.55). MP-81 (88.44) recorded the lowest number of leaves. Under open condition, MP-81 (308.89) recorded the highest number of leaves, followed by MP-73 (302.78). The least was recorded by MP-85 (243.33).

At seed maturation stage, all the accessions showed significant difference among them under both shade and open conditions. Under shade condition, MP-73 (126.78) recorded the highest number of leaves. MP-76 (104.89), MP-85 (96.78) and MP-83 (95.33) and MP-74 (93.89) were on par. The least number of leaves was recorded by MP-81 (79.22). Under open condition, maximum number of leaves was observed in MP-73 (270.78) closely followed by MP-81 (267.67). MP-85 (223.67) recorded the least number of leaves.

4.2.1.3 Leaf area (Table 5)

Leaf area differed significantly among the accessions at all the four stages of growth under open as well as shaded conditions.

At pre-flowering stage, under shade condition, maximum leaf area was recorded by MP-73 (435.71 cm^2) followed by MP-76 (346.28 cm^2). The leaf area was found to be the least in MP-83 (141.75 cm^2). Under Open condition, leaf area was found to be maximum in MP-76 (1256.40 cm^2). It was on par with MP-73 (1105.20 cm^2). MP-83 (292.80 cm^2) recorded the lowest leaf area.

At flowering stage, highest leaf area was recorded by MP-76 (1876.95 cm^2) under shade condition followed by MP-85 (1576.67 cm^2) and MP-73 (1204.97 cm^2)

Table 5. **Growth parameters of *Clitoria ternatea* at four growth stages : leaf area (cm^2)**

Sl. No.	Accession No.	Pre-flowering (45 DAS)		Flowering (90 DAS)		Seed formation (135 DAS)		Seed maturation (180 DAS)	
		Shade	Open	Shade	Open	Shade	Open	Shade	Open
1.	MP – 73	435.71	1105.20	1204.97	6217.20	5574.57	13953.60	4976.04	12481.20
2.	MP – 74	154.02	602.40	568.52	3554.40	3753.89	7812.00	2697.55	7034.40
3.	MP – 76	346.28	1256.40	1876.95	7491.60	5482.26	9367.20	3922.34	8678.40
4.	MP – 81	179.32	295.20	559.37	2203.20	1499.12	4006.80	1342.93	3474.00
5.	MP – 83	141.75	292.80	360.23	1897.20	1963.39	4428.00	1500.24	3967.20
6.	MP – 85	307.23	624.00	1576.67	3402.00	3644.68	5698.80	2813.11	5256.00
CD (0.05)	-	95.05	463.71	922.95	884.82	465.69	1359.70	257.81	1460.55

DAS – Days after sowing

Least leaf area was recorded by MP-83 (360.23 cm^2). Highest leaf area at flowering stage was recorded by MP-76 (7491.60 cm^2) under open condition. It was followed by MP-73 (6217.20 cm^2). MP-83 (1897.20 cm^2) recorded the least leaf area under open condition.

At seed formation stage, maximum leaf area was recorded by MP-73 (5574.57 cm^2) under shaded condition closely followed by MP-76 (5482.26 cm^2). Least leaf area was recorded by MP-81 (1499.12 cm^2). Under open condition, leaf area was highest in MP-73 (13953.60 cm^2). It was found to be the least in MP-81 (4006.80 cm^2).

At seed maturation stage, under shade condition, leaf area was maximum in MP-73 (4976.04 cm^2). MP-81 (1342.93 cm^2) recorded the least leaf area. Under open condition, maximum leaf area was recorded by MP-73 (12481.20 cm^2). MP-81 (3474.00 cm^2) recorded the least leaf area.

Highest leaf area was recorded by MP-73 under both conditions of light at seed maturation stage.

4.2.1.4 Number of pods per plant (Table 6)

Significant difference was observed among the accessions under shade as well as open condition.

Under shade condition, at seed formation stage, maximum number of pods per plant was recorded by MP-76 (14.78). It was on par with MP-85 (11.33). MP-81 (6.45) recorded the least number of pods per plant. Under open condition, MP-73 (61.67) recorded maximum number of pods per plant,

Table 6. Growth parameters of *Clitoria ternatea* at seed formation and seed maturation stages : number of pods per plant

Sl. No.	Accession No.	Seed formation (135 DAS)		Seed maturation (180 DAS)	
		Shade	Open	Shade	Open
1.	MP – 73	10.89	61.67	25.78	82.11
2.	MP – 74	9.56	51.67	22.55	69.11
3.	MP – 76	14.78	54.22	27.11	75.11
4.	MP – 81	6.45	20.78	17.78	51.78
5.	MP – 83	9.34	43.33	21.67	65.89
6.	MP – 85	11.33	34.67	24.45	61.55
CD (0.05)	-	3.61	6.67	1.90	4.60

Table 7. Growth parameters of *Clitoria ternatea* at seed formation and seed maturation stages : pod length (cm)

Sl. No.	Accession No.	Seed formation (135 DAS)		Seed maturation (180 DAS)	
		Shade	Open	Shade	Open
1.	MP – 73	6.67	9.93	9.83	10.05
2.	MP – 74	6.61	9.73	9.57	9.91
3.	MP – 76	7.08	9.89	9.97	10.01
4.	MP – 81	5.79	9.83	9.22	9.88
5.	MP – 83	6.90	9.91	9.88	9.88
6.	MP – 85	6.55	9.89	9.70	9.97
CD (0.05)	-	0.55	NS	0.15	0.07

NS - Not significant
DAS – Days after sowing

followed by MP-76 (54.22). MP-76 was on par with MP-74 (51.67). Least number of pods was recorded by MP-81 (20.78).

At seed maturation stage, under shade condition, MP-76 (27.11) recorded the highest number of pods, closely followed by MP-73 (25.78) and MP-85 (24.45). MP-76 and MP-73 were on par. MP-81 (17.78) recorded the least number of pods per plant. Under open condition, MP-73 (82.11) was found to be superior in terms of number of pods per plant. MP-81 (51.78) recorded the least number of pods per plant.

4.2.1.5 Pod length (Table 7)

At seed formation stage, significant difference could be observed among the accessions under shade condition, but there was no significant difference among them under open condition. In shade, maximum pod length was recorded by MP-76 (7.08 cm) closely followed by MP-83 (6.90 cm) and they were on par. The lowest pod length was recorded by MP-81 (5.79 cm).

At seed maturation stage, accessions differed significantly in pod length under both conditions. Under shade condition, MP-76 (9.97 cm) recorded the maximum pod length. MP-83 (9.88 cm) and MP-73 (9.83 cm) were on par with MP-76. MP-81 (9.22 cm) recorded the lowest pod length. Under open condition, MP-73 (10.05 cm) recorded the highest pod length, closely followed by MP-76 (10.01 cm) which were on par. The lowest pod length was recorded by MP-83 (9.88 cm) and MP-81 (9.88 cm).

4.2.1.6 Number of seeds per pod (Table 8)

Significant difference was observed among the accessions under shade condition at seed formation and seed maturation stages. But the number of seeds per pod showed no significant difference under open condition.

At seed formation stage in shade, highest number of seeds per pod was recorded by MP-76 (8.56) which was on par with MP-73 (8.33), MP-83 (8.22) and MP-85 (7.78). Least number of seeds per pod was recorded by MP-81 (6.89).

At seed maturation stage in shade, maximum number of seeds per pod was recorded by MP-76 (9.33). It was on par with MP-73 (9.22), MP-83 (9.11) and MP-85 (9.00). MP-81 (8.44) recorded the least number of seeds per pod.

4.2.1.7 Root length (Table 9)

No significant difference in root length was noted among the accessions at pre-flowering stage under shade as well as open conditions.

At flowering stage, accessions differed significantly under open condition, but no significant difference could be observed under shade. In open, maximum root length was recorded by MP-76 (37.70 cm) which was closely followed by MP-81 (35.68 cm). These two were on par. The lowest root length was recorded by MP-83 (28.28 cm).

At seed formation stage, significant difference was noted among the accessions under both conditions. Under shade condition, root length was

Table 8. Growth parameters of *Clitoria ternatea* at seed formation and seed maturation stages : number of seeds per pod

Sl. No.	Accession No.	Seed formation (135 DAS)		Seed maturation (180 DAS)	
		Shade	Open	Shade	Open
1.	MP – 73	8.33	9.22	9.22	9.67
2.	MP – 74	7.56	9.22	8.78	9.56
3.	MP – 76	8.56	9.44	9.33	9.78
4.	MP – 81	6.89	9.11	8.44	9.33
5.	MP – 83	8.22	9.22	9.11	9.33
6.	MP – 85	7.78	9.55	9.00	9.89
CD (0.05)	-	0.96	NS	0.38	NS

Table 9. Growth parameters of *Clitoria ternatea* at four growth stages : root length (cm)

Sl. No.	Accession No.	Pre-flowering (45 DAS)		Flowering (90 DAS)		Seed formation (135 DAS)		Seed maturation (180 DAS)	
		Shade	Open	Shade	Open	Shade	Open	Shade	Open
1.	MP – 73	21.80	21.97	32.07	33.68	36.44	54.08	29.34	51.93
2.	MP – 74	12.87	19.15	23.98	33.52	43.06	64.80	35.97	62.58
3.	MP – 76	19.31	20.68	31.02	37.70	35.40	44.76	28.62	43.17
4.	MP – 81	16.70	21.25	27.62	35.68	40.89	50.82	31.57	49.40
5.	MP – 83	18.06	19.62	24.13	28.28	42.14	60.06	33.58	57.97
6.	MP – 85	16.53	20.56	26.75	33.68	35.19	45.10	29.33	43.25
CD (0.05)	-	NS	NS	NS	2.43	5.77	4.31	2.48	3.84

NS – Not significant

DAS – Days after sowing

maximum for MP-74 (43.06 cm) which was on par with MP-83 (42.14 cm) and MP-81 (40.89 cm). The lowest root length was for MP-85 (35.19 cm). Under open condition, MP-74 (64.80 cm) recorded the maximum root length, which was significantly different from all other accessions. MP-76 (44.76 cm) recorded the lowest root length.

At seed maturation stage, significant difference was there among the accessions both under shade and open conditions. Under shade condition, root length was maximum for MP-74 (35.97 cm) followed by MP-83 (33.58 cm) and they were on par. Lowest root length was recorded by MP-76 (28.62 cm). Under open condition, maximum root length was recorded by MP-74 (62.58 cm). Root length was lowest for MP-85 (43.25 cm) and MP-76 (43.17 cm).

Irrespective of the light condition, MP-74 recorded maximum root length at the last two stages of growth.

4.2.1.8 Root girth (Table 10)

At pre-flowering stage, no significant difference was observed among the accessions under shade as well as open conditions.

At flowering stage, accessions differed significantly under open condition, but no significant difference was observed under shade. In open, root girth was maximum for MP-81 (3.93 cm) followed by MP-76 (3.62 cm) and MP-74 (3.52 cm). The lowest root girth was recorded by MP-83 (2.90 cm).

At seed formation stage, accessions showed no significant difference in root girth under shade condition. In open, there was significant difference

Table 10. Growth parameters of *Clitoria ternatea* at four growth stages : root girth (cm)

Sl. No.	Accession No.	Pre-flowering (45 DAS)		Flowering (90 DAS)		Seed formation (135 DAS)		Seed maturation (180 DAS)	
		Shade	Open	Shade	Open	Shade	Open	Shade	Open
1.	MP – 73	0.83	1.80	2.60	3.47	3.13	3.98	2.91	3.83
2.	MP – 74	0.34	1.29	1.57	3.52	3.31	4.63	3.16	4.50
3.	MP – 76	0.78	1.67	2.59	3.62	3.15	3.87	2.86	3.80
4.	MP – 81	0.77	1.55	2.39	3.93	2.77	4.07	2.63	3.91
5.	MP – 83	0.38	1.23	1.58	2.90	2.98	4.16	2.83	4.09
6.	MP – 85	0.61	1.66	2.89	3.42	2.99	3.83	2.84	3.77
CD (0.05)	–	NS	NS	NS	0.23	NS	0.22	0.14	0.17

Table 11. Yield parameters of *Clitoria ternatea* at four growth stages : fresh weight of leaves (g)

Sl. No.	Accession No.	Pre-flowering (45 DAS)		Flowering (90 DAS)		Seed formation (135 DAS)		Seed maturation (180 DAS)	
		Shade	Open	Shade	Open	Shade	Open	Shade	Open
1.	MP – 73	4.36	11.94	12.02	49.24	41.39	124.11	33.62	97.09
2.	MP – 74	1.13	4.01	6.11	81.22	36.48	115.10	27.64	88.60
3.	MP – 76	2.89	9.72	18.51	106.82	37.33	112.99	27.50	91.59
4.	MP – 81	2.69	7.30	8.27	63.18	32.27	140.76	33.64	95.65
5.	MP – 83	1.20	4.99	6.89	32.06	45.44	113.37	33.14	86.70
6.	MP – 85	2.82	10.29	15.01	53.13	33.03	99.03	24.33	80.21
CD (0.05)	-	1.58	NS	NS	10.27	6.19	14.16	3.98	3.83

NS – Not significant
DAS – Days after sowing

among the accessions. Root girth was found to be highest for MP-74 (4.63 cm). MP-85 (3.83 cm) recorded the lowest value for root girth.

At seed maturation stage, accessions varied significantly in root girth under both conditions of light. In shade, MP-74 recorded the maximum root girth of 3.16 cm. The lowest value was observed in MP-81 (2.63 cm). In open, MP-74 had the highest value of 4.50 cm, whereas the lowest was recorded in MP-85 (3.77 cm).

4.2.2 Yield and yield attributes

4.2.2.1 Fresh weight of leaves (Table 11)

At pre-flowering stage, accessions differed significantly in fresh weight of leaves under shade condition. MP-73 (4.36 g) recorded the highest leaf fresh weight. The lowest value for leaf fresh weight was recorded by MP-74 (1.13 g). Under open condition, no significant difference was noted among the six accessions.

At flowering stage, accessions showed no significant difference among them under shade condition. However, they differed significantly under open condition. Fresh weight of leaves in open was maximum for MP-76 (106.82 g), followed by MP-74 (81.22 g). The lowest fresh weight was recorded by MP-83 (32.06 g).

At seed formation stage, there was significant difference among all the accessions under shade as well as open conditions. Under shade condition, the highest value for fresh weight of leaves was recorded by MP-83 (45.44 g) which was or par with MP-73 (41.39 g). MP-85 (33.03 g) and MP-81 (32.27 g) recorded the lowest values. Under open condition, MP-81 (140.76 g) recorded the highest leaf fresh weight, whereas the lowest was recorded for MP-85 (99.03 g).

At seed maturation stage also, accessions showed significant difference among them under shade as well as open conditions. In shade, fresh weight of leaves was maximum for MP-81 (33.64 g) closely followed by MP-73 (33.62 g) and MP-83 (33.14 g). Fresh weight was lowest for MP-85 (24.33 g). Under open condition, MP-73 (97.09 g) recorded the highest fresh weight of leaves, followed by MP-81 (95.65 g) which were on par. MP-85 (80.21 g) recorded the lowest value.

4.2.2.2 Dry weight of leaves (Table 12)

At pre-flowering stage, there was significant difference in leaf dry weight among the accessions under shade as well as open conditions. In shade, MP-73 (1.43 g) recorded the highest dry weight of leaves. It was on par with MP-76 (0.94 g). Lowest dry weight of leaves was observed in MP-83 (0.36 g) preceded by MP-74 (0.37 g). Under open condition also, MP-73 (4.58 g) was found to be superior followed by MP-85 (3.34 g). The leaf dry weight under open condition was lowest in MP-74 (1.33 g).

At flowering stage, accessions showed no significant difference among them under shade condition. But they differed significantly in open. Under open condition, maximum dry weight of leaves was recorded by MP-76 (34.77 g). MP-83 (9.83 g) recorded the lowest dry weight of leaves.

Table 12. Yield parameters of *Clitoria ternatea* at four growth stages : dry weight of leaves (g)

Sl. No.	Accession No.	Pre-flowering (45 DAS)		Flowering (90 DAS)		Seed formation (135 DAS)		Seed maturation (180 DAS)	
		Shade	Open	Shade	Open	Shade	Open	Shade	Open
1.	MP – 73	1.43	4.58	3.85	15.91	12.24	40.20	8.19	26.05
2.	MP – 74	0.37	1.33	1.80	25.35	9.37	36.87	12.02	23.47
3.	MP – 76	0.94	2.99	4.65	34.77	9.07	36.22	8.17	23.73
4.	MP – 81	0.85	2.42	2.68	21.48	9.60	44.04	9.09	25.35
5.	MP – 83	0.36	1.55	1.98	9.83	16.53	35.43	8.53	23.13
6.	MP – 85	0.73	3.34	3.98	16.03	11.20	31.97	6.57	21.48
CD (0.05)	-	0.55	1.93	NS	3.17	2.78	5.38	1.22	1.12

NS – Not significant
DAS – Days after sowing

At seed formation stage, there was significant difference in leaf dry weight among the accessions both under shade and open conditions. Under shade condition, the highest leaf dry weight was recorded by MP-83 (16.53 g) which was significantly different from all other accessions. The least weight was recorded by MP-76 (9.07 g). Under open condition, MP-81 (44.04 g) recorded the highest value for leaf dry weight followed by MP-73 (40.20 g). The lowest dry weight of leaves was recorded by MP-85 (31.97 g).

At seed maturation stage, accessions differed significantly among them in leaf dry weight under shade as well as open conditions. In shade, MP-74 (12.02 g) recorded the maximum dry weight of leaves followed by MP-81 (9.09 g). Lowest dry weight of leaves was recorded by MP-85 (6.57 g). In open, MP-73 (26.05 g) recorded the highest dry weight of leaves closely followed by MP-81 (25.35 g). The lowest value was recorded by MP-85 (21.48 g).

4.2.2.3 Fresh weight of shoot (Table 13)

At pre-flowering stage, accessions showed significant difference among them in fresh weight of shoot under shade condition. Maximum fresh weight was recorded by MP-73 (5.89 g) followed by MP-85 (4.23 g). Fresh weight of shoot was lowest for MP-74 (1.46 g). In open, no significant difference could be noticed.

At flowering stage, pooled analysis indicated that there was significant difference in fresh weight of shoot between shade and open conditions. Accessions also showed significant difference among them. Under shade,

Table 13. Yield parameters of *Clitoria ternatea* at four growth stages : fresh weight of shoot (g)

Sl. No.	Accession No.	Pre-flowering (45 DAS)		Flowering (90 DAS)			Seed formation (135 DAS)		Seed maturation (180 DAS)		
		Shade	Open	Shade	Open	Mean	Shade	Open	Shade	Open	Mean
1.	MP – 73	5.89	16.83	21.02	89.71	55.37	145.51	212.24	101.97	209.03	155.50
2.	MP – 74	1.46	5.71	9.88	127.31	68.59	109.42	219.40	97.78	210.67	154.22
3.	MP – 76	4.15	15.27	30.78	198.23	144.50	116.46	220.41	97.78	217.75	157.77
4.	MP – 81	4.14	12.02	14.75	148.98	81.86	95.39	263.98	77.41	236.89	157.15
5.	MP – 83	1.71	7.55	10.10	65.91	38.01	110.67	198.82	99.44	195.37	147.40
6.	MP – 85	4.23	15.94	30.08	103.55	66.81	85.62	172.02	71.19	170.98	121.08
Mean	-	-	-	19.43	122.28	-	-	-	90.93	206.78	-
CD (0.05)	-	2.29	NS	-	-	-	11.91	21.41	-	-	-
<u>CD for pooled analysis</u>											
For light conditions					37.34					19.65	
For accessions					64.68					34.03	
For interaction					91.47					48.13	

NS – Not significant
DAS – Days after sowing

fresh weight of shoot was highest for MP-76 (30.78 g) closely followed by MP-85 (30.08 g). The lowest shoot fresh weight was recorded by MP-74 (9.88 g). Under open condition, maximum shoot fresh weight was recorded by MP-76 (198.23 g). It was on par with MP-81 (148.98 g) and MP-74 (127.31 g). MP-83 (38.01 g) recorded the lowest shoot fresh weight under open condition. Shoot fresh weights of accessions MP-76, MP-74 and MP-81 under shade differed significantly from those under open condition.

At seed formation stage, all the six accessions differed significantly among them under both shade and open condition. Under shade condition, highest fresh weight of shoot was recorded by MP-73 (145.51 g). The next best performers were MP-76 (116.46 g), MP-83 (110.67 g) and MP-74 (109.42 g) and these three were on par. The lowest value was recorded by MP-85 (85.62 g). Under open condition, MP-81 (263.98 g) recorded the maximum shoot fresh weight and it was significantly different from all others. MP-85 (172.02 g) recorded the lowest value.

At seed maturation stage, the results of pooled analysis indicated that fresh weight of shoot under open condition differed significantly from that under shade condition (Fig.1). The various accessions exhibited significant difference in shoot fresh weight among them. Under shade condition, maximum value for shoot fresh weight was recorded by MP-73 (101.97 g), closely followed by MP-83 (99.44 g). MP-85 (71.19 g) recorded the lowest shoot fresh weight. Under open condition, MP-81 (236.89 g) recorded the highest value whereas MP-85 (170.98 g) recorded the lowest shoot fresh weight. All the accessions showed significantly higher shoot fresh weight under open condition when compared to shade.

4.2.2.4 Dry weight of shoot (Table 14)

At pre-flowering stage, the accessions showed significant difference among them under both conditions. In shade, maximum shoot dry weight was recorded by MP-73 (1.90 g). It was on par with MP-76 (1.32 g) and MP-81 (1.23 g). The lowest value for shoot dry weight was recorded by MP-74 (0.43 g) and MP-83 (0.53 g). In open, MP-73 (5.56 g) recorded the highest shoot dry weight and it was on par with MP-85 (4.33 g), MP-76 (4.08 g) and MP-81 (3.32 g). MP-74 (1.68 g) recorded the lowest value.

At flowering stage, pooled analysis indicated that there was significant difference in shoot dry weight between shade and open conditions. The accessions showed no significant difference among them. In shade, maximum shoot dry weight was recorded by MP-76 (8.17 g) followed by MP-85 (7.45 g) and MP-73 (6.83 g). Lowest value was for MP-74 (2.81 g) and MP-83 (2.81 g). In open, maximum shoot dry weight was recorded by MP-76 (63.09g) and it was on par with MP-81 (45.99 g) and MP-74 (40.38 g). MP-83 (22.15 g) recorded the lowest value. The accessions MP-76, MP-74 and MP-81 showed significantly higher dry weights of shoot under open condition.

At seed formation stage, when pooled analysis was carried out, significant difference was noticed between shade and open conditions. But accessions showed no significant difference among them. In shade, the highest value for shoot dry weight was for MP-73 (39.02 g) closely followed by

Table 14. Yield parameters of *Clitoria ternatea* at four growth stages : dry weight of shoot (g)

Sl. No.	Accession No.	Pre-flowering (45 DAS)		Flowering (90 DAS)			Seed formation (135 DAS)			Seed maturation (180 DAS)		
		Shade	Open	Shade	Open	Mean	Shade	Open	Mean	Shade	Open	Mean
1.	MP – 73	1.90	5.56	6.83	28.99	17.91	39.02	68.23	53.63	40.19	71.36	55.77
2.	MP – 74	0.43	1.68	2.81	40.38	21.60	33.93	72.60	53.27	35.26	73.99	54.62
3.	MP – 76	1.32	4.08	8.17	63.09	35.63	37.95	68.60	53.28	39.23	73.20	56.21
4.	MP – 81	1.23	3.32	4.89	45.99	25.44	27.39	84.00	55.70	29.01	84.83	56.92
5.	MP – 83	0.53	2.00	2.81	22.15	12.48	36.59	64.58	50.58	37.95	66.02	51.98
6.	MP – 85	1.17	4.33	7.45	31.38	19.41	26.76	55.43	41.095	27.56	57.63	42.60
Mean	-	-	-	5.49	38.66	-	33.65	68.91	-	34.86	71.17	-
CD (0.05)	-	0.74	2.68	-	-	-	-	-	-	-	-	-

<u>CD for pooled analysis</u>

	Flowering (90 DAS)	Seed formation (135 DAS)	Seed maturation (180 DAS)
For light conditions	11.76	9.49	8.73
For accessions	NS	NS	15.12
For interaction	28.80	23.26	21.38

NS – Not significant
DAS – Days after sowing

Fig. 1 Shoot yield (fresh weight) of *Clitoria ternatea* accessions at seed maturation stage

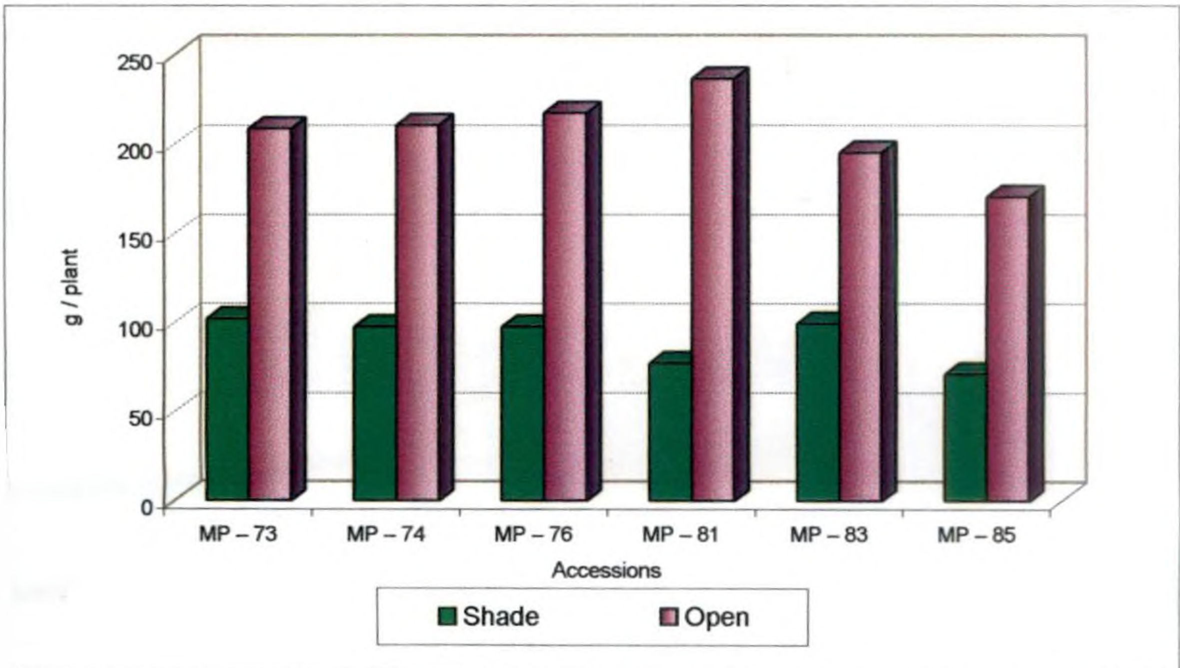
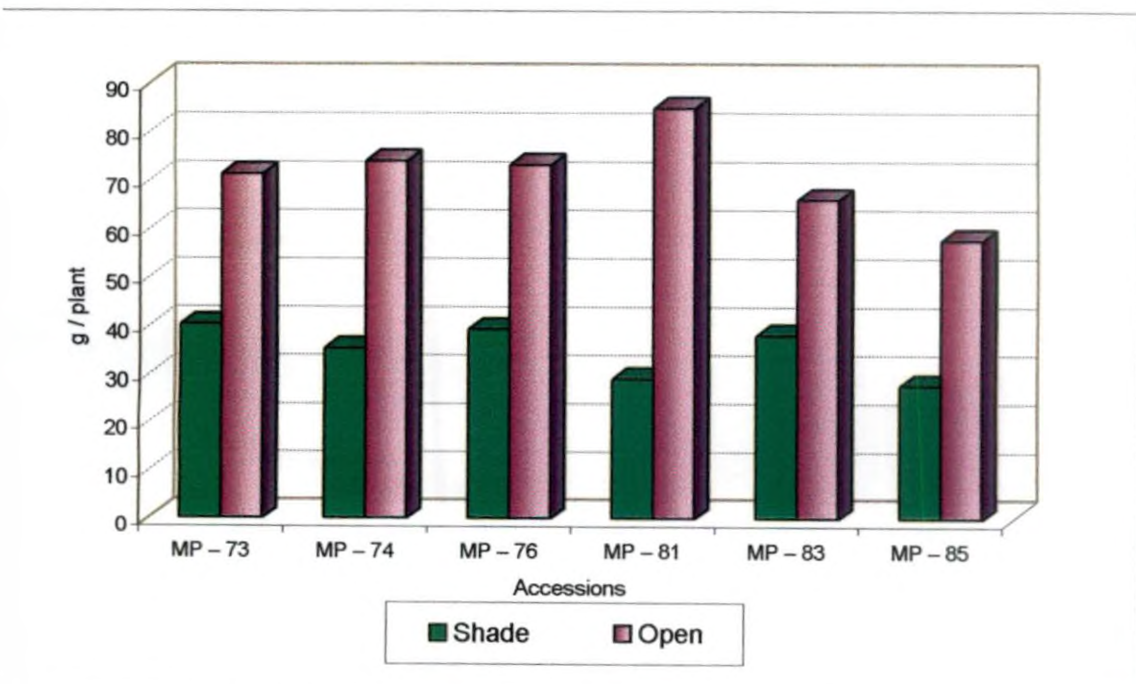


Fig. 2 Shoot yield (dry weight) of *Clitoria ternatea* accessions at seed maturation stage



MP-76 (37.95 g) and MP-83 (36.59 g). MP-85 (26.76 g) recorded the lowest value. In open, MP-81 (84 g) recorded the highest dry weight of shoot whereas MP-85 (55.43 g) recorded the lowest dry weight. All the six accessions showed higher values for shoot dry weight under open condition.

At seed maturation stage, pooled analysis showed that accessions differed significantly in shoot dry weight between shade and open conditions (Fig.2). The accessions differed significantly among them under shade condition. Maximum shoot dry weight was for MP-73 (40.19 g) closely followed by MP-76 (39.23 g). The lowest value for shoot dry weight was recorded by MP-85 (27.56 g). Under open condition, shoot dry weight was highest for MP-81 (84.83 g) and lowest for MP-85 (57.63 g). Higher shoot dry weights were exhibited by all the accessions under open condition.

4.2.2.5 Fresh weight of pods (Table 15)

At seed formation stage, accessions showed significant difference in fresh weight of pods among them, under shade as well as open conditions. In shade, MP-76 (22.71 g) recorded the highest value. The lowest fresh weight of pods was recorded by MP-81 (8.47 g). In open, MP-73 (86.48 g) recorded the highest value followed by MP-76 (75.31 g). MP-76 and MP-74 (70.54 g) were on par. As in shade, the lowest fresh weight was recorded by MP-81 (32.86 g) under open condition.

At seed maturation stage also, all the six accessions differed significantly among them in shade as well as in open (Fig.3). In shade, highest value was for MP-76 (37.58 g) which was on par with MP-73 (37.53 g),

Table 15. Yield parameters of *Clitoria ternatea* at seed formation and seed maturation stages : fresh weight of pods per plant (g)

Sl. No.	Accession No.	Seed formation (135 DAS)		Seed maturation (180 DAS)	
		Shade	Open	Shade	Open
1.	MP – 73	14.78	86.48	37.53	120.00
2.	MP – 74	12.93	70.54	35.47	103.69
3.	MP – 76	22.71	75.31	37.58	109.25
4.	MP – 81	8.47	32.86	26.22	75.73
5.	MP – 83	13.98	64:33	31.76	96.44
6	MP – 85	11.24	53.53	34.89	90.65
CD (0.05)	-	5.78	9.96	2.75	6.83

Table 16. Yield parameters of *Clitoria ternatea* at seed formation and seed maturation stages : dry weight of pods per plant (g)

Sl. No.	Accession No.	Seed formation (135 DAS)			Seed maturation (180 DAS)		
		Shade	Open	Mean	Shade	Open	Mean
1.	MP – 73	6.45	33.75	20.10	9.18	35.33	22.26
2.	MP – 74	6.70	25.63	16.17	13.31	30.32	21.82
3.	MP – 76	11.25	23.32	17.29	15.29	32.13	23.71
4.	MP – 81	4.59	12.03	8.31	14.79	22.04	18.42
5.	MP – 83	8.28	22.65	15.47	11.78	28.65	20.22
6	MP – 85	4.72	20.50	12.61	14.58	26.27	20.42
Mean	-	7.00	22.98	-	13.15	29.13	-
CD for pooled analysis							
For light conditions			5.75			5.39	
For accessions			9.96			NS	
For interaction			14.08			13.21	

NS – Not significant
DAS – Days after sowing

MP-74 (35.47 g) and MP-85 (34.89 g). MP-81 (26.22 g) recorded the lowest fresh weight. In open, MP-73 (120 g) recorded the highest value. MP-76 (109.25 g) and MP-74 (103.69 g) were on par. MP-81 (75.73 g) recorded the lowest value for pod fresh weight.

4.2.2.6 Dry weight of pods (Table 16)

At seed formation stage, pooled analysis indicated significant difference in pod dry weight between shade and open conditions as well as among the accessions. In shade, MP-76 (11.25 g) recorded the highest dry weight and the lowest was recorded by MP-81 (4.59 g). In open, MP-73 (33.75 g) recorded highest value and it was on par with MP-74 (25.63g). MP-81 (12.03 g) recorded the lowest value for pod dry weight. The accessions MP-74, MP-85, MP-83 and MP-73 exhibited significantly higher pod dry weights under open condition.

At seed maturation stage also when pooled analysis was carried out, significant difference in pod dry weight was noticed between shade and open conditions (Fig.4). But, accessions showed no significant difference among them. In shade, MP-76 (15.29 g) recorded the highest pod dry weight closely followed by MP-81 (14.79 g) and MP-85 (14.58 g). MP-73 (9.18 g) recorded the lowest pod dry weight. In open, MP-73 (35.33 g) recorded the highest value followed by MP-76 (32.13 g). The lowest dry weight of pods was recorded by MP-81 (22.04 g). In open, pod dry weights were significantly higher for MP-76, MP-74, MP-83 and MP-73 when compared to those under shade condition.

Fig. 3 Pod yield (fresh weight) of *Clitoria ternatea* accessions at seed maturation stage

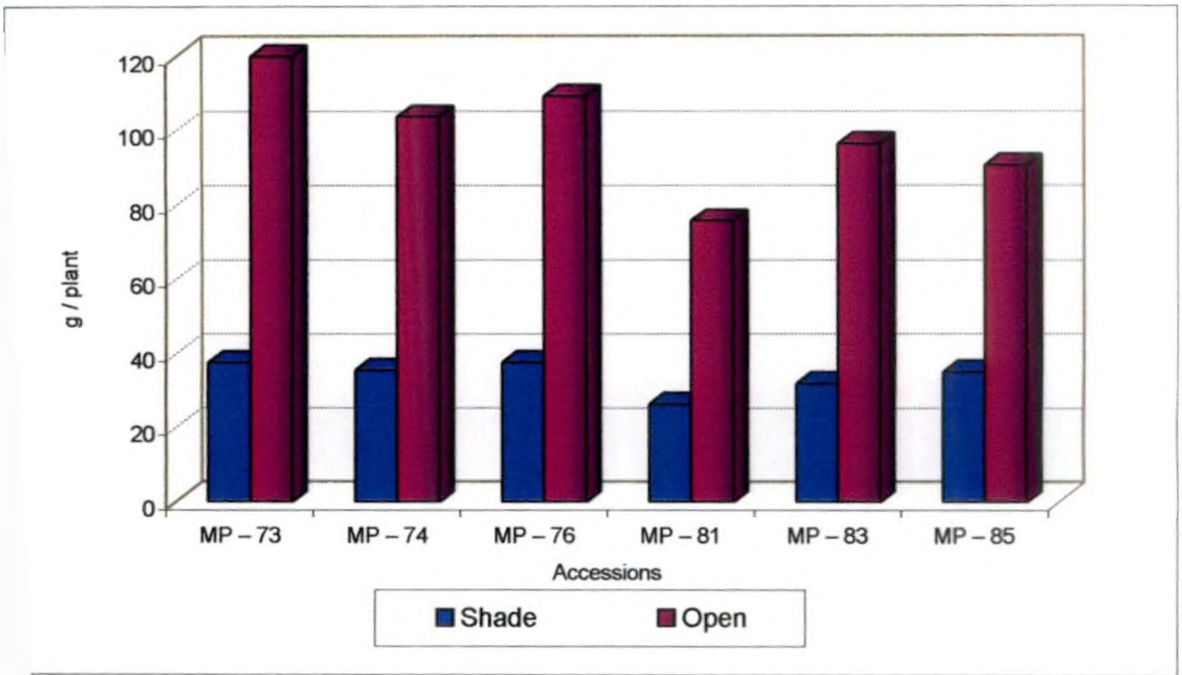
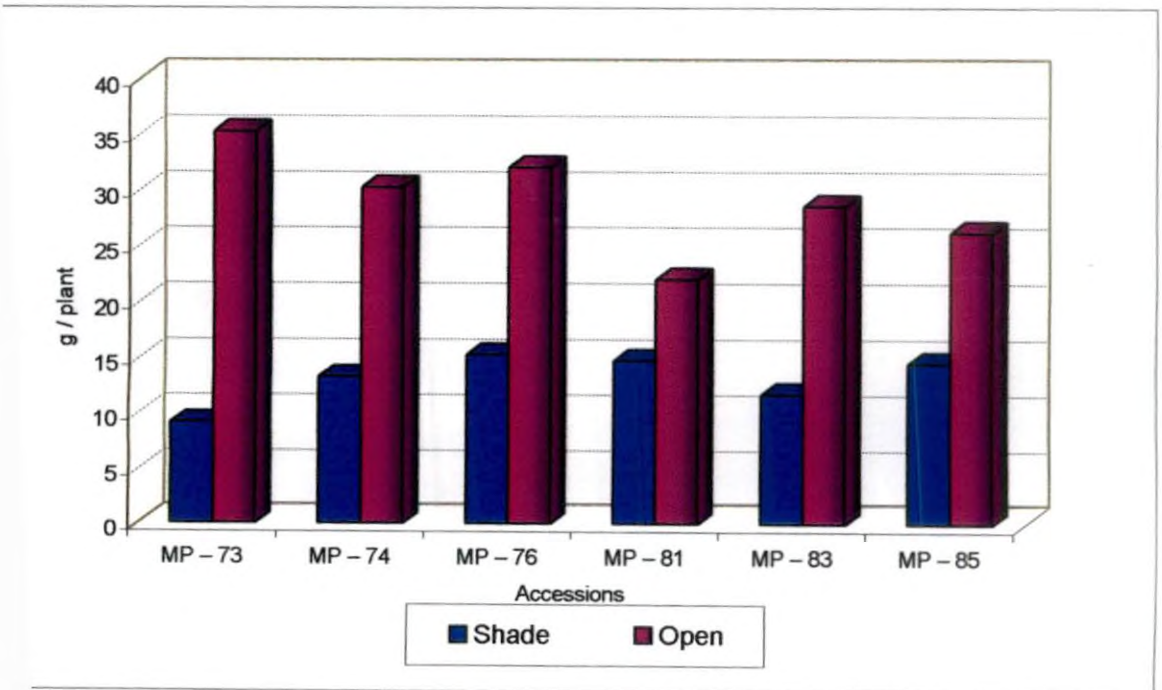


Fig. 4 Pod yield (dry weight) of *Clitoria ternatea* accessions at seed maturation stage



4.2.2.7 Fresh weight of root (Table 17)

At pre-flowering stage, there was no significant difference among the accessions in open as well as shade conditions.

At flowering stage, accessions showed no significant difference among them under shade condition, but they differed significantly under open condition. In open, MP-81 (16.37 g) recorded the highest fresh weight of roots closely followed by MP-85 (16.16 g) and they were on par. MP-83 (9.93 g) recorded the lowest value for fresh weight of root.

At seed formation stage, significant difference in root fresh weight was observed among the accessions under shade and open conditions. Under shade condition, MP-83 (19.47 g) recorded the highest root fresh weight. It was on par with MP-81 (17.19 g) and MP-74 (17.09 g). MP-76 (12.50 g) recorded the lowest value. In open, MP-74 (20.85 g) was found to be superior, closely followed by MP-83 (20.50 g). The lowest fresh weight of roots was for MP-76 (15.01 g).

At seed maturation stage also, there was significant difference in root fresh weight among the accessions in shade as well as open conditions (Fig.5). In shade, MP-76 (12.27 g) recorded the maximum fresh weight whereas, the lowest value was for MP-73 (7.71 g). In open, MP-74 (20.73 g) recorded the highest value for root fresh weight closely followed by MP-83 (20.09 g). They were on par. The lowest value was recorded by MP-76 (13.42 g).

Table 17. Yield parameters of *Clitoria ternatea* at four growth stages: fresh weight of root (g)

Sl. No.	Accession No.	Pre-flowering (45 DAS)		Flowering (90 DAS)		Seed formation (135 DAS)		Seed maturation (180 DAS)	
		Shade	Open	Shade	Open	Shade	Open	Shade	Open
1.	MP – 73	1.98	2.73	5.11	14.00	12.76	19.32	7.71	18.44
2.	MP – 74	0.47	1.37	3.44	15.27	17.09	20.85	11.61	20.73
3.	MP – 76	1.11	2.70	4.31	10.48	12.50	15.01	12.27	13.42
4.	MP – 81	1.20	2.70	4.69	16.37	17.19	18.78	8.06	18.22
5.	MP – 83	0.63	1.50	2.53	9.93	19.47	20.50	8.82	20.09
6.	MP – 85	1.11	2.83	4.01	16.16	13.76	16.15	9.17	16.06
CD (0.05)	-	NS	NS	NS	0.93	2.98	1.59	0.87	1.98

NS – Not significant
DAS – Days after sowing

4.2.2.8 Dry weight of root (Table 18)

At pre-flowering stage, pooled analysis indicated that there was no significant difference in root dry weight between shade and open conditions. But the accessions differed among them significantly. MP-73 (0.71, 0.74 g) recorded the highest root dry weight and MP-74 (0.15, 0.36 g) recorded the lowest under shade and open conditions respectively.

At flowering stage, pooled analysis showed that there was significant difference in root dry weight between shade and open conditions. Significant variation was noticed among the accessions also. In shade, MP-73 (1.62 g) was found to be superior, followed by MP-81 (1.49 g). The lowest dry weight was for MP-83 (0.84 g). In open, MP-81 (5.97 g) recorded the highest value for root dry weight, closely followed by MP-85 (5.73 g). MP-83 (3.39 g) recorded the lowest value. All the accessions recorded significantly higher root dry weights under open condition.

At seed formation stage, pooled analysis indicated that there was no significant difference between shade and open conditions. But the accessions differed significantly among them. Highest value of root dry weight under shade condition was recorded for MP-85 (7.77 g), which was on par with the value recorded under open condition (5.57 g). Lowest value for root dry weight was for MP-76 under both shade (4.05 g) and open (4.92 g) conditions and they were on par. No significant difference was noticed in the root dry weight with regard to the shade and open conditions.

Table 18. Yield parameters of *Clitoria ternatea* at four growth stages : dry weight of root (g)

Sl. No.	Accession No.	Pre-flowering (45 DAS)			Flowering (90 DAS)			Seed formation (135 DAS)			Seed maturation (180 DAS)		
		Shade	Open	Mean	Shade	Open	Mean	Shade	Open	Mean	Shade	Open	Mean
1.	MP – 73	0.71	0.74	0.73	1.62	4.99	3.31	4.43	7.46	5.95	3.09	5.84	4.47
2.	MP – 74	0.15	0.36	0.26	0.95	5.02	2.99	5.86	8.01	6.94	5.04	7.08	6.06
3.	MP – 76	0.40	0.71	0.56	1.15	3.40	2.28	4.05	4.92	4.49	3.60	4.61	4.11
4.	MP – 81	0.39	0.70	0.55	1.49	5.97	3.73	7.51	7.80	7.65	3.38	7.33	5.36
5.	MP – 83	0.20	0.39	0.29	0.84	3.39	2.12	7.52	7.87	7.70	3.81	6.94	5.38
6.	MP – 85	0.40	0.70	0.55	0.99	5.73	3.36	7.77	5.57	6.67	4.98	5.13	5.06
Mean	-	0.38	0.60	-	1.17	4.75	-	6.19	6.94	-	3.98	6.16	-
CD for pooled analysis													
For light conditions		NS			0.87			NS			1.20		
For accessions		0.40			1.51			2.66			2.07		
For interaction		NS			2.14			NS			2.93		

NS – Not significant

DAS – Days after sowing

Fig. 5 Root yield (fresh weight) of *Clitoria ternatea* accessions at seed maturation stage

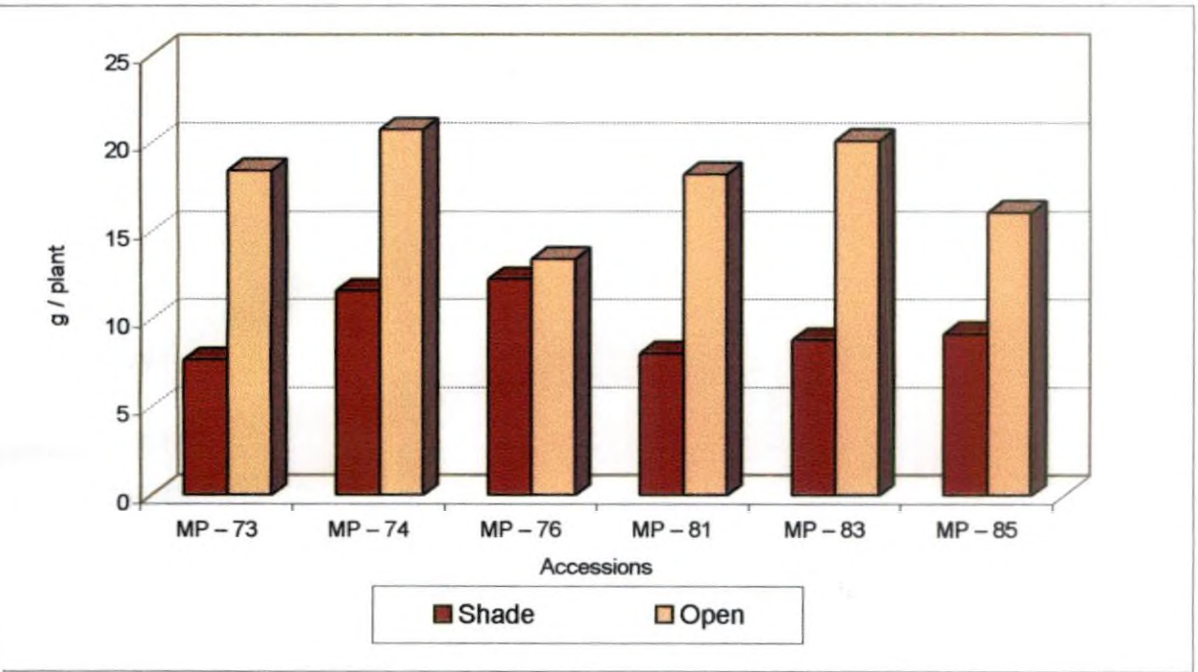
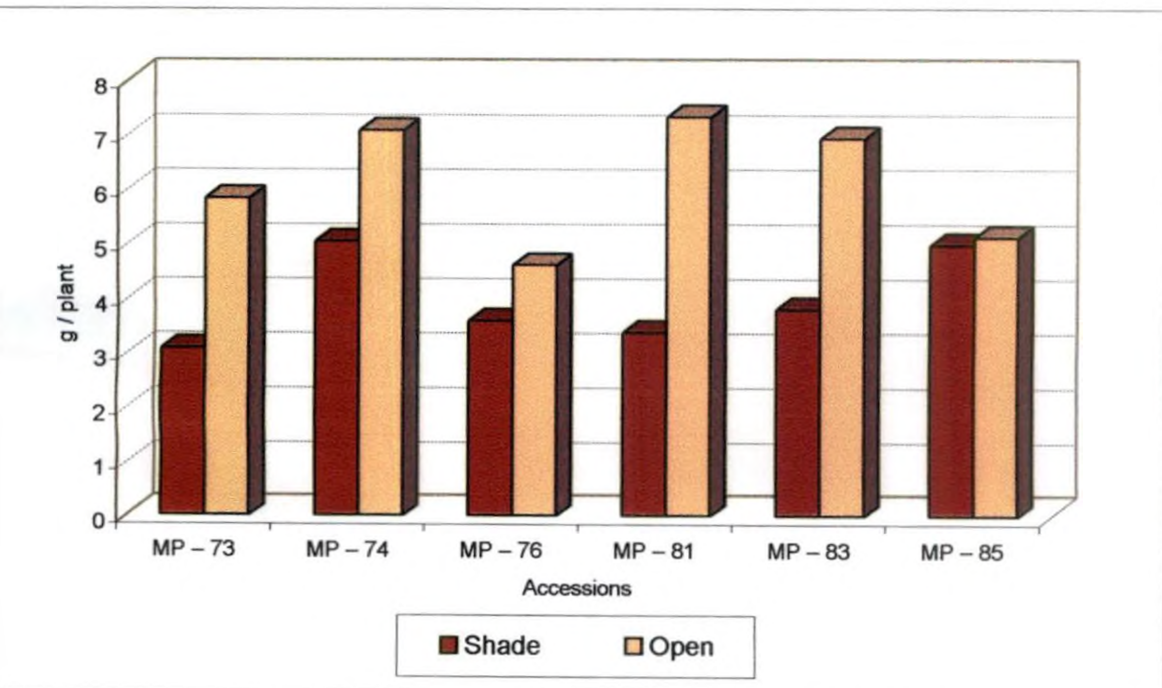


Fig. 6 Root yield (dry weight) of *Clitoria ternatea* accessions at seed maturation stage



At seed maturation stage, pooled analysis indicated that the accessions differed significantly in root dry weight between shade and open conditions (Fig. 6). Under shade condition, MP-74 (5.04 g) recorded the highest root dry weight, closely followed by MP-85 (4.98 g). MP-73 (3.09 g) recorded the lowest. In open, MP-81 (7.33 g) recorded the maximum root dry weight, whereas MP-76 (4.61 g) recorded the lowest. Root dry weights of MP-83 and MP-81 under open condition were significantly higher than those under shade condition.

4.2.3 Root nodule characteristics

4.2.3.1 Number of root nodules (Table 19, Fig.7 and 8)

At pre-flowering stage, pooled analysis was carried out and no significant difference was noticed between the shade and open conditions. But the accessions differed significantly among them. Maximum number of root nodules were recorded by MP-73 (13.67) and MP-76 (14.78) under shade and open conditions respectively.

At flowering stage, there was no significant difference among the accessions under shade condition. But under open condition, accessions showed significant difference among them. Greatest number of root nodules under open condition was recorded by MP-76 (25.00). The next best performer was MP-73 (20.67). Least number of root nodules was recorded by MP-81 (15.22).

At seed formation stage also, there was no significant difference among the accessions under shade. In open, they differed significantly. MP-76 (21.11)

Table 19. Root nodule characteristics of *Clitoria ternatea* at three growth stages: number of root nodules

Sl. No.	Accession No.	Pre-flowering (45 DAS)			Flowering (90 DAS)		Seed formation (135 DAS)	
		Shade	Open	Mean	Shade	Open	Shade	Open
1.	MP – 73	13.67	11.44	12.56	15.17	20.67	12.33	17.11
2.	MP – 74	1.67	2.72	2.20	10.67	16.67	9.78	13.22
3.	MP – 76	5.17	14.78	9.97	13.89	25.00	10.78	21.11
4.	MP – 81	5.83	7.39	6.61	6.33	15.22	6.33	11.89
5.	MP – 83	1.50	2.17	1.83	13.94	19.00	11.00	15.89
6.	MP – 85	9.11	10.33	9.72	10.00	19.33	9.00	15.67
Mean	-	6.16	8.14	-	-	-	-	-
CD (0.05)	-	-	-	-	NS	4.11	NS	3.13

CD for pooled analysis	
For light conditions	NS
For accessions	6.10
For interaction	8.62

NS – Not significant
DAS – Days after sowing

Fig. 7 Number of root nodules of *Clitoria ternatea* accessions at first three growth stages under shade condition

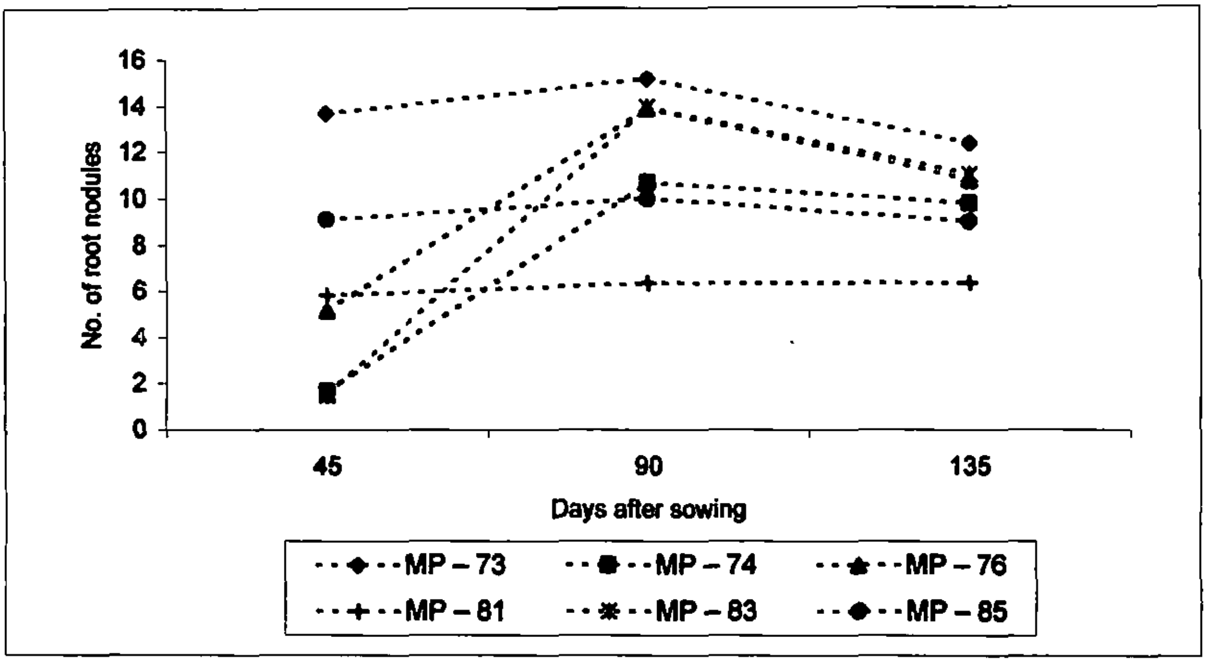
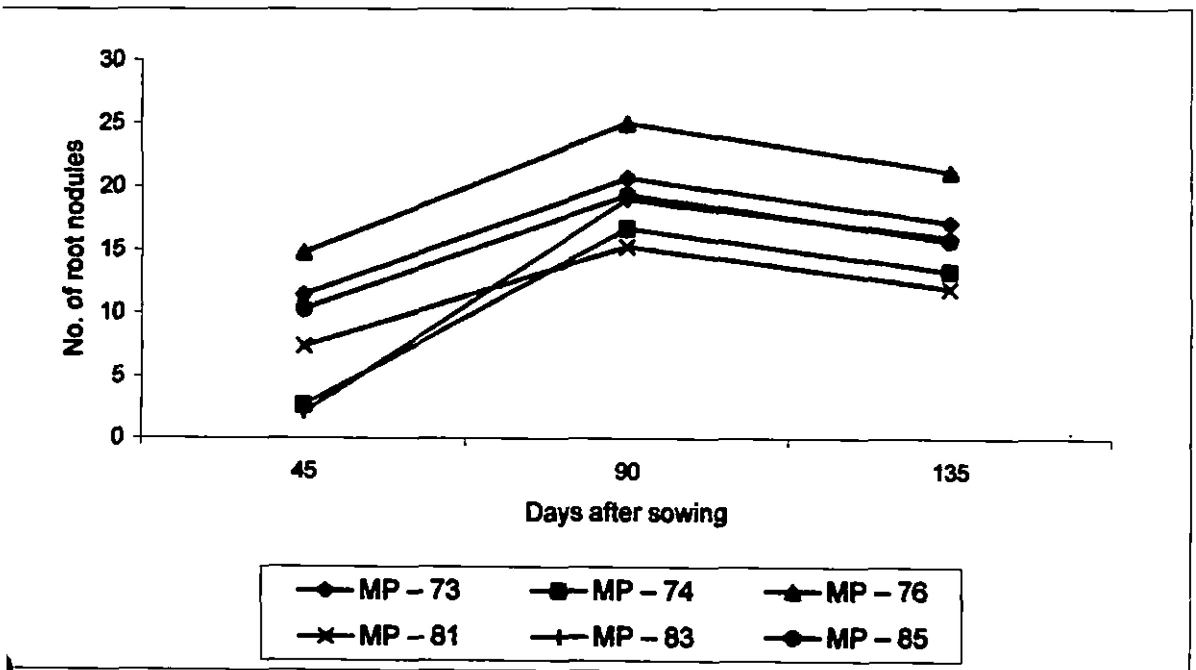


Fig. 8 Number of root nodules of *Clitoria ternatea* accessions at first three growth stages under open condition



recorded the greatest number of root nodules. MP-73 (17.11), MP-83 (15.89), MP-85 (15.67) were on par. MP-81 (11.89) recorded the lowest number of root nodules.

4.2.3.2 Fresh weight of root nodules (Table 20)

At pre-flowering stage, pooled analysis revealed that there was no significant difference among the accessions or between the shade and open conditions. Interaction was also not significant.

At flowering stage, no significant difference was there among the accessions in shade. But in open, MP-76 (2.26 g) recorded the highest value for fresh weight of nodules, followed by MP-85 (1.71 g). The lowest value was recorded by MP-81 (1.21 g).

At seed formation stage, pooled analysis showed no significant difference between shade and open conditions. However, accessions varied among them significantly. In shade, maximum fresh weight of root nodules was recorded in MP-73 (0.90 g) and it was on par with that in open (1.27 g). The least value in shade was observed in MP-81 (0.16 g) which was on par with the value of MP-81 obtained in open (0.70 g). In open, highest fresh weight was recorded in MP-76 (1.87 g) which differed significantly from the value in shade (0.34 g). MP-74 (0.57 g) recorded the lowest value under open condition. In open, fresh weight of root nodules was significantly higher for MP-76, MP-85 and MP-83.

Table 20. Root nodule characteristics of *Clitoria ternatea* at three growth stages: fresh weight of root nodules (g)

Sl. No.	Accession No.	Pre-flowering (45 DAS)			Flowering (90 DAS)		Seed formation (135 DAS)		
		Shade	Open	Mean	Shade	Open	Shade	Open	Mean
1.	MP – 73	0.70	0.36	0.53	0.89	1.68	0.90	1.27	1.09
2.	MP – 74	0.03	0.04	0.03	0.31	1.48	0.28	0.57	0.43
3.	MP – 76	0.05	1.14	0.60	0.37	2.26	0.34	1.87	1.11
4.	MP – 81	0.08	0.20	0.14	0.19	1.21	0.16	0.70	0.43
5.	MP – 83	0.02	0.03	0.03	0.56	1.52	0.36	1.31	0.83
6.	MP – 85	0.30	0.56	0.43	0.59	1.71	0.27	1.29	0.78
Mean	-	0.20	0.39	-	-	-	0.39	1.17	-
CD (0.05)	-	-	NS	-	NS	0.26	-	-	-
<u>CD for pooled analysis</u>									
For light conditions			NS					NS	
For accessions			NS					0.51	
For interaction			NS					0.73	

NS – Not significant

DAS – Days after sowing

4.2.3.3 Dry weight of root nodules (Table 21)

At pre-flowering stage, pooled analysis showed that there was no significant difference between shade and open conditions, or among the different accessions.

At flowering stage, when pooled analysis was carried out, no significant difference could be noticed between shade and open conditions. Accessions also showed no significant variation among them. MP-76 and MP-81 recorded significantly higher nodule dry weights under open condition when compared to shade.

At seed formation stage, nodule dry weight showed no significant difference among the accessions under shade condition. Under open condition, MP-76 (0.36 g) recorded the highest value followed by MP-83 (0.28 g) and they were on par. The lowest value was recorded by MP-74 (0.19 g).

4.2.4 Physiological parameters

4.2.4.1 Leaf area index (Table 22)

At pre-flowering stage, leaf area index (LAI) differed significantly among the accessions under both shade and open conditions. Under shade, maximum LAI was recorded by MP-73 (0.12) closely followed by MP-76 (0.10). These two were on par with MP-85 (0.09). The lowest leaf area index under shade was recorded by MP-74 (0.04) and MP-83 (0.04). In open, MP-76 (0.35) recorded the highest value followed by MP-73 (0.31). They were on par. The lowest value was for MP-81 (0.08) and MP-83 (0.08).

Table 21. **Root nodule characteristics of *Clitoria ternatea* at three growth stages: dry weight of root nodules (g)**

Sl. No.	Accession No.	Pre-flowering (45 DAS)			Flowering (90 DAS)			Seed formation (135 DAS)	
		Shade	Open	Mean	Shade	Open	Mean	Shade	Open
1.	MP – 73	0.16	0.12	0.14	0.21	0.33	0.27	0.20	0.25
2.	MP – 74	0.003	0.009	0.01	0.10	0.25	0.17	0.08	0.19
3.	MP – 76	0.02	0.21	0.12	0.09	0.36	0.23	0.11	0.36
4.	MP – 81	0.03	0.04	0.03	0.03	0.37	0.20	0.04	0.23
5.	MP – 83	0.006	0.005	0.01	0.20	0.31	0.26	0.11	0.28
6.	MP – 85	0.08	0.14	0.11	0.15	0.33	0.24	0.07	0.21
Mean	-	0.05	0.09	-	0.13	0.33	-	-	-
CD (0.05)	-	-	-	-	-	-	-	NS	0.08

CD for pooled analysis		
For light conditions	NS	NS
For accessions	NS	NS
For interaction	NS	0.22

NS – Not significant
DAS – Days after sowing

Table 22. Leaf area index of *Clitoria ternatea* at four growth stages

Sl. No.	Accession No.	Pre-flowering (45 DAS)		Flowering (90 DAS)		Seed formation (135 DAS)		Seed maturation (180 DAS)	
		Shade	Open	Shade	Open	Shade	Open	Shade	Open
1.	MP – 73	0.12	0.31	0.34	1.73	1.55	3.88	1.38	3.47
2.	MP – 74	0.04	0.17	0.16	0.99	1.04	2.17	0.75	1.95
3.	MP – 76	0.10	0.35	0.52	2.08	1.52	2.60	1.09	2.41
4.	MP – 81	0.05	0.08	0.16	0.61	0.42	1.11	0.37	0.97
5.	MP – 83	0.04	0.08	0.10	0.53	0.55	1.23	0.42	1.10
6.	MP – 85	0.09	0.17	0.44	0.95	1.01	1.58	0.78	1.46
CD (0.05)	-	0.03	0.13	0.26	0.25	0.10	0.38	0.07	0.40

DAS – Days after sowing

At flowering stage, there was significant difference among the accessions in both conditions of light. In shade, MP-76 (0.52) recorded the maximum value whereas lowest value was recorded by MP-83 (0.10). In open, MP-76 (2.08) recorded the highest leaf area index followed by MP-73 (1.73). The lowest value was for MP-83 (0.53).

At seed formation stage, the accessions differed significantly among them under both open and shade conditions. Under shade condition, leaf area index was highest for MP-73 (1.55) closely followed by MP-76 (1.52). MP-74 (1.04) and MP-85 (1.01) were on par. The lowest LAI was recorded by MP-81 (0.42). Under open condition also, MP-73 (3.88) recorded the highest LAI. It differed significantly from all other accessions. MP-81 (1.11) recorded the lowest value.

At seed maturation stage also, significant difference was noticed among the accessions under shade as well as open conditions. Under shade condition, MP-73 (1.38) recorded the highest LAI whereas MP-81 (0.37) recorded the lowest value. Next to MP-73 (1.38) was MP -76 (1.09). However, they differed significantly. In open also, MP-73 (3.47) had the highest LAI followed by MP-76 (2.41). MP-81 (0.97) recorded the lowest LAI.

4.2.4.2 Leaf area duration (Table 23)

Leaf area duration (LAD) varied significantly among the accessions under shade as well as open conditions during the three periods of growth.

For the period from pre-flowering to flowering (45-90 DAS), MP-76 (13.89 days) had the highest LAD under shade condition. MP-85 (11.78 days)

Table 23. Leaf area duration (days) of *Clitoria ternatea* for three periods of growth

Sl. No.	Accession No.	Period 1 (45-90 DAS)		Period 2 (90-135 DAS)		Period 3 (135-180 DAS)	
		Shade	Open	Shade	Open	Shade	Open
1.	MP – 73	10.26	45.77	42.37	126.07	65.94	165.22
2.	MP – 74	4.52	25.98	27.01	71.04	40.32	92.79
3.	MP – 76	13.89	54.68	46.00	105.37	58.79	112.79
4.	MP – 81	4.79	15.62	12.86	38.82	17.77	46.75
5.	MP – 83	3.13	13.69	14.53	39.53	21.66	52.47
6.	MP – 85	11.78	25.16	32.63	56.88	40.35	68.47
CD (0.05)	-	5.83	6.77	7.20	10.69	3.43	13.92

Table 24. Physiological parameters of *Clitoria ternatea*: net assimilation rate (g m^{-2} day^{-1}) for three periods of growth

Sl. No.	Accession No.	Period 1 (45-90 DAS)		Period 2 (90-135 DAS)		Period 3 (135-180 DAS)	
		Shade	Open	Shade	Open	Shade	Open
1.	MP – 73	1.40	1.39	1.57	1.03	0.12	0.06
2.	MP – 74	1.23	3.49	2.51	1.43	0.58	0.16
3.	MP – 76	1.22	2.20	1.68	0.35	0.28	0.44
4.	MP – 81	1.85	5.96	5.04	2.41	1.25	0.70
5.	MP – 83	1.83	3.66	5.49	3.47	0.32	0.38
6.	MP – 85	1.16	3.17	1.80	1.40	0.62	0.31
CD (0.05)	-	NS	1.43	1.19	1.16	0.43	0.29

NS – Not significant
DAS – Days after sowing

followed MP-76. The least LAD was observed in MP-83 (3.13 days). Under open condition also, MP-76 (54.68 days) recorded the highest LAD followed by MP-73 (45.77 days). The lowest value for LAD in open was recorded by MP-83 (13.69 days) preceded by MP-81 (15.62 days).

During the period from flowering to seed formation (90-135 DAS), MP-76 (46 days) recorded maximum LAD under shade followed by MP-73 (42.37 days). They were on par. LAD was the least for MP-81 (12.86 days) preceded by MP-83 (14.53 days). Under open condition, MP-73 (126.07 days) recorded the highest LAD followed by MP-76 (105.37 days). The least was observed in MP-81 (38.82 days).

For the period from seed formation to seed maturation (135-180 DAS), MP-73 (65.94 days) recorded the maximum value for LAD under shade. It was the least for MP-81 (17.77 days) preceded by MP-83 (21.66 days). In open also, LAD was highest for MP-73 (165.22 days) followed by MP-76 (112.79 days). MP-81 (46.75 days) recorded the lowest LAD.

4.2.4.3 Net assimilation rate (Table 24)

Net assimilation rate (NAR) varied significantly among the accessions under open condition during the three periods of growth. Under shade condition also, accessions differed significantly except during period 1.

During the period from pre-flowering to flowering, MP-81 was observed as having the maximum NAR of 5.96 g m^{-2} day^{-1} under open condition. MP-

83 (3.66 g m^{-2} day^{-1}), MP-74 (3.49 g m^{-2} day^{-1}) and MP- 85 (3.17 g m^{-2} day^{-1}) were on par. The lowest NAR was observed in MP-73 (1.39 g m^{-2} day^{-1}).

For the period from flowering to seed formation, maximum NAR was observed for MP-83 (5.49 g m^{-2} day^{-1}) under shade condition followed by MP-81 (5.04 g m^{-2} day^{-1}). MP-83 and MP-81 were on par. MP-73 (1.57 g m^{-2} day^{-1}) recorded the lowest NAR value preceded by MP-76 (1.68 g m^{-2} day^{-1}). In open, MP-83 (3.47 g m^{-2} day^{-1}) recorded the highest NAR and it was on par with MP-81 (2.41 g m^{-2} day^{-1}). MP-76 (0.35 g m^{-2} day^{-1}) recorded the lowest value.

For the period from seed formation to seed maturation, MP-81 (1.25 g m^{-2} day^{-1}) had the highest NAR under shade. The least was recorded by MP-73 (0.12 g m^{-2} day^{-1}). Under open condition, NAR was found to be the highest for MP-81 (0.70 g m^{-2} day^{-1}). The lowest value was recorded for MP-73 (0.06 g m^{-2} day^{-1}).

4.2.4.4 Crop growth rate (Table 25)

During the period from pre-flowering to flowering, there was no significant difference in crop growth rate (CGR) among the accessions under shade. But, they differed significantly under open condition. In open, CGR was observed as maximum for MP-76 (4.59 g m^{-2} day^{-1}) followed by MP-81 (3.47 g m^{-2} day^{-1}). MP-81 (3.47 g m^{-2} day^{-1}) and MP-74 (3.37g m^{-2} day^{-1}) were on par. MP-83 (1.80 g m^{-2} day^{-1}) recorded the least value for CGR under open condition.

For the period from flowering to seed formation, accessions differed significantly among them under both conditions of light. In shade, highest

Table 25. Physiological parameters of *Clitoria ternatea*: crop growth rate (g $m^{-2}day^{-1}$) for three periods of growth

Sl. No.	Accession No.	Period 1 (45-90 DAS)		Period 2 (90-135 DAS)		Period 3 (135-180 DAS)	
		Shade	Open	Shade	Open	Shade	Open
1.	MP – 73	0.50	2.41	2.42	3.96	0.16	0.19
2.	MP – 74	0.21	3.37	2.63	3.07	0.44	0.32
3.	MP – 76	0.65	4.59	2.54	0.88	0.30	1.02
4.	MP – 81	0.30	3.47	2.04	2.67	0.47	0.66
5.	MP – 83	0.18	1.80	3.01	3.93	0.15	0.40
6.	MP – 85	0.50	2.51	1.83	2.21	0.49	0.47
CD (0.05)	-	NS	0.54	0.70	0.99	NS	0.41

Table 26. Physiological parameters of *Clitoria ternatea*: absolute growth rate (g day^{-1}) for three periods of growth

Sl. No.	Accession No.	Period 1 (45-90 DAS)		Period 2 (90-135 DAS)		Period 3 (135-180 DAS)	
		Shade	Open	Shade	Open	Shade	Open
1.	MP – 73	0.18	0.87	0.87	1.43	0.06	0.07
2.	MP – 74	0.08	1.21	0.95	1.10	0.16	0.11
3.	MP – 76	0.23	1.65	0.91	0.32	0.11	0.37
4.	MP – 81	0.11	1.25	0.73	0.96	0.17	0.24
5.	MP – 83	0.07	0.65	1.08	1.42	0.06	0.15
6.	MP – 85	0.18	0.90	0.66	0.79	0.18	0.17
CD (0.05)	-	NS	0.19	0.25	0.36	NS	0.15

NS – Not significant
DAS – Days after sowing

CGR was recorded by MP-83 (3.01 g m^{-2} day^{-1}). This was on par with MP-74 (2.63 g m^{-2} day^{-1}), MP-76 (2.54 g m^{-2} day $^{-1}$) and MP -73 (2.42 g m^{-2} day^{-1}). MP-85 (1.83 g m^{-2} day $^{-1}$) recorded the lowest value in open, MP-73 (3.96 g m^{-2} day^{-1}) recorded the highest CGR closely followed by MP-73 (3.93 g m^{-2} day^{-1}). MP-76 (0.88 g m^{-2} day^{-1}) recorded the lowest CGR.

During the period from seed formation to seed maturation, no significant difference could be noticed among the accessions under shade. However, they differed significantly in open, where MP-76 (1.02 g m^{-2} day^{-1}) recorded the highest CGR. The lowest value was for MP-73 (0.19 g m^{-2} day^{-1}) preceded by MP-74 (0.32 g m^{-2} day^{-1}).

4.2.4.5 Absolute growth rate (Table 26)

For the period from pre-flowering to flowering stage, no significant difference was there among the accessions under shade condition. Under open condition, absolute growth rate (AGR) was the highest for MP-76 (1.65 g day^{-1}) followed by MP-81 (1.25 g day^{-1}) and MP-74 (1.21 g day^{-1}). The lowest value for AGR was recorded by MP-83 (0.65 g day^{-1}).

During the period from flowering to seed formation stage, accessions differed significantly in AGR under both light conditions. In shade, AGR was maximum for MP-83 (1.08g day^{-1}) followed by MP-74 (0.95 g day^{-1}). They were on par. MP-85 (0.66 g day^{-1}) had the least AGR. In open, the highest value for AGR was recorded in MP-73 (1.43 g day^{-1}) closely followed by MP-83 (1.42 g day^{-1}). MP-76 (0.32 g day^{-1}) recorded the lowest value.

During the period from seed formation to seed maturation stage, there was no significant difference among the accessions under shade condition. In open, MP-76 (0.37g day^{-1}) had the highest AGR. MP-76 was on par with MP-81 (0.24 g day^{-1}). The lowest value was observed in MP-73 (0.07 g day^{-1}).

4.2.4.6 Relative growth rate (Table 27)

During the period from pre-flowering to flowering stage, no significant difference could be noticed in relative growth rate (RGR) among the accessions under shade. Under open condition, MP-74 had the highest RGR (0.08 g day^{-1}). This was on par with MP-76 (0.06 g day^{-1}), MP-83 (0.06 g day^{-1}) and MP-81 (0.06 g day^{-1}). The lowest value for RGR was recorded in MP-73 (0.04 g day^{-1}).

For the period from flowering to seed formation, accessions varied significantly among them under shade and open conditions. In shade, maximum RGR was recorded by MP-74 (0.06 g day^{-1}) and MP-83 (0.06 g day^{-1}). MP-85 (0.03 g day^{-1}) recorded the lowest RGR. In open, MP-83 (0.02 g day^{-1}) and MP-73 (0.02 g day^{-1}) were found to have maximum RGR, whereas the lowest was recorded in MP-76 (0.004 g day^{-1}).

During the period from seed formation to seed maturation also, accessions differed significantly among them under both conditions of light. Under shade condition, highest value for RGR was observed in MP-81 (0.004 g day^{-1}) and MP-85 (0.004 g day^{-1}). These were on par with MP-74 (0.003 g day^{-1}) and MP-76 (0.002 g day^{-1}). The lowest value for RGR was recorded by MP-83 (0.001 g day^{-1}) and MP-73 (0.001 g day^{-1}). Under open

Table 27. Physiological parameters of *Clitoria ternatea* : relative growth rate (g day^{-1}) for three periods of growth

Sl. No.	Accession No.	Period 1 (45-90 DAS)		Period 2 (90-135 DAS)		Period 3 (135-180 DAS)	
		Shade	Open	Shade	Open	Shade	Open
1.	MP – 73	0.03	0.04	0.04	0.02	0.001	0.001
2.	MP – 74	0.04	0.08	0.06	0.01	0.003	0.001
3.	MP – 76	0.04	0.06	0.04	0.004	0.002	0.004
4.	MP – 81	0.03	0.06	0.04	0.01	0.004	0.002
5.	MP – 83	0.04	0.06	0.06	0.02	0.001	0.001
6.	MP – 85	0.04	0.05	0.03	0.01	0.004	0.002
CD (0.05)	-	NS	0.02	0.02	0.006	0.002	0.001

Table 28. Harvest indices of *Clitoria ternatea* in terms of root, pod and root + pod

Sl. No.	Accession No.	Root		Pod		Root + pod	
		Shade	Open	Shade	Open	Shade	Open
1.	MP – 73	0.18	0.31	0.06	0.05	0.24	0.37
2.	MP – 74	0.25	0.27	0.09	0.06	0.34	0.34
3.	MP – 76	0.26	0.29	0.06	0.04	0.32	0.33
4.	MP – 81	0.31	0.19	0.07	0.07	0.38	0.26
5.	MP – 83	0.21	0.28	0.07	0.07	0.28	0.35
6.	MP – 85	0.31	0.30	0.11	0.06	0.42	0.35
CD (0.05)	-	0.04	0.02	0.01	0.01	0.05	0.02

NS - Not significant
DAS - Days after sowing

condition, MP-76 (0.004 g day^{-1}) recorded the highest RGR. The lowest value for RGR was observed in MP- 74 (0.001 g day^{-1}), MP-83 (0.001 g day^{-1}) and MP- 73 (0.001 g day^{-1}).

4.2.4.7 Harvest indices (Table 28)

Harvest indices (HI) varied significantly among the accessions for root, pod and root and pod taken together under both conditions of light.

Root

Highest HI for root under shade was obtained in MP-85 (0.31) and MP-81 (0.31). These were followed by MP-76 (0.26) and MP-74 (0.25) which were on par. MP-73 (0.18) recorded the least HI for root under shade preceded by MP-83 (0.21). Under open condition, MP-73 (0.31) had the highest HI for root closely followed by MP-85 (0.30) and MP-76 (0.29) which were on par. MP-81 (0.19) recorded the lowest HI for root in open.

Pod

MP-85 (0.11) recorded the highest HI for pod under shade. This was followed by MP-74 (0.09). MP-76 (0.06) and MP-73 (0.06) recorded the least value. In open, the maximum value for HI (pod) was obtained for MP-83 (0.07) and MP-81 (0.07), whereas the least was observed in MP-76 (0.04).

Root + pod

HI (root + pod) was recorded as highest under shade condition in MP-85 (0.42). This was followed by MP-81 which recorded a value of 0.38. These were on par. MP-73 (0.24) had the lowest HI for root + pod. In open, MP-73 (0.37) recorded the maximum value for HI (root + pod) followed by MP-85 (0.35) and MP-83 (0.35), which were on par with MP-73. The least HI for root + pod was observed in MP-81 (0.26).

4.3 Phytochemical analysis

4.3.1 Soil analysis before and after the experiment for content of N, P and K

4.3.1.1 Soil nitrogen (Table 29)

Before the commencement of the experiment, the soil analysis revealed a value of 222.66 kg ha^{-1} of nitrogen under shade and 244.61 kg ha^{-1} of nitrogen under open condition.

After the experiment, the soil nitrogen content varied significantly among the plots where the accessions were grown, both under shade and open conditions.

In shade, soil nitrogen was the highest in the plot where MP-81 was grown. The nitrogen content was 249.83 kg ha^{-1}. This was followed by the plot where MP-85 was grown. It recorded a value of 242.52 kg ha^{-1}. The least was shown by the plot where MP-83 (232.06 kg ha^{-1}) was grown, preceded by the plot of MP-76 (234.15 kg ha^{-1}).

In open, the plot where MP-81 was grown showed the highest nitrogen content (265.51 kg ha^{-1}). This was on par with that of MP-85 (260.29 kg ha^{-1}). The lowest soil nitrogen content was recorded in the plot where MP-83 (246.70 kg ha^{-1}) was grown.

Table 29. Nitrogen, phosphorus and potassium status (kg ha^{-1}) of soil at harvest (180 DAS) of *Clitoria ternatea*

Sl. No.	Accession No.	Nitrogen		Phosphorus		Potassium	
		Shade	Open	Shade	Open	Shade	Open
1.	MP – 73	238.34	257.94	28.26	32.15	133.89	163.87
2.	MP – 74	237.29	252.97	23.14	28.64	125.61	131.56
3.	MP – 76	234.15	250.88	18.35	21.72	65.32	82.55
4.	MP – 81	249.83	265.51	27.85	32.21	112.51	108.40
5.	MP – 83	232.06	246.70	17.86	20.44	78.94	85.76
6.	MP – 85	242.52	260.29	19.98	24.78	150.87	163.87
CD (0.05)	-	3.86	5.54	3.35	2.89	5.49	7.09

Table 30. Nitrogen content (per cent) of *Clitoria ternatea* at four stages of growth

Sl. No.	Accession No.	Pre-flowering (45 DAS)		Flowering (90 DAS)		Seed formation (135 DAS)		Seed maturation (180 DAS)	
		Shade	Open	Shade	Open	Shade	Open	Shade	Open
1.	MP – 73	2.81	3.05	3.66	3.78	3.49	3.53	3.32	3.47
2.	MP – 74	3.41	3.55	4.28	4.17	3.65	3.93	3.43	3.78
3.	MP – 76	3.55	3.82	3.98	4.38	3.81	4.19	3.50	3.90
4.	MP – 81	3.73	3.91	3.91	4.35	3.22	4.11	2.98	3.80
5.	MP – 83	2.85	2.99	3.69	3.57	3.31	3.49	3.12	3.30
6.	MP – 85	2.78	2.89	3.59	3.72	3.17	3.36	2.91	3.18
CD (0.05)	-	0.13	0.10	0.10	0.17	0.09	0.16	0.11	0.23

DAS – Days after sowing

4.3.1.2 Soil phosphorus (Table 29)

Before the commencement of the experiment, phosphorus content of the soil was observed to be 35.44 kg ha^{-1} and 46.85 kg ha^{-1} under shade and open conditions respectively.

After the experiment, soil phosphorus content varied significantly among the different plots under both conditions of light.

The plot of MP-73 showed the highest phosphorus content of 28.26 kg ha^{-1} under shade, closely followed by the plot of MP-81 (27.85 kg ha^{-1}). These were on par. The lowest soil phosphorus content was observed in the plot of MP-83 (17.86 kg ha^{-1}).

In open, the soil phosphorus was found to be the highest in the plot of MP-81 (32.21 kg ha^{-1}). This was closely followed by the phosphorus content in the plot of MP-73 (32.15 kg ha^{-1}). The plot where MP-83 was grown recorded the lowest phosphorus content of 20.44 kg ha^{-1}.

4.3.1.3 Soil potassium (Table 29)

Before the commencement of the experiment, content of soil potassium was 174.33 kg ha^{-1} in shade and 203.40 kg ha^{-1} in open.

After the experiment, soil potassium content differed significantly among the different plots under open as well as shaded conditions.

Under shaded condition, the highest soil potassium content was obtained in the plot where MP-85 (150.87 kg ha^{-1}) was grown. The soil potassium content was lowest in the plot of MP-76 (65.32 kg ha^{-1}) preceded by that of MP-83 (78.94 kg ha^{-1}).

Under open condition, the plots of MP-85 (163.87 kg ha^{-1}) and MP-73 (163.87 kg ha^{-1}) recorded the highest soil potassium content. The lowest was in the plot of MP-76 (82.55 kg ha^{-1}) preceded by that of MP-83 (85.76 kg ha^{-1}).

4.3.2 Plant nitrogen (Table 30)

Plant nitrogen content varied significantly among the accessions in all the four stages of growth under both shade and open conditions.

At pre-flowering stage, MP-81 recorded the maximum nitrogen content (3.73 %) under shade. This was followed by MP-76 (3.55 %) and MP-74 (3.41 %). Nitrogen content was the least in MP-85 (2.78 %). In open, maximum nitrogen content was observed in MP-81, which recorded a value of 3.91 % closely followed by MP-76 (3.82 %). MP-85 recorded the least nitrogen content of 2.89 % under open condition.

At flowering stage, the highest nitrogen content was obtained in MP-74 (4.28 %) under shade condition. The content of nitrogen was lowest for MP-85 (3.59 %). Under open condition, maximum nitrogen was found to be present in MP-76 (4.38 %), which was on par with MP-81 (4.35 %). The nitrogen content of MP-83 (3.57 %) was found to be the least.

At seed formation stage, MP-76 recorded the highest nitrogen content of 3.81 per cent under shade followed by MP-74 (3.65 %). MP-85 recorded the lowest value of 3.17 %. Under open condition also, the highest value was

Table 31. Crude alkaloid content (per cent) in seeds of *Clitoria ternatea*

Sl. No.	Accession No.	Crude alkaloid content	
		Shade	Open
1.	MP – 73	0.40	0.43
2.	MP – 74	0.39	0.36
3.	MP – 76	0.40	0.39
4.	MP – 81	0.25	0.32
5.	MP – 83	0.33	0.41
6.	MP – 85	0.35	0.42
CD (0.05)	-	0.02	0.04

recorded for MP-76 (4.19 %) closely followed by MP-81 (4.11 %). MP-85 (3.36 %) recorded the least.

At seed maturation stage, MP-76 was observed to contain maximum nitrogen of 3.50 per cent under shade. This was followed by MP-74 (3.43 %). The lowest content of nitrogen was observed in MP-85 (2.91 %). In open, MP-76 (3.90 %) recorded the highest nitrogen content. This was followed by MP-81 (3.80 %). MP-76, MP-74 (3.78 %) and MP-81 (3.80 %) were on par.

4.3.3 Crude alkaloid content (Table 31)

Crude alkaloid content varied significantly among the accessions under both conditions of light. However, there was no significant variation between shade and open conditions.

In shade, maximum crude alkaloid (0.40 %) was obtained in MP-76 and MP-73. These were on par with MP-74 (0.39 %). The lowest content of alkaloid was recorded in MP-81 (0.25 %).

In open, MP-73 recorded the highest crude alkaloid content of 0.43 %, which was on par with MP-76 (0.39 %). The lowest alkaloid content under open condition was recorded by MP-81 (0.32 %).

4.4 Correlation analysis

The phenotypic and genotypic correlation coefficients were estimated for important pairs of characters *viz.*, plant length, number of leaves, leaf area, number of pods per plant, length of pod, number of seeds per pod, root length, root girth, dry weight of leaves, dry weight of shoot, dry weight of pods, dry

Table 32. Phenotypic correlation coefficients of growth and yield characters in *Clitoria ternatea*

Characters			x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}
Plant length (cm)	x_1	S	1.0000												
		O	1.0000												
Number of leaves	x_2	S	0.1143	1.0000											
		O	05704	1.0000											
Leaf area (cm^2)	x_3	S	0.1495	0.8850**	1.0000										
		O	-0.0655	0.4579	1.0000										
Number of pods	x_4	S	0.4599	0.7571**	0.8330**	1.0000									
		O	-0.2546	0.2521	0.8763**	1.0000									
Length of pod (cm)	x_5	S	0.4512	0.6899*	0.5586	0.8321**	1.0000								
		O	0.1227	0.2195	0.8105**	0.7569**	1.0000								
Number of seeds	x_6	S	0.4140	0.6792*	0.6061	0.8337**	0.8934**	1.0000							
		O	-0.0821	-0.2911	0.3162	0.2947	0.5865	1.0000							
Root length (cm)	x_7	S	-0.6136	-0.3485	-0.5017	-0.4316	-0.2650	-0.3617	1.0000						
		O	-0.5709	0.0615	-0.0720	0.0763	-0.4217	-0.3677	1.0000						
Root girth (cm)	x_8	S	-0.3691	0.3285	0.3549	0.4413	0.3171	0.2593	0.5175	1.0000					
		O	-0.5774	-0.0610	-0.1710	-0.0243	-0.4491	-0.2193	0.8721**	1.0000					
Dry weight of leaves (g)	x_9	S	-0.6910*	-0.1404	-0.1634	-0.2914	-0.2831	-0.3405	0.7569**	0.5436	1.0000				
		O	0.5054	0.9592**	0.4357	0.2380	0.1627	-0.4166	0.1299	-0.0586	1.0000				
Dry weight of shoot (g)	x_{10}	S	-0.0999	0.6144	0.5187	0.4570	0.6362*	0.5175	-0.0636	0.2982	0.1845	1.0000			
		O	0.5859	0.7593**	-0.0349	-0.1794	-0.1957	-0.3942	0.2077	0.2022	0.6822*	1.0000			
Dry weight of pods (g)	x_{11}	S	0.4714	-0.6065	-0.3981	-0.1041	-0.2526	-0.1904	-0.0268	-0.1696	-0.0233	-0.5639	1.0000		
		O	-0.3125	0.2406	0.8632**	0.9940**	0.7172*	0.2380	0.1275	0.0245	0.2324	-0.1886	1.0000		
Dry weight of root (g)	x_{12}	S	-0.0490	-0.2939	-0.2277	0.0403	-0.0709	-0.1445	0.4453	0.5562	0.2326	-0.4559	0.3751	1.0000	
		O	-0.0774	0.1792	-0.4188	-0.4230	-0.6541*	-0.4034	0.7422*	0.6003	0.2213	0.4374	-0.4017	1.0000	
Harvest index	x_{13}	S	0.2947	-0.6297	-0.4672	-0.2703	-0.4814	-0.3822	0.0592	-0.1603	-0.1123	-0.9128**	0.8270**	0.5832	1.0000
		O	-0.6365*	-0.3409	0.5457	0.7275*	0.5206	0.3790	0.0457	-0.0428	-0.2786	-0.7745**	0.7442*	-0.4337	1.0000

S - Shade
O - Open

* Significant at 5 % level
** Significant at 1 % level

Table 33. Genotypic correlation coefficients of growth and yield characters in *Clitoria ternatea*

Characters			x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}
Plant length (cm)	x_1	S	1.0000												
		O	1.0000												
Number of leaves	x_2	S	0.0063	1.0000											
		O	0.5990	1.0000											
Leaf area (cm^2)	x_3	S	0.1331	0.9346	1.0000										
		O	-0.0548	0.4835	1.0000										
Number of pods	x_4	S	0.4506	0.8118	0.8677	1.0000									
		O	-0.3297	0.2747	0.9346	1.0000									
Length of pod (cm)	x_5	S	0.4224	0.6927	0.5663	0.8419	1.0000								
		O	0.1046	0.3023	0.9506	0.8048	1.0000								
Number of seeds	x_6	S	0.5205	0.8441	0.7346	0.9417	1.0436	1.0000							
		O	-0.2307	-0.4411	0.8411	0.7113	1.1364	1.0000							
Root length (cm)	x_7	S	-0.8601	-0.5194	-0.5804	-0.5995	-0.3706	-0.5522	1.0000						
		O	-0.6482	0.0588	-0.0679	0.0794	-0.5138	-1.0780	1.0000						
Root girth (cm)	x_8	S	-0.5168	0.3387	0.3814	0.4046	0.3027	0.2474	0.4716	1.0000					
		O	-0.7038	-0.0880	-0.1645	-0.0346	-0.5726	-0.8043	0.9145	1.0000					
Dry weight of leaves (g)	x_9	S	-0.8663	-0.3284	-0.2108	-0.3580	-0.3881	-0.4824	0.8829	0.6304	1.0000				
		O	0.5373	0.9756	0.4811	0.2680	0.2887	-0.4639	0.1584	-0.0889	1.0000				
Dry weight of shoot (g)	x_{10}	S	-0.1455	0.7369	0.5764	0.5899	0.7558	0.8294	0.0305	0.4310	0.1880	1.0000			
		O	0.5882	0.8630	-0.0252	-0.2364	-0.2608	-0.9490	0.1664	0.1930	0.7875	1.0000			
Dry weight of pods (g)	x_{11}	S	0.5100	-0.7642	-0.4338	-0.2230	-0.3597	-0.4323	-0.1129	-0.3162	-0.0442	-0.5837	1.0000		
		O	-0.3800	0.2576	0.9162	0.9994	0.7634	0.6994	0.1536	0.0430	0.2531	-0.2290	1.0000		
Dry weight of root (g)	x_{12}	S	-0.0878	-0.3659	-0.2416	0.0082	-0.1023	-0.1999	0.4294	0.5708	0.2565	-0.4625	0.3670	1.0000	
		O	-0.1269	0.2089	-0.5057	-0.5123	-0.8595	-1.7952	0.7880	0.6824	0.3498	0.5322	-0.4486	1.0000	
Harvest index	x_{13}	S	0.3200	-0.7907	-0.5155	-0.3976	-0.6023	-0.6845	-0.0627	-0.3057	-0.1285	-0.9180	0.8373	0.5846	1.0000
		O	-0.6984	-0.3995	0.5893	0.7730	0.6006	0.9232	0.1076	-0.0015	-0.3254	-0.7825	0.7755	-0.5220	1.0000

S - Shade
O- Open

weight of root and harvest index (root + pod). The correlation coefficients are presented in the form of matrices in Table 32 and Table 33.

4.4.1 Correlation between shoot yield (dry weight) and other characters in shade

The phenotypic correlation was found to be high and positive for pod length (0.6362), number of leaves (0.6144), leaf area (0.5187), number of seeds per pod (0.5175), and number of pods per plant (0.4570). Highest negative correlation was shown by harvest index (-0.9128) followed by dry weight of pods (-0.5639) and dry weight of root (-0.4559).

The genotypic correlation of shoot yield with all the characters except plant length (-0.1455), dry weight of pods (-0.5837), dry weight of root (-0.4623) and harvest index (-0.9180) was positive. The highest positive correlation was for number of seeds per pod (0.8294) followed by length of pod (0.7558) and number of leaves (0.7369).

4.4.2 Correlation between shoot yield (dry weight) and other characters in open

The highest positive phenotypic correlation was recorded by number of leaves (0.7593) followed by dry weight of leaves (0.6822) and plant length (0.5859). Harvest index (-0.7745) and number of seeds per pod (-0.3942) recorded high negative correlation.

Correlation analysis revealed a high positive genotypic correlation of shoot yield with number of leaves (0.8630) followed by dry weight of leaves

(0.7875), plant length (0.5882) and dry weight of root (0.5322). Highest negative genotypic correlation was exhibited by number of seeds per pod (-0.9490) followed by harvest index (-0.7825).

4.4.3 Correlation between pod yield (dry weight) and other characters in shade

The phenotypic correlation was found to be high and positive for harvest index (0.8270), plant length (0.4714) and dry weight of root (0.3751). All other characters showed negative correlation with pod yield under shade condition. However, the highest negative correlation was recorded for number of leaves (-0.6065).

High and positive genotypic correlation was recorded by harvest index (0.8373). Plant length (0.5100) and dry weight of root (0.3670) also showed high positive correlation. Correlation was high and negative for characters like number of leaves (-0.7642), dry weight of shoot (-0.5837) and leaf area (-0.4338).

4.4.4 Correlation between pod yield (dry weight) and other characters in open

Number of pods per plant (0.9940) had the highest positive phenotypic correlation with pod yield followed by leaf area (0.8632) and harvest index (0.7442). High negative correlation was observed for dry weight of root (-0.4017) and plant length (-0.3125).

The genotypic correlation was found to be high and positive for number of pods per plant (0.9994) followed by leaf area (0.9162), harvest index (0.7755) and length of pod (0.7634). Dry weight of root (-0.4486) and plant length (-0.3800) recorded high negative correlation.

4.4.5 Correlation between root yield (dry weight) and other characters in shade

Harvest index (0.5832), root girth (0.5562), root length (0.4453) and dry weight of pods (0.3751) showed high positive phenotypic correlation whereas dry weight of shoot (-0.4559) showed high negative correlation.

The genotypic correlation was found to be highest for harvest index (0.5846) followed by root girth (0.5708) and root length (0.4294). High negative correlation was shown by dry weight of shoot (-0.4625).

4.4.6 Correlation between root yield (dry weight) and other characters in open

The phenotypic correlation was found to be high and positive for root length (0.7422), root girth (0.6003) and dry weight of shoot (0.4374). Highest negative correlation was recorded for number of nodules (-0.7141) followed by length of pod (-0.6541).

The genotypic correlation was highest for root length (0.7880). Root girth (0.6824), dry weight of shoot (0.5322) and dry weight of leaves (0.3498) also recorded high positive correlation. Highest negative correlation was recorded for number of seeds per pod (-1.7952) followed by length of pod (-0.8595).

4.5 Selection index

Discriminant function technique was used for the construction of selection index based on sixteen selected important characters *viz*., plant length, number of leaves, leaf area, number of pods per plant, length of pod, number of seeds per pod, root length, root girth, dry weight of leaves, dry

Table 34. Selection index scores and ranks of *Clitoria ternatea* accessions

Sl. No	Accession No.	Shade		Open	
		Selection index score	Rank	Selection index score	Rank
1	MP-73	22688.06	1	1335746	1
2	MP-74	15757.94	4	1319247	3
3	MP-76	19580.18	2	1324231	2
4	MP-81	11585.33	6	1308547	6
5	MP-83	12188.43	5	1310045	5
6	MP-85	16106.89	3	1313720	4

weight of shoot, dry weight of pods, dry weight of root, number of root nodules at seed formation stage, dry weight of root nodules, harvest index (root + pod) and crude alkaloid content. The selection indices were worked out as follows :

Under shade condition,

$$I = -57.37406\ X_1 - 25.67099\ X_2 + 0.8639764\ X_3 + 219.6169\ X_4 + 733.6596\ X_5 - 571.0849\ X_6 + 3.357437\ X_7 - 1759.364\ X_8 - 55.27855\ X_9 + 283.2736\ X_{10} - 464.7247\ X_{11} - 480.2743\ X_{12} + 14.97219\ X_{13} - 212.7141\ X_{14} + 37629.39\ X_{15} - 798.6285\ X_{16}$$

Under open condition,

$$I = 218.2256\ X_1 + 203.5923\ X_2 + 1.17589\ X_3 - 1196.434\ X_4 + 9657.67\ X_5 + 427.9669\ X_6 - 456.9879\ X_7 + 18074.28\ X_8 - 2044.139\ X_9 + 1373.485\ X_{10} - 491.5875\ X_{11} + 2177.127\ X_{12} + 1774.433\ X_{13} - 30014.7\ X_{14} + 426126.7\ X_{15} + 127298.5\ X_{16}.$$

The selection index scores are presented in Table 34 along with ranking of each accession.

Under open condition, MP-73 ranked first followed by MP-76 and MP-74. MP-81 was the poorest performer. Similar trend was observed under shade condition also except that MP-85 performed better than MP-74. Irrespective of the light condition, it was observed that MP-73 and MP-76 are the top ranking accessions.

Discussion

5. DISCUSSION

The present study entitled 'Evaluation of selected Sankhupushpam (*Clitoria ternatea* L.) lines for yield, alkaloid content and nodulation' was carried out at the College of Agriculture, Vellayani from June to December 2000. The study aimed at selecting the most promising line(s) of *Clitoria ternatea* for open as well as shaded conditions.

The results of the study are discussed in this chapter.

5.1 Seed characterization and germination

When the seeds of the lines selected for the study were subjected to germination trial, three accessions MP-73, MP-83 and MP-85 exhibited more than 80 per cent germination. Higher germination percentage of these accessions may be attributed to their high genetic vigour. The accession MP-73 took least number of days (14 days) to achieve 50 per cent germination. Total number of days taken to achieve 50 per cent germination varied from 14 to 21 days in various accessions. This may be due to the genetic variation among the accessions.

With regard to hundred seed weight, it ranged from 4 – 6 g in various accessions. Of the six accessions under study, MP-76 recorded the highest hundred seed weight of 6g.

There was variation in the colour and appearance of different accessions, which may be attributed to their differences in genetic make up.

5.2 Growth parameters

5.2.1 Shoot characters

Shoot characters include plant length, number of leaves and leaf area.

Considerable variation was noticed in plant length among the accessions at seed formation and seed maturation stages both under shade in coconut garden and under open condition (Table 3).

Variation in plant length within legumes is purely a function of genetic make up (Bose, 1963).

The observations indicated higher values for plant length in all the accessions under open condition when compared to those under shade. This was in conformity with the findings of Sunitha (1996) in *Clitoria ternatea*. Reduction in plant length under shade may be due to the physiological and ecological influence, especially light, which limits growth of crops in mixtures (Blackman and Black, 1959). Existence of tight competition for eco-physiological requirements like water, nutrients and light might have resulted in an unfavourable situation for rapid vegetative growth thereby causing a reduction in plant height (Anilkumar, 1984).

The plant length of all the accessions exhibited an increasing trend throughout the growth period under shade as well as under light. In mothbean, a similar trend was recorded by Kulkarni and Karadge (1991). As per the observation, maximum plant length at seed formation and seed maturation stages was recorded by MP-76 and MP-81 under shade and open conditions respectively. Lowest values for plant length at seed formation stage were recorded by MP-81 and MP-85 under shade and open conditions respectively. At seed maturation stage, MP-74 exhibited the lowest plant length under both conditions of light. The observations indicated that the same accessions did not show superior performance during all stages of plant growth.

Number of leaves per plant showed significant variation among the accessions at all stages of growth except at pre-flowering stage under open condition and at flowering stage under shade condition (Table 4). Variation in number of leaves among the accessions may be attributed to the fact that it is purely a function of genetic make up and environmental conditions (Gardner *et al.*, 1988). In all the six accessions, greater number of leaves were produced under open condition. This may be due to the lack of competition for light, space, water or nutrients in a pure cropping system, resulting in higher production of leaves and branches. This observation is in line with that of Sunitha (1996) in *Clitoria ternatea*. Prabhakar *et al.* (1979) also obtained higher leaf number in plots of cassava where no intercrop was raised. In cassava, the leaf number decreased when grown under shade in coconut gardens (Sreekumari *et al.*, 1988). Susan (1989) observed a decrease in the number of leaves with shading in ginger and turmeric.

The study of the data on the number of leaves per plant revealed that it showed an increasing trend upto the seed formation stage and thereafter it declined, which may be attributed to leaf shedding caused by senescence. Similar observations were made by Jyothi (1995) in vegetable cowpea, Nair (2000) in *C. ternatea* and Samuel (2000) in *Mucuna pruriens*. In almost all the accessions, the greatest increment in leaf production was between the period of pre-flowering and flowering. A similar report was made by Samuel

(2000) in *Mucuna pruriens*. Irrespective of the light condition, MP-73 produced maximum number of leaves at seed maturation stage.

Leaf area showed significant variation among the accessions at all the four growth stages under shade as well as open conditions (Table 5). As in the case of number of leaves, leaf area also showed an increasing trend from pre-flowering to seed formation stage and a declining trend from seed formation to seed maturation stage. This is because leaf area is a function of the number of leaves. At pre-flowering, seed formation and seed maturation stages, maximum leaf area was recorded for MP-73 under shaded condition whereas at flowering stage, MP-76 recorded the highest leaf area. However, under open condition, MP-76 recorded the highest leaf area at pre-flowering and flowering stages, while MP-73 showed maximum leaf area at seed formation and seed maturation stages.

From the data, it can be assessed that leaf area is higher under open condition. This can be attributed to the better vegetative growth of the plants under open condition which resulted in the greater number of leaves and hence increased leaf area. MP-73 recorded maximum leaf area under shade as well as open conditions at seed maturation stage.

5.2.2 Pod characters

Pod characters consist of number of pods per plant, pod length and number of seeds per pod.

Number of pods per plant showed significant variation among the accessions under shade as well as open conditions at seed formation and seed maturation stages (Table 6). Under shaded condition, highest number of pods was obtained for MP-76 whereas under open condition MP-73 yielded the highest number of pods. Production of pods was more under open condition. This may be due to the more efficient and profuse flowering under open condition as reported by Sunitha (1996).

Pod length showed significant variation among the accessions except under open condition at seed formation stage (Table 7). As in the case of number of pods per plant, MP-76 recorded maximum pod length under shaded condition while MP-73 recorded maximum pod length under open condition. Pod length was found to be the least for MP-81 in both the stages under shade and open conditions. Pod length varied among the accessions in accordance with characteristic genetic make up. This is in justification with the reports of Nair (1966) regarding pod length in cowpea. Relatively higher pod length was recorded under open condition. This may be attributed to the increased general vigour of the plants under open condition due to the abundant and continuous availability of solar radiation.

Number of seeds per pod showed significant variation among the accessions under shaded condition (Table 8). On the other hand, in open, all the accessions were on par in terms of number of seeds per pod. Maximum number of seeds per pod was recorded in MP-76 under shade in both the stages, whereas minimum was recorded in MP-81.

5.2.3 Root characters

Root characters include root length and root girth.

Root length showed significant variation among the accessions under both light conditions at seed formation and seed maturation stages. Under open condition root length recorded significant variation at flowering stage (Table 9). Irrespective of the light condition, MP-74 recorded the highest root length at seed formation and seed maturation stages. Root length was found to be higher under open condition than under shade. There are similar reports of higher root length under open condition by Sunitha (1996) in *Clitoria ternatea* and *Atylosia scarabaeoides*. This might be due to more vigorous and faster growth rate of the plants under open condition when compared to that under shade in coconut garden.

There was considerable variation among the accessions in root girth under both shade and open conditions at seed maturation stage and under open condition at flowering and seed formation stage (Table 10). MP-74 recorded the highest root girth under both conditions. Root girth was found to be more under open condition. This might be due to a variety of factors like lesser competition for nutrients which would have provided favourable condition for thickening of roots.

Root length and root girth showed an increasing trend upto the seed formation stage and after that both declined. This is in line with the findings of Barber (1978) in soybean and Nair (2000) in *Clitoria ternatea.*

5.3 Nodule characteristics

Nodule characteristics consist of number of nodules, fresh weight and dry weight of nodules.

From the data on nodule count, it was evident that it differed significantly among the accessions at all stages of growth under shade as well as open conditions except at flowering and seed formation stages under shaded condition (Table 19).

Maximum number of nodules under shaded condition was noticed in MP-73 whereas under open condition MP-76 had the highest nodule count. Nodule count was found to be the lowest at pre-flowering stage. From pre-flowering to flowering stage it showed an increasing trend and then decreased at seed formation stage. In the first stage, the root growth might have been too less to accommodate more number of nodules, which has increased considerably in the second stage resulting in maximum nodulation. At seed maturation stage, nodules were absent. Nair (2000) also obtained similar results in *Clitoria ternatea* under shaded condition. According to Russell (1961) the nodules of annual legumes tend to die out during active flowering and seed setting stages. Number of root nodules was found to be higher under open condition when compared to that of shade. This conforms to the finding of Whyte *et al.* (1953) that nodulation is poor under shaded condition. They also reported that the infection of plants by nodule bacteria and the effectiveness of the nodulation in terms of nitrogen fixation improve as the supply of light increases.

As in the case of nodule count, fresh weight and dry weight of nodules showed an increase upto flowering stage and then decreased (Table 20 and 21). MP-73 recorded the highest nodule count, nodule fresh weight and nodule dry weight under shaded condition, whereas MP-76 ranked first for these characters under open condition.

5.4 Yield and yield attributes

5.4.1 Leaf yield

Fresh weight of leaves was found to vary significantly among the accessions at all stages of plant growth except at pre-flowering stage under open condition and at flowering stage under shade condition (Table 11). In the case of leaf dry weight, except at flowering stage under shaded condition, significant variation was observed among the accessions (Table 12).

In almost all the accessions, highest increment in leaf yield was between pre-flowering and flowering stages. Leaf yield was found to decrease at the seed maturation stage. This increasing trend upto seed formation stage and declining trend afterwards can be explained by the production of leaves at all stages and shedding of leaves at the last stage due to senescence as reported by Samuel (2000). MP-81 and MP-73 recorded the maximum leaf fresh weight at seed maturation stage under shade and open conditions respectively. MP-74 and MP-73 recorded the highest leaf dry weight under shaded condition and open condition respectively at seed maturation stage. Leaf yield was found to be higher under open condition.

5.4.2 Shoot yield

Fresh weight and dry weight of shoot were found to vary significantly among the accessions under both conditions except in the case of fresh weight of shoot under open condition at pre-flowering stage (Table 13 and 14). A declining trend during seed formation to seed maturation stage could be noticed in shoot fresh weight. This decline may be attributed to the leaf shedding and senescence (Kulkarni and Karadge, 1991). However, the shoot dry weight showed a slight increase from seed formation to seed maturation. This is in line with the reports of Nair (2000) in *Clitoria ternatea*. The highest increment in shoot yield was observed between pre-flowering and flowering stage. This agrees with the findings of Samuel (2000) in *Mucuna pruriens*. Fresh weight and dry weight of shoot were comparatively superior under open condition. This is due to their better vegetative growth in terms of plant length, number of branches and number of leaves under open condition as reported by Sunitha (1996).

5.4.3 Pod yield

The yield of pods was found to differ significantly among the accessions under shade as well as open conditions (Table 15 and 16).

Based on the available data, it can be assessed that the pod yield varied according to the number of pods per plant. Under shade, the highest pod yield was recorded in MP-76 and under open condition MP-73 showed highest pod yield. It was observed that the accessions which showed good vegetative growth gave higher pod yield also. This may be attributed to the overall genetic superiority of these accessions over the others. Fresh weight and dry weight of pods were superior under open condition as reported by Sunitha (1996).

5.4.4 Root yield

Analysis of the data on root yield revealed that fresh weight of root varied significantly among the accessions at seed formation and seed maturation stages under shade as well as open conditions and at flowering stage under open condition (Table 17). The dry weight of roots showed significant variation among the accessions at all stages of growth under both shade and open conditions (Table 18).

The increase in root yield at every stage of growth upto seed formation stage can be attributed to the increase in root length and root girth. Thereafter, the root weight declined. This conforms to the report of Nair (2000) in *C. ternatea*. Decline in root weight may be due to poor primary root growth (Gardner *et al.*, 1988). Under open condition, root yield was found to be higher. This is in agreement with the findings of Sunitha (1996). This superiority in root yield under open condition can be attributed to the greater number of lateral roots, greater root length and girth under open condition. Nelson (1964) observed that root girth is usually inhibited by low light intensities and this can lead to a reduction in assimilate flow to the root system.

5.5 Physiological parameters

5.5.1 Leaf area index (LAI)

The leaf area index was found to differ significantly among the accessions at all stages of growth under both shade and open conditions (Table 22).

The LAI was found to be the least at pre-flowering stage. It increased from pre-flowering to flowering stage, reached the maximum at seed formation stage and decreased afterwards. The declining trend at later stage can be attributed to leaf shedding caused by senescence which reduced the leaf number, hence total leaf area and LAI. Maggie (1989) observed a similar trend in cowpea. It is also supported by the findings of Nair (2000) in *C. ternatea* and Samuel (2000) in *Mucuna pruriens*. According to Pearce and Mitchel (1990), LAI is found to lower during reproductive phase, as vegetative growth is reduced at this phase. The trend of variation in LAI was observed to be similar to that of leaf number and leaf yield, as LAI is a function of these characters. The data indicated higher values of LAI at all stages under open condition when compared to shade condition. This is in conformity with the report of Bleasdale (1973) that the optimum LAI depends not only on the arrangement of leaves in the canopy but also on the light intensity that the canopy receives. MP-73 and MP-76 recorded higher values for LAI under both light conditions.

5.5.2 Leaf area duration (LAD)

Leaf area duration showed significant variation among the accessions under shade as well as open conditions (Table 23) during the three different periods of growth *viz.*, pre-flowering to flowering (45-90 DAS), flowering to seed formation (90-135 DAS) and seed formation to seed maturation (135-180 DAS).

The lowest LAD was observed between pre-flowering and flowering stages. It increased subsequently and reached maximum between seed formation and seed maturation stages. This conforms to the findings of Nair (2000) in *C. ternatea* and Samuel (2000) in *Mucuna pruriens*. As in the case of LAI, MP-73 and MP-76 recorded higher values for LAD. This could be attributed to the fact that LAD is a function of LAI which in turn has got an association with the number of leaves. Though the number of leaves showed a decrease at seed maturation stage, LAD was found to be maximum between seed formation and seed maturation stage. This may be attributed to the fact that for perennial legumes, vegetative shoots are generated from axillary buds to replace them at the senescence of fruiting shoots as reported by Gardner *et al.* (1988). Irrespective of the light condition, MP-73 was found to have the highest leaf area duration during the period from seed formation to seed maturation, while MP-81 recorded the least. LAD was found to be higher under open condition.

5.5.3 Net assimilation rate (NAR)

Net assimilation rate varied significantly among the accessions in all periods of growth and under shade as well as open conditions except under shade during the first period (Table 24).

Maximum NAR was observed in MP-81 during the period from pre-flowering to flowering and from seed formation to seed maturation. However, during flowering to seed formation stage, maximum NAR was recorded in MP-83.

Under shaded condition, NAR was highest during flowering to seed formation stage, and it declined towards the final stage. The trend was almost similar to that shown by LAD. Similar trend in NAR was obtained by Samuel (2000) in *Mucuna pruriens*.

However, under open condition NAR showed a declining trend towards seed formation and seed maturation stages. The value was highest during the initial stages. Similar trend in NAR was observed in *Cicer arietinum* by Haloi and Baldev (1986). Downward drift of NAR with plant age was observed by Gardner *et al.* (1988).

5.5.4 Crop growth rate (CGR)

Under open condition, crop growth rate varied significantly among the accessions during all the three periods of growth. However, no significant difference could be noticed among the accessions during pre-flowering to flowering stage and seed formation to seed maturation stage of growth under shaded condition (Table 25).

During the period from pre-flowering to flowering, maximum CGR was shown by MP-76. From flowering to seed formation stage, CGR was the highest for MP-83 under shade and MP-73 under open condition. From seed formation to seed maturation stage of growth, MP-76 recorded maximum crop growth rate under open condition.

In shade, CGR showed an increasing trend towards the second period of growth (flowering to seed formation) and then it declined towards the third period (seed formation to seed maturation). The decline in growth rate also corresponded with reduction in LAI, nodule count and nodule weight during the same period of plant growth. The results obtained are in conformity with the findings of Samuel (2000) in *Mucuna pruriens*. Pearce and Mitchel (1990) opined that CGR was closely related to the LAI and that it could be considered as the most meaningful term for growth analysis.

Under open condition, most of the accessions (except MP-83 and MP-73) showed a declining trend from the initial to final period of growth.

As per the data, CGR values were higher under open condition. The observation was in line with that of Ramadasan and Satheesan (1980) in turmeric cultivars. Ramanujam and Jose (1984) found that the CGR of cassava grown under shade were reduced significantly when compared to those plants grown under normal light.

5.5.5 Absolute growth rate (AGR)

As in the case of CGR, absolute growth rate varied significantly among the accessions during all the three periods of growth under open condition. In shade there was no significant difference among the accessions during the period from pre-flowering to flowering and from seed formation to seed maturation (Table 26).

During the first and third periods of growth, MP-76 recorded maximum AGR under open condition. From flowering to seed formation stage, AGR was maximum for MP-83 and MP-73 under shade and open conditions respectively.

AGR displayed similar trend in variation among the periods of growth similar to that of CGR. This may be because CGR is a function of AGR and the whole plant dry matter is taken into consideration for their computation.

In shade, the value of AGR was the highest during flowering to seed formation stage whereas under open condition, AGR showed the highest value during the pre-flowering to flowering stage (except for MP-83 and MP-73).

5.5.6 Relative growth rate (RGR)

RGR varied significantly among the accessions during all the three periods of growth except during the first period (pre-flowering to flowering) under shade condition (Table 27).

During the initial period of growth, MP-74 exhibited highest RGR under open condition. During the period from flowering to seed formation, MP-83 and MP-74 showed the highest relative growth rate under shade whereas MP-83 and MP-73 recorded maximum RGR under open condition. During the third period (seed formation to seed maturation) of growth, MP-85 and MP-81 recorded the highest RGR under shade condition whereas MP-76 recorded maximum under open condition.

In shade, RGR showed a slight increase in almost all the accessions (except MP-85 and MP-76) from first to second period of growth. During the final period of growth, it showed a declining trend.

In open, RGR showed a declining trend throughout the growth period and it was maximum during pre-flowering to flowering stage. This was in line with the finding of Haloi and Baldev (1986) who reported high value of RGR at the initial growth stages in *Cicer arietinum*. Similar reports were made by Nair (2000) in *C. ternatea* and Samuel (2000) in *Mucuna pruriens*.

5.5.7 Harvest indices (HI)

Harvest indices showed significant variation among the accessions for root yield, pod yield and root and pod yield taken together (Table 28).

HI for root yield under shade was found to be the highest in MP- 85 and MP-81. Under open condition, MP-73 recorded the maximum value.

Highest HI for pod yield was observed in MP-85 under shade. In open, the maximum value was recorded for MP-81 and MP-83.

When root and pod yield were taken together, the highest HI was observed in MP-85 and MP-73 under shade and open conditions respectively.

From the data, it was found that as the root and pod yield increased, HI increased. This is because, harvest index is related to economic yield.

HI (root + pod yield) for almost all the accessions (except MP-85 and MP-81) under open condition were higher than those under shade. This agrees with the report of Susan,(1989) who obtained the highest harvest index in ginger under open condition.

5.6 Phytochemical analysis

5.6.1 Soil nutrient status

5.6.1.1 Soil nitrogen content

The soil nitrogen content in the experimental site where the various accessions were grown showed significant variation under shade and open conditions (Table 29).

Under shade, the initial soil nitrogen content of the experimental site was 222.66 kg ha^{-1}. In open, 244.61 kg ha^{-1} of soil nitrogen was recorded before the commencement of the experiment.

The post-experiment data on analysis revealed that a range of 9.40 kg ha^{-1} to 27.17 kg ha^{-1} of nitrogen had been fixed by various accessions under shade. Under open condition, nitrogen fixed ranged from 2.09 to 20.90 kg ha^{-1}. Irrespective of the light condition, the accession MP-81 fixed comparatively higher level of soil nitrogen followed by MP-85. Potential for nitrogen fixation was found to be the least in MP-83.

Higher soil nitrogen content under shade may be attributed to the lower uptake of nitrogen by the crop under shaded condition. Sunitha (1996) reported that nitrogen uptake under open condition is superior to that under shade in *C. ternatea*. In legumes, nitrogen uptake varied from 15 to 60 kg ha^{-1} (Mercy, 1981).

5.6.1.2 Soil phosphorus content

There was significant variation among the accessions in soil phosphorus content under shade as well as open conditions (Table 29).

Before the commencement of the experiment, the soil phosphorus content was 35.44 kg ha^{-1} and 46.85 kg ha^{-1} under shade and open conditions respectively.

After the experiment, soil phosphorus status was maximum in the plots of MP-73 and MP-81 under shade and open conditions. Lowest content of soil phosphorus was noticed in the plots of MP-83. This indicates higher uptake of phosphorus by MP-83 and lower uptake by MP-73 and MP-81. The uptake of phosphorus ranged from 7.18 to 17.58 kg ha^{-1} under shade and from 14.64 to 26.41 kg ha^{-1} under open condition. This is in conformity with the report of Sunitha (1996) that uptake of phosphorus is higher under open condition.

5.6.1.3 Soil potassium content

The content of soil potassium varied significantly among the plots of various accessions (Table 29).

Soil analysis revealed an initial potassium content of 174.33 kg ha^{-1} under shade and 203.40 kg ha^{-1} under open condition.

After the experiment, highest soil potassium content was observed in the plots of MP-85 under shade condition whereas in open, the plots of both MP-85 and MP-73 showed high soil potassium content. Lowest content of soil potassium under both conditions was observed in MP-76. An uptake of 23.46 kg ha^{-1} to 109.01 kg ha^{-1} of potassium under shaded condition and

39.53 kg ha^{-1} to 120.85 kg ha^{-1} under open condition was noticed. This is in line with the findings of Sunitha (1996) who observed a higher uptake of potassium under open condition in *Clitoria ternatea*.

5.6.2 Plant nitrogen content

Percentage of plant nitrogen varied significantly among the accessions at all stages of growth under both shade and open conditions (Table 30).

At pre-flowering stage, maximum nitrogen content was observed in MP-81. At flowering stage, MP-74 recorded the highest content of nitrogen under shade and MP-76 recorded the highest nitrogen content under open condition. At seed formation and seed maturation stages, MP-76 had the highest nitrogen content.

The plant nitrogen content showed an increase upto flowering and then decreased at seed formation and seed maturation stages. This is in conformity with the report of Nair (2000) in *C. ternatea*.

5.6.3 Crude alkaloid content

The crude alkaloid content in seeds varied significantly among the accessions under both shade and open conditions (Table 31).

Under shaded condition, maximum alkaloid content was recorded in MP-76 and MP-73. They were on par with MP-74. Under open condition, MP-73 recorded maximum content of crude alkaloid and it was on par with MP-85, MP-83 and MP-76. MP-81 recorded the lowest content of alkaloid in seeds.

5.7 Correlation studies

Yield is a complex character influenced by many characters either on positive or negative direction. So, selection for yield should take into account related characters as well. Correlation provides information on the nature and extent of relationship between pairs of characters. Therefore, analysis of yield in terms of genotypic and phenotypic correlation coefficients of component characters leads to the understanding of character that can form the basis of selection. The important yield characters in this study are shoot yield, pod yield and root yield. The extent of association between yield and other characters are measured by genotypic and phenotypic correlation coefficients.

5.7.1 Correlation between shoot yield and other characters

Under shade, shoot yield was found to show high positive phenotypic and genotypic correlations with length of pod, number of leaves, leaf area, number of seeds per pod and number of pods per plant. High negative correlation was exhibited by harvest index and dry weight of pods.

In open, phenotypic and genotypic correlations were high and positive for number of leaves, dry weight of leaves and plant length. Harvest index and number of seeds per pod exhibited high negative correlation.

A positive association between plant length and shoot yield reported in *Mucuna pruriens* by Samuel (2000) supports the present finding. In cowpea, positive correlation was observed between leaf area and biomass production by Natarajaratnam *et al.* (1984).

5.7.2 Correlation between pod yield and other characters

In shaded condition, phenotypic and genotypic correlations were high and positive for harvest index and plant length. High negative correlation was exhibited by the number of leaves. Under open condition, genotypic and phenotypic correlations were high and positive for number of pods per plant, leaf area and harvest index. Dry weight of root and plant length recorded high negative correlations.

The positive association of pod yield with number of pods per plant was in line with the results reported by Sharma *et al.* (1988), Sreekumar *et al.* (1996), Resmi (1998), Pournami (2000) and Vidya (2000) in cowpea. A positive correlation between yield and leaf area in hybrid maize plants during water stress reported by Mehrotra *et al.* (1968) supports the present findings. High and positive correlation of pod yield with harvest index is in line with the finding of Kavitha (1982) in blackgram that grain yield is positively correlated with harvest index. Positive association of plant height and yield was presented by Doss *et al.* (1974) in soybean. Abraham *et al.* (1992) reported that under partially shaded condition, seed yield per plant exhibited positive correlation with height, pods per plant and harvest index in blackgram.

5.7.3 Correlation between root yield and other characters

Under shaded condition, phenotypic as well as genotypic correlations showed high and positive values for harvest index, root length and root girth whereas dry weight of shoot showed high negative correlation. In open, root yield showed high and positive phenotypic and genotypic correlations with root length, root girth and dry weight of shoot. Length of pod recorded high negative correlation.

5.7.4 Selection index

The selection index scores based on sixteen characters *viz.*, plant length, number of leaves, leaf area, number of pods per plant, length of pod, number of seeds per pod, root length, root girth, dry weight of leaves, dry weight of shoot, dry weight of pods, dry weight of root, number of root nodules at seed formation stage, dry weight of root nodules, harvest index (root + pod yield) and crude alkaloid content were used to identify superior accessions suited for shade as well as open conditions.

The accessions MP-73 and MP-76 were found to show superior performance under both conditions.

The present study was conducted under two conditions of light; under shade in a coconut garden and in open as a pure crop. However, for almost all characters studied all the accessions showed superior performance under open condition. Usually no intercrops are recommended in coconut garden between 8 and 25 years of age of the palms. In the present experiment carried out in a coconut garden with palms of about 19 years of age, shoot, pod and root yield of all the accessions were inferior to those under open condition. However, phytochemical analysis revealed no significant variation in the seed alkaloid content of *Clitoria ternatea* accessions grown under shaded and open condition. The accessions MP –73 and MP-76 were found to show superior performance under both conditions with respect to growth and yield characters.

Summary

6. SUMMARY

A study on 'Evaluation of selected Sankhupushpam (*Clitoria ternatea* L.) lines for yield, alkaloid content and nodulation' was carried out at the College of Agriculture, Vellayani from June to December 2000. Cultural trial of selected lines was carried out under shade in a coconut garden and also as a pure crop in open. Phytochemical analysis and correlation studies were carried out and selection indices were worked out for identifying superior lines.

Seeds of six superior lines of *Clitoria ternatea* identified from the genetic stock evaluation trial by Nair (2000) were selected.

Observations such as hundred seed weight, seed colour, external appearance of seeds, germination percentage and days to fifty per cent germination were made. Seeds of MP-73 recorded the highest rate of germination (90 per cent) and least number of days to attain fifty per cent germination (14 days).

The six selected accessions were put under cultural trial under two conditions *viz.*, under shade in a coconut garden and as a pure crop in open. Growth and yield parameters and physiological parameters were studied under both conditions.

Significantly superior plant length was observed for MP-76 (191.56 cm) and MP-81 (257 cm) under shade and open conditions respectively. Number of leaves and leaf area were significantly superior in MP-73 under both conditions. Under shade, the number of leaves was 126.78 and under open, it

was 270.78 leaves. Leaf area of MP-73 was 4976.04 cm^2 and 12481.20 cm^2 under shade and open conditions respectively.

Maximum number of pods per plant under shade condition was recorded for MP-76 (27.11) whereas under open condition, MP-73 recorded the maximum (82.11). Highest pod length under shade was shown by MP-76 (9.97 cm). On the other hand, under open condition, MP-73 (10.05 cm) recorded maximum pod length. As far as number of seeds per pod is concerned, MP-76 (9.33) ranked first under shade. But under open condition, all the accessions were on par.

Maximum root length was recorded for MP-74 (35.97 cm, 62.58 cm) under shade as well as open conditions. With regard to root girth also, MP-74 (3.16 cm, 4.50 cm) recorded highest values under shade and open conditions.

Highest number of root nodules at flowering stage was observed in MP-73 (15.17) under shade and in MP-76 (25) under open condition. In shade, maximum nodule fresh weight was recorded by MP-73 (0.89 g) whereas in open, MP-76 (2.26 g) recorded the maximum. Nodule dry weight was found to be the highest in MP-73 (0.21 g) and MP-81 (0.37 g) under shade and open conditions respectively.

Maximum leaf yield on fresh weight basis was obtained in MP-81 (33.64 g) under shade and MP-73 (97.09 g) under open condition. However, dry weight of leaves was found to be the highest in MP-74 (12.02 g) under shade and MP-73 (26.05 g) under open condition.

Maximum shoot yield was recorded for MP-73 (101.97 g, 40.19 g) under shade and for MP-81 (236.89 g, 84.83 g) under open condition on fresh weight basis and dry weight basis respectively.

Pod yield was found to be the highest for MP-76 (37.58 g, 15.29 g) under shade and for MP- 73 (120 g, 35.33 g) under open condition on fresh weight basis and dry weight basis respectively.

Root yield on fresh weight basis was found to be the highest for MP-76 (12.27 g) under shade and MP-74 (20.73 g) under open condition. On dry weight basis, root yield was maximum for MP-74 (5.04 g) under shade and MP-81 (7.33 g) under open condition.

The greatest leaf area index was observed for MP-73 (1.38, 3.47) under shade and open conditions respectively. Leaf area duration was found to be the highest during seeding to seed maturation stage (135-180 DAS) and the highest value was recorded in MP-73 (65.94, 165.22 days) under shade and open conditions respectively.

In shaded condition, net assimilation rate (NAR) was highest during flowering to seed formation stage (90-135 DAS) and MP-83 (5.49 g m^{-2} day^{-1}) recorded the highest value. Under open condition, NAR was highest during pre-flowering to flowering stage (45-90 DAS) and the highest value was recorded in MP-81 (5.96 g $m^{-2}day^{-1}$).

Crop growth rate (CGR) was highest during flowering to seed formation stage (90-135 DAS) under shaded condition. The highest value was recorded for MP-83 (3.01 gm^{-2} day^{-1}). Under open condition, maximum CGR was recorded for MP-76 (4.59 g m^{-2} day^{-1}) during pre-flowering to flowering stage.

In shade, highest absolute growth rate was shown by MP-83 (1.08 g day^{-1}) during flowering to seed formation stage, whereas MP-73 (1.43 g day^{-1}) recorded the maximum under open condition.

Under shaded condition, relative growth rate (RGR) was found to be the highest during the second period of growth (flowering to seed formation) and the value was highest (0.06 g day^{-1}) for MP-74 and MP-83. In open, maximum RGR was recorded for MP-74 (0.08 g day^{-1}) during pre-flowering to flowering stage.

Harvest index for root yield was found to be the highest (0.31) for MP-85 and MP-81 under shade and MP-73 under open condition. Harvest index for pod yield was maximum for MP-85 (0.11) under shade and MP-83 (0.07) and MP-81 (0.07) under open condition. When root and pod yield were taken together, MP-85 (0.42) and MP-73 (0.37) recorded highest values under shade and open conditions respectively.

The highest amount of nitrogen fixation was observed in the plots of MP-81 (249.83 kg ha^{-1}, 265.51 kg ha^{-1}) under shade and open conditions respectively. The content of phosphorus was found to be the highest in the plots of MP-73 (28.26 kg ha^{-1}) under shade and MP-81 (32.21 kg ha^{-1}) under open condition. The potassium content was found to be the maximum in the plots of MP-85 (150.87 kg ha^{-1}) in shade and under open condition, highest value (163.87 kg ha^{-1}) was recorded in the plots of MP-85.

The highest content of plant nitrogen was observed at the flowering stage. During this stage, MP-74 (4.28 per cent) recorded the highest nitrogen content under shade and MP-76 (4.38 per cent) recorded the maximum under open condition.

Under shaded condition, MP-73 and MP-76 were found to be superior in terms of crude alkaloid content (0.40 per cent) in seeds and they were on par with MP-74 (0.39 per cent). In open, MP-73 (0.43 per cent) recorded the highest crude alkaloid content. It was on par with MP-85 (0.42 per cent), MP-83 (0.41 per cent) and MP-76 (0.39 per cent). However, there was no significant variation between shade and open conditions.

The phenotypic and genotypic correlation coefficients were worked out for important pairs of characters. Shoot yield (dry weight) showed highest positive genotypic correlation with number of seeds per pod (0.8294) under shaded condition. In open, genotypic correlation was very high and positive for number of leaves (0.8630).

Pod yield (dry weight) exhibited highest positive genotypic correlation with harvest index (0.8373) and number of pods per plant (0.9994) under shade and open conditions respectively.

Root yield (dry weight) showed highest positive genotypic correlation with harvest index (0.5846) and root length (0.7880) under shade and open conditions respectively.

Based on the selection index scores developed using sixteen selected important characters, MP-73 (Thiruvattar White) and MP-76 (Vattiyoorkavu White) showed superior performance under shade as well as open conditions.

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Appendix

APPENDIX – I

Weather data during the crop period

Sl. No.	Month and year	Temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)	No. of rainy days
		Maximum	Minimum			
1	June 2000	29.32	22.73	83.25	232.3	19
2	July 2000	30.07	22.37	80.18	87.0	12
3	August 2000	28.56	22.12	84.98	257.8	20
4	September 2000	28.62	21.55	89.07	92.2	9
5	October 2000	30.04	21.88	88.71	210.8	13
6	November 2000	29.25	20.89	83.77	119.1	9
7	December 2000	30.24	20.21	77.45	47.74	3

EVALUATION OF SELECTED SANKHUPUSHPAM (*Clitoria ternatea* L.) LINES FOR YIELD, ALKALOID CONTENT AND NODULATION

BY

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ABSTRACT OF THE THESIS
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ABSTRACT

The present study entitled 'Evaluation of selected Sankhupushpam (*Clitoria ternatea* L.) lines for yield, alkaloid content and nodulation' was carried out at the Department of Plantation Crops and Spices, College of Agriculture, Vellayani from June to December 2000.

Six superior lines evolved from a preliminary screening of genetic stock conducted by Nair (2000) were raised under shade, as an intercrop in coconut garden and in open as a pure crop.

Various biometric observations were taken at four different stages of plant growth, *viz.*, pre-flowering (45 DAS), flowering (90 DAS), seed formation (135 DAS) and seed maturation (180 DAS) stages. These included observations on shoot yield, root yield and pod yield. Nodule characteristics were also recorded.

Phytochemical analysis was carried out after harvest of the crop to estimate the crude alkaloid content in the seeds of each accession.

Analysis of the results revealed maximum shoot yield for MP-73 and MP-81 under shade and open conditions respectively. The highest pod yield was recorded for MP-76 under shade and for MP-73 under open condition. Root yield on fresh weight basis was found to be the highest for MP-76 under shade and MP-74 under open condition. On dry weight basis, root yield was maximum for MP-74 under shade and for MP-81 under open condition.

Maximum nodulation at flowering stage was observed in MP-73 and MP-76 under shade and open conditions respectively. MP-73 and MP-76

recorded higher crude alkaloid content in seeds under shade condition. In open, maximum crude alkaloid was obtained in MP-73.

Both yield and nodulation were found to be higher under open condition whereas the crude alkaloid content showed no significant variation between shade and open conditions.

From the study, the accessions MP-73 (Thiruvattar White) and MP-76 (Vattiyoorkavu White) were found to show superior performance under both conditions.