SHADE RESPONSE OF COMMON RAINFED INTERCROPS OF COCONUT PART II LEGUMES

BY

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THESIS

Submitted in partial fulfilment of the requirement for the Degree

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur
KERALA - INDIA

1982

DECLARATION

I hereby declare that this thesis entitled the "Shade response of common rainfed intercrops of coconut Part II legumes" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

13/9/82

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CERTIFICATE

Certified that this thesis entitled the "Shade response of common rainfed intercrops of coconut Part II legumes" is a record of research work done independently by Kum. SANSAMMA GEORGE, 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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ACKNOWLEDGEMENTS

I wish to express my deep sense of gratitude and heartfelt thanks to Dr. R. Vikraman Nair, Professor of Agronomy, Kerala Agricultural Development Project, College of Horticulture, Vellanikkara, for suggesting the problem, and for his expert guidance, constant encouragement, keen interest and constructive criticism throughout the course of this investigation.

I am greatly indebted to the guidance of the members of the advisory committee, Dr. P.C. Sivaraman Nair, Director of Research, Kerala Agricultural University; Shri. K.P. Madhavan Nair, Associate Professor of Agronomy, College of Agriculture, Vellayani; Dr. A.I. Jose, Professor and Head, Department of Soil Science and Agricultural Chemistry, College of Horticulture and Dr. E. Tajuddin, Professor of Agronomy, Communication Centre, Mannuthy.

To Shri. P.V. Prabhakaran, Associate Professor, Department of Agricultural Statistics, I express my sincere thanks for the help rendered in the analysis of the data.

Sincere thanks are also due to Dr. C. Sreedharan, Professor and Head, Department of Agronomy, Shri. V.K.G. Unnithan, Associate Professor (Agricultural Statistics), Shri. M. Abdulsalam, Assistant Professor (Agronomy), Shri. P.K. Ashokan, Assistant Professor (Agronomy) and

CERTIFICATE

We, the undersigned, members of the Advisory Committee of Kum. Sansamma George, a candidate for the degree of Master of Science in Agriculture with major in Agronomy, agree that the thesis entitled the "Shade response of common rainfed intercrops of coconut Part II legumes" may be submitted by Kum. Sansamma George, in partial fulfilment of the requirement for the degree.

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Dr. J. Thomas, Assistant Professor (Agronomy), College of Horticulture for the help rendered during the course of the study.

I am also thankful to Dr. P.K. Gopalakrishnan, Associate Dean, College of Horticulture, Vellanikkara for the help and facilities provided.

I wish to place on record my sincere gratitude to all my friends for their timely help and co-operation which have always been a source of inspiration for me.

I acknowledge with pleasure, the protective warmth and blessings of my beloved mother, brother and sisters.

The award of Junior Fellowship by the Indian Council of Agricultural Research is gratefully acknowledged.

12/9/82

SANSAMMA GEORGE

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Introduction

INTRODUCTION

In many of the crops solar energy available is a crucial factor determining the final yield. This factor is to be considered when recommending intensive cropping systems like intercropping and multiple cropping along with coconut, as the returns from the associated crops would depend on their response to shade. Results reported by the Central Plantation Crops Research Institute, Kasaragod, Kerala, indicate that intercropping in coconut gardens has bright prospects for maximising profitability of coconut gardens. But the species employed should be compatible and competition should not deter the yield of either the main crop or the associated crop.

The profitability of intercropping in any cropping system is dependent on the extent of competition for the three basic inputs of production, viz., light, water and nutrients. Of these factors, the performance of the associated crops raised in the interspaces of tall perennial crops is mainly dependent on the competition for light. The growth habit and canopy disposition of coconut palm is such that the quantum of light that infilters through the canopy is markedly affected by the age of the palm. It has been estimated to range from

10 to 70 per cent depending upon the age of the palm in a space-planted coconut plantation. To get reasonable profit from the associated crops, they have to be selected for shade tolerance and the extent of tolerance will be the criteria for fitting these crops under varying shade situations. In a similar study taken up during the previous year, five tuber crops were screened for their shade responce. In the present study, four leguminous crops are included.

The primary objectives of the present study are:-

1. To study the yield response of common rainfed leguminous crops under varying intensities of shade.

2. To select leguminous crops suitable for different intensities of shade and to predict their yields under varying shade situations.

3. To categorise legumes as shade loving, shade tolerant, shade intolerant and shade sensitive.

4. To study the nutrient removal of the crops under shade so that it could be used as a tool for tentatively arriving at fertilizer schedules for these crops under shade.

Review of Literature

REVIEW OF LITERATURE

The experimental results on the response of crops to varying intensities of shade are highly variable. A review pertaining to this aspect is given below, classifying the effects on different characters with a brief summary of the general trend. Since literature available on shade response of legumes alone is meagre, similar works on other crops are also included in the review. The shade levels tried in each of these experiments apparently had been highly variable and these had not been mentioned in many of the reports. Wherever the shade levels are mentioned, these are included in the review. Where these are not available, the overall effects of shade (irrespective of its intensity) are only presented.

1. Plant height

Review of work done indicates that effect of shade on plant height varies widely. Response to shade may be positive as in the case of soybean, ginger, cowpea etc. or negative as in grain sorghum. In tomato, the response was reported as positive, negative or neutral.

Allen (1975) noticed that soybean grown under 70 per cent shade grew much taller (120 cm) than those in the open (80 cm). In ginger higher light intensity reduced plant height (Aclan and Quisumbing, 1976). Tarila et al.

(1977) reported that in cowpea, plants grown under shade were taller than those in the open. A shade response study conducted by Lalitha Bai (1981) revealed that plant height in all the crops studied, viz., coleus, colocasia, sweet potato, ginger and turmeric, increased with increasing intensities of shade.

Contrary to the above reports, height of grain sorghum was found to be decreasing with increasing shade from 0 to 50 per cent (Palis and Bustrillos, 1976).

Cooper (1969) observed that in the case of tomato, shading either decreased or had no effect on mean stem extension rate. It was also noted that the effect of shade on plant height was either positive, negative or neutral depending on the time of the year and age of the plant.

2. Number of branches

In general, the shade effect on branching is found to be adverse. But in chilli, branching was found to be more in plants shaded during their early vegetative growth.

Tarila et al. (1977) reported that in cowpea higher light intensity increased the number of branches. In rice, tillering was found to be greatly reduced by shading plants to 20 per cent of full sunlight (Kemp and Whingwiri, 1980). But in chilli (Capsicum frutescens L.) more flowers were produced as a result of increased branching, when they were exposed to low light intensity of 800 foot candles than at

1600 foot candles (Deli and Tiessen, 1969).

3. Nodulation in legumes

Investigations have proved beyond doubt that the nodulation and nodule activity in legumes are affected by light intensity. The three components of total nodule activity (TNA) that could account for the response pattern are, number of nodules per plant, weight per nodule and specific nodule activity (Wahua and Miller, 1978). In general, number of nodules per plant was more in unshaded plants, but the specific nitrogenase activity was found to be affected differently in different crops.

Pritchett and Nelson (1951) observed that in alfalfa nodulation essentially stopped at light intensities below 257 foot candles. Wahua and Miller (1978) reported that in soybean nitrogen fixation was highest at 20 per cent shade and it decreased in decreasing amounts as shading increased. Nabie and Kumazawa (1979) observed that in soybean, size and number of nodules decreased by shading. However, in natural light the highest values of nodule size corresponded to lower nodule numbers. The decrease in nodulation under low light intensity was associated with decline in canopy photosynthesis and reduced photosynthate supply to nodules (Allison, 1935; Lawn and Brun, 1974 and Latimore et al., 1977). Trang and Giddens (1980) tried four shade intensities, viz., 0, 19, 40 and 62 per cent, in soybean. The plants with no shade produced higher nodule mass and number than those under shade. However total nodule activity (acetylene reduction assay) was greatest at 18 per cent shading. Lawn and Brun (1974) observed declining nodule activity at 50 per cent light cut off in soybean.

4. Leaf development

Structural and morphological characteristics of leaves are reported to be influenced by shading. Generally leaf expansion increases and thickness decreases with shading.

Hardy (1958) studied the nature of leaves of cocoa seedlings under varying intensities of shade and observed that leaves produced under heavy shade were much larger, often attained a length of 20 to 24 inches and were thinner, heavier, and contained higher proportion of water. In clove, though the mean number of leaves produced per plant remained nonsignificant, increased light intensity resulted in greater leaf area (Beinhart, 1963). Cooper and Qualls (1967) observed that leaves of both alfalfa and birdsfoot trefoil (<u>Lotus corniculatus</u> L.) when grown in the sun were thicker than shade leaves. The thickness appeared to be related to both, a larger number and greater size of palisade and mesophyll cells. Panikar <u>et al</u>. (1969) observed that in tobacco length and breadth of leaves were increased by 15.1 and 17.6 per cent respectively under shade as compared to unshaded plants. Observations on the epidermis of chilli

(Capsicum annuum) indicated that shading increased leaf surface, cell division and cell expansion (Schoch, 1972). Shading treatments caused some delay in the senescence of leaves in pigeonpea, but the senescence retarding effects were far too less spectacular than those observed with chick-pea (Sheldrake and Narayanan, 1976). Tarila et al. (1977) reported that in cowpea, higher light intensity improved leaf area and the leaves of shaded plants were thinner, showing poor development of palisade tissue and spongy-mesophyll cells.

5. Chlorophyll content

General observation was that high light intensity destroys chlorophyll in plants. But in crops like pea, and wheat, increasing shade intensities have been found to have adverse effects on chlorophyll content. Changes in the position of chloroplast according to the differences in light intensity have also been recorded.

Khossian (1970) noticed reduction in leaf pigments at high light intensity in the case of bean plants. An evaluation was made of the chlorophyll concentration of dark green (normal) and pale green (chlorophyll deficient) phenotypes of a soybean mutant, when grown at 10 and 30 klux light intensities (Koller and Dilley, 1974). At 30 klux chlorophyll concentration of the pale green phenotype progressively declined to one tenth of the amount at 10 klux intensity, while that of the dark green phenotype remained unaffected. Okali and Owusu (1975) observed that in cocoa plants, the chlorophyll content per unit leaf fresh weight was significantly greater in deep shade. Collard et al. (1977) observed that in weeping fig (Ficus benjamina L.) increasing shade levels increased chlorophyll content, plant size and visible quality. In rice cv. Vijaya, the chlorophyll content was high even under low light, suggesting the positive association of the trait with the adaptability of the cultivar to subdued light conditions of the Kharif (Nayak and Murty, 1980). Bjorkman and Holmgren (1963) observed that chlorophyll content per unit weight of leaf was found to increase in the case of plants grown at lower light intensities, but the chlorophyll content per unit area of leaf surface was very often lower than that in plants grown in open. Similar observations were made by Cooper and Qualls (1967) in alfalfa and birdsfoot trefoil.

Contrary to the above reports, Higazy et al. (1975) observed that in the case of pea (Pisum sativum), the concentration of total chlorophyll as well as its components 'a' and 'b' decreased by increasing shade intensities. In wheat, all pigments decreased significantly with increasing shade intensities viz., 100, 60, 40 and 20 per cent full sunlight, but the ratio of chlorophyll a:b remained constant at all shade intensities (Moursi et al., 1976a).

Priestly (1929) opined that the chloroplasts in leaves under lower light intensities adjusted themselves for greater light absorption. Shaded leaves had only limited number of plastids and they were found arranged at right angles to the light rays, thus increasing the area for light absorption. In bean, the chloroplasts had only reduced starch in spite of extensive grana (Crookston et al., 1975).

6. Stomatal frequency and stomatal behaviour

In plants like cocoa, alfalfa, barley, Capsicum annuum, birdsfoot trefoil etc. the number of stomata per unit area of leaf was found to decrease with increasing shade levels. As for stomatal behaviour, there were specific threshold values of light intensity for each of the crops, at which stomata start to open and close.

Hardy (1958) observed that in cocoa leaves grown under shade, the epidermal cells were longer and they had lesser number of stomata per unit area, than those in the open. Cooper and Qualls (1967) observed that alfalfa and birdsfoot trefoil had less stomata per unit area of leaf in the shade. Number of palisade and mesophyll cells and the cell volume appeared greatest in leaves exposed to sun and palisade layer was more clearly differentiated. Holmgren (1968) concluded that higher intensities of light during the growth of plants generally increased the stomatal frequency but there was no significant changes either in the length of the stomatal pore or in the size of the guard cells. Stomatal frequency on the lower surface of the flag leaves of 649 cultivars of barley was tested and it was found that increased light intensity resulted in higher stomatal frequency (Miskin and Rasmusson, 1970). Schoch (1972) reported that shade decreased the number of stomata per mm^2 and the percentage of stomata in relation to other cells in *Capsicum annuum*.

Hardy (1958) differed on the possibility of cocoa being a shade loving plant. By applying the oil infilteration method for assessing the degree of stomatal closure, it had been shown that the stomata of cocoa leaves exposed to full intense and direct illumination (13,500 foot candles). remained completely open and transpired freely as long as water supply was plentiful. As against this, the stomata of coffee leaves were reported to partially close whenever the intensity of illumination exceeded 8,000 to 8,500 foot candles and in the shade, they always remained open provided the light intensity was not so less - a characteristic phenomenon of shade loving plants. In the case of cocoa, the stomata began to close when the light intensity was reduced to less than 500 to 700 foot candles, which was about 5 per cent of the full sunlight. Under ordinary circumstances, the stomata began to open at about 6 A.M. and maintained their maximum size between 8 A.M. and 4 or 5 P.M., after which time they started closing because of diminishing light intensity.

Transpiration measurements were made on attached leaves of three C_3 species - wheat, barley and dandelion and three C_4 species - maize, green foxtail (Setaria viridis L.) and pigweed (Amaranthus retroflexus L.) in different light intensities. Stomata of C_3 species were less prone to closure than were stomata of C_4 species, as the light intensity was decreased. The greater water use efficiency of C_4 plants might be due in part to the better control of water loss, because the stomata were more responsive to environmental changes than were the stomata of C_3 species (Akita and Moss, 1972).

7. Photosynthesis and dry matter accumulation

Sunlight being the source of energy for plants for photosynthesis, the rate and subsequent dry matter accumulation in general are found to be adversely affected by shading. But in ginger, coffee etc. positive influence was reported. Still in some other crops like pineapple, there was no appreciable decrease in dry matter accumulation even upto 75 per cent shading.

Singh (1967) noticed that exposure of ginger to intense light was detrimental to photosynthesis. In arabica coffee seedlings shaded to provide 25, 50 or 75 per cent light, the best growth was with 50 per cent light

(Silveira and Maestri, 1975). In pineapple, dry matter accumulation in leaves was comparable both in open and under shade upto flowering stage (Radha, 1979). Wong and Wilson (1980) from the studies on the effect of shading to 100, 60 and 40 per cent of full sunlight on the growth of green panic grass and siratro in pure and mixed swards defoliated at 4 weeks and 8 weeks stage, reported that individual leaves of shaded green panic had greater photosynthetic activity than those from full sunlight.

In pea (Pisum sativum L.) average dry weight of the plant was 7.2 g in full sunlight and it got reduced to 5.4 g in 50 per cent light (Dolan, 1972). Crookston et al. (1975) reported that in bean photosynthesis per unit area of shaded leaf was reduced by an average of 38 per cent. Moursi et al. (1976b) observed that the efficiency of solar energy conversion in wheat decreased with increasing shade (100 to 20 per cent full sunlight) from 1.44 to 0.37. In shade experiments with cogon grass (Imperata cylindrica), Patterson (1980) observed that after 69 days, the plants of three ecotypes produced on an average three times as much total dry weight in full available sunlight as in 56 per cent full light and 20 times as much as in 11 per cent full sunlight. The plants from the shaded and exposed habitats did not differ significantly in their response to shading. Benjamin et al. (1981) observed that the starch concentration in the shaded leaves of soybean declined steadily over 24 hour period. Further more, there was essentially no additional incorporation of C^{14} into starch in the shaded leaves, indicating that starch synthesis had ceased within 30 minutes of shading. In soybean when the photosynthetically active leaf area was decreased by 70 per cent by shading, the rate of photosynthesis of unshaded leaflets increased by 50 per cent within 2 days after shading and this compensated for 50 per cent of the loss in net carbon assimilation which would have occurred without any shading (Peet and Kramer, 1981).

8. Growth analysis

Experimental results on effect of shade on growth analysis factors show wide variation between plants. Parameters like leaf area index (LAI), relative growth rate (RGR), net assimilation rate (NAR), specific leaf weight (SLW) etc. are considered here.

Cooper and Qualls (1967) associated the increase in the ratio of leaf area to leaf weight which occurs due to shading of alfalfa and birdsfoot trefoil, with changes in their leaf morphology. In alfalfa, both specific leaf weight and net photosynthesis were higher under intense light than under shade (Pearce and Lee, 1969). These features of the leaves changed with changing light intensity at all the stages of maturity measured. Wolf and

Blaser (1972) reported that in alfalfa with 100 per cent normal day light, the specific leaf weight (SLW) and net carbon exchange (NCE) values remained high through the growth cycle; however these values declined sharply with light intensity of 27 and 45 per cent of normal light. The data suggested that the decline of photosynthetic efficiency and SLW of the basal leaves were caused by low light intensities in the lower layers of dense canopies. In shaded green panic swards, the LAI was found increased, while in siratro, the LAI decreased with increasing shade (Wong and Wilson, 1980).

Hardy (1958) observed the lowest NAR at highest shade level and vice versa, in cocoa. In the case of cocoa seedlings, NAR was not influenced by shade intensity ranging from 25 to 75 per cent (Gopinathan, 1981). In coleus, there was a drastic decline in mean NAR when shading was more than 50 per cent, whereas in turmeric, no general trend in NAR with increasing levels of shade could be noticed (Lalitha Bai, 1981). In cocoa, Evans and Murray (1953) recorded the greatest RGR at a light intensity between 30 to 60 per cent of full day light. Okali and Owusu (1975) observed that RGR was maximal for cocoa plants under medium shade. Janardhan and Murty (1980) observed that in rice under low light conditions, the RGR, NAR and SLW were reduced whereas LAI, leaf area ratio (LAR) and relative leaf growth rate (RLGR) were increased.

9. Yield and yield attributes

Based on the level of shade tolerance, the final yield of crops is reported to either increase, decrease or remain unaffected under varying light intensities. In crops like tomato, tea, chilli, chickpea and ginger partial shading was found beneficial while soybean, cowpea, bean and groundnut recorded reduced yield under subdued light.

Edmond et al. (1964) conducted shade experiments in tomato and maximum yield was obtained from plants receiving only 45 per cent of full sunlight. In Capsicum annuum L. more flowers were produced on plants exposed to low light intensity (Deli and Tiessen, 1969). Aclan and Quisumbing (1976) reported that the yield of ginger under full sunlight was just as high as those obtained under 25 and 50 per cent illumination. Joseph (1979) noticed that the tea clones under shade gave much higher yield than in exposed plots. But in another experiment it was reported that shading the bushes to about 45 per cent light intensity with cloth screen about 60 cm above the plucking table depressed new shoot growth and yield of tea (Aono et al. 1976).

Major and Johnson (1974) recorded the effects of light intensity ranging from 2 to 100 klux on days to flowering and post flower development on two soybean cultivars. Days from planting to flowering, final plant height and internode number increased as light intensity increased but no detectable effects of light intensity was observed on days from flowering to beginning of pod till, flowering to termination of flowering, flowering to maturity and final seed yield. Prine (1976) reported that in soybean yield reduction was found maximum, when the plants were shaded just prior to flowering. Wahua and Miller (1978) found that number of pods per plant and seed yield in soybean were highly and negatively correlated with shade. Seed yields of soybean plants shaded to reduce sunlight by 20, 47, 63, 80 and 93 per cent were 90, 75, 48, 18 and 2 per cent respectively of that obtained from unshaded plants.

Graman (1974) observed that decreasing the amount of photosynthetically active radiation by 40 to 60 per cent by shading in beans (Vicia faba) resulted in decreased production of flowers, though it decreased the shedding of young pods. Tarila et al. (1977) reported that in cowpea, high light intensity delayed flowering, but increased blossom and pod number and improved seed yield. Leelavathi (1979) observed that in blackgram graded shading of 25, 50 and 75 per cent reduced plot yield by 5.11, 22.35 and 42.43 per cent respectively of the control value. Pod number, seed number and pod length were improved at 25 per cent shading but with severe shading every attribute declined in value. Saxena and Sheldrake (1976) reported that in chickpea, pod number per unit area was found improved under shaded condition in Hyderabad, while similar trials at Hissar with 77, 45 and 10 per cent light transmission resulted in yield reduction. In another experiment with chickpea Saxena et al. (1980) observed that the flowering in all the cultivars tried was enhanced by enriched light intensity, and that the critical intensity was higher for cultivars of late duration than the early cultivars. Williams (1980) reported that the growth of groundnuts during the preflowering stage was varied by shading treatments and that it influenced subsequent growth and development by varying the establishment of reproductive sink. An (1982) conducted a shade response study in groundnut, shading the crop at flowering, pegging, pod filling and maturity. Shading at peak flowering reduced the number of flowers per plant, shading at pegging and pod filling stages reduced total peg and pod number and reduced seed yield. Shading for 21 days during pod filling caused the greatest yield loss.

10. Quality of produce

Effect of shade on quality aspects of crop produce varies widely. In general, protein content increases and carbohydrate content decreases with shading.

Adedipe and Ormrod (1974) reported the unfavourable effect of greater light intensities in cowpea in terms of reduced plant height, increased leaf area and with a marked decrease in carbohydrate content. Graded shade levels of 20, 47, 63, 80 and 93 per cent on soybean was found to have little effect on oil and protein contents of seeds, except that protein content was highest and oil content lowest at 93 per cent shade (Wahua and Miller, 1978). Leelavathi (1979) reported that shading in blackgram resulted in increased carbohydrate status of the seed and a larger pool of soluble nitrogen. In pea, shading of the pericarp of fruits increased the rate of uptake of assimilates into seed from leaves, slowed down the hydrolytic processes and increased the accumulation of sucrose in seeds (Chetverikova, 1981). While investigating the light intensity effects on metabolism, growth and development and yield components of groundnut, An (1982) observed that shade increased the oil content of older fruits, regardless of the date of fruit formation and the starch and reducing sugar contents of seeds. Total carbohydrate content was higher in the shaded fruits and it was correlated positively with oil content.

Hwang (1968) reported that shading in pineapple after flowering gave higher grade fruit than unshaded, the unshaded fruits suffered from sunburn and gave lower canning ratios than shaded treatments due to sunscorch. Radha (1979) observed that the quality of fruits in general, decreased in pineapple under shaded conditions. While acidity of fruits increased, there was a general reduction in sugar and ascorbic acid content. Aono et al. (1976) found that shading the tea bushes to about 60 to 45 per cent light intensity with cloth screens about 60 cm above the plucking table improved the green tea quality. The quality was directly related to the shade intensity and this improvement in quality was the greatest during the first plucking season.

11. Nutrient content

In general, the mineral nutrient status of plants has been found to improve under shading as in the case of apple, cocoa, spinach and tea. On the contrary, the adverse effect of shade on nutrient content has been reported in soybean, siratro and cocoa seedlings.

Kraybill (1922) recorded higher contents of moisture and nitrogen in shaded leaves of apple. The potassium content of some grass species when under 85 to 90 per cent shade was nearly double than those in full day light (Myhr and Saebo, 1969). In cocoa leaves also the nitrogen and moisture content was higher when the plants were grown under shade (Guers, 1971). Cantliffe (1972) observed that in spinach, the concentration of potassium in the tissues increased with reduction in light intensity. Rodriguez et al. (1973) analysed *Dracaena sanderiana* plants grown at 5 shade intensities for foliar nitrogen, phosphorus, potassium, calcium and magnesium and it was found that the different shades had little effect on the leaf nutrient content except that high shade intensity increased potassium and magnesium especially in young leaves. Lalitha Bai (1981) reported that in all the plant components of the different crops tried, viz., coleus, colocasia, sweet potato, turmeric and ginger, contents of nitrogen, phosphorus and potassium increased with increasing intensities of shade.

Wahua and Miller (1978) reported that in soybean total leaf and stem nitrogen contents were largely and negatively correlated with shade. Trang and Giddens (1980) also got similar results with soybean. Wong and Wilson (1980) observed that the nitrogen yield of siratro in pure sward declined with shading. In the case of cocoa seedling, Gopinathan (1981) noticed higher percentage of nitrogen, phosphorus and potassium in plants grown under direct sunlight than in the shaded plants.

12. Susceptibility to diseases and pests

The slightly higher humidity and slower drying under the shade in some cases were found to favour disease and pest outbreak. But contrary results are also reported as in the case of oil palm and hybrid maize.

Moss and Stinson (1961) while studying the differential response of hybrid corn to shade observed that stalk rot attacked 66 per cent of the hybrids tolerant of thick planting in the open and 55 per cent in the shade. In contrast, the intolerant hybrids were 7 per cent infested in the open and completely free of stalk rot in the shade. Thus although, there was dramatic differences in the degree of stalk rot infestation, the differences favoured the intolerant hybrids and did not explain the differential response in the shade. Rajagopalan (1974) noticed that in oil palm over a period of 3 nursery seasons, shading of seedlings particularly during the hot dry period (September - January) was highly effective to the control of blast disease caused by Pythium splendens and Rhizoctonia lamellifera. Contrary to the above reports, the incidence of Phytophthora palmivora on Amazon cocoa was consistently and significantly higher on plots with medium and dense shade regimes (Dakwa, 1979). Garcia et al. (1981) reported that yield of tannier (Xanthosoma sp.) in a field affected by 'mal seco' which destroys its root system, was higher under 53 per cent artificial shade when compared to full sunlight. In another experiment where 'mal seco' did not occur, yields decreased under 53 and 70 per cent shade. Investigation on the incidence of coffee berry borer in coffee plantations revealed that the attack was more severe in shaded plots (Gramer and Godoy, 1971).

Materials and Methods

MATERIALS AND METHODS

With a view to assess the effect of shade on the leguminous crops and to study their suitability for intercropping in coconut gardens, a field trial was conducted with some of the common leguminous crops of Kerala, viz., cowpea (Vigna unguiculata (L.) Walp), blackgram (Vigna mungo (L.) Hepper), groundnut (Arachis hypogaea L.) and redgram/pigeon pea (Cajanus cajan (L.) Millsp.), under different shade intensities during the year 1981.

The experiment was conducted at the College of Horticulture, Vellanikkara, Trichur, Kerala, India, which is situated at 10°32' N latitude and 76°10' E longitude at an altitude of 22.25 meters above mean sea level.

Cropping history of the experimental field

The present study was conducted in the same plot in which another shade response study was conducted during the previous year, with some tuber crops.

Soil

The soil of the experimental site was deep, well drained sandy clay loam. The data on the physical and chemical characteristics of the soil are given in Table 1.

Table 1. Mechanical composition and chemical properties of the soil.

A. Mechanical composition

Coarse sand	-	29.05 per cent
Fine sand	-	21.81 per cent
Silt	-	23.19 per cent
Clay	-	25.95 per cent

B. Chemical properties

Constituent	Content in soil	Rating	Method used for estimation
Total nitrogen	0.1039%	Medium	Microkjeldahl (Jackson, 1958)
Available phosphorus (Bray-I extract)	2.149 ppm	Low	Chlorostannous reduced molybdo-phosphoric blue colour method (Jackson, 1958)
Available potassium (Neutral normal Amm.acetate extract)	105.565 ppm	Medium	Flame photo-metric (Jackson, 1958)
pH (1:2.5 soil: water ratio)	4.5	Low	pH meter (Jackson, 1958)

Season and climate

The experiment was conducted during the period from May to October 1981. Among the four crops grown, redgram was sown on May 29th, blackgram on 30th May, cowpea on 2nd June and groundnut on 12th June 1981. Harvesting of all the crops was highly staggered mainly because the days to maturity differed with levels of shade in all the crops.

The meteorological data for the crop periods are presented in Appendix I. The area has a humid tropical climate. The weekly average range in meteorological parameters relating to individual crops are given in Appendix II and the month-war details of climatological parameters for 20 years are given in Appendix III. As evidenced from these data, the climatological conditions were normal with fairly well distributed rainfall, throughout the growing season, although the maximum rainfall was recorded in the month of June in the present year, with a greater than average intensity. The temperature received ranged from 20.93°C to 30.66°C, during the cropping season.

Materials

Seeds

The following varieties of the crops were used for the trial.

Crop	Variety	Varietal description	Spacing
Cowpea	Kanakamani	Released from Rice Research Station, Pattambi. Medium duration. Dual purpose - as grain and vegetable.	30 x 15 cm

Crop	Variety	Varietal description	Spacing
Blackgram	T-9	Developed at Kanpur. Early maturing erect and black seeded.	30 x 15 cm
Groundnut	TMV-2	Bunch type; yield 1100 to 1650 kg of pods per ha with 49.4% oil. A cosmopolitan variety.	15 x 15 cm
Redgram	CO-I	Short statured redgram variety released from Coimbatore.	45 x 15 cm

In all the cases, the seeds were sown dibbled in rows at spacings specified above.

Fertilizers

Each of the crop received the respective cultural and manurial practices as per the package of practices recommendations of the Kerala Agricultural University (Anon, 1978). Nitrogen, phosphorus and potassium were supplied through urea, superphosphate and muriate of potash, respectively.

Shading

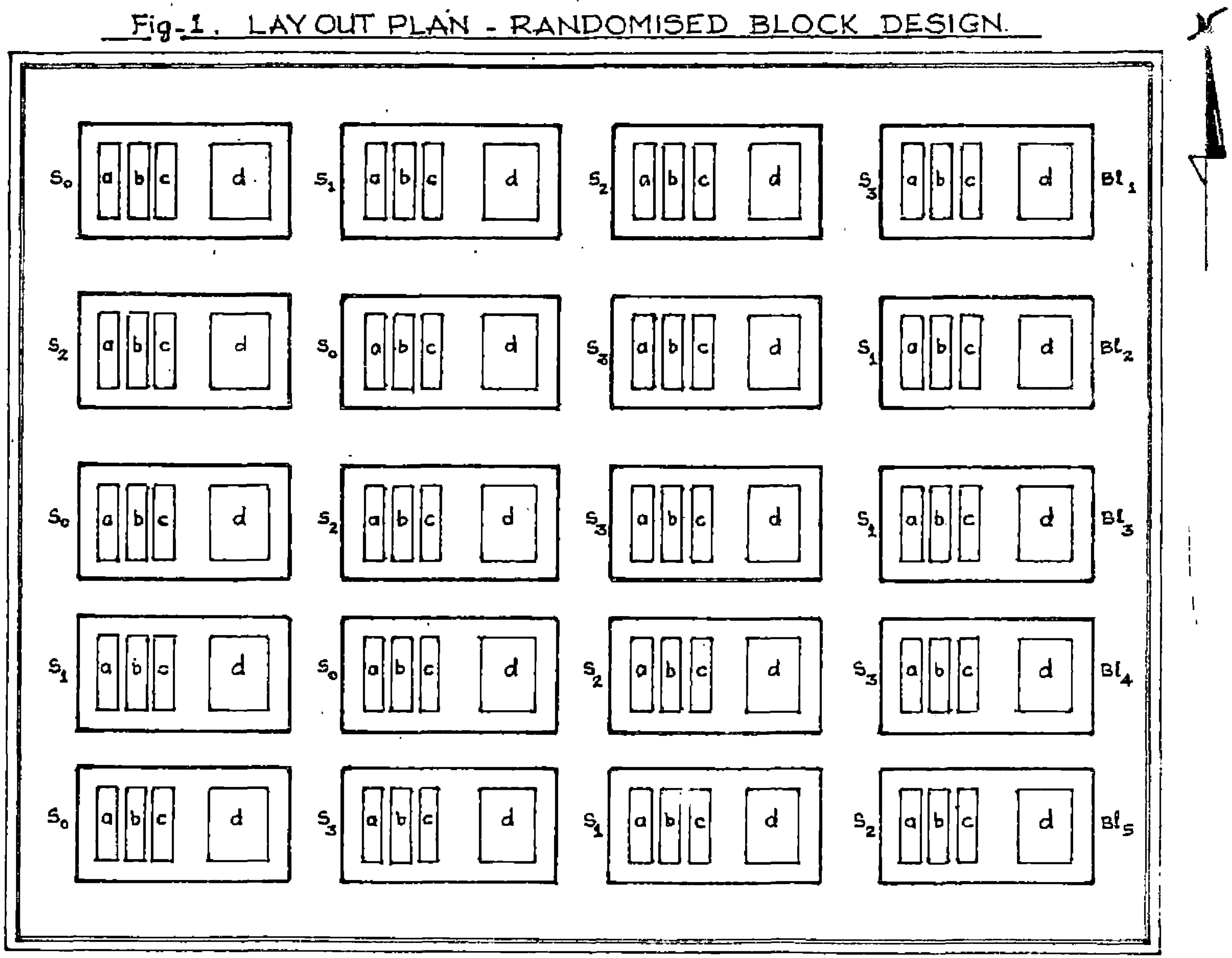
Unplaited coconut leaves were used for providing shade to the desired level.

Methods

Lay out of the experiment

The experiment was laid out in a randomised block design with five replications. The shade treatments were

Fig-1. LAY OUT PLAN - RANDOMISED BLOCK DESIGN.



Bl.1 – Block 1	S_0 – 0 percent shade.	a – cowpea.
Bl.2 – " 2	S_1 – 25 " "	b – blackgram.
Bl.3 – " 3	S_2 – 50 " "	c – groundnut.
Bl.4 – " 4	S_3 – 75 " "	d – redgram.

common for all the crops tested and thus four different crops were tested together in a contiguous area. The lay out of the experiment is given in Fig.I.

Treatments

The treatments consisted of four intensities of shade as given below.

S_0 - 0 per cent shade (no shade)
S_1 - 25 per cent shade (low shade - range 20-30%)
S_2 - 50 per cent shade (medium shade - range 45-55%)
S_3 - 75 per cent shade (high shade - range 70-80%)

Provision of shade

Artificial shading to the desired level was provided by placing unplaited coconut leaves on erected pandals. Pandals of size 11 m x 6 m were individually erected for each shade level by fixing wooden reapers on wooden posts. Sufficient space (3 m) was provided between the treatments so that mutual shading of shade levels were minimised. Each pandal was covered on all the sides with unplaited coconut leaves except from the ground for 60 cm level to avoid direct entry of slant rays. Raised beds were taken leaving a border of 1 m within each shaded area to avoid slant ray border effect. An 'Aplab' luxmeter was used for adjusting the shade intensities. Frequent checks were made throughout the course of experiment and appropriate adjustments made to maintain the shade intensities at the desired levels.

General growth of the crop

Growth of cowpea, blackgram and groundnut in general was satisfactory. As for redgram, CO-I, a variety reputed for its short stature elsewhere, grew so tall in 75 days, that they overgrew the pandal and so for this crop, the data on shade response during the early vegetative growth alone were recorded.

Observations

1. Plant characters

A. Biometric observations

Ten plants were taken at random after eliminating the border rows and all the biometric observations were recorded from these plants at 30 days intervals. A seperate sampling area was marked for destructive sampling to record the nodulation counts and for growth analysis. These samples collected were used for chemical analysis subsequently.

1. Plant height

From the observation plants marked for biometric observations, the height of the plant was measured from the base of the plant to the growing tip of the longest vine or the tallest branch as the case may be and the average worked out.

2. Number of branches

The number of branches on the observation plants were counted and the average worked out.

3. Nodulation

Plants for destructive sampling were used for the nodule count. Plants were dug out carefully after loosening the soil around them with the help of a hand hoe. The total number of root nodules and the effective nodules were counted and the average worked out. Grouping of nodule into effective and ineffective were made using visual observations of colour of the nodule centre. Pink colour of the cut surface of the nodule was taken as the indication of effectiveness. This grouping was not done in the case of groundnut because of practical difficulties in making out the differences in colour.

4. Chlorophyll content of leaves

Chlorophyll 'a', 'b' and total chlorophyll contents of each of the crops was estimated periodically by spectrophotometric method as described by Starnes and Hadley (1965). The last fully mature leaf from each of the crops was used for the estimation.

A known weight of the representative sample, collected from the plants at random, was taken in a mortar in the presence of excess acetone. A pinch of calcium carbonate was added to prevent pheophytin formation and the contents were then well ground and filtered through a Buchner funnel. The brei was washed repeatedly with fresh acetone (80 per cent) until washing was colourless. The extract and washings were then made upto 250 ml. The optical density (A) of an aliquot was measured using a spectrophotometer (Spectronic-20) at wave length of 645 nm and 663 nm. The contents of chlorophyll 'a' and 'b' and total chlorophyll (mg g^{-1} fresh weight) were then estimated using the following relationships.

Chlorophyll a = $12.72\ A_{663} - 2.58\ A_{645}$

Chlorophyll b = $22.87\ A_{645} - 4.67\ A_{663}$

Total chlorophyll (Chlorophyll (a+b)) = $8.05\ A_{663} + 20.29\ A_{645}$

5. Leaf area index (LAI)

Leaf area index of each of the crops was worked out following the gravimetric method (Ruck and Bolas, 1956). Destructive sampling was followed and five plants from each of the plots were uprooted at different growth stages and their leaves separated. Ten leaves at random were chosen and their impressions traced accurately on quality bond paper of known area per unit weight. The traced portions of the paper were then cut out and weighed.

From this, the area of the sample leaf was calculated from the weight to area relationship.

The leaves were then dried, in a hot air oven at 70±2°C to constant weight and the dry weight of these leaves and the rest of the leaves were recorded separately. Total leaf area for the five plants sample was then calculated using the weight to area relationship and total dry weight of leaves. Thus the LAI for each of the crops was calculated at different stages using the following equation.

$$LAI = \frac{\text{Total leaf area of five plants}}{\text{Land area occupied by five plants}}$$

6. Specific leaf area (SLA)

Specific leaf area was worked out as follows:

$$SLA = \frac{(LA_1/LW_1) + (LA_2/LW_2)}{2}$$

Where,

LA_1 = Total leaf area at 1st stage

LA_2 = Total leaf area at 2nd stage

LW_1 = Total leaf weight at 1st stage

LW_2 = Total leaf weight at 2nd stage

7. Leaf weight ratio (LWR)

Leaf weight ratio was calculated as follows:

$$LWR = \frac{(LW_1/W_1) + (LW_2/W_2)}{2}$$

Where,

LW_1	-	Total leaf dry weight at 1st stage
LW_2	-	Total leaf dry weight at 2nd stage
W_1	-	Total dry weight of plant at 1st stage
W_2	-	Total dry weight of plant at 2nd stage

8. Total dry weight

Plants marked out for destructive sampling were uprooted and oven dried to constant weights at 70$\pm$2°C. The weight of the material was found out and total dry matter yield was expressed as g plant^{-1}.

9. Net assimilation rate (NAR)

The procedure given by Watson (1958) as modified by Buttery (1970) was followed for calculating the NAR. The following formula was used to arrive at the NAR expressed as g m^{-2} day^{-1}.

$$NAR = \frac{W_2 - W_1}{(t_2 - t_1)\ \frac{(A_1 + A_2)}{2}}$$

Where,

W_2	=	Total dry weight of plant g m^{-2} at time t_2
W_1	=	Total dry weight of plant g m^{-2} at time t_1
(t_2-t_1)	=	Time interval in days
A_2	=	Leaf area m^{-2} at time t_2
A_1	=	Leaf area m^{-2} at time t_1

10. Absolute growth rate (AGR)

Absolute growth rate was worked out as follows:

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

Where,

W_2 = Total dry weight of plant at time t_2

W_1 = Total dry weight of plant at time t_1

B. Yield and yield components

1. Yield of pods

The pods harvested from the net plot area were sun dried to the desired moisture level for safe storage. In the case of blackgram and cowpea, the pods were threshed, winnowed, cleaned and weight of the clean seeds was recorded. In the case of groundnut the weight of the unshelled pods was taken. Yield was expressed in kg ha^{-1} in all cases.

2. Date of flowering

The dates on which 50 per cent of the plants in the net plot area had flowered was recorded and the days from sowing to flowering were calculated as the date of flowering.

3. Days to maturity

The date of harvest of each of the crops under each treatment was noted and days from sowing to harvest were worked out.

4. Number of pods per plant

Average number of pods per plant was worked out by counting the total number of pods from the observation plants.

5. Weight of pods per plant

Average weight of pods per plant was calculated from the total weight of all the pods from the observation plants.

6. Number of seeds per pod

Twenty pods were selected at random from the observation plants, the total number of seeds counted and the average worked out.

7. 100 seed weight

From each plot, 100 dry seeds were taken at random, and their weight recorded.

8. Shelling percentage

Shelling percentage was calculated at harvest using the following formula.

$$\text{Shelling percentage} = \frac{\text{Dry weight of seeds}}{\text{Dry weight of pods}} \times 100$$

9. Yield of haulm

Stover obtained from each net plot was sun dried and total weight was recorded. Yield was expressed in kg ha^{-1}.

10. Harvest index

Harvest index values for the different crops were calculated as follows:

$$HI = \frac{Y_{econ}}{Y_{biol}}$$

Where

Y_{econ} = Dry weight of seeds

Y_{biol} = Total dry weight of plants (excluding roots)

C. Quality characters

1. Percentage of well formed grains

From each plot, 100 dry seeds were taken at random and the number of well filled grain was recorded by visual observation. From this, the percentage of well formed grains was calculated.

2. Protein content of seeds

The protein content of seeds was calculated by multiplying the nitrogen content of air dried seeds with the factor 6.25 (A.O.A.C., 1950).

3. Protein yield

The protein yield was calculated from the protein content of seeds and total seed yield and expressed in kg ha^{-1}.

4. Oil content of seeds

In groundnut, the oil content of oven dried seeds was estimated by using cold percolation method and expressed as percentage (Nambudiri *et al.*, 1970).

D. Chemical studies

1. Nitrogen, phosphorus and potassium contents of plants.

Plant samples collected for recording dry weight were used for chemical analysis. The sample plants as a whole were ground and total analysis was done. The nitrogen, phosphorus and potassium contents were determined using microkjeldahl method, colorimetrically (Vandomolybdophosphoric yellow colour method) and Flame photometrically respectively (Jackson, 1958).

2. Uptake of nutrients

The total uptake of nitrogen, phosphorus and potassium by the plants was calculated from the nutrient contents and dry weight of the plant and expressed as kg ha^{-1}.

II. Soil characters

Composite soil samples were taken replicationwise before the start of the experiment. After the experiment, individual samples were collected from the area occupied by each crop. The total nitrogen, available phosphorus and available potassium contents in these samples were estimated using microkjeldahl method, colorimetrically

(Chlorostannous reduced molybdophosphoric blue colour method) and Flame photometrically, respectively (Jackson, 1958).

Statistical analysis

The data on different characters were subjected to statistical analysis by using the analysis of variance technique for Randomised Block Design (Panse and Sukhatme, 1978).

Response curves also were fitted to describe the relationship between intensities of shade and yield of the crop as per the method suggested by Snedecor and Cochran (1967). The total percentage variation in yield explained by the fitted models was also evaluated by finding the coefficient of determination R^2.

Results and Discussion

RESULTS AND DISCUSSION

Herein, the results on the shade response of the four crops involved in the present study are furnished and discussed separately for individual crops. A brief summary of the major conclusions drawn out of the study succeeds each discussion.

Cowpea

Cowpea (*Vigna unguiculata* (L.) Walp)

RESULTS

I. Plant characters

A. Biometric observations

1. Plant height

The data are presented in Table 2 and the analysis of variance is given in Appendix 4.

There was no significant difference in plant height due to different shade levels at any of the growth stages. It was also noted that there was a three fold increase in plant height during the period between 30th and 60th days and that after 60th day, the increase in plant height was nominal.

2. Number of branches

The data are presented in Table 2 and the analysis of variance is given in Appendix 4.

The data revealed that the number of branches at all the stages of plant growth was reduced significantly by shading. During the early stage, *viz*., one month after sowing, branching was there only in plants grown in full sunlight. At all the shade levels, the number of branches increased with advancing age.

3. Nodulation

The data are presented in Table 2 and Fig.2. The able 2. Effect of shade on plant height, number of branches and nodulation of cowpea at different growth stages.

Shade intensity (per cent)	Plant height (cm) (days after sowing)			Number of branches plant^{-1} (days after sowing)			Total number of nodules plant^{-1}		No. of effective nodules plant^{-1} (days after sowing)	
	30	60	75	30	60	75	30	60	30	60
0 (no shade)	30.01	116.65	160.04	1.56 (1.595)	2.36 (1.83)	3.32 (2.06)	27.12 (5.265)	6.08 (2.52)	18.64 (4.37)	1.20 (1.49)
25 (low shade)	30.18	159.94	162.58	0 (1)	1.44 (1.55)	1.80 (1.64)	16.88 (4.19)	3.32 (2.04)	8.12 (2.997)	1.60 (1.59)
50 (medium shade)	31.07	141.24	151.28	0 (1)	0.92 (1.39)	1.03 (1.42)	11.52 (3.5)	3.60 (1.90)	6.32 (2.506)	0.32 (1.14)
75 (high shade)	30.88	146.44	157.52	0 (1)	0.76 (1.28)	0.92 (1.35)	11.32 (3.46)	1.60 (1.60)	5.92 (2.62)	0.65 (1.27)
SEm ±	0.24	9.40	5.50	0.03	0.08	0.10	0.23	0.32	0.24	0.15
C.D.(0.05)	NS	NS	NS	0.09	0.26	0.32	0.70	NS	0.74	NS

NS = Not significant Figures in parenthesis indicate $\sqrt{x+1}$ transformed values.

Table 3. Effect of shade on contents (mg g^{-1} fresh weight) of chlorophyll 'a', 'b', total chlorophyll and chlorophyll a:b ratio of cowpea leaves at different growth stages.

Shade intensity (per cent)	Chlorophyll 'a' (days after sowing)		Chlorophyll 'b' (days after sowing)		Total chlorophyll (days after sowing)		Chlorophyll a:b (days after sowing)	
	45	75	45	75	45	75	45	75
0 (no shade)	1.04	1.05	0.97	0.96	2.02	2.01	1.08	1.09
25 (low shade)	0.99	1.22	1.19	1.16	2.17	2.27	0.97	0.95
50 (medium shade)	1.27	1.14	1.30	1.09	2.57	2.23	0.97	1.04
75 (high shade)	1.17	1.29	1.16	1.27	2.33	2.57	1.01	1.02
SEm 6 ±	0.99	0.06	0.09	0.10	0.16	0.15	0.05	0.05
C.D.(0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Fig. 2. EFFECT OF SHADE ON TOTAL AND EFFECTIVE NODULES IN COWPEA AT DIFFERENT GROWTH STAGES.

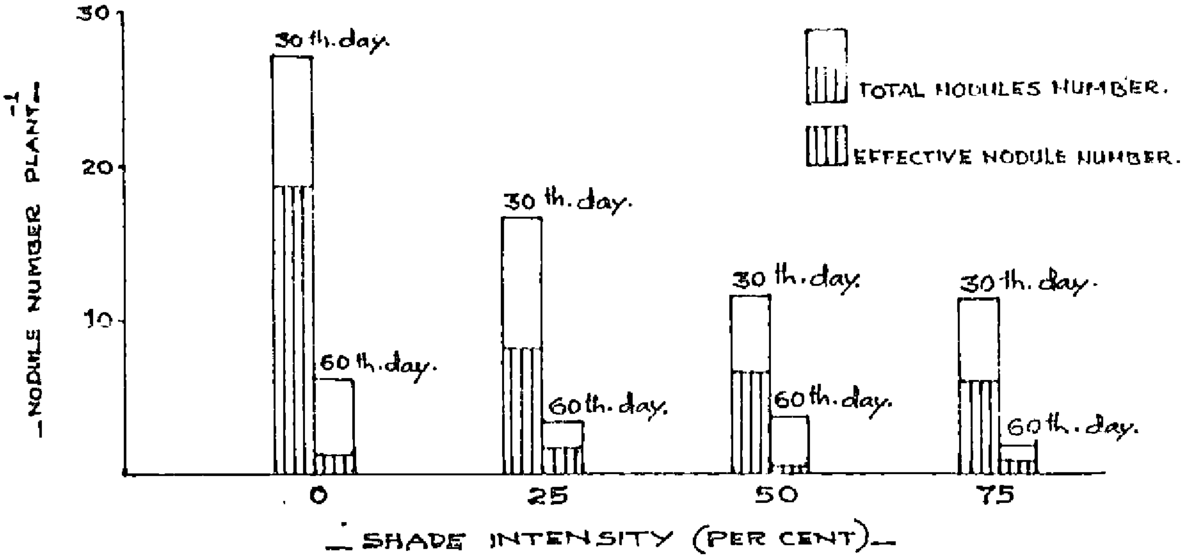
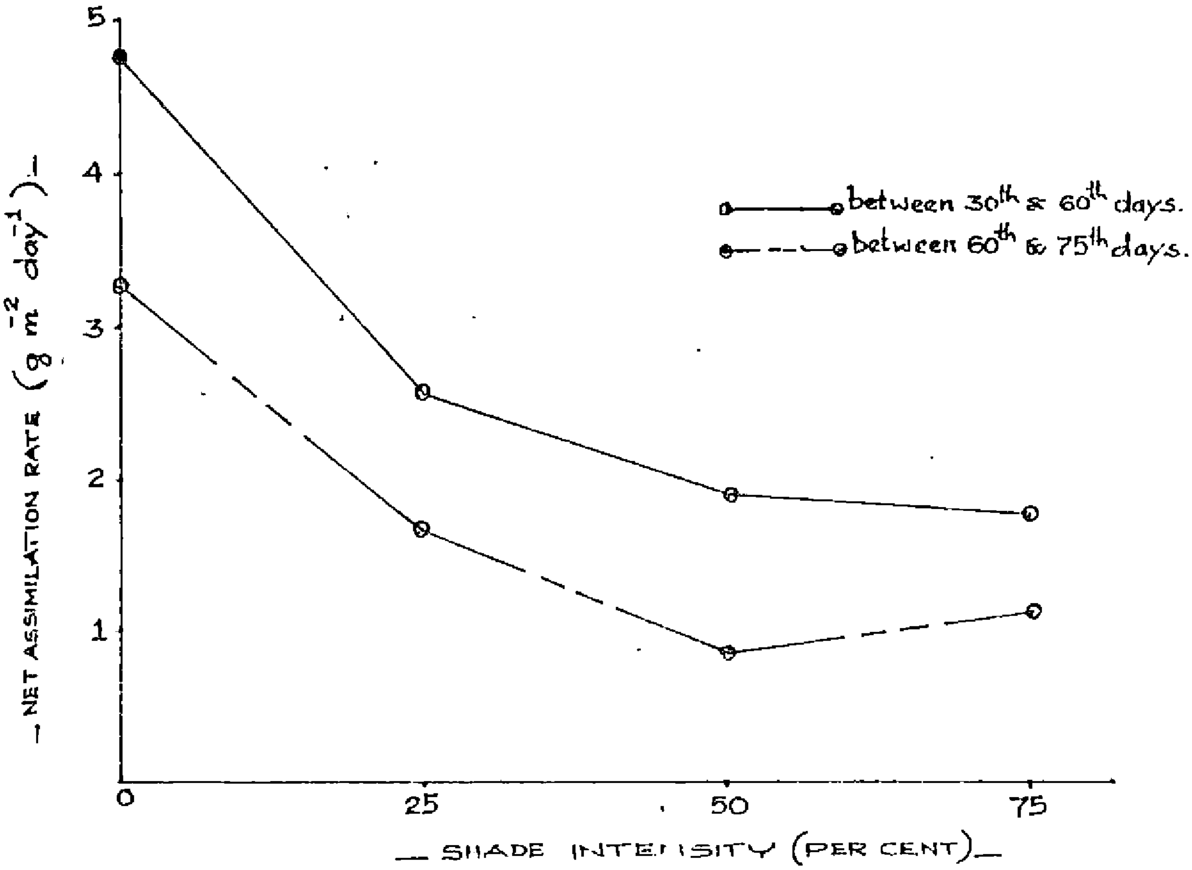


Fig. 3. EFFECT OF SHADE ON NET ASSIMILATION RATE OF COWPEA AT DIFFERENT GROWTH STAGES.



analysis of variance is given in Appendix 4.

Nodulation in terms of both the total number of nodules as well as number of effective nodules was significantly influenced by shading during the early stages. Nodulation decreased steadily upto 50 per cent shade and with more intense shading, the difference was not perceptible. Though the trend in mean values remained the same, on 60th day, the differences fell short of statistical significance. The maximum nodule number was recorded on 30th day and on 75th day very few if any, nodules were found retained on the plants.

4. Chlorophyll content of leaves

The data are presented in Table 3 and the analysis of variance is given in Appendix 5.

The effects of shade on total chlorophyll as well as its components 'a' and 'b' were not significant at any of the stages. Though the contents recorded were minimum in plants grown under full sunlight, no distinct trend could be elucidated as to the response to increasing shade levels. The ratio of chlorophyll a:b remained almost constant at different shade intensities over the stages.

5. Leaf area index (LAI)

The data are presented in Table 4 and the analysis of variance is given in Appendix 6.

Shading failed to influence leaf area index at any of the growth stages. But in general the LAI was found to increase with increasing intensities of light. Over the stages, LAI recorded was maximum on 60th day and towards maturity it decreased substantially at all the shade levels. This decrease was more distinct in plants grown under full sunlight.

6. Specific leaf area (SLA)

The data are presented in Table 4 and the analysis of variance is given in Appendix 6.

The specific leaf area of cowpea was found to be significantly affected by shading at all the stages. The maximum and minimum SLA were recorded for plants under 75 per cent shade and for plants without shade respectively. Comparison between stages indicated a decline in specific leaf area with advancing age.

7. Leaf weight ratio (LWR)

The data are presented in Table 4 and the analysis of variance is given in Appendix 6.

The data showed that the effect of shade on leaf weight ratio was significant only between 60th and 75th days of sowing, when it increased with increasing intensities of shade. It was also noted that the leaf weight ratio decreased over stages, and this trend was more conspicuous under higher light intensities.

Table 4. Effect of shade on leaf area index, specific leaf area and leaf weight ratio of cowpea at different growth stages.

Shade intensity (per cent)	Leaf area index (days after sowing)			Specific leaf area (cm^{-2} g^{-1})		Leaf weight ratio	
	30	60	75	Between 30th and 60th days	Between 60th and 75th days	Between 30th and 60th days	Betwen 60th and 75th days
0 (no shade)	0.71	3.97	1.81	376.54	339.09	0.46	0.21
25 (low shade)	0.59	3.00	2.53	447.08	446.78	0.45	0.28
50 (medium shade)	0.37	2.99	1.91	533.26	464.36	0.44	0.32
75 (high shade)	0.55	2.15	1.62	621.81	557.93	0.48	0.34
SEm ±	0.08	0.64	0.38	20.24	26.12	0.02	0.02
C.D.(0.05)	NS	NS	NS	62.36	81.67	NS	0.06

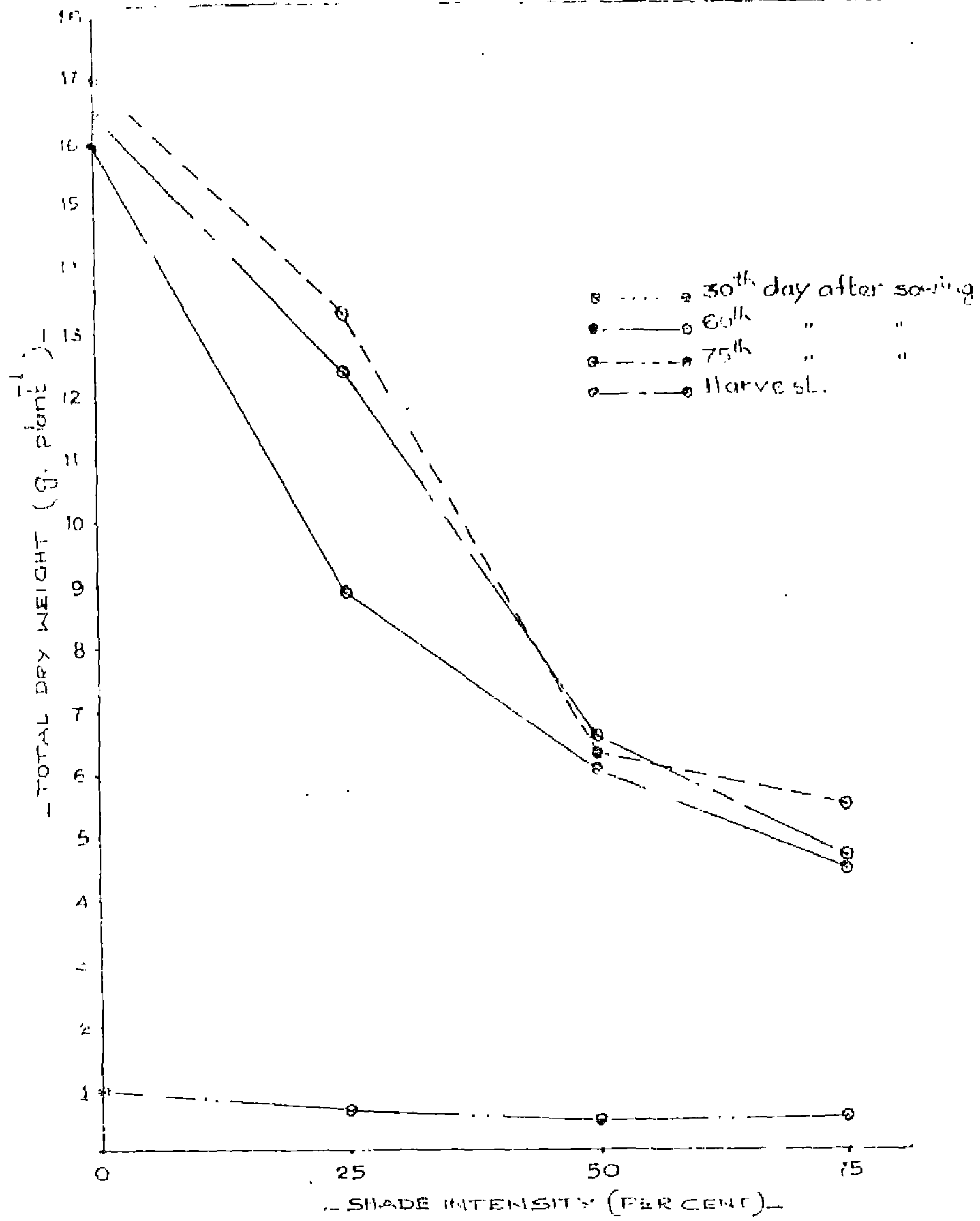
NS = Not significant

Table 5. Effect of shade on total dry matter production, net assimilation rate and absolute growth rate of cowpea at different growth stages.

Shade intensity (per cent)	Total plant dry weight (g $plant^{-1}$) (days after sowing)				Net assimilation rate (g m^{-2} day^{-1})		Absolute growth rate (g day^{-1} $plant^{-1}$)	
	30	60	75	Harvest	Between 30th and 60th days	Between 60th and 75th days	Between 30th and 60th days	Between 60th and 75th days
0 (no shade)	0.95	15.94	17.04	17.04	4.76	3.27	0.48	0.20
25 (low shade)	0.67	8.87	13.30	12.34	2.57	1.65	0.23	0.34
50 (medium shade)	0.43	6.02	6.29	6.55	1.90	0.84	0.17	0.04
75 (high shade)	0.48	4.41	5.44	4.58	1.76	1.11	0.12	0.06
SEm ±	0.08	1.70	1.87	1.56	0.72	0.96	0.12	0.13
C.D.(0.05)	0.20	5.20	5.77	4.82	2.23	NS	0.16	0.18

NS = Not significant

Fig. 4. EFFECT OF SHADE ON DRY MATTER ACCUMULATION OF COWPEA AT DIFFERENT GROWTH STAGES



8. Total plant dry weight

The data are presented in Table 5 and Fig. 4. The analysis of variance is given in Appendix 7.

Total dry weight of plant at all the stages of crop growth was significantly higher for plants grown without shade and there was a steady decline with increasing shade intensities. At all the shade levels, there was a spectacular increase in total dry weight between 30th and 60th days.

9. Net assimilation rate (NAR)

The data are presented in Table 5 and Fig. 3. The analysis of variance is given in Appendix 7.

During the period between 30th and 60th days, NAR was found affected significantly by shading. Net assimilation rate was found maximum in plots without shade and a low shade of 25 per cent resulted in roughly 50 per cent decrease in NAR value. With further increase in shade intensity the NAR decreased further. Though statistically on par, the net assimilation rate recorded between 60th and 75th days was also found maximum for plants grown under full sunlight.

10. Absolute growth rate (AGR)

The data are presented in Table 5 and the analysis of variance is given in Appendix 7.

shading had significant effect on absolute growth rate at all the growth stages. Plants without shade recorded a higher AGR, and the value was found decreasing with advancing age. But between 60th and 75th days, the AGR was found to be the highest at 25 per cent shade and it was even higher than that of plants without shade.

B. Yield and yield components

1. Date of flowering

The data are presented in Table 6 and the analysis of variance is given in Appendix 8.

The data revealed that full light intensity hastens flowering in cowpea. The delay in flowering increased progressively with increasing intensities of shade.

2. Days to maturity

The data are presented in Table 6.

The maturity period was longer with increasing intensities of shade. Plants under 75 per cent shade took 18 days more to reach harvesting stage, when compared to plants grown under full sunlight.

3. Yield of grain

The data are presented in Table 6 and Fig. 5. The analysis of variance is given in Appendix 8.

The yield of grain was significantly influenced by shade. The grain yield declined drastically even with low able 6. Effect of shade on date of flowering, days to maturity, yield of grain, yield of haulm and harvest index of cowpea.

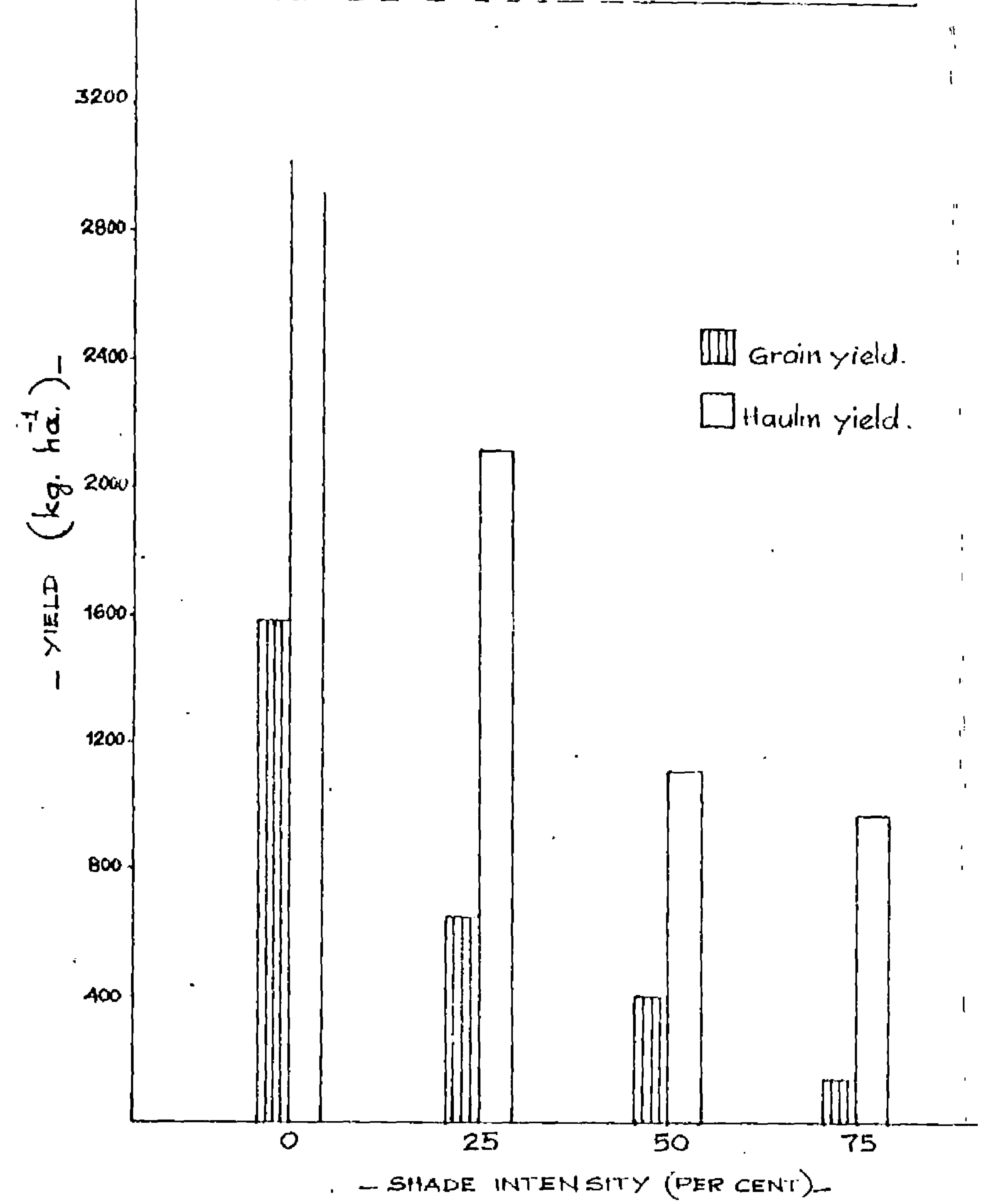
Shade intensity (per cent)	Date of flowering (days after sowing)	Days to maturity (days after sowing)	Yield of grain (kg ha^{-1})	Yield of haulm (kg ha^{-1})	Harvest index
0 (no shade)	46	75	1582.22	3037.69	0.34
25 (low shade)	49	81	664.79	2118.31	0.26
50 (medium shade)	56	88	403.56	1111.24	0.27
75 (high shade)	59	93	145.78	976.14	0.13
SEm ±	0.46		76.90	308.30	0.03
C.D.(0.05)	1.41		237.13	950.14	0.10

Table 7. Effect of shade on number of pods per plant, weight of pods per plant, number of seeds per pod, 100 seed weight and shelling percentage of cowpea at harvest.

Shade intensity (per cent)	Number of pods $plant^{-1}$	Weight of pods (g $plant^{-1}$)	Number of seeds pod^{-1}	100 seed weight	Shelling percentage
0 (no shade)	0.92	9.82	15.56	11.96	75.15
25 (low shade)	4.35	3.58	14.81	9.86	72.22
50 (medium shade)	3.70	1.16	14.65	9.72	65.88
75 (high shade)	2.42	0.27	12.94	8.98	65.01
SEm ±	0.30	0.50	0.57	0.41	3.14
C.D.(0.05)	0.93	1.62	1.74	1.26	NS

NS = Not significant

Fig. 5. GRAIN AND HAULM YIELDS OF COWPEA AS AFFECTED BY VARYING INTENSITIES OF SHADE.



shade of 25 per cent, and with further increase in shading intensity, the decline continued. With intense shading of 75 per cent, the economic produce obtained was very meagre. Calculated as percentages of the yield in the open, the yields at 25, 50 and 75 per cent shade intensities were 42.02, 25.51 and 9.21 per cent respectively.

Response curve

A quadratic polynomial was found to give the best fit to the yield data (Fig. 6 and the analysis of variance in Appendix 35). The equation of the curve is given below.

$$Y = 493.13-228.48x+41.21x^2$$

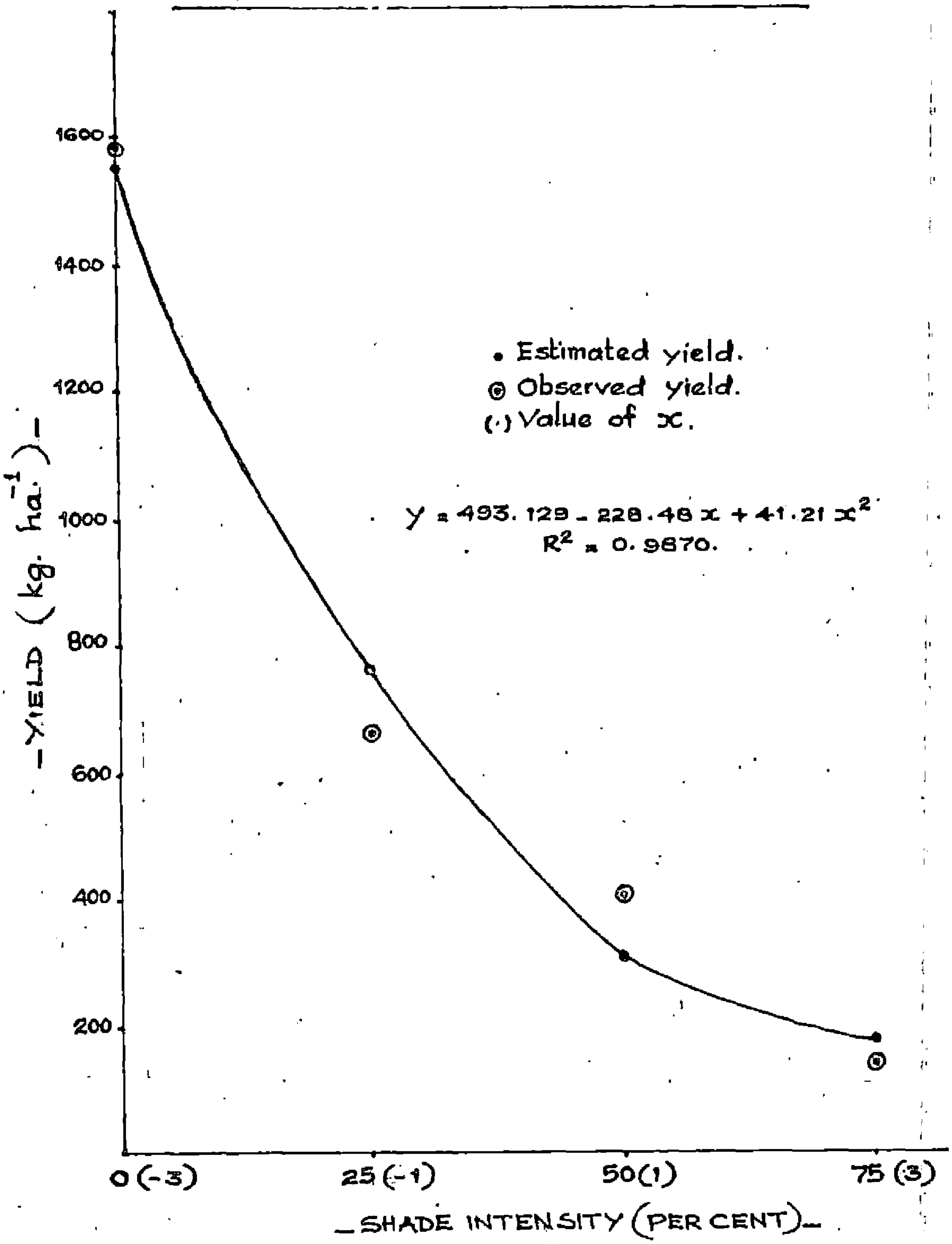
The coefficient of determination R^2 of the equation being 0.9870, 98.7 per cent of the total variation in the response can be explained by the fitted polynomial.

4. Yield of haulm

The data are presented in Table 6 and Fig. 5. The analysis of variance is given in Appendix 8.

Though not as conspicuous as the grain yield, the haulm yield also registered the maximum value when the plants were grown in full sunlight. When shading increased, the haulm yield declined progressively, the minimum value being when the crop was receiving only 25 per cent light.

Fig. 6. YIELD RESPONSE OF COWPEA TO DIFFERENT INTENSITIES OF SHADE.



5. Harvest index (HI)

The data are presented in Table 6 and the analysis of variance in Appendix 8.

The harvest index showed significant variation due to shading only between medium and high shade levels. The maximum HI of 0.34 and minimum of 0.13 were registered under full sunlight and 75 per cent shade respectively.

6. Number of pods per plant

The data are presented in Table 7 and the analysis of variance is given in Appendix 9.

The pod numbers under low, medium and high shade were found to be 48.76, 41.48 and 27.13 per cent of that in the open. Between 25 and 50 per cent shade, the value was found to be statistically on par, and between other shade levels, there was significant difference in pod number per plant.

7. Weight of pods per plant

The data are presented in Table 7 and the analysis of variance is given in Appendix 9.

The weight of pods per plant decreased sharply with shading and it followed more or less an identical trend as that of the grain yield.

8. Number of seeds per pod

The data are presented in Table 7 and the analysis

of variance in Appendix 9.

The number of seeds per pod remained almost the same with varying shade intensities upto 50 per cent. Further reduction in light intensity reduced the number significantly. 15.56 and 12.9 were the maximum and minimum values recorded in plots without shade and those shaded to 75 per cent respectively.

9. 100 seed weight

The data are presented in Table 7 and the analysis of variance in Appendix 9.

The 100 seed weight was the highest in plots without shade. The value registered a significant decline at 25 per cent shade, but with further increase in shade intensity, the change in 100 seed weight was not statistically significant.

10. Shelling percentage

The data are presented in Table 7 and the analysis of variance is given in Appendix 9.

Though the shelling percentage was highest in plots without shade, the differences between varying intensities of shade were not conspicuous and these remained statistically at par.

C. Quality aspects

1. Protein content of seeds

The data are presented in Table 8 and the analysis of variance is given in Appendix 10.

Shading failed to influence the protein content of cowpea seeds. The protein content remained more or less constant at varying shade intensities.

2. Protein yield

The data are presented in Table 8 and the analysis of variance is given in Appendix 10.

The protein turnover from grain was highly and significantly influenced by shading. The plots under low, medium and high shade intensities recorded protein yields of 34.97, 26.69 and 8.80 per cent of that in full sunlight.

3. Percentage of well formed grains.

The data are presented in Table 8 and the analysis of variance in Appendix 10.

Between open and low shade treatments, there was significant difference in the percentage of well formed grains; the value at low shade being only 69.38 per cent of that under full sunlight. Between low, medium and high shade levels, the percentages of well formed grains did not differ significantly.

Table 8. Effect of shade on protein content of seeds, protein yield and percentage of well formed grains of cowpea.

Shade intensity (per cent)	Protein content (per cent)	Protein yield (kg ha^{-1})	Percentage of well formed grains
0 (no shade)	22.93	359.57	73.80
25 (low shade)	19.25	125.76	51.21
50 (medium shade)	21.00	95.98	46.84
75 (high shade)	21.18	31.64	48.64
SEm ±	1.52	17.25	5.06
C.D.(0.05)	NS	53.15	15.58

NS = Not significant

Table 9. Effect of shade on nitrogen, phosphorus and potassium content of cowpea.

Shade intensity (per cent)	Nitrogen content (per cent) (days after sowing)		Phosphorus content (per cent) (days after sowing)		Potassium content (per cent) (days after sowing)	
	75	Harvest	75	Harvest	75	Harvest
0 (no shade)	1.98	1.98	0.23	0.23	1.50	1.50
25 (low shade)	1.92	2.03	0.21	0.23	1.66	1.70
50 (medium shade)	1.82	1.80	0.23	0.24	1.74	1.81
75 (high shade)	2.02	2.02	0.21	0.21	0.82	1.87
SEm ±	0.21	0.22	0.08	0.08	0.12	0.06
C.D.(0.05)	NS	NS	NS	NS	0.13	0.18

NS = Not significant

D. Chemical studies

1. Content and uptake of nitrogen

The data on the content of nitrogen of the whole plant along with the total uptake of nitrogen by the plants are presented in Tables 9 and 10 and Fig.7. The analysis of variance is given in Appendices 11 and 12.

Effect of shade on the nitrogen content of the whole plant was studied 75 days after planting as well as at harvest of the crop. Since plots under full sunlight were harvested on the 75th day, these stages coincided. The content of nitrogen did not differ significantly between shade intensities of any of the stages; so also, over the stages the values were almost constant.

As for total nitrogen uptake by the plants, the trend was identical with the effect of shade on total dry matter production. The uptake recorded was maximum for plants grown under full sunlight, the reverse was true for plants under heavy shade.

2. Content and uptake of phosphorus

The data on the content of phosphorus of the plants along with the total phosphorus uptake of the plants are presented in Table 9 and 10 and Fig. 7. The analysis of variance is given in Appendices 11 and 12.

The general trend of the phosphorus content and total uptake was identical to that of nitrogen. Over the stages, the phosphorus content increased with advancing age.

Table 10. Effect of shade on nitrogen, phosphorus and potassium uptake of cowpea.

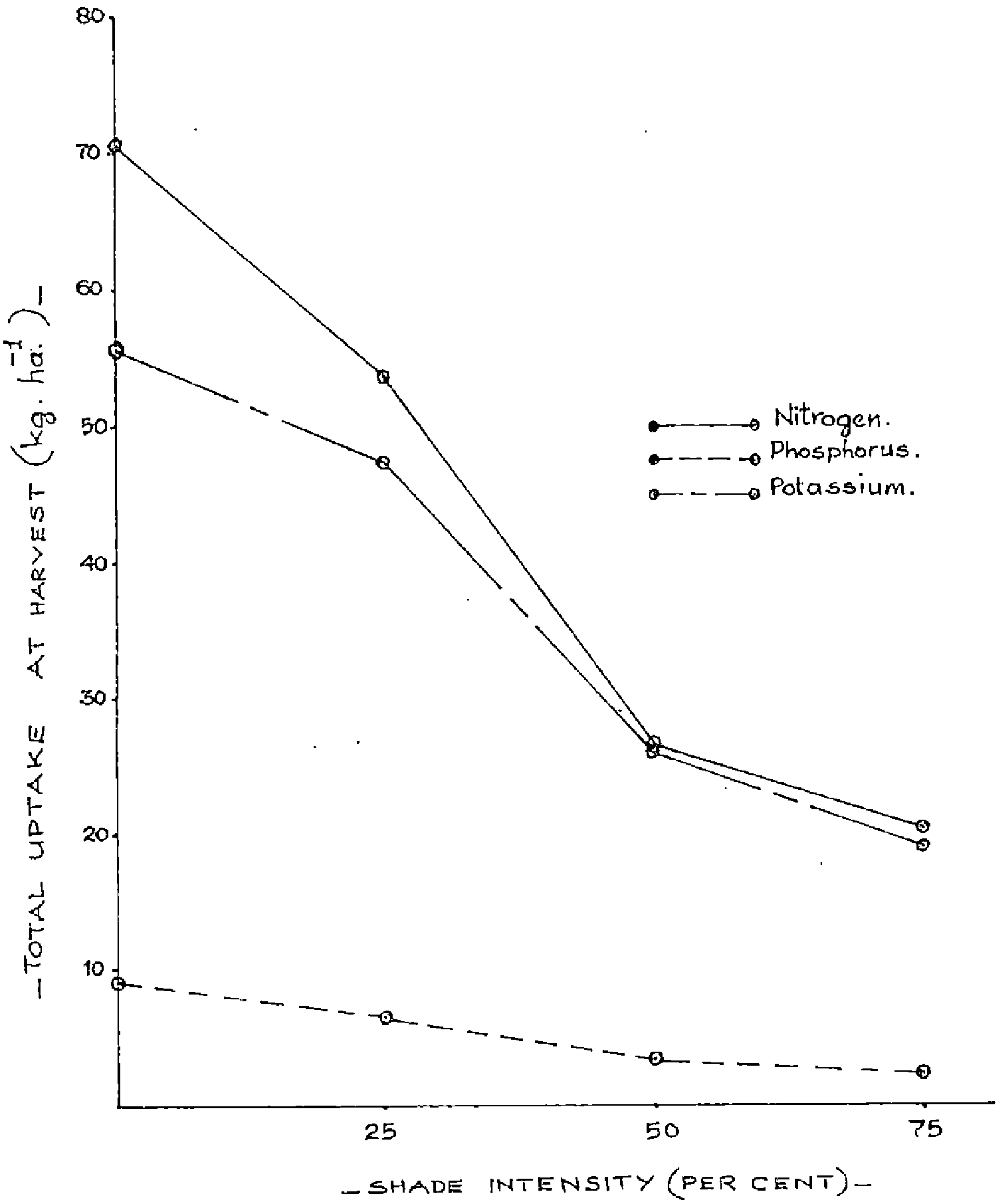
Shade intensity (per cent)	Nitrogen uptake ($kg\ ha^{-1}$) (days after sowing)		Phosphorus uptake ($kg\ ha^{-1}$) (days after sowing)		Potassium uptake ($kg\ ha^{-1}$) (days after sowing)	
	75	Harvest	75	Harvest	75	Harvest
0 (no shade)	70.64	70.64	8.95	9.05	55.43	55.43
25 (low shade)	54.52	53.76	5.56	6.34	45.80	47.35
50 (medium shade)	22.02	26.70	2.79	3.50	21.09	26.79
75 (high shade)	17.55	20.50	1.84	2.19	15.42	19.11
SEm ±	2.35	5.94	1.07	0.82	6.22	6.16
C.D.(0.05)	25.74	18.29	3.30	2.53	19.19	18.97

Table 11. Nutrient status of soil after the crop of cowpea

Shade intensity (per cent)	Nutrients		
	Total nitrogen (per cent)	Available phosphorus (ppm)	Available potassium (ppm)
0 (no shade)	0.09	3.09	143.24
25 (low shade)	0.16	3.99	152.83
50 (medium shade)	0.11	5.14	154.41
75 (high shade)	0.11	4.25	163.22
SEm ±	0.02	0.78	12.40
C.D.(0.05)	NS	NS	NS

NS = Not significant

Fig-7. UPTAKE OF NITROGEN, PHOSPHORUS AND POTASSIUM AS AFFECTED BY VARYING SHADE INTENSITIES IN COWPEA.



3. Content and uptake of potassium

The data on the potassium content as well as total potassium uptake of the plants are presented in Table 9 and 10 and Fig. 7. The analysis of variance is given in Appendices 11 and 12.

At both the stages studied, the effect of shade on the potassium content of the plants was significant. Potassium content increased with increasing intensities of shade. For plants under shade, the content increased with advancing age.

Uptake of potassium increased with advancing intensities of light as well as with advancing age, but was not in direct proportion to the dry matter production, as the influence of shade on content of potassium and the total dry matter production was just the reverse.

II. Soil characters

Soil nutrient status

The data on the soil nutrient status after the cultivation of cowpea are presented in Table 11 and the analysis of variance is given in Appendix 13.

None of the nutrients studied, viz., nitrogen, phosphorus, and potassium showed statistically significant differences in plots maintained at varying shade intensities. As compared to the pre-experimental nutrient status of the soil, there was a marked increase in the content of all the nutrients.

DISCUSSION

The results of the present study indicated that the grain yield of cowpea falls substantially because of shading. Even the low shade of 25 per cent reduced the grain yield by more than 50 per cent and with more intense shading, the yields progressively decreased. When the light intensity was reduced by 75 per cent, the yield potential was only 9 per cent of that at full sunlight. It may be concluded from such a shade response that cowpea is a legume with no special adaptation for growth under shade and that it may be classified as 'shade sensitive'. This crop may therefore not be suited for intercropping.

The above yield trend was, however, inconsistent with the extent of response of the crop in terms of dry matter accumulation and other growth characters. The dry matter accumulation under low, medium and high levels of shade when expressed as percentage of that under full illumination were 75.12, 39.79 and 27.91 per cent respectively, while the yields under these shade levels were to the tune of 42.0, 25.5 and 9.2 per cent respectively of that in the open. Such a larger extent of decline of grain yield, than dry matter yield with increasing shade intensities may be taken to indicate that cowpea failed to translocate the accumulated carbohydrates to the economic part in proportionate amounts under shade. There were probably some more factors that affected translocation of synthesised carbohydrates to the grain under shade, in addition to the availability of carbohydrates. The data on harvest index would further substantiate this. Another important conclusion that may be drawn from the above is the better suitability of this crop for cultivation for fodder purpose than for grain.

The decline in dry matter accumulation is in agreement with the findings of Dolan (1972) in pea; Crookston <u>et al</u>. (1975) in bean and Benjamin <u>et al</u>. (1981) in soybean. This decline could be attributed to mutual shading and leaf parasitism. Since when shaded, the light reaching the canopy was limited, a larger proportion of leaves would tend to fall below saturating light intensities or even below compensation point. An assessment of the extent of mutual shading that might have occurred can be had from the data on leaf area index (Table 4) and net assimilation rate (Table 5). Shading failed to influence LAI at any of the growth stages. With a canopy having the leaf area index on par with that of plants grown without shade, the lower leaves of the shaded plants must have suffered substantial parasitism. The data on net assimilation rate would further indicate the extent of such mutual shading. As expected, there was a significant fall in NAR at higher shade levels.

The canopy was sparse during the early stages and became denser between 30th and 60th days. After that, there was a drastic decline in LAI, which is attributable to the leaf senescence and shedding. Contrary to the expected trend, the NAR also went down during this period, presumably due to the deterioration of photosynthetic ability of the leaves of this stage. The specific leaf area showed a significant increase with increasing intensities of shade. This being the ratio of leaf area to leaf weight, an increase in SLA with shading may represent an adaptive mechanism, since for each unit weight of dry matter partitioned into leaves, a greater amount of area is exposed to available light (Cooper and Qualls, 1967). The differences in leaf weight ratio remained nonsignificant during the early stages but it showed a substantial increase with shading between 60th and 75th days which is attributable to low leaf senescence and leaf fall under shade, Sheldrake and Narayanan (1976) obtained similar results in chickpea and pigeonpea.

The data on harvest index revealed that partitioning of assimilates to the economic part was significantly influenced by shading. A quantitative estimate of the difference in the partitioning of assimilates can be had from the data (Table 6). The percentages of dry matter translocated to the grain were 34.1, 26.2, 27.9 and 13.6 at 0, 25, 50 and 75 per cent shade, respectively.

The above effects of lower rates of photosynthesis and translocation were reflected in all the primary yield components, viz., number of pods per plant, seeds per pod and test weight which registered significant decrease with increasing shade levels. Also, the plants under shade took more time to reach flowering stage. Both flowering and harvesting were delayed progressively with increasing levels of shade intensity. This is however, contradictory to the evidence given by Tarila et al. (1977).

As in the case of yield components, the growth components and nodulation also generally showed a decline with increasing shade levels. The only exception was in the case of plant height which was not affected significantly by shading. Both the total number of nodules and the number of effective nodules also were lower under shade. A decrease in nodulation and nitrogen fixation due to decreased availability of carbohydrates induced by shading has been reported widely (Allison, 1935; Wilson, 1935; and Hardy and Havelka, 1975). Such a decrease in nitrogen fixation by legumes under shade is also of practical importance especially as an expected advantage of intercropping with legumes is the gain in symbiotically fixed atmospheric nitrogen. Though an assessment of the extent of contribution from soil nitrogen could not be made from the present study, a net loss of nitrogen from the soil by removal by the legume under shade cannot, however, be excluded especially when this crop is raised for grain purpose.

Chlorophyll contents, both in terms of total chlorophyll as well as its components 'a' and 'b' were not affected by shading. It may be recalled that the review also shows wide species differences in the shade response of crops in terms of chlorophyll content.

Of the quality aspects, the protein content of seeds remained more or less the same irrespective of the intensity of light received. This is in agreement with the result obtained by Wahua and Miller (1978) in soybean.

The contents of nutrients, nitrogen and phosphorus in tissues were nearly the same at all shade levels. On the contrary, the total nutrient uptake followed the same trend as that of dry matter accumulation with plants in the open recording the highest uptake and those at intense shade, the lowest. The elution of the expected dilution effect may be explained by the better foraging capacity of the plant roots receiving full sunlight. In the case of nitrogen, the greater nitrogen fixing capacity of the plants in the open, as evidenced by the better nodulation must have further helped the plants getting full sunlight to maintain a high level of nitrogen. However, an identical trend was not noted in the case of potassium content which showed a persistent increase with increasing shade intensities. Similar results of increase in content of potassium by shading have been widely reported in several crops (Myhr and Saebo, 1969; Cantliffe, 1972 and Rodriguez et al., 1973). The uptake of potassium on the contrary, registered significant decrease with increasing shade levels which indicated that the effect of decreasing dry matter production had the dominant influence in deciding the total uptake and that it could more than compensate the increased contents resulting from shading. Another point of importance is that the extent of decrease in yield is much more than the extent of decrease in uptake of nutrients which indirectly indicates that the utilization efficiency of these nutrients would be less under shade than in the open.

Data on the analysis of soil after cropping (Table 11) indicated that they were statistically on par between shade levels. But the available potassium content registered an increase with increasing intensity of shade, which might be attributed to the lower uptake of potassium by the crop at higher shade levels. A similar trend was not noted in the case of phosphorus presumably because the total crop removal of this nutrient was small as compared to potassium and in the case of nitrogen because of the interfering influence of nitrogen fixation. As compared to the pre-experimental nutrient status of the soil, there was a marked increase in the content of all the nutrients.

This is attributable to the shedding of leaves and consequent addition of organic debris which in turn (being a legume) was rich in the nutrients especially nitrogen. The added fertilizers must also have contributed to the improvement of the soil nutrient status.

The general conclusions on the results and discussion may be summarised as follows.

1. There was drastic decline in yield of cowpea even with low levels of shade and hence the crop may be classified as 'shade sensitive'. It may not therefore be suited for intercropping for grain purpose.

2. Since the reduction in the total phytomass production was not so sharp, this crop may be better suited for intercropping in coconut garden for fodder purpose.

Blackgram

Blackgram (*Vigna mungo* (L.) Hepper)

RESULTS

I. Plant characters

A. Biometric observations

1. Plant height

The data are presented in Table 12 and the analysis of variance is given in Appendix 14.

Shading failed to have any significant influence on plant height at any of the stages. When compared to the early stage, the increase in plant height between 30th and 60th days after sowing was very rapid at all the shade levels.

2. Number of branches

The data are presented in Table 12 and the analysis of variance is given in Appendix 14.

Branching was significantly affected by shading at all the stages. During the first 30 days of plant growth, only the plants grown in full sunlight had branches. Between 30th and 60th days, shaded plants also branched, but with intense shading of 75 per cent most of the plants remained single stemmed throughout the growth period.

3. Nodulation

The data are presented in Table 12 and Fig.8. The analysis of variance is given in Appendix 14.

Table 12. Effect of shade on plant height, number of branches and nodulation in blackgram at different growth stages.

Shade intensity (per cent)	Plant height (cm) (days after sowing		Number of branches $plant^{-1}$ (days after sowing)		Total number of nodules $plant^{-1}$ (days after sowing)		Number of effective nodules $plant^{-1}$ (days after sowing)	
	30	60	30	60	30	60	30	60
0 (no shade)	19.27	49.76	0.54 (1.23)	2.90 (1.95)	3.68 (2.08)	3.32 (2.03)	1.56 (1.56)	3.24 (1.9)
25 (low shade)	21.37	53.50	0 (1)	1.24 (1.5)	4.96 (2.36)	2.52 (1.8)	1.24 (1.56)	1.08 (1.4)
50 (medium shade)	20.78	59.90	0 (1)	1.14 (1.46)	3.52 (2.1)	2.52 (1.79)	1.04 (1.42)	1 (1.38)
75 (high shade)	18.79	64.11	0 (1)	0.36 (1.16)	1.32 (1.52)	3.48 (2.07)	0.12 (1.05)	0.96 (1.38)
SEm ±	0.95		0.03	0.04	0.24	0.28	0.09	0.23
C.D.(0.05)	NS	NS	0.09	0.11	NS	NS	0.29	0.71

NS = Not significant   Figures in parenthesis indicate x+1 transformation

Table 13. Effect of shade on contents (mg g^{-1} fresh weight) of chlorophyll 'a', 'b', total chlorophyll and chlorophyll a:b ratio of blackgram leaves at different growth stages.

Shade intensity (per cent)	Chlorophyll 'a' (days after sowing)		Chlorophyll 'b' (days after sowing)		Total chlorophyll (days after sowing)		Chlorophyll a:b (days after sowing)	
	45	75	45	75	45	75	45	75
0 (no shade)	0.74	1.45	0.79	1.41	1.53	2.87	0.94	1.03
25 (low shade)	0.88	1.61	0.89	1.81	1.77	3.44	0.99	0.90
50 (medium shade)	1.01	1.75	1.09	1.86	2.11	3.61	0.92	0.94
75 (high shade)	1.03	1.73	1.18	1.82	2.22	3.55	0.89	0.95
SEm ±	0.03	0.08	0.05	0.09	0.07	0.15	0.03	0.04
C.D.(0.05)	0.08	0.24	0.14	0.28	0.21	0.47	NS	NS

NS = Not significant

Fig. 8. EFFECT OF SHADE ON TOTAL AND EFFECTIVE NODULES IN BLACKGRAM AT DIFFERENT GROWTH STAGES.

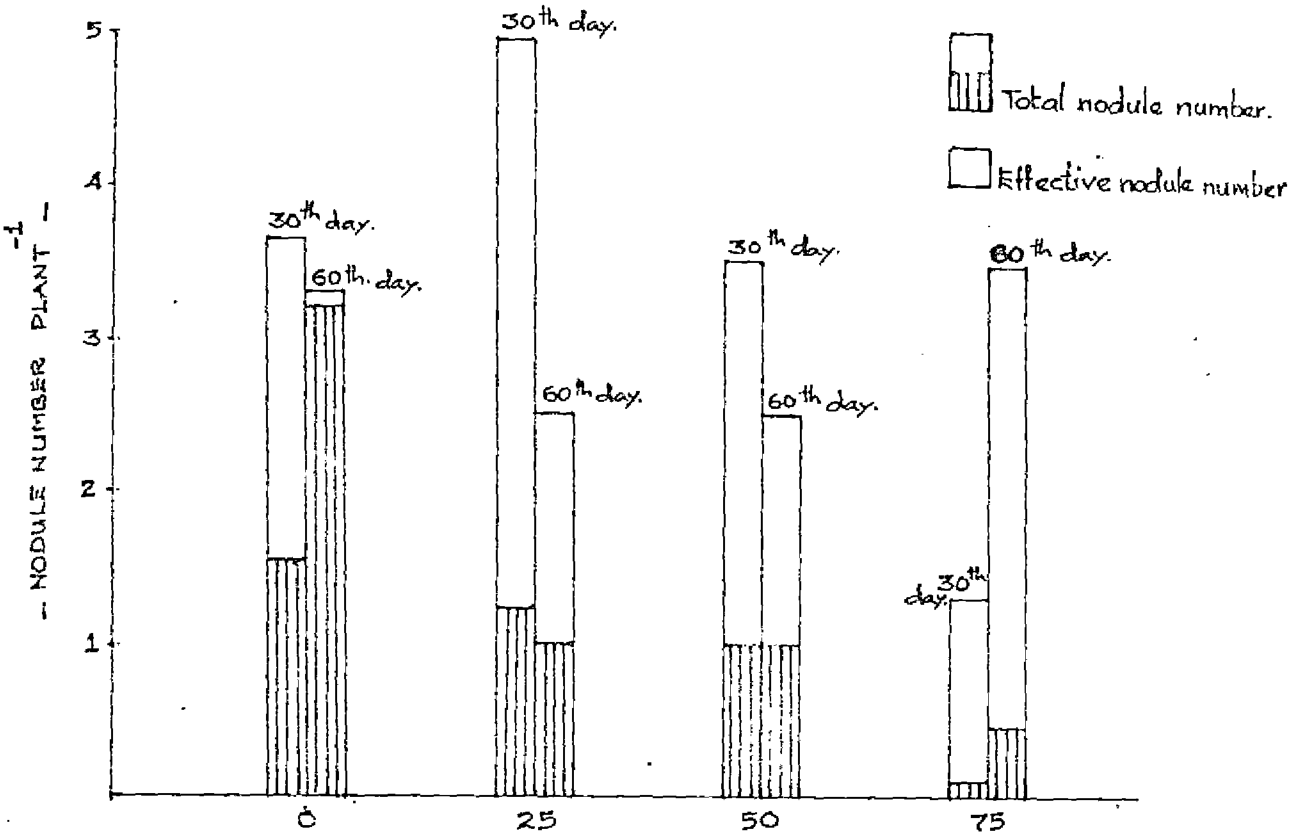
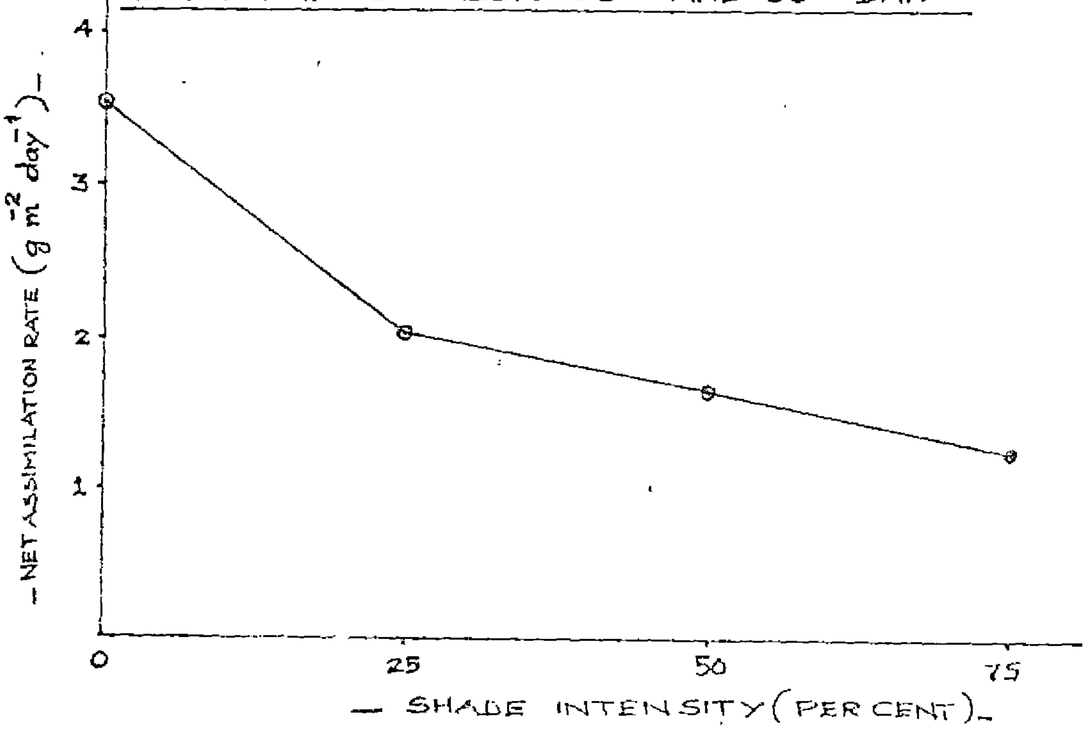


Fig. 9. EFFECT OF SHADE ON NET ASSIMILATION RATE OF BLACKGRAM BETWEEN 30th. AND 60th. DAY.



In general, nodulation in blackgram was sparse and it did not show significant difference between the shade levels in terms of total nodule number. But effectiveness of nodules was significantly higher in plants getting higher intensity of light at both the stages studied. Towards harvest, the plants did not retain the nodules at all.

4. Chlorophyll content of leaves

The data are presented in Table 13 and the analysis of variance is given in Appendix 15.

Both the total chlorophyll and its components 'a' and 'b' were affected by the varying intensities of light. Visual observations also showed that plants under shade had greener leaves. It was also noted that the chlorophyll content increased conspicuously with advancing age, at all the shade levels. At all the stages, the maximum and minimum values were recorded by plants under 75 per cent shade and by those grown in open respectively. The ratio of chlorophyll a:b remained more or less unaffected by shading.

5. Leaf area index (LAI)

The data are presented in Table 14 and the analysis of variance is given in Appendix 16.

The effect of shade on leaf area index was significant on 30th day of sowing but it remained statistically on par on the 60th day. On 30th day, plants grown without shade had maximum LAI and it progressively decreased with increasing

Table 14. Effect of shade on leaf area index, specific leaf area and leaf weight ratio of blackgram at different growth stages.

Shade intensity (per cent)	Leaf area index (days after sowing)		Specific leaf area ($cm^2\ g^{-1}$)	Leaf weight ratio
	30	60	Between 30th and 60th days	Between 30th and 60th days
0 (no shade)	0.35	2.37	474.66	0.78
25 (low shade)	0.25	1.92	525.77	0.60
50 (medium shade)	0.13	1.45	563.79	0.60
75 (high shade)	0.13	1.03	602.01	0.42
SEm ±	0.05	0.44	17.34	0.12
C.D.(0.05)	0.15	NS	NS	NS

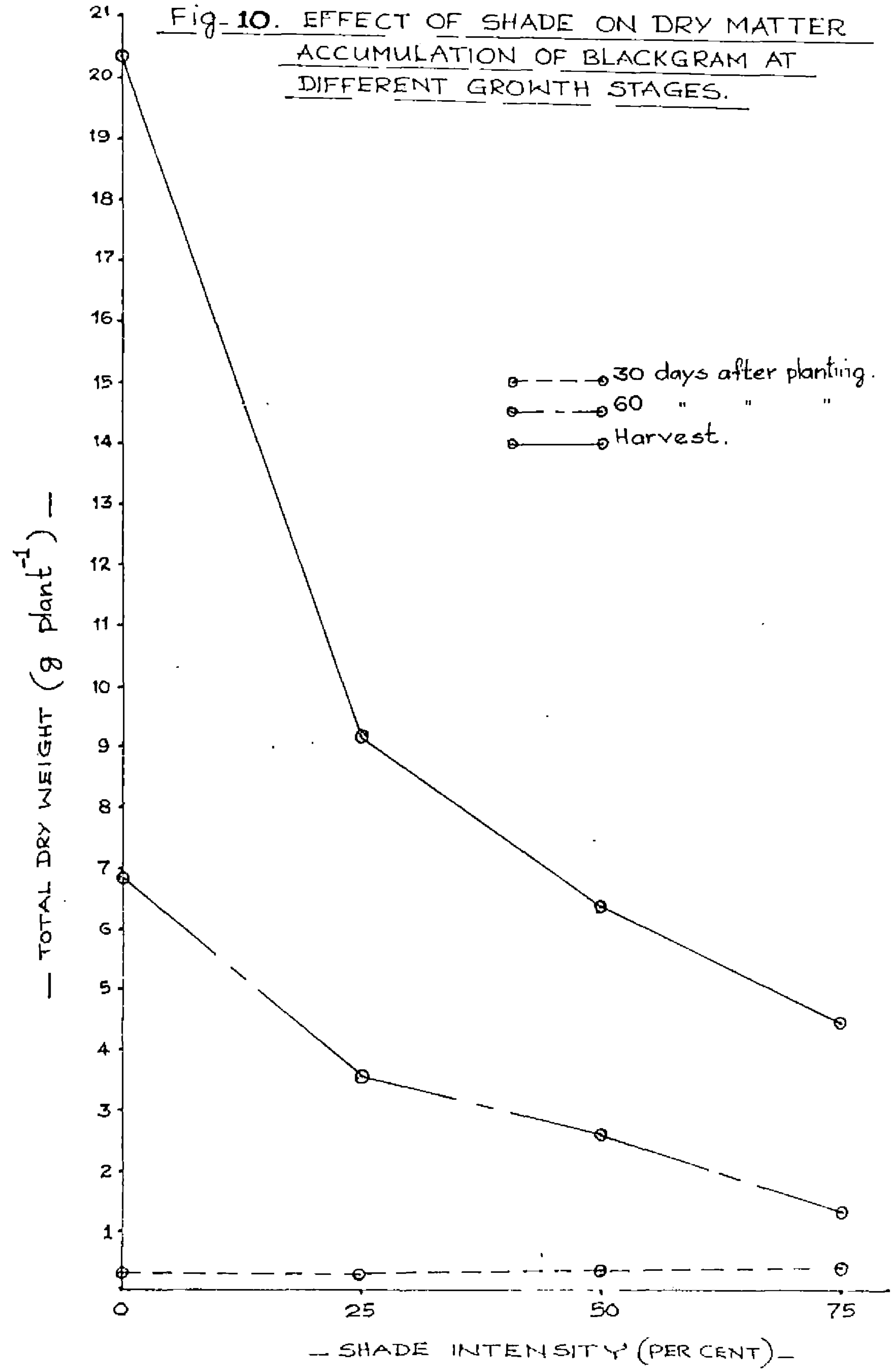
NS = Not significant

Table 15. Effect of shade on total dry matter production, net assimilation rate, and absolute growth rate of blackgram at different growth stages.

Shade intensity (per cent)	Total dry weight ($g\ plant^{-1}$)			Net assimilation rate ($g\ m^{-2}\ day^{-1}$)	Absolute growth rate ($g\ day^{-1}\ plant^{-1}$)
	30	60	Harvest	Between 30th and 60th days	Between 30th and 60th days
0 (no shade)	0.29	6.85	20.34	3.51	0.22
25 (low shade)	0.29	3.56	9.23	2.02	0.10
50 (medium shade)	0.30	2.67	6.42	1.66	0.07
75 (high shade)	0.38	1.37	4.45	1.24	0.03
SEm ±	4.9	0.95	1.48	0.11	0.07
C.D.(0.05)	NS	2.94	4.56	1.85	0.09

NS = Not significant

Fig-10. EFFECT OF SHADE ON DRY MATTER ACCUMULATION OF BLACKGRAM AT DIFFERENT GROWTH STAGES.



intensities of shade upto 50 per cent shade. With more intense shading, further decrease in LAI was not perceptible.

6. Specific leaf area (SLA)

The data are presented in Table 14 and the analysis of variance is given in Appendix 16.

The specific leaf area had an increasing trend with increasing intensities of shade, but the difference fell short of statistical significance.

7. Leaf weight ratio (LWR)

The data are presented in Table 14 and the analysis of variance is given in Appendix 16.

The data revealed that shading did not have any significant influence on leaf weight ratio.

8. Total plant dry weight

The data are presented in Table 15 and the Fig.10 analysis of variance is given in Appendix 16.

During the first 30 days of plant growth, the dry matter production under varying intensities of light remained more or less the same. But by 60th day, the plants in open recorded significantly higher dry weight and there was a steady decline in total dry weight with increasing shade intensities. The trend was the very same at the time of harvest as well. Dry weight at harvest when expressed as percentage of that in the open was 45.4, 31.6 and 21.9 respectively at low, medium and high shade. The gain in dry weight during the period between 30th and 60th days after sowing was highly perceptible at all the shade levels.

9. Net assimilation rate (NAR)

The data on net assimilation rate between 30th and 60th days after sowing are presented in Table 15 and Fig.9. The analysis of variance is given in Appendix 16.

The net assimilation rate was significantly higher in plants without shade. The maximum value of 3.5 g m^{-2} day^{-1} and minimum of 1.24 g m^{-2} day^{-1} were recorded by plants grown in open and plants under 75 per cent shade respectively.

10. Absolute growth rate (AGR)

The data are presented in Table 15 and the analysis of variance is given in Appendix 16.

Absolute growth rate was significantly higher in plants grown without shade, when compared to shaded plants. But between the plants exposed to different shade intensities, the AGR showed no significant difference.

D. Yield and yield components

1. Date of flowering

The data are presented in Table 16 and the analysis of variance is given in Appendix 17.

The data revealed that plants getting full sunlight flowered much earlier, when compared to the shaded ones.

Table 16. Effect of shade on date of flowering, days to maturity, yield of grain, yield of haulm and harvest index of blackgram.

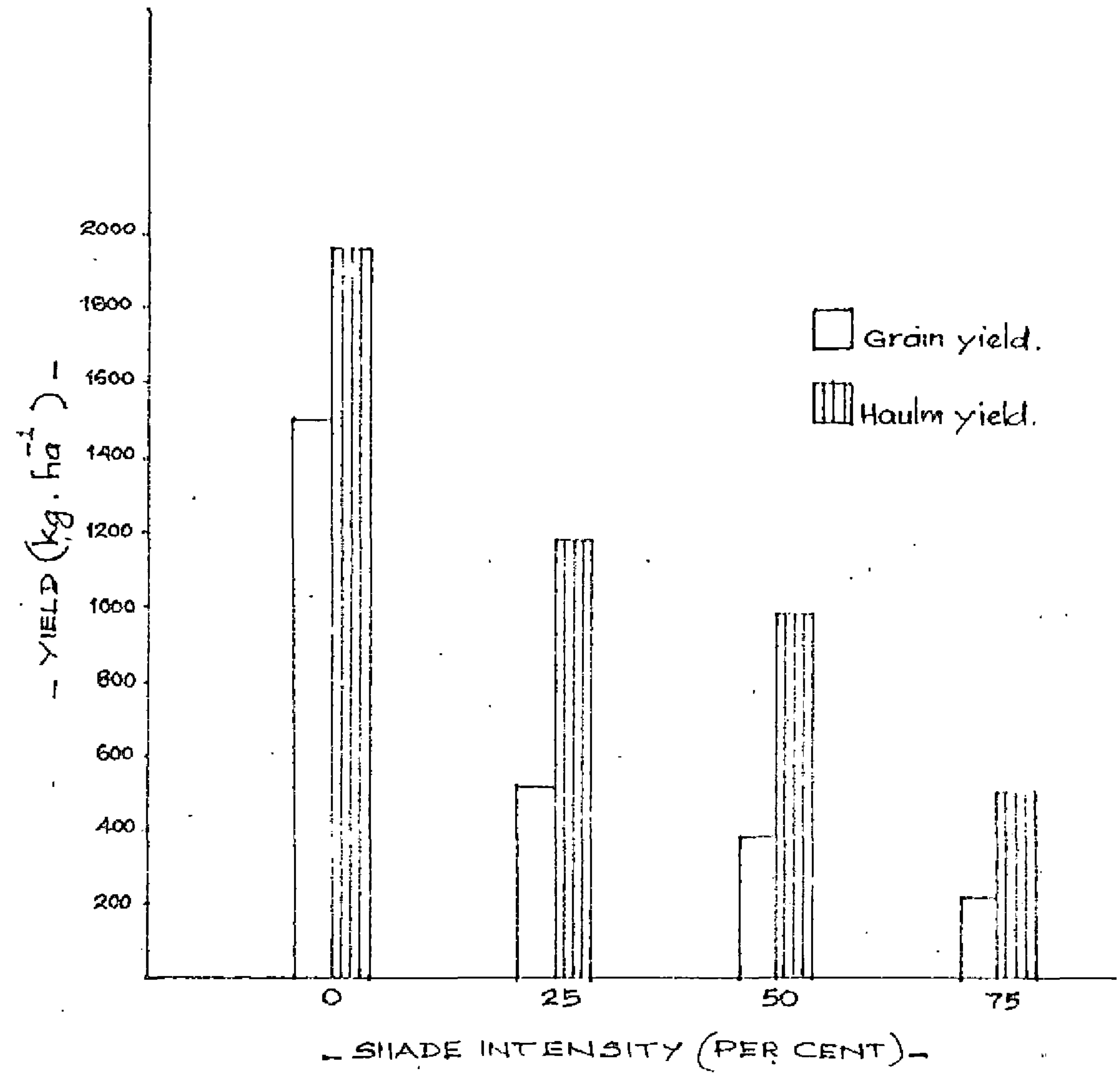
Shade intensity (per cent)	Date of flowering (days after sowing)	Days to maturity (days after sowing)	Yield of grain (kg ha^{-1})	Yield of haulm (kg ha^{-1})	Harvest index
0 (no shade	37	90	1500.74	1963.26	0.44
25 (low shade)	40	99	528.29	1184.25	0.32
50 (medium shade)	43	103	389.63	988.44	0.31
75 (high shade)	46	105	216.29	510.89	0.31
SEm ±	0.34		158.02	278.81	0.05
C.D.(0.05)	1.05		486.94	859.17	NS

NS = Not significant

Table 17. Effect of shade on number of pods per plant, weight of pods per plant, number of seeds per pod, 100 seed weight and shelling percentage of blackgram at harvest.

Shade intensity (per cent)	Number of pods plant^{-1}	Weight of pods (g plant^{-1})	Number of seeds pod^{-1}	100 seed weight (g)	Shelling percentage
0 (no shade)	44.36	10.93	6.83	4.40	61.82
25 (low shade)	20.04	3.96	6.50	4.12	40.73
50 (medium shade)	13.60	3.16	6.44	4.03	55.84
75 (high shade)	9.52	1.62	5.64	3.74	56.64
SEm ±	4.30	1.79	0.26	0.12	3.87
C.D.(0.05)	13.24	3.59	0.50	0.36	12.00

Fig. 11. GRAIN AND HAULM YIELD OF BLACKGRAM AS AFFECTED BY VARYING INTENSITIES OF SHADE.



Days taken for flowering were progressively more as the intensity of shade increased.

2. Days to maturity

The data are presented in Table 16.

Attainment of maturity was hastened by more intense sunlight in blackgram. The delay with shading was more conspicuous between plants in open and the plants shaded to 25 per cent.

3. Yield of grain

The data are presented in Table 16 and Fig. 11. The analysis of variance is given in Appendix 17.

The grain yield was significantly affected by shading. When expressed as percentage of the yield in the open, the yields at 25, 50 and 75 per cent shade were 35.2, 26.0 and 10.5 per cent respectively.

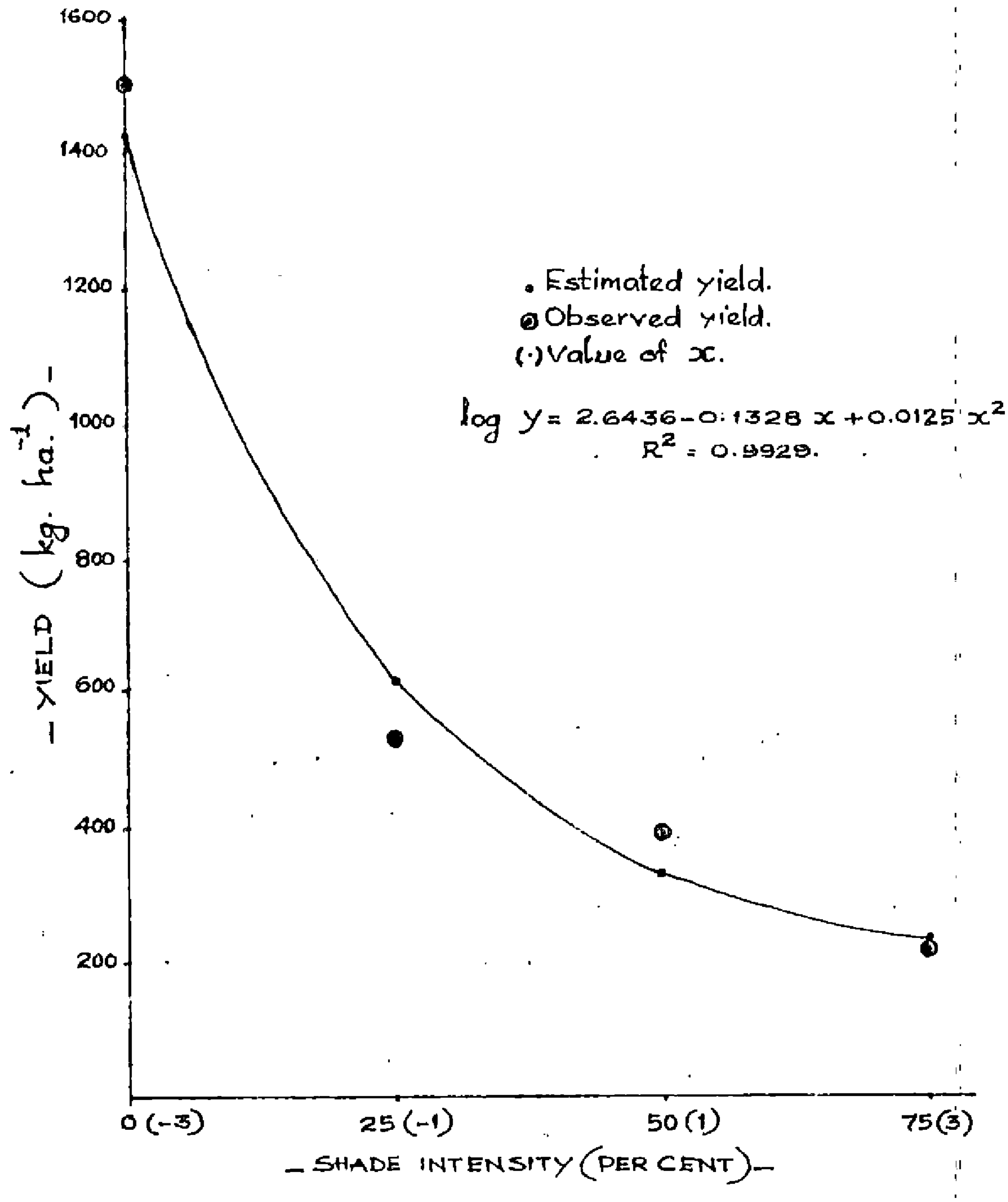
Response curve

The yield data were transformed to logarithms using $\log_{10} Y$ transformation. A quadratic polynomial was found to give the best fit to the transformed yield data (Fig. 12 and the analysis of variance in Appendix 35). The equation of the curve is given below.

$$\mathrm{Log}_{10}\, Y = 2.6436-0.1328x+0.0125x^2$$

The coefficient of determination R^2 of the above equation being 0.9929, 99.29 per cent of the total

Fig. 12. YIELD RESPONSE OF BLACKGRAM TO DIFFERENT INTENSITIES OF SHADE.



variation in the response can be explained by the fitted polynomial.

4. Yield of haulm

The data are presented in Table 16 and Fig. 11. The analysis of variance is given in Appendix 17.

Shading significantly decreased the haulm yield of blackgram. The haulm yields at 25, 50 and 75 per cent shade levels were 60.3, 50.4 and 26.0 per cent of the haulm yield in the open.

5. Harvest index

The data are presented in Table 16 and the analysis of variance is given in Appendix 17.

The data revealed that the harvest index was not significantly affected by shading.

6. Number of pods per plant

The data are presented in Table 17 and the analysis of variance is given in Appendix 17.

The pod numbers under low, medium and high shade were found to be 45.2, 30.7 and 21.6 per cent of that in the open. The decline in pod number was sharper between plots receiving full light intensity and those that were shaded to 25 per cent.

7. Weight of pods per plant

The data are presented in Table 17 and the analysis

of variance is given in Appendix 17.

The declining trend in weight of pods per plant when shaded was more or less identical to the shade effect on grain yield. The plots getting full sunlight registered significantly higher pod weight per plant, and the value decreased drastically under low shade. Between different shade levels, the difference was not conspicuous.

8. Number of seeds per pod

The data are presented in Table 17 and the analysis of variance is given in Appendix 17.

The number of seeds per pod in open plots was significantly higher than that in plots which received 25 per cent of full sunlight. With further increase in shading intensity, the differences were statistically nonsignificant.

9. 100 seed weight

The data are presented in Table 17 and the analysis of variance is given in Appendix 17.

100 seed weight was the highest in plots receiving maximum light intensity. With decreasing light intensities, the value showed a decreasing trend.

10. Shelling percentage

The data are presented in Table 17 and the analysis of variance is given in Appendix 17.

Compared to that of shaded plots, the shelling

Table 18. Effect of shade on protein content of seeds, protein yield and percentage of well formed grains of blackgram.

Shade intensity (per cent)	Protein content (per cent)	Protein yield (kg ha^{-1})	Percentage of well formed grains
0 (no shade)	18.38	276.10	83.83
25 (low shade)	16.45	86.81	69.02
50 (medium shade)	16.10	64.47	68.64
75 (high shade)	17.46	37.17	67.60
SEm ±	1.26	24.47	5.72
C.D.(0.05)	3.90	34.60	17.62

Table 19. Effect of shade on nitrogen, phosphorus and potassium content of blackgram.

Shade intensity (per cent)	Nitrogen content (per cent) (days after sowing)		Phosphorus content (per cent) (days after sowing)		Potassium content (per cent) (days after sowing)	
	60	Harvest	60	Harvest	60	Harvest
0 (no shade)	2.15	2.42	0.25	0.28	1.59	1.03
25 (low shade)	2.40	2.22	0.32	0.27	1.78	1.76
50 (medium shade)	2.57	2.17	0.34	0.28	1.69	1.78
75 (high shade)	2.46	2.34	0.35	0.29	1.73	1.80
SEm ±	0.11	0.12	0.01	0.01	0.03	0.18
C.D.(0.05)	NS	NS	0.03	NS	0.11	NS

NS = Not significant

percentage of open plots was significantly higher. The value decreased sharply when shaded to 25 per cent, but with further increase in shading the shelling percentage remained statistically non-significant between varying shade intensities.

C. Quality aspects

1. Protein content of seeds

The data are presented in Table 18 and the analysis of variance is given in Appendix 18.

Shading did not have any influence on protein content of seeds. The content remained more or less constant at varying shade intensities.

2. Protein yield

The data are presented in Table 18 and the analysis of variance is given in Appendix 18.

Unlike protein content, protein yield was significantly influenced by shading. The plots under low, medium and high shade intensities had protein yields which were 31.7, 23.6 and 13.6 per cent of the protein yield under full sunlight.

3. Percentage of well formed grains

The data are presented in Table 18 and the analysis of variance is given in Appendix 18.

The percentage of well formed grains decreased sharply with shading. But between different levels of shade, the difference was not significant.

D. Chemical studies

1. Content and uptake of nitrogen

The data on the content of nitrogen of the whole plant along with the total uptake of nitrogen by the plants are presented in Table 19 and 20 and Fig. 13. The analysis of variance is given in Appendix 19.

Effect of shade on the nitrogen content of the whole plant was studied at 60 days after sowing as well as at harvest of the crop. At both the stages, the content remained unaffected by the light intensity. It was also noted that towards maturity, there was some dilution effect in nitrogen content, except in plots receiving full sunlight.

Total nitrogen uptake by the plants was significantly higher in unshaded plots and this trend was more or less consistent with the dry matter production. There was conspicuous increase in total uptake at harvest, when compared to the uptake values at 60th day.

2. Content and uptake of phosphorus

The data on the content of phosphorus of the plants along with the total phosphorus uptake of the plants are presented in Table 19 and 20 and Fig. 13. The analysis of variance is given in Appendix 19.

Table 20. Effect of shade on nitrogen, phosphorus and potassium uptake of blackgram.

Shade intensity (per cent)	Nitrogen uptake (kg ha^{-1}) (days after sowing)		Phosphorus uptake (kg ha^{-1}) (days after sowing		Potassium uptake (kg ha^{-1}) (days after sowing)	
	60	Harvest	60	Harvest	60	Harvest
0 (no shade)	32.04	109.03	3.76	13.10	23.32	91.18
25 (low shade)	17.98	46.04	2.50	5.46	15.66	34.86
50 (medium shade)	13.27	30.42	1.94	4.08	9.39	26.32
75 (high shade)	7.54	23.27	1.03	3.09	5.14	17.09
SEm ±	5.03	9.80	0.63	1.05	3.55	6.80
C.D.(0.05)	15.49	30.21	1.84	3.25	10.93	20.97

Table 21. Nutrient status of soil after the crop of blackgram.

Shade intensity (per cent)	Nutrients		
	Total nitrogen (per cent)	Available phosphorus (ppm)	Available potassium (ppm)
0 (no shade)	0.10	3.59	162.00
25 (low shade)	0.11	5.39	160.00
50 (medium shade)	0.13	4.60	167.60
75 (high shade)	0.16	3.69	166.80
SEm ±	0.02	0.99	4.99
C.D.(0.05)	NS	NS	NS

NS = Not significant

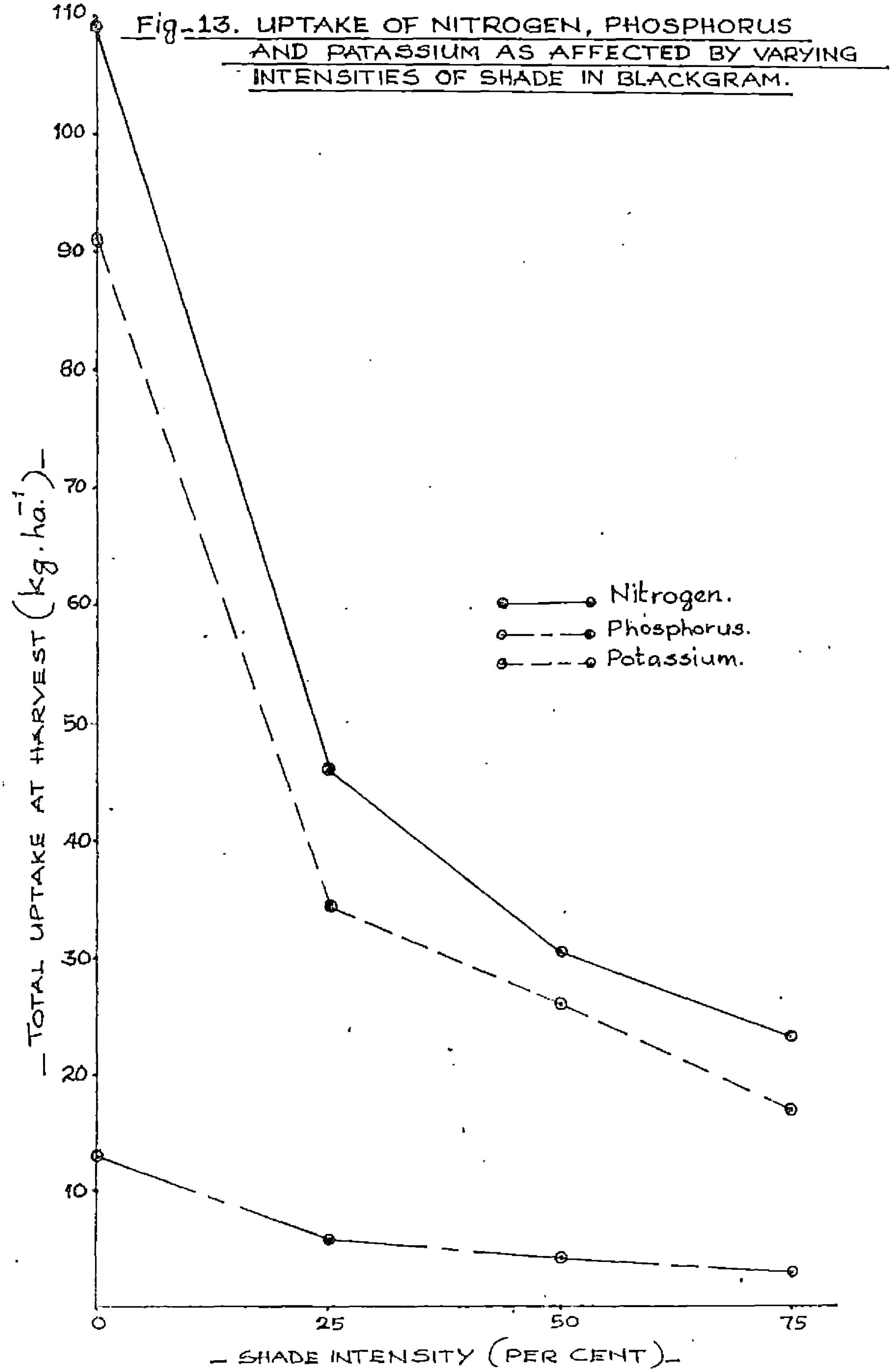


Fig-13. UPTAKE OF NITROGEN, PHOSPHORUS AND PATASSIUM AS AFFECTED BY VARYING INTENSITIES OF SHADE IN BLACKGRAM.

The phosphorus content of the plant, showed significant increase with increasing intensities of shade on 60th day, but at harvest shade failed to have any influence on the phosphorus content. On 30th day, the plots without shade had a phosphorus content of 0.25 per cent while that increased to 0.35 per cent, when the plots were shaded to 75 per cent. But uptake values were still highest for plots receiving full sunlight and it declined to a minimum value at 75 per cent shade.

3. Content and uptake of potassium

The data on the potassium content as well as total potassium uptake of the plants are presented in Table 19 and 20 and Fig. 13. The analysis of variance is given in Appendix 19.

The trends in potassium content and uptake were similar to that of phosphorus. On 60th day, shaded plants had significantly higher potassium content, when compared to the unshaded plants, but with increasing intensities of shade, the content was found to decrease. At harvest, no distinct trend could be made out and the values remained statistically on par.

Uptake at both the stages were higher for unshaded plants and it decreased with increasing shade levels.

II. Soil characters

Soil nutrient status

The data are presented in Table 21 and the analysis of variance is given in Appendix 20.

Soil nutrient status after cropping of blackgram did not differ significantly between varying shade levels. But when compared to the pre-experimental status, a marked improvement was noted in the content of all the nutrients.

DISCUSSION

The results of the present study indicated that blackgram is still another leguminous crop for which high light intensity is essential for realising its full yield potential. The grain yield was found to decline so drastically with shading that the yield at low, medium and high shade when expressed as percentages of the yield in the open were only 35.2, 26.0 and 10.5 respectively. From the response curve, it is seen that this crop is highly shade sensitive and so may not be suited for raising under partial or heavily shaded conditions.

In this crop, the yield response seems to be nearly identical to the dry matter production. This similarity in the trend along with the fact that the harvest index was not affected by shading points out that the photosynthetic mechanism was mainly responsible for the drastic decline in yield. An insight into the probable reasons for such differences in photosynthetic efficiency of the plants under varying intensities of shade can be had from the data on leaf area index and net assimilation rate (Table 14 and 15). The canopy was denser for the plants in the open during the early stage, but by 60th day, the shaded plants developed leaf area index on par with that of plants receiving full sunlight. Though the LAI still remained low, more intense mutual shading must have been there under shade as evidenced by the lower net assimilation rate of the shaded plants. The NAR was distinctly higher in the open, which indicated that the mean photosynthetic efficiency per unit of leaf area was higher for plants receiving full sunlight. This higher mean efficiency along with the higher LAI, especially during the early stage must have contributed to the significantly higher dry matter accumulation in the open. The dry matter production under low, medium and high shade levels were 45.4, 31.6 and 21.9 per cent of that under full illumination. Such a drastic decline in total dry matter production by shading at various levels is inconsistent with the trend of results on cowpea in this study and of the reported trend in similar shade-intolerant and sensitive crops like coleus and sweet potato (Lalitha Bai, 1981), which generally registered dry matter accumulation in proportion to the intensity of light. Such a trend, of course, is possible if the degree of mutual shading is severe under shade. However, the occurrence of such a high degree of mutual shading is not probable in this case, as the mean LAI were quite low (in the range of 1.03 to 2.40) and were well below the optimum reported for most of the crops. The only possible explanation could be that even at low leaf densities, there had been substantial effects of mutual leaf shading induced by the low branching of the crop under shaded conditions, leading thus to overlapping of leaves. It may also be recalled that observations on the branching of this crop indicated significant branching suppression under shade. It should also be noted that there was no special adaptation in blackgram in terms of specific leaf area. The leafiness as measured by the leaf weight ratio also was not influenced by shading.

Almost all the yield components were favoured by the receipt of full sunlight, which in turn was reflected in the final grain yield recorded. The number of pods per plant, number of seeds per pod and 100 seed weight were significantly higher in the open. The shelling percentage was also higher in plants receiving full sunlight. Also, the flowering and attainment of maturity were hastened by higher light intensities.

An evaluation of the effect of shade on growth components indicated that branching was significantly higher in the open, which is in line with some other reports (Gourley, 1920 in peaches; Beinhart, 1963 in white clover and Tarila et al., 1977 in cowpea). But plant height was unaffected by the varying levels of light. Nodulation in general was sparse which indicated that the native rhizobium was not much infective. The total number of nodules was not affected by shading but the effectiveness was definitely higher in the open which indicated that for better nitrogen fixation also, full sunlight was favourable. The reasons for this have been discussed already while dealing with cowpea.

The chlorophyll content of leaves (Table 13) was found significantly affected by shading. The total chlorophyll and its components were found to be increasing steadily with shading. Similar observations of increasing chlorophyll content because of shading have been reported in other crops like bean (Khossian, 1970), soybean (Koller and Dilley, 1974), cocoa (Okali and Owusu, 1975), weeping fig (Collard et al., 1977) and alfalfa and birdsfoot trefoil (Cooper and Qualls, 1967). The chlorophyll a:b ratio was found affected neither by shade levels nor by the advancing age.

Though the total dry matter accumulation was significantly higher in plots in the open, the expected dilution effect was not observed in the case of nitrogen content of plant tissue. This is attributable to the more effective nitrogen fixation under full sunlight. It may be noted that the number of effective nodules also was significantly higher in the open. The trend in the nutrient uptake however was similar to that of dry matter accumulation, as expected. The phosphorus content increased steadily with increasing intensities of shade and the maximum was recorded at 75 per cent shade. This is attributable to the above mentioned dilution effect. On the contrary, the uptake was higher for the plots in the open, which indicated that the greater dry matter production more than compensated for the decrease in the phosphorus content at higher light intensity. Potassium content followed a trend more or less similar to that of phosphorus, both in terms of content and uptake. The extent of decline in uptake of the nutrients by shading was found to be nearly the same as that of grain yield which indicated that the foraging ability and not the utilization efficiency of nutrients was affected adversely by shading.

The data on the soil nutrient status (Table 21) revealed that the nutrient content was not influenced significantly by shading. This must be because, the greater uptake under full sunlight was counterbalanced by the significant shedding of leaves and consequent addition of organic debris into the soil. The marked increase in the nitrogen status of the soil when compared to the pre-experimental nutrient content can also be attributed to this. The addition of fertilizers must have helped the soil to gain in the contents of phosphorus and potassium.

The general conclusions from the discussion can be summarised as follows:-

1. Based on the shade response, blackgram is to be classed as 'shade sensitive'. It is hence not suited for intercropping in coconut gardens.

2. The photosynthetic mechanism was mainly responsible for the variation in the yield under varying shade intensities.

3. Harvest index was not much affected by shading in blackgram.

Groundnut (<u>Arachis hypogaea</u> L.)

RESULTS

I. Plant characters

A. Biometric observations

1. Plant height

The data are presented in Table 22 and the analysis of variance is given in Appendix 21.

The plant height increased with increasing intensities of shade at all the stages, but the difference was statistically significant only during the first stage. It was also noted that the rate of increase in plant height was more or less steady between the stages.

2. Number of branches

The data are presented in Table 22 and the analysis of variance is given in Appendix 21.

Though the plants under all levels of light intensities had branches during the early stage itself, branching was significantly higher for the unshaded plants. The number of branches increased with advancing age irrespective of light intensities received. At all the stages, the number of branches was significantly higher in the open.

Table 22. Effect of shade on plant height, number of branches and nodulation in groundnut at different growth stages.

Shade intensity (per cent)	Plant height (cm) (days after sowing)			Number of branches plant^{-1} (days after sowing)			Total number of nodules plant^{-1} (days after sowing)		
	30	60	90	30	60	90	30	60	90
0 (no shade)	20.91	59.64	82.88	3.44	4.28	4.44	10.04 (3.27)	39.12 (6.28)	18.88 (4.19)
25 (low shade)	26.52	60.16	84.35	2.21	3.72	3.60	8.42 (3.03)	29.12 (5.63)	17.78 (4.05)
50 (medium shade)	28.88	63.84	88.04	1.94	2.96	3.72	7.84 (2.92)	30.36 (5.54)	19.45 (4.47)
75 (high shade	29.53	60.04	86.64	1.04	2.24	2.32	7.28 (2.27)	25.60 (5.14)	15.82 (4.08)
SEm ±	1.33	2.26	0.22	0.26	0.20	0.22	0.34	0.28	0.41
C.D.(0.05)	4.08	NS	NS	0.79	0.62	0.67	NS	NS	NS

NS = Not significant Figures in parenthesis indicate x+1 transformation

Table 23. Effect of shade on contents (mg g^{-1} fresh weight) of chlorophyll 'a', 'b', total chlorophyll and chlorophyll a:b ratio of groundnut leaves at different growth stages.

Shade intensity (per cent)	Chlorophyll 'a' (days after sowing)		Chlorophyll 'b' (days after sowing)		Total chlorophyll (days after sowing)		Chlorophyll a:b (days after sowing)	
	45	75	45	75	45	75	45	75
0 (no shade)	2.25	1.24	2.28	1.26	4.53	2.49	0.99	0.95
25 (low shade)	2.33	1.38	2.46	1.52	4.80	2.90	0.91	0.91
50 (medium shade)	2.49	1.51	2.61	1.61	5.10	3.12	0.95	0.96
75 (high shade)	2.50	1.51	2.65	1.63	5.16	3.14	0.94	0.93
SEm ±	0.05	0.07	0.07	0.05	0.09	0.10	0.03	0.03
C.D.(0.05)	0.14	0.21	0.21	0.14	0.29	0.31	NS	NS

NS = Not significant

Fig. 14. EFFECT OF SHADE ON TOTAL NODULE NUMBER IN GROUNDNUT AT DIFFERENT GROWTH STAGES.

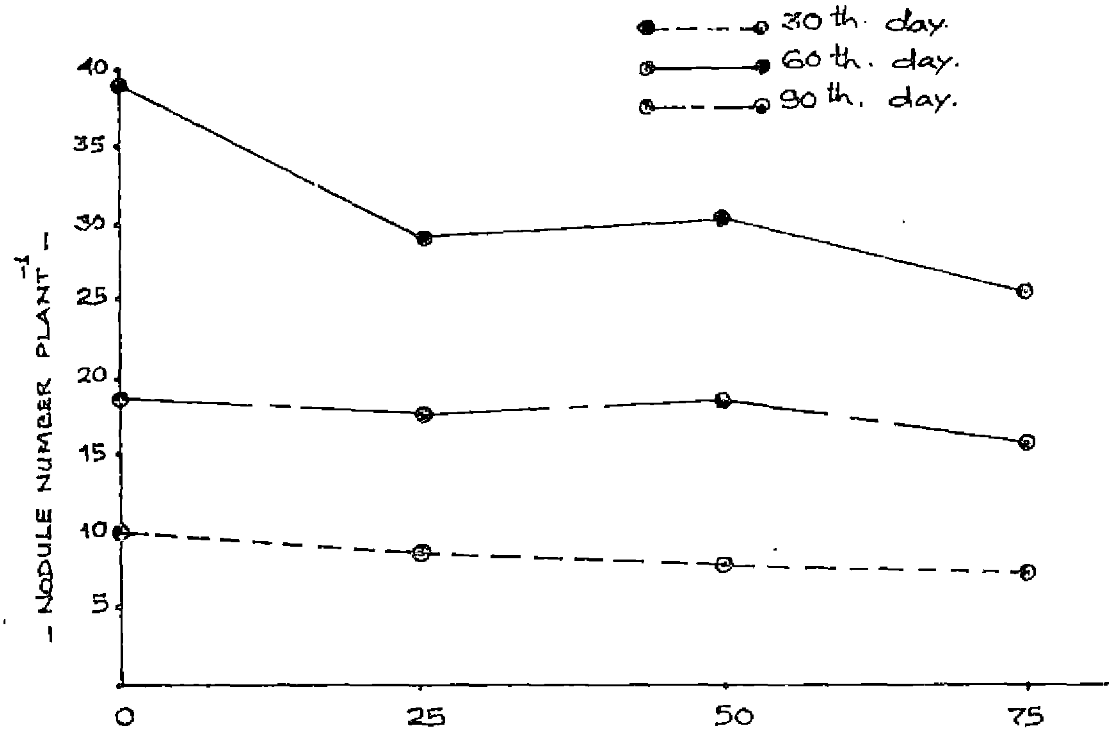
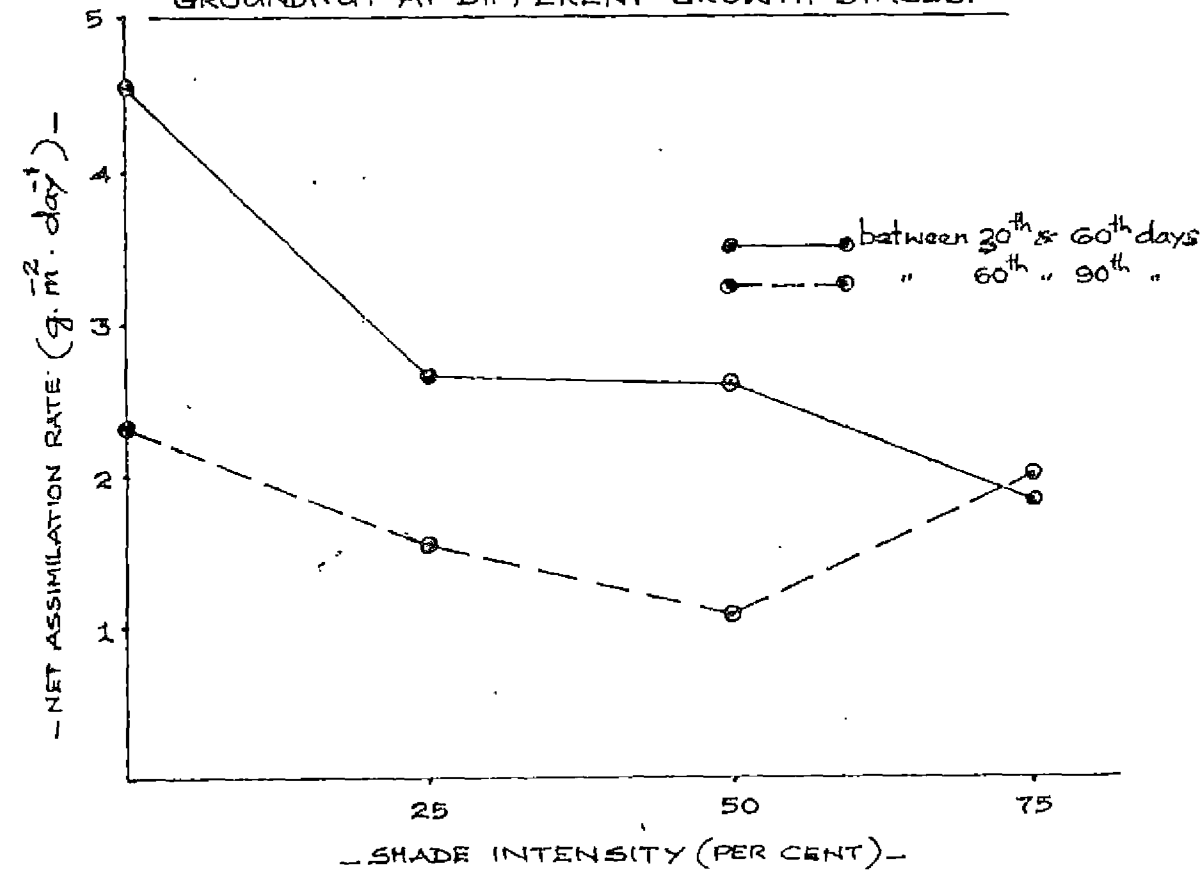


Fig. 15. EFFECT OF SHADE ON NET ASSIMILATION RATE OF GROUNDNUT AT DIFFERENT GROWTH STAGES.



3. Nodulation

The data are presented in Table 22 and Fig. 14. The analysis of variance is given in Appendix 21.

Total number of nodules was not affected significantly by varying intensities of light at any of the stages. Nodule number was maximum on 60th day and by 90th day, the nodule number decreased at all the shade levels. Data on effective nodules were not collected in this crop.

4. Chlorophyll content of leaves

The data are presented in Table 23 and the analysis of variance is given in Appendix 22.

Shading had significant effect on chlorophyll content of leaves both in terms of total chlorophyll as well as its components 'a' and 'b'. The total chlorophyll and its components increased with increasing shade intensities and the maximum value was noted when the plants were shaded to 75 per cent. It was also noted that towards maturity, the pigment content decreased conspicuously. Over the stages, the maximum value was recorded 45 days after sowing and on 75th day, the content was visibly lower at all the shade levels. The ratio of chlorophyll a:b remained nearly the same at all the shade levels, at all the growth stages.

5. Leaf area index (LAI)

The data are presented in Table 24 and the analysis of variance is given in Appendix 23.

The leaf area index was significantly higher for plants growing unshaded, on 60th day. At other stages, though the value was still higher for plants growing in the open, the differences were not statistically significant. There was a very conspicuous increase in LAI during the period between 30th and 60th days after sowing. Towards maturity, the LAI decreased substantially and this decrease was more perceptible for plants growing unshaded.

6. Specific leaf area (SLA)

The data are presented in Table 24 and the analysis of variance is given in Appendix 23.

Shading affected specific leaf area significantly at all the stages. SLA of plants increased with decreasing intensities of light, but between 50 per cent and 75 per cent shade the specific leaf area was more or less the same. With advancing age, the SLA increased though not significantly.

7. Leaf weight ratio (LWR)

The data are presented in Table 24 and the analysis of variance is given in Appendix 23.

Shading did not affect the leaf weight ratio at any of the stages.

8. Total plant dry weight

The data are presented in Table 25 and Fig.16. The analysis of variance is given in Appendix 24.

Table 24. Effect of shade on leaf area index, specific leaf area and leaf weight ratio of groundnut at different growth stages.

Shade intensity (per cent)	Leaf area index (days after sowing)			Specific leaf area (cm^2 g^{-1})		Leaf weight ratio	
	30	60	90	Between 30th and 60th days	Between 60th and 90th days	Between 30th and 60th days	Between 60th and 90th days
0 (no shade)	0.50	6.30	3.14	251.23	263.64	0.45	0.28
25 (low shade)	0.71	4.22	3.95	291.32	321.39	0.48	0.36
50 (medium shade)	0.43	3.22	2.02	344.21	364.84	0.44	0.33
75 (high shade)	0.50	2.31	2.01	346.51	368.43	0.44	0.33
SEm ±	0.17	0.45	0.52	13.79	12.92	0.02	0.02
C.D.(0.05)	NS	2.27	NS	42.50	39.82	NS	NS

NS = Not significant

Table 25. Effect of shade on total dry matter production, net assimilation rate, and absolute growth rate of groundnut at different growth stages.

Shade intensity (per cent)	Total dry weight (g $plant^{-1}$) (days after sowing)				Net assimilation rate (g m^{-2} day^{-1})		Absolute growth rate (g day^{-1} $plant^{-1}$)	
	30	60	90	Harvest	Between 30th and 60th days	Between 60th and 90th days	Between 30th and 60th days	Between 60th and 90th days
0 (no shade)	1.48	11.60	17.78	15.88	4.53	2.32	0.33	0.20
25 (low shade)	1.37	7.86	11.04	9.21	2.68	1.56	0.21	0.10
50 (medium shade)	0.88	4.94	5.69	7.52	2.64	1.10	6.10	0.05
75 (high shade)	1.30	3.11	5.52	6.14	1.88	2.00	0.06	0.12
SEm ±	0.28	0.97	1.06	0.85	0.36	0.58	0.08	0.09
C.D.(0.05)	NS	2.98	3.28	2.57	1.10	NS	0.11	0.12

NS = Not significant

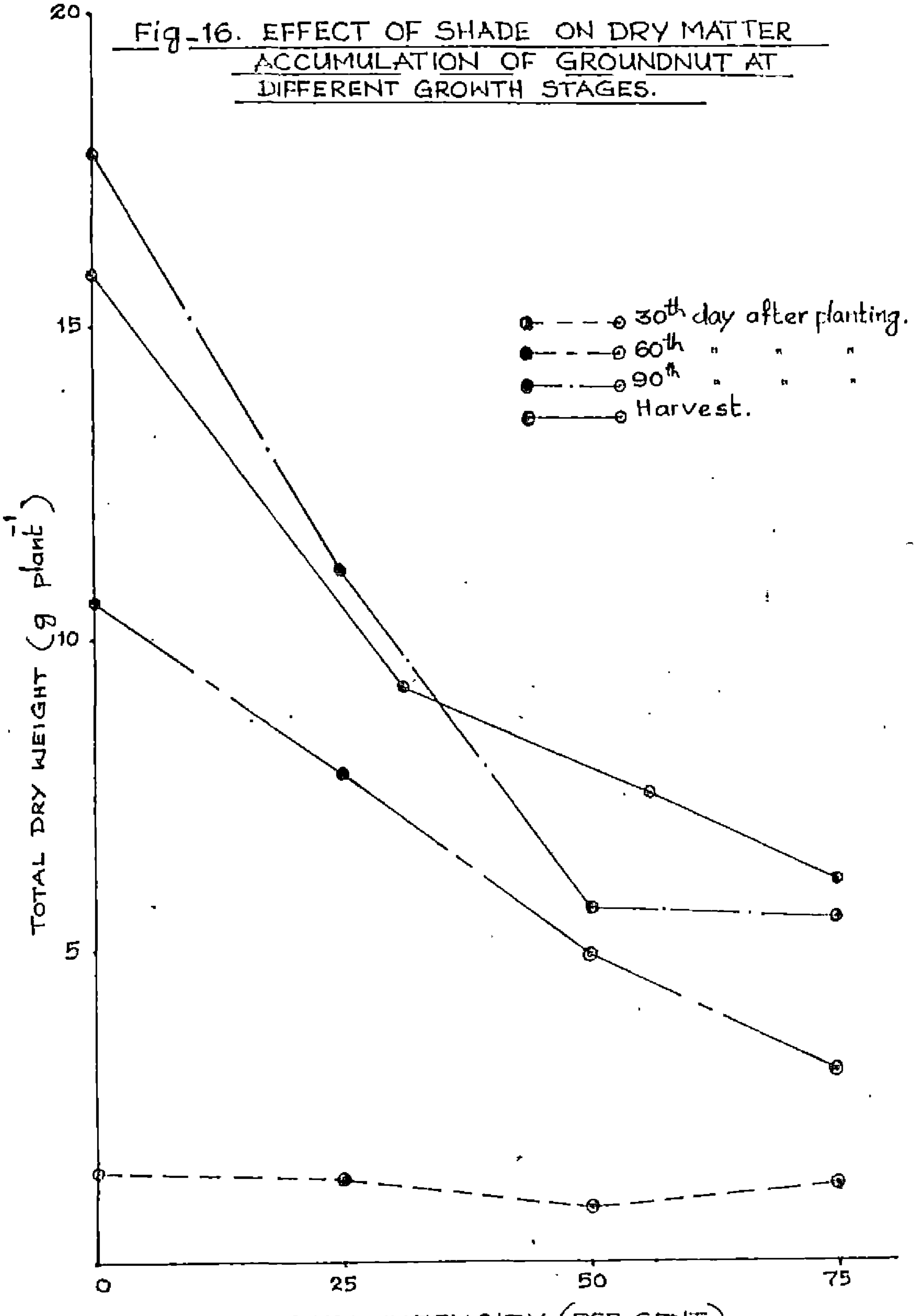


Fig-16. EFFECT OF SHADE ON DRY MATTER ACCUMULATION OF GROUNDNUT AT DIFFERENT GROWTH STAGES.

During the first 30 days after sowing the total dry weight of plants remained statistically on par. Later the gain in dry weight by plants grown in full sunlight was significantly higher and the maximum dry weight was recorded by the unshaded plants. The dry weight decreased progressively with increasing intensities of shade. At harvest, the plants in open and under low shade level had a slight decrease in total dry weight when compared to that on 90th day, but for plants under medium and high shade, the dry weight was maximum at harvest. At all the shade levels, the gain in dry weight was very conspicuous between 30th and 60th days after sowing.

9. Net assimilation rate (NAR)

The data are presented in Table 25 and Fig.15. The analysis of variance is given in Appendix 24.

Unshaded plots had significantly higher net assimilation rate between 30th and 60th days after sowing. At other stages the difference remained statistically on par. In plants under full sunlight and also under low, and medium shade levels, the maximum NAR was noted between 30th and 60th days after sowing, but with intense shading, the change in NAR was small.

10. Absolute growth rate (AGR)

The data are presented in Table 25 and the analysis

of variance is given in Appendix 24.

The absolute growth rate was significantly higher for plants grown under full sunlight and it decreased steadily with increasing shade levels. The AGR decreased with advancing age in plots getting upto 50 per cent shade, but under more intense shade, the value increased towards maturity.

B. Yield and yield components

1. Date of flowering

The data are presented in Table 26 and the analysis of variance is given in Appendix 25.

The data revealed that the flowering date was hastened with the receipt of full light intensity. The delay in flowering in shaded plots increased steadily with increasing intensities of shade.

2. Days to maturity

The data are presented in Table 26.

Groundnut, when shaded, required more time to reach maturity. The plants under 75 per cent shade could be harvested only after 11 days of harvesting of plants in the open.

3. Yield of pods

The data are presented in Table 26 and Fig. 17. The analysis of variance is given in Appendix 25.

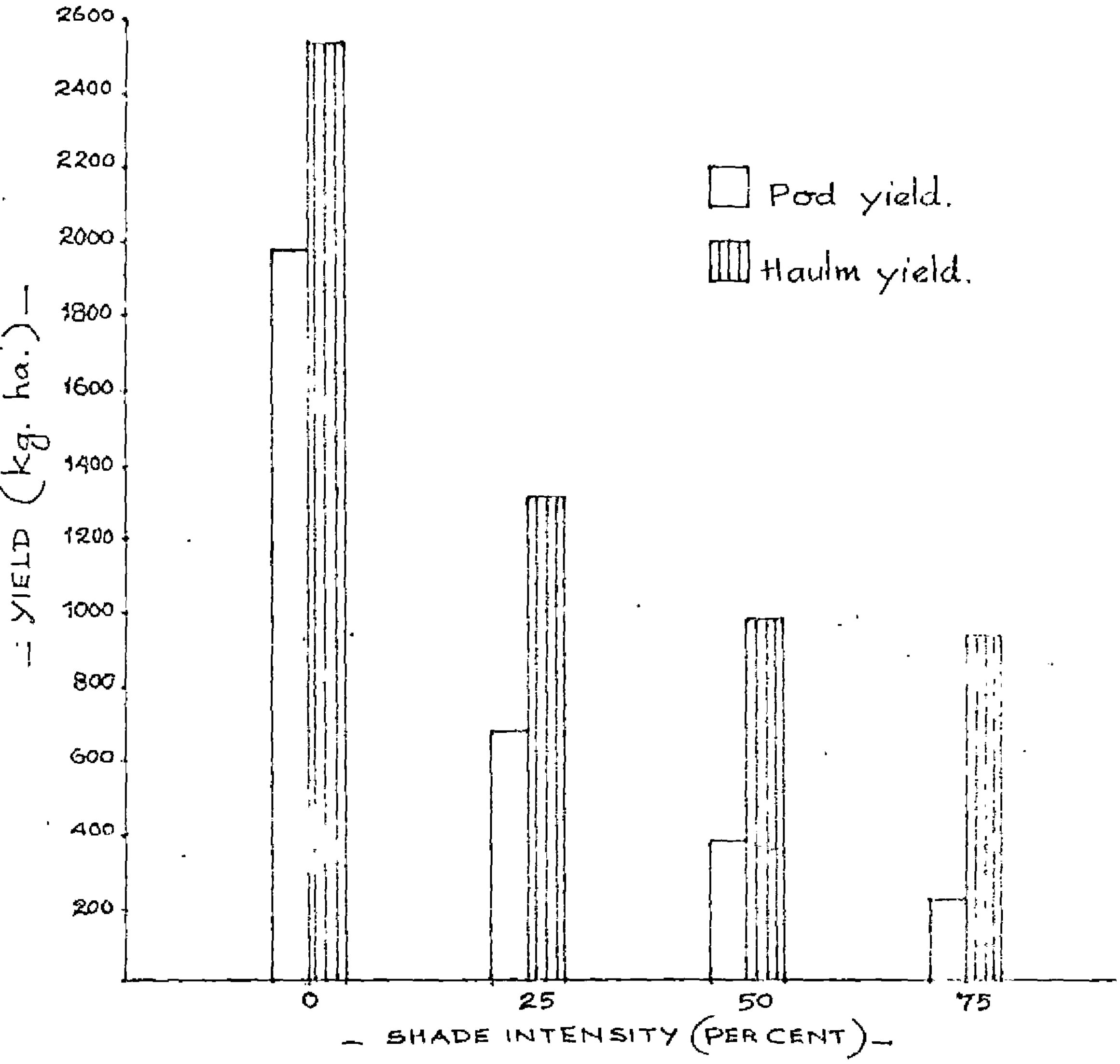
Table 26. Effect of shade on date of flowering, days to maturity, yield of grain, yield of haulm and harvest index of groundnut.

Shade intensity (per cent)	Date of flowering (days after sowing	Days to maturity (days after sowing)	Yield of pods (kg ha^{-1})	Yield of haulm (kg ha^{-1})	Harvest index
0 (no shade)	16	105	1980.44	2556.15	0.44
25 (low shade)	19	111	688.44	1314.56	0.34
50 (medium shade)	22	114	389.33	992.27	0.29
75 (high shade)	25	116	236.44	939.04	0.25
SEm ±	0.56		97.27	200.40	0.04
C.D.(0.05)	1.71		229.76	618.84	0.14

Table 27. Effect of shade on number of pods per plant, weight of pods per plant, number of seeds per pod, 100 seed weight and shelling percentage of groundnut at harvest.

Shade intensity (per cent)	Number of pods (plant^{-1})	Weight of pods (g plant^{-1})	Percentage of two seeded pods	100 seed weight (g)	Shelling percentage
0 (no shade)	14.62	4.46	87.84	31.30	66.60
25 (low shade)	6.64	1.55	63.80	27.67	43.85
50 (medium shade)	4.64	0.83	52.81	22.68	41.18
75 (high shhde)	3.44	0.53	43.21	15.47	34.14
SEm ±	0.74	0.22	7.30	0.74	33.83
C.D.(0.05)	2.28	0.67	22.51	2.26	11.79

Fig. 17. POD AND HAULM YIELD OF GROUNDNUT AS AFFECTED BY VARYING INTENSITIES OF SHADE.



The pod yield was significantly affected by shading. When expressed as percentage of yield in the open, the yields at 25, 50 and 75 per cent shade were 34.8, 19.7 and 11.9 per cent respectively.

Response curve

The yield data were transformed to logarithms using $\log_{10} Y$ transformation. A quadratic polynomial was found to give the best fit to the yield data (Fig.18 and the analysis of variance in Appendix 35). The equation of the curve is given below.

$$\text{Log}_{10} Y = 2.6989 - 0.1513x + 0.0151x^2$$

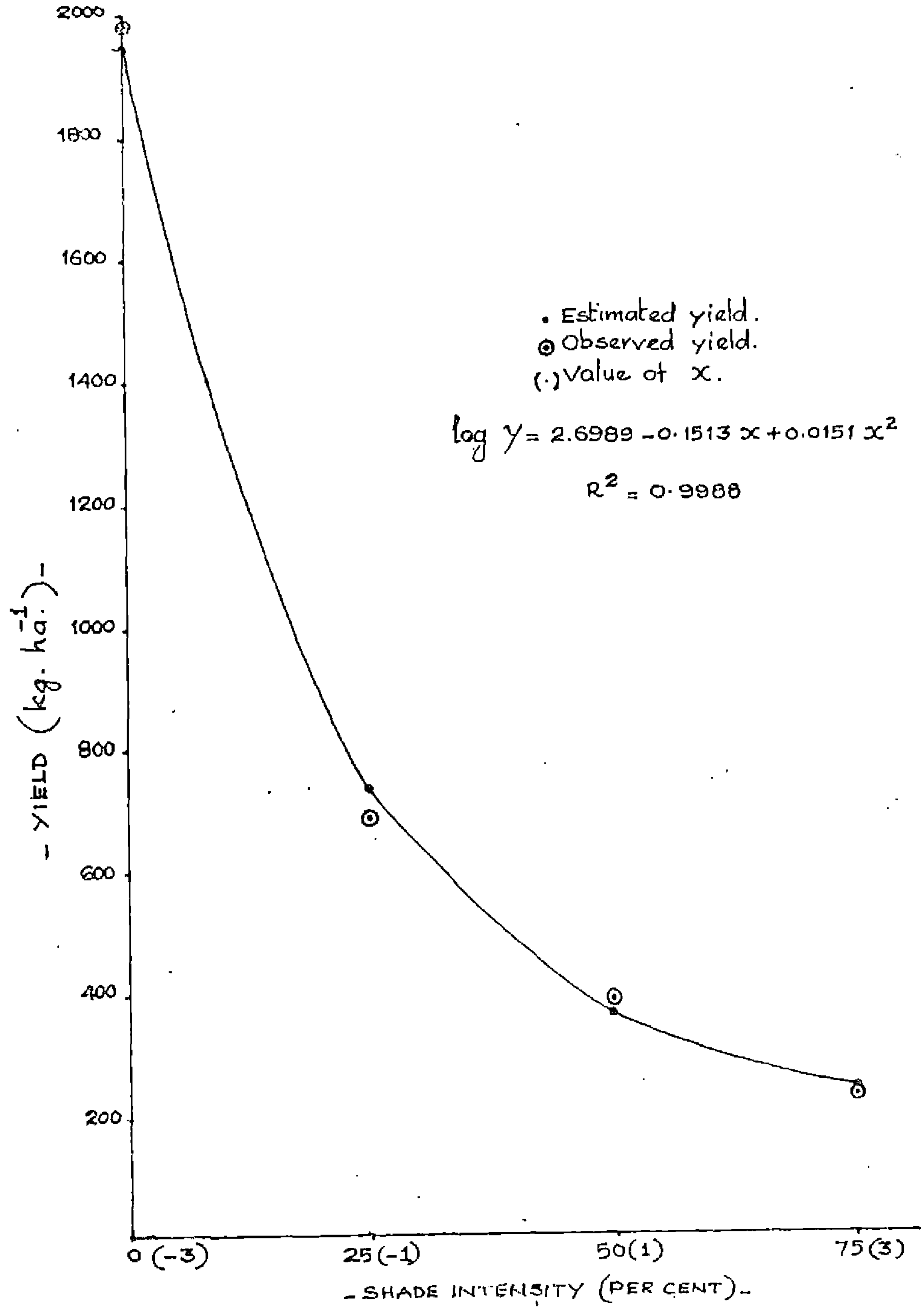
The coefficient of determination of the equation was 0.9988 which showed that 99.88 per cent of the variation in response can be explained by the fitted polynomial.

4. Yield of haulm

The data are presented in Table 26 and Fig. 17. The analysis of variance is given in Appendix

With the shading the haulm yield declined significantly but between different intensities of shade, the difference was not significant. The haulm yields at 25, 50 and 75 per cent shade were 51.4, 38.8 and 36.7 per cent of the haulm yield in the open.

Fig. 18. YIELD RESPONSE OF GROUNDNUT TO DIFFERENT INTENSITIES OF SHADE.



5. Harvest index (HI)

The data are presented in Table 26 and the analysis of variance is given in Appendix 25.

The harvest index of the crop was maximum for the unshaded plots. It went down with shading and was minimum for the plots receiving 25 per cent light.

6. Number of pods per plant

The data are presented in Table 27 and the analysis of variance is given in Appendix 26.

The number of pods per plant was significantly higher in unshaded plants and it decreased with increasing intensities of shade.

7. Weight of pods per plant

The data are presented in Table 27 and the analysis of variance is given in Appendix 26.

The trend in effect of shade on weight of pods per plant was similar to the trend in pod yield. The plants growing in open and the highly shaded plots had maximum and minimum weight of pods per plant respectively.

8. Percentage of two seeded pods

The data are presented in Table 27 and the analysis of variance is given in Appendix 26.

87.8 per cent of the pods produced under full sunlight were two seeded. It went down to 65.8 per cent by shading to 25 per cent, which was significantly lower than that in the open. Under medium and high shade, the values were as low as 52.8 and 43.2 per cent, respectively.

9. 100 seed weight

The data are presented in Table 27 and the analysis of variance is given in Appendix 26.

Pods developed under full sun light recorded significantly higher 100 seed weight. The 100 seed weight decreased steadily with increasing intensities of shade.

10. Shelling percentage

The data are presented in Table 27 and the analysis of variance is given in Appendix 26.

The shelling percentage under low shade was significantly lower than that under full sunlight. But between plants exposed to low, medium and high intensities of shade, the difference was not statistically significant.

C. Quality aspects

1. Protein content of kernals

The data are presented in Table 28 and the analysis of variance is given in Appendix 27.

The protein content of kernals remained more or less constant under different intensities of shade.

2. Protein yield

The data are presented in Table 28 and the analysis of variance is given in Appendix 27.

Table 28. Effect of shade on protein content of seeds, protein yield, percentage of well formed grain and oil content of groundnut.

Shade intensity (per cent)	Protein content (per cent)	Protein yield (kg ha^{-1})	Percentage of well formed seeds	Oil content (per cent)
0 (no shade)	26.25	228.72	86.80	44.68
25 (low shade)	25.15	62.81	66.00	46.86
50 (medium shade)	25.75	29.30	39.40	50.30
75 (high shade)	26.80	15.83	22.60	40.66
SEm ±	0.91	19.22	2.29	1.28
C.D.(0.05)	2.81	59.23	7.07	3.94

Table 29. Effect of shade on nitrogen, phosphorus and potassium content of groundnut.

Shade intensity (per cent)	Nitrogen content (per cent) (days after sowing)		Phosphorus content (per cent) (days after sowing)		Potassium content (per cent) (days after sowing)	
	90	Harvest	90	Harvest	90	Harvest
0 (no shade)	1.85	2.02	0.19	0.19	1.42	1.37
25 (low shade)	1.74	2.02	0.20	0.20	1.56	1.51
50 (medium shade)	1.68	2.08	0.20	0.20	1.65	1.61
75 (high shade)	2.13	2.23	0.20	0.20	1.68	1.61
SEm ±	0.22	0.21	0.004	0.02	0.04	0.04
C.D.(0.05)	NS	NS	NS	NS	0.13	0.11

NS = Not significant

Protein content of seeds being almost constant, the protein yield followed a trend identical with that of pod yield, under varying intensities of shade. The plots in the open produced significantly higher amount of protein when compared to that of shaded plots.

3. Percentage of well formed kernels

The data are presented in Table 28 and the analysis of variance is given in Appendix 27.

Pods developed under full sunlight had well formed kernels in them, and they registered the highest percentage of well formed seeds. The value decreased steadily with increasing intensities of shade.

4. Oil content of kernals

The data are presented in Table 28 and the analysis of variance is given in Appendix 27.

The oil content of groundnut seeds increased with increasing shade upto 50 per cent. More intense shading decreased the oil content. The maximum value of 50.3 per cent was recorded at 50 per cent shade.

D. Chemical studies

1. Content and uptake of nitrogen

The data on the content of nitrogen of the whole plant along with the total uptake of nitrogen by the plants are presented in Table 29 and 30 and Fig. 19. The analysis of variance is given in Appendices 28 and 29.

Nitrogen content and nutrient uptake values were studied 90 days after sowing as well as at harvest. The nitrogen content of the plant remained statistically on par. The content was higher at harvest when compared to that at 90 days after sowing.

The uptake of nitrogen was significantly higher for unshaded plants at both the stages and it decreased steadily with increasing intensities of shade. The uptake values did not differ much between stages for plants in open and those under low shade but for medium and heavily shaded plots, the uptake of nitrogen at harvest was perceptibly higher.

2. Content and uptake of phosphorus

The data on the content of phosphorus of the plants along with the total phosphorus uptake of the plants are presented in Table 29 and 30 and Fig. 19. The analysis of variance is given in Appendices 28 and 29.

The trend of phosphorus content and uptake under varying shade intensities was more or less identical to that of nitrogen. The uptake was maximum for unshaded plots and it decreased with increasing intensities of shade. Over stages, both the content and uptake values did not differ much.

3. Potassium content and uptake

The data on potassium content and uptake of plants

Table 30. Effect of shade on nitrogen, phosphorus and potassium uptake of groundnut.

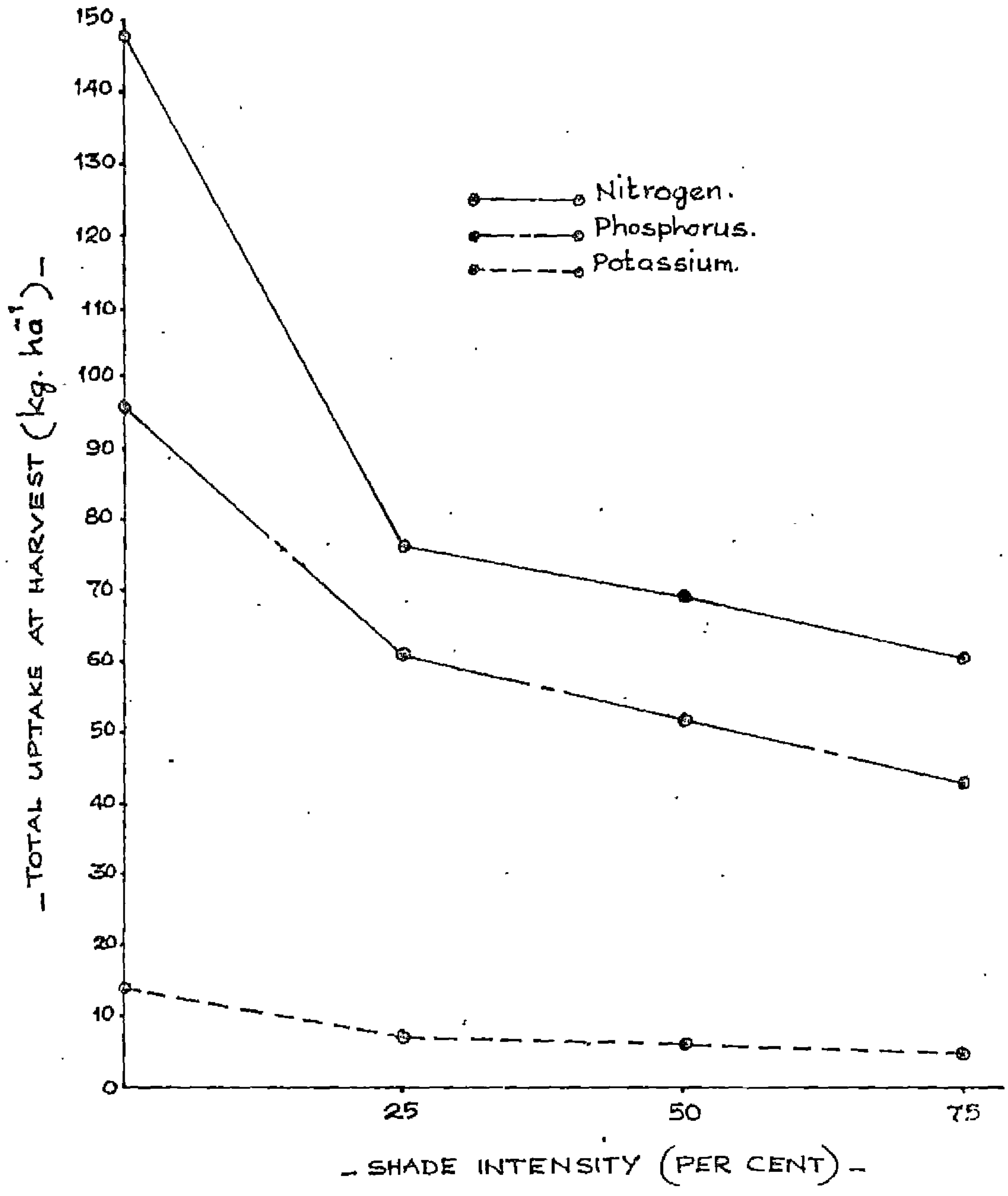
Shade intensity (per cent)	Nitrogen uptake ($kg\ ha^{-1}$) (days after sowing)		Phosphorus uptake ($kg\ ha^{-1}$) (days after sowing)		Potassium uptake ($kg\ ha^{-1}$) (days after sowing)	
	90	Harvest	90	Harvest	90	Harvest
0 (no shade)	134.97	148.33	14.52	13.69	18.82	96.83
25 (low shade)	90.74	76.10	10.24	7.48	78.33	61.55
50 (medium shade)	36.69	69.03	5.03	6.71	40.24	52.58
75 (high shade)	49.55	61.91	4.94	5.40	39.94	43.88
SEm ±	14.43	9.62	1.43	1.19	9.82	5.84
C.D.(0.05)	44.45	29.65	4.40	3.68	30.26	17.99

Table 31. Nutrient status of soil after the crop of groundnut.

Shade intensity (per cent)	Nutrient		
	Total nitrogen (per cent)	Available phosphorus (ppm)	Available potassium (ppm)
0 (no shade)	0.77	3.30	160.00
25 (low shade)	0.15	7.19	180.00
50 (medium shade)	0.14	5.19	163.60
75 (high shade)	0.11	4.95	157.60
SEm ±	1.76	0.74	7.30
C.D.(0.05)	NS	2.28	NS

NS = Not significant

Fig. 19. UPTAKE OF NITROGEN, PHOSPHORUS AND POTASSIUM AS AFFECTED BY VARYING INTENSITIES OF SHADE.



are presented in Table 29 and 30 and Fig. 19. The analysis of variance is given in Appendices 28 and 29.

The potassium content of both the stages studied was significantly higher for shaded plots and over the stages it did not differ conspicuously. The potassium content at harvest was 1.37 per cent in the open and the highest value of 1.6 per cent was recorded by plants receiving 75 per cent shade.

The uptake values were higher for unshaded plots and it decreased with increasing intensities of shade, but this decline was not as conspicuous as that of nitrogen and phosphorus.

II. Soil characters

Soil nutrient status

The data are presented in Table 31 and the analysis of variance is given in Appendix 30.

The total nitrogen content of soil did not show any significant variation between different shade levels, though it showed an increasing trend with increasing shade levels. But the available phosphorus was significantly higher at 25 per cent shade. The available potassium content also was highest at 25 per cent shade but the difference fell short of statistical significance.

Compared to pre-experimental nutrient status of the soil, all the nutrients studied, showed a marked increase after cropping with groundnut.

DISCUSSION

In the present study, groundnut registered a mean yield of 1980.4 kg ha^{-1} in the open. When calculated as percentage of the yield in the open, the mean yields at 25, 50 and 75 per cent shade levels were 34.8, 19.7 and 11.9 per cent respectively. This drastic decline in yield indicated that as in the case of cowpea and blackgram, in terms of pod yield, groundnut is also not suited for intercropping in coconut garden under partial or heavy shade. As evidenced by the response pattern, groundnut may be included in the class of shade sensitive crops which will not be generally suitable for intercropping.

In this crop, the dry matter accumulation under different shade levels was almost in proportion to the amount of light available to the plants on 60th day (Table 25). At the other stages, there were considerable leaf shedding which affected the observations on total dry matter production. Even with such loss in plant parts, the extent of decline in dry matter production at this stage was considerably less than the extent of yield decline. A decline in dry matter accumulation in proportion to the intensity of illumination is an expected trend as has been noted in the case of cowpea in the present study and in the case of coleus and sweet potato as reported earlier

(Lalitha Bai, 1981). The reasons for this have been discussed while dealing with cowpea. The fact that there had been much more drastic decline in yield by shading than dry matter production naturally points to the involvement of some sort of inhibition of translocation of synthesised materials to the economic part induced by shading. The data on harvest index will support this conclusion further. It may also be recalled that the same trend has been noted in the case of cowpea also in the present study and in sweet potato in the earlier study (Lalitha Bai, 1981).

The decline in dry matter yield with lower light intensities can be explained by studying the data on leaf area index (Table 24) and net assimilation rate (Table 25) wherein the trend was almost identical with that of cowpea. With the leaf area index well above 4.0, mutual shading would have been there even in the open. With increase in shade levels, mutual leaf shading and parasitism would have gone up substantially. However such excessive parasitism was counterbalanced to an extent by a steady and marked decrease in LAI with increasing shade levels (Table 24). But this could not completely take care of the decreased availability of light as evidenced by the simultaneous decrease in net assimilation rate. Similar observations were made in cowpea in the present study and in sweet potato (Lalitha Bai, 1981) in the earlier work. Another notable feature is the increase in specific leaf area. According to Cooper and Qualls (1967) this is an adaptation for exposing larger area to available light. However, this probable advantage may not be effective in crop canopies as it is a decrease in LAI that may be beneficial to avoid parasitism under shade. Among the factors responsible for bringing down LAI under shade, an important role probably was played by branching behaviour. The number of branches was considerably lowered by shading.

The role of translocation efficiency in deciding the final pod yield can be quantitatively estimated from the data on harvest index (Table 26). The harvest index ranged from a mean of 25.2 to 44.3 per cent at different shade levels. The maximum value of 44.3 per cent in the open declined steadily with increasing shade levels which indicated the influence of shade on partitioning of assimilates. The significance of this in contributing to the shade response of this crop had been discussed already.

As in the case of other legumes studied, the trend in yield components and growth components measured were nearly identical to the yield pattern. However, unlike in the case of cowpea, nodulation was unaffected by the levels of shade in terms of total nodule number. Flowering and attainment of maturity were delayed in this crop also as in the case of cowpea and blackgram.

The total chlorophyll content and its components 'a' and 'b' increased with increasing intensities of shade. Such an increase in chlorophyll content with shading was noted in many other crops also as cited in the discussion on shade response of blackgram.

The quality of the kernels in terms of protein content was not influenced by shade. Similar results had been obtained by Wahua and Miller (1978) in soybean. But the oil content increased with increasing intensities of shade upto 50 per cent and with more intense shading, the content decreased (Table 28). This is in agreement with the results of An (1982) in groundnut.

The trends in mineral nutrient content and the uptake by the plants were nearly identical with that of cowpea and so the possible reasons as discussed for that crop may be applicable for groundnut also.

In the case of nutrient content of soil, significant difference between shade levels was observed only in the case of available phosphorus. However, the trend was erratic and no valid conclusions could be drawn. The marked improvement in nutrient status after cropping of groundnut may be attributed to the addition of organic debris through leaf fall and the addition of nutrients through fertilizers.

The general conclusions from the discussion can be summarised as follows:-

1. Based on the shade response, groundnut may be grouped as a 'shade sensitive' crop and hence it is not suited for intercropping in coconut gardens.

2. The photosynthetic mechanism along with the translocation efficiency was responsible for the decrease in yield under shade.

3. Excessive leaf parasitism was counterbalanced to an extent by a steady and marked decrease in LAI with increasing shade levels.

Redgram (*Cajanus cajan* (L.) Millsp.)

As already indicated in Materials and Methods, for redgram, the data on shade response of early stages alone were recorded. So this part of the study may be treated as a trial to find out the effect of different intensities of shade on early vegetative growth and the Results and Discussion are given accordingly. The probable indications of the response pattern obtained are also discussed.

RESULTS

I. Plant characters

A. Biometric observations

1. Plant height

The data are presented in Table 32 and the analysis of variance is given in Appendix 31.

The height of plants was found significantly affected by shade at both the stages studied (30 days and 60 days after sowing). The height recorded was maximum for the plants receiving full illumination and it decreased steadily with increasing intensities of shade.

2. Number of branches

The data are presented in Table 32 and the analysis of variance is given in Appendix 31.

Table 32. Effect of shade on plant height, number of branches in redgram at early stages.

Shade intensity (per cent)	Plant height (cm) (days after planting)		Number of branches plant^{-1} (days after planting)	
	30	60	30	60
0 (no shade)	59.30	131.32	6.96 (2.818)	19.52 (4.53)
25 (low shade)	44.70	98.14	1.18 (1.414)	7.52 (2.85)
50 (medium shade)	32.48	71.48	0 (1)	1.60 (1.57)
75 (high shade)	32.20	61.15	0 (1)	0.48 (1.18)
SEm ±	2.23	5.26	0.11	0.17
C.D.(0.05)	6.88	16.21	0.34	0.55

Figures in parenthesis indicate x+1 transformation

Table 33. Effect on shade on contents (mg g^{-1} fresh weight) of chlorophyll 'a', 'b', total chlorophyll a:b ratio of redgram leaves at early growth stages.

Shade intensity (per cent)	Chlorophyll 'a' (days after sowing)		Chlorophyll 'b' (days after sowing)		Total chlorophyll (days after sowing)		Chlorophyll a:b (days after sowing)	
	45	75	45	75	45	75	45	75
0 (no shade)	1.54	1.34	1.64	1.25	2.82	2.59	0.98	1.06
25 (low shade)	1.69	1.48	1.80	1.37	2.96	2.83	0.94	1.05
50 (medium shade)	1.73	1.47	1.89	1.42	3.32	2.89	0.92	1.01
75 (high shade)	1.53	1.71	1.90	1.59	3.44	3.29	0.80	0.06
SEm ±	0.11	0.03	0.09	0.03	0.19	0.06	0.08	0.02
C.D.(0.05)	NS	0.13	NS	0.09	NS	0.19	NS	NS

NS = Not significant

The plants in the open had significantly higher number of branches when compared to the shaded plants. On 30th day, the fully illuminated plants had on an average 6.96 branches, while under low, medium and high shade levels, the number of branches was as low as 1.18, 0 and 0 respectively. With advancing age, the shaded plants also branched, but the trend in branching behaviour remained more or less identical.

3. Nodulation

In redgram, the native rhizobia were found non-infective, in the present study. Only a few plants in the open had nodules if any. None of the plants in the shade had any nodules, irrespective of the intensity of shade.

4. Chlorophyll content

The data are presented in Table 33 and the analysis of variance is given in Appendix 32.

The content of chlorophyll in terms of total chlorophyll as well as its components 'a' and 'b' increased with increasing intensities of shade. The difference was statistically significant only on 75th day when, the plants in the open low, medium and high shade levels had 2.59, 2.84, 2.89 and 3.29 mg g^{-1} fresh weight of leaves, of chlorophyll in them respectively. The ratio of chlorophyll a:b remained more or less the same under different shade levels, but the ratio increased with advancing age.

5. Leaf area index (LAI)

The data are presented in Table 34 and the analysis of variance is given in Appendix 33.

The data revealed, that the leaf area index was highly affected by shading. The leaf area index ranged from 0.16 to 1.16 on 30th day in the highly shaded and open plots respectively while on 60th day the range was 0.62 to 9.12. The leaf area index was maximum in open plots and it declined sharply with shading at all the stages. It was also noted that from 30th to 60th days after sowing, the increase in LAI was very conspicuous especially in the open.

6. Specific leaf area (SLA)

The data are presented in Table 34 and the analysis of variance is given in Appendix 33.

The specific leaf area was not influenced by shading in this crop.

7. Leaf weight ratio (LWR)

The data are presented in Table 3 and the analysis of variance is given in Appendix 33.

The data revealed that shading failed to influence leaf weight ratio significantly.

8. Total plant dry weight

The data are presented in Table 35 and the analysis

Table 34. Effect of shade on leaf area index, specific leaf area and leaf weight ratio of redgram at early growth stages.

Shade intensity (per cent)	Leaf area index (days after sowing)		Specific leaf area ($cm^2\ g^{-1}$)	Leaf weight ratio
	30	60	Between 30th and 60th days	Between 30th and 60th days
0 (no shade)	1.15	9.12	506.58	0.50
25 (low shade)	0.39	2.63	530.89	0.44
50 (medium shade)	0.26	1.98	518.71	0.50
75 (high shade)	0.16	0.62	548.40	0.48
SEm ±	0.09	0.69	38.98	0.03
C.D.(0.05)	0.29	2.13	NS	NS

NS = Not significant

Table 35. Effect of shade on total dry matter production, net assimilation rate and absolute growth rate of redgram.

Shade intensity (per cent)	Total dry weight ($g\ plant^{-1}$) (days after planting)		Net assimilation rate ($g\ m^{-2}\ day^{-1}$)	Absolute growth rate ($g\ day^{-1}\ plant^{-1}$)
	30	40	Between 30th and 60th days	Between 30th and 60th days
0 (no shade)	4.37	22.11	2.01	0.59
25 (low shade)	1.38	6.79	2.32	0.18
50 (medium shade)	0.71	4.22	2.28	0.11
75 (high shade)	0.32	2.24	2.44	0.06
SEm ±	0.29	2.35	0.37	0.10
C.D.(0.05)	2.88	7.19	NS	0.32

NS = Not significant

of variance is given in Appendix 34.

The dry matter production decreased significantly with decrease in intensity of light at both the stages. When expressed as percentage of the dry weight in open, that under low, medium and high shade levels were 30.7, 19.1 and 10.1 respectively on 60th day. At all the shade levels, the dry weight increased conspicuously from 30th day to 60th day after sowing.

9. Net assimilation rate (NAR)

The data are presented in Table 35 and the analysis of variance is given in Appendix 34.

The net assimilation rate was not affected by shading between 30th and 60th days after sowing.

10. Absolute growth rate (AGR)

The data are presented in Table 35 and the analysis of variance is given in Appendix 34.

Absolute growth rate was significantly higher for the unshaded plots and it decreased steadily with increasing intensities of shade.

DISCUSSION

In the present study, the effect of shading on the biometric growth components was very drastic indicating the possibility of redgram being highly shade sensitive. The general loss of vigour with low light availability was evident in all the growth components measured.

The plant height was highest in the open and it decreased steadily with decreasing levels of light. This is in confirmity with the results of Palis and Bustrillos (1976) in grain sorghum. The adverse effect of shading on branching was very drastic. This morphological feature must have had a very important role in deciding the leaf area index and canopy dispositions.

As discussed earlier in other three crops, if dry matter accumulation could be taken as an indication of the final yield, the conclusion that could be drawn is that in redgram, the yield realisable would be very low under shade. The mean value of dry matter accumulation under low, medium and high shade were only 30.7, 19.1 and 10.1 respectively of that in the open, which was less than proportionate to the amount of light available. The leaf area index was very high in the open, but the NAR was unaffected by the extent of light available. This shows that the plant had developed an adaptation to reduce the extent of mutual shading by bringing about a drastic decline in LAI, which was more or less effective in this crop. No adaptive mechanism in terms of SLA was noticed, and it may be concluded that the extent of mutual shading in low light intensities was substantially low.

As in the case of blackgram thus, growth of plant and canopy development appears to have been drastically inhibited by shading in the case of redgram also. The extent of depression of vegetative development of this crop was the highest among all the crops included in the present study and those studied earlier (Lalitha Bai, 1981). Though the final yield trend of the crop could not be studied in the trial, it appears that the yield decline would be substantial under shade even if synthesised materials are translocated in proportionate amounts to the economic part. It would thus make this crop unsuitable for cultivation under shade both as a grain crop and also a green manure.

Summary

SUMMARY

A field experiment was conducted at the College of Horticulture, Vellanikkara, during the period from May to October, 1981 to study the shade response of some leguminous crops, viz., cowpea, groundnut, blackgram and redgram. The results of the experiment are summarised below.

1. All the legumes tried, viz., cowpea, blackgram, groundnut and redgram were found shade sensitive. A quadratic polynomial fitted to the logarithm was found to give a close fit to the yield response of blackgram and groundnut. In cowpea, quadratic polynomial with no transformation was found to give a better fit to the response curve obtained. In all of them, the yield decreased drastically even with low shade of 25 per cent and with more intense shading, the decline continued progressively. The early vegetative growth of redgram also was found highly suppressed by shading.

2. In blackgram, the photosynthetic mechanism appears to have the dominant role in the shade response obtained. In cowpea and groundnut the partitioning and translocation of assimilates also were found to have a decisive role in deciding the final yield. In redgram, all the biometric characters measured including branching and LAI were highly suppressed under shade which was

reflected on the sharp decline in total dry matter production.

3. The declining effect of shade on photosynthesis and translocation were reflected in all the primary yield components. In all the crops, the number of pods per plant, number of seeds per pod, test weight and shelling percentage decreased significantly with increasing shade levels. The flowering and attainment of maturity in all the crops were delayed progressively with increasing intensities of shade.

4. Total dry matter production in all the crops studied went down with shading. In cowpea and groundnut, it was proportionate to the amount of light available, while for blackgram and redgram, it was less than proportionate to the quantum of light available.

5. Plant height in cowpea and blackgram was unaffected by the intensity of shade. For groundnut, plant height increased with increasing shade intensities, while the reverse was true for redgram.

6. Branching in all the crops wase adversely affected by shading. For redgram and blackgram, the branching suppression was more conspicuous.

7. In cowpea, nodulation both in terms of total number and number of effective nodules was higher in plots receiving full sunlight. For blackgram, the total number

was not affected by shading, while the effectiveness of nodules was significantly higher in the open. The total number of nodules was not influenced by shading in groundnut whereas in redgram there was practically no nodulation at all.

8. Total chlorophyll and its components 'a', 'b' were unaffected by shade in cowpea. But for all the other crops, it increased with increasing intensities of shade. The chlorophyll a:b ratio was not influenced by shading in any of the crops.

9. In general, the unshaded plants had denser canopy. But for cowpea, the difference in LAI was non-significant at all the stages. In blackgram on 30th day, it was significantly higher in the open , while in groundnut, significant difference was noted on 60th day. For redgram at all the stages studied, the plots in the open had higher LAI.

10. In cowpea and groundnut, specific leaf area was higher for shaded plots while for blackgram and redgram it was significantly higher in shaded plots between 60th and 75th days after sowing.

11. In all the crops except redgram, the NAR was significantly higher in unshaded plots. For redgram, it remained unaffected.

12. Of quality aspects, protein content was unaffected by the intensity of light received in all the crops, whereas the protein yield and percentage of well formed grains were significantly higher in the open. In groundnut, the oil content increased with shading upto 50 per cent and with more intense shading it came down.

13. The content of nitrogen in the plant tissue was not affected by shading in any of the crops. Phosphorus content was also unaffected except for in blackgram, where, on 60th day, phosphorus content was significantly higher in shaded plots. Potassium content showed a persistent increase with shading in all the crops.

14. The uptake of all the nutrients increased with increasing intensities of light in all the cases. It was also noted that the dry matter production had the dominant role in deciding the total uptake and that the higher dry weight of the unshaded plots more than compensated for the higher content of potassium in shaded plots.

15. There was marked improvement in the nutrient status of the soil after the cropping of all the legumes; when compared to the pre-experimental nutrient status. Content of nutrients in the soil was more or less unaffected by shading, except that in cowpea, available potassium content increased with increasing intensities of shade.

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Appendices

Appendix 1. Weather data (weekly average) for the period May 1981 to October 1981.

Month and date	Week No.	Temperature °C		Rainfall (mm)	Relative humidity (per cent)		Sunshine (No. of hours of bright sunshine)	Soil temperature °C (5 cm depth)	
		Maximum	Minimum		Fore-noon	After-noon		Fore-noon	After-noon
May 28 to June 3	22	29.53	23.00	33.14	92.07	87.63	1.70	24.41	29.21
4-10	23	29.32	22.83	37.14	94.21	93.00	1.44	22.86	29.29
11-17	24	27.36	22.54	55.86	94.86	86.25	2.26	23.39	28.23
18-24	25	28.26	22.09	39.61	95.17	85.36	1.26	22.68	28.40
25 to July 1	26	29.16	22.08	6.43	90.77	77.79	3.59	23.40	30.29
July 2 - 8	27	29.86	22.80	23.19	80.43	81.00	5.37	24.73	30.46
9-15	28	29.10	22.00	22.13	91.93	83.30	3.50	24.59	29.66
16-22	29	30.66	23.14	4.60	88.70	69.07	6.64	24.38	31.13
23 -29	30	28.00	22.70	21.43	95.07	86.75	6.46	23.60	27.29
30 to August 5	31	28.56	22.37	11.67	93.36	83.67	3.43	23.66	28.30
August 5-12	32	28.64	22.04	3.71	93.07	83.36	3.27	23.57	28.50
13-19	33	28.46	22.96	37.71	93.14	81.79	1.71	22.93	27.67
20-26	34	28.14	20.93	5.91	94.71	73.33	5.17	22.93	29.62
27 to Sept. 2	35	29.66	23.27	1.27	93.57	70.29	5.07	23.90	31.00
Sept. 3-9	36	30.24	23.23	13.33	92.57	70.14	7.00	27.05	32.68
10-16	37	28.64	22.53	17.09	93.64	83.50	3.79	23.54	28.98
17-23	38	27.90	22.90	39.83	94.29	87.67	1.69	25.03	28.52
24-30	39	30.24	23.01	4.83	92.57	71.43	7.00	23.14	30.29
October 1-7	40	30.87	22.83	1.57	89.71	73.29	6.97	24.37	32.61

Source: B Class Observatory, Vellanikkara, Trichur.

Appendix 3. Monthwar details of climatological parameters for 20 years from 1961 to 1980
(Average for 20 years taken together)

Month	Temperature		Humidity		Sunshine hours	Rainfall in mm*	No. of rainy days
	Maximum	Minimum	Forenoon	Afternoon			
January	31.90	21.32	78.20	44.04	8.45	10.6	3
February	34.37	21.97	77.33	38.61	8.33	275.0	24
March	35.67	23.47	85.61	45.41	8.21	3586.0	27
April	35.54	25.00	85.75	54.59	7.29	1257.0	112
May	33.21	24.78	89.07	64.37	5.20	4867.7	259
June	30.34	23.46	93.23	77.84	3.31	12646.8	524
July	28.58	22.95	94.69	82.24	2.02	17490.5	570
August	29.57	23.14	94.37	78.36	2.65	8803.5	476
September	30.15	23.47	92.68	71.71	4.32	4484.4	340
October	30.78	23.34	90.78	70.49	4.66	5247.5	331
November	31.02	22.89	84.57	63.97	6.36	2912.9	170
December	30.77	22.22	77.86	56.33	6.83	944.3	43

*Total rainfall received for 20 years

Source: Meteorological Station, Mannuthy

Appendix 4. Analysis of variance for the effect of shade on plant height, number of branches and nodulation in cowpea at different growth stages.

Source	df	Mean squares									
		Plant height (days after sowing)			Number of branches $plant^{-1}$ (days after sowing)			Total no. of nodules $plant^{-1}$ (days after sowing)		Number of effective nodules $plant^{-1}$ (days after sowing)	
		30	60	75	30	60	75	30	60	30	60
Block	4	3.1121	1629.56*	723.08*	0.0046	0.0889	0.2212	0.7878	0.4633	0.8423	0.0358
Treatment	3	0.7451	690.66	278.31	0.4431	0.2813**	0.5138**	3.5611	0.7064	3.5401**	0.1899
Error	12	0.2861	443.27	151.63	0.0046	0.0361	0.0548	0.2557	0.5037	0.2867	0.1149

*Significant at 5 per cent level **Significant at 1 per cent level

Appendix 5. Analysis of variance for the effect of shade on contents of chlorophyll 'a', 'b', total chlorophyll and chlorophyll a:b ratio of cowpea leaves at different growth stages.

Source	df	Mean squares							
		Chlorophyll 'a' (days after sowing)		Chlorophyll 'b' (days after sowing)		Total chlorophyll (days after sowing)		Chlorophyll a:b (days after sowing)	
Block	4	0.0109	0.0217	0.0239	0.0313	0.0459	0.0776	0.0244	0.0129
Treatment	3	0.0439	0.0548	0.0917	0.0849	0.2553	0.2622	0.0159	0.0081
Error	12	0.0396	0.0210	0.0402	0.0512	0.1302	0.1142	0.0131	0.0134

Appendix 6. Analysis of variance for the effects of shade on leaf area index, specific leaf area and leaf weight ratio of cowpea at different growth stages.

Source	df	Mean squares						
		Leaf area index (days after sowing)			Specific leaf area		Leaf weight ratio	
					Between 30th and 60th days	Between 60th and 75th days	Between 30th and 60th days	Between 60th and 75th days
Block	4	0.0332	3.8814	0.1416	3630.08	3987.14	0.0084	0.0065
Treatment	3	0.0982	2.7711	0.8532	54995.31**	40248.63**	0.0014*	0.0158**
Error	12	0.0304	2.0703	0.7167	2047.75	3511.95	0.0025	0.0024

*Significant at 5 per cent level　　**Significant at 1 per cent level

Appendix 7. Analysis of variance for the effect of shade on dry matter production, net assimilation rate and absolute growth rate of cowpea at different growth stages.

Source	df	Mean squares							
		Total dry weight (days after sowing)				Net assimilation rate		Absolute growth rate	
		30	60	75	Harvest	Between 30th and 60th days	Between 60th and 75th days	Between 30th and 60th days	Between 60th and 75th days
Block	4	0.1107*	31.83	11.26	25.37	2.87	5.64	0.1674	0.2526
Treatment	3	0.2804**	130.25**	156.46**	157.92**	9.63	5.98	0.6491**	0.4695*
Error	12	0.0312	14.42	17.56	12.23	2.62	4.63	0.0739	0.0899

*Significant at 5 per cent level　　**Significant at 1 per cent level

Appendix 8. Analysis of variance for the effect of shade on date of flowering, yield of grain, haulm yield and harvest index of cowpea.

Source	df	Mean squares			
		Date of flowering (days after sowing)	Yield of grain	Yield of haulm	Harvest index
Block	4	0.8751	68230.62	67945.58	0.0097
Treatment	3	181.6611**	1957653.02**	4642895.62**	0.0372**
Error	12	1.0417	29606.84	475339.99	0.0053

**Significant at 1 per cent level

Appendix 9. Analysis of variance for the effect of shade on number of pods per plant, weight of pods per plant, number of seeds per pod, 100 seed weight and shelling percentage of cowpea at harvest.

Source	df	Mean squares				
		Number of pods plant^{-1}	Weight of pods plant^{-1}	Number of seeds pods^{-1}	100 seed weight	Shelling percentage
Block	4	0.9160	2.0093	1.0029	0.5232	56.17
Treatment	3	40.0032**	70.5910**	6.3210*	8.1611**	124.41
Error	12	0.4562	1.2601	1.6010	0.8367	49.30

*Significant at 5 per cent level **Significant at 1 per cent level

Appendix 10. Analysis of variance for the effect of shade on protein content of seeds, protein turn over and percentage of well formed grain of cowpea at harvest.

Source	df	Mean squares: Protein content	Protein turn over	Percentage of well formed grain
Block	4	6.4724	5085.99*	57.07
Treatment	3	11.2744	104362.21**	793.41**
Error	12	11.5974	1488.19	127.77

*Significant at 5 per cent level **Significant at 1 per cent level

Appendix 11. Analysis of variance for the effect of shade on nitrogen, phosphorus and potassium content of cowpea.

Source	df	Mean squares: Nitrogen content (days after sowing)		Phosphorus content (days after sowing)		Potassium content (days after sowing)	
		75	Harvest	75	Harvest	75	Harvest
Block	4	0.1179	0.1290	0.0005	0.0013	0.0032	0.0032
Treatment	3	0.0380	0.0562	0.0008	0.0047	0.0909**	0.1300**
Error	12	0.2238	0.2405	0.0347	0.0014	0.0088	0.0171

**Significant at 1 per cent level

Appendix 12. Analysis of variance for the effect of shade on nitrogen, phosphorus and potassium uptake of cowpea.

Source	df	Mean squares					
		Nitrogen uptake (days after sowing)		Phosphorus uptake (days after sowing)		Potassium uptake (days after sowing)	
		75	Harvest	75	Harvest	75	Harvest
Block	4	209.18	237.37	6.24	7.99	182.16	357.04
Treatment	3	3282.96**	2752.56**	46.92**	46.72**	1855.81	1472.96**
Error	12	349.01	176.22	5.73	3.38	193.82	189.47

**Significant at 1 per cent level

Appendix 13. Analysis of variance for the nutrient status of soil after the crop of cowpea.

Source	df	Mean squares		
		Total nitrogen	Available phosphorus	Available potassium
Block	4	0.0024	2.6340	153.21
Treatment	3	0.0052	3.5525	335.73
Error	12	0.0015	3.0107	777.73

Appendix 14. Analysis of variance for the effect of shade on plant height, number of branches and nodulation in blackgram.

Source	df	Mean squares							
		Plant height (days after sowing)		Number of branches plant^{-1} (days after sowing)		Total number of nodules plant^{-1} (days after sowing)		Number of effective nodules plant^{-1} (days after sowing)	
		30	60	30	60	30	60	30	60
Block	4	3.1156	163.63	0.0049	0.1575	0.2310	0.1259	0.0728	0.2725
Treatment	3	7.4462	205.21	0.0661**	5.4133**	0.6207	0.1126	0.2830**	0.3335
Error	12	4.7407	93.72	0.0049	0.2567	0.2929	0.3887	0.0450	0.2685

**Significant at 1 per cent level

Appendix 15. Analysis of variance for the effect of shade on contents of chlorophyll 'a', 'b', total chlorophyll and chlorophyll a:b ratio of blackgram leaves at different growth stages.

Source	df	Meansquares							
		Chlorophyll 'a' (days after sowing)		Chlorophyll 'b' (days after sowing)		Total chlorophyll (days after sowing)		Chlorophyll a:b (days after sowing)	
		45	75	45	75	45	75	45	75
Block	4	0.0026	0.0088	0.0088	0.0364	0.0201	0.0239	0.0062	0.0163
Treatment	3	0.0885**	0.0965	0.1634**	0.2145**	0.4923**	0.5813*	0.0089	0.0132
Error	12	0.0036	0.0291	0.0105	0.0413	0.0228	0.1164	0.0052	0.0019

*Significant at 5 per cent level **Significant at 1 per cent level

Appendix 16. Analysis of variance for the effect of shade on leaf area index, specific leaf area, leaf weight ratio, total dry matter production, net assimilation rate and absolute growth rate of blackgram at different growth stages.

Source	df	Mean squares: Leaf area index 30	Leaf area index 60	Specific leaf area Between 30th and 60th days	Leaf weight ratio Between 30th and 60th days	Total plant dry weight (days after sowing) 30	Total plant dry weight 60	Total plant dry weight Harvest	Net assimilation rate Between 30th and 60th days	Absolute growth rate Between 30th and 60th days
Block	4	0.0041	0.3556	8821.58	0.0159	0.0185	1.0504	25.99	0.2173	0.0073
Treatment	3	0.0558*	1.6875	14768.54	0.1092	0.0096	27.2911**	251.75**	4.8903	0.1601**
Error	12	0.1157	0.9471	15032.21	0.0663	0.0083	4.5601	10.98	0.5340	0.0241

*Significant at 5 per cent level

**Significant at 1 per cent level

Appendix 17. Analysis of variance for the effect of shade on date of flowering, yield of grain, yield of haulm, harvest index, number of pods, weight of pods, number of seeds per pod, 100 seed weight and shelling percentage of blackgram at harvest.

Source	df	Mean squares								
		Date of flowering (days from sowing)	Grain yield	Haulm yield	Harvest index	No. of pods plant^{-1}	Weight of pods plant^{-1}	No. of seeds pod^{-1}	100 seed weight	Shelling percentage
Block	4	2.7511	78837.55	477402.70	0.0088	116.72	4.82	0.0790	0.0303	5.01
Treatment	3	75.0000	1656929.27**	1827066.21*	0.0197	1216.77**	85.02**	1.3857*	3.7030*	269.18*
Error	12	0.5833	124848.39	388676.25	0.0109	92.24	6.79	0.3445	0.0699	73.61

*Significant at 5 per cent level **Significant at 1 per cent level

Appendix 18. Analysis of variance for the effect of shade on protein content of seeds, protein turn over and percentage of well formed grain of blackgram.

Source	df	Mean squares		
		Protein content	Protein turn over	Percentage of well formed grain
Block	4	7.6162	3522.86	57.51
Treatment	3	5.2894	58915.51**	298.18
Error	12	8.0002	2994.05	163.61

**Significant at 1 per cent level

Appendix 19. Analysis of variance for the content and uptake of nitrogen, phosphorus and potassium in blackgram.

Source	df	Mean squares											
		Nitrogen content (days after sowing)		Phosphorus content (days after sowing)		Potassium content (days after sowing)		Nitrogen uptake (days after sowing)		Phosphorus uptake (days after sowing		Potassium uptake (days after sowing)	
Block	4	0.0407	0.0603	0.0020	0.0066	0.0204	0.1358	32.02	954.25	0.495	12.66	7.20	234.65
Treatment	3	0.1578	0.0657	0.0102**	0.0005	0.0336*	0.0765	547.54**	7633.37**	6.52**	103.58**	313.25**	55559.31**
Error	12	0.0557	0.0698	0.0008	0.0005	0.0067	0.1546	126.45	480.53	1.99	5.58	62.93	231.63

*Significant at 5 per cent level **Significant at 1 per cent level

Appendix 20. Analysis of variance for the nutrient status of the soil after the crop of blackgram.

Source	df	Mean squares		
		Total nitrogen	Available phosphorus	Available potassium
Block	4	0.0004	3.1279	58.80
Treatment	3	0.0034	3.6119	42.33
Error	12	0.0011	4.9300	124.66

Appendix 21. Analysis of variance for the effect of shade on plant height, number of branches and nodulation in groundnut at different growth stages.

		Mean squares								
		Plant height (days after sowing)			Number of branches $plant^{-1}$ (days after sowing)			Total number of nodules $plant^{-1}$ (days after sowing)		
Source	df	30	60	90	30	60	90	30	60	90
Block	4	7.4080	28.3411	11.6351	0.2325	0.1050	0.2031	0.3146	1.2337	2.8550*
Treatment	3	84.0686**	19.1914	10.9290	4.9065**	3.9600**	3.8881**	0.2185	1.1216	0.1823
Error	12	8.7812	25.4815	4.6112	0.3297	0.2051	0.2363	0.5680	0.3950	0.8225

*Significant at 5 per cent level **Significant at 1 per cent level

Appendix 22. Analysis of variance for the effect of shade on contents of chlorophyll 'a', 'b', total chlorophyll and chlorophyll a:b ratio of groundnut at different growth stages.

		Mean squares							
		Chlorophyll 'a' (days after sowing)		Chlorophyll 'b' (days after sowing)		Total chlorophyll (days after sowing)		Chlorophyll a:b (days after sowing)	
Source	df	45	75	45	75	45	75	45	75
Block	4	0.0047	0.0085	0.0183	0.0292	0.0286	0.0526	0.0440	0.0124
Treatment	3	0.0716**	0.0858*	0.1452**	0.1414**	0.4179**	0.4568**	0.0040	0.0046
Error	12	0.0107	0.0228	0.0226	0.0107	0.0432	0.0511	0.0044	0.0061

*Significant at 5 per cent level **Significant at 1 per cent level

Appendix 23. Analysis of variance for the effect of shade on leaf area index, specific leaf area and leaf weight ratio of groundnut at different growth stages.

Source	df	Mean squares: Leaf area index (days after sowing) 30	60	90	Specific leaf area: Between 30th and 60th days	Between 60th and 90th days	Leaf weight ratio: Between 30th and 60th days	Between 60th and 90th days
Block	4	0.0373	1.5656	3.4385	2717.68	870.96	0.0007	0.0109*
Treatment	3	0.0820	14.6594**	4.4522	10490.99**	11945.54**	0.0015	0.0065
Error	12	0.1468	1.0039	1.3612	951.08	834.99	0.0016	0.0027

*Significant at 5 per cent level **Significant at 1 per cent level

Appendix 24. Analysis of variance for the effect of shade on total dry matter production, net assimilation rate and absolute growth rate of groundnut at different growth stages.

Source	df	Mean squares: Total dry weight plant^{-1} (days after sowing) 30	60	90	Harvest	Net assimilation rate: Between 30th and 60th days	Between 60th and 90th days	Absolute growth rate: Between 30th and 60th days	Between 60th and 90th days
Block	4	0.1529	10.2899	6.0139	1.6445	1.9053	4.7562	0.0692	0.0153
Treatment	3	0.3589	74.7465**	167.0501**	93.1125**	6.3496**	2.8837	0.3780**	0.1004
Error	12	0.3822	4.6855	5.6529	3.4758	0.6450	1.6734	0.0326	0.0404

**Significant at 1 per cent level

Appendix 25. Analysis of variance for the effect of shade on date of flowering, yield of pods, yield of haulm and harvest index of groundnut at harvest.

Source	df	Mean squares			
		Date of flowering	Yield of pod	Yield of haulm	Harvest index
Block	4	3.3751	4951.03	399112.01	0.0079
Treatment	3	75.0511**	3149825.52**	2854315.98**	0.0349*
Error	12	1.5416	47310.18	201643.50	0.0100

*Significant at 5 per cent level **Significant at 1 per cent level

Appendix 26. Analysis of variance for the effect of shade on number of pods per plant, weight of pods per plant, percentage of two seeded pods, 100 seed weight and shelling percentage at harvest.

Source	df	Mean squares				
		Number of pods $plant^{-1}$	Weight of pods $plant^{-1}$	Percentage of two seeded pods	100 seed weight	Shelling percentage
Block	4	2.18	0.0250	10.05	0.4496	142.09
Treatment	3	64.78**	15.9476**	1844.66**	234.8110**	986.82**
Error	12	2.73	0.2394	22.33	2.7111	73.25

**Significant at 1 per cent level

Appendix 27. Analysis of variance for the effect of shade on protein content, protein turn over, percentage of well formed grain and oil content of groundnut.

Source	df	Mean squares			
		Protein content	Protein turn over	Percentage of well formed grain	Oil content
Block	4	4.0270	309.73	24.84	12.32
Treatment	3	2.7604	48905.67**	4031.01**	81.02**
Error	12	4.1785	1847.33	26.33	8.17

**Significant at 1 per cent level

Appendix 28. Analysis of variance for the effect of shade on nitrogen, phosphorus and potassium content of groundnut.

Source	df	Mean squares					
		Nitrogen content (days after sowing)		Phosphorus content (days after sowing)		Potassium content (days after sowing)	
		90	Harvest	90	Harvest	90	Harvest
Block	4	0.0034	0.3463	0.0002	0.0022	0.0133	0.0011
Treatment	3	0.1986	0.0535	0.0002	0.0001	0.0694**	0.0625**
Error	12	0.2354	0.2186	0.0001	0.0015	0.0089	0.0065

**Significant at 1 per cent level

Appendix 29. Analysis of variance for the effect of shade on nitrogen, phosphorus and potassium uptake of groundnut.

		Mean squares					
		Nitrogen uptake (days after sowing)		Phosphorus uptake (days after sowing)		Potassium uptake (days after sowing)	
Source	df	90	Harvest	90	Harvest	90	Harvest
Block	4	152.06	532.44	6.37	3.45	289.26	83.85
Treatment	3	9872.95**	8032.51**	106.54**	67.81**	3114.49**	2698.10**
Error	12	1040.57	462.86	10.19	7.11	482.17	170.42

**Significant at 1 per cent level

Appendix 30. Analysis of variance for the nutrient status of soil after the crop of groundnut.

		Mean squares		
Source	df	Total nitrogen	Available phosphorus	Available potassium
Block	4	0.0048	6.1589	197.84
Treatment	3	0.0031	12.7215*	510.61
Error	12	0.0043	2.7438	266.63

*Significant at 5 per cent level

Appendix 31. Analysis of variance for the effect of shade on plant height and number of branches in redgram at early stages.

		Mean squares			
		Plant height (days after sowing)		Number of branches plant^{-1} (days after sowing)	
Source	df	30	60	30	60
Block	4	55.60	211.61	0.0816	0.3213
Treatment	3	821.88*	4913.19**	3.7184**	11.0514**
Error	12	24.90	138.31	0.0601	0.1605

*Significant at 5 per cent level   **Significant at 1 per cent level

Appendix 32. Analysis of variance for the effect of shade on contents of chlorophyll 'a', 'b', total chlorophyll and chlorophyll a:b ratio of redgram leaves at early growth stages.

		Mean squares							
		Chlorophyll 'a' (days after sowing)		Chlorophyll 'b' (days after sowing)		Total chlorophyll (days after sowing)		Chlorophyll a:b (days after sowing)	
Source	df	45	75	45	75	45	75	45	75
Block	4	0.0146	0.0178	0.1206	0.0134*	1.8985**	0.7113*	0.0239	0.0017
Treatment	3	0.0541	0.1130**	0.0741	0.1030**	0.4870	0.4409**	0.0316	0.0025
Error	12	0.0582	0.0085	0.0414	0.0038	0.1802	0.0192	0.0299	0.0023

*Significant at 5 per cent level   **Significant at 1 per cent level

Appendix 33. Analysis of variance for the effect of shade on leaf area index, specific leaf area and leaf weight ratio of redgram at early growth stages.

Source	df	Mean squares: Leaf area index (days after sowing) 30	60	Specific leaf area Between 30th and 60th days	Leaf weight ratio Between 30th and 60th days
Block	4	0.1063	10.1940	4998.15	0.0071
Treatment	3	1.0221**	71.5897**	1592.92	0.0379
Error	12	0.0445	2.3802	7599.70	0.0043

*Significant at 5 per cent level **Significant at 1 per cent level

Appendix 34. Analysis of variance for the effect of shade on total dry matter production, net assimilation rate and absolute growth rate of redgram.

Source	df	Mean squares: Total dry weight (days after sowing) 30	60	Net assimilation rate Between 30th and 60th days	Absolute growth rate Between 30th and 60th days
Block	4	1.4669*	72.75	0.4678	0.1845
Treatment	3	16.8210	408.08*	0.1692	7.2031**
Error	12	0.4156	27.24	0.5118	0.0545

*Significant at 5 per cent level **Significant at 1 per cent level

Appendix 35. Analysis of variance for the yield response of different crops to varying intensities of shade.

Source	df	Mean squares		
		Cowpea (Y)	Blackgram ($\log_{10}Y$)	Groundnut ($\log_{10}Y$)
Total	3			
Regression	2	137830.16*	1183032.00**	1528618.40**
Error	12	35190.81	16691.66	3607.05

Y = Actual yield

* = Significant at 5 per cent level

** = Significant at 1 per cent level

PLATE 1

A general view of the experimental field

PLATE 2

Groundnut as affected by varying shade intensities

PLATE 3

Effect of shade on redgram in early growth stages

SHADE RESPONSE OF COMMON RAINFED INTERCROPS OF COCONUT PART II LEGUMES

BY

SANSAMMA GEORGE

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the
requirement for the Degree

Master of Science in Agriculture

Faculty of Agriculture
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1982

ABSTRACT

An experiment was conducted at the College of Horticulture, Vellanikkara, during the period from May to October 1981, to study the shade response of four common leguminous crops of Kerala.

The experiment was laid out in randomised block design with four levels of shade and five replications.

The study revealed that all the legumes tried, viz., cowpea, blackgram, groundnut and redgram, were all shade sensitive. In redgram, observations on the shade response of the crop, during the early vegetative growth alone were taken. These observations showed that the growth components were all highly suppressed under shade. In the other crops, pod yield was reduced by more than 50 per cent even by low shade of 25 per cent, and with more intense shading, the decline continued progressively. In blackgram and redgram, the photosynthetic mechanism appeared to be mainly responsible for deciding the final yield whereas in cowpea and groundnut the partitioning and translocation of assimilates also appeared to have a decisive role. All the yield components like number of pods per plant, number of seeds per pod and test weight were higher for the unshaded plants. For cowpea and blackgram, the plant height was unaffected by shading. In groundnut, the plant height

increased with increasing shade intensity while the reverse was the case with redgram. Branching in all the crops decreased significantly with increasing intensities of shade. The content of total chlorophyll increased with shading in blackgram, groundnut and redgram, while in cowpea, it was not influenced by shading. Flowering and time of maturity were hastened by the receipt of full sunlight in all the crops.

The contents of nitrogen and phosphorus in the plant tissues were unaffected by shading, whereas potassium showed a persistent increase with increasing shade. The pattern of nutrient uptake was more or less identical to that of dry matter accumulation. In all the cases, the nutrient status of the soil after the cropping of the legumes showed a marked improvement, when compared to the pre-experimental nutrient status.