# SHADE RESPONSE OF COMMON RAINFED INTERCROPS OF COCONUT 

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## THESIS

Submitted in partial fuifilment of the requirement for the degree

# ftiaster of $\mathfrak{S t i}$ iente in $\mathfrak{A g r i c u l t u r e ~}$ 

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## DEOLARATION


#### Abstract

I hereby declare that this thesis entitied the "Shade response of common rainfed interarope of coconut" is a bonafide rocord of rocearch work done by me during the course of ree日arch and the thesie has not previously formed the babis for the award of to me of any degree, diploma, associateahip, fallowship or other slailar title, of any other University or Society.


Vellanikicara,
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3rd October. 1981.

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CEATIPIOATE

Certified that this theele encitiod the "Shade reeponec of common rajnfed interorops of coconut" is a record of research work done independently by Kum. Lalitha Bai, E.f. undor my gaidance and auporViaion and that it ham not propiounly formed the babia for the aword of any degree, fellouship of besooiatebilp to her.

in. VIGMAHAM WAIR,
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## GEDTETCATE

We, the umaersyguea, monbert of the AAvigosy Comittse of Kum. Ialitha Eai, B.E., a condidate for the degree of Mester of Science in Agrioulture with major in Agronozy, agree that the thesie entitled the "Shade reaponse of comon rainfed intercrops of cooonnt" riay be eubraittea by Kua, Laistha Bai, F, K. in partial fuleinent oi the requirenent for the degree.


## AGKHOWLEIGEAEHTS

It gives me fmense ploanure to exprese ay deep senge of eratitude and indebtednegs to Dr.R.Vikraman Nass, Head of the Depertment of Agronomy, College of Hortioultiure, Vollentikkara, for hie constant encouragement, subtained interest, valuable guidance and constructive oritiohems during the entire coures of the researoh work and preparation of this nasuroript.

I wish to place on record mindebtadness to Dr. P.C. Sivaramen Heir, Diseotor of Research, Rerala Mgricuitural Dnivereity (former Asmociate Dean, College of Horticulture) for providing the necoseary facilities; for his keen intereat ond timely euggestions during the progress of this research worls.

I am also thankful to Dr.E.K. Gopalakrishnan, Aemociate Dean 1/o, College of Horticultare, Vellanikiksra for the helpa and facilities provided.

I gratefuliy acknowledgo Dr. E. Tajudain, Profescor of Agromomy, Regional Agricultural Research Station, Pilicode and DroA.I.Joate, Head of the Dopartment of Soil Science and Agricultural Chemistry, College of Hortioulture for their valuable auggostions, constant and unfailing helpe turoughout the course of thie investigation.

I all grateIul to Sri.P.V. Prabhmaran, Associate Professor (Agricultural Statistics), Colloge of Horticulturesfor hie valuable advice in the dealgn of the experimont and statistical procedures.

Sy thames are due to Sri.V.K. Gopinathen Unuithan, Agsigtant Profeasor (Agricultural statistics), College of Horticulture, for his aincere help in the etatiotical analysic of the atats.

The helpe rendored by Bri.R.K. Aghoican, Aesiotant Proiessor (Agronony), Sri. K. Eudhokara, Junior Aeaietant Professor (Agronomy) and gri. M. Abdul Salam, Absiotant Profesmor (Agronoay), College of Horticultire, in the preparation of bamuecript are graterulis acjonowledged.

I an thankful to Sri. A. Augustin, Agsistant Erofomer (KADP) ad Sri. 过thow Jacob, Junior Amelatent Professor (Agricultural Cncasistry), College of Horticulture, for their helps in cheaical analyeie.

I would like to take this opportunity to record ny sincere feelings of gratitude to all ay friende for their timely help et varioug stages of the investigation.

On a poraonal note, I an exateful to ay parente, hrothers and sistere, those love and offection had alway boen a source of inmpiration for me.

The award of Junior Fellowship by the Indian Council of Agricultural Researoh is gratefully achnowiedged.

INHITEA BAI, E.E.

## COHTENTS

2age
IHTRODUCTION ..... 1
REVIEN OF HITERATURE ..... 4
KATERTALS AMD METHODS ..... 28
BESULTS AND DISCUBSION ..... 39
Sweet potato ..... 40
Colour ..... 63
Colocania ..... 87
Turnoriso ..... 113
Ginger ..... 136
SUIMARY ..... 158
REFEREACES
APPENDIOES

## IIST' OF IULUSMATIONS

1. Lay out plan
2. Effect of chade on airy mattor acoumalation of sweet potato at different stages of growth
3. Tuber and heulm yield of eweet potato an affected by varying intensities of chace
4. Tield response of aweet potato to difforent intecmition of shade
5. Uptake of aitrogen, phosphorus and potasoium as affected by varying intensitioe of enade in eweet potato
6. Sfiect of enade on totel any matter production of - coleus at different stages of plant growth
7. Yield of coleus ab effected by varying shade intensitien
B. Yield response of coleus to varying intensitien of shade
8. Optake of nitzogen, phosphorus and potasaium as arfeoted by varying shade intensities in coleus
9. Effect of ehade on total ing matter production of oolocasia nt differont grouth atages

## 11. Tield of oolocania as affeoted by varying shade intenoitieg

12. Field response of colocasia to varying shade levels
13. Upiake of nitrogen, phonghorus and potangium as affected by dipferent ahade interaities in colocasia
14. Esfect of shade on total dey mattor production of
turmeric at harveat
15. Field of tumieric an affeoted by varying ahade
intensities
16. Field response of turmeric to different lovels of ahnde
17. Uptake of nitrogen, phonphorus and potaselum as affeoted by varying shade intenaitien in turueric
18. Effect of shade on ary matter production of einger at dirferent otages of growth.
19. Field of ginger as affeoted by varying ahade intensitiee
20. Tield reaponge of Einger to different ghade intemoitioe
21. Total uptake of nitrogen, phosphorus and poteasium as affeoted by different ehade intenoitioc in ginger.

## INTRODUCTION

## 2ETHODUOTION

Hesearah on muitiple cropping in coconut gardon was taken up only aince 1970, though the practice of cultivating aropa in the interapaces of ooconut had been a comon practice in Kerala. Eariy studies conducted neinly at the Central Plentation Orope Research Institute, Rasaragode, have indicated that there is enough scope for inteneifying cropping in coconut gardens eapecially as the coconut roots actively exploit only about 20 per cent of the lend area. However, tuccess of this mat of inter and mixed oropping hed been highly variable. It has been discermed that auch differencee in the auccena of erop conbination arise mainly out of differences in the cozpetition between crops for the three basic inputs of production $\sigma$ is. ilght, weter and nutrients. The conpetition for these feotors is reflected both in terme of a deorease in gield of the main crog becsuse of competition for water and nutriont and eleo in terme of poor performance of sesocieted crop mainly aue to competition for ligit.

Prelsminary studies comducted at the Central Piantation Crope Roacarch Inetitute have Indicated that the amount of light that filters tinrough tine coconut onnopy
io meriediy affeotod by the age of coooant pajm. It has boen estimated that the light infiltration can rango from en low ag 10 par cent to as auch ae 70 por cent depending upon age or the pain in a space - planted cocomut plantation. Based on this indication, the eeneral peconmendation asd beon that multiple cropping in coconut garden osn be taken up before the 10 th gear ond after 20 th year of planting. Even so, the 1iluminetion intencity in the interspace of coconut atill showe wide variations from about 20 to 70 per cent. With the idea of getting reasonable and profitaible returns from the associated arop, the general recommondetion again can bo to grow shado-loving and shede-tolerant plents in ottuations of higher ahade intensity. It was in this context of selecting orops that woild be autioble for interarogping in varioue shade estuntions that the present study we taken up. Though such stuatee on the mhade response of some crope have been reported, no work on these 3 lnes has bem done in tropical aropa that could be cultivated along with coconut.

The pramary objeotives of the prosent study were:
i) To study the gield response of comion rainfed interorope of coconut undor varying intengities of ehade.
ii) To seleot crops suitable for different intenelites of ehade and to predict their giolds under varying chade eituations.
iii) To categorite crope as shade-loving, Ehade-tolarant, shade-Intolerast and shade-sengitive.
iv) To etudy the ratrient removal of oropa under shade so that it could be used as a tool for tentatively arriving at fertilizer sonedules for these orope under ohade.

## REVIEN OF HITBRAMURE

Regearch work on the responge of orop: to varying intonsitien of ghade is relatively scanty especially in the case of tropical orops that are comonly cultiveted as interoropa of perennial crops. The iiterature avaiLable on this aspeot on the comon egricuituraliy inportant crops io reviewed in thio chapter. The ghade levela tried in each of theas experiments apparently had been highly variable and theoc had not been mentioned in many of the reporte. tharever the ahade levele are mentioned, thege are inoluded in ino review. Whero thege are not avaiJable, the overall efreots of shade (irrespective of itn Intensity) are ong presented.

The review io given olaseifying the offect of made on the following characters with a brief sumary of the genaral trend of reported reaulte under each.

1. Plant height

The reported reaults ind loate that the zesponge to sinade on plent hejgit may be pooitive as in toluncco, ginger and cowpen or negative as in grain sorghum or pogiṭive, negative or neutrel ae in tomato.

Pandkar ot QI. (1969) noticed that in tobreco plont helgit inoreased by 35.2 per cont under ehade as compared to unghaded plants. Aclan and Quisumbing (1976) observed that in the caøe of ginger, plants grown under the full oumzigat were ohorter then thoge in the onade. Tarila at al. (1977) reported that in cowpea. higher light intensity reduced glant height.

The helght of grain eorghun planta wes found to decreage with increasing levels of made from 0 to 50 por corit (Palis and Bugtrillon; 1976).

Cooper (1969) obsorved in the case of tomato that shadins oither decreased or had no effoct on mean eten extonsion rato. It wan also noticed that 好e offect of erade on plent heigit was eithar positive, negative or neutral depending on the time of year and age of tine plant.
2. Nusber of laranchos

The responge to ahade on nugber or aranones produced per plant io negative as reported in peaches, clover, coupea and many other plants.

Dugege (1903) elucidated that plazts under shaded conaitions exhibited reauced number of branchee. Dnder
shade, the peach plants produced oniy leseer number of branches whioh were willowg and shender (Gourley, 1920). Eesnhart (1963) concluded that increased inght intenaity resulted in increased brenching in white clover. Tarile ot al. (1977) reported that in cowpea, higher iight intengity increased brancing of the plante.
3. Hodulation in loguaes

Bffect of shade on nodulation in leguree 20. generaliy adverbe. However, Increases in nodulation consequent to increased illumination had been reported to adversely affeot nodule acifity and gize.

Light intengity had been shown to affect erowth, nodulation and gyabiotic introgen firation in legumen (Gibson, 1971; Bethlenfalvay and Pillilpe, 1977; Wahua and biller, 1976) and this war related to the photompthate gupply to zodules (Allison, 1935 Wilson, 1935; Hardy and Havelka, 1975 and Latinore et al., 1977). Nodulation of alfalfa had been observed essentially to stop at ilsat intensitios of less thon 257 foot candlen (Rritchett and Helson, 1951). Rabie and Kumezawa (1979) reported that in soyreano, size and number of nodules decreaged by shading. However, in natural light, the highest valuos of zodule biae corresponded to lower nodule
nuabere. Refeot of shade on sogbean was studied by Treng and Gidanc (1980) at four shade intengitiea ( $0,18,40$ and 62 per cont) and they reported that the plants with no shado produced ingrier nodule mase and namber than those under shade. However, total nodule activity (acetylene reduction asasg) was grentest at 18 ger cent eheding. Hong and iflison (1930) observed reduced nodulation of Macroptilium atropuppuredin cr. Sivatro under chade.

## 4. Leal dovolopnent

The reported results on the response to shede on leaf development géneraily indicatod increaced leaf expangion and dacrecsed leaf thicknees with mading. In the case of total leas area, there wore decreases in sone plants whereas in apple and tonato, there were increases hecause of shading. The results on vegetative growth were variable, it generally deareabing with shading. In the case of tomato, the repozts indicate onhanoed vegetative grouth vecanee of enadiag.

Rolis (1903) reported that citrus planta which were Erown under 50 per cent phade devoloped thinner leaver with a greater leaf area; however, the total leaf arca per plant was lessa In many horticultural plants, Clark (1905) observed that for leaf develonment, low light intensity was most favourable and intense light cauced deoreased lenf
growth reaultine in grallor and thicker leavas. Gourley (1920) reported that in apples, shading regultad in the production of loosely pacted meeophyll tiesues and thinner opidersal cells in leaves ana in inoreased leas area. Increased leaf area consequent to ohading had aleo been reported by Porter (1937) in tomato plents. Hardy (1953) studied the nature of leaves of cocoa seedilinge unảer varying intenaities of ehade and observed that leaves produced under heavg shade wore much larger, often attained a length of 20 to 24 inches and wore thimer, heavier and contained higher proporition of water. In general, the leaves of ghaded plants were thinner ghowine poor development of palisade tiesue anc spougy-memophyll cell (Boardmen, 1977).

Titrua plante grown undor 50 per cent ahade develoged considerably leas total leaf area per plant (Rolfs, 1903). Beinhart (1963) reported that Increased iigat intensity reaulted in greater deaf area in clover though tinc mean number of leavee produced per plant rearined non-algnificant. Panikat et al. (1969) observed that in tobacco, length and breadtin of leaves were inoreased by 15.1 end 17.6 per cent, respeotively, under mada as compared to unahaded plantr. From the brial on the offecte of shade on the grouth and photogyntibtic capacity of the
exotio moxious weed itchgrass (Rothoollia exaltats I.f.) Pattergon (1979) stated that leaf area production was not severely retarded by shedingi the plante grown at 2,25 and 60 per cent gunlight had respectively, 1.7, 42 and 99 per cent of the leaf area or the plants grown at 100 per cent gunlight. In another experisont with three ecotypes of cogon grase (Imperata oylincrica) grown under three light intenaities, viz., 100, 56 and 11 per cent of full sunlight, Ratterson (1980) reported that after 89 days, the planto of all the ecotypes produced, on an average, three times as muah leaf area in full sunlight an in 58 par cont full ligint and 20 tines as auch as in 11 per cent full light. In a 30-year,: old Trinitario cocoa pientetion, Eoger (1970) obeerved that the flusijing intenelty, lenf number and tatal foliar aurfece per tree were greater in unsiaded tree日 than those under light or moderate biade. Fiarila et al. (1977) reported that in coupea, higier light Sntensity improved leas area and plemt sizé. Hadha (1979) observed that number of leaves in pineapple weo not influoncea by thading.

Porter (1937) istudied the effact of three ligat intensitios viz. 1139.9, 533.1 and 261 foot candes on the photogynthotic afficiency of tomsto planit and observed that uitiz decrease in light intemaity, there wae increaged
vegetative grouth an meabured by both freeh and dry woight.
5. Chlorophyll contento

Most of the roported ovidences show that the concontration of chlorophyll por unlt weight of loaf increasen with ehading as reporied in the caee of plante like cocoe, tea, strawbery, been, alfalsa, birdsioot trefoil, eto. Sut the chloroplabt conteat ger unit lear aurface hae been found to decrease with shading as in alfalfa, biropioot trefoil and in eono other plante. In crops like compea, wheat atc., increasing mhade intensitise have becn. Found to decroase the chlorophyll content per unit leaf weigit. Changee in the pooition of chloroplast according to tho differonces in light intensity have also been mangrted.
clart (1905) obeerved tiat in the case of striwberry, alrect suilight of high intensity resultod in the destruction of chlorophyil. Increased chlorophyl2 cantent woo noticed in the leaves of gheded cocon planto (Evans and Surrey; 1953; Guers, 1971). Sinllar obsorvaiions were made by Ramarweal (1960) and Venkatamani (1961) in tian case oí tea. Knossien (1970) noticod reduction in tho loof pignent at hign intongity of 1 lent in the case of bean plante. Radia (1979) observed that chlorophyll 'a', ' $b$ ' and total cilorophyll contenta of leaves were fomat to
increase as the intensity of ahade increaced in pineapple. Oceli and Owusu (1975) noticed that, in cocoa plants, tio chlorophyll content per unit lear freen weight was signisicently greater in deep aheade. Chlorophyll content per unit weight of leat was found to frorease in the case of plants grown at lower light intensities, but the chlorophyll content per unit area of leaf aurface was very often lower than the plente grows in open (Bjoricuan and Holneren, 1963). Elmilar observations were obtanned by Cooper and gualls (1967) in the cabo of alfanfa and birdafoot trefoil.

Contrasy to the above reporte, in the cane of corpea, Higazy et al. (1975) observed that the concentration of total chlorophyll as well as its componente 'a' and "b" decreased by increasing ahode intrenelty. In wheat, Koursi et al. (1976a) observad that all pigaents decreasad aignificantiy with increasing ahode intenoities vie., 100, 60, 40 or 20 per cent full bunligat; but the ratio of chlorophyll asb remained constant at all made intensifiea.

While discussing the blology of livine cirloroplast, Priestly (1929) atatod that the chloyoplaste in leaves would undergo changee in poaition according to tho differences in 21 gint intensity. It was pointed out that in leaves of plenta grown under lower ilght intengitiee the
plastide vero liaited in number and they wero arranged at right angles to the lighi rays and were larger in size, thue incroasing the area for light absorption.
6. Stomatal iroquency and atomatel opening

In plants lise cocon, alralia, birdsfoot trePoll etc. rosponce to ghade on the number of otomata per unft area of leaf hes been reported to be negative. It has aleo been obseryed thet the light intensity at which atomata starts to open aud close in plants is aomething which is highly variable between orope; there are opecific threahold valuee of light intensity, for each of the crops at whion atomata atart to open and close. For example, in the caee of cocoa, the otomate otart ologing whenever light intensity falls below 500 to 700 foot candles and remain fully open at intense and asreot illumination, whereas in coffee, tine stomata romain partially close whenever the light inteneity exceeded 8000 to 8500 soot candles.

Hardy (1953) observed that in the cese of cocon, the leaves produced under made had lebs mumber of otomata per unit area, an the opidernal celle in the leaves were longer. Cooper and Qualle (1967) observed tint alfalfa (迫dicago gativa $L_{0}$ ) and 'Tana' birdofoot trefoil (Iotus complcuzatus d.) had more stomata per unit area of leaf vien grown in the enade. Humber of palisade and mesophyll celle and the
coll voluae appeared greatest in leaven exposed to gun and palisade layor was more olearly differentiated. ilolingren (1963) neported that aigher intencition of light during the growth of plente generally increased line stomatal frequency but there was no algufficont changeo either in the length of atomatal pore or in the alze of guard colle.

Hiardy (1953) afifered on the posetbility of cocos boins a ghade-loving plant and reported the followinc reaulte. By applying the oil infisitration aethod for assessing the degree of storstal chosure, it had been shown that the stomata of cocon leaves exposed to full intense and alrect illumination ( 13,500 foot candlee) reasined completely open and transpired froely an lons as water aupply was plentiful. As againet thie, tho stoanta of coffee leaves were reported to parinally close whener the intensity of illumination exceeded 8,000 to 0,500 foot cendles and in the ghade, they always romained open provided the lignt intensity was not so less - a characteristic phenomenon of ehade-loving plants. In the case of cocoa, the leaf stamata began to olose whon the light intencity was reduced to less than 500 to 700 foot cendlesp whici was about 5 per cent of the full sunlight. It wea aleo observed that under ordingry circuatences, the stomate began to open at about 6 AM and maintained their geximum
sise betwean 3 AR gnc 4 or 5 RN, after which tiac $1 t$ gtarted closing cecause of dininiching light intemeity. 7. Photoaynthesia and dry matter accumulation

Photogynthosis and dry qabter accumulation have been reported to be edversely affected by shading in any of the plonts. winile in the case of ginger poeitive influence was reported. The extent of decline. In dry matter accumulation was however, varying between plants. In the cese of gineapple, thero was no appreciable decraage in dry matior accumulation even upto 75 per cent ohading.

Singh (1967) reported that exposure of ginger to intense lignt is detrimental to photosynthesis. According to Minoru and Howi (1969) Einaibor mioga, Rose. requires a paturating light intensity of 200 kilolux. In the trial on potied arabica coffee seedlinge shaded to provide 25, 50 ox 75 per cent 1igint, Eilveira and baeetri (1973) found that the beat erowth (as manaured by ary matter produotion) was with 50 per cent light. Radha (1979) noticed comparable dry matter accunulation in the leaven of pineapple both in ehade and in the open upto flowering stage. It was also geeni that the reduction in total dry mation accumlation was not considerable in opite of anad1ng upto 75 per cent. Wong and wilaon (1980), from the studies on the exfect of ghading to 100,60 and 40 per cent
of full sunilight on the growth of green-panio erase and siratro in pure and mixed swarde defoliated at 4 waeks and a weeks stage reportod that individual loaves of shaded greon-pazaic had greater photosynthetic activity than those fron full ounlight.

It was reported by Dugger (1903) that ghading either partially or completely reduced the corbondioxide aesimilation and thereby the available constructive aeteriale for plants. In tomato plents, Porter (1937) obuerved that total emount of phowoeyntinates decreased with decrease in light intenaity. Esnediot (1941) reported that plente of Agropyron prigtatuma A. emithit and Boutelous gracilis grown in shade had maller axy welgit. ingr and Saebo (1969) from tine triad on the effecte of ehade on growih, development and chemical composition in some grass apecies observad that ghading greaily reduced dxy aatter gieids particulariy in Fesinca rubra, Loliun perome and phleum pratonse. Agrostio tonuid, Pog palustris and poa Wrivialia were the least aifeoted. It was also observed thet heading was retarded and deoreaged by ohading particulerly in Phlous pratenge. At lifer light intengitiea, photogynthetio rate. per unit chlorophylil in the case of cocoa was found to be hignest for leaves in the open which eugeested that photosyratheizic eificienoy was increaced by eroth in full dey 1ight (Baker and Hardiwiok, 1973). Kouret gt 旦. (1976b)
found that the effiolonog of solar energy convereion in wheat decpeased with increasing made ( 100 to 20 per cent full sunlight) from 1.44 to 0.37 . In the case of erain sorghuen plante eubjected to 0,25 or 50 per cent shade, It was found that total ery matter decreased with inorease in ahade (Palis and Buetri2los, 1976). The effecte of shade on the growth and photogynthetio capactiv of the exotic noxioum weed itcingrass was studied by Ratterson (1979). It was found that shading naricedly reduced dry matter production and thai at 40 deys after plemting, plants grown in 2, 25 and 60 per cent aunilght had 0.3, 16 and 55 per cent, respectively, of the dry weight of the plante groun at 100 per cent sunlight. In shade experiments with cogon crease, Ratterson (1980) observed tiat after 89 dags, ine plants of three ecotyper produced on an average three tires as much total dry weight in full availeble gunifgt as in 55 per cent full ligitt and 20 timen es much as in 11 per cent full light. The plonte fros the shaded and exposed habitats Eenerally did not differ sienificantly in their responses to ahading. Wong and Wilmon (1980) reported that leaves of ehade-grown Siretro had a lower photorynthetio potential than in the full sumlight treatment.
8. Growth analyeis

Review of work aone indicates that effect of whade on
leal area index (IAI) of plante varied widely. In the case of green-panic, the response was poaitive, while in Biratio, it wac noeative. Ir cocos, net assimilation rate (FAR) was not influenced ky shade in ono of the axperinents whereas in another, deorease in IAR vith increasing shade was reported. Also, a negainve response to ohade on Hifl in wheat had been reportod. In cocoa, pelative grouth rate (RCR) hat beon positivoly influenced Dy shading, while leaf area railo (ya) showed a negative relationship.

Woug and Wilaon (1980) obsorved an tncreased Lal in shaded greermpanio swarde ard a deoreased Lay in maded Bifatro. When a crop of grath sorghum was subjected to O. 25 or 50 per cent shade, the LAI wae found io deorease with increase in shado (Paiss and Bustrillos, 1976).

Hardy (1958) observed Lowest har at highest shade level and vicemerga in cocoa. In the case of cocos seed2ings, Gopinathan (1981) observed that, RAil wae not inEHuenced by increase in shade intenaity ranging irom 25 to 75 per cent. Soures et g1. (1976b) Found that the TINR of wheat dearsased with increasing shade intensitiee fror 5.7 to 3.2 and troas 11.9 to $0.0 \mathrm{E} \mathrm{m}^{-2}$ day $^{-1}$ at 00 to 95 and 95 to 100 daye respectively when the 11ent intensity was brought down zron 100 to 20 per cent full aunlight.

From the otudioe on light and fertilicer requiremento of cocoa, Evans and durray (1953) recorded greatest RG? at a lichi intengity between 30 to 60 per cent of full day light. Okali add Owum (1975) observed that RGR was maximal For cocoa plants frown under aeditin shade.

Cooper and eualls (1967) soticed that the increase in the ratio of leas area to leaf welght whion occure due to chacing of legue (alialifa and bixdafoot treioil) wae associated with chances in lear norphology.
9. Yield and yiela attributer

The eeneral effeot of ahade on final yield of crope was that of a decrease in the cabs of apple, peachea, corghum, coybear, cowpea and cocoa. Reports of increaces In yield congecuent to shading wore noted in cocoa, tomnto, tea and areanpanc. In the case of ginger, reduction in gield was reported onily at very intense ahader.;

Bdmond et al. (1964) conductod ahade experinente in tomatoos and axamurn yield was obtemied from plants receiving ouly 45 per cent of full manlight. Joseoh (1979) seporied thai the tea clones under ehade gave auch nighor yileld then in expobed plotis. None and Wileon (1990) from the studies on the effect or illuminetion at 100 , 80 cnd 40 per oent of eunlight on the erowth of eleatro and ureenpenic in pure and 50:50 mixture swarde, defoliated every

4 $\left(D_{4}\right)$ or $8\left(D_{8}\right)$ weoks, observed that sheding to 60 and 40 per cent of full ounlieht inorensed the ehoot yield of areen-panic in pure sward by 30 and 27 per cent, reepectively in tho $D_{6}$, but reduced it in the $D_{4}$ treatment by three and 14 per cent.

Kraybill (1922) observod cecreased. fruit bud fornation in apole and peachen under shade. Freeman (1929) in the earliest recorded field experimont to determine the optinua degree of ainde for cocoa reported that ilghbiy sheded cocoz gave higher yield than those wider intence shede. The number of flowers per tree vas found to be 60 to 70 per cent more in cocoa under aoderately shaded trees than in mehaded trees (Boyer, 1974). In tine onee of ionato, Porter (1937) obsorved a decreace in fruit groduction with the decrease in light intenaity. In shading experimente with tomato in waich the light inteneity was Iowered to 50 or 25 per cent of that of the controis, Eakiyam (1968) noticed that tine greater the ohading, the Lowor was the fruit welgat. Boneta Garcia and Bosque Lago (1973) observed that nore yield was obtuined when coffee was groun in full gunlight tian when erow in partial shade ( 40 ger cent). Buttrose (1974) observed a decrease in tine number of flower bud initieted in ginaded cocoa conpared to menaded cocoa. Graman (1974) observed that
decresering the amount of photomontinetically active radiation by 40 to 60 per oent oy sheeing in boan (Vicia faba) plonte resulted 12 decreased production of flowere, whough it deoreased the enedding of goung pods. Experiments with wheat at ohede intenoitieo ranging from 20 to 100 per cont full light showed that increase in gaade intengity decreased the number of tillers and spike日, dry woight, fruiting exficiency, crain weight per plant and yield of erain and atraw (Loursi ct al., 1976c). Hono ct al. (1976) observec thet shadine tea busher to about 45 per ceat light inteasity with clotin screen about 60 en above the plucking table depressed new shoot growth and jield. It was aleo found that the phade intensity was suvercely rolated to yiold and this docrease in yiela was highest during the first plucking souson, Lalis ond Duetrilios (1976) sound that, in sorghua, grain yiejd and grain-straw ratio decreased Whth flnorease in chading ransing from 0 to 50 per cent. Hueng (1977) in a trial in which rice plante were grown with or without 90 per cent shading observed that enading decreased spikelet number per panicle oy 54 per cent giving a higher proportion of dogenerated opikelete. Tarila et al. (1977) reported that in cowpea high light intensity delayed flowering, but increaged blossom and pod numbers add improved eeed field. Hehue and ialler (1978) obeerved thet
seed yields of soybean plants Bhaded to reduce aunlight by 20, 47, 65, 80 end 93 per cent were $90,75,48,18$ and 2 per cent, reepectively, of that obtained from unshaded plante. they alco found that number of pode per plont and seed gield wera highiy and negatively correlated with ehede. Venisatectarlu and Srinivaban (1978) conducted a trial to study the influence of low light intensities on rice and observed that gield loss was greatest with continual shading at 40 to 50 per oent of natural light.

In the care of wheat, reduction in grain yield due to increasing ehade was ourvilinearly related to radiation axch that anell reduction had litile effeot on yield at any developmental skage (Ficier, 1975). Aclen and Quisumbing (1976) reported that gield of eingor under full munlight was just as high as those obtajned under 25 and 50 per cent light attenuation. When light attenuation was over 50 per cent, the yield decreased. Radhe (1979) observed thist the frust weigat of pineapile with crown was not influenced by ehading. But the contribution of crowns to the fruit weigat increased as the intensity of chade increased. Congequently, there was a reduction in fruit weight without crown. It was also obzerved that eliadins above 25 per cent was benefigial to the extent of reducing peel and core weight of the fruits.
10. Quality of produce

The regponse to ahade on the quality of produce varies widely. In eeneral, protein content increases and carbohydrate content decreaese with shading.

Highr and Seebo (1969) observed tiat in some grass epecies, the crude aeh and protein contente were approximately doublea by ahaaing to 10 to 15 per cent of the intenaity of natural light whereas the augar contente approximately haived; and eerious lodging occurred ao a result of reduotion in fibre content. Shading wat found to increage the concentration of total coluble and grotein nitrogen in the grain tieeue wion 20 to 100 per cent full light was uried on wheat (Mourgi ot al., 1976c). Palis and Buatrillos (1976) obeerved in thepage of grain sorghum plante eubjeoted to 0,25 or 50 per cent shade that protein increased while carbohydrate decreased with decrease in light. Aclan and Quisuabing (1976), in the case of einger recorded loveat otarch oontent in rhizomes from the plante grown under 75 per cent enude. In an experiment where sogbean plante were gaded at the four-wifoliate leaf stage to reduce sumilgit by $20,47,63,60$ and 93 per cent, it was seen that ehade had litile effeot on' 011 and protein contents of seed except that protein content yás highest and oil content lowest at 93 per cent siade (vabua and railler, 1978).
ilwang (1968) reported that ohading pineapple after flowaring gave higher grade fruits than unghaded; the unghaded fruit suffered from sunburn and geve lower canning ratios than the shaded treatment due to sun scorch. Radha (1979) observed that quality of fruits in general decreaged in pinoapple under maded conditions. While the aoidity of frutts increased, there was a general reduction in sugar and ascorbic acid contents.

Aono et gl. (1976) found that shading tea busien to about 45 ner cent listht intensity with cloth gereene about 60 ca above the plucking table, improved the ereen tea quality. It was noticed that the quelity was directly rolated to the shede iniengity and this increase in quality was the grearest in the sirst plucking season.
11. Nutriont contont

In general, the mineral nutrient status of plante has been found to feprove under shading es in the cage of apple, cocon, spinach and tea. In the case of soybean, on the contrary, nitrogen content was found to bo positively related to illumination levels. Also, adverge affect of shade on nutrient content has been reported in siratro. oocoa seedlings and pineapglo.

Mybr and Caebo (1969) found that notaseivn onntente
were approximately doubled by ehading some grase epecies to 10 to 15 per cent of the intensity of natural light. phosphorus, calolui and magnebium conberte also increased under sheding. Kreybill (1922) observed hicher contente of moisture and niturogen in ahaded apple leaves. Guers (1971) reported that cocor leaves exposed to direot aunIlght contasnod Iese noisture and nitrogen than chaded leaves. American Holly plant exhibited higher anounts of potassium and magreaium in leaf tibsues when the plente wore grown at 92 por cent chado (Fretz and Iunhan, 1971). Cantiliffe (1972) observed in sitnech that the conceniration of potaselus in the tissue increased vith reduction In the light inteariw. nrecaena ganderiena plante grown at ifye ahade intencitien were analysed for folier ritrocen, phoophorus, poteocium, calcium end magnesium and it was found that the different shaies had inttle eifect on the leaf nutrient contont excopt that higi shade interaity inoreabed potegsiun end megneain especielly in youns leaves (Roariguer et al., 1973). Ralna (1979) observed thet the uptake pattern of anjor mutrienhs in pineapple vae noi greatly influenced by ehading. It was aleo noticed tinat mading increased the magnestim content of leaven at all atagea of growth main nitrocen content ab leter gtages of growth. Oladocun (1980) reported that in the oose of coffee,
ahade significantly affected plant nitrogen, phoophorus and potassium contents, According to, Wong and Hilson (1980), aitrogen accumiation in all the plant components of green-panio was marizedly fmproved by slueding.

Hahue and ${ }^{\text {Hilliler (1978) in their trial on soybean }}$ with shade levels of $20,47,63,80$ or 93 per cent observed that total leaf and stem aitrogen contente were highly and negatively correlated whensade. Wong and lilison (1980) observed that the nitrogen yield of airatro in pure mard deolined with shading. Treng and Giddens (1980) concluded from their eizade experiment that boybean plonte without shade had higicer mitrogen content. In the case of cocoa eosalings, Copinethan (1931) noticed nigier percentage of nitrogen, phosphorus and potassium in plants erown under direat minlight than in tine anded plonte. However, between the plants exposed to difforent ehade intensitieb, the nuterient contente phowed no significant differences.
12. General growth of plante

Vincon (1923) brought out the effect of enading on a number of horticultural planta such as apple, paaches, cherry, atrarberry, tomato, radien, potato and geraniua. Slonder oteme, Erester length of internodes, leaveb with larger and emaller croes-section, increasec aonsure contents
were all reported as general effeots of ghading on plant growth.

Evans (1951) deacibed a ghade experinent in which cocoa was erown under difierent artifioial ghade levels. V12. 15, 25, 50, 75 and 100 per oent day light. Resulta during the first year chowed that cooon made the bost growth at 25 to 50 per cent cunlight but planty receiving 50 per cent light were of bettor chape. As plants became 'bieger and autoghaing developed, the 75 per oont light plot improved its position, Uith increasing light intemeity, the need of nitrogen fertilizer becane morg apparent. The result of a shade and fartiliser axperinent on cocoa conduoted in Trinidad chowed that 50 per cent shado gave tio greatost early growth and highost initial fielde or cocoa (Hurray. 1953). Evene and Nurray (1954) Erom their mbudien on light and fertilizer reguirements for young cocoa reported that optymum light intengity for young cocoa during the first year appeared to be between 25 and 60 per cent and Intensitien above 75 per cent retarded the growtin. There was some indication that the optimum light intensity increased with aize of the plant and congequent eelf-shoding. Optinua growth of cocoa seodiings was attained in ghade rather then In full day light (Goodall, 1955; flurd and Cuninghan, 1961; Abomantrg and Kwakwa, 1965). The nost favouraoze lignt
intensity for cocoa ceedinge hed been stated to be about 25 per cent of rull amlight (Hardy, 1953). It was also stated that the anount of ligit may gradually bo incroased. to full gunlight, when complote leaf shading had been attained, the overinead chade being kystenaticalis reacoed. The growth in elze of plant was generalis least when lieht intensity was greatest.

Contrary to the ajove reports, Cumidnghen and Burridge (1960) etressed that hish rates of growith asy bo attained by cocoa seedlings in sull day light provided fertilizer is applied to the soil, precautione are taken to maintain a favourable water baience and to minimige damege by wind and ingect pests. It was also observed tinat in particuler circuastances, chade may be benefioial in limiting insect peet damage, and eupprossing weed growth. Fiener (1975) found that shading always reduced growth of wheat plante epproximately in direct proportion to the reduction in radiation. Gopinatinan (1981) observed that intermediate shede ( 50 to 55 per cent) was best for the bettor growth of cocoe seedlings; with the advanoing age of the plont, the intense ahade ( 75 per cent) which appeared to be superior in the very eardy stages (upto two monthe) proved inforior to the interaediate, ghade level of 50 to 55 per cent.

MATERIALS AND METHODS

## WATHIALS AED GERTODS

A ifeld experinent was conducted to investigate the ahade reaponse of comin rainfed intercrops of coconut viz. aweot potato (Ipomoea batatag (I.) Iem.). coleus (Colous parvitlorue Banth.), colocamia (Colocsala geculenta (I.) Schott), tumeric (Curcuma longa ino) and ginger (zingiber oficicinale Rosc.) under different intenolties of shade, during the year 1980-31.

The oxperiment was carried out at the College of Horticulture, Vellanikitars, Trichur, Kerala; India, waich is mituated at $10^{\circ} 32^{\prime \prime} 11$ latifuce and $76^{\circ}$ 10 E longitude at an altitude of 22.25 metore above mean sea level. Cropping hystory of the field

The area was left fallow during the previous four to five gears and was under rubber prior to it. So11

The soil of the experinental stie was deep welldrained aandy clay loais. The data on tre physical and cremical properties of the soil are given in fable 1. Season and ollante

The experiment weis conducted during the period

Sabie 1. Hechemical composition and chemical gropertion of the eoll


| Conre cand | $: 25.00$ per cent |
| :--- | :--- |
| Fine band | $: 23.10$ per cent |
| Gilt | $: 21.20$ per oent |
| Ciay | $: 29.70$ per cont |

B. Gheratcal properties

| Constituent | Content | Mating | Method uced fer. entination |
| :---: | :---: | :---: | :---: |
| Total nstrogen | $\begin{aligned} & 0.072 \\ & \text { per cent } \end{aligned}$ | medium | Siorokjoldanl <br> (Jeckron, 1953) |
| Avalleble phesphorue (Bray-I extract) | 1.827 pq (2 | Low | chlorontannoun <br> reduced molybdo- <br> ghoaphoric blue <br> colour method <br> (Jackeon, 1958) |
| Available potanelum (Heutral normal amonium acetsto extract) | 143.60 pram | high | F2ane Photometric (Jackeon, 1953) |
| $\begin{aligned} & \text { pHy } \\ & (1: 2.5 \text { coileweter } \\ & \text { satio) } \end{aligned}$ | 4.5 |  | (Jan motornen, 1998) |

Hay 1980 to Jemunzy 1981. Among the ilve crope erown, turmerio, colooabla and ginger werd planted on 27 th, 23 th and 30 th of. Hay 1980. Sweet potato and coleus were planted on 21st gnd 23rd June 1930. Individual orope were harvested at the ond of the maturiky periode of the respective crope. Thus sweet potato, coleus, colocaeda, turmeric and ginger were harvested 110, 125, 180, 220 and 225 days after plonting or sprouting. respectively.

The meteorological data for the orop periode are presented in Appendix 1. The area hee a humid tropical climate. The weekly avarage daily range in moteoroloficel parameters relating to individual chope are given in Appendix 2. Turmerio and ginger crops underwent a drougit period of about two and a half montin at the later atarges of grow'th. Coleus and colocasia had a ghort period of drougit for about 15 and 25 days, respoctively, at the later period of the orop growth, wisch wae congenial for the proper meturest of the crops.

The elimate ae a whole was guitable for the normal arowth of all the oropa weied.

## Materiels

## Seeds

jocel varietioe of weet potato, coleus and colocaele,
> 'Kagthuri thanais' variety of turmoric and 'Sugeijen' variety of ginger were used for the trial.

In the case of sweet potato, 45 days old 20 to 25 ca long vine cuttinge were planted on ridges 60 cm apart, at a aistance of 20 cm between cutinge in $4 \mathrm{~m} \times 1.2 \mathrm{~m}$ area. One month old coleus slips ( 10 to 12 cm long) were planted on raised beds of elze $4 \mathrm{a} x 1 \mathrm{~m}$ at a spacing of 15 cin $\times 15$ cm. Colocasia side tubers, ench weighing 40 to 45 g were planted on the ridges 60 cm apart at a spacing of 45 on on the ridgee in $3 \mathrm{~m} \times 4 \mathrm{marea}$. Fingor rhizomes of turmeric each welghing 20 to 25 g were plonted in sall pits waken at a apacing of $15 \mathrm{~cm} \times 30 \mathrm{~cm}$ on raleed beda of gize 4 a $x 1 \mathrm{~A}$. In the caso of ginger, bito of rhizomes of size 15 g colleoted from hoalthy, ajeasc free plents wore plented in saall pite teken on raised bede of size $4 \mathrm{~m} \times 1 \mathrm{~m}$ at a agacing of $25 \mathrm{~cm} \times 25 \mathrm{~cm}$.

## Fortilizers

Each of the crops received the respective cultural and manuriai practices as per the packege of practices recomendetions of the Kerala Agricultural University (INJ, 1978). Fitrogen, phosphorus and potassiua were supplied throueh amoniua sulphate, superpinosphate and muriate of potainh, respectivoly.

Fig 1. Lay-out plan Rexhomised biock dosign.


## Brading

Unplatted coconut leavoe tere uced for providing shade to the deaired level.

## Kothode

Lay out of the experiment

The experiment :ins laid out in a randoaised block design with five roplications. The mades were comon for all the five crops terted and thus five differont oropa were teated together in a contiguous orea. The ley out plan of the experiment is given in Fig. 1.

Preatoents

The treatrente consisied of four intensities of efade as given belod.
$S_{0}-0$ per cent shade (no ehade)
$\mathrm{s}_{1}-25$ per cent made (low mhade)
$\mathrm{S}_{2}-50$ per cont cinde (mediun chade)
$s_{3}-75$ per cent anade (hich phode)
grovision of shade
Artifiuial shcuing to the deoirsd level wae obtolned by placing unglaited coconut leaves on erected pandale.

Pendals of ofre $11 \mathrm{~m} \times 6 \mathrm{~m}$ were individually ereoted for aach phade loval by rixing wooden reapers on poste. Sufficient space ( 3 m ) was provided between the treatments so that autual chading of chade lavele were minigised to the exient possible. Tach pandel was covered on all the sides with unlaited coconut leaves except for 60 ca from the grourd level to avola the direct entry of slent rays. Rasaed bedg were taken leaving a bordor area or 1 a within the cinde lovele to avoid the border effect considerably. An Aplab luxaeter was used for adjusting the ghade intensities. Frequent checks were made throughout the course of experinent to aaintain the onode intensitier to the demined levele.

General growtin of the crops

In general, the growth of the crope was satisiactory. However, the growth and development of colocasia plants were highly zotarded during theferrly phase due to colocasia blight (Phytophthora palatorea (Eutior) Eutler) in apite of the prophylactio and contirol acacures token.

Observations
I. Plant chercoters
A. Biometric observations

Sho following crowth conraoterg were recorded at
montily intervale in sweot potato, coleus and colocasia. In the case of ginger and tumeric, observatione were takén at bimonthly intervals.

1. Plont heigit

The height of ten randomiy seleoted plants in each of the crops wae measured from the base to the tip of the longest vine or tallest tiller or branch at the cabe nay be, and the average worized out.
2. G1rth at coller

This observation was teken only in colocaaia where the circumference at the coller of the most vigorous tiller of 10 rendomly selected plante was takon and the mean value computed.
3. sumber of branchea or tillore

The number of aerial shoots arising around a aingle plant was noted in 10 randomly selected plants and the average worked out. In the case of coleus and sweet potato, the number of branches in plante were recorded for calculating the mean number of brancher por plant.
4. Leal area index (IAI)

Leaf aroa index of each of the crops was worked out

Sollowing the gravimetric nothod (Ruck and Bolas, 1956). Debtructive bampline wan followed and three plante in each of the crops were uprooted at different grow staces and their leaves ceparated. Ifive leaver were chosen at randon the inncase or colocagla and turgeric and 10 leaves in sweet potato, colous and ginger and the leaf mpressione were traced acourately on quality bond paper of mown aren per unit woigit. The traced porifone of paper were then cut out and welehed. From this, the area of the eample leof wan calculated from the welght to area relationchip.

The leaves were then dried, in a not air oven at 70 to $80^{\circ} \mathrm{C}$ to conftant welght and the ary weicht of these leaver and the rest of the leaven were recorded eeparabely. Total leaf evea.for three plonte was then calculated using the weight to area relationchio ard total dry weight of leavee. Thus Lin for esch of the crope wes onloulated at different otages using the following equation.

$$
\text { LAI }=\frac{\text { Total leaf erea of threo plante }}{\text { hand area occapied by three plants }}
$$

5. Chlorophyll cortent of leaver

Chlorophyll ' $a$ ', ' $b$ ' and total chloropayli content of each of the crops were estianted periodically by epeotrophotometrio method as dezcribed y starnes and Hadley (1965).

Fully acture leavea vere uced for the ogtimation and second temingl leaf was used in each of whe crop, except in eweet potato where the second green leax fron the tip was uged, gince the terminal leaves were tender and purple.

One gram of the repreantative gemplo, colleoted irom five pianta choaen at randon, was taken in a mortar in the presence of excess acetone. A pinch of calciun carbonate wes added to provent pheaphytin foratition end the contents were then eround well and filtered througi a Buchnor fannel. The brel was washed replatediy with frech acetone (B0 per cent) until the wabhing was colourloas. The extract and wabhinge vere then made upto 250 ml . The optical denelty (A) of an aliquot was meanured ueing a speotrophotoreter (Spectronso-20) at wavelength of 645 mand 663 nm. The contents of chlorophy21 "a". "b" and total chlorophril (ag e" Presh weight) were thon estimated uaing the following relationshipe.

6. Total dxy weigint

Leaves, aten + petiole (or pacudobten:, and tubere or rhizones. of the uprooted plente were eeparated and
aried to constont weighte at 70 to $80^{\circ} \mathrm{C}$ in hot air oven. Prom the ary weight of coaponent parts for three plante, average dry weight per plant for these parte wae worked out. The sua of disy weight of compononts gave the total dry natter gield, expreaced as $g^{-1}$ plant.

## 7. Net asajinilation rate (NAR)

The procedure given by hatson (1958) as modilied by Buttery (1970) was followed for calculating the SAR. The following formala was used to arrive at the mal expresed as $\mathrm{gai}^{-2} \mathrm{day}^{-1}$.

$$
\begin{aligned}
& \text { NAR } \left.=\frac{W_{2}-H_{1}}{\left(t_{2}-t_{1}\right)\left(A_{1}+A_{2}\right)} \frac{2}{2}\right) \text { whore, } \\
& W_{2}=\text { total dry weignt or plant } \mathrm{g} \mathrm{~m}^{-2} \text { at time } t_{2} \\
& w_{1}=\text { total dry welght of plent } g \mathrm{~m}^{-2} \text { at idene } \mathrm{t}_{1} \\
& \left(t_{2}-t_{1}\right)=\text { time interval in daye } \\
& A_{2}=\text { leaf arean } n^{-2} \text { at time } t_{2} \\
& A_{1}=\text { leaf area } m^{-2} \text { at time } t_{1}
\end{aligned}
$$

## 6. Field (yield of rhizopes or tubers)

The gield of rhizomes or tuberg in reopective crops was recorded from the net aren mariced for recording the sield. The net plot areas were 2.40, 1.33. 6.00, 3.35 and $3.25 \mathrm{sq} . \mathrm{m}$. respectively, in the case of eweet potato, colsus,
colocasia, turmeric and gingor and the gield was expressed ag $t \mathrm{ha}^{-1}$ of freah welght.
9. Yield of haulm (top)

The giold of top (vegetaitve parts) in individual crops wes recorded from the net area and expresaed as $t h a^{-1}$ of dry woight.
10. Harvest Index (III)

Harvest index valuer for the different crope were calcilated as follows.

HI $\frac{Y . e c o n . ~}{\text { Y }}$, where,
Y econ. $a$ dry weight of rhizomes or tubers
I biol. F totil dry welght of plants (exaluding roots)

## B. Ghemical studies

1. Content of fertilizor nutrients

Samplee of plant componenter collected for recording the dry weight were ueod for cheaical analyais. The nitrogen, phosphorus and potacsiun contents of leaf, sten + petiole (or pesudosten) and tubers or rhisones) at different stages of growth were determined by ubing Autoanalyzer (Technicon-II), colorimetrically (Vanadomolybdophosphoric yellow colour method) anc Flame Photometarically, respectively (Jackson, 1953).
2. Uptake of ferinlizer mutrienís

The total ustake of nituogen, phoaphorus and potacsium by the plant and indiviaual plant parts were calculated, at aifferent otagee of growth, from the nutricat contents und dry welghte of plant parts at airferent atageg of Erowth and expreased as $\mathrm{kg} \mathrm{he}^{-1}$.
II. Eoil characters

Contont of fertilizer mutrionte in zoil

Composite coil cempies were taken replicationwiee before the etrati of the experinent. After the experimenti, Individual monplea were colloctod from the area oceupied Ly each orop. The tobel nituogen, available paosphorus and available potambium contente in these samples ware estimetad using microijeldanl netiod, Colorimetrically (Cnlolostomnous redaced molycdophosphoric blue colour nethod) asd Plame Photometrically, respectively (Jacirgom, 1953). Statiotical mnalysea

The data on different choracters were subjected to statiotical analysia follouing the method of Enedecor and Cochras (1967).

RESULTS AND DISCUSSION

## RESULTS AND DISCUSSION

As there are five crops involved in the present etudy and as the responses of these erope to varying ahade intensition wore vastly different, the reaults ore furniahed and discused eeparately for individual crope. A brief sumary of the exajor conclusions drawn out of the study succeeds each disouseion.

Sweet potato

# Sweet potazo <br> (Ipomoea batatas ( $\mathrm{J}_{*}$ ) Ien.) <br> RESULTS 

I. Plant charactors
A. Biometric observations

1. Length of vine

The data are presented in Table 2 and the annlysis of variance in Appendiz 3.

The effect of anade on the length of vine in sweet potato was gignificant only in the intermediate stages of growth viz. 60 and 90 daye after planting. No general trend with inoreasing levels of ahade was observed except ati 90 days after planting when the length of vine increased uith increasing shade inteneities.

Ovor the stages, the vine length wav found to increase with advancing, age. The extent of increame in vine length botween atages was much greater at the intense shade of 75 per cent.
2. Number of brancher

The deta are presented in Table 2 and the analyaid of veriance in Appendix 3.

The effect of ghade on number of branchee produced by a plant was highly perceptible and algnificant at all stages of plant grow'th. The number of branches deoreased tremendously with increasing intensities of enade. At all stager, the diffarence between the different ghade levels and the plento in the open wee highly perceptible.

With advencing age, the nurober of braneles inoreased at all ahade levele.
3. Leas area index

Tha data are presented in sable 2 and the analysis of veriance in Appendix 3.

There was significsut offect of ghade on ISI at all stagee of growith with plote without shade and highest chade levele recordung the maximum and minimu values, respectivoly, at all otages. The LAI values doarased with increasing shade lovols at all stages.

Between atagee, the leaf area index showed an inoreasing trend with advancing age at all shade levels but the extent of increase is much nigher in the plot without ghede.
4. Chloroghyll content of leaves

Fine data on the content of chlorophyll 'a', "b',

Tablo 2. Effect of ainado on lengit of vine, mumber of branohes and lear area index of aweot potato at different growth atageo

| Shade intenaity (per cont) | Iengeth or vine (an) (deye aftex plontime) |  |  | $\begin{aligned} & \text { Yuinber ai pranciaes } \\ & \text { (days anter planbing) } \end{aligned}$ |  |  |  | Leaf area inder (doys after planting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 30 | 60 | 90 | 30 | 60 | 90 | $\begin{gathered} z_{\mathrm{Br}} \\ \text { cyegt } \end{gathered}$ | 30 | 60 | $90^{\circ}$ | liervaet (110) |
| 0 (no chade) | 70.3 | 185.3 | 276.2 | 8.5 | 20.7 | 21.3 | 22.7 | 2.72 | 3.01 | 7.55 | 11.09 |
| 25 (100 ensie) | 98.5 | 246.0 | 356.3 | 3.0 |  | 14.6 | 12.9 | 1.53 | 4.84 | 6.37 | 6.74 |
| 50 (redius ahaid | 89.0 | 271.6 | 391.7 | 2.9 | 5.1 | 10.1 | 15.0 | 1.20 | 2.68 | 4.53 | 6.60 |
| 75 (high chede) | 73.6 | 222.4 | 400.2 | 2.3 |  | $7 \cdot 1$ | 8.8 | 1.16 | 2.45 | 3.03 | 2.74 |
| CD ( ${ }_{\text {O }}$ ( 0.05 ) | 7.75 | 16.4 50.6 | 17.8 54.8 | 0.8 2.3 | 1.0 3.0 | 1.4 | 1.7 5.3 | 0.32 0.97 | 0.69 | 0.59 | 0.90 |

Table 3. Effect of shade on contents (ag $g^{-1}$ fresh woight) of chlorophyll ${ }^{2} a^{5}, b^{\prime}$ and total chlorophyli; chlorophyll am xatio of ewear potato legvee at aifferent Erowth etages

| Ghade fritensity (per cent) | Chlorophyll ${ }^{\circ}$ a' (days after plantixg) |  |  | Calorophyil 'b" (daye after planting) |  |  | Total chlorophyll <br> (daye after planting) |  |  | Chlorophyll asb (dayse after planking |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 80.95 birndst |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | 80 | 95 | dervest | 80 |  | criges | 30 | 95 Harveat |  |
| 0 (no shad | 1.54 | 1.62 | 1.65 | 1.90 | 1.84 | 1.95 | 3.44 | 3.46 | 3.59 | 0.81 | 0.33 | 0.85 |
| 25 (10w ahnce) | 1. 53 | 1.58 | 1.50 | 1.87 | 1.82 | 1.70 | 3.40 | 3.40 | 3.21 | 0.82 | 0.57 | 0.89 |
| 50 (mediua | 1.59 | 1.65 | 1.70 | 1.97 | 1.57 | 2.00 | 3.58 | 3.52 | 3.71 | 0.81 | 0.33 | 0.35 |
| $75 \text { (h1gh }$ | 1.62 | 1.52 | 1.66 | 2.00 | 1.79 | 1.94 | 3.62. | 3.31 | 3.60 | 0.61 | 0.85 | 0.35 |
| CD ${ }^{\text {cos }}$ | 0.05 | 0.07 | 0.04 | 0.07 | 0.03 | 0.00 | 0.11 | 0.14 | 0.12 | 0.01 | 0.02 | 0.01 |
| CD(0.05) | mes | Ein | 0.15 | \% | E | 5 | 36: | We | Wi* | M | WS | Wis |

total chlorophyli and ratio of chlorophyll a-b are presented in Table 3 and the analyges of variance., in Appendix 4.

In general, the effect of shade on totel chlorophyll and its components was not alenifioant, ot ony of the stagee of growin considered. The content ranged from 1.50 to $1.70,1.70$ to 2.00 and 3.21 to $3.71 \mathrm{mg} \mathrm{g}^{-1}$ fresh weight, in the case of chlorophyll ' $a$ ', ' $b$ ' and total chlorophyll, respectively. The content of these fectors showed high variability and no general trond could be noticed with increcoing ahado levels.

Tho ratio of ahlorophyll a-b remained almoat constant in different ohade densities at all growth ategee.
5. Total ans weight

The data are presented in Table 4 and Fig. 2. The analyoie of variance is givon in Appendix 5.

Shading had a aignificont effect on plant dry weight at all growth stages. The total plant ary woight exhibited a steop decrease with increasing shade levele. The ary weight in the plot without ehade was algnificently higher than at all shade levels.

Table 4. Erfect of shace on movas ary maver prodnction, net agsiailation rate, tuber jiela, hall jicla and harvest index of aweet potato

| Shade intensitf (per cent) | Total dry velcint (s plont ${ }^{-7}$ ) (amy aftar planting) |  |  |  | Het asminila sion_tate <br>  |  | $\begin{aligned} & \text { Tukar } \\ & \text { yiold } \\ & \text { (f ha } \\ & \text { hresh } \\ & \text { velght) } \end{aligned}$ |  | ```garvent index t)``` |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 50 | 60 | 90 | Harvast (110) | Eetween <br> $30 \& 60$ daya | $\begin{aligned} & \text { 5eturem } \\ & 608.90 \\ & \text { days } \end{aligned}$ |  |  |  |
| 0 (no ehade) | 18.64 | . 65.32 | 145.28 | 149.55 | 3.48 | 2.63 | $\begin{gathered} 7.654 \\ (0.9377) \end{gathered}$ | 16.00 | $\begin{gathered} 0.263 \\ (0.1012) \end{gathered}$ |
| 25 (10w shade) | 7. 10 | 38.54 | 74.46 | . 73.00 | 2.79 | 2.25 | $\begin{gathered} 1.631 \\ (0.4201) \end{gathered}$ | 10.38 | $\begin{gathered} 0.094 \\ (0.0390) \end{gathered}$ |
| 50 (ceaina chade | ) 5.61 | 18.62 | 48.48 | 36.76 | 1.84 | 1.78 | $\begin{gathered} 0.737 \\ (0.0557) \end{gathered}$ | 5.95 | $\begin{gathered} 0.012 \\ (0.0050) \end{gathered}$ |
| 75 (high shade) | 4.61 | 12.68 | 24:36 | -18.70 | 1.24 | 1.25 | $\begin{gathered} 0.000 \\ (0.0000) \end{gathered}$ | 5.94 | $\begin{aligned} & 0.000 \\ & (0.0000) \end{aligned}$ |
| Stem | 2.04 | 4.09 | 0.76 | 11.35 | 0.26 | 0.82 | 0.17 | 0.40 | 0.032 |
| ci (0.05) | 6.28 | 12.61 | 26.98 | 34.93 | 0.81 | His | 0.53 | 1.24 | 0.097 |

FS = Hot elmificant
(Figures in parontheais reprecont $\log _{10}(5+1)$ wransforad values)

Fig.2-Effect of shade on dey matter accumulation of sweet potato at different stages of $g$ row th.


Fig. 3.- Tubes and haulm yield of sweet potato as affected by varying intensities of shade.
a. Tuber yield (fresh wight)


intensity (per cent)
b. Haulm yield (dry waigh

The plant dry weight increased with advancing ege at all the shade lovels. The extent of increase was moot marked during the period between 30 and 60 days after planting.
6. Net assiailation rate

The data are presented in Table 4 and the onalgale of variance in Appondix 5.

There was alomificant effect of ehade on $\operatorname{Har}$ in sueet potato onls bstween 30 and 60 daye after plonting. The EnR went on inoreaeing with decresse in shade intensitiee. Though an identicai trend was noticed between 60 and 90 days aiter plonting, the differences zell short of Btathatical aigniricance.

Over the stagea, the whr was found to decrease at all ghade levele. The decreaes was more consplcuous in the plote without ehade.
7. Tuber gield

The data are presented in table 4 and Fqg. 3. The analyais of varience is given in Appendix 5.

The gield of tuber was algnificentiy influenced by shade. The gield declined rapialy with inoroaelne enede intengities and the intence ohade ( 75 par cent) levol

Fig. 4-yield response of sweet potato to different intensities of shade.

resulted in no harvestable produce. The plants wathout shade gave the highest gield of $7.65 \mathrm{t}_{2 \mathrm{a}^{-1}}$ which was aignificontly higher than that at low ( 25 per cent) and medium ( 50 per cent) shade lovels. Calculated as percentagas of the gield in the open, the gielde at low. medium and high ehade intensitiee were $21.3,1.8$ ond 0.0 per cont, respeotively.

## Response curve

The gield data were tronsformed to logarithas usine the log $(y+1)$ traneformation. A quadratic polynomial was found to give a better fit to the traneformed data (Fig. 4 and the analysio of variance in Appendix 48). The equation of the curve ig given below.

$$
\log _{10}(y+1)=0.2089-0.1589 x+0.0289 x^{2}
$$

The comesficient of deterianntion was found to be 0.9951 which showed that 99.51 per oent of the total veriation in the responge oan be explained by the fitted polynomial.
B. Field of haulm

The data are pregented in Table 4 and Fige3. The analyais of variance is given in Appendix 5.

As in the cace of tuber yield, there was gignificant
affect of shade on haule yield in aweet potato. The maximum jield was recorded in the open and mininum jield at higin shade levels. Tine jield of heulm in low, aedium and high ghade levels were found to be 64.9, 37.3 and 37.0 per cent of that in the open.
9. Harvest index

The data are presented in Table 4 and the analyale of variance in Appendix 5.

The responee due to chade on harveat index of sweat poteto was highly peroeptible and significant. Tine maxiaum and ninimun values were in plots without shade and medium to high ahade levela, reapectively.
B. Cherical studies

1. Content and uptake of nitrogen

The date on the conteat of nitrogen in leaf, otem + petiole snd tubers along with the total upteke of nitrogen are presented in Table 5 to 6 and Pig.5. The analysen of variance are given in Appendix 6.

In general, shade had a significant effect on tiose charectera at all growth stages. The content varied from 3.54 to $4.34,1.29$ to 1.89 and 0.36 to 0.56 per ceat in

Table 5. Effect of shade on nitrogen content of lear and atea + petiole or sweet potato at different grouth atsges

| Shede intonsity (per cent) | Ioaf nitrogen content (per cont) (days after plenting) |  |  |  | Stem + petiole nitrogen content (por cent) (daye after planting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 30 | 60 | 90 | $\begin{gathered} 110 \\ \text { (harvegt) } \end{gathered}$ | 30 | 60 | 90 | $\begin{gathered} 110 \\ \text { (hervest) } \end{gathered}$ |
| 0 (no ohade) | 3.97 | 3.78 | 3.54 | 4.13 | 1.44 | 1.43 | 1.29 | 1.43 |
| 25 (low ehade) | 4.10 | 4.16 | 3.99 | 4.35 | 1.77 | 1.62 | 1.45 | 1.55 |
| 50 (medium ghade) | 3.88 | 4.23 | 3.84 | 4.05 | 1.02 | 1.76 | 1.40 | 1.57 |
| 75 (high shade) | 4.15 | 4.01 | 4.34 | 4.18 | 1.84 | 1.89 | 1.49 | 1.62 |
|  | 0.11 | 0.03 | 0.12 | 0.05 | 0.03 | 0.03 | 0.06 | 0.01 |
| CD (0.05) | HS | 0.08 | 0.36 | 0.17 | 0.08 | 0.08 | 8 | 0.04 |

HS $=$ Not sfenificant

Table 6. Erfect of chade on the nitrogen content of tuber and on the total upteke of aitrogen by eweet potato at different growtin stages.

| Shade intengity (per cent) | Tuber nitrogen content (per cent) (days alter plenting) |  |  |  | Total uptake of nitrogen ( $\mathrm{kg} \mathrm{ha}^{-1}$ ) (days after pianting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 30 | 60 | 90 | $\begin{gathered} 110 \\ \text { (harvest) } \end{gathered}$ | 30 | 60 | 90 | $\stackrel{110}{\text { (harvest) }}$ |
| 0 (no ebrde) |  | 0.62 | 0.36 | 0.70 | 39.73 | 153.19 | 186.43 | 244.57 |
| 25 (low ehade) |  | 0.81 | 0.56 | 0.80 | 17.29 | 82.74 | 135.79 | 146.97 |
| 50 (nedium shrde) |  |  |  | 0.80 | 13.29 | 42.45 | 86.34 | 126.44 |
| 75 (high misce) |  |  |  |  | 11.27 | 30.13 | 48.45 | 38.53 |
| SEm ${ }^{4}$ |  |  |  |  | 4.22 | 8.58 | 10.80 | 22.37 |
| CD (0.05) |  |  |  |  | 13.00 | 26.45 | 33.29 | 68.92 |

TS = Not aignificant
the oase of leaf; atem + petiole and tubere, respectively, at the aifferent stages. The variation in the content was wide and it is difficult to derive general trend. it was also noted that the nitrogen content of leaves was found to be 2.0 to 5.0 times nore than that of aten + petiole.

The uptaice of nitrogen by leaf, atem + petiole and tubers were also calculated separatoly and all thege were found to be significentiy influenced by ghading at all the growth stageg. The total uptacce of nitrogen closely followed the total dry weight, at ell the growth otagee. The plants without ahade and with high ehade recorded the maxinum and minimur uptake values, respeotively. The uptake ghowed a drastic decline with increasing chade intensities.

Over the stages, the uptaice went on increasing with advoncing age; while the content remained almost at the samo level.
2. Content and uptake of phosphorus

The data on the content of phosphorus in leaf, etem + petiole and tubere along with the total uptake of phosphorus are prosented in Table 7 to 8 and Fig.5. The nnilyses of voriance are given in Appendix. 7.

Table 7. Bffect of sinade on photghorus contont of leaf and stem + potiole of - weet potato at alfierent grouth atages

| Shade intensity (per canl) | İear phosphorue content (por cent) (days after plenting) |  |  |  | Sten.+ patiole phonphorus conkent (per cent) (dess after plenting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 30 | 60 | 90 | $\begin{gathered} 110 \\ \text { harvegt) } \end{gathered}$ | 30 | 60 | 90 | $\begin{gathered} 110 \\ \text { (harvest) } \end{gathered}$ |
| 0 (no phade) | 0.35 | 0.33 | 0.30 | 0.38 | 0.21 | 0.24 | 0.20 | 0.22 |
| 25 (10w elade) | 0.43 | 0.36 | 0.29 | 0.37 | 0.31 | 0.23 | 0.19 | 0.21 |
| 50 (gedius ohade) | 0.37 | 0.38 | 0.32 | 0.41 | 0.25 | 0.21 | 0.19 | 0.25 |
| 75 (high ahade) | 0.40 | 0.29 | 0.37 | 0.10 | 0.29 | 0.26 | 0.19 | 0.21 |
| SEA $\pm$ | 0.01 | 0.02 | 0.01. | 0.01 | 0.01 | 0.02 | 0.07 | 0.01 |
| CD (0.05) | 0.02 | ES | 0.02 . | 0.04 | 0.02 | Eis. | HS | 0.02 |

ES $=$ Hot bigniifeant
sable 8. Effect of shada on phosphorue contont of tuber and total uptake of phosphorus by aweet potato at difforent growth stages

| Bhade interielty (per cent) | Tuber phosphorus cortent (per cent) (daye after planting) |  |  |  | Totel uptake of phoaphorus (deys aiter plenting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 30 | 60 | 90 | $\begin{gathered} 110 \\ \text { (narveat) } \end{gathered}$ | 30 | 60 | 90 | $\begin{gathered} 110 \\ \text { (harvest) } \end{gathered}$ |
| 0 (no mhede) | 0.14 | 0.15 | 0.11 | 0.11 | 4.15 | 19.14 | 23.50 | 29.03 |
| 25 (10w ohade) |  | 0.15 | 0.16 | 0.12 | 2.25 | 8.93 | 13.39 | 14.87 |
| 50 (nediun shade) |  |  |  | 0.10 | 1.46 | 4.36 | 9.10 | 16.62 |
| 75 (hignsehade) |  | - | - | - | 1.30 | 2.97 | 5.01 | 4.22 |
| SEm + | - | - | - | - | 0.50 | 1.35 | 1.22 | 2.27 |
| CD (0.05) | - | - | - | - | 1.55 | 4.12 | 3.76 | 7.01 |

[^0]The sigaificant effect of ehate on phooptorua content of leaf and stem + petiole was noticad only at certain etagea of growth but the total uptake of phosphorum wea significantily influenced by ehading at all the atagee of growth. The contants ranged fros 0.29 ; to $0.43 ., 0.19$, to 0.31 and 0.100 to 0.16 ; por cent, reppeotively in the case of leaf, sten + petiole and tubere, at all ataget of growth in all the shade levels. The variation in content between troataents was wide and no general trend could be observed.

In apite of the non-algnificant effect of ahade on the phosphorus oontent of plant parte at certain atages, the uptake of phosphorus was found to be denificantiy influenced by shading at different atages of growth. The total uptake of phosphorus showed a aimilar trend as in the case of total uptake of nitrogen and that of the total dry woight at all the growth exagea, with the plante without shade and at intenge ghede recording the maximun and minisur uptake vilues, reapective2y. With advancing age, the uptrice want on increasing at all ehade levels and the exient of Inoreaee was more at low and medium mede level.e.

## 3. Content and uptake of potassium

> The data on the content of potagsium in the leaf.

Table 9. Effect of shade on potabsium content of lear and aten + petiole of sweet potato at differont growth stages

| Shade intensity (per cent) | Ieaf gotassius content (per cent) (daye arter planting) |  |  |  | Stem + petiole content (per cont) <br> (days after planting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 30 | 60 | 90 | $\begin{gathered} 110 \\ \text { (harvest) } \end{gathered}$ | 30 | 60 | 90 | $\begin{gathered} 110 \\ \text { (hervest) } \end{gathered}$ |
| 0 (no ahade) | 4.23 | 4.22 | 3.59 | 4.04 | 5.58 | 4.88 | 3.89 | 4.85 |
| 25 (104 mhade) | 4.58 | 3.83 | 3.46 | 4.20 | 6.16 | 5.03 | 3.89 | 4.43 |
| 50 (mealua chede) | 4.58 | 4.40 | 3.72 | 4.34 | 6.65 | 5.22 | 4.42 | 5.53 |
| 75 (higha made) | 4.79 | 8.42 | 3.85 | 4.50 | 6.84 | 5.60 | 4.17 | 4.75 |
| SEA $\pm$ | 0.04 | 0.10 | 0.04 | 0.02 | 0.11 | 0.18 | 0.05 | 0.03 |
| CD ( ${ }_{0}$ | 0.12 | 0.30 | 0.12 | 0.06 | 0.33 | 0.05 | 0.15 | 0.09 |

Table 10. Effect of ghade on potaseiun coutent of triber and on total ugtake of potassium by aweet potato at difierent croulin atages

| Shade intensity (per cent) | Fuber potaseium content (per cent) (days after planting) |  |  |  | Total potassium aptake (kg ha ${ }^{-1}$ ) (days aftor planting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 30 | 60 | 90 | $\stackrel{110}{(\text { narvest) }}$ | 30 | 60 | 90 | $\begin{gathered} 110 \\ \text { (harvest) } \end{gathered}$ |
| 0 (no shade) | 1.54 | 1.45 | 1.61 | 1.47 | 73.88 | 318.29 | 390.66 | 499.49 |
| 25 (10w shade) |  | 1.15 | 1.43 | 1.55 | 32.18 | 147.61 | 226.42 | 249.33 |
| 50 (medun ahnde) |  |  |  | 1.64 | 26.36 | 75.23 | 168.55 | 286.71 |
| 75 (high ahade) |  |  |  |  | 22.11 | 54.65 | 82.57 | 72.02 |
| SEm + |  |  |  |  | 8.92 | 18.05 | 22.60 | 42.67 |
| CD (0.05) | - | - | - | - | 27.48 | 55.64 | 69.64 | 131.49 |

Fig.5- Uptake of nitrogen, phosphorus and
potassium as affected by varying shade

stem + petiole and tubers along with the total uptike of potasalum are presented in Tables 9 to 10 and Yig.5. The analyaie of variance is given in Appendix 8.

The effect of shade on the above oharacters was found to be algaificant at all the growth stages. The content ranged irom 3.46 to $4.79,3.88$ to 6.84 and 1.15 to 1.64 por cent in the leaf, stem + petiole and tuberb, respeotively, at all shade lerels, throughout the growth atages. As in the oase of nitrogen and phosphorug contente, the potaseiw content also chowed high variability betwoen ehade levels at different stages of growth.

The potasmiun uptake of individual plent components, Viz. leaf, stem + petiole and fubers, was algaificantly influenced by ahading at all erowth stages. Total uptake of potassiun by the plant closely followed the trend of total uptace of nitrogen and phoophorus and the total dry weight of plant.
II. Boil characters

Soil nutrient stetus

The data on the soil nutrient ewatue arter cropping with sweet potato aro prosented in the Table 11. and the analyais of variance is given in Appendix 9.

Shade hed a significant effeot on the contente of

Table 11. Futrient etatus of the goil after the orop of sweet potato

| Shade intoneity (per cent) | Nuterient |  |  |
| :---: | :---: | :---: | :---: |
|  | Totel <br> iitrogen <br> (per cont) | Availeble phosphorue (ppin) | Available poterefun (ppa) |
| O (no ahade) | . 0.106 | 1.40 | 89.88 |
| 25 (20w ahade) | 0.125 | 2.77 | 95.23 |
| 50 (asatun ghade) | 0.087 | 1.51 | 97.15 |
| 75 (hath shade) | 0.103 | 3.30 | 195.20 |
| $\operatorname{sen} \pm$ | 0.004 | 0.202 | 1.472 |
| CD (0.05) | 0.013 | 0.624 | 1.536 |

total nitrogen, available phosphorus and available potabelum in the soil after the cultivation of aweet potato. The available potassiun content of the soil showed an increasing trend with incressing ainade levels. Howover euch definite pattern wae not obgerved with tatal aitmogen and available phoophorue.

On comparicon with the initial nutrient status, the total nitrogen showed a alight increase while a decrease was noted in the case of evailable phosphorue and available potassiun contents.

## DISCUSSION

The resulte of the present atudy indicated that there was a mharp decrease in gield due to mading in aweet potato. The percentege jields $2 \% 25$ and 50 per cent enade levels were 21.3 and 1.8, respeotively, of tinat in une open and af 75 per cent shade, there was no hapvestable produce. The regonee to increagine levele of shade followed an exponential pattom. Based on the gield trend, ereet gotato may be clacsified as 'gade-sanaltiva' and this orop may not hence bo considered euited for interoropping.

The above drastic decrease in gield is inconsietent with the gencral frowth porfowance of the plant quasured in terme of dry nattor accualation and other growth observations. In the cace of dry metter jield at harvent (Table 4), the percentage valuea wore $48.8,44.3$ and 12.5 per cent respectively (or that in the open) at 25 , 50 and 75 por cent shade. As aentioned aniler, the pattern of responge in termo of suot of the other growth charactors was aloilar to that of ary mattor acoumuiation with minor 1ndividual exceptione. Absuming that total ary matter gield nay be ueed as a measure of the photorgnthetio accumulation'by the plents, it may be concluded that the sweet pointo plant failed to tranglocato the photoagnthates to
the economic plent dart an shade intonolites inoroased. The decrease in dry matter accumulation consequent to a decroase in illuaination must normally be oxpeoted as a larger propertion of leaves would tend to fall below eaturating light intensities or oven below conpenation points with increasing shade levels.

An asesesment of the extent of mutual madine that might have occurred oan be had from the data on leaf area inder (Fabla 2). In general, the canops was denge and LAI high. In the open, the IAI valuee wore greator than 4.0 oven from 30 days after planting and reacked the palk of 11.0 at harvent. Though reports on the optiava LAI of sueet potato are not available fron interature, a conparison with an optimur of 3.0 to 4.0 reported for gebame uith horizontally oriented leaves (Arnon, 1975) would indicate that LAI of this eweet potato crop was probably euperoptimal. One of the important factore that deoides the optimum values of LAS is the leas orientation. it has been reported that in sweet potiato, mutual ehading is reduoed to an extent through the scattering of leaves in difforent positions because of the differencea in the length of petioles (Onwuexe, 1978). Even with such adaptailong, therc was presumably some parasition by the lower leaves even in the open as ovidenced by
the near horizontal leaf orientation and the high leas area indices. As had begn pointed out earlier, with serease in ahade levela, mutual leaf ahadjng and parasitiga would have gone up eubstantialls. However, such oxcesaive parasitism wag counteracted to an extent by a steady and mavked decrease in JAI with increasing ehade level.s.

The data on net aseinilation rato (Table 4) would furtiner indicate the efficiengy of the leaven for photosynthate accunulation. If the ajove mentioned countorbalonoing by a decreaee in LAI was complete and effootive, the sair would have remanned the eame at all ghade levels. The results, on the contrary, ahowed a decrease in this erowth oharacteriatic witin fnoreasing shade indicating again that the proportion of leaves at lower levele of illumination fnercesed becauge of shading, oven though mading was accompaniediby a decresse in the leaf density. Eseed on the obgervations on LAT and MAR, it nay thus be concluded that both deoreace in photosynthetic area and a leorease in the aonn afficlency of the leaves were responsible for the decrease in ary matter accualuletion because of ehading.

While the above two would adequately expiain the variation in dsy matter accumulation and other growth
parameters, these would not explein tile draetic difference in the rasponso in theso charaeters with that of tuber yiexd. Presumably, there was some other influance of chade that decided the partitioning and trenslocation of photosjnthatee to the tubers. A quantitative e日tleante of ouch a dirference in the partitioning of assimilates con be had from the data of baryeet index (Table 4) which was to the tune of 26.0 per cent at full liluminetion and wioh dropped down to $9.4,1.2$ and 0.0 per cent, respectively, at 25,50 and 75 per cont sinede levels.

While mogt of tine erowth charactere followed the same trend as that of the dxy matiter nocualation, length of Fine increased with increasing miade levele. Thougia reports and explanation for such a behaviour of meot gotato are not available, increased length (height) bocause of minding has been reportod in crope like tobacco (Panikar ot el.,1969), ginger (Aclan and Culeumbing, 1976) and cowpea (Tarila
 affected because of anading in aweet potato, though the general trend of reported reaults on other crope was that of en increased chlorophyll content because of madinc (Clark, 1965 in strawberry; Evens and Harray, 1953; Guers, 1971; Okali and Oviant, 1975 in cocoa; Ramewent, 1960 and Venketament, 1961 in tea; Khoselen, 1970 In besn; Cooper
and Qualls, 1967 in alfalfa and blrdsfoot trefoil, Radna, 1979 in pineapple).

The content of the nutrienta, nitrogen, phosphorus and potaselum in tiesueb vas neariy the bame at all shade levele barcing protraoted deviations at cortain stages. the total ugtake of nutidente at harvest, on the contrary, ehowed wide variabion with plants in the open recording the highest uptake and those at intence ahade, the lowest. In general, the uptake of nutrients followed the name oxpected trend as that of dry mater accualation. The frot that there was no doureage in the contont of the nutrients because of dilution effect piay be teken to indicate that the supply of mutrients was alequate from soll. That tine extent of decreape in gield is auch more than the extent of decrease in upteke of nutrients indireotly indiontes that the utilieation effsciency of there nutriente would be lese under ahade than in tine open.

Iata on the coil nuirient atatua aftor oropping (Table 11) would indioate that the aifferences in the contents of nitrogen and phosphorus in coil beiween the chade lovels, though were statiatically gienificant, did not follow any digtinct patteris. In the obse of potasesum, there was a nearly steads increaso in the contente with
increase, in shade levele. A comparison with the ugtake of this nutrient at hervest (Table 10), would ahow that it Pollowed just the reverse trend in the case of uptake. The larger uptake of potacoizar at lower ehade levels might have thus contriduted towards the observed variation in the content of this nutrient in the eoil after oropping.

As compared to the premexperimeatal nutrient statue of the soil, there was a marked increase in the content of nitrogen and a decrease in the case of potasalum after the crop season. The change in phogphorus content was inconsiatent. While the decrease in potassiun content could be explajned as alue to the substintial removal of this autriont from the eoil to the extent of 72.02 to $499.49 \mathrm{kE} \mathrm{he}^{-1}$ at the different enade levalo (Table 10). the increase, in nitrogen content is difficult to explain. The only reacon for this increace appearg to bo thet during the collection of post-inervest moil ausples, oubstantial quantitice of orgenic debria frcm the orgenic manure initially addel might have been included over and above the orgenic matier addition through lear fall.

The general trend of the resulto and the conclueions out of these may do sumaijiged as follows:

1. There was an exponential decrease in yiela of awot potato with increaging ehade levels and hence this orop may be olataified as "ehado-senoitive'. It may not therefore be a crop sulted sor interoropping.
2. There appeare to be some influence of ghade on the pertitioning and tranelocotion of asotailates. This in refleoked in the asriked dinferences in the responsed to ahading betweon dry matier aocumiation and tuber yielde.
3. Sweet poiato appears to be a crop with adaptation for bubatantial adjustrents in leaf area to avoid excessive leấ paragitisn.
4. It appearn that the utilication efficiencier of the nutriente added would be maricedis less under shade than in tine open.

Coleus

Coleus
(Coteue perviflorug, Benth.)
nESULIS
I. Plant characters
A. Bionetric obrarvations

1. Blant height

The onta are presonted in Table 12 and the nalyste of variance in Appendix 10.

Chede had aicnificont affect on plent heledt onidy at 95 dayo aster plantiog. Though varying, glent hoight ehowed an fnoreastin trond upto intermedinto (50 per cent) ginde level and then deoreased at the intenge enade of 75 por cent, but wes more tions thet ins the ope.
2. Mumber of branches

The data are presented in rable $\mid 2$ and the analysics of veriance in Appondiz 10.

Shode nad bicmificant offect on thin nuber of branciea oniy at the initial atage of growth. The general trend wae one of a decreses in tho number af branchee with inoreesin; ehade intencitios at ail stages of growth. The lowect valugo were recorded at the intense ( 75 per cent) shate level.

The number of branchee inoreased with advancing age of the plent.
3. Leaf area indez

The deta are presented in Tavio 12 and the analysis of variance in Appendix 10.

Ieaf area index in coleus. was not significantiy influenced by shade at any of the growth etegen. At 95 days after planting, the value went on increasing uith increaping intensities of chade upto the intersediate chade level and then had a decrease at tive intense sinade level, while at other stages the IAI values decreased with increasing shade 1evele. At hamest, the meximum In was recorded by plants at low ehade intensity.

Dver the ghages, the IAI values increased witn aquancang age upto 95 days after planting in the cace of low and gedius ehade levelo wiile in the oase of no ghade and intense chade levels, the value went on decreasing after 65 dayg of growth.
4. Ghlorophyll content of Leaves

The data on the content of chlorophyll 'a', "b' axd total chloroplyyil along with the ratio of cinlorophyll a-b are progented in table 13 and the analyees of varianco in Appendix 11.

Table 12. Effeot of ghado on plant heleht, number of branches and Lear area index of coleus af varioun growth-etagos


HS Rot aimificant

The chlorophyll 'a', 'b" and total chlorophyll contenta were found to be aignificantly affected by ahade at all etagee of growth. The content of total chlorophyil and its componente went on inoreasing with fnoreasing levels of ghade, with tine plants in the intense ( 75 per cent) shade level and those without shade recordine. the maxiaum and minimus contents, respeotively.

Towarde maturity of the orop, the contents of chlorophyll ' $a$ ' and total chlorophyll, in general, showed a declining trend, while that ois chlorophyll 'b' resained nearly constant.

The offect of ehade on the watio of ohlorophyll a-b was not--alguificant and it remained almost constant at the different shede levele. Thore wan a drop in the ratio at harvest as comparec to that at the eariy stagea of growth. 5. Total dry woight

The data on the total dry weigit per plant are presented in table 14 and Fig. 6. The analyais of variance is givon in Appendix 12.

Total dry weigit per plant was aignificantly influenced by shading at all the grouth etages. The general trand noticed was that of a decrease with inoreasing shado levels.

The maximum and mininuin values wore recorded by plants without ehading and at intense shade robpectively, at al: stagee of grouth. The onky exception was at the 95 days after plenting.

Over the siages, the pajue went on increasing with advencing age, at ail shede levele. Howover, at low and mediun gade levels, there wae a fall in dny matter accumuiation at hargest. The increasing trond was almost steady in all shade levole, at the other stasoe of growth. 6. Net Resimilation rato

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

There was eignificant effect of shade on IAR only betreen 35 and 65 days after planting, when the highe日t and lowest valuee wero recorded by plants without ehade and at intense made lovels, respectively. The effect 0 : shade on NAAR between 65 and 95 dage after planting was not eienificent; there was however, a dractic declino in nean MAN when shading wae more than 50 ger cent.

With advancing age, there was a chavip deciine in UAR. 7. Nuaber of tubers

The data are pressated in Teble 14 and the analymis of vapiance in Appendix 12.

Table 14. Effect of made on total dry welgit, net aseinjlation rete, number of tubers, tuber jield, hanim jield and harvegt index of colela

| Shade intensity (per cent) | Total dxy veight (e plant ${ }^{-1}$ ) (days after planting) |  |  |  | Het assimilation rate <br>  a ${ }^{1}$.. i.....; |  | $\begin{aligned} & \text { Nurber of fubers } \\ & \text { plant } \\ & \text { (days artic } \\ & \text { planting) } \end{aligned}$ |  |  | Fuber <br>  eregh woight) |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 35 | 65 |  | 125 c | Between <br>  <br> 65 daye | $\begin{aligned} & \text { Botween } \\ & 65 \mathrm{~d} \\ & 95 \mathrm{day} \end{aligned}$ | $\text { n } 65$ | 95 | $\begin{aligned} & 125 \\ & \text { arvest } \end{aligned}$ |  |  |  |
| 0 (no chade) | 3.65 | 22.46 | 31.50 | 43.89 | 3.30 | $1.08$ | $\begin{array}{r} 4.24 \\ (2.18) \end{array}$ | 17.7 | 27.1 | 34.10 | 4.80 | 0.61 |
| 25 (low ahada) | 1.97 | 16.55 | 35.10 | 31.95 | 3.34 | 2.26 | $\begin{aligned} & 1.56 \\ & (1.43) \end{aligned}$ | 12.6 | 37.5 | 26.56 | 2.39 | 0.60 |
| 50 (medium zhade | $) 1.73$ | 13.38 | 24.04 | 23.57 | 2.34 | 1.36 | $\begin{array}{r} 0.86 \\ (1.17) \end{array}$ | 6.7 | 33.0 | 20.04 | 3.54 | 0.54 |
| 75 (high shade) | 1.19 | 8.13 | 9.90 | 17.24 | 1.99 | 0.15 | $\begin{array}{r} 0.00 \\ (0.71) \end{array}$ | 1.7 | 39.8 | 9.92 | 2.24 | 0.49 |
| OEm $\pm$ | 0.39 | 1.20 | 3.70 | 5.05 | 0.35 | 0.58 | 0.22 | 1.2 | 3.9 | 2.11 | 0.53 | 0.03 |
| CD (0.05) | 1.20 | 7.16 | 11.39 | 15.57 | 1.06 | HS | 0.63 | 3.6 | 12.1 | 6.50 | 1.62 | 0.07 |

ES = Fiot Eignificant
Figures in perenthesis represent $\sqrt{\mathrm{z}+\frac{1}{2}}$. traneforaed values.

Fig. 6_ Effect of shade on total dey matter.
production of coleus at different stages


Fig.7-yicld of coleus as
affected by varying shade intensities.


Shade had elgaifioant effect on number of tubers at the early itages of growth, at 65 and 95 dage after planting. The maximum and minimum values were recorded by plente in the opex ( 0.0 per cent saado) and at tise intense ( 75 per cent) shade level, reepectively at these stagee and it ghowed a drastic decline with increaging ehade denoities. The trend of reeults at harveot (125 days after planting) was marizediy disferent with the plante in the open recording the lowest tubar nunber and those at the intense ghade, the higiost. The differences between the verious shade levele were however, not atatistically eignificant. At 35 deyg after planting, no tuber was formed in any of the onade levele, while at 65 days after plenting no tuber wass found at the intense shade of 75 per cent.

Over the stages, the value went on inareasing with advencing age.
8. Tuber yield

The data are presented in Table 14 and Fig. 7. The analyeis of variance is given in Appendix 12.

There was siguificant effect of shade on tuber yield in coleus. The maximum gield was obtained from the plants whthout ahside and the aloinum yield from tine antencely shaded plants. The yield data showed a decreasing trend

Fign- . gield response of coleus to varying. shade intersities.

- Estimatad gield
- Obserued yield $\dagger$ value of $x$


With inoreasing chade intensitiec. Almo the differences betweon the ahade levele were atatiatioally signifioant. The yiold obtained at low, medium snd high ehade levelw, expressed as percentage of that at the opon (no hade) were 77.7. 53.8 and 29.1 per cent, respectivoly.

Robponse curve

The tuber gield as a function of shade intencity showed a linear repponse (Fig. 8 and the analyoig of variznce in Appendix 48). The equation of the line is given below.

$$
y=22.66-3.95 x
$$

Whe compificient of deteraination $\mathrm{A}^{2}$ of the above line being 0.9913 , 99.13 per cent of total variation in the response can be explained by the fitted polynomial. 9. Yield of haule

The data are presented in Table 14 and the analysio of variance in Appondix 12.

The effeot of shade on haula yield of coleus was not significant and it ranged from 2.24 to $4.80 \mathrm{t} \mathrm{ha}^{-1}$ ary matter. Ko general trend with fncreasing shade inteneities was noticed.

Toble 15. Effect of chade on nitrogen content of coleus leaf and sten + petiole at different growth atages

| Shade Intensity (por cent) | Leaf aitrogen content (per cent) <br> (days after planting) |  |  |  | Sten + petiole niftrozen content (par cent) (days aftar planting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 35 | 65 | 95 | $\underset{\text { (horvest) }}{125}$ | 35 | 65 | 95 | $\frac{125}{(\text { harvest) }}$ |
| 0 (no shede) | 3.39 | 1.75 | 1.57 | 1.25 | 1.60 | 0.75 | 0.56 | 0.62 |
| 25 (10w ghade) | 4.11 | 2.14 | 1.25 | 1.38 | 2.01 | 0.93 | 0.65 | 0.53 |
| 50 (redivia zhade) | 4.17 | 2.59 | 1.91 | 1.41 | 2.14 | 1.12 | 0.514 | 0.89 |
| 75 (nity shade) | 4.16 | 3.33 | 2.67 | 1.90 | 2.41 | 1.52 | 1.33 | 0.91 |
| $\mathrm{SEm}_{\text {ct }}$ | 0.02 | 0.06 | 0.04 | 0.02 | 0.05 | 0.02 | 0.01 | 0.01 |
| CD (0.05) | 0.61 | 0.17 | 0.12 | 0.07 | 0.03 | 0.03 | 0.04 | 0.02 |

Table 16. Effect of ainade on nitrogen content of tuber and on total uptake of nitrogon by coleus at different growin stages

| Shadecintensity <br> (per cent) | Taiver nitrogen content (per cent) (deye aftar plantiling) |  |  |  | Total uptate of nitrogen (ken ha (day after planting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 35 | 65 | 95 | $\begin{gathered} 125 \\ \text { (narveet) } \end{gathered}$ | 35 | 65 | 95 | $\begin{aligned} & 125 \\ & \text { (harveet) } \end{aligned}$ |
| 0 (no ghade) |  | 0.52 | 0.58 | 0.67 | 21.52 | 23.91 | 23.23 | 26.93 |
| 25 (lou fhede) |  | 0.64 | 0.61 | 0.63 | 11.71 | 21.18 | 25.39 | 19.54 |
| 50 (aedium phade) |  |  | 0.62 | 0.85 | 12.96 | 20.31 | 24.86 | 18.20 |
| 75 (high chade) |  | - | 0.50 | 0.96 | 11.53 | 16.14 | 15.87 | 15.62 |
| $5 \mathrm{Sm} \pm$ |  |  | 0.04 | 0.02 | 2.92 | 3.27 | 4.16 | 3.73 |
| CD ( 0.05 ) |  | - | W | 0.06 | HS | 咀 | WS | H9 |

10. Hervest index

Tae data are preaented in Table 14 and the analyeio of varience in Appendix 12.

Shaie aignificantly affected the harvest index in coleve and the value went on deoreasing with increasing ghade intensities, with plents in the open and et intence shade levele recording tine maxinum and minimum values, respectively.
B. Chemical studies

1. Content and uptake of nitrogon

The data on the content of aitrogen in the leaf, stem + petiole and tubers and the total uptake of nitrogen by plant as a whole are presented in the Table 15 to 16 and Flg. 9: The analysea of variance are given in Appendices 13 to 14.

Sffect of shade on the nitrogen content of leaf, stem + petiole and tuber was gignificant at all the growth stages. The differences in the uptaise of nitwogen be iween the various ghade levels were not significant at any of tiae etages of growth. The nitrogen content in the plant components in generai, showed an increasing trend with inoreasIng ehade intensities, In the case of upteke, the general

Table 17. Effect of ohade on phosphorus contont of coleus leaf and stam + petiole at different growth atages

| Shade intensity (per cent) | Leaf phosphorus content (per cont) (agy after planting) |  |  |  | Stem + petiole phomphorus contant (per cent) (days after planting) |  |  | $\begin{aligned} & 125 \\ & \text { (harvest) } \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 35 | 65 | 95 | $\begin{gathered} 125 \\ \text { (harveat) } \end{gathered}$ | 35 | 65 | 95 |  |
| 0 (no shade) | 0.38 | 0.23 | 0.23 | 0.21 | 0.27 | 0.19 | 0.14 | 0.13 |
| 25 (10w ghade) | 0.40 | 0.29 | 0.23 | 0.23 | 0.29 | 0.23 | 0.20 | 0.13 |
| 50 (mediun ghade) | 0.42 | 0.36 | 0.24 | 0.20 | 0.24 | 0.25 | 0.17 | 0.15 |
| 75 (high anade) | 0.43 | 0.38 | 0.22 | 0.18 | 0.28 | 0.18 | 0.21 | 0.14 |
| S5m | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 0.04 | 0.005 | 0.005 |
| CD (0.05) | 0.02 | 0.02 | 0.03 | 0.02 | st | 0.04 | 0.02 | 0.01 |

$$
\text { NS }=\text { Kot significant }
$$

Table 18. Effect of shade on phosphorus content of tuber and on total uptake of phosphorus by coleus at different grouth stages

| Shace intensity (per cent) | Tuber phoephorus content (per cent) (dego altor planting) |  |  |  | Total uptake of phoephoras (ing ha ${ }^{-1}$ (days after pianting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 35. | 65 | 95 | $\begin{gathered} 125 \\ \text { (narvest) } \end{gathered}$ | 35 | 65 | 95 | $\begin{gathered} 125 \\ \text { (hervest) } \end{gathered}$ |
| 0 (no shade) |  | 0.20 | 0.22 | 0.19 | 2.51 | 3.91 | 5.09 | 6.26 |
| 25 (lov shade) |  | 0.21 | 0.22 | 0.21 | 1.19 | 3.64 | 6.32 | 4.30 |
| 50 (medium mhade) |  |  | 0.22 | 0.22 | 1.35 | 3.37 | 4.21 | 3.71 |
| 75 (high ahade) |  | - | 0.17 | 0.17 | 1.18 | 1.82 | 1.84 | 2.33 |
| Skm |  | - | 0.01 | 0.01 | 0.32 | 0.56 | 0.67 | 0.70 |
| CD (0.05) |  | - | 形 | 0.02 | 0.99 | Lis | 2.06 | 2.16 |

trend was that of a decrease with increasing ehade levels. With the intence ohade and that without ghade levels recording the meximur and wininum contente, reapeotively, and Viee vorsa in tho came of total upiake of nitrogen.

Over the stasee, the content in the leas and sten + potiole ghowed a decrabsing trend with advoncing age until harvest. In the ease of tuber, a slight jnorease was noticed at homvest. Total uptake of nithocen showed an increasing trend upto the premarvest stage. At the time of harrest, it deareaged azcept in the case of plants in the open.
2. Content and uptake of phosphorus

Fine data on tha content of phosphorus in leaf, etem 4 potiole and tuberg and the total wotake of phongionus are presented in mades 17 to 18 and 5 s. 9. Tne analysea of variance are given $5 n$ Appondiceo 14 to 15.

Tuere was gigntizcant oifect of shade on phoppharus content in $20 a f$, stea potiole and taber and on the to inl uptake of phoaphorue at almost all gtages of plont growti. The content ramged from 0.13 to $0.43,0.13$ to 0.29 and 0.17 to 0.22 per onnt $\pm n$ leat, btea + petiole and tubor. rempeotively. The rosulto were hichly variable and the only general trend that could be noticed was that the

Table 19. Effect of shate on potaselum content of coleus leaf and ntea + petiole at various grow th stages

| Shade intensity (per cent) | Leat poterelum content (per cent) <br> (days aftor planting) |  |  |  | sten + petiole potassium contant (per cent) (degs after planting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 35 | 65 | 95 | $\begin{gathered} 125 \\ \text { (narvest) } \end{gathered}$ | 35 | 65 | 95 | $\stackrel{125}{\text { (harveet) }}$ |
| 0 (no minade) | 4.50 | 2.37 | 2.12 | 1.52 | 6.90 | 4.20 | 3.40 | 2.82 |
| 25 (104 shade) | 5.39 | 3.08 | 2.34 | 1.39 | 7.90 | 5.99 | 4.28 | 3.68 |
| 50 (nedius shade) | 5.21 | 3.25 | 2.35 | 1.54 | 7.97 | 6.33 | 4.76 | 4.40 |
| 75 (high ghade) | 5.09 | 3.98 | 3.22 | 1.99 | 7.99 | 6.77 | 5.14 | 4.40 |
| SEm $\pm$ (05) | 0.05 | 0.05 | 0.08 | 0.05 | 0.05 | 0.05 | 0.21 | 0.09 |
| CD (0.05) | 0.14 | 0.17 | 0.26 | 0.15 | 0.15 | 0.14 | 0.66 | 0.27 |

Table 20. Effect of ghade on potabsius content of tuber ond on total aptaize of potagsium by coleue at different grouth stages

| Shade intensity (per cent) | Tuber potasalus content (per cont) (days after plaming) |  |  |  | Total uptake of potassiua ( kg ha ${ }^{-7}$ ) (daye after plenting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 35 | 65 | 95 | $\begin{gathered} 125 \\ \text { (harvest) } \end{gathered}$ | 35 | 65 | 95 | $\frac{125}{(\text { harveat) }}$ |
| 0 (no ghade) |  | 2.35 | 2.04 | 2.20 | 32.77 | 59.82 | 84.81 | 84.98 |
| 25 (low shade) |  | 1.80 | 2.16 | 2.30 | 18.07 | 63.19 | 90.85 | 71.93 |
| 50 (nediua shade) |  |  | 1.95 | 2.30 | 19.39 | 52.61 | 60.89 | 57.95 |
| 75 (hign shade) |  |  | 1.86 | 2.30 | 15.57 | 36.42 | 33.50 | 43.05 |
| 9 Sam |  | - | 0.11 | 0.09 | 4.11 | 7.62 | 12.80 | 9.68 |

103 - Hot significont
phosphorus content ahowed an increasing trend with increasing shade inteneitiee at the eariy gtages of growth. The total phosphorus uptaice also did not show any aistinct pattem betseen the shade levels except at 65 and 125 daye of "growth when the uptake went on decreasing with incresing minade levels.

With age, the leaf phosphorus content gnowea a declinAng trend at all stages of erowth. similar observation could be made in the cage of aten + petiole at lower ahade levels. At mediun and hign shade levela, no distinct trend could be noticed. In eenoral; the total uptake of phosphorue went on increasing with advanoing age, ai all the ahade levele.
3. Content and uptake of potamiun

The data on the content of potesaium in lear, stem + petiolo and tubere and the total uptake of potagelua are given in Table 19 to 20 and Fige 9. The anelyeen of variance are given in Appendices 15 to 16.

Significent effect of shado on the potassium content of leaf and atell + petiole was observed at all the growth ataged. In the case of tuber potabaium content, gignificance could be noted only at 35 dage after planting and in the case of total uptake at 35 and 95 days of erowth. Except at 35 and 95 days after planting, in the case of leaf and

Fig. 9. Uptake of nitrogen, phosphorus and
potassium as a affected by varying shade
intensities in coleus.

phosphorus contert showed an incressing trond uith increasing sinade intensitiee at the early stages of growth. The total phosphorus uptaire also did not chow any distinct pattern between the chade levels except at 65 and 125 days of growth when the uptake went on decreasing with increasing chade levele.

With age, the leaf phosphorus content enowed a deolinAng trend at all atages of Erowth. Simizar observation could be mede in the case of stem. + petiole at lower ahade levele. At mediun ond high shade levele, no aistinct trend could be noticed. In eeneral, the total uptake of phoaphorue went on increasing with davanoing age, at all the ohade levele.
3. Content and uptake of potaraiun

The data on the content of potagaium in leaf, stem + petiols and tubers ond the total uptake of potagaiua are given in fable 19 to 20 and Fig. 9. The snalyges of varionce are given in Appendices 15 to 16.

Significant ofteor of enace on the potasoium contont of leaf and stem + petiole was observed at all ting growth etages. In the case or tuber poteseium content, eignificance could be noted only at 35 days after planting and in the case of total uptake at 35 and 95 days of erowth. Except at 35 and 95 days after planting, in the case of leaf and

- tem + petiole the potaselum consent went on incressing with increaving shade level at all the growth atages. Wo distinct irend was noticed in the case of tuber potasolum content and it ranged srom 1.80 to 2.35 per cent. The total uptake of potaesium aid not mow any distinct trent.

Over the stages, the coritent in the lear and sten 4 petiole showed a declining trend while tuber potaceium contont, in general, showed a olight increase. Uptake of potassiun was increasing with edvancing age upto 95 days after planting end it ahowed a alight deoline at the fintermediate ahado levels. It went on increasing upto harvest in the case of plonts without shade and at intonse enade.

II. Soil characterb

Soil nutrient otatus

The data on the soil nutpient atatue arter the cultivation of coleus are prosented in Table 21 and the analyais of variance in Appendix 17.

The differences in the content of total nitrogen and available potagsium in the soil at different ahade levels were aignificant. No diatinct trend could be observed in total 31 trogen and available phosphorus content with increasing ahade levels but the avallable potsestum content In the boil wag higher at higher chade levels.

Table 21. Effect of ehade on matriont etatus of soil ofter the orop of coleus

| Shade intena1ty (per cont) | Total nitrogen (per cent) | Available photpinorue (ppr) | Ava11able potareiva (pps) |
| :---: | :---: | :---: | :---: |
| 0 (no made) | 0.10 | 1.62 | 73.34 |
| 25 (10w mhade) | 0.07 | 2.30 | 77.57 |
| 50 (nodium shade) | 0.10 | 1.92 | 82.56 |
| 75 (high mhade) | 0.08 | 1.29 | 101.57 |
| $\mathrm{SEm} \pm$ | 0.003 | 0.27 | 1.94 |
| C12 (0.05) | 0.009 | 0.83 | 5.93 |

Comparison with the pre-experimental soll nutriont etatus phowed a glight increase in the total nitirogen content at all the ahade levels except at low ehode. Availeble phosphorus ghoved a elight inorease at low and medium shade levels. The potabsiun contont was mach lower aftor the orop seagon, the extent of deorease being lower at higher shade lovela.

## DISCUSSIOK

The reaulto of the present study indicated that the decrease in gield of tuber in coleus was proportionate to the intenelty of shade and was almost linoar. The maximum gield was obtained in plots uithout ghade and the yielde obtained at 25, 50 and 75 per cent phade levels were 77.7, 50.8 and 29.1 per cont, respectively, of that in the open. An evidenced by the frvercely proportional and linear reaponce of tuber gield to ehade, it may be concluded that coleue is a plant with no speolal adaptrition for growth under enace and may hence be claesified as 'ghade-intolerant'. Such a ghade reoponse will qualify this crop as suitiole for intercropping only under conditione of amplo ilght infiltration. As a rougn indication, it may be noted that in intoreropping situations uith about 50 per cont light infiltration, the yield will be hall as muoh as thet in the open.

Among the two comporente that contributed towards tuber gield vize, tuber number and tuber waight, there wae a positive influence of shads on the number of tubers. However, the contribution by this component towards the sinal gield was meagre and in lact, the relation between the tuber numbor and tubor rield anneared to be inverat. An
indicated from the data on plant height (Table 12), the plante under siade tended to grow longer at least upto snternediato ghade levels and they apparentiy yore slender and weak. The anoote tended to trail on the soil surface which induced tuber formation at the nodes in contact With the soil. Though this contributed eubstantially towards the taker number (Table 14), these failed to develog properly end thus influence the final tuber gield.

An fneight into the probable mechanism responsible for the ahade responce of inis crop can be had froil the comparison of the responec on dry matter accumulation of the arop (Table 14). Total dry veight of the plant at the different atages zolloved an identionl decrease as that of tuber gield, because of ahading. Aesuming again, that dry mater accumulation would be a meabure of photosynthetic accumulation, it may be conoiderea that the photongthetio factors were elnost ezclugively responaible for the observed reaponses to chade.

It may also be worthwile to diecues the componente that were reeponsible for tine variation in dry, matter gield. Amone the two componente that contributo toward photoaynthate aoomulation Viz. leas area and leaf efficienoy. there was increase in leaf area because of shading upto the inturmediate ( 50 per cent) shade level followed by a
conspiouous deciline at intenge (75 per cent) shade. The increase in leaf area index bocaute of shading mey perhaps be a plant adaptation to expose larger photoaynthetic sarface under liaited illumination. However, as indicated by the hish leaf area indices and the almost anverse relation batween dry matter accumilation and the LAI upto the intermediate shade level, it may be concluded that such a plent adaptation was not adventageous in plant comunitios of this crop. A comparison of the Jal values (Table 12) Hould reveal thet the mean values were well above 4.00 at and boyond 65 days after planting and the moan maxinum of 9.46 was noted in the opea, 65 days after planting. The fact that the leaf orientation in coleue is apparently near-horizontal and that the laaf area indices were cosparatively high indicate that there was probably strong muiual shading oven in the open. Since there was inoreane in LaI due to shading, there was prodably much more of mutual shading at these ghede levels. These would have normalily deoreased the efficiency of leaves to photoryntiosiae by nating a larger proportion of lowor leaf surfaces elthar at gub-gaturation or paresitic levele. Therefore, even though there was increase in the photosynthetic surface because of shadingy it did not result in an increase in dry matter yield.

A quantitative estiantion of the efficiency of the

Leave to photosyntherise can be had from the data on net assimilation rate (Table 14). However, theee Sigures are availadie only unto 95 daye after plenting ae further celculation of this growth chafeoteristic could not be done because of leas ehedding after this atage. The avallable deta upto the yeriac of 95 days after plantine. generaliy indicatod a decreage in the officiency of the leaves due to shading.

Even though the patterns of giold and diy mater accunulation followed a precictable deorese with inoreasing ahade levels, the treud in plent helght (Table 12) appesred to be affecent. Hith increasing shsice levels, the plants tended to be taller and this effect wae nearls concletent. Such an induction of plant hoight increase by ohade is in conforaity with the resulte reported on many other crope (Panikar, at al., 1969 in tobacco: Aclan and Quieumbing, 1976 in ginger and marile et al., 1977 in coypea).

The contente of to
(chlorophyil. 'a' and "b') (Table 13) were aignificantly fufluenced by sheding and theis contents went on increasing with incroasing enado levels. This is in egrement uith the findings of Glark (1905), Evane and Murray (1953). Guers (1971), Remansasi (1960), Venicetameni (1961),

Thossien (1970), Okeli and Owusa (1975), Bjorizani and nolmgren (1963), Cooper and Quelle (1967) and Radha (1979). The differences in the ratio of chlorophyll amb reasined non-algnificant and it was loweat at the later stages at all ghade levels which ghoved that the oontent of chlorophyll " $b$ ' fncreaned wille that of chlorophyll ' $a$ ' decreased.

The contents of the nutriente nitrogen, phosphoris and potagsiun in the plent parts showed a porelstent increase because of ehading. One roason attributizble to this is tho dilution offact at high light intensitiea because of higher dry matter, production but the involvenent of other physioIogical factore on the accumalation of nutrients connot be ruled out. The induction of an increase in contonta of aineral nutriente by ohadine has been widely reported in geveral orope (Kyhr and Saeho; 1969; Kraybill, 1922; Guers, 1971; Fretz and Dunham;, 1971; Cantliffe, 1972; Rontiguez at al., 1973; Radha, 1979 and When and Wileon, 19e0). The uptake of these nutriente, on the contrary, regietered a oonspiououe deorease with inoreasing shado levels, the differencer between shade levela being atatisticaliy algnificant in the cass of phosphorius and potassium at most of the stages. Though in the case of nitrogen, this did not attain levels of statistical significance, the trend was ateady and conspicuoue. These decreaser in uptake of
nutrients because of shading would indicate that the effect of deoreasing dsy matter production had the dominont influsnce in decidine total uptake and it could aore then compeneate the increased contents of nutriente rosultink fron shading.

Another encillasy conclusion is that the orop requiregent of nutpiento would be aubstantialiy lese pader chade. If the upteke is taken as en indox of orop requireaent, the quantity of fertilizer needed by this crop would be 72.56. 67.86 and 58.0 per cent, respectively, in the oase of nitrogen at 25,50 and 75 per cent shade levels. The correaponding values for phoaphorus would be 63.69, 59.27 and 37.22 per cent and in the case of potaceium 94.64. 68.19 and 50.66 per cent, nespectively.

Analyele of the soil after harvest of the crop (Table 21) ghowed a ateady inoreage in the content of available potasoium with increasing ehade levels. There was no consistent pattern in the case of total nitrocen and available phosphorus. he comparod to pre-experimental soil etatue, the potagelum content after harvest of the orop was markediy less and that of nitrogen conspieuously more. The avallable phosghorus content ahowed only blight, but protracted changee. The reasone for the deoreage in the content of available potassiun and for the increase in aitrogen content had beon
discuseed already, wisle dealings with ewest potato.

The general conclusion on the resuits and diecuesion may be sunmarised as follows.

1. There was a bignificant decrease in the yield of tuber which was proportionate to the intenelty of ehade and was almost linear. Hence, it may be considered that. coleus is a plant uith no epecial adaptation for growth under chade and may therefore be claselfied as eshadeintolerant'. This would qualify this crop as suitable for interaropping onls under conditions of ample light infilitration.
2. Photosynthetic fectore appear to be almost exclusively resporsible for the obeerved responcee to ahade.
3. There was an increase in leaf area because of anding upto the intermediaie ( 50 per cent) ehade lovel, but it did not result in an increage in dry mattor yield. Strong autual ehading appeared to be probable even in the open.
4. The fertilizer requirenent by the crop would be aubstantially leas under ehoding. Indications are that the nutrient requiremonte of a orop upto 50 per cent shade intensity mag be about 70 per cent of that for a cole crop in the open.

Colocasia

## Colocaela

(Colocapia onculanta ( $\mathrm{I}_{0}$ ) Schott.)
MESUKTG
I. Plant charaotora
A. Blonetric observations

1. Plant height

The data are presented in Table 22 and the analyale of $\operatorname{variance}$ in Appendix 10.

Shade had a elenificant offect on plant helght in oolocasia only at 60 and 90 deys after sprouting when the plant height wont on deorsaaing with inorvasing shade intensity. The plents in the intense ( 75 por cent) ahade recorded the loweet heleht which was atatiaticaily inferior to that at ouber chade levelf. The treatment recelving Iull illumination (0 per cent ehade) recorded the maximum height which wae et par with 25 and 50 per cent ohade. At the eapiler and later otages, the diffarences between. shaes levols vas not aignificant.

Over the etagee, the plant heisat inoreased upto 60 days of sprouting and after this atage a ateady decrease in height wae noticed. The extent of decine after 60 days of aprouting appeared to be ateoper at lower ehade intenoities.
2. Girth at collas

The daka ase gremented in Table 22 and the analyeqs of varience in Appendix 18.

GIrthet collar wan significantly affeoted only at 60 daye after opsouting, when tho higheat and lowest values wero necorded by pleate without shading and at high sade intencities. The girth at intense anedo was statisticeliy inferior to that at other shade levels.

Collar girth was maximan at 60 days aftor sprouting in all shade levels, and then altornate decreaeo and inoreaso was notioed after 60 deya of growth until 150 daye after eproutinge Agoin, as in the case of plant height, extant of deoreace in girth ver arore conepicuous at lower ghade intensitien.
3. Number of tillerg

The data are presented in Table 23 and the analyele of variance in Appendix 19.

Enade had a signifioont effect on this ohareoter at all tagea of plant growth excepting 30 days after groutinge At thege tages, the planta at full illuaination Fecorded the msxinum value. Towest value wes noted at intense (75 per cent) ghade Level at all stages. There

Table 22. Effect of shade on height of giant and girtil at collar of colocasia at different erowth stagee

| Shade intonsity (per cont) | Helght of plants (cm) (daye aiter eprouting) |  |  |  | Girth at collar (cm) <br> (days after sprouting) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 30 | 60 | 70 | 120 | 150 | 30 | 60 | 90 | 120 | 150 |
| 0 (no phade) | 55.3 | 82.6 | 73.5 | 51.3 | 45.6 | 11.2 | 16.3 | 8.5 | 11.8 | 7.9 |
| 25 (100 minade) | 59.1 | 7 7 .1 | 65.9 | 39.2 | 52.0 | 10.2 | 13.7 | 8.7 | 10.1 | 8.9 |
| 50 (nedium eiade) | 68.2 | 68.6 | 62.4 | 57.1 | 51.2 | 11.4 | 12.4 | 8.8 | 9.3 | 9.0 |
| 75 (high shade) | 57.5 | 51.9 | 50.8 | 55.1 | 51.9 | 9.4 | 9.0 | 8.1 | 9.6 | 8.7 |
| Sinn | 4.3 | . 5.0 | 3.5 | 3.2 | 3.0 | 0.9 | 1.0 | 0.4 | 0.7 | 0.4 |

WS $=$ Not significant
Table 23. Effect of ahade on tiller production end leaf area index of colocasia at various grouth atages

| Shade inteñaity (per cent) | Huaber of tillers plant ${ }^{-1}$ (days after eprouting) |  |  |  | Lear area index <br> (deys elter eprouting) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 30 | 60 | 90 | 120 | 150 | 30 | 60 | 90 | 120 | 150 |
| 0 (no rhade) | 4.3 | 11.2 | 11.3 | 13.5 | 12.4 | 0.67 | 1.43 | 0.83 | 0.83 | 0.41 |
| 25 (Jow shade) | 4.9 | 7.7 | 9.7 | 11.9 | 17.7 | 0.73 | 1.13 | 1.07 | 0.74 | 0.55 |
| 50 (medium made) | 3.7 | 5.5 | 7.0 | 10.3 | 8.1 | 0.76 | 0.55 | 0.67 | 0.80 | 0.54 |
| 75 (high shace) | 3.1 | 3.4 | 4.9 | 5.2 | 5.6 | 0.68 | 0.57 | 0.55 | 0.31 | 0.48 |
| 567 | 0.7 | 1.0 | 1.0 | 1.3 | 1.4 | 0.10 | 0.30 | 0.13 | 0.09 | 0.07 |
| CD (0.05) | WS | 3.1 | 3.1 | 3.9 | 4.5 | \$5 | 2is | 15 | 0.29 | HS |

IfS $=$ Hot significant
was a steady deorears in the number or tillere with increasing chado intensities at all the stages of growth. Thouga the differencen between the inaiviáual treatment were not always blgaificant, the general trend was one of decreage in the nuaber of tillere with increasing ginade levele.

With advanoing age, she number of aide sprouts showed an inoreasing trend upto 120 days after aprouting followed by a slight fall between 120 cma 150 days of growth oxcept at the intense shade $1 e v e l$.

## 4. Lear area index

The data are precentod in Table 23 and the malyoie of voriance in Appendix 19.

Sigrificant efiect of alrade on heaf area index in colocesia wes noticed onis at 120 days after eprouting when the IaI in the open was found to be oignititcantly lower than at all other shade levels waich themselves were on par. Ho general trend of treatsent differences could be noted mainly becauge this observation was violated by the acinage of the crop.

Ovor tho otages. LAI was found to be maximum at 60 dass after aprouting at lower shade levels and then there was a decreasing trend until 150 days aftor sprouting.

Table 24. Exfect of chade on content of chlorophyll ' $a$ " and " $b$ " (age $e^{-1}$ frean veigat) of colocasia leaves at marious groutin atagee

| Shade intensity (per cent) | Chlorophyil "a' (deys after aprouting) |  |  |  | Calorophyil "b" (Gays after sprouting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 80 | 110 | 140 | 170 | 80 | 110 | 140 | 170 |
| 0 (no shade) | 1.51 | 1.70 | 1.44 | 1.29 | 1.85 | 2.18 | 1.90 | 0.91 |
| 25 (10\% shade) | 1.30 | 1.70 | 1.48 | 1.22 | 1.57 | 2.13 | 1.94 | 0.65 |
| 50 (medtua ghade) | 1.59 | 1.90 | 1.53 | 1.48 | 1.83 | 2.47 | 2.05 | 1.10 |
| 75 (nigh mhade) | 1.58 | 1.78 | 1.71 | 1.58 | 1.92 | 2.24 | 2.29 | 1.28 |
| SEm $\pm$ | 0.04 | . 0.04 | 0.03 | 0.03 | 0.11 | 0.05 | 0.06 | 0.06 |
| CD ( 0.05 ) | 0.12 | 0.13 | 0.10 | 0.09 | HS | 0.20 | 0.17 | 0.18 |

NS = Mot olgnificent
Table 25. Erfect of phade on total ealorophyll content (mg $g^{-1}$ freeh veigint) and chlorophyll a-b ratio of colocasia leaveo at vasious growth stagee

| $\underset{(\underset{F}{ } \text { Ser cent) }}{\text { Sade }}$ | Total chloropiny 21 (days after eprouting) |  |  |  | chloropayll aso (dayg after eprouting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 80 | 110 | 140 | 170 | 80 | 110 | 140 | 170 |
| 0 (no ghade) | 3.34 | 3.88 | 3.34 | 2.20 | 0.34 | 0.78 | 0.76 | 3.43 |
| 25 (10w ghade) | 2.87 | 3.83 | 3.42 | 2.07 | 0.83 | 0.80 | 0.77 | 1.44 |
| 50 (neasum anade) | 3.66 | 4.36 | 3.64 | 2.58 | 0.79 | 0.77 | 0.77 | 1.36 |
| 75 (hich shado) | 3.50 | 4.02 | 4.00 | 2.86 | 0.92 | 0.79 | 0.75 | 1.27 |
| 95m | 0.10 | 0.11 | 0.09 | 0.07 | 0.01 | 0.01 | 0.01 | 0.05 |
| CD (0.05) | 0.31 | 0.33 | 0.27 | 0.22 | 0.04 | 0.02 | me | H5 |

HS M IVot algaifleant

Other then this general observation, no valld conciusion on the trand could be drawn on the otagerwise variation of individual treatments.
5. Chlogophyll content of leavee

The data on coutente of chlorophyll ' $a$ ', ' $b$ ' and total chlorophylif ratio of ohlorophy $11 \mathrm{a}-\mathrm{b}$ are presented in Table 24 to 25 and the onalvses of variance in Aviendices 20 to 21.

At alnost all stages, the effect of ahede on the contents of cilorophyll ' B ", " $b$ ' and total chlorophyll were found to be eigniffcont. still no generel trend on the variation tith inoreasing shade levels could be discemed. The effect of ahade on chlorophyil atb was found to be significant only at early stages. Here again, no genoral concluaion could be drawn on the trend of reaulte.

Stagomide comparison of the chlorophyll contento showed that the contoat of chiorophyli ' $a$ ' rasained the eane while that of chlorophyil ' $b$ ' decreamed after 140 days of grouth. Consequently total content decreased and the ratio inoreased.

## 6. Total dry weight

The data are presented in Table 26 and Fig. 10 . Tho analyeis of variance is given in Appendix 22.

Table 26. Effect of chade on total dry weight, tuber giedd, hauln gield and hervest index of colocasia

| Shade. intenaity (per cent) | Total dry woight ( 8 plent ${ }^{-7}$ ) <br> (days aftar sprouting) |  |  |  |  |  | Yield of tuber (t ha $\mathrm{ha}^{-1}$ fresh weight) |  | $\begin{aligned} & \text { Yield of } \\ & \text { heula } \\ & \text { (ty hat } \\ & \text { dry weigh } \end{aligned}$ | Earvert index $)$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 30 | 60 | 90 | 120 | 150 | 180 |  |  |  |  |
|  |  |  |  |  |  | (herrast) Totaltuber |  | Side tuper |  |  |
| 0 (no stuede) | 12.6 | 54.7 | 66.6 | 99.8 | 105.4 | 131.4 | 17.51 | 12.54 | 0.21 | 0.948 |
| 25 (10w ehade) | 12.1 | 35.6 | 55.0 | 70.3 | 95.5 | 112.5 | 16.77 | 11.06 | 0.28 | 0.947 |
| 50 (nedius ehade) | 12.2 | 15.3 | 28.6 | 61.4 | 75.3 | 109.2 | 15.77 | 9.75 | 0.41 | 0.922 |
| 75 (high ehade) | 9.0 | 11.4 | 20.2 | 20.4 | 44.5 | 61.0 | 7.29 | 3.47 | 0.39 | 0.875 |
| 85. $\pm$ | 1.6 | 6.9 | 6.4 | 7.6 | 10.0 | 12.9 | 1.81 | 1.34 | 0.07 | 0.012 |
| CD (0.05) | HS | HS | 19.7 | 23.5 | 30.9 | 39.7 | 5.58 | 4.12 | Ws | 0.038 |

MS $=$ Hot algaificent


Fig:11. Yield of colocasia as affectad by vasying shade intzusities.


The results indicated that cinade had a gignificant offeot on plant dry woight throughout the growth stagee exoopt at the indutal stages. Barring the initial stage, in general, there was a decline in plant dry welght with increasing intensitios of enade. However, the treatment differences were algnificant from 90th day onwarde.

The plant any veicht alowed a mariked and steady increase over the stages. The extent of buch inorease was prograseively higner with deoreasing ghede levels.
7. Net aseimilation rate

NAR was elso caloulated betwoen different etages but the data ere not presented since those were violated much by occasional asosge ofthe crop by olight (Phytaphthora palmivora (Butier) Butler) and aleo by the attack by wild boar.
6. Triber yiola

The data ace presented in Table 26 and Fig. 11. The anslysis of variance 2 a given in Appendix 22.

The tuber yiold was alemificantly affected by chade. The plants in the open recoraed the higizest gield of both total tubers and eide tuberb, and that at the intense shade level the lowest jield. The yield ahowed a declining trend

Fig. 12_ yield eesponse of colocasia to vatying
shade levels.

wath inoreaeing shede intengitien. However, the gield at full illumination yae statistically at par with loy ( 25 per cent) and mediun ( 50 per cent) mhade levels. It was aleo noticed thet the proportion of side tubers to total tuber gield decreased with inoreasing ehade intenesties 1.e. 71.62, 65.75, 61.03 and 47.6 per cent at full illumination, low, nediun and high ohade levele, respectively. Calculated as percentage of the gield in the open, the gielde at low, hediun and high ohade levels ware $95.8,90.1$ and 41.6 per cont, reapectively.

Reeponse ourve

Bffect of different intenettion of ehade on tuber yield of colocasia was not lisear but was exponential. The logaritho of gield as a function of ghede inteneity wae found to give parabolic itt to the data (P1g. 12 and the analyeis of varience in Appendix 48). The equation of the ourve is as follows.

$$
\log _{10} y=1.2311-0.0584 x-0.0198 x^{2}
$$

The comefficient of determination of the curve was found to bo 0.9105 , which showed that 91.03 per cent of the total varistion in the response can be explained by the ilited polynomial.
9. Field of haulm

The data ore presented in Table 26 and the amaysis of variance in Appendix 22.

The influonce of ehado on haulm gield was not migmificent and it ranged from 0.21 to $0.41 \mathrm{tha}^{-1}$. Mininua yleld was obtafned from the plante in the opon.
10. Harveet indox.

The date ace prosented in Table 26 and the malyais of veriance in Appendix 22.

It was noticed that shade had a significant effect on the hervest index of colocasia. The value showed a declining trend uith increasing shede Intenalities. The plants in the open and at intense shade level recorded the maximum and minimum values, reapectively, but the paluea at 25 and 50 per cent ghade wore abatistically at par with that in the open.
B. Chericsi studies

1. Content and uptake of nitrogen

The data on the contont of nitrogen in leaf. pasuioatem and tubore and the total uptake of nitrogon by the plant are presented in Tablee 27 to 20 and Fig. 13. The enalyses of variance aro given in Appendices 23 to 24.

Table 27. Affect of ehade on nifrogen content of leaf and pseuciostem of colocasia at different grow th otages

| Shede inteneity (per cent) | Leaf nitrogen content (per cent) (days aiter aprouting) |  |  |  |  |  | Pseudoster nitrogen content (per (dags after oprouting) cent) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 30 | 60 | 90 | 120 | 150 | $180$ <br> arvest) | 30 | 60 | 90 | 120 | 150 | $180$ <br> arvest |
| 0 (no ghade) | 3.84 | 4.20 | 4.07 | 3.86 | 3.81 | 3.08 | 2.14 | 1.81 | 1.87 | 1.64 | 1.50 | 1.63 |
| 25 (low ehade) | 4.33 | 3.99 | 4.18 | 4.30 | 3.75 | 3.00 | 2.43 | 1.69 | 1.95 | 1.89 | 1.53 | 1.54 |
| 50 (medium ohade) | 4.17 | 4.09 | 4.71 | 4.11 | 3.83 | 2.85 | 2.26 | 2.06 | 2.02 | 1.83 | 1.34 | 1.36 |
| 75 (hich shade) | 4.01 0.03 | 4.89 0.07 | 4.75 0.17 | 4.44 0.06 | 4.25 0.07 | 3.07 | 2.06 0.03 | 1.94 0.10 | 2.10 0.03 | 2.35 | 1.85 0.03 | 1.74 0.03 |
| CD ( ${ }_{0}$.05) | 0.11 | 0.23 | 0.35 | 0.19 | 0.21 | 0.12 | O. 10 | HS | 0.09 | 0.07 | 0.08 | 0.10 |

HS a Mot sigmificant
Table 23. Effect of shads on nitrogen content of tuber and on totel nitrogen uptgive of colocesia at various exouti atages

| Ghade intenelty (per cent) |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 30 | (daye after eprouting) |  |  |  | (daye arter sprouting) |  |  |  |  |  |  |
|  |  | 60 | 90 | 120 | 150 | $180$ arree | 30 | 60 | 90 | 120 | 150 | $180$ <br> ryest |
| 0 (no chade) |  | 0.44 | 0.47 | 1.22 | 1.18 | 1.26 | 14. |  | 34 |  | 53.62 | 63.79 |
| 25 (low mhade) | - | 0.45 | 0.44 | 1.34 | 1.18 | 1.24 | 15.3 | 25.72 | 32.41 | 44.95 | 49.22 | 53.65 |
| 50 (medium medo) |  | 0.60 | 0.46 | 0.44 | 1.14 | 1.38 |  | 13.68 | 20.70 |  |  | 56.90 |
| 75 (higa made) |  | 0.56 | 0.48 | 0.67 | 1.26 | 1.49 | 10.5 | 12.12 | 16. 15 | 12.14 | 26.25 | 35.08 |
| SEa $\pm$ |  | 0.02 | 0.01 | 0.03 | 0.01 | 0.03 |  | 5.40 | 4.03 |  | 5.20 | 5.85 |
| CD (0.05) | - | 0.05 | 0.03 | 0.03 | 0.03 | 0.03 | HS | 16.6 | 12.42 | 13.11 | 16.04 | NS |

HS = Dot sigrificant

In general, the content of aitrogen in the leaf, pseudoetor and tubere and the total ugtake of mitrogon were found to be oignificantly affected by the different chade levela, throughout the growth stages. The average nitsogen contont ranged frow 2.85 to $4.69,1.34$ to 2.43 and $0.4 \%$ to 1.49 per cont, respeotively, in the case of Leaf. pereudosten and tubere. The mean total uptaike of nitrogen ranged trom 10.56 to $63.79 \mathrm{~kg} \mathrm{ha}^{-1}$. Though we differences in aitrogen content betweon different ehade levole were giatieticalig oignifioant at all mtages of growth, the variabilitivy in the reaults were too high to draw any gineral concluelon. The total uptaice of nitrogon showed a trond of deorease with increasing shade intenaitiee. It may be notod that tho to tal dry sater aecualulation by the plant also ehowed an identionl trend.

Over the ategea, the content aid not show nuch reduction at later atages of growth in the oase of leaf and psaudostem, waile in the trbere, a elight increace wac noticed at the correspondins period, at ell the shade intenelties. The total uptake of the nutrients yont on fnoreabing with advanoing age, the maximum uptake values being recorded at the harveet stage, at all the ghade levele.

Table 29. Effect of shade on phomphorus content of lear and pseudosten of colocasia at different growth stagea

| Shade intenatity (per cent) | Leal phoephorus content (per cont) (daye after gprouting) |  |  |  |  |  | Peeudosten phoghorus coniant (per cent) (days efter sprouting) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 30 | 60 | 90 | 120 | 150 | $\begin{gathered} 180 \\ \text { (harvest) } \end{gathered}$ | 30 | 60 | 90 | 120 | $150$ | $\begin{gathered} 180 \\ \text { arvest) } \end{gathered}$ |
| 0 (no ghade) | 0.46 | 0.44 | 0.39 | 0.45 | 0.43 | 0.27 | 0.56 | 0.60 | 0.48 | 0.43 | 0.57 | 0.33 |
| 25 (lou chade) | 0.52 | 0.43 | 0.37 | 0.45 | 0.40 | 0.23 | 0.59 | 0.48 | 0.43 | 0.47 | 0.51 | 0.43 |
| 50 (mediki mhade) | 0.54 | 0.54 | 0.38 | 0.43 | 0.42 | 0.23 | 0.45 | 0.73 | 0.39 | 0.46 | 0.45 | 0.32 |
| 75 (higi ehade) | 0.57 | 0.57 | 0.42 | 0.51 | 0.40 | 0.23 | 0.60 | 0.61 | 0.40 | 0.53 | 0.43 | 0.35. |
| Snx $\pm$ | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.03 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD $\left(\overline{0}_{0} 05\right)$ | 0.04 | 0.02 | NS | 0.04 | ES | 0.03 | 0.03 | 0:03 | 0.03 | 0.02 | 0.04 | 0.04 |

Table 30. Effect of shade on tuber phosphorus content and on total uptake of phosphorus by colocasia at different growth atages

| Shade Intensity (per cent) | Tuber phosphomus content (per cent) (dags after aprouting) |  |  |  |  |  | Total uptake of phoephorus ( $\mathrm{kg} \mathrm{ha}{ }^{-1}$ ) (dage after sproating) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 30 | 60 | 90 | 120 | 150 | $\begin{aligned} & 180 \\ & \text { (narvert } \end{aligned}$ | 30 | 60 | 90 | 120 | 150 | $\begin{gathered} 180 \\ \text { (hervest) } \end{gathered}$ |
| 0 (no shade) | - | 0.22 | 0.25 | 0.18 | 0.21 | 0.33 | 2.42 | 8.48 | 7.98 | 8.60 | 9.03 | 16.16 |
| 25 (low shasie) |  | 0.23 | 0.12 | 0.22 | 0.16 | 0.29 | 2.49 | 5.12 | 4.92 | 7.98 | 7.40 | 11.91 |
| 50 (aediam shade) | - | 0.24 | 0.11 |  | 0.32 | 0.19 | 2.26 | 3.05 | 2.63 | 5.02 | 9.51 | 7.64 |
| 75 (high shade) |  | 0.26 | 0.14 | 0.25 | 0.27 | 0.16 | 1.97 | 2.19 | 2.18 | 2.85 | 4.65 | 3.72 |
| CDE ( 0 | - | 0.03 | 0.01 0.03 | 0.01 | 0.03 0.09 | 0.02 | 0.30 | 1.07 3.31 | 0.73 | 1.11 | 1.14 | 1.14 |
| (1).05) | - | NS | 0.03 | 0.03 | 0.09 | 0.06 | HS | 3.31 | 2.24 | 3.42 | 3.52 | 3.52 |

MS $=$ Hot significant
2. Content and uptake of phosphorus

The data on the content of phosphorus in leaver, peoudostem and tubers along with the total uptake of phosphorue are precented in Tablem 29 to 30 and Fig. 13. The analyses of varience are given in Appendices 25 to 26.

There was slgatifioant affect of ahade on tine contont of thie nutrient in the.leaf, peoudostom and tuber in almost all the growth btages. The average content renged from 0.23 to $0.577,0.327$ to 0.73 and $0.11 \%$ to 0.33 por cent, reapoctively, in the leas, preudostem and tuber. As in the cese of nitrogen content in the pient parte, the variability in the phosphorus content dus to mading was also too high to draw out any general conclusion. Betweon the plont conponente, the content was the nignent in paondostem and the least in tubore, at all the stages of growth. Jugt like mitrogom uptake, the phoaphorue uptake by plante also diowed an identical trend ae that of total ary wejgit.

Comparison betwean the atages, showed that the aontent in the leaf and peeudosten deoreased aftor 120 degs after sprouting, while the content in wise tuber rexained nearly the same. The total uptake of the autrient mowed a $\quad$ eteadr increase upto 150 daye nfter aprouting followad by

Table 31. Effect of zhade on leaf and peeudoatem potaseiur content of colocasia at different growth stagee

| Thade intensity (per cont) | Loat potacaium content (per cent) <br> (days after sprcuting) |  |  |  |  |  | Pseudosiea potagsiun content (per cent) (days after sprouting) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 30 | 60 | 90 | 120 | $150$ | $180$ | 30 | 60 | 90 | 120 | 150 | $\begin{gathered} 180 \\ \text { (harveat) } \end{gathered}$ |
| 0 (no shado) | 5.75 | 5.06 | 4.29 | 4.43 | 4.01 | 2.96 | 8.89 | 8.67 | 7.01 | 7.39 | 6.70 | 5.37 |
| 25 (low mhade) | 6.52 | 5.26 | 4.74 | $4: 65$ | 4.14 | 3.14 | 9.45 | 8.85 | 7.35 | 7.70 | 7.08 | 5.82 |
| 50 (seadua rhade) | 5.69 | 4.81 | 4.71 | 4.60 | 4.70 | 3.48 | 9.64 | 9.12 | 8.01 | 3.03 | 7.29 | 5.78 |
| 75 (hich chade) | 5.92 | 5.27 |  |  |  |  |  |  |  |  |  | 6.98 |
|  | 0.11 0.35 | 0.07 0.22 | 0.06 0.19 | 0.09 0.28 | -0.08 | 0.09 0.30 | 0.10 0.30 | 0.08 | 0.08 | 0.07 | 0.09 0.28 | 0.15 0.47 |
| (0.05) | 0.35 | 0.22 | 0.19 | 0.28 | 0.23 | 0.30 | 0.30 | 0.24 | 0.26 | 0.22 | 0.28 | 0.47 |

Fable 32. Effect of shade on tuber potaeedim content and on total uptake of potasein by colocabia at dificrant grouth stage

|  | Tuber potassiua content (per cent) (acys after oprouting) |  |  |  |  |  | Total uptwice of potaesiun (kg has (days after bprouting) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 30 | 60 | 90 | 120 |  | $80$ veat) | 30 | 60 | 90 | 120 | 950 | $180$ |
| O (no ghade) |  | 2.6 | 2.60 | 2.48 | 2. | 2. |  | 106. |  | 118.14 |  |  |
| 25 (10w chade) |  | 2.81 | 2.63 | 2.76 | 2.25 | 2.55 | 40.12 | 75.81 | 32.05 | 92.99 |  |  |
| 50 (nodibi ahade) |  | 3.26 | 2.54 | 2.49 | 2.23 | 2.62 | 35.91 | 34.53 | 47.34 | 81.17 | 83.7 | 1110.46 |
| 75 (nigh ahade) | = | 3.58 | 2.92 | 2.72 | 2.38 | 2.71 | 25.75 | 27.05 | 37.34 | 35.58 | 51. | 660.45 |
| $\operatorname{SDA}(\mathbb{O} .05)$ | - | 0.03 0.10 | 0.07 | -0.06 | 0.07 | 0.06 | 4.69 | 14.23 | 10.23 31.52 | 9.91 30.55 | 3.7 | 12.00 |
| CD (0.05) | - | $0.10$ | $0.22$ | $0.17$ | HE | $0.19$ | DS | $43.96$ | 31.52 | $30.55$ | 30 | $36.98$ |

Fig. 13- uptake of nitrogen, phosphorus and potassium

a daoreace in the case of medium and high shade levels and eubstantial increase in the case of plants in the open and at 20 w ahede interieity.
3. Content and uptake of potassium

The data on the potascium oontent in the leaf, pesudostem and tubers along with the total uptake of potaseluan are given in Table 31 to 32 and Fig. 13. The anelywee of variance are given in Appondices 27 to 28.

The effect of cinde on the content and uptake of potaselum was significant at all the atages of growth. Barring the slight variationsat some of the atages, the leas and pseudoatem contente of this oleant increased with increasing shade intensities. The range in potativin In the leaf, pseudostem and tubors were, reepectively, fron 2.96. to $5.62,5.78$ to 9.77 and 2.25 to 3.53 per cent. The peoudostea and tuber potabsiun contente wore almosi one and a half times more and tao times leas than that in the'leaf, respectively at all the crowth stagea. The potaseiua uptake olosely followed the pattern of nitrogen and phosphorius uptake, which decreased with increasing ahade intenaities.

With adfonoing age, the contente in all the plant components chowed decraasing urend at all the ahade

Table 33. lintrient status of the soil after the crop of colocasia

|  | Soil nutirients |  |  |
| :---: | :---: | :---: | :---: |
| Shode intenai站 (per cent) | Total nitrosen (per cenb) | Available phozphorus ( $\mathrm{p} p \mathrm{~m}$ ) | Avoliable potaaziua (ppra) |
| 0 (no shade | 0.101 | 1.00 | 117.12 |
| 25 (10w ehede) | 0.113 | 3.05 | 127.87 |
| 50 (mediun mhade) | 0.098 | 1.57 | 137.09 |
| 75 (algi minads) | 0.117 | 2.93 | 144.0 |
| SEn $\pm$ | 0.003 | 0.19 | 2.02 |
| OD (0.05) | 0.003 | 0.59 | 6.25 |

intergitice wheread the ugtake chowed an increasing trend. thue maximus uptake was noticed at the harvest etrge.
II. Soil choracters

Soil muzient atatao

Fine data on the aoil nutrient statze after the orop of colocnela ase presented in Rable 33 and the analyois of variance is Appendiz 29.

There was olgnificant exfeot of shade on soil nutrient statua after the orop of colocasia. Ho genemal trend with increasing shade levels was noticed except in the case of available potaseiun, which increaeec with increasing intenoities of babde.

On comparison with the pre-experimental nutrient statue (Table 1) it was observed that avallable phoophorus content decreaced while available potasbiuw content increased. The total nitrogen content was found to be slightiy inoreaced after cropping with colocasia.

## DISCISSIOM

The discussion of the results on colocasia ney be done only with the reservation that there had been nome demage of the experimental orop at disferont stages. The danages occurred because of the incidence of blight (Phytophthora palmivora (Butior) Butier) that mainiy afleoted the leavee and becaume of damage to the tender leaves at the early atages by the wild boar. Atteapt on indexing the degreas of dasage ves not ande as it occurrad at varying periode at widely varying intensities. As it was felt that dasage was grosely minor; the gield levels even with damege wore reasonably high and the retulte were atill dependabie, the data are prosented end discussed.

Ropults on tuber gield indicated that the gield decreased bocause of ehading. But the extont of decrease with increasing ghade levela followed a difforent pattern from that of other crope, with the yield decrease being sanall upto 50 per ceat thading. Subetential yield deorease occurred only at the intense ahade levol of 75 per cent. Expreesed as percentage of the gield in the open, the gield at 25,50 and 75 per cent chade levele, ware $95.8,90.1$ and 41.6 per cent, respectively. A najor difference in the tuber developenent gattern was the the contribution by side
tubers was higher at lower ahade intencities. The corresponding valueg of the percentage weight of alde tubera (expresed an percentage of the total tuber veight) were 71.6, $66.0,61.3$ and 47.6 yer cent, reapeotively, at full illuaination, iow, medius and high chade levele. The pattern of total tuber gield with increabinc shade levels pollowed an expononital trend and the equation of the curve wan as follows.

$$
\log _{10} y=1.2311-0.0534 x-0.0198 x^{2}
$$

Ae would be evident from a erephionl presentation of this funotion, the gield decrense was vary aasil upto 50 per cont ahade and there was a harp decline aftarwerde. Statigtical analgaic of the siold data showed that the jielde in the open, 25 and 50 per cent mhaces were at par and the gield at intense shade of 75 por cent wae significantly lower. Based on thie yield trend it aag be anfe to assume that thic orop has aome mechanian by wich ylold deorease ís inhiolted upto reasomble ehade levels and that thin crop may thoreione be olasaified as 'shade-tolerant'. It would therofore qualisg thie orop to be a euttable intercrop in shede siturtione atleast upto 50 per cent ILeht snfiztration.

A discussion on the probable eeohe for euch a ehade toleronce of thle crop may be made with
the help of the other growth end growth exalysis observetiono. A comparison with total dry watter accunulation (Table 26) would indicste that the pattems of reepoine on-tuber yield and dry matter accumulation were nearly Lientical. This siailarity in the trend along with the faet that the differences in the hervest index were minor betweon chade levels aray be talen to inaicate tiat photosynthetlo aechanisa was mainly responaible for the variation in Jield. Uniliee in the case of eweet potato, where was practically little influence of shade on the tranelocation of photosynthates.

An explenation for the above dxy weight and buber yield responsee may be obtained from the data on leal arca index (Table 23). Unlite in the case of oroge-11ke aweet potato and coleus, where the canopies were denee, it was relatively a eparse eanopy in colocagia. the LAI valued were well below 1.0 at almost all the atages with the mean maxinum being only 1.43 in the open, 60 days after eprouting. Even in this treataento the daI values ware well below 1.0 at all tho other stages. As fudiosted by such low leaf area indicos, there was praotioally ilttle chance of oanopy overlapging and mutual oheding at any of the chade levols. Reports generally show thet individual leaf layere of most of the crop plonta reach photoqnthetic esturation at
one-fourth the total solar intensity (Wit, 1967). In the absence of a aignificant mutusi shading, sate of photocynthesis csnnot therefore bo expected to dearease with rasmonable ahading. As indicated inoin the data, it was only at the intense ghede of 75 per cout, that the leaves functioned at sub-anturation light intensities.

Unilico in the case of nost of the other crope tested, leaf donaity in colocasia was alnost unaffected by gaedins. It wac this inherent indoility of the plant to jnoreane the photoaynthetie auriace under shade that was probably remponsibie, at least partiy, for the lack of decreane in giold becauee of ghadiag. To put it in other worde, the colocasia plant te inherently incapable of utilieing the solar radiation efficiently when grown in the open. It would also follow tiat when frown in plant communties, there is scope for aubstantial increase in the gield of the crop ky'ralejing the plant pophation. To conclude, it is the frability of the plont to produce dense canoples and the wide opacing that was given, that were reaponsible for the whade tolerance of this orop. One related concluelom that zay be drawn from the general yield repponse and the senoral trond of LaI values is that there is meope for inoreasing the gield of this crop substantieliy by an inorease in plant population when planted in the open.

A depondable measure of the degres of mutual chading could have beon obtained from the data on net assiailation rate, but because the values were highly violated by orop demage, the resulte ware higily varlable ond, bence, not presented.

Aa had been indicated earlier, the ability of the planta for translocating the carbohyarates to the economio pert was not affected by phaing. The harvent index values In the open, 25. 50 and 75 per cent shade Lovele were, reepeotively, $94.8,94.7,92.2$ and 87.5 por cont. Though the aiffermees do not appeer to be conspicuoue, the herveot index values at medium and high ehade levels were significantly lower than those in the ogen and in the low gnado level.

The effect of anede on the growth parameters was nearly ginilar to that of dry welight and tubse gield. Unilice in the came of aweet potato and coleus, there vas $n 0$ pergietent trend of an increace in plant height bacause of mading.

The chlorophyll content of jeaven (Tables 24 and 25) yay found to be alenificantify influenced hy shading and the contents of total chlorophyll and ite components were found to be increased by hading upto 50 and 75 per cont. shailar obeervations of increase in chlorophyll contemt
booalue of ehading have been reported in crops like girawberry (Clark, 1965), cocoa (Evano and Lurray, 1953; Guers, 1971; 0kali and Owusu, 1975), toa (Ramaswami, 1960 and Venkatonant, 1961), begn (Khossien, 1970), alfalfe arce birderoot trafoil. (Cooper and qualle, 1967) and in pineapgle (Radra, 1979). Uith odvancine age, the content was found to decrease. The ratio of onlorophyll a-b at the Lasi gtage of chlorophyli eatination ( 170 deys after sprouting) wan found to increaco entrply at ell chade levele. Probably, a fester rate of destruetion of chlorophyli 'b' than ${ }^{\prime} a$ ' is thun indicater.

The contents of the manerad nurriente, niturogen, phosphorue and potagsiua in the plant parte followed no distinct trend, though treatment disferonces wero aignificant at some stages. The faot that the contente of the nukrionte did not vary vith difzerences in day matter accumalation, may be taken to indicate tiat mutrient supplying pouer of tine soil was adequete. She uptaine of matritents on tho contery, followed the etine expected trend an thet of dry mattor acoumulation, though the differences in uptalo upto intermediato ( 50 per cent) enade level were not epproiable and orten not significant. It mey therefore be reasonable to assume that the ferililzor roguirement for this orop grown as an intercrop, mey also
be nearif the aane as that of a sole crop cultivated in the open. The total quantitieg of nutrient removed by plante at harvest in the open ware 63.8. 16.2 and 144.1 $\mathrm{kg} \mathrm{ha} \mathrm{h}^{-1}$ of nitrogen, phosphorus and potassiun, respectively.

The nutrient content of the soil after cropping (Table 33) followed the gane trend as that of sweet potato and coleus with the potaosium contont increasing with increasing shade levels. Compared to pre-experimental soil analgsis data (Table 1), there wae a general fnorease In the contont of mitrogen and a substantial decrease in the content of potagesum. Variations in phobphorus content detween anade levels ahowed wide fluctuations. Discussion on thece aepaots has been covered in detail while dealing with sueat potato.

The general conclucions or the reande and dibcuasion may be sumaribed as follows

1. There was a merginal non-sienificant decrease in jield because of chading upto 50 per cent in the case of colocesia, though the highest yields wero obteined in the open. This crop may therefore be considered as - shade-tolerant and womla be hishiv austable for interoropping.
2. Photosymtietic mechomiga appears to bo repponsible for the shade response in this crop. There appeare to be no marked Influance of ehade on the tranelocation of carbohydrates to the tubors.
3. At the normal plonting denisity, colocasia produces only a aparse casopy, thouch it appearb that the crop can ataxd mach deneer canopien in the open and that the yield can be aubstentielly incroased by closer plantias when grown as gole crop.
4. Unlike in tine case of sweet potato and coleus, leaf area in colocasia does not bubstantiaily increase beoauso of theding.
5. The crog requirement of fertilizer rutrienta does not appear to be very much asiected by ehading upto 50 per cent. The fortilizer requireatnt for the sole crop of colocasia may therefore hold good in the cese of interoropped colocasia also as long ag ehading ie not intenge.

Turmeric

Turneric
(Curcuna Longe $I_{0}$ )
gesulf
I. Plant characters
A. Biometrio observations

1. Ylant helght

The data are presentod in rable 34 and the anelysis of varinnce in Appendix 30.

Slenificont effect of shede on plont height was noticed only at the later atages of growth. In general, the height of plants wont on increseing with increasing Intensities of shade upto the intermediate ( 50 per cent) chads level and then nowed a deorease at the intonse (75 por cent) gaade level. As momally expeoted, tise plant hoight went on jnoreasing with advancing age at all shado intensidiez.
2. Number of tillers

The data are precented in Table 34 and the analysis of variance in Appendix 30.
'Signilicant erfeot of sinade on tiller producion by the plant was noisced at 60 and 180 daye artor aprouting.

At these atagee, the number of tillers per plant wont on decreasing with increasing ehade intenaitieg. At 120 dasy of growth, the naxitum number of tiller wan noticed at the low ghade lovel.

Over the stagen, no general trend in tine tiller production was notiead.
3. Leaf area index

The data are presentod in Table 34. and the analysie of varamiace in Appenăsc 30.

The InI in turgeric was oignificantiy influenced by ehading onis at 60 days of growth. The mean valuee varied widely due to dipferent ehade levels at different otages and it ranged from 2.21 to 15.77. The loweat Iai palues were noticed at the intenge shade level at all etages of growth.

There wag sharp increase in the IAI values with advancing age, the mezimum extont of increase being noticed at the internediait ginade level.
4. Chlorophyil content of leavoe

The date on the contenti of chlorophyil ' $a$ ', " $b$ ', total chlorophyll and tie ratio of chloropigy 11 a-b are preaented in Table 33 and the analycis of variance in Appenaix 31.

Table 34. Bfect of shade on plant heigat. number of tillexe and lear area index of turneric at different growth atoges

| Shade intensity (per cent) | Hoight of plant (cn) <br> (days apter sprouting) |  |  | ```Number of fillerg glant-1 (days aftor oprouting)``` |  |  | Leaf area index <br> (days after sprouting) |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 60 | 120 | 180 | 60 | 120 | 180 | 60 | 120 | 180 |
| 0 (no made) | 64.7 | 104.5 | 115.5 | 5.3 | 2.5 | 4.1 | 4.05 | 9.57 | 15.77 |
| 25 (10\% Ehade) | 55.9 | 109.0 | 126.0 | 4.3 | 3.0 | 2.1 | 2.89 | 10.57 | 11.97 |
| 50 (medium shade | 65.7 | 119.4 | 144.0 | 3.9 | 2.1 | 2.2 | 2.89 | 11.46 | 13.44 |
| 75 (high shade) | 57.5 | 107.0 | 133.9 | 2.1 | 1.7 | 1.9 | 2.21 | 8.91 | 9.61 |
| Skm $\pm$ | 3.5 | 3.7 | 3.5 | 0.6 | 0.4 | 0.4 | 0.27 | 1.18 | 2.00 |
| CD (0.05) | 18 | 58 | 10.8 | 1.3 | HS | 1.1 | 0.82 | HS | His |

$$
\mathrm{NS}=\operatorname{Hot} \text { sigmificant }
$$

Iable 35. Effect of piade on content (ag $g^{-1}$ Iresh weight) of chloropayli " $a$ ". " $b$ " and total chlorophyli; ratio of chlorophyll a-b of turmeric. leaves at dipferent growth atages

| Shade inteneity (per cent) | Chlorophy $11 .{ }^{\prime}$ a' (daya after aprouting) |  | Chiorophyli :b* (days efter sprouting) |  | Total chlorophyll (deys after sprouting) |  | Chlorophyll a-b (days after sprouting |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 100 | 160 | 100 | 160 | 100 | 160 | 100 | 160 |
| 0 (no shads) | 0.78 | 0.63 | 1.10 | 0.78 | 1.83 | 1.41 | 0.71 | 0.31 |
| 25 (104 ahacis) | 0.95 | 0.69 | 1.26 | 0.85 | 2.21 | 1.54 | 0.76 | 0.82 |
| 50 (atediun mhade) | 1.14 | 0.87 | 1.43 | 1.07 | 2.57 | 1.94 | 0.79 | 0.81 |
| 75 (high shade) | 1.18 | 0.97 | 1.54 | 1.19 | 2.73 | 2.16 | 0.77 | 0.82 |
| SEm | 0.04 | 0.05 | 0.05 | 0.07 | 0.08 | 0.11 | 0.01 | 0.03 |
| CD (0.05) | 0.12 | 0.14 | 0.14 | 0.21 | 0.25 | 0.35 | 0.04 | 195 |

$\mathrm{NI}=$ Hot dgnificant

The content of total chlorophyll and its componenta were significmidy influencod by chading at all stages of growth. Also the ratio of chloroninyll a-b was algnificantiy affected by chading except at 160 daye of growth. Tise content of total chlorophyil as well agite coaponente incroased with increasing ehode intengitien. The content at full illumination was found to be gtatietioally lower than et the afferorit shade intonaitiea viz. 25, 50 and 75 per cent ehade levele. The ratio of chlorophyil a-b also inoreasod with increaging shade intensity upto medium shade and then decreased.

Comparison between tho stages enowed that the total chlorophy 12 as well as both of 1 te components decreased with advanolue age of tho orop in all shode levele. But the ratio of chlorophyil a-b increased with advanoing age. 5. Total dxy weight

The data are pregented in Table 36 and Fig. 14. The analgeis of varience is given in Appondix 32.

There was significant effect of phade on total dry woight of plant only at the 60 days of growth. The general trend noticed was that of a decrease in total dry weicht with increastas shade intensity. The dry weight at full illunination waich was oignificentily higher than thet at

Table 36. Bffect of ghede on total. dry weight, net.agsimilation rate, tuber yield, hale pield ond harvest index of tupmeric

| Shsde intensity <br> (per cent) | Total dry weignt ( g plant ${ }^{-1}$ ) (daye after aprouting) |  |  |  |  | Bet aspinila-tion rate(E EA-2 dayBetween Botween60 to 120 to120 days 180days |  | Tubes <br> yield <br> (thas <br> fresh <br> weight) | $\begin{aligned} & \text { Haulm } \\ & \text { yitid } \\ & \text { (the } \\ & \text { woight. } \end{aligned}$ | Harvest index |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 60 | 120 | 180 | $\stackrel{220}{(\text { hervent }}$ | $\begin{aligned} & \text { Harvert } \\ & \left(t h a^{-1}\right) \end{aligned}$ |  |  |  |  |  |
| O (no ghaca) | 12.63 | 37.42 | 95.22 | 83.34 | 10.85 | 1.40 | 1.56 | 48.91 | 4.94 | 0.587 |
| 25 (1or ehade) | 7.66 | 38.08 | 81.43 | 94.01 | 10.41 | 1.60 | 1.63 | 48.84 | 3.62 | 0.657 |
| 50 (medium mhade) | 7.24 | 37.72 | 78.41 | 89.62 | 12.05 | 1.58 | . 1.54 | 53.26 | 5.10 | 0.577 |
| 75 (high shade) | 4.67 | 24.99 | 62.49 | 55.69 | 7.89 | 1.36 | 1.49 | 28.89 | 2.75 | 0.649 |
| $\mathrm{SEm} \pm$ | 0.94 | 3.99 | 11.02 | 7.05 | 0.755 | 0.18 | 0.41 | 3.31 | 0.44 | 0.025 |
| CD (0.05) | 2.83 | NS | Ns | 21.72 | 2.327 | ES | NS | 10.19 | 1.35 | HS |

is = Not slenificant

other ghede treateats, at 60 degs of growth, foll ehort of alatiaticajly mienificant avgeriority at later etages.

Over the otagec, the plent ary welght increased marizediy with advanoing age of the plont upto 180 days after aprouting. Begond this atage, tho change in dry waight was not impreasive.
6. Net esalmilation xate

The data are presented in Table 36 and the anolysie of variance in Appendix 32.

The effect of dhade on GAB between 60 and 120 days arter egrouting wee found to bo not sleniflegnt. Ro goneral trend in har with forreasine levele of chede could be noticed.

Similarly, no manked stage-wise variation in RAR vae ovident.
7. Yield

The data are presented in Table 36 and Fig. 15. The analysie of variance ie given in Appendix 32.

The rhizome gield tac found to bs eignipfoantiy influenced by the ahade treataente. daximuz yield was recorded at tine interaediate ( 50 per cont) nede lovel whion was followed by that at full illuaination. This was
olosely followed by the low ( 25 per cent) shade intenaity and the lowest field was noted at the intence ( 75 per cent) Bhade level. The yield at intense ahade wae eigaificantiy lower than thst at other ahade intensities, wion were at par.

The gielde obtained at the low, gedium and high basde levela were 99.86, 108.89 and 57.76 per cent reopectively, of that in the open.

Reaponse ourve
The yield of mingone obtoined at different ghade intensitiea have ceen represented as a function of shade end a cublo polynomial fitted to the logarithme of gield Hag found to give a cloee fit of the reaponse curve obtained (Fifg. 16. and the analygis of variance is given in Appenaix 49). The equation of the carve obtained is an Sollows

$$
I_{I_{10}} y=1.7234+0.0267 x-0.0165 x^{2}-0.0072 x^{3}
$$

The co-efficient of determination $\mathrm{R}^{2}$ was found to be 0.9999. It ahowod that 99.99 per cent of total variation in the response ons be expleinod by the intted polynemial. 8. Yield oi hauln

The data are. presented in rable 36 and the analymis of variance 12 Appendix 32.

Fig.16. yield response of turmeric to different levels of shade.

- estimated yield.


Table 37. Effect of chade on nitrogen content of leaf and pseudoctean of turneric at aifferent growth otageg

| Shade intensity (per cent) | Inaf nitrogen content (per cent) (dage after sprouting) |  |  |  | Peeudosten nitrogen content (per cent) (dogs after sprouting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 60 | 120 | 180 | $\begin{gathered} 220 \\ \text { (harvest) } \end{gathered}$ | 60 | 120 | 180 | $\begin{gathered} 220 \\ \text { (naryest) } \end{gathered}$ |
| 0 (no ehacie) | 2.42 | 1.73 | 1.31 | 0.72 | 1.20 | 0.63 | 0.56 | 0.52 |
| 25 (10w shade) | 2.72 | 1.79 | 1.56 | 0.84 | 1.55 | 0.61 | 0.55 | 0.67 |
| 50 (nedius ginde) | 2.34 | 1.88 | 1.62 | 0.88 | 1.67 | 0.66 | 0.57 | 0.55 |
| 75 (high minde) | 2.66 | 2.07 | 1.76 | 1.02 | 1.51 | 0.86 | 0.67 | 0.64 |
|  | 0.02 0.06 | 0.02 0.07 | 0.01 0.05 | 0.04 0.29 | 0.02 0.07 | 0.01 0.04 | 0.01 0.02 | 0.01 |

Table 38. Effect of shade on nitrogen content of risizome and on total natake of nitrogen by tarmeric at different growhi atage

| Shade intensity (per cent) | Ihizome aitrogen content (per eent) (days after sprouting) |  |  |  | Totel uptake of nitrogen (kg ha-1 (acys after sprouting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 60 | 120 | 180 | $\begin{gathered} 220 \\ \text { (harvest) } \end{gathered}$ | 60 | 120 | 180 | $\begin{gathered} 220 \\ \text { (harvest) } \end{gathered}$ |
| 0 (no shade) | 1.47 | 0.83 | 0.82 | 1.39 | 52.12 | 96.50 | 192.06 | 186.70 |
| 25 (low made) | 1.71 | 0.67 | 0.80 | 1.27 | 36.50 | 100.38 | 172.95 | 215.42 |
| 50 (nedius shade) | 1.80 | 0.96 | 0.90 | 1.38 | 37.96 | 107.52 | 178.92 | 216.85 |
| 75 (hich mhade) | 2.02 | 1.06 | 0.97 | 1.45 | 22.95 | 70.84. | 157.49 | 139.82 |
| SEM ${ }_{\text {c }}+$ | 0.04 | 0.02 | 0.02 | 0.02 | 4.39 | 10.45 | 24.77 | 17.50 |
| CD ( 0.05 ) | 0.14 | 0.05 | 0.07 | 0.05 | 13.52 | WS | FS | 53.93 |

DS = Hot gignificant

The effect of chade on haulus yiela was not elgmificant; sleo no general trend with increasing shade levels could be observed.
9. Harvest index.

The data are presented in rable 36 axd the analyais of varionce in Apgendix 32.

The harvest indox in tarneric was not aignificantiy influenced by enoding end the meximua value was noticed at low ( 25 per cent) ahade level and the ainimum at the intermediate (50 per cent) made level.
B. Cheraical studies

1. Oontont and uptake of nituogen

The data on the nitrogen coniont of leaf, pgeudoeten and shizowe along with the total uptake of nitrogen are prosented in tables 37 to 38 and Fig. 17. The analyses of variance are given in Appendices 33 to 34.

Effeot of ehade on the aitrogen content of leaf, peandosten and shizone was aignifiont at all atages of growth, but totai uptake of the nutriont was elgnificant only at the 60 and 220 dayo of exowth. In general, the leas and raizome nitwogen contente inoreased with increacins enede intensities, whereas the psoudostom content paried

Table 39. Esfect of ghade on phosphoras content of leaf and peoudot tea of tarmeric at different growth stagee

| Shade intencity (per cent) | Lear phosphorus content <br> (per cont) <br> (days after gprouting) |  |  |  | Requdoetem phosphoxas content (per cent) <br> (dage after aprouting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 60 | 120 | 180 | $220$ <br> ryeg | 60 | 120 | 180 | $\begin{gathered} 220 \\ \text { (hervegt) } \end{gathered}$ |
| 0 (no shade) | 0.25 | 0.20 | 0.15 | 0.11 | 0.27 | 0.21 | 0.13 | 0.14 |
| 25 (low shade) | 0.28 | 0.20 | 0.20 | 0.11 | 0.33 | 0.22 | . 0.22 | 0.13 |
| 50 (mealiun bhade) | 0.26 | 0.22 | 0.21 | 0.11 | 0.39 | 0.24 | 0.18 | 0.15 |
| 75 (high ehace) | 0.28 | 0.25 | 0.23 | 0.14 | 0.33 | 0.25 | 0.16 | 0.12 |
| Stan | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.03 | 0.01 |
| CD ( 0.05 ) | HS | 0.02 | 0.04 | 0.01 | 0.02 | 0.03 . | HS | 0.02 |

HS $=$ Hot aigaificant

Table 40. Effect of shade on phosphoras content of raizome and on total uptake of phosphorus by funeric at aifferent grouth atages

| shade intenelty (per, cent) | Rhizome phosphorus content (per cont) <br> (daye after aprouting) |  |  |  | Total uptake of phosphorus ( $\mathrm{k}_{6} \mathrm{ha} \mathrm{a}^{-1}$ ). <br> (dage after aprouting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 60 | 120 | 180 | $\begin{aligned} & 220 \\ & \text { arveat }) \end{aligned}$ | 60 | 120 | 180 | $\begin{gathered} 220 \\ \text { (harvesi) } \end{gathered}$ |
| 0 (no shade) | 0.21 | 0.18 | 0.23 | 0.41 | 6.96 | 16.35 | 37.71 | 37.58 |
| 25 (low shade) | 0.23 | 0.25 | 0.21 | 0.30 | 4.82 | 18.54 | 36.91 | 45.34 |
| 50 (rediam shade) | 0.24 | 0.28 | 0.33 | 0.31 | 5.04 | 20.05 | 44.99 | 45.08 |
| 75 (high mhade) | 0.27 | 0.25 | 0.25 | 0.29 | 3.10 | 13.88 | 30.53 | 25.10 |
| SDam $\pm$ | 0.01 | 0.07 | 0.07 | 0.06 | 0.64 | 1.87 | 6.11 | 4.01 |
| CD (0.05) | 0.03 | 0.04 | 0.04 | IS | 1.96 | 15 | TS | 12.35 |

IS $=$ Not elgnificant

Widely uith fucreasing shade levela and no general pattern could be anoticed. In the case of uptake of this nutrient, there was no porceptible aifferences in the mean valuea Detreen full illuaination, low and medium shade intensities, but that at intonse ghade were generally lower.

The contents of nitrogen in all the plant component enowed a declining teren ufth advoneing age of the plont except that at harvest the chizome nitrogen content mowed an increse an compared to the earlier etage. The uptake went on shoreasing with advancing age upto harvesì except at full illunination in which the increase was noted only upto 180 days of exrowth.
2. Content and uptake of phosphorus

The data on the phosphorus content of lear, peeudosten and rhizome and on the total uptize of phoaphorus by tho plent as a whole are presented in soole 39 to 40 and Fig. 17. The analyels of varience are eiten in the Appandices 35 to 36.

In general, significont effeot of ehade on phosphorue content of afferent plant componente and the uptake of this nutrient was observed at almost all stages of grouth. The content was fomd to inorease with increape in shade in the case of leaf, whereme this was noticed only upto 120 daye of growtin in the case of proudoation and rhizomes.

Table 41. Effect of ahade on potassium content of leaf and pseudosiem of tarmeric at different grouth atages

| Shade intengity (per cent) | Leaf potassium content (per cont) (dayn after aprouting) |  |  |  | Pseuanoten potassium content (per cent) <br> (anys after aprouting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 60 | 120 | 180 | 220 | 60 | 120 | 180 | 220 |
|  | (naryers |  |  |  | (harvest) |  |  |  |
| 0 (no shade) | 5.06 | 4.17 | 3.78 | 2.79 | 6.47 | 4.40 | 3.26 | 2.41 |
| 25 (104 shade) | 5.44 | 4.66 | 4.22 | 3.68 | 7.02 | 5.54 | 3.78 | 3.50 |
| 50 (nediun shado) | 5.43 | 4.40 | 4.37 | 3.62 | 7.70 | 4.86 | 3.65 | 3.24 |
| 75 ( high shade) | 5.25 | $4: 90$ | 4.36 | 4.25 | 7.84 | 6.16 | 4.50 | 4.04 |
| SEat | 0.06 | 0.03 | 0.12 | 0.07 | 0.12 | 0.06 | 0.07 | 0.09 |
| CD ( $\mathrm{O}_{2} 05$ ) | 0,19 | 0.26 | 0.36 | 0.22 | 0.37 | 0.19 | 0.22 | 0.27 |
| rable 42. | Effect of ahede on potassium content of rhizone end on total uptake of potascium by turmeric at different growtin stages |  |  |  |  |  |  |  |
| Shade inteneity (per cent) | Rhisome potassium content (por cent) (days aftem spronting) |  |  |  | Total uptake of potaseiun (kg ha- ) (days after eprouting) |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  | 60 | 120 | 180 | $\begin{gathered} 220 \\ \text { (harvest) } \end{gathered}$ | 60 | 120. | 180 | $\stackrel{220}{(\text { harrest })}$ |
| 0 (no shade) | 4.82 | 3.25 | 2.74 | 3.31 | 153.82 | 327.04 | 671.68 | 546.10 |
| 25 (10w chade) | 5.45 | 3.80 | 3.54 | 3.40 | 98.51 | 404.45 | 688.14 | 731.27 |
| 50 (rediun shade) | 5.22 | 3.70 | '3.45 | 3.34 | 102.19 | 369.56 | 660.23 | 677.04 |
| 75 (h2gh ghade) | 5.40 | 4.36 | 3.80 | 3.71 | 63.68 | 249.71 | 573.00 | 489.27 |
| SEat | 0.08 | 0.06 | 0.09 | 0.07 | 13.30 | 42.68 | 92.66 | 53.05 |
| CD ( 0.05 ) | 0.25 | 0.18 | 0.27 | 0.21 | 40.93 | NS | HS | 163.78. |

WS mot eienificant

Fig: 17-uptake of nitrogen, phosphorus and potassium as affected fy varying shade


In the case of upteine, the lowest values were noticed at the nifloet shade, thougit not significant.

Over the etsges, the contrut went on decreasine with advancing age in all plant parts includins phizonen whereat the uptake increased with time at all ainde levele.
3. Content and uptake of potaseium

The data on the potasgium content in leaf, pseudoetes and rinizoze and the total uptatre of potaesiua are eiven in Tables 41 to 42 and Pis. 17. The analysee of variance are given 22 Appendicem 37 to 33 .

The effect of shade on the potnesium content of leaf, preudoeter ard rhizowe was signtricant at all growth stages. The uptake was aiknificantiy influenced only at 60 and 220 dags of growih. The content increased with increasing intenoities of enade. In the case of total uptatro, the low and medium shede levels recorded higier values, those of intence ginde and that in the open being low and comparable.

With advencing age of the crop the content in all the plant components deorereed gradually so that by harvest the conponenis contannea the lowest content of the nutrient. Whorasa the upioke went on increaoing with advencing age upto the 190 deys of growh. Apter this atage, there was

Table 43. Soil nutrient otatur aitor the crop of turmerio

| Shade intensity (per cont) | Hutrients |  |  |
| :---: | :---: | :---: | :---: |
|  | Total <br> nitrogen <br> (pan cant) | Avallabio phosphorus ( ppm ) | Available potaseium (ppin) |
| O (no ehade) | 0.139 | 2.93 | 92.53 |
| 25 (10w chade) | 0.112 | 2.42 | 110.98 |
| 50 (medium chade) | 0.113 | 3.60 | 97.15 |
| 75 (high shade) | 0.065 | 2.87 | 120.96 |
| SEa $\pm$ | 0.002 | 0.37 | 2.20 |
| CD (0.05) | 0.005 | 1.16. | 6.78 |

a silght increage at mon intensities of shade and a decline in somo otheres.
II. Soil charecters

So12 nutsient atatue

The data on the content of total aitrogen, avolleble phoephorus and available potageiun in the soil after the crop are presented in pabie 43 and the analyeis of variance in. Appendix 39.

The effeot of shade on the nutrient gtatus of the goil thoueh vas aignidicant, no general trend in the nutrient content wtheincreasing intensitien of ehade could be noticed. Comparison with the pre-expersmental nutrient staius indicated that the available phosphorua content increaged and that of availabla potassium decreased The total nitwogen was lower at high ahade levela aftor the cropping as oompared to tho pre-oxperimental eoll 1evol.

## MIEUUESION

The gield of rhisomen in turneric was the highest at 50 per cont shade intensity and as compared to the gield in the open, the percontage gield at this ahade level wan 108,89. At the low shade level of 25 per cont, the gield was nearly the same ( 99.86 por cent) ses that In the open. Intense ( 75 per cent) shading led to a substanitial decrease in gield to the tuno of 42.22 per cont. The differences in gield between the full 1llumination, 25 and 50 per cent shade levele were howaver, not etatistically signifiognt. of the various regression models testedito define the variation in yield as a function of chade intenoity a cubio polynoaial fittod to the logarithm of giold was found to be the best, the coefficlent of detemination $\mathrm{R}^{2}$ being 0.9999 . As there is an inorease in jield boause of ahoding, thin orop may well be clasaified as "ehade-loving" and as the yield oven at the intenee shade level is reasonable, this orop will be highly suititble for interoropping.

A compardson with dry matter yield (Table 36) Indicated no strict ofmilarity with the trend in rhizome yield. The data on harvest index indicated that there was also no improvement in translooation of photoaynthates towarde the
economio part becauge of ehading. As these data on dry matter açumulation and harveat index did not juotify the observed trend in rhizone giold, it in difficult to interpret the resuits. Aseuning that the sampling error: in dry matter e日tiastion was subetential, an attexat was made to extrapolate the dry matier gield at harvast from the data on yield of chizome ond haulm and the moleture percentage of exmple plants at harve日t. These exarapolated data bre also presented in Table 36. On atatietical analyole of there data on dry matter gield, it was also found that the coefficient of variation for thees deta wae lower (15.22) then that for the eample (19.55).

A atudy of the extrapolated dry velght values would indicate that the dxy natter accualation and rhizome yield followed a neariy identical pattern. Taking the yield in the open as 100 per cent, the corresponding values for rhizome gield at 25 , 50 and 75 per cent ohade levols were 99.36, 109.89 and 57.78 per cent, respectivoly and those of dry mattor gieid 95.9, 111.1 and 72.7 per cent respectively. The above aicilarity in the trend of dry weight and phizose gield indicates that the photosynthetio rate had a doninant role in deoiding the observed response to ahede.

An explonation for the above variaiion in dry matter
acousulation can be had from on ovaluation of the data on leaf area inder ( $2 a b 1034$ ) and not usaiailation rate (Table 36). Ag would be evident from the relatively hieh IAI values espectally after 120 dage of growtin, the turnerio canopy vas fairly donse. the mean maximun LAI value of 15, 8 was noticed et full illumsnation 180 days aftor aprouting. Even though the loaf orientation was apparently naar vertieal, an the IAI values ware excegeively high and much higher than the opifaum reported for cereals with near vertical loaf orientation (4 to 7 for pice ae roported by Yoshida, 1972), there was presuagbly cubatantial autual ghadinc and probably some leaf paraoltian. The extent of leaf parasitien would have normalis increased becauge of ohading, but such a probable effect Io not raflected on the dry aatter accumplation and it may have to be presumed that there wene other feotore invoived in thie. One of those factore could probaily be the giomatal olosure at intence illumination ag hag been raported In the case of coffee (Hardy, 1958). However, report on such a etomatal bshaviour of turmeric were not available from interature. Ansusing that this vas the faotor regponsible for the ghode responee of tinis crop, it may be deduced from the deta on ding matter accumulation that the stomatal clobure had the dominant infiluence upto the intermediate shade level. Beyond thie level, availabilito
of light for photosynthesis, probably, became the deciaive 11miting factor.

A study of the data on IAI would also show that though not statistioaily adenificont, the mean LaI values were aubetensially low at intense ahede level. An adaptation of the plent to avoid excesmive parasitien by an adjustrent of thi is thue indicated in this orop also.

Data on not aenimilation rate Indicated lack of alknificant difference between the different shade levele. If the above explenation of a atomatal luhibition at highor 1llumination was operative, the NAR would have been the highent at 50 per cent shade. A comparison of the rean values indicated higner IMR values at 50 and 75 per cont ghade thon in the open between the first two stages of obeervation ( 60 and 120 days after sprouting) wherean between the seoond and third atages (120 and 180 days after sprouting), tine higheat mean velues wore noted in the open. The only juetification for tho lack of persistent auperiority in HAR at the intermedinte shade level appeare to be that the gampling errore were high especialis in the determination of dry matter yield ac had been indicated earlier.

Date on harvest index dild not ohow significent differences between ghade levelb. Date on hervost index recaloulated from extrapolated valuen also did not finow etatistical sifnificance. It may thus be concluded tiat.

In general, the exten of tranolocation of carbongarateo to the economio part was not affected by shading.

Anong the other growth characters, plant height followed nearly the name trend as that of ary antier accumalation and ringone yield. Filler muaber, on the contrary, showed a ateady decrease with increase in anode intensivy. However, ae would be evident from the data on sal, this decreage in tiller number did not substantially influence the jeaf area.

Contents of chlorophyll ' $a$ ', ' $b$ ' and totel chiorophyll (Table 35) wore found to incrcase oteadily ulth trareaging Bhede lavelg and the aisferenoes betwoen tho different ahaie levels also were olgnifiennt. Though reports on the increased chlorophyll content because of shadine on turaeric were not available from-literature, inorease in oflorophyll contont because of ohading has beors reported in crops lite atrawberry (Clorth, 1965), cocoa (Evane and furroy, 1953; Guera, 1971; Orali ard Ownea, 1975), tea (lameawain, 1960 and Venkotamani, 1961), bean Enoseien, 1970), alialfa and birdsioot trefoil (Coojer and Guale, 1967) and pimeapple (adhe, 1979). The ratio of chloropizyll ambreanined constant et 160 days after sproutinc though at the eariser atage ( 120 days), an fncrease in satio with shading was noted. Wita age, the content of
chlorophyll and its components chlorophyll ' $a$ ' and ' $b$ ', decreased but the ratio of chlorophyll a-i increased. The probable reasons for such a phenomenon have been discuseed already while dealing with colocaela.

In general, the contents of aineral nutrients, nitrogen, phosphorue and potaseluai in the plent parts increaged with increasing shade intensities and the difierercen betmen different shaco levele wore significant at alrsost all the atages. This observation caniot be axplained ac Ane to the dilution offect as the dry usuter accumulation and gield were the highest at the interaodate anede lovel. Reports on auch an influence of shade are not available in literatare. The only indication that can be given ia that thore appears to be a tendency to accumulate nutriente in the tissuea under shade in turmeric. The total uptake of nutrients at harveet miowed oignificant differonces boiveen the shade levels and the pattern of varistion was nearly the seme an that of dry mattor accumulation and rhizone yiedd. Calculated as percentage of the uptake in the opon, the total crop removale at 50 per cent shede ware $116.2,120.0$ and 124.0 per cent, rempectively, of nitrozen, phosphorus and potaselum. Ab indicated by these percentage uptake values, it appears that a orop of taraeric at 50 por cont
chado level would need an additional 20 per cent of the applied fertiliser nutriente, tinen that cultivatad in the open.

The nutrient atatus of the soil ghowed atetiatically gignificant differences after the crop season. Though adgnificent, the Adfferences between increasing shade levela were hignly variable. Comparimon with the preexperimental soil nutirsent atatus (Table 1) indicated an increage in the content ois total nitrogen and availoblo phosphorus and a deorence in aveliable potaselum. The reseong for these have been dipousged earlier.

The conclugions from the above dicouseion nay be given ab follows:

1. Tield of rificonen in turmeric followed a cubio sesponee With increasing gande intaneities and the higheet gield was noted at 50 gor eent shade level. Though thore is a substantial decyease in yield with further increase in shade, the yield levels are still high at the intence (75 per cent) shade level. Turmeric say therefore be olaerified as 'chade-loving' and it may be concluded either that this crop is alghly suited for interoroppine or even that thie ie more custed to intercropotng then for cultivaidion as a sole crop in the open.
2. Differences in the photosynthetio rate eppear to havo the decisive influence on the shade responce of this crop.
3. Turmeric produces a relatively denee canopy under natural conditions. But excebsive lear parasitien induced by shading in thie orop is at least partly counter-acted by a decrease in canopy denelty.
4. Tne harvert index of the crop is not very much influenced by Ehading upto intermedinte made levols.
5. It appears that the fertilizer requirement of turaerio mhaiod to 50 per cont may bo about 20 per cont more than the gonerol recomendation given for a sole crop in the open.

Ginger

# Ginger <br> (Zingiber officinale Romc.) 

1. Plant characterg
A. Blonetric obsexvationc
2. Plant height

The data are preaented in Table 44 and the analyoie of variance in Appendix 40.

Effect of shade on plent hoight wae elgnificant at all atages of growth except at the firmt atage. The value, in general, wont on inoreazing with inoreaeing levels of ehade, and the plants in the opon recorded the jeaot value mioh was olgnificently lower than that at the other shade leveln.
2. Nuaber of tillern

The atata are presunted in Table 44 and the enalyois of variance in Appendix 40.

Tiller produotion was siguificantly influenced by shade only at the inttial otage of erowth, a decrease in the moan number of tillers was noticed with increasing shade intensities, at all otages of growth.

The tiller number sinowed an inoreave with advancing age.
3. Ieal area index

The data are presented in Table 44 and the analfeid of variance in Appondix 40.

The effect of shede on Lal in ginger was not siguificant of any of the growth Btages. The nean rai valuee ranged from 0.50 to $0.75,2.13$ to 3.45 and 5.48 to 7.18 at the 60,120 and 180 dagy aftor gprouting.

Over the etages, the Jal values showed a marp increase, but wis increase was more conepicuous it 25 and 50 per cent thade levels.
4. Chlorophyll content of leaves

The data on the content of chlorophyll ' $a$ ', ' $b$ ' and total chlorophyll along witi the ratio of chlorophyla $a-b$, are presented in zaose 45 and the analyaes of variance in Appendix 41.

Effect of ghade on the content of total chlorophyll as well as its components was significentiy influenced by shading. the constent of these chowed an increasing trend with inoreasing made intensities. In apite of the aignificant effect of shade on total chlorophyll and its components, the effeot of shade on the ratio of chlorophyli e-b renained non-mignificant at both of the otages.

Table 44. Effect of shede on plont hoight, number of tillers and leaf area index of ginger at different grouth atages

| Shade intensity (per cent) | Height of plant (om) <br> (days after eprouting) |  |  | $\begin{aligned} & \text { Huaber of tiflers } \\ & \text { plant } \\ & \text { (daso after sprouting) } \end{aligned}$ |  |  | Leaf area index (days after sprouting) |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 60 | 120 | 180 | 60 | 120 | 180 | 60 | 120 | 180 |
| 0 (no miade) | 28.8 | 46.7 | . 46.6 | 8.7 | 16.1 | 16.0 | 0.75 | 3.45 | 6.21 |
| 25 (low shade) | 31.1 | 54.8 | . 59.6 | 5.0 | 15.5 | 14.9 | 0.50 | 3.11 | 6.56 |
| 50 (nedium shade) | 28.1 | 57.5 | . 63.9 | 6.2 | 9.0 | 15.9 | 0.55 | 2.13 | 7.18 |
| 75 (high shade) | 28.1 | 57.0 | 66.5 | 5.7 | 11.8 | 13.3 | 0.60 | 2.24 | 5.48 |
| Sma +05 | 2.2 | 1.9 | 2.4 | 0.3 | 2.1 | 1.1 | 0.11 | 0.48 | 0.67 |
| CD ( 0.05 ) | WS | 5.8 | 7.5 | 2.6 | \% | [S | HS | WS | IIS |

NS = Hot eignificent
Table 45. Effect of ahade on contong (mg $g^{-1}$ freah weight) of chlorophyll ' a ', " $b$ ' and total chloropingli; ratio of chloropayll a-i of ginger leaves at different growth etages

| Shade Intensity (per cent) | Chlorophyll 'a' (days arter sprouting) |  | Chaloropky $11^{\prime} b^{\prime}$ (daga after sprouting |  | ```Total colorophyll (days after aprouting)``` |  | $\begin{aligned} & \text { Chloropiglll a-b } \\ & \text { (dayo after } \\ & \text { gprouting } \end{aligned}$ |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 100 | 160 | 100 | 160 | 100 | 160 | 100 | 160 |
| 0 (no shade) | 0.95 | 0.84 | 1.22 | 1.04 | 2.17 | 1.88 | 0.79 | 0.81 |
| 25 (low chade) | 1.13 | 1.18 | 1.36 | 1.42 | 2.50 | 2.60 | 0.83 | 0.85 |
| $50^{\circ}$ (nediua shade) | 1.37 | 1.33 | 1.75 | 1.75 | 3.12 | 3.09 | 0.78 | 0.78 |
| 75 (high alsade) | 1.46 | 1.56 | 1.80 | 1.63 | 3.25 | 3.39 | 0.82 | 0.85 |
| $\mathrm{sem}+$ | 0.04 | 0.19 | 0.03 | 0.06 | 0.11 | 0.11 | 0.03 | 0.03 |
| CD ( 0.05 ) | 0.14 | 0.18 | 0.24 | 0.20 | 0.35 | 0.34 | HS | RS |

WE $=$ Not Bignificant

The content of chlorophyll varied erratioalis with advanoing age, but the ratio of chiorophyil a-b somained almost the same at all the stagee of growth.

## 5. Total ary weight

The data are presonted in Table 46 and Fig. 18. The analysif of variance is given in Appendix 42.

The effect of ahede on total dry matter production by a plant was significant onis at 120 days after sprouting. The mexinum and mininum values wore noted at full 1llumination and at intense shede levele, respectively; The value ahowed a decreasing trend with inareasing anade intemaities at all the stages of growth.

Over the etages, the totel ary aetter production increased with advancing age, the extent of inorease being maximus at the lou ( 25 per cent) shade level.
6. Net asaimilation rate

The data are preaented in Table 46 and the analyais of variance in Appendix 42.

The effect of ahade on net assimilation rate in ginger was not olgnificant betwoen any of the growth stages.

Table 46. Effect of shade on total ary matter production, net agsimilation rate, rhizome sield. hanin yield and harvest index of ginger


HS = Not significant
Taile 47. Effect of shade on mitrogen content of lear and poeudosten of ginger at difterent growth ataget

| Shade intensity (per cont) | $\begin{aligned} & \text { Leal nitrogen content } \\ & \text { (per cent) } \\ & \text { (doys aftor sprouting) } \end{aligned}$ |  |  | Fseludooten nitrogon content (per cent) <br> (daye after sprouting) |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 60 | 120 | 180 | 60 | 120 | 180 |
| 0 (no shado) | 4.10 | 2.85 | 2.54 | 3.08 | 1.14 | 0.93 |
| 25 (10w chade) | 4.04 | 2.97 | 2.66 | 2.64 | 1.26 | 1.00 |
| 50 (rediun made) | 3.84 | 2.65 | 2.70 | 2.75 | 1.38 | 0.92 |
| 75 (high ahade) | 3.99 | 3.64 | 3.02 | 2.86 | 1.43 | 0.81 |
| 9En + | 0.06 | 0.01 | 0.05 | 0.06 | 0.03 | 0.09 |
| CD ( $\overrightarrow{0}_{0}$.05) | 18 | 0.05 | 0.17 | 0.20 | 0.11 | HS |

NS $=$ Not algnificant

Eig:18- Effect of shade on total dey matter production. of -ginger at different stages of plant growth.


Fig.19-yield of ginger as -affected by varying
shade intensities.


The values ranged from 1.89 to $2.32 \mathrm{~g}_{\mathrm{m}} \mathrm{m}^{-2}$ daj ${ }^{-1}$. Ho general trend in Hif with increasing ohade level could be noticed. Hith edvancing age, the HAR showed a decrease at low shade and in the open, while it mowed an increase at medium shade level and at high shede it renainod nearly tatio.
7. Yield (Raizome gield)

The data are procented in Table 46 and Fig. 19. The analysis of vorience is given in Appendiz 42.

Shade hed a aignificant effect on the rhisome yield In ginger. The yield increased with inoreasing ahade upto the low ( 25 per oent) shade intonsity, and mowed a decilnIng trend with furthor inoreace in saade intenalty. Thos the caximun yield of $22.22 t \mathrm{ha}^{-1}$ was recorded at 25 per cont chado jntensity. The yielde oibtained at low, qeaium and high ghade levela were $105.6,92.83$ and 66.65 per oont, reapectively, of that at full illumination. The gield at intenoe ( 75 por cont) ahede web alenifioantly lower than at tize other gade inteneities.

Remponse curve
The yield of rhicomed obtained at incroaing intengities of shade have beon represented graphieally as a funotion of shede and a quadrailo equation fitted to the

Fig: 20- yield response of ginger to varying

- Estimated yirild.
- observed yield.
$t$ value of: $x$
$\log _{10} y=1.3295-0.0292 x-0.0805 x^{2}$
$P^{2}=0.9998$.

13

logarithen of gield wae found to be the beiter fit to the response ourve tinue obtained (Fis. 20 and the analyole of variance in Appendix 48). The equation of tire ourve is as followas

LuE.0y $=1.3295-0.0292 x-0.0105 x^{2}$
The comefficient of deteraination $R^{2}$ wne found to bo 0.9998 waich indicate that the proposed model alnost Pully describes the biological phenomonon. The optsmum intengity of ahede for einger as worked out from the oquation is 20.12 per cent.
B. Yield of hauln

The data are presonted in Table 46 and the analysis of veriance $2 n$ Appendix 42.

The effect of ghade on yield of hauim in ginger was not afcuificast. The gean yield was, however, the lowedt at intence shade levol and highest in the open.
9. Haxvert index

The data are procented in Table 46 and the analysis of variance in Appondix 42.

The affoct of shede on the harvest index in ginger was aignificent. However, values nhowad a decreasing trend with inoreesing intensitios of ohode, which ranged from 50 to 64.2 per cent.
B. Chemicel atudies

1. Content and uptake of nitrogen

The dater on the content of aitrogen in leas. pseudosten and sinizome along with the total upteke of nitrogen are presented in Tables 47 to 48 and Pig. 21. The endyees of variance are given in Appendicen 43 to 44.

The effeot of ghede on the aitrogen content of leaf and pseudociea wae signdsicant at all etages of growtin oxcepting one, while in the oase of raisome significant effeot wan noticed only at the harvest etage. But the differences in uposke of nitrogon between the diffevent chade levele was not efenificant at all growth stages. The content varied froa 2.54 to $4.10,0.84$ to 3.08 and 0.93 to 3.71 per cont, reapectively, in the leaf, pacudostom and risomen at difforent atages.

With age, the content of ntirogen in all the plont components chowed a decreasing trend upto 180 days after sprouting But in the case of rhizoae, tione was an $1 n$ crease in nitrogen content fron f60th day to haryeat. Even so, the percentage oontent of thie nutriont at harvert was only about half ae auch as at 60 dags after aprouting. The total uptase of nitrogen by the plants went on inoraseing aty a rapid rate vith adranoing ase of the plant upto

Table 48. Effect of sheds on nitrogen content of ginger rinizomon and on total uptake of $n \boldsymbol{n t r o g e n}$ by ginger at different growth atages

| Shade intensity (por cent) | Rhizome nitrogen contont (yer cent) (daye after eprouting) |  |  |  | Total uptake of nitrogen (keg ha ${ }^{-1}$ ) (dapo after sprouting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 60 | 120 | 180 | $\begin{aligned} & 225 \\ & \text { harvest) } \end{aligned}$ | 60 | 120 | 180 | $\begin{gathered} 225 \\ \text { (haspert) } \end{gathered}$ |
| 0 (no shade) | 2.88 | 1.08 | 0.94 | 1.47 | 23.03 | 62.87 | 134.00 | 118.95 |
| 25 (104 chade) | 3.43 | 7.07 | 1.12 | 1.44 | 11.83 | 60.53 | 144.37 | 128.39 |
| 50 (rediun shate) | 3.66 | 1.14 | 0.98 | 1.49 | 13.29 | 36.75 | 135.12 | 107.69 |
| 75 (aign onade) | 3.71 | 4.07 | 0.93 | 1.87 | 12.75 | 41.36 | 98.35 | 125.80 |
| $\mathrm{SEs}+$ | 0.33 | 0.03 | 0.05 | 0.018 | 3.04 | 7.21 | 14.29 | 14.73 |
| CD (0.05) | W5 | NS | 188 | 0.056 | HS | * | \%S | NS |

HS = Fot significant

Table 49. Bifect of ahade on phosphorus content of einger leaf and pseudosten at diferent grouth steges

| Shede intentity ( por cent) | Leal phosphoxius content (per cent) (days after bprouting) |  |  | Psoudoster phogphorus convent (per cent) <br> (days altsf sprouting) |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 60 | 120 | 180 | 60 | 120 | 180 |
| 0 (no ainde) | $0: 25$ | 0.26 | 0.25 | 0.40 | 0.19 | 0.21 |
| 25 (low mhade) | 0.27 | 0.29 | 0.23 | 0.36 | 0.32 | 0.21 |
| 50 (reaium ohade) | 0.28 | 0.33 | 0.30 | 0.35 | 0.23 | 0.22 |
| 75 (hygh shada) | 0.27 | 0.32 | 0.26 | .0.38 | 0.29 | 0.17 |
| SEP + | 0.02 | 0.07 | 0.008 | 0.01 | 0.01 | 0.01 |
| CD ( 0.05 ) | HS | 0.04 | 0.024 | WS | 0.04 | 0.07 |

180 deys and then 16 decreased excopting at the intense ehade level. Tino rate of uptake with odvancing age was greateat in the case of plants which vere erown at 25 per cent shade intensity.

## 2. Content and uptake of phosphorue

The data on the content of phosphorue in the leaf, pacuasterin and rhizome end the total uptaka of phosphorus are given in Tebles 49 to 50 and Fig. 21. The analyean of variance are given in Appendices 44 to 45.

The affect of ahade on the phoophorue content of plent component and total uptake of phosphorue reanined aignificant at almost all the grouth atages. Ho general trend in the variation of the phosphorue content with inoreasing chade intenaities could be noticed. The content of this element varied fron 0.23 to $0.33,0.17$ to 0.40 and 0.17 to 0.61 per cont, reepectively in the leaf, peouiontom and rhizomes at aifforent grouth atages.

The changes in the content of phosphoras with advancIng age was aimilor to that in the case of nitrogen content in the leaf, peoudostem and rhizome. Phosphorus ugtake mhowed a discernible increase with advanoing stages of growth upto 180 dage of erouth.

Table 50. Effect of ahado on phosphorus content of ginger rhizoaed and on total aptake of phobphorus by ginger at differeat erowth stages

| Shade intengity (per cent) | finizone phosphoras content (per cent) (Agys after gprouting) |  |  |  | Total uptake of phosphorus ( $\lg \operatorname{ha} a^{-1}$ ) (dags after sprouting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 60 | 120 | . 180 | $\begin{gathered} 225 \\ \text { (harvest) } \end{gathered}$ | 60 | 120 | 180 | $\begin{gathered} 225 \\ \text { (harvest) } \end{gathered}$ |
| 0 (no ghade) | 0.57 | 0.24 | 0.17 | 0.24 | 2.43 | 8.95 | 19.42 | 19.41 |
| 25 (low ghade) | 0.48 | 0.26 | 0.21 | 0.28 | 1.21 | 9.53 | 21.91 | 30.02 |
| 50 (mealum ghade) | 0.61 | 0.20 | 0.21 | 0.26 | 1.47 | 5.39 | 22.61 | 18.26 |
| 75 (high chede) | 0.58 | 0.25 | 0.17 | 0.29 | 1.36 | 5.21 | 13.20 | 17.99 |
| S89 | 0.02 | 0.02 | 0.01 | 0.01 | 0.34 | 1.12 | 2.20 | 3.55 |
| CD (0.05) | 0.06 | WS | 0.03 | 0.02 | PS | 3.46 | 6.79 | 10.94 |

HS $=$ Not significant
Table 51. 空fect of shade on potassium content of leaf and psendoster of ginger at different growth ghages

| Shade Intensity (per cent) | Leal potamaium content (per cent) <br> (days efter sprouting) |  |  | Rseudoster potaseiva content (per cent) <br> (days efter sprouting) |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 60 | 120 | 130 | 60 | 120 | 180 |
| 0 (no shade) | 3.72 | 3.50 | 2.74 | 7.50 | 6.40 | 5.36 |
| 25 (100 shade) | 4.20 | 3.76 | 2.98 | 7.50 | 6.90 | 5.90 |
| 50 (nedium shade) | 4.72 | 3.92 | 2.95 | 7.80 | 6.74 | 6.30 |
| 75 (high ahade) | 4.40 | 4.32 | 3.55 | 8.48 | 7.47 | 6.51 |
| Sm $\pm 05$ | 0.08 | 0.12 | 0.03 | 0.07 | 0.09 | 0.09 |
| CD (0.05) | 0.25 | 0.36 | 0.24 | 0.21 | 0.29 | 0.29 |

3. Content and uptake of potassiun

The data on the content of potnesiun in the leaf, paeudoetem and rhizome and on the total uptaice or poteeaiua are presented in Tablee 51 to 52 and Ple. 24. The analysee of variance are given in Appendices 46 to 47.

Influence of shede on the potassiun content of Leaf, pseudosten and raizome was signiricent at all the atages of growth. However, the effect on total uptake of potangitu remained mon-significant. No genoral trend in the nutrient contont with increasing ehede level wa epparent in any of the plant components. Yet, comparatively lower concentration of potassium in plont porta were obtained almost always in plasts grown at full illumnation.

The change in potansium content with age was eimilar to that of nitrogon and phosphorus in the different plant parts. The total upteke of phosphorus ehowed a wharp increase with advanoing stages of growth at all shade levele.

## II. Soil charactors

Soil nutrient otatus

The data on the total nitrogen, avallable phosphorus and availablo potamelua in the moil after the cros are

Table 52. Effect of gheds on potabsium content of giager rhizomea and on total uptake of potageiun by einger at different growth tages

| Shade intensity (por cent) | Hinizome potesolum content (por cent) (Cays after sprouting) |  |  |  | Total uptake of potassium <br> (kg hee?) <br> (days after eprouting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 60 | 120 | 120 | $225 \text { (xvect }$ | 60 | 120 | 180 | $\begin{gathered} 225 \\ \text { (narvest) } \end{gathered}$ |
| 0 (no shade) | 5.76 | 4.17 | 2.00 | 2,30 | 37.65 | 172.11 | 263.87 | 279.17 |
| 25 (low ohade) | 5.84 | 4.39 | 2.38 | 2.30 | 19.57 | 163.81 | 305.78 | 320.75 |
| 50 (nedium shade) | 5.82 | 4.56 | 2.60 | 3.02 | 23.33 | 102.18 | 324.53 | 271.20 |
| 75 (high shade) | 6.18 | 4.10 | 2.75 | 3.25 | 22.42 | 99.84 | 246.64 | 308.89 |
| SPm ${ }^{\text {a }}$ | 0.10 | 0.03 | 0.07 | 0.06 | 5.95 | 21.82 | 31.34 | 25.50 |
| CD (0.05) | 0.31 | 0.24 | 0.21 | 0.18 | HS | M | 75 | HS |

Table 53. Soll natrient atatus after the crop of ginger

| Uutriont |  |  |  |
| :---: | :---: | :---: | :---: |
| Shede intensity (per cent) | Potal nitrogen (per ceat) | Available phoophorus (pan) | Availeble potasesium ( $\mathrm{p} \mathrm{pn}^{2}$ ) |
| 0 (no mhady) | 0.109 | 2.12 | 96.0 . |
| 25 (10w mhade) | 0.140 | 2.24 | 98.3 |
| 50 (medius ahade) | 0.109 | 1.63 | 112.0 |
| 75. (hign ghnde) | 0.087 | 2.24 | 124.8 |
| SBm ${ }^{\text {t }}$ | 0.007 | 0.30 | 1. 54 |
| CD ( 0.05 ) | 0.005 | dS | 4.19 |

[^1]fig. 21- Uptake of nitrogen, phosphorus and potassium as affected by different shade levels in ginger.

presented in Table 53 and the analyais of variace in Appendix 47.

The differences in coil nitrogen and available potasiua contente betweon the ghade levels were significent. In the case of potasgium, the content were higiar at higher ghado levels. the nitrogen contents in soil appoared to follou the sare trend as that of arop jield with the higheat content at the low shede, followed by that in the open. The lowest nitrogen content was corrosponding with the intonse chade level. The differences in available phosphorus content were not significant.

Comparison with the pre-sxperimental nutrient atatus indicsted a decrease in available phosphorus and available potaesiun and an inorease in the nitrogen content bocause of the cropping.

## DISCUSSIOX

There was increase $2 n$ the giold of rhizomes in ginger with chading upto low ( 25 per cent) intensity. At higher chade levels, a deoreasing trend in giold was noticed but the axtant of docrease was marginal upto Intermediate ( 50 per cent) ahsde. Even at intence (75 per cent) shede, the decreage in gield wac not as conspicuoug an in orops like colocacia and coleus. Taking the jield in the open as 100, the comparable yields for 25, 50 and 75 per cent shade levels wero 105.6, 92.8 and 65.7 per cent, reapectively. Statisticul analyaie of the data indicated that there was no algnificant difference in Jield upto 50 per cont shede intensity. Among the regreseion models tested, the quadratic equation fitted to the logarithas of gield was found to be the beet to define the variation in jield with increasing ahade inteneities. The optimua shade level calculated from the equation was 20.12 per cent. The fact that the sield trend is quadratic and that thero is no atatisticaliy significant decrase in gield upto 50 per cent anading may quality this crop to be classed as 'ahade-loving'. It would thus make this crop highly saltable for intercropping. The reaite also indicate that the crop would EIve reasonable roturno even intenea shede levels.

Dry natter accumulation by plants (Table 46) followed nearly the game trend as that of chizome yield and the percontage values at 25, 50 and 75 per oant ahade Levels were 111.53: 90.86 and 87.42 , respectively. Theme data on dry matror accumulation show that ahading did not reeult in any eppreciable decrease in the rato of photosynthceis apto the intermediate levela of 50 per cent shade. Not only that there was no decrease in photoryntheass, but shading also tended to inorease the dry natter sccumulation by the plenta. Cuch a better performence of this erog under ghede thas in the open has been seported earlior by Aclen and Quisumbing (1976). In oroge like tomato (Edwond gt al., 1964), tea (Joseph, 1979), biratro and green panic (Wong and Wilsoa, 1900) also, such trend has beon reported. The explenation given for the botter performance of cropa under shade than in the open is uhat there is often a tirreshold, illumination intensity beyond which the stomata of such shade loving plante tend to close (Hardy, 1958 on coffee). Though the involvanent of such a factor on ginger aleo cannot be exoluded, the influonce of such a factor had been necosearily meagre on this crope

An evalustion of the reqults on leaf area Index (Table 44) would ahow thet the crop producod reasonably
conse canopien after about 120 days of grouth. The aean InI at this stage waa vell above 4.0 at all ehade intensitieg. Unilise in the case of aweet potato and colous, the denesty of the canopy was not vary high and the mean maximun LaI was only 7.2. The fact that the Lhi was not very high at any of the growth atages, and that ginger leaves are nearly ereot in poaition, exclude the posmibllity of otrong mutual shading and leaf parasitien in the open. Evon though a dearease in the intensity of 1musination night have adversely arfeoted the photoaynthetic rate at inoreasing chade inteneities, theac eifeoto vere not promably conspicuous upto 50 per cent made. If at all this was oporatiog, the offeot of tinis factor was, probably, wore than cospensated by the adventage of better atosatal opening at. 25 per cent ohade intenalty. At intence ghade levels, light boceme the dominant limiting footor as expacted and dry matiter secualation deoreaced substantially. Decresesed gield in elinger when ehading was over 50 por cent had beon reported by Hinoriu and Hord (1969) and Aolan and Guisuabing (1976). Another oonspicuous observation from the re日ulte on ISI is that thore was no statiotically aienificant increase in canopy dengitr because of chading.

The harvest fudex ranged hrom a mean of 50.0 to 64.2 per cent at the affiement shade levels. Tine bigheet
value of 64.2 por cent was noticed at full illuaination and there was a steady decline with increasing shade 1evele. Thore are thue indications of the influnce of ahade on the partitioning of assimilates by the crop. Evon though the ingheat II viluee wore noted in the open, the influence of euch high II values was. not refleoted on rhizone gield, presumbly becaume these were more than compenseted by the higier rate of photomgtheais at the low ghado lovel.

The differences in mean ast asolinization zate at adfferent made levele wore not mienifionnt. The only conepiouous difference wag betweon the Intente made level and other khade regince.

Other growth charactors like plant height and tiller nuaber followed alightly different patterne as compared to dry mettor acoumalation and field. In the case of tiller number, there was almost a steady deorease with increase in enade intensitios at the last tage of obacrVation thouga the differonceswere not gtatistioally signifiegnt. In the cane of plant helent, there was oteady inorease with inorease in shade intenelity upto the intense shade level. The differences in plont height were also statieticaliy significant. Acian and Quinusibing (1976) observed that ginger plants erown under full eunlizht wore
ohorter and had lesaer number of leaves per tiller but gielde were just at high as those obtained under 75 and 50 por cent ilgat intencities, When hading was over 50 per cent, gield deoreaged. It was alao raported that ginger periorned beat when grows under alight ahade bat not in oxcese of 50 per cent shoding. The present results are aleo almost in agreement with that of the above one. As had been mentioned earlier, oimilar raport of increased plant height under ghade are available on other crops like tobacco (Panikar ot al., 1969) and coupea (Tarila et gi.,1979).

The totel chlorophyll and its components 'a' and 'b' incroased with increaning shade intomeitiea and the differences between the various shsde levels were atatistically eiguificant. This is in agreement with the obgervations made by Erans and kurrey (1953): Remaewami (1960), Ventatamani (1961); Clark (1965): Cóoper ond Gusila (1967); Guers (1971); Okali and Owusu (1975) and Radia (1979). The retio of ohlorophyll a-b did not ehow any distinct trend of variation with inoreacing ahade inteneities and the differances between the different ahede levele remained nonsigniricant.

The aifferences in the content of aitrogen, phoaphoria and potasaium in the pient parts wore statlatically elenificant at most of the steges. The results were however, highis variable, though there was a tendency towarde a
higher content of these nutrients under thade as cospared to that in the open. The differences in the uptake of nutrients excopt in the case of phopphorus were aignificant at all etages of plant growth. Hore again, variability was verg high and the only valid concluaion out of the date is that the treatment giving the highest gield (low ohace level) also recorded the hignomt uptake values. Calculated ae percentage of the uptake in the open, the orop renoval of nitrogen, phosphorus and potasoium at this Low ehede level wore 107.34, 154.66 and 114.89 per cent, reapectively. At acdium and intence ghade levels, the uptake was noarly the same as that in the open. It may therefore be concluded that the fertilizer requirersent of ginger under how ehade will be around 110 per cent in the case of nitrogen and potessium and about 150 per asnt in the case of phosphoxus. The sesuits also indicate that there is little scope for bringing down the fertilizer doses et medium and intense anede levels, though the gields are comparatively 10.

The variation in the content of aineral nutriente In eoil betwoen shado levels and the general trend of nutiriont contonts as compared to the pre-experimental soil anslyaie figures (Table 1) were nearly siailar to those of other crops like coleus and colocasia. The reasons for ench a trend have been diecuseed already.

The aalient features from the above ajscusesion may be sumbrised as follows.

1. The ghade responge of yield of shizomer in ginger followed a quadratic pattern uith the shade optimum at about 20.11 per cont. As the pexformence of the crop so bettor under chade than in the open, thie crop any be congidertd ohede-loving. Even at intence shade Ievel, the raiko:ie gield ia reasonable. Thene would make this crop hishly euitable as an interorop in oocomut gardene.
2. Dry netter accuaulation by the plant followed nearly the same pattorn as that of rhizome yicld. Indications are thut that photosynthetio aechenise hed a deoisive rolo or the chade pogponge of this crop.
3. In addition to the photosgnthotic factors, partitioning of agetmilates aleo appeare to havo been Imfluenoed by shade. piento reoeiving more of 1ilumination tended to tranclocate a higher proportion of carbohyarate to the phizome.
4. Lear area in ginger is not appreciably altered by chading.
5. Hutual ahading and the consequont leaf parabitien may not be high in a sole orop of cinger wow cuitivated in the open. These faotors probably asourte importance onily at intense ehade levels.
6. The fertilizer zequirenent for interoropped ginger nay be 10 to 50 per cent higher than that of a sole crop at the low shade levels. At the medium and high chade levela; requirenent of fortilizere may be almont the seme as that of a crop in the open.

## SUMMARY

## guldany

An experinent wes coniluoted at the College of Horticulture, Vellandeacara to suag the ahade reaponee of coman rainfed tatororops of cooonut, Viz. eweot potato, coleus, colocssia, turnoric and elnger. Realta of the exporiment ase aumoriaed below.

1. Baged on bhade responee of: these arops, Eweet potato shade-sengitive, colecis as may be classifiod sa, enade-intolerant, colocabia as ahade-tolerant; and ginger and tumeric as shadeloving. Sweet potato enowed a drastio decreage in giold with increasing shede intencity, while in colocaeda the decrease in yield wae not, marisod upto 50 per cent ehade intengity. Coleus thowed a linear deoreage in yiela ainoat in proportion to the increase in ainde intenaity. Turnoric and ginger gave maximan yielda at 50 and 25 por cent snace antensties: respectively.
2. Coleus ahowed a 2 inear reeponse to verying ahode intenm atitea. A quadratic equation sittod to the Jogarithon of $(y+1)$. (where $y$ is the yield at difeferent ghade inteneities), was (Sound to give a close fit to the yield pemponse of oweet potato to varying levole of made. In colocaeia and ginger, a quadratic polynomial and in turneric a cubio polgnomisl sitted to the logarithm of yield were the better ilt to the peaponse curvee obtained.
3. Photosynthetio aechanisa appeare to heve dominant role In the ehade regponse of all the orops excepting eweet potato. In the case of eweet potato, partitioning end tranclocation of aseimilates weg advereely affeoted by ahading.
4. Crops like aweet potato, colene and turaeric produced denge canopies. The canopy density of ginger was relatively lower. Colocabia produced only a sparse canopy at the normal planting deneliy, even in the open, thus indicating thet there 1a acope for increasing the yield of this orop subgtantially by olocer planting When growin ar a sole orop in the opon. Sueet potato exhibitcd a marised doereabe in canopy donelty at higher shade fatencities.
5. Excepting colocasia, plant height (length of vine in cweet potato) in all the crops increased with increasing intensities of shade.
6. Number of bronchos (tillers) in all the crope aigaificontiy decreased with inorenetne levels of shade.
7. The effect of ahade on content of chlorophyll " $a$ " " $b$ " snd total onlorophyll in leates was significant in all the arops excepting sweet potato. In colens, einger and turaeric the chlorophyll comtent increased with inaraasing enade intensities, while no general trend wan noticed in colocasia.
B. The ratio of cilorophyll a-b remained almost a constent in swaot potato, coleus and singer, waile in turmerio, the ratio inoreased with increasing shade intensity upto mediun ahade and then deoreased. In the case of colocenia, no genersi trend wae noticea.
8. Contents of niturogen, phosphorus and potaselum in all the plent components of the difiorent orope froressed ufth incrsaming inteneitice of shede.
9. The uptake of these mutrionte by the individual orops followed an identical pattern ag that of dry natter accumuation. Thus in eweot potato, ooleus and colocasia, the uptake decreabed with increased shede inteneity while in turmenic and ginger, the maxinura uptake values were recorded at modium ond how shade intensities, respeotively.
10. It appears that in aweet potaro, the uilifeation efficiencies of the nutriente added would be markedis less under shade than in the open. The nutrient removal by a crod of coleus grown under interaediate chad level was about 70 per cent of thai for a sole crop in the open. The nubrient removal by colocaeia was nearig tine same as that in the open upto the intel mediate ( 50 per cent) shade level. Turresicie grown at about 50 per cent shade removed about 20 per cent more
or fertiliger nutriente then a cole arop in the open. An additional 10 per cent of the mutrients was renoved by a crop of ginger under low ( 25 per cent) hade intenaity. In ali the orope excepting ginger, nutrient uptaice docressed coneiderably at intonse ( 75 per cent) ahade levols. Ginger plantm recorded higher uptake values at this ainade levels as compared to the open.
11. It was concluded from the investigations that sweet potato io uneuitable for interaropping. Coleus might be alaltable only under conditions of ample light intiltration. The crops colocasia, turneric and ginger may be conbidered highly ouited for interoropping.

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## APPENDICES

Appendix 1. Weather data (weekiy average) for the period Hay 1980 to January 1981

| Honth and date | Weok No. | Tomperature ${ }^{\circ} \mathrm{C}$ |  | $\begin{gathered} \text { Rainfali } \\ \text { in }(m a n) \end{gathered}$ | $\begin{aligned} & \text { Helative } \\ & \text { hunidity } \\ & \text { (por oent) } \end{aligned}$ |  | Sun ohine No. of | So11 tomperatwre ${ }^{\circ} 0$ |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Vazi" | Hinn: |  |  |  | ${ }^{2} 5 \mathrm{c}$ | apth) |
|  |  | mum | 1013 |  |  |  |  | thours of | Pore | After |
|  |  |  |  |  | Fore noon | After noon | buight aun- | noon | noon |
| (1980) |  |  |  |  |  |  |  |  |  |
| yay 28- | 22 | 31.9 | 23.1 | 11.6 | 95. | 82.6 | 4.0 | 25.6 | 32.8 |
| June 3-10 |  |  |  |  |  |  | 4.0 | 25.6 | 32.8 |
| June ${ }_{11-10}$ | 23 | 31.2 | 23.3 | 45.4 | 94.3 | 87.6 | 1.1 | 24.9 | 29.2 |
| $11-17$ $18-24$ | 84 | 32.2 | 22.9 | 14.5 | 95.0 | 76.8 | 5.8 | 26.1 | 30.5 |
| 95-24 | 25 | 29.5 | 23.2 | 40.8 | 95.3 | 94.3 | 1.7 | 24.9 | 28.3 |
| 25-July 1 | 26 | 29.3 | 22.7 | 36.2 | 94.3 | 93.6 | 1.6 | 24.4 | 23.8 |
| July $2-8$ | 27 | 28.6 | 22.3 | 43.3 | 94.0 | 83.4 | 3.1 | 23.8 | 29.4 |
| 9-15 | 28 | 29.1 | 22.3 | 56.0 | 95.0 | 91.3 | 2.0 | 23.5 | 30.6 |
| 16-22 | 29 | 29.8 | 22.9 | 33.7 | 95.4 | 93.6 | 4.1 | 24.7 | 30.0 |
| 23-29 | 30 | 29.9 | 22.2 | 29.1 | 95.7 | 82.7 | 2.5 | 24.9 | 23.7 |
| 30-August | 31 | 29.0 | 22.3 | 7.5 | 95.9 | 80.1 | 2.7 | 24.4 | 29.5 |
| 6-12 | 32 | 30.2 | 22.5 | 12.8 | 95.3 | 86.4 | 5.6 | $24: 3$ | 23.7 |
| 13-19 | 33 | 30.5 | 22.1 | 50.6 | 97.1 | 82.3 | 2.4 | 24.3 | 30.6 |
| 20-26 | 34 | 29.7 | 22.6 | 12.9 | 93.1 | 84, 1 | 4.7 | 25.0 | 30:1 |
| $\begin{gathered} \text { 27-Septen- } \\ \text { ber } 2 \end{gathered}$ | 35 | 30.4 | 22.2 | 11.1 | 95:9 | 73.4 | 5.6 | 24.7 | 31.9 |
| Sept.3-9 | 38 | 30.7 | 22.4 | 2.9 | 95.7 | 67.4 | 6.3 | 24.7 | 35.1 |
| 10-16 | 38 | 31.6 | 23.4 | 0.0 | 95.7 | 61.4 | 8.2 | 26.1 | 41.2 |
| 17-23 | 36 | 32.4 | 22.8 | 2.9 | 39.9 | 62.4 | 9.1 | 23.4 | 39.2 |
| 24-30 | 35 | 32.1 | 23.2 | 13.4 | 95.8 | 74.5 | 6.3 | 25.3 | 32.0 |
| $\begin{gathered} 00 t 000 r \\ 1-7 \end{gathered}$ | 40 | 31.7 | 23.8 | 12:0 | 92.3 | 74.0 | 6.3 | 25.6 | 35.0 |
| 8-14 | 41 | 32.4 | 23.5 | 7.7 | 45.7 | 69.7 | 5.2 | 25.5 | 36.0 |
| 15-21 | 42 | 32.2 | 21.2 | 18.4 | 97.7 | 72.8 | 4.3 | 26.2 | 32.9 |
| 22-28 | 43 | 31.5 | 20.9 | 4.7 | , 90.8 | 69.7 | 6.4 | 25.8 | $34: 1$ |
| 29-2№versber 4 | 44 | 32.7 | 20.6 | 3.2 | 87.3 | 49.8 | 9.6 | 24.9 | 33.0 |
| + ${ }^{5-11}$ | 45 | 32.8 | 23.0 | 4.0 | 90.5 | 62.8 | 8.5 | 25.3 | 32.1 |
| 12-18 | 46 | 32.0 | 23.0 | 12.7 | 92.2 | 70.9 | 5.4 | 26.9 | 37.5 |
| 19-25 | 47 | 31.6 | 23.1 | 14.2 | 89.1 | 76.3 | 7.1 | 25.3 | 36.0 |
| $\begin{aligned} & 26-\text { Decem* } \\ & \text { ber }^{2} \end{aligned}$ | 48 | 31.8 | 21.9 | 0.0 | 86.1 | 69.9 | 8.9 | 24.2 | 37.2 |
| 3-9 | 49 | 32.1 | 20.8 | 0.0 | 87.6 | 67.4 | 9.3 | 24.6 | 36.9 |
| 10-16 | 50 | 33.0 | 22.6 | 0.0 | 89.9 | 63.7 | 9.0 | 24.0 | 38.0 |
| 17-23 | 51 | 32.3 31.9 | 22.5 | 0.0 | 84.7 | 62.4 | 8.2 | 23.9 | 38.7 |
| $(1981)^{24}$ | 52 | 31.9 | 21.3 | 0.0 | 85.2 | 65.1 | 7.6 | 24.1 | 38.5 |
| Jan. 1-7 |  | 33.5 | 20.4 | 0.0 | 82.7 | 56.1 | 9.0 | 24.0 | 30.0 |
| - 8 -14 | $\frac{2}{3}$ | 32.9 | 20.5 | 0.0 | 82.7 | 46.0 | 9.7 | 24.1 | 39.1 |
| $15-21$ $22-28$ | 3 | 33.1 | 22.1 | -0.0 | 83.0 | 45.4 | 10.1 | 24.1 | 39.3 |
| 22-28 | 4 | 34.0 | 22.2 | 0.0 | 82.6 | 49.1 | 9.9 | 24.0 | 39.2 |

Sources B Claes observatory, Vellenikikara, irichur.

Appendix 2. The weeicly average daily range in meteorological pareneters relating to individugl crops tried

| Moteorologial paracteters | crop |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Sueot potato | Coleus | Colocasia | Turmeric | Ginger |
| Temperature ${ }^{\circ} \mathrm{C}$ |  |  |  |  |  |
| Maximum | $\begin{aligned} & 29.080 \\ & 32.4 \end{aligned}$ | $39.0 \text { to }$ | $\begin{aligned} & 29.0 \text { to } \\ & 33.0 \end{aligned}$ | $\begin{aligned} & 29.0 \text { to } \\ & 33.5 \end{aligned}$ | $\begin{aligned} & 29.0 \text { to } \\ & 33.5 \end{aligned}$ |
| Hinimua | $\begin{aligned} & 22.1 \\ & 23.8 \end{aligned}{ }^{\prime}$ | $\begin{aligned} & 20.9 \text { to } \\ & 23.8 \end{aligned}$ | $\begin{aligned} & 20.8 \text { to } \\ & 23.8 \end{aligned}$ | $\begin{aligned} & 20.4 \text { to } \\ & 23.8 \end{aligned}$ | $\begin{aligned} & 20.4 \text { to } \\ & 23.8 \end{aligned}$ |
| Rasnfall |  |  |  |  |  |
| Intencity (mf) 2 | 2579.4 | 2907.9 | 3754.2 | 3754.2 | 3754.2 |
| Frequeney (days) |  | 82 | 104 | 104 | 104 |
| Sunahine |  |  |  |  |  |
| Numbor of hours OI bright sunmine | 1.6 9.9 | 1.6 to 9.9 | 1.6 9.6 | 1.1 to 9.7. | $\begin{gathered} 1.1 \text { to } \\ 10.1 \end{gathered}$ |
| Reletive humidity (per cent) |  |  |  |  |  |
| Forenooni | 89.9 to 97.1 | $89.9 \text { to }$ $97.1$ | 84.7 to 97.7 | $82.1 \text { to }$ $97.7$ | $\begin{aligned} & 82.1 \text { to } \\ & 97.7 \end{aligned}$ |
| Afternoon | $\begin{aligned} & 61.4 \text { to } \\ & 94.3 \end{aligned}$ | 61.4 to 94.3 | 61.4 to 94.3 | $45.4 \text { to }$ $94.3$ | $\begin{aligned} & 45.4 \text { to } \\ & 94.3 \end{aligned}$ |

So11 tomperature
at 5 cm depth $\left(\mathrm{C}_{\mathrm{C}}\right)$

| Forenoon | 23.5 to | 23.5 to | 23.5 to | 23.5 to | 23.5 to |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | 23.4 | 23.4 | 23.4 | 23.4 | 23.4 |
| arternoon | 23.3 to | 23.3 to | 23.3 to | 28.3 to | 28.3 to |
|  | 39.2 | 39.2 | 39.2 | 39.3 | 39.3 |

* A raing cay is one in which the rainfall intensity 1. $\geq 2.5$.

Appendix 30. Analyses of variance for the effect of ehate on length of vine, number of branches and leaf area index of sweet potato


Hean squares

| Source |  | Chloropayil 'a' (days after planting) |  |  | Chloropingil "b" (days after planting) |  |  | Totel chlorophyil (daye after planting) |  |  | Calorophyll a:b (dage after plant-iny) ina) |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 80 | 95 | $\begin{aligned} & 110 \\ & \text { arveet) } \end{aligned}$ | 80 | 95 | $\begin{gathered} 110 \\ \text { (harvegt) } \end{gathered}$ | 80 | 95 | $\begin{gathered} 110 \\ \text { (harvegt) } \end{gathered}$ | 80 | $95$ | $\begin{gathered} 110 \\ \text { arvest) } \end{gathered}$ |
| Block | 4 | 0.01 | 0.02 | 0.003 | 0.01 | 0.03 | 0.02 | 0.03 | 0.08 | 0.04 | 0.0014 | 0.004 | 0.002 |
| Treatment |  | 0.01 | 0.02 | 0.036* | 0.02 | 0.01 | 0.09 | 0.06 | 0.04 | 0.24 | 0.0001 | 0.002 | 0.002 |
| Ercor | 12 | 0.01 | 0.02 | 0.009 | 0.02 | 0.03 | 0.03 | 0.06 | 0.10 | 0.07 | 0.0009 | 0.002 | 0.001 |

- Significant at 5 per cont level

Appendix 5. Anslysas of pariance for the effeot of anade on total ary weight, net asainilation rate, tuber gield, haulm gield and barvegt index, of gueet potato

| Source | df | Mesn squares |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | $\begin{aligned} & \text { Total aj welsit plant } \\ & \text { (days after planting) } \end{aligned}$ |  |  |  | Hot assinilation rast |  | $\begin{aligned} & \text { Taber } \\ & \text { yield } \end{aligned}$ | $\begin{aligned} & \text { Haula } \\ & \text { Yiold } \end{aligned}$ | Harvest index |
|  |  | 30 | 60 | 90 | 110 Be twean Betwean <br> (harvention 60 days $60 ~$ <br> 00 daye |  |  |  |  |  |
| Block | 4 | 15.64 | 215.03 | 348.17 | 997.42 | 0.72 * | 0.40 | 0.06** | 3.14* | 0.005 |
| Treatant | 3 | 212.32 | 5656.81 | 13656.5 ${ }^{* *}$ " | 14637.35. | $4.94{ }^{\text {\% }}$ | 1.90 | 0.93 ** | 113.80 * | 0.023 |
| Error | 12 | 20.74 | 83.67 | 383.25 | 644.34 | 0.35 | 3.35 | 0.015 | 0.60 | 0.005 |

F Sienilicant at 5 per cont level
** Slgnificant at 1 per cont level
Appendiz 6. Anulymee of variance for the offect of shade on nitnogen content of loaf and atea + petiole and for total uptake of nitrogen by aweet potsto


[^2]Appondix 7. Analyses of veriance for the effect of shade on phosphorus content of leaf and stem + petiole and total uptske of phosphorue of sweet potato

| Source | dt | Hean squares |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Leal phosphorus content (dags after planting) |  |  |  | Sten + petiole phosphorus content <br> (days after plantiag). |  |  |  | Totel uptake of phosphorus (daye after planting) |  |  |  |
|  |  | 30 | 60 | $90$ | $\begin{gathered} 110 \\ \text { (harvest) } \end{gathered}$ | 30 | 60 | 90 | $\begin{aligned} & 110 \\ & \text { harvegt) } \end{aligned}$ | 30 | 60 | 90 | $\begin{gathered} 110 \\ \text { (narvert) } \end{gathered}$ |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Error | 120 | 0.00010 | 0.0021 | 0,000 | 010.0010 | 0.0002 | 0.0017 | 0.0004 | 0.00015 | 1.27 | . 8.88 | 7.46 | 25.85 |
| - sieniricamt at 5 per-cent lovel <br> * Significant at 1 per cont level |  |  |  |  |  |  |  |  |  |  |  |  |  |

Appendix B. Analyges of varinnce for the effect of shado on potarolum content in leaf nill sterit petiole and botal uptaice of potnedim in sweet potato


| Block 4 | 0.17* ${ }^{\text {\% }}$ | 0.24 | $0.0{ }^{*}$ | $0.033^{* *} 0$ | 0.090 | 0.07 | 0.04 | $0.10{ }^{\text {² }}$ | 393.70 | 4024.155317 .46 | 13664.70 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Treatant 3 | $0.27^{*}$ | $0.3{ }^{\text {T* }}$ | $0.1{ }^{*}$ | $0.193^{\text {雨 }}$ | $7.59^{*}$ | 0.48" | $0.33^{* *}$ | $1.077^{* *}$ | $2345.50^{* \prime}$ | 7167 方. $86^{* *} 34440.78$ | 153965.35 |
| Error 12 | 0.01 | 0.05 | 0.01 | 0.0020 | 0.06 | 0.014 | 0.012 | 0.004 | 397.75 | 1629.76 2553.22 | 5103.60 |

* Siguificant at 5 per cent level
** Sienificant at 1 par cent level

Appendix 9. Analyses of variance for the effect of shada on the eoll nutrient otatus after the crop of sueet potato

| Source | ds | Nutrient |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  |  | Total altrogen | Available phoephorus | Available potnasium |
| Block | 14 | 0.0001 | 1.356 | $52.99{ }^{\text {* }}$ |
| Treatment | 3 | $0.001{ }^{* *}$ | 10.228*** | 756.56** |
| Error | 12 | 0.0001 | 0.475 | 13.52 |

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

Appondix 10. Analgees of variance for the affect of shade on plant height, number of brencher and leaf aren incex of coleus

| Source | di | Hesn squares |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | $\begin{gathered} \text { plant heignt } \\ \text { (doys after planting) } \end{gathered}$ |  |  |  | Wubler of brancioc (dags after planting) |  |  |  | Leaf area index <br> (days after planting) |  |  |  |
|  |  | 35 | 65 | 95 | $\begin{gathered} 125 \\ \text { (harvest) } \end{gathered}$ | $)^{35}$ | 65 | $95$ | $\begin{aligned} & 125 \\ & \text { harvegt } \end{aligned}$ | 35 | 65 | 95 | $\begin{gathered} 125 \\ \text { (harvest) } \end{gathered}$ |
| Block | 4 | 1.89 | 44.55 | 115.3 | 154.61 | 4.67 | 36.52 | 104.70 | 313.07 | 0.87 | 9.79 | 2.77 | 5.50 |
| Treatront | 3 | 4.37 | 75.40 | 342.9 | * 125.03 | 59.81 | 33.10 | 162.07 | 32.60 | 1.81 | 8.18 | 27.43 | 1.85 |
| Srror | 12 | 9.21 | 34.32 | 46.5 | 152.85 | 12.76 | 14.04 | 64.98 | 104.24 | 0.36 | 10.10 | 16.25 | 5.51 |

* Sigaificant at 5 per cent level
* Sigulifcent at 1 per cent level

Appendix 11. Anelyces of variance for the effect of shede on the contente of chlorophyil 'a'. 'b'; and total chlorophyll ratio of onlorophyil amb of coleus leaves

| Source | Hean squaras |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Chlorophyly "a" (days aftor plonting) |  |  | Chalorophyll "b" (Cays after plenting) |  |  | Total chlorophyli (days efter planting) |  |  | Chlorophyll a:b (ayse eftar Di.anting) |  |  |
|  | 80 | 110 | $125$ <br> arvest) | 80 | 110 | $\begin{gathered} 125 \\ \text { harvest) } \end{gathered}$ | 80 | 110 | $\begin{gathered} 125 \\ \text { (narvest? } \end{gathered}$ |  | $110$ <br> (h | $\begin{aligned} & 125 \\ & \text { survent) } \end{aligned}$ |
| Block | 40.009 | 0.05 | 0.01 | 0.01 | 0.05 | 0.07 | 0.02 | 0.17 | 0.11 | 0.012 | 0.02 | 0.01 |
| Tratarent | $30.19{ }^{*}$ | 0.20 | $0.18{ }^{\text {** }}$ | 0.28** | 3.06** | $0.16^{*}$ | 1.04 ** | 0.99 | 0.67 ** | 0.001 | 0.02 | 0.03 |
| Error | 120.019 | 0.03 | 0.005 | 0.01 | 0.02 | 0.03 | 0.003 | 0.10 | 0.006 | 0.014 | 0.01 | 0.01 |

[^3]Appendix 12. Anslyeas of veriance for the effect of ahede on total dry antter production, net assimilation rate, number of tubers, tuber jield, haule yield and harvest index of coleus
hean aquares

| Source | de | Total axy velgat (days after planting) |  |  |  | Net aselpaliationrate |  | n Suaber of tubers (dags aftar planting) |  |  | Tuberyield | $\begin{aligned} & \text { Heula } \\ & \text { gield } \end{aligned}$ | Harvest inder |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | $95 \text { (har }$ | $\frac{125}{x+e g t)}$ | $\begin{aligned} & \text { Between } \\ & 35 \text { \& } \\ & 65 \text { daga } \end{aligned}$ | $\begin{aligned} & \text { Botuoen } \\ & 65 \text { d } \\ & 95 \text { daga } \end{aligned}$ | 65 | 95 (h | $\frac{125}{125}$ |  |  |  |
| BLock | 4 | 0.54 | 30.43 | 81.22 | 58.72 | 0.35 | 1.82 | 0.12 | 5.05 | 631.37 | 24.08 | 0.31 | 0.003 |
| Traatment | 3 | 5. 5 告 | $180.09^{*}$ | 621.957. | 683.78 | 2.65 | 3.78 | 1.03* | 241.9\% | 155.69 | 525.43* | $5.50{ }^{\text {\% }}$ | $0.01{ }^{\text {* }}$ |
| Brror | 12 | 0.76 | 26.98 | 68.30 | 127.72 | 0.59 | 1.65 | 0.24 | 6.38 | 76.70 | 22.21 | 1.38 | 0.003 |

* Sleniflcant at 5 per cent leval
** Significont at 1 por cent level
Appendix 13. Analyseg of variance for the effect of shade on nitrogen contentis of coleua leaf, stem + petiole and tuker


Appendix 14. Analyses of variance for the offect of ghade on totel uptake of nitrogen by coleus and for the content of phosphoras in doleus leaf and eten + petiole

## Hean equares

| Source | dif | Total uptske of nitrogen (days efter plonting) |  |  |  | Phosphoris content of leal Sten + petiole phosphorue (days after planting) content <br> (dage aftar plonting) |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 35 | 65 |  | $\begin{gathered} 125 \\ \text { nsprest) } \end{gathered}$ | 35 | 65 | 95 | $\frac{125}{\text { (harvest) }}$ | 35 | 65 | 95 | $\begin{gathered} 125 \\ \text { (harvest) } \end{gathered}$ |


| Block | 4 | $269.50 *$ | 63.22 | 71.41 | 37.58 | 0.005 | 0.0004 | 0.001 | 0.0002 | 0.0003 | 0.0011 | 0.0003 | 0.0004 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |

* signilicant at 5 per cont level
** Significant at 1 per cent level
Apsendix 15. Analycea of variance for the effect of chade on phosphorus content of coleus tuber, total uptake of phosphorus by coleue and potaselum content in coleus loaf


## yean squgres

| Source | Tuber phomphorue content Totell uptake of phoaphorus (days aiter plenting) (days after planting) |  |  |  |  |  | Leaf potarsiua content (days after plentiag) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 95 | $\begin{gathered} 125 \\ \text { (harvest) } \end{gathered}$ | 35 | 65 | 95 | $\begin{gathered} 125 \\ \text { (narvest) } \end{gathered}$ | 35 | 65 | 95 | $\begin{gathered} 125 \\ \text { (harvest) } \end{gathered}$ |
| Block 4 | 0.001 | 0.0007 * | 3.09 | 1.63 | 2.2 | 1.30 | 0.0 | 0.02 | 0.02 | 0.03 |
| Treatment 3 | 0.001 | 0.0025** | 2.04 | 4.38 | 17.90 | 13.34 | 0.74 | 2.0 | $1.18{ }^{\text {N }}$ | $0.29 *$ |
| Frror 12 | 0.001 | 0.0001 | 0.52 | 1.56 | 2.23 | 2.45 | 0.01 | 0.01 | 0.04 | 0.01 |

[^4]Appendix 16. Analyces of variance for the effeot of sinede on potaboiun content of coleus atem + peciole and tuber; and for the total uptake of potaselun by coleus


- Slenificant at 5 per cent level
* Signiricmt at 1 per cont levol

Appendix 17. Anelyeis of variance for the affect of ghede on goil mutrient statas after tice crod of colous

| Souroe | d | Hutirient |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  |  | Totel nitrogen | Avallable phoaphorus | Available potaesiva |
| Block | 4 | 0.0001 | 2.23 | 87.84 |
| Ireatment | 3 | 0,0011** | 4.81 | 1211.98******* |
| Bryor | 12 | 0.00005 | 1.96 | 29.58 |

** Stenificant at 1 per cent leval

Appendix 18. Analysee of variance for the effect of ehade on plant hoight and nollar eirth of colocesia


Appendix 19. Andiyses of variance for the effect of shade on nuaber of tillere and leaf area index of colocasia

| Source | Hean quares |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | dif | Rumber of tillere plent ${ }^{-1}$ (days after eprouting) |  |  |  |  | Leaf area inder (dags after oprouting) |  |  |  |  |
|  |  | 30 | 60 | 90 | 120 | 150 | 30 | 60 | 90 | 120 | 150 |
| Block | 4 | 0.65 | 1.30 |  | 7.32 | 1.33 | 0.21* | 0.13 | 0.02 | $0.14{ }^{*}$ | 0.02 |
| Treatatat | 3 | 2.88 | 55.28 | 40.12* | 64.4B** | $50.57{ }^{*}$ | 0.01 | 0.93 | 0.25 | $0.2{ }^{* *}$ | 0.02 |
| Error | 12 | 2.34 | 5.22 | 5.22 | 8.15 | 10.46 | 0.05 | 0.44 | 0.09 | 0.04 | 0.02 |

Appendir 20. Anslyseb of variance for the effect of ahede on content of calorophyil 'a' and ' $b$ ' of colocacia leaves


Appendix 22. Analysem of variance for the effect of anade on total dry matter production, Ifold of total tubers, side tubere and hallefor harve日t index of colocabla


* Significant at 5 per cont levol
an glenificant at 1 per cont level

Appendix 24. Analysee of varisnce for the effect of ghade on nitrogen content of tuber and for total uptake of nitrogen by colocasia

| Source | dt | Lean quaree |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Tuber niturogen content (daye efter sprouting) |  |  |  |  |  | Total uptake of nstrogen (days after sprouting) |  |  |  | $\begin{gathered} 180 \\ \text { (harvogt) } \end{gathered}$ |
|  |  | 60 | 90 | 120 | 150 | $\begin{gathered} 180 \\ \text { (harvest) } \end{gathered}$ | 30 | 60 | 90 | 120 | 150 |  |
| Block | 4 | 0.002 | 0.000 | 0.006 | 0.0001 | 0.005 | $165.33^{* *}$ | 18.77 | 76.95 | 140.06 | 129.99 | 63.72 |
| Treetaent | 3 | 0.034 | 0.001 | 0.734** | 0.013* | $0.163^{*}$ | 22.62 | 742.41* | 376.74 | $1869.85^{*}$ | 741.83 | 752.59 |
| Error | 12 | 0.0012 | 0.000 | 0.004 | 0.001 | 0.003 | 18.82 | 145.55 | 81.22 | 90.49 | 135.42 | 234.67 |

* Sienifieant at 5 per cent level
** Significant at 1 per cent level
Appenaix-25. Analyses of variance for the effect of shade on phosphorus content of leaf and pseudosten of colocasia


Appendix 26. Analysea of vaxiance for the offect of shade on tuber phomphorue content of colocnela and for the total uptake of phosphorus by colocasia

| Hean aquares |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Source | af | Tuber phomphorue content (dags after sprouting) |  |  |  |  | Total phobphorue uptake (dags aftor aprouting) |  |  |  |  |  |
|  |  | 60 | 90 | 120 | 150 | $\begin{gathered} 180 \\ \text { Carvest) } \end{gathered}$ | 30 | 60 | 90 | 120 | 150 | $\begin{gathered} 180 \\ \text { (harvest) } \end{gathered}$ |
| Block | 4 | 0.003 | 0.001 | $0.00{ }^{\text {\% }}$ | 0.002 | 0.003 | $5.25{ }^{*}$ | 1.62 | 2.79 | 2.58 | 3.57 | 2.69. |
| Treataent | 3 | 0.002 | 0.021* | $0.010^{*}$ | 0.025 | $0.033^{*}$ | 0.27 | $39.19{ }^{* *}$ | 35.24** | 35.94* | 24.07 | 144.27*** |
| Error | 12 | 0.003 | 0.0004 | 0.0006 | 0.004 | 0.002 | 0.46 | 5.77 | 2.65 | 6.15 | 6.51 | 6.46 |

* Significant at 5 por cont level
* Significant at 1 per ceat level

Appendix 27. Analysen of variance for the offect of ohade on potaseiun content of leaf and paeudorter of colocesia

| Source | di | Hean squeres |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Leal potaceius content <br> (days after gprouting) |  |  |  |  | Pseadostea potassian content (days after sprouting) |  |  |  |  |  |  |
|  |  | 30 | 60 | 90 | 120 | 150 | $180$ | 30 | 60 | 90 | 120 | 150 | $\begin{gathered} .180 \\ \text { (herveat) } \end{gathered}$ |
| Block | 4 | 0.16 | $0.27^{* *}$ | 0.01 | 0.12 | 0.07 | 0.05 | 0.29 年 | $0.25^{*}$ | $0.1{ }^{\text {²* }}$ | $0.13{ }^{*}$ | 0.05 | 0.03 |
| Trentinent | 3 | $0.92^{* *}$ | $0.23{ }^{\text {* }}$ | $0.54{ }^{\text {* }}$ | $0.7{ }^{\text {* }}$ | $0.92^{* \prime}$ | 0.58 ${ }^{\text {F }}$ | $0.77{ }^{\text {\% }}$ | 0.18 | $1.77^{*}$ | 1.23** | $0.98{ }^{\text {\% }}$ | $1.68{ }^{* *}$ |
| Errar | 12 | 0.06 | 0.03 | 0.02 | 0.04 | 0.03 | 0.05 | 0.05 | 0.03 | 0.03 | 0.02 | 0.04 | 0.12 |

[^5]Apgondix 28. Analgaes of varionce for the offect of shade on potsebius content of colocsela tuber and for the total nptate of potasaing by colocadia

| Source | dit | Tuber potasmina content (days after aprouting) |  |  |  |  | Total uptake or potaseium (days after sprouting) |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 60 | 90 | 120 | 150 | ${\underset{c}{\text { (narvest) }}}_{180} 30$ | 60 | 90 | 120 | 150 | $\begin{gathered} 180 \\ \text { (harvest) } \end{gathered}$ |
| Block . | 4 | 0.05 | 0.025 | $0.0{ }^{* *}$ | 0.05 | $0.07^{\prime \prime} 967.2{ }^{\text {\% }}$ | . 346.11 | 610.18 | 657.02 | 474.36 | $36 \quad 137.19$ |
| Ircatient | 3 | $0.09{ }^{*}$ | 0.143 | $0.11^{* *}$ | . 0.02 | $0.12{ }^{*} 182.07$ | $6830.64{ }^{\text {a }}$ | 3833.73* | *5970.77** | 2934.60 | (**6117.59** |
| Exror | 12 | 0.006 | 0.027 | 0.015 | 0.02 | 0.02119 .57 | 1017.70 | 523.00 | 491.43 | 475.79 | 9 720.04 |

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

Appendix 29.' Analyses of variance for the effect of shade on cosil nutriont atatus after the orop of colocasis


Appendix 30. Analyses of variance for the effect of shade on plant height, number of tillers and leaf area index of turaeric

| Source | dit | Mean squarea |  |  |  |  |  | Lear |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | plent height (deye after aprouting) |  |  | Number of tillers plant $\boldsymbol{T}^{1}$ (tays after sprouting) |  |  | Leal aroa index <br> (days after gprouting) |  |  |
|  |  | 60 | 120 | 180 | 60 | 120 | 180 | 60 | 120 | 180 |
| Block | 3 | $\begin{aligned} & 152.5 \\ & 129 \end{aligned}$ | 1103. | 124.7 730.3 | 1.34 8.94 | 1.01 1.58 | $3.17{ }^{*}{ }^{\text {m }}$ \% $5.34{ }^{\text {a }}$ | 1.47 2.94 | $\begin{array}{r} 25.08 \\ 6.28 \end{array}$ | 411.11 33.47 |
| Ireataent Error | 3 12 | 122.5 61.2 | 215.4 68. | 730.3 69.7 | 8.94 1.66 | 1.58 0.79 | 5.34 0.62 | 2.94 0.35 | 6.99 | 20.04 |
|  | lena | $\begin{aligned} & \text { icant } a \\ & \text { icant } \end{aligned}$ | $\begin{aligned} & \text { per } \\ & \text { per } \end{aligned}$ | level <br> $t$ level |  |  |  |  |  |  |
| Appendix 31 |  | Analysee of variance for the offoct of ahade on content of chlorophyli ' $a$ ', ' $b$ ' and total chlorophyll; calorophyll a-b ratio of turmerio leaves |  |  |  |  |  |  |  |  |

Hean equares

| Source | di | Calorophyll "a" <br> content <br> (daye after <br> sprouting |  | ```Chlorophyll 'b' content (caga after sprouting)``` |  | Total calorophyll <br> content <br> (days after <br> sproutins |  | Chlorophyll a:b <br> (asys after sprouting) |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 100 | 160 | 100 | 160 | 100 | 160 | 100 | 160 |
| Blocis | 4 3 12 | $\begin{aligned} & 0.04 \\ & 0.17 \end{aligned}$ | $\begin{aligned} & 0.02 \\ & 0.13^{* *} \end{aligned}$ | 0.09 0.18 0.01 | $\begin{aligned} & 0.04 \\ & 0.18 \\ & 0.02 \end{aligned}$ | 0.23 0.71 0.03 | $\begin{aligned} & 0.10 \\ & 0.61^{* *} \\ & 0.06 \end{aligned}$ | $\begin{aligned} & 0.002 \\ & 0.007 \\ & 0.001 \end{aligned}$ | $\begin{aligned} & 0.0036 \\ & 0.0001 \\ & 0.0043 \end{aligned}$ |
| Error | 12 | 0.01 | 0.01 | 0.01 | 0.02 | 0.03 | 0.06 | 0.001 | 0.0043 |

---- Signiricant at 5 per cent level
** Sigaificant at 1 per cent lerel

Appendix 32. Analyges of variance for the effect of shade on total ary matter production, net assimilation zate, rhizome yield, haulm yield, and hervest index of turmeric

| Source | df | Hean squares |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | $\begin{aligned} & \text { Total ary welght (g plant }{ }^{-1} \text { ) } \\ & \text { (dsye efter sproutig ) } \end{aligned}$ |  |  |  | Het ansinilation rate |  | Rhisome sield | $\begin{aligned} & \text { Laula } \\ & \text { yield } \end{aligned}$ | Harvest index |
|  |  | $60 \quad 120$ | $180$ | $220{ }^{2} 2$ | 20 harvent) $4 \mathrm{ha}^{-1}$ | Betreen 60 t <br> 120 day | $\begin{aligned} & \text { Between } \\ & 120 e^{2} \\ & 180 \text { dage } \end{aligned}$ |  |  |  |
| Block | 4 | $17.11{ }^{\text {¹ }} 230.65$ | 1301.71 | 619.87 | 6.3 | 0803 | 0.19 | 95.32 | 0.93 | 0.003 |
| Treatjent | 3 | $55.32^{*} 203.61$ | 902.54 | 1481.67 | 13.43* | 0.03 | 0.32 | $594.03^{* *}$ | 6.26* | 0.009 |
| Error | 12 | $4.38 \quad 79.70$ | 607.39 | 248.54 | 2.85 | 0.15 | 1.10 | 54.73 | 0.96 | 0.003 |

* Significant at 5 per cent levol
** Signisicent at 1 per cent level
Appendix 33. Analysen of variance for the effect of enade on nitrogen contont of leaf and paendostem of turmeric

- signisicant at 5 per cent level
* Sigaificant at 1 per cent level

Appendix 34. Analysee of variance for the effeot of shade on nitrogen content of turmorio rhicone and for the total uptaice of nitrogen by turatric
uean aguarea

| Sourc | di | Ahigome nitrogen content (days after eprouting) |  |  |  | sotal uptake of nitrozen (dags eftar oprouting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 60 | 120 | 180 | $\begin{gathered} 220 \\ \text { (harvest) } \end{gathered}$ | 60 | 120 | 180 | $\begin{gathered} 220 \\ \text { (Harvest) } \end{gathered}$ |
| Block | $4$ | $0.005$ |  | $0.002$ |  | $391.38$ | 2470.18* | 6618.29 |  |
| Ireatanent | 3 | $0.25{ }^{*}$ | $0.052^{\text {13 }}$ | 0.029* | $0.030^{* *}$ | $710.87^{74}$ | 1287.94 | 1027.58 | $6493.52$ |
| Siror | 12 | 0.010 | 0.001 | 0.003 | 0.002 | 96.30 | 546.12 | 3066.65 | 1531.21 |

- Signiricant at 5 per cent level
* Significent at 1 per cent level

Appendix 35. Amalyaes of variance for the uaffect of ghade on phosphorua content of leat and pseudoaten of turmeric

| Soursoe | $0 x$ | Mean squares |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Jeat phopphorua content |  |  |  | Peuaden phophorus contert |  |  |  |
|  |  | 60 | 120 | 180 | $\begin{gathered} 220 \\ \text { (harvest) } \end{gathered}$ | 60 | 120 | 180 | $\begin{gathered} 220 \\ \text { (harveat) } \end{gathered}$ |
| Black | 4 | 0.001 | 0.0003 | 0.0003 | 0.0002 | 0.0001 | 0.0001 | 0.003 | 0.0004 |
| Treatment | 3 | 0.002 | $0.003^{* *}$ | $0.006^{* \prime \prime}$ | $0.0013^{* *}$ | $0.014{ }^{\text {c }}$ | $0.0015^{*}$ | 0.006 | $0.0003^{*}$ |
| Brror | 12 | 0.001 | 0.0002 | 0.0008 | 0.0001 | 0.0003 | 0.0004 | 0.005 | 0.0002 |

[^6]Appendix 36. Analysee of variance for the effect of ahade on phosphorus content of turmeric rhimones and for the total uptake of phogphotus by turneric

Mean squares

| Source | df | inizome phoophorus contont (deys after aprouting) |  |  |  | Total uptake of phosphorus (ciaye after aprouting) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 60 | 120 | 180 | $\begin{gathered} 220 \\ \text { (harvest) } \end{gathered}$ | 60 | 120 | 180 | $\begin{gathered} 220 \\ \text { (harvest) } \end{gathered}$ |
| Black | 4 | 0.0003 | 0.0007 | 0.001 | 0.015 | 7.75** | $63.08{ }^{\text {\% }}$ | 238.34 | 145.91 |
| Freatment | 3 | 0.0029* | $0.0091 *$ | 0.015* | 0.013 | 12.47** | 36.18 | 175.20 | 450.39** |
| Ecror | 12 | 0.0006 | 0.0009 | 0.007 | 0.017 | 2.02 | 17.57 | 186.47 | 80.32 |

* Signsficant at 5 per cont level
** Signilicant at 1 per cent ievel
Appendix 37. Analynes of variance for the effect of shade on potaseium content in leaf and pseudostan of turmeric

| Source | df | Yean aquares |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Ieaf potaseiva content (days after aprouting) |  |  |  | Psendortem potaseium content (days arter aprouting) |  |  |  |
|  |  | 60 | 120 | 180 | (harvest) | 60 | 120 | 180 | $\begin{gathered} 220 \\ \text { (harpept) } \end{gathered}$ |
| Block | 4 | 0.018 | 0.100 | 0.119 | 0.015 | 0.021 | 0.027 | $0.174^{* *}$ | 0.029 |
| Treatment | 3 | 0.161* | $0.50{ }^{*}$ | $0.384 *$ | 1.808** | 2.020** | $2.977^{* *}$ | 1.341** | $2.306^{* *}$ |
| Brror | 12 | 0.019 | 0.036 | 0.069 | 0.026 | 0.072 | 0.019 | 0.026 | 0.038 |

* Significont at 5 per cent level
* Sifnificant at 1 per cent level

Appenaix 38. Analysea of variance for the offect of chede on potansiun content of turmeric rhizone and for the total uptake of potagelum by turnerio

| Hean squares |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Source | dr | Rhizone potassiun content (days after sproutine) |  |  |  | Total uptake of potsosium (days arter sprouting) |  |  |  |
|  |  | 60 | 120 | 180 | $\begin{gathered} 220 \\ \text { haxtecti } \end{gathered}$ | 60 | 120 | 180 | $\begin{gathered} 220 \\ \text { Chacreat } \end{gathered}$ |
| Block | 4 | 0.036 | 0.045 | 0.013 | 0.013 | 3039.02* | 42892.4 | 98760.6 | 39894.0 |
| Treatment | 3 | 0.409** | 1.040 | 1.023** | $0.170^{* *}$ | $6898.93^{4}$ | 22212.2 | 12021.3 | 63093.8' |
| Error | 12 | 0.033 | 0.016 | 0.038 | 0.024 | 884.03 | 9107.4 | 42925.3 | 14124.1 |

* Significant at 5 per cont level
* Significant at 1 per cont lovel

Appendix 39. Analyees of veriance for the offect of shade on zoil nutrient atatus after the orop of turaeric

| Source | Mean squares |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  | dr | Total nitrogen | Available phosphorus | Available potassium |
| Block | 4 | 0.00001 | 0.106 | 52.76 |
| Treatient | 3 | $0.0048^{* *}$ | $2.775{ }^{*}$ | 1055.23** |
| Error | 12 | 0.00001 | 0.711 | 24.19 |

[^7]sppendix 40. Analyses of variance for the offect of ghade on plant hoight, number of tillers and leaf aree index of ginger

| Source | di | Mean dquaren |  |  |  |  |  | Leas area ináex (daya aiter aprouting) |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Plant helgint <br> (dege after sprouting) |  |  | Humber of tillers plent ${ }^{-1}$(days after agrouting) |  |  |  |  |  |
|  |  | 60 | 120 | 180 | 60 | 120 | 180 | 60 | 120 | 180 |
| Block | 4 | 17.90 | 61.55 | 15.17 | 4.06 | 21.13 | 22.11* | 0.02 | 0.68 | 2.80 |
| Ireatament | 3 | 8.93 | 125.01 | $307.74{ }^{*}$ | $13.13{ }^{\circ}$ | 56.51 | 7.74 | 0.05 | 2.10 | 2.53 |
| Error | 12 | 24.57 | 17.34 | 29.23 | 3.54 | 21.87 | 5.39 | 0.06 | 1.13 | 2.24 |

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

Appendix 41. Analyses of verience for the effect of ahade on content of chlorophyil ' $a$ '. ' $b$ ' and total chiorophy31; chlorophyll a: $b$ of ginger leaves

Moan equares

| Source dis | $\begin{gathered} \text { Caiorophy } 21 \\ \text { (days ofter }{ }^{\prime} \mathrm{B}^{\prime} \\ \text { oprouting) } \end{gathered}$ |  | chlorophylil ${ }^{\circ} \mathrm{b}^{\prime}$ (days aftar eprouting |  | Total ohlorophy 11 (days after pprouting) |  | Calorophyil a:b (days after sprouting) |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 100 | 160 | 100 | 160 | 100 | 150 | 100 | 160 |
| Block 4 | 0.04* | 0.07** | 0.07 | 0.23** | 0.19 | $0.51{ }^{* *}$ | 0.006 | $0.025^{*}$ |
| Treatment 3 | $0.26{ }^{\text {* }}$ | 0.46 ** | 0.40 ** | $0.66{ }^{\text {** }}$ | $1.31^{\text {\#* }}$ | $2.19{ }^{\text {** }}$ | 0.002 | 0.006 |
| Error 12 | 0.01 | 0.02 | 0.03 | 0.02 | 0.06 | 0.06 | 0.005 | 0.005 |

[^8]Appendix 42. Analysee of variance for the effect of chado on total dry matter production, net esolmilation rate, rhicone gield. hauln yield and harvent index of ginger

| Source | ds | yean equares |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Totel ary welght (Caye after oprouting) |  |  | abt asaicilation rate <br> g) |  |  | Inszone sield | Houlm | Tarvest index |
|  |  | 60 | 120 | 180 | $\begin{gathered} 225 \\ \text { (narveat) } \end{gathered}$ | Betwcen 60 * <br> 120 day | betureen 120 \% 180 day: |  |  |  |
| Blook | 4 | 0.82 | 25.32 | 153.61 | 24.5 .49 | 0.14 | 0.11 | 2.73 | 0.22 | 0.00 |
| Treatment | 3 | 3.66 | .152.05* | 582.38 | 1741.18 | 0.87 | 0.63 | $65.59{ }^{\text {c }}$ | 1.01 | $0.020{ }^{\text {² }}$ |
| grior | 12. | 1.58 | 36.95 | 184.12 | 149.97 | 0.28 | 0.83 | 9.34 | 0.72 | 0.005 |

* Significant at 5 per cont level.

Appendix 43. Anelysed of tariance for the effect of sbade on content of nitrogen in leap, peandostea ana zhizome of ginger

| Source | ds |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Leaf gitrogen content (days after spro |  | Peeudocten niltrogon content <br> ng) (dags after sprouting) |  |  |  | Rhizons nitrogen content (days after sproutine) |  |  |  |
|  |  | 60 | 120 | 180 | 50 | 120 | 100 | 60 | 120 | 180 | $\begin{aligned} & 225 \\ & \text { ngryesta } \end{aligned}$ |
| Block | 4 | $0.10{ }^{*}$ | 0.007* | 0.078 | . 0.007 | 0.006 | 0.036 | 0.421 | 0.006 | 0.012 | $0.003^{*}$ |
| Ireatrent | 3 | 0.06 | $0.919^{*}$ | 0.207 | $0.17{ }^{*}{ }^{*}$ | 0.083 | 0.027 | 0.733 | 0.007 | 0.039 | $0.21 i^{* 5}$ |
| Error | 12 | 0.02 | 0.001 | 0.006 | 0.021 | 0.006 | 0.043 | 0.541 | 0.004 | 0.015 | 0.002 |

[^9]
## Appendix 44. Analyten of variance for the effect of thade in total uptake of nitrogen by ginger and for the content of phosphorus on ginger leaf and pseudosten



Appondix 46. Analyses of variance for the effect of shade on potaesion content in leaf, pseudosten end rhizome of ginger

\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|c|c|}
\hline \multirow{3}{*}{Source} \& \multirow{3}{*}{di} \& \multicolumn{10}{|c|}{Heen squares} \\
\hline \& \& \multicolumn{7}{|l|}{Leaf potemaiur content Pseudoetem potassium oontent (deys after sprouting) (dage after sprouting)} \& \multicolumn{3}{|l|}{\begin{tabular}{l}
Bindzoina potaselua contant \\
(days after eprouting)
\end{tabular}} \\
\hline \& \& 60 \& 120 \& 180 \& 60 \& 120 \& 180 \& 60 \& 120 \& 180 \& \[
\begin{gathered}
225 \\
\text { harvest) }
\end{gathered}
\] \\
\hline Block \& 4
3 \& 0.03
0.88 \& \[
\begin{aligned}
\& 0.25^{*} \\
\& 0.59
\end{aligned}
\] \& 0.10
0.60 \& 0.19
1.07 \& 0.04
\(1.00{ }^{\text {a }}\)

0.04 \& $$
\begin{aligned}
& 0.01 \\
& 0.63^{\prime \prime}
\end{aligned}
$$ \& 0.03

0.18 \& 0.03

0.25 \& $$
\begin{aligned}
& 0.01 \\
& 0.53
\end{aligned}
$$ \& \[

$$
\begin{aligned}
& 0.001 \\
& 0.231^{*}
\end{aligned}
$$
\] <br>

\hline Frror \& 12 \& 0.03 \& 0.07 \& 0.03 \& 0.02 \& 0.04 \& 0.04 \& 0.05 \& 0.03 \& 0.02 \& 0.016 <br>
\hline
\end{tabular}

* Significant at 5 por cent leval
** Sleniricant at 1 per cent lovel
Appendix 47. Analyses of variance for the effoct of bhade on total uptake of potaseium Dy ginger and for the 8011 nutrient otatue after the crop of ginger

| Souroe | di | Hean squarob |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Total potasalum uptake <br> (axys after eprouting) |  |  | Soil natrient statue |  |  |  |
|  |  | 60 | 120 | 180 | ${ }_{(\text {harvest })}^{225}$ | $\begin{aligned} & \text { Total } \\ & \text { nitrogen } \end{aligned}$ | Available phosphorus | Avallable potagelum |
| Block | 4 | 96.75 | 1376.13 | 2576.78 | 6447.37 | 0.0000 ${ }^{\text {" }}$ | 0.21 | 13.25 |
| Trastant | 3 | 327.69 | 7531.54 | 6195.45 | 2787.95 | $0.0024^{*}$ | 0,99 | $1133.8{ }^{* *}$, |
| Error | 12 | 177.33 | 2381.29 | 4909.63 | 3251.08 | 0.00001 | 0.46 | 11.55 |

- Slanilicant at 5 par cent level
* Eignificant at 1 por cent level

Appendix 48. Anelyaes of variance for the gield response of different crops to varying intensities of chade

| Crop |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Source af | $\begin{aligned} & \text { Suget potato } \\ & \left(\log _{10}(\bar{y}+1)\right. \end{aligned}$ |  | Colene (y) |  | $\begin{aligned} & \text { 2olocaesa } \\ & \left(\log _{10} y\right) \end{aligned}$ |  | $\begin{aligned} & \text { Furaerio } \\ & \left(\log _{10} y\right) \end{aligned}$ |  | $\begin{aligned} & \text { Ginger. } \\ & \left(\log _{10} y\right) \end{aligned}$ |  |
|  | sum of squares | mean squares | Eus of squares | $\begin{aligned} & \text { sean } \\ & \text { squareg } \end{aligned}$ | gum of quares | $\begin{aligned} & \text { mean } \\ & \text { aquares } \end{aligned}$ | Elat of squares | - saean | tur of gouares | mean <br> squares |
| Treatrent 3 | 2.7966 | 0.9322 | . 1576.44 | 525.48 | 0.4865 | 0.1622 | 0.2144 | 0.714 | 0.1217 | 0.0406 |
| 1) Linear 1 | 2.5241 | $2.5244^{* *}$ | 1562.62 | 1562.62** | 0.3037 | $0.3037^{* *}$ | 0.0995 | $0.099{ }^{\text {\% }}$ | 0.0317 | $0.0817^{* *}$ |
| ii) Quadra-1 | 0.2670 | $0.2670^{* *}$ | 8.33 | 3.33 | 0.1630 | $0.1630^{*}$ | 0.0350 | $0.0950^{* *}$ | 0.0400 | $0.0400 *$ |
| 1i1) Cubic 1 | 0.0055 | 0.0055 | 5.49 | 5.49 | 0.0198 | 0.0198 | 0.0299 | $0.029{ }^{* *}$ | 0.0000 | 0.0000 |
| Error 12 | 0.1736 | 0.0145 | 266.57 | 22.21 | 0.2264 | 0.0189 | 0.0585 | 0.0049 | 0.0619 | 0.0052 |

[^10]
# SHADE RESPONSE OF COMMON RAINFED INTERCROPS OF COCONUT 

BY
LALITHA BAI, E. K.

## ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requireme for the degree

# flaster of Stiente in Agriculture 

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy<br>COLLEGE OF HORTICULTURE<br>Vellanikkara - Trichur<br>KERALA - india<br>1981

## ABSTRACT

An expergmont was conducted at the College of Hortioulture, Vellonickara during 1980-81 to sindy tho shade responge of five comion rasnfed intercrops of coconut graiden.

The experiment was laid out in randomised blocs deolen with four levels of shade and five replicelions.

The atudy revealed that sweet potato cam:ot be cultivated under anade ab it is a 'shademensitive" crop, while coleus 18 buitable only where light insilitation is high. Colocasia, turaerio and ginger were found suitable for intercropped altuations. Colocasie appeare to be 'anade-tolerant while einger and turneric are indicated as 'shade-loving' . Theze two made-loving crops are best ountod mader shaded aituations upto 25 and 50 por cent made, respectively. Photogynthetic mechanten apjears to have a decisiva role on the shace reaponce of all these arops oxcepting bweet potato. Excepting colocasin, plont height (length of vine) in all the crope increased with Increasing ahade intensities. Lumber of branchee (tiliera) in all the crops slenificentiy deareased with inoreabing intenoities of ahade. The content of total chlorophyll and
its compoucnita were bignificantly influenced by ghading in ell the crope.

The contents of nitrogen, phosphorue and poteosiun In all the plant oomponents of all the orope inoreased because of shading. The uptate of all the nutrientb followed an sdentionl pattern as that of ary matter accumatation in all the crope。


[^0]:    wS $=$ Iot significant

[^1]:    KS = Hot significent

[^2]:    * Significant at 5 per cent level
    * Significant at 1 per cont level

[^3]:    * Significant at 5 per cent level
    ** Significant at 1 per cent level

[^4]:    - Sicnificant at 5 per cont level
    * Slgnificant at 1 per cont level.

[^5]:    * Slenificant at 5 por cent level
    * Sigalifcant at 1 per cent level

[^6]:    * Sigaificant et 5 per cent level
    **Significont at 1 per cent level

[^7]:    * Sigaificant at 5 per cent level
    * Significont at 1 per cont level

[^8]:    - olenificant at 5 per cont leyel
    * Significant at 1.por cont levol

[^9]:    4 Significent at 5 per cont level

    * Significant at 1 par cent level

[^10]:    y mactual yiclas

    * Significent at 5 por cent level
    ** Sigairicant at 1 per cent level

