PRODUCTION POTENTIAL OF CASSAVA (*MANIHOT ESCULENTA* CRANTZ) INTERCROPPED IN COCONUT GARDENS

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DECLARATION

I hereby declare that this thesis entitled "Production potential of cassava (*Manihot esculenta* Crantz) intercropped in coconut gardens" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellayani,
28th July, 1986

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CERTIFICATE

Certified that this thesis, entitled "Production potential of cassava (Manihot esculenta Crantz) intercropped in coconut gardens" is a record of research work done independently by Sri. T.V.Ramakrishnan Nayar under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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C O N T E N T S

LIST OF TABLES

LIST OF ILLUSTRATION

INTRODUCTION

INTRODUCTION

Although coconut is assigned the status of a plantation crop in our country, it is essentially a crop of small and marginal farmers. The average size of coconut garden is 0.22 ha and more than 98% of the holdings are less than 2 hectares. Consequently the income from coconut alone is quite insufficient to sustain the dependent families. Further the sole crop of coconut does not provide adequate on-farm employment even for the family labour. Hence to generate additional income from the limited land holdings, intercropping in coconut gardens is a common practice. The small size of the holdings makes it uneconomical to the owners to invest large amounts to install irrigation facilities. As a result in most of the coconut gardens rainfed tubercrops like cassava and yams are preferred as intercrops. Another important reason for the popularity of tuber crops, especially cassava as an intercrop in coconut garden, is that, while the coconut gives the cash income for the farmer, the cassava tubers partially meet the food requirement of the family. Nowadays, there is added interest in cassava since it serves as raw material for animal feed, starch and sago industry and for production of alcohol.

Krishna Marar (1964) studied the extent of inter-cropping in coconut gardens and stated that in 20% of the coconut gardens cassava was found as an intercrop. From a vary recent survey it was reported that 40% of the cassava area in Trivandrum district is under the upland coconut gardens (CTCRI, 1984). A very conservative estimate shows that about 1.5 lakh hectares of coconut gardens in Kerala are intercropped with cassava, which constitute about 50% of the total area under cassava.

The effect of intercropping cassava in coconut gardens was investigated by many research workers and reported that there was no perceptible deleterious effect on the productivity of coconut palms, due to the above practice, provided both crops are separately and adequately manured (Kannan and Nambiar, 1976; Gopalasundaram and Nelliat, 1979). Although Cassava is recommended as an intercrop in coconut gardens (KAU, 1982), information on optimum planting density, fertiliser requirement etc. for cassava grown as intercrop in coconut gardens is very meagre. Basic information on growth, nutrient uptake and productivity of cassava intercropped in coconut gardens is also lacking.

The productivity of cassava intercropped in coconut garden ranges from 40% to 50% of the sole crop. Preliminary studies conducted from Central Tuber Crops Research Institute

(CTCRI) indicated that the sink capacity of storage roots of cassava grown under coconut shade is low, when compared to that of shoot. In this connection it may be noted that several research workers have reported the beneficial effect of growth regulators, in promoting translocation of assimilates to the storage organs in tuber crops. Hence the present study was taken up with the following objectives:

(i) To determine the optimum planting density of cassava for intercropping in coconut gardens.

(ii) To assess the influence of growth regulators on the yield and quality of tubers of cassava intercropped in coconut gardens.

(iii) To study the growth, nutrient uptake and response to nitrogen, phosphorus and potassium by cassava grown as intercrop in coconut gardens.

(iv) To evaluate the productivity and to work out the economics of intercropping cassava under different levels of fertilizer application.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Very little information on the performance of cassava or other tropical tuber crops intercropped with plantation crops vis-a-vis partially shaded conditions is available at present. Most of the published work relates to cassava grown as sole crop in open fields. So the literature reviewed here mostly relates to such studies. Wherever available, the work on cassava cultivated under partially shaded conditions is also reviewed.

2.1 Varietal difference

The yield potential of cassava varieties differs significantly depending upon environmental factors and management practices. Only a few experiments on the varietal performance of cassava intercropped in coconut gardens had been reported.

Experiments were conducted by CTCRI to test the performance of some released hybrids and a few other promising lines of cassava under intercropping in coconut gardens at three locations viz., Sreekariyam, Balaramapuram and Pilicode (CTCRI 1978). From this study it was reported that (1) yield reduction of cassava intercropped in coconut gardens was to the tune of 50% to 67%, (2) the varietal difference in number of tubers per plant was significant only at Balaramapuram, (3) the number of tubers per plant was half under shade, compared to plants in the open, (4) though HCN content was higher in all the varieties grown under coconut, Malayan-4 and the hybrid Sreevisakham (1687) registered lower HCN content, (5) Organoleptic test revealed that Sreevisakham and Malayan-4 were non bitter while all others were bitter in taste. (6) Considering the quality and yield of tubers among the released hybrids Sreevisakham was found to be superior. However higher tuber yields were obtained from H-165 and H-2304, but their tubers were poor in quality. Menon and Nayar (1978) also reported higher tuber yield by H-165 intercropped in coconut gardens.

In another preliminary study conducted at coconut research station, Balaramapuram, fourteen genotypes of cassava having different morphological characters were tested under coconut and reported that varieties Sreevisakham, H-165, H-2304, H-97 and Ci-590 recorded fairly good yield (CTCRI, 1979).

The minikit trials undertaken to assess the performance of the two hybrid varieties of cassava, Sree Sahya and Sree Visakham, in coconut gardens, also indicated the superiority of the latter (CTCRI, 1983a).

2.2 Planting density

Plant density exerts marked influence on yield potential of cassava. Choice of optimum planting density for cassava depends on many factors like varietal characteristics, soil fertility, rainfall and the system of cropping.

2.2.1 Optimum planting density

In the strict sense there is no optimum plant population, but there is an optimum range of plant population and with-in this range yield becomes constant. Plant population below and above this range cause a depression in economic yield. The main considerations for working out the optimum spacing or plant population are the branching behaviour of the variety, the variations in soil fertility, cultural practices and final use of the produce.

In a study on plant population at Central tuber crops research institute, during 1968-70, it was found that a spacing of 90 x 90 cm (12,345 plants ha^{-1}) in the branching types of cassava and a spacing of 75 x 75 cm (17,777 plants ha^{-1}) in the non branching types produced maximum yields (CTCRI 1970).

In a similar study conducted later at the same institute the optimum planting density for the branched, non-branched and the dwarf types, was found to be 12,345, 17,777 and 27,777 plants ha^{-1} respectively (Mandal _et_ _al_. 1973).

Enyi (1973) from Tanzania reported highest root yield for cassava planted at 12,345 plants ha^{-1}.

Gurnah (1973) observed that, in the forest zone of Ghana, the local 'Ankra' variety gave the best output of tubers at a density of 18,519 plants ha^{-1}. The yields were found to reduce at populations lower and higher than this.

Castillo (1974) reported that in the Philippines a planting rate of 10,000 to 11,250 plants ha^{-1} is recommended for cassava.

The results of experiments conducted at CIAT since 1970 indicated that optimum planting density under that condition was 10,000 plants ha^{-1} for short and tall types with errect growing habits. For tall types with branching habits the optimum population was found to be 5000 plants ha^{-1} (Cock <u>et al</u>. 1977).

In Seirra Leone, Godfrey-Sam-Aggrey (1978) found 7000 plants ha^{-1} as the optimum density of planting for cassava.

According to Gunasena <u>et al</u>. (1980) cassava plants intercropped in coconut gardens at spacings 61 x 61 cm and 91 x 91 cm produced 11.93 t ha^{-1} and 14.49 t ha^{-1} of tubers, respectively.

Villamayor and Distreza (1982) recommended a population 13,000 - 15,000 plants ha^{-1} for the variety Golden Yellow in the Philippines.

Ofuna and Ndubizu (1983) found that a planting density of 10,000 plants ha^{-1} gave the best yields for cassava and plantain when cassava was intercropped in plantain.

2. Effect of planting density on growth

Enyi (1973) reported that response to different planting densities was dissimilar in cassava varieties. In general it was observed that increase in plant population increased the height of plants and total dry matter production. It was also reported that while mean crop growth rate increased with increase in plant population, mean net assimilation rate and relative growth rate decreased with higher plant density. Leaf area index and leaf area duration also tended to increase with increase in plant population.

In a preliminary trial carried out by CTCRI to find out the effect of different spacing and topping on cassava intercropped in coconut gardens it was observed that plants were taller under lower plant population and shorter under dense planting. It was also reported that the leaf area index at the time of harvest recorded higher values with increase in plant population per unit area (CTCRI, 1979).

Gunasena *et al.* (1980) from a study on effect of spacing and nitrogen on the growth and yield of cassava intercropped in coconut gardens in Sri Lanka reported that total dry matter production was maximum at closer spacing.

Experiments conducted at CTCRI to study the effect of planting density on growth and development of morphologically contrasting genotypes revealed that, the height of all genotypes increased when the plant population per unit area was increased. The number of nodes and the number of leaves were less at denser planting except in one cultivar. In the case of tall genotypes the leaf area index was very high at higher plant densities, as compared to the normal planting density of 12,340 ha^{-1}, resulting in lower crop growth rate and total biomass production (CTCRI 1981).

2.2.3 Effect of planting density on yield attributes

It was reported that the number of roots $plant^{-1}$ in cassava was not influenced by plant population. But decrease in yield at high planting density was due to marked decrease in mean root weight, associated with increase in plant population (CIAT, 1972).

According to Enyi (1973) the spacing effect on cassava tuber yield was associated with differences in the rate of bulking.

However, Gurnah (1973) in an experiment in Tanzania, found that increase in plant population beyond 18,519 ha^{-1} resulted in decrease in average number and weight of tubers $plant^{-1}$.

Mohankumar *et al.* (1975) also reported that in the high yielding cassava variety H-165 the number and weight of tubers $plant^{-1}$ decreased as the plant population increased from 12,300 to 28,000 plants ha^{-1}.

Cock *et al.* (1977) observed that the reduction in yield above the optimum planting density was due to a reduced harvest index. Less vigorous plants normally have higher harvest indices and consequently, they respond to dense planting. The decrease in harvest index above the optimum density has been attributed to the possible result of intense competition and also decline in drymatter, due to leaf fall.

Godfrey-Sam-Aggrey (1978) evaluating the effect of different plant populations/unit area in cassava reported that the number of tubers and mean weight of tubers decreased significantly with increase in planting density.

Plant population had no significant influence on dry-matter content of tubers or on harvest index of cassava variety H-2304, intercropped in coconut gardens (CTCRI, 1979). However, Gunasena et al. (1980) observed higher drymatter productivity at closer spacings in cassava intercropped in coconut gardens.

2.3 Role of Growth regulators on tuber crops

Recent investigations on the role of growth regulators on the growth and yield of tuber crops especially potato, have brought out the beneficial effects of some of them, in increasing the yield by altering the drymatter distribution. In general, gibberellins promote the activity of the shoot whereas the antigibberellins favour the sink activity of the tubers. Some of the morphoregulants which are reported to have marked antigibberellin effects are cycocel, ethrel, alar, B-nine and RSW-0411. Influence of these growth regulators on growth attributes and yield of tuber crops are briefly reviewed here.

2.3.1 Influence of growth regulators on growth attributes

Cycocel (2-Chlorethyl trimethyl ammonium chloride also known as CCC and Chlormequat) is a plant growth regulant, the application of which causes treated plants to be compact and sturdy with shortened internodes, peteoles and dark green leaves.

Jung (1967) noted that application of cycocel caused increase in protein and photosynthetic pigments in plants, which might have increased the photosynthetic activity and promoted root growth.

Growth retardation of the haulms in potato, due to foliar application of cycocel, had been reported by several workers (Humphries and Dyson, 1967; Radwan et al. 1971; Purohit and Rajendra, 1971).

According to Das Gupta (1976) cassava plants treated with cycocel exhibited higher relative growth rate.

Morphoregulant effect and consequent improvement in dry-matter partitioning in tuberous crops resulted by the application of ethephon (2-Chloro ethyle phosphonic acid) were reported by several investigators.

Muthukrishnan et al. (1976) recorded that ethephon at 2000 ppm sprayed on cassava foliage caused bending of petioles and arrest of apical dominance leading to production of more lateral branches. The terminal leaves were twisted and clustered round the apex but this effect was temperory as plants regained normal growth after a week. Reduction in plant height to the extent of 7.60% also was reported by them due to ethephon treatment.

Similar effects due to foliar spray of ethrel on sweet potatoes were also reported by Muthukrishnan et al. (1976).

Biswas et al. (1980) found supression in vine length and reduction of number of leaves in sweet potato due to ethephon and cycocel treatments.

Shashikala Khanna et al. (1980) also observed reduction in length of vines of sweet potato as a result of foliar application of ethrel and cycocel.

In a study on cassava on the influence of antigibberellin substances like Alar (N, N-dimethyl amino succinamic acid) and RSW-0411 it was found that application of these compounds caused marked change in drymatter distribution. Though the total drymatter production was not altered, there was considerable reduction in drymatter accumulation in the shoots. Reduction in leaf area and shoot enlongation were also noted (Melis and Van Standen, 1983).

2.3.2 Influence of growth regulators on yield

Ridwan et al. (1971) observed that, cycocel increased the activity of carbohydrate hydrolising enzymes in potatoes making the photosynthates more mobile and thereby increasing the tuber yield.

El-Fouly *et al.* (1971) reporting the yield increase upto 33% in sweet potato due to spraying cycocel at 500 ppm stated that, the increase in yield might have been from the larger root system in treated plants.

Muthukrishnan *et al.* (1974) observed that ethrel as foliar spray and soil treatment caused significant increase in yield of sweet potato.

Significant increase in sweet potato yield was reported by Nambiar *et al.* (1976) with cycocel treatment at concentrations 50-150 ppm.

Das Gupta (1976) evaluated the effect of different concentrations of cycocel (500, 1000, 1500 and 2000 ppm) in Seirra Leone. He found that spraying cycocel at 1500 ppm on cassava foliage at monthly intervals from first month to the fourth month gave significant increase in yield (41%) of cassava.

Experiments conducted to study the effect of different concentrations of ethephon (ethrel) on cassava revealed that application at 250 and 500 ppm produced increased tuber yields over control; the increase was 17.87 and 20.31% respectively (Muthukrishnan *et al.* 1976). It was also found that application of morphoregulants like phosphone - D, malichydraside and alar had no significant effect in tuber yield of cassava.

Abdul Vahab and Mohanakumaran (1980) recorded increase in tuber number and length of sweet potato plants treated with cycocel at 250, 500 and 1000 ppm. Significant increase in tuber girth was noticed only at higher rates of application.

Increased tuber productivity in sweet potato due to ethrel application was reported by several other investigators also. (Abdul Vahab and Mohanakumaran, 1980; Biswas et al. 1980; and Shashikala Khanna et al. 1980).

According to Melis and Van Standen (1983) there was significant increase in yield of cassava as a result of treatment with antigibberellin substances like alar and RSW-0411.

2.4 Responses of cassava to major plant nutrients

Cassava is generally grown on infertile soils. Moreover, cassava extracts large amounts of nutrients, especially N and K from the soil. So continuous cultivation of cassava without adequate fertilization would lead to soil depletion and reduced yields. The nutritional requirement and response to fertilization of cassava especially under open conditions had been studied by many workers. But similar study under partially shaded conditions is very meagre.

2.4.1 Response to nitrogen

Nitrogen is very essential for the proper growth and yield of cassava as it is a basic component of protein, chlorophyll, enzymes, hormones and vitamins. It is a constituent of the cyanogenic glycosides, linamarin and lotaustralin which produce hydrocyanic acid when cells are damaged.

2.4.1.1 Effect of nitrogen on growth attributes

In a tank culture study when nitrogen was omitted from the nutrient solution, severe reduction in plant height and weight was noticed by Krochmal and Samuels (1967).

Significant increase in plant height, leaf number and leaf retention was reported by Mandal et al. (1971) with added nitrogen. According to Natarajan (1975) at 30, 60 and 90 days of planting there was no significant difference in plant height between levels of nitrogen. But at later stages of growth the higher level of nitrogen (150 kg ha^{-1}) significantly increased plant height. Difference in number of leaves due to graded levels of nitrogen was significant only in the early stages of growth.

Increase in plant height, leaf area and leaf area duration and leaf size due to incremental doses of nitrogen was observed by Ngongi (1976).

Pillai and George (1978) observed increase in plant height and weight due to higher levels of nitrogen in M-4 variety of cassava.

Nair (1982) studying the response to 3 levels of nitrogen (50, 125 and 200 kg ha^{-1}) at two locations reported maximum plant height, number of nodes and number of functional leaves at the highest level of nitrogen, whereas increase in leaf area was attained only upto 125 kg N ha^{-1}.

From a study on the effect of six levels of nitrogen (0, 50, 100, 150, 200 and 250 kg ha^{-1}) at constant dosages of P_2O_5 and K_2O at 100 kg ha^{-1} on cassava variety H-2304, significant increase in leaf area index was observed at higher levels of nitrogen (CTCRI, 1983a). Increase in crop growth rate and dry matter production with increase in levels of N were also reported in the above study.

2.4.1.2 Effect of nitrogen on yield attributes and yield

Vijayan and Aiyer (1969) found that mean number of tubers $plant^{-1}$ increased with increase in nitrogen levels from 0 to 75 kg N ha^{-1}, in cassava varieties M-4 and H-165. But increase in nitrogen beyond 75 kg ha^{-1} had depressing effect on tuber number $plant^{-1}$. However, higher levels of nitrogen had no significant influence on tuber number, length and girth, of cassava according to Natarajan (1975).

Ofori (1970) recorded positive response in tuber number upto 67 kg N ha^{-1}.

On the other hand Asokan et al. (1980) observed that length, girth and number of tubers in cassava are not significantly affected by different levels of nitrogen (60, 120 and 180 kg ha^{-1}) tried. Nair (1982) observed that higher levels of nitrogen (ie. 120 kg ha^{-1} and 200 kg ha^{-1}) increased the number of tubers and mean weight of tubers. The length and girth of tubers were unaffected.

Kasele et al. (1983) from a study on effect of different levels of nitrogen on cassava grown under artificial shade reported that, nitrogen did not affect tuberisation, but significantly increased number of tuberous roots. It was also noted that nitrogen levels had no significant influence on number and size of storage cells.

Significant increase in cassava tuber yield as a result of nitrogen application upto 100 kg N ha^{-1} wase reported by many investigators.

On the acid peat soils of Malaysia, Chew (1970) observed that cassava yields increased mostly by applying 180 kg N ha^{-1}. For similar soils, Kanapathy (1974) recommended 120 kg N along with 75 kg K ha^{-1}, to get good yields from continuous cultivation of cassava.

In Western Nigeria, Amon and Adetunji (1973) recommended about 25 kg N ha^{-1}, while Obigbesan and Fayemi (1976) obtained high yields of 56 and 64 t ha^{-1} in 15 months, by applying 60 and 90 kg N ha^{-1}, respectively.

From Indonesia Hadi and Gozallie (1975) reported response upto 90 kg N ha^{-1}.

Fox et al. (1975) obtained significant response upto 120 kg N ha^{-1} in ultisols having 0.17% N in Puerto Rico. But in the same soil type having 0.23% N there was no response to applied nitrogen by cassava.

Significant response upto 100 kg N ha^{-1} was recorded in CIAT (1977).

In Thailand where cassava grown mainly on grey or red yellow podzolic soils of moderate acidity (pH5) and low organic matter content, the crop responded mainly to the application of 50-100 kg N ha^{-1}. (Sittibusaya and Kurmarohita 1978).

Results of field experiment conducted in red sandy loam soils of north Malabar showed increase in yield due to higher levels of nitrogen application upto 180 kg ha^{-1}. (Asokan et al. 1980).

Gunasena et al. (1980) from Sri Lanka reported that cassava intercropped in coconut gardens had no significant response to different levels of applied nitrogen (44.8, 67.2, 89.6 kg ha^{-1}).

Application of 125 kg N ha^{-1} resulted in maximum tuber yield in red loam soils and in coastal sandy loam soils of Kerala (Nair, 1982). In both these soil types nitrogen at 200 kg ha^{-1} had depressing effect on cassava tuber yield.

At CTCRI among the different levels of nitrogen (0, 50, 100, 150 and 200) tried, for high yielding varieties of cassava 100 kg N ha^{-1} was found to be optimum. Beyond 100 kg N ha^{-1} the yield tended to decrease or the effect was not significant (CTCRI, 1983a).

Under artificial shade higher levels of nitrogen had no significant influence on cassava tuber yield, but significantly increased the shoot yield (Kasele et al. 1983).

Preliminary reports of a manurial experiment to fix the fertilizer dose for cassava at Pilicode, indicated that among the levels of N tried (25, 50, 75 and 100 kg ha^{-1}) highest tuber yield was obtained at 75 kg N ha^{-1} (KAU, 1984).

2.4.1.3 Effect of nitrogen on quality

Many research workers have reported the beneficial effect of nitrogen nutrition in increasing the starch content of cassava tubers. (Mandal et al. 1971, Natarajan, 1975; Pillai and George, 1978).

However, Vijayan and Aiyer (1969) noted a decrease in starch content of tubers with increase in nitrogen beyond 75 kg ha^{-1}.

Starch content of tubers was not affected by level of nitrogen application according to Muthuswamy and Chiranjivi Rao (1979).

Influence of nitrogen on HCN content of cassava had been studied in detail. Higher rates of N application stimulates the synthesis of protein and cyanogenic glycosides and inhibits synthesis of starch (Malavolta et al. 1955; Dias, 1966).

Sinha (1969) found no correlation between the HCN content of leaves and that of roots. He concluded that the sites of HCN metabolism are different, for these two plants parts and suggested that N should be applied foliarly in order to reduce the HCN content of roots associated with high soil N application.

2.4.1.4 Effect of nitrogen on the uptake of nutrients

Mohankumar and Nair (1969) observed increase in the percentage of nitrogen and potassium in plant parts with increases in rate of nitrogen application.

Rajendran _et al_. (1976) also reported increased potassium uptake by higher doses of nitrogen. Pushpadas _et al_. (1976) recorded increase in nitrogen content of the plant with higher levels of nitrogen nutrition.

A decrease in phosphorus and potassium contents of leaf blade and stem of cassava was observed by Okeke _et al_. (1979) due to nitrogen nutrition. But petiole potassium showed a linear response to applied nitrogen.

Increase in uptake of nitrogen and potassium in cassava due to increased levels of nitrogen application was observed by Nair (1982).

2.4.2 Response to phosphorus

Phosphorus has a very favourable effect on the root system of cassava and on the uptake and utilisation of nitrogen. It is essential for the phosphorylation of starchy reserves necessary to carry on the vegetative growth during the early stages of development.

2.4.2.1 Effect of phosphorus on growth attributes

Krochmal and Samuels (1968) observed a slight reduction in plant growth due to absence of P in the nutrient solution, but no deficiency symptom was observed.

Asher (1975) also reported reduction in total drymatter production and found that more than 70% reduction of drymatter was required before cassava plants developed symptoms of deficiency.

It was reported that in the absence of P total drymatter production was reduced to 10% of that of normal, but no deficiency symptom could be observed (CIAT, 1977).

Edwards <u>et al</u>. (1977) found that cassava has an extremely high P requirement, ranging from 50-70 μm for maximal growth.

However permanent manurial experiment conducted at CTCRI indicated that exclusion of P from the manurial schedule of cassava had no significant adverse effect on growth characters (CTCRI, 1981).

2.4.2.2 Effect of phosphorus on yield attributes and yield

Factorial experiments in which 3 levels of P (10, 20 and 40 kg P ha^{-1}) were tried, indicated that the number and size of tubers of cassava were not influenced by P applied alone or in combination with N and K (Chadha, 1958).

It was reported that higher rates of applied P increased the foliage yield resulting in lowering the harvest index (CIAT, 1977).

Studies conducted at CTCRI indicated that absence of P in the fertilizer schedule of cassava had no significant effect on mean number of tubers and weight of tubers (CTCRI, 1981).

In Brazil, Normanha (1951) observed that P was the main limiting nutrient for cassava, where he recommended the application of 26-52 kg P ha^{-1}. However, Acosta and Perez (1954) in Costa Rica did not observe response to P in cassava except where N was applied.

Chadha (1958) obtained 25% increase in yield with 35 kg P ha^{-1}. From Ghana, Stephens (1960) and Takyi (1972) reported highest yields with 10 and 20 kg P ha^{-1}, respectively. De Geus (1967) recommended 57 kg P ha^{-1} for cassava in Madagascar.

Albuquerque (1968) obtained maximum yields with 44 kg P ha^{-1} in the Amazon estuary. Vijayan and Aiyer (1969) reported highest yields at 44-65 kg P ha^{-1}.

For the Malaysian peat soils Chew (1970) recommended 22 kg P ha^{-1} although Kanapathy and Keat (1970) did not observe P response in these soils.

Tarazona *et al*. (1973) reported a positive response upto 131 kg P ha^{-1} in 13 out of 14 experiments conducted in the farmers fields located in acid P deficient soils of Cauca and Meta states of Colombia. They did not find much correlation between the response to applied P and the soil available P. Nunes *et al*. (1974) reported 86% yield increase with application of 17 kg P ha^{-1}.

In the oxizols of Colombia significant response to application of 87 kg P ha^{-1} was observed resulting in increased yield from 7 to 25 t ha^{-1}. Although at low rates of P both foliage and root yield increased, there was only increase of foliage yield at higher rates of P (CIAT, 1977).

Curva (1977) obtained a significant response only to 52 kg P ha^{-1} in eastern Peru.

In Thailand Sittibusaya and Kurmarohita (1978) recommended the application of 22-44 kg P ha^{-1} for the north eastern parts and 44-88 kg P ha^{-1} for the exhausted soils of the south east.

In acid laterite soils of Kerala with low available P content (10-15 kg P ha^{-1}) cassava responded to P application upto 44 kg P ha^{-1}. Continuous application of P at 44 kg P ha^{-1} resulted in build up of P status to the extent 100 kg P ha^{-1} and in such cases there is no response to P application (CTCRI, 1983a).

2.4.2.3 Effect of phosphorus on quality

Malavolta *et al.* (1955) found a reduction in starch content of cassava tubers from 30 to 25%, when P was eliminated from the nutrient solution.

Vijayan and Aiyer (1969) reported significant influence of P at higher levels, on the quality of cassava tubers. Application of P upto 44 kg ha^{-1} enhanced the starch content and reduced the HCN content.

However, Muthuswamy et al. (1974) reported that application of phosphorus had no significant influence on the HCN content of cassava tubers.

Prema et al. (1975) reported improvement in quality parameters like dry matter content, starch content and crude protein content with higher levels of P application especially in combination with nitrogen. The best result was obtained at 44 kg P combined with 150 kg N ha^{-1}. Further, they observed the beneficial effect of reducing the HCN content of cassava tubers, due to P application at higher levels.

Thomas Kurien et al. (1976) found that there was significant reduction in HCN content of cassava tubers due to phosphorus nutrition.

2.4.2.4 Effect of Phosphorus on the uptake of nutrients

Increase in the uptake of P by cassava with higher levels of application was observed upto 66 kg P ha^{-1}. (Vijayan and Aiyer, 1969).

Phosphorus content of cassava tissue increased with the application of P, but decreased with the application of potassium. It was also reported that in the absence of potassium, calcium increased the phosphorus content in plants (Thampan, 1979).

Studies conducted at CTCRI revealed that effect of higher levels of P on P concentration and uptake was not significant (CTCRI, 1982).

2.4.3 Response to potassium

Potassium is essential for carbohydrate translocation from the tops to the roots (Malavolta et al. 1955). According to Sereeponk (1977) the primary nutrient factor limiting cassava production was potassium. Reduction in tuber yields and adverse effects on quality of tubers due to inadequate supply of potassium to cassava, had been reported by many research workers.

2.4.3.1 Effect of potassium on growth attributes

Dias (1966) observed excessive branching in K deficient plants.

Krochmal and Samuels (1968) reported that K deficiency is characterised mainly by reduced plant growth and early senescence of older leaves and petioles, which fall prematurely.

According to Ngongi (1976) K deficiency decreased leaf size, leaf lobe number, leaf retention and plant height. Increase in plant height, leaf area and leaf size with incremental doses of potash from 0 to 240 kg ha^{-1} was reported by the same author. Maximum values of plant fresh weight and total dry matter were observed by him at low levels of potash application.

Several other investigators could not get significant response to levels of potassium, on such growth characters (Pushpadas and Aiyer, 1976; Ramaswamy and Muthukrishnan, 1980).

Asokan and Sreedharan (1980) observed increase in plant height and top yield at higher levels of potassium applied to cassava.

Increase in plant height in the later stages and growth of cassava due to K application was reported by Nair (1982).

To study the influence of K on growth and productivity of cassava, experiments were conducted for two consecutive seasons with graded levels of K from 0 to 208 kg ha^{-1}, at CTCRI. Application of potassium increased plant height, node number, leaf size and LAI when compared to control. Beyond 42 kg K ha^{-1} there was no significant response (CTCRI, 1983a).

Application of potassium alone to cassava grown under artificial shade significantly reduced the shoot dry weight (Kasele et al. 1983).

2.4.3.2 Effect of potassium on yield attributes and yield

Mandal and Mohankumar (1972) observed no difference in number of tubers by application of low levels of potassium ranging from 33 to 66 kg K ha^{-1}. However, tuber number was significantly high at 83 kg K ha^{-1}. Application of potassium beyond 83 kg K ha^{-1} did not significantly influence the tuber size (Mohankumar and Hrishi, 1973).

Similarly higher rates of potassium did not influence tuber number. But significant difference in tuber size was observed (Ngongi et al. 1976).

According to Pushpadas and Aiyer (1976) application of K significantly increased the number of tubers $plant^{-1}$.

In cassava grown under shaded conditions application of K alone or in combination with N resulted in early tuberisation (Kasele et al. 1983). They also observed increase in number and size of storage cells and number and size of tubers in cassava grown under artificial shade.

Several workers have reported positive yield response by cassava to application of potassium.

In eastern Nigeria, Irving (1956) reported K response on light acid soils. In Western Nigeria, Amon and Adetunji (1973) recommended the use of 50 kg K ha^{-1}. But Obigbesan (1977) did not find any significant response to application of 50-75 kg K ha^{-1}.

For cassava production in Madagaskar K deficiency was found to be the main limiting factor and so application of 92 kg K ha^{-1} was recommended. (Roche et al. 1957; De Geus, 1967).

Chew (1970) recommended application of 92-133 kg K ha^{-1} for Malaysian peat soils, for continuous cropping with cassava. Samuels (1970) obtained response to 83 kg K ha^{-1} in Puerto Rico. In Colombia K response was observed in 11 out of 14 trials in farmer's fields. Ngongi (1976) obtained significant response to 200 kg K ha^{-1}.

CIAT (1977) reported maximum yield with 133 kg K ha^{-1}.

On the basis of experiments in cultivators fields in Kerala, India, Chadha (1958) observed that mean response to doses of Potash, varied from 19 to 43% for 66 kg K ha^{-1} and 23-75% for 133 kg K ha^{-1}.

Kumar et al. (1971) reported significant response to 83 kg K ha^{-1}. According to them at higher levels K caused depressing effects on cassava yield.

Pushpadas and Aiyer (1976) obtained maximum tuber yield from the high yielding hybrid cassava H-165 at 208 kg K ha^{-1}.

Rajendran et al. (1976) reported that 83 kg K ha^{-1} was the optimum for cassava and higher rates resulted in luxuary consumption.

From an experiment to study the effect of different levels and time of application of potassium for the hybrid cassava H-97, Asokan and Sreedharan (1977) observed maximum tuber yield at 93 kg K ha^{-1}. However according to Ramaswamy and Muthukrishnan (1980) higher levels of K had no significant effect on yield of cassava.

Nair and Kumar (1982) reported that 85 kg K ha^{-1} was the optimum for tuber yield in cassava, since the cassava hybrid H-97, gave an yield of 30.74 t ha^{-1} with the above dose compared to 25.34 t ha^{-1} in K_0 treatment.

However, Ramanujam (1982) got response to K application only upto 42 kg K ha^{-1}.

Kasele et al. (1983) stated that cassava grown under artificial shade produced higher tuber yield, as a result of application of potassium alone or in combination with nitrogen.

In a study on response to different levels of N and K by cassava intercropped in coconut gardens at Pilicode, no significant increase in yield was noticed due to K application at higher levels (KAU, 1984).

2.4.3.3 Effect of potassium on quality of tubers

The effect of potash nutrition in enhancing the starch content of cassava tubers was observed by several investigators

(Natarajan, 1975; Muthuswamy and Chiranjivi Rao, 1979).

Pushpadas and Aiyer (1976) secured maximum starch yield at 208 kg K ha^{-1}. Linear increase in starch yield with higher rates of potassium application upto 200 kg K ha^{-1} was reported from CIAT (1979). Nair and Kumar (1982) observed only a slight increase in starch content by potassium fertilisation.

Potassium alone or in combination with nitrogen reduced the HCN content of cassava tubers (Indira _et al_. 1972). Ramanujam (1982) also reported reduction in the HCN content of tubers and leaves of cassava variety 2304 by potassium nutrition. The lower dosage of K (42 kg K ha^{-1}) was not effective in reducing the cyanide concentration. But with the application of potash beyond 83 kg K ha^{-1} the HCN content was reduced by 40 to 76% compared to control.

Beneficial effect of potassium in increasing the starch content and reducing the HCN content of cassava tubers was reported by Nair (1982).

2.4.3.4 Effect of potassium on nutrient uptake

Mohankumar and Nair (1969) found an increase in potassium uptake by plant parts due to nitrogen fertilisation. Kumar _et al_. (1971) also observed a similar increase in potassium uptake by higher dosages of nitrogen. Ngongi et al. (1976) noted severe sulphur deficiency in cassava due to higher rates of K application.

Spear *et al.* (1978) demonstrated that higher concentrations of potassium in solution reduced the uptake of calcium and magnesium by cassava. Nair (1982) reported increased uptake of potassium by cassava with increased levels of application.

2.4.4 Combined effects nitrogen, phosphorus and potassium

Cassava requires higher levels of nutrients to produce maximum yield. Apart from the availability of adequate quantities of nutrients in the soil it is also necessary to have a proper balance between the nutrients both in the soil and in the plant. The nitrogen-potassium ratio is specially significant in cassava nutrition. A faulty phosphorus-potassium ratio may upset the uptake of nitrogen (Thampan, 1979). Antagonistic effects between potassium and magnesium and potassium and sulphur are also reported (Howeler, 1981). So a balanced availability of nitrogen, phosphorus and potassium is essential for maximum productivity.

Cock (1975) has shown that cassava has an optimum leaf area index of 2.5-3.5 and higher rates of fertilization may lead to excessive top growth and leaf area index of more than four. Higher levels of fertility increased leaf size, the number of active apices and the rate of leaf formation per apex, but had no effect of leaf life. Cassava grown under low fertility, restricted its leaf area, but maintained leaf photosynthetic efficiency (CIAT, 1979). Further the distribution index was higher, indicating that most of the carbohydrates produced were transported to the roots (CIAT, 1980).

Cassava is very sensitive to over fertilization, making it excessively leafy particularly at higher plant populations (Howeler, 1980). Hence the proper level of fertilization and the right balance of nutrients are of utmost importance.

2.4.5 Fertilizer recommendation for cassava

In Costa Rica, Schmitt (1955) recommended application of 50-70 kg N, 26-30 kg P and 108 kg K per hectare.

Chew (1970,) found that application of 180 kg N 22 kg P and 92-133 kg K (each per hectare) was required for cassava in the peat soils of Malaysia.

Takyi (1972) for the forest soils of Ghana recommended application of 60 kg N, 20 kg P and 209 kg K per hectare.

Ahmed (1973) reported that cassava responded to 124 kg N, 29 kg P and 98 kg K ha^{-1} in Serdang region of Malaysia. In the Kuala Lumpur region of the same country, Cheing (1973) got response upto 150 kg N, 30 kg P and 150 kg K ha^{-1}.

Tarazona *et al.* (1973) found that the best rate of fertilizer application for cassava was 50-60 kg N, 131 kg P and 42-50 kg K, in the inceptisols of Colombia. The recommendations from CIAT was 100 kg N, 87-175 kg P and 133 kg K per hectare, for the oxisols of Colombia (CIAT, 1974 & 1975).

Hadi and Gozallie (1975) in Java, Indonesia got response to 90 kg N, 13 kg P and 42 kg K ha^{-1}.

At CTCRI various hybrids and selections of cassava were tested at low, medium and high levels of fertility. All the high yielding hybrid varieties of cassava produced best yields when 100 kg N, 44 kg P and 83 kg K per hectare, were applied (CTCRI, 1983a).

2.4.6 Nutrient removal by cassava

It is generally considered that cassava exhausts the soil and removes large amounts of N and K in each harvest. According to Prevot and Ollagnier (1958) among tropical crops cassava extracts the largest amount of K from the soil as it has the highest K/N ratio in the harvested produce. Other crops with high K/N ratios are bananas, oil palm, pineapple, coconut and sugarcane, whereas rice, maize and cotton have relatively low K/N ratios. Hongsapan (1962) pointed out that per ton of food produced cassava depletes soil nutrient reserves less than maize, sugarcane, bananas or cabbage. However on a per crop basis cassava removed more nutrients than most other tropical crops like maize, oil palm and rubber (Kanapathy,1974).

Different estimates on the removal of major nutrients by cassava have been reported. The variations in these estimates may be due to difference in soil conditions, cultivars, plant age at harvest etc.

Asher et al. (1980) reported that 164 kg N, 31 kg P and 200 kg K ha^{-1} are removed by 30 t roots harvested.

Howeler (1981) reviewing the literature on mineral nutrition of cassava reported that on an average cassava extracts about 2.30 kg N, 0.5 kg P and 4.10 kg K per tonne of roots, when only the roots are removed from the field. If the whole plant is removed for forage and planting materials, these amounts would increase to 4.91 kg N, 1.08 kg P and 5.83 kg K t^{-1}. Besides K, cassava extracts large amounts of N, but the removal of P is relatively low.

Studies conducted at CTCRI, Trivandrum showed that cassava removed 180-200 kg N, 15-22 kg P and 140-160 kg K ha^{-1} to produce an yield of 30 t ha^{-1} fresh tubers (CTCRI, 1983a).

2.4.7 Effect of NPK fertilization on soil nutrient content

Rajendran *et al.* (1971) observed that application of nitrogen at and above 100 kg ha^{-1} resulted in an increase in soil available nitrogen ranging between 16 to 75 kg ha^{-1}.

Mohankumar and Maini (1977) in an experiment to study the effect of Molybdenum and nitrogen on the yield and quality of cassava reported that application of incremental doses of nitrogen slightly enhanced the available nitrogen status of the soil.

With increasing dose of potash application above 100 kg ha^{-1} the amount of available potassium in the soil after the crop increased, there by suggesting the possibility of a small residual effect due to high rates of K application (Kumar *et al.* 1977).

Chan (1980) from a long term fertilizer experiment in Malaysia reported that the total soil nitrogen was reduced by cropping with cassava, under all levels of application (0 to 112 kg N ha^{-1}) and was apparently not affected by N application. It was also found that the available P status of the soil increased with levels of P application to the crop. However the exchangeable K and water soluble K in the soil were not affected by the levels of K applied (0 to 156 kg K ha^{-1}) to cassava.

Nair (1982) reported significant increases in available N and K status of the soil under cassava, due to increased levels of application; both in sandy and red loam soils.

Studies conducted at CTCRI revealed that continuous application of P at 44 kg ha^{-1} resulted in build up of available P status of the soil to the extent of 100 kg P ha^{-1} (CTCRI, 1983b)

2.6 Correlation studies

Muthukrishnan et al. (1973) found that the tuber yield of cassava was positively correlated with plant height and number of nodes $plant^{-1}$, tuber length and girth. Williams (1974) concluded that high yield in cassava was associated with high mean tuber weight rather than with tuber number.

Studies at CIAT revealed that root dry matter production was highly correlated with total dry matter production (CIAT, 1975).

Holmes and Wilson (1976) recorded significant negative correlation between tuber number and mean tuber weight.

High positive correlation between cassava root yields and total plant fresh weight was observed by Ngongi (1976). He also found positive correlations between root yields, leaf area index, leaf area duration and total dry matter production per hectare. Rajendran *et al.* (1976) observed that uptake of both nitrogen and potassium by cassava was positively correlated with tuber yield. Biradar *et al.* (1978) recorded significant positive correlation between mean root weight and tuber yield.

Ramanujam and Indira (1980) found that plant height, node number and stem thickness have no relationship with tuber yield.

Nair (1982) reported that tuber number and mean tuber weight were highly correlated with tuber yield. He also observed that plant uptake of nitrogen and potassium at harvest was highly correlated with yield.

From the review of literature presented here, it is evident that the response of cassava to different planting densities, treatment with growth regulators and applied nutrients is highly variable, due to varietal and edaphoclimatic factors. It is also clear that, very little research work has been carried out on cassava inter-cropped with coconut palms or other perennial crops.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Field experiments to evaluate the production potential of two cassava varieties viz. Malayan-4 and Sreevisakham grown as intercrop in coconut gardens, were carried out for two consecutive seasons of 1983-84 and 1984-85 at the coconut research station, Balaramapuram. There were two experiments- (A) Effect of different plant populations and growth regulators on cassava intercropped in coconut gardens. (B) Response to different levels of N, P and K by cassava raised as intercrop in coconut gardens. The details of experimental site, season and weather conditions, materials used and methods adopted are presented in this chapter.

3.1 Experimental site

3.1.1 Location

The coconut research station, Balaramapuram, Trivandrum is situated at 8° north latitude and 76° 57' east longitude, at an altitude of 64 meters above mean sea level.

3.1.2 Soil

The soil of the experimental garden was red loam belonging to the Vellayani series and texturaly classed as sandy clay loam. It was low in available nitrogen and potassium and medium in available phosphorus. The mechanical composition and chemical properties of the soil are given in Table 1.

Table - 1 Soil characteristics of experimental fields

		F I	F II
A.	Mechanical composition		
1.	Coarse sand	34.70%	34.40%
2.	Fine sand	33.06%	33.26%
3.	Silt	4.02%	4.12%
4.	Clay	28.07%	28.00%
B.	Chemical properties		
1.	Total nitrogen	0.42%	0.44%
2.	Available nitrogen	137.00 Kg ha^{-1}	143.00 Kg ha^{-1}
3.	Available phosphorus	24.15 "	23.92 "
4.	Available potassium	48.27 "	51.23 "
5.	Organic carbon	0.49%	0.51%
6.	pH	5.30	5.40

3.1.3 Nature and cropping history of the coconut garden

The coconut palms in the garden selected for the experiment were spaced at 7.5 m apart and of 20-25 years age. In the interspaces of the trees no intercropping was carried out for five years, prior to the commencement of the experiment.

3.2 Season

The experiments were conducted during the main cassava planting season of June to April in 1983-84 and 1984-85.

3.3 Weather conditions

The mean annual rainfall is 1738 mm. The mean annual maximum and minimum temperatures are 30.7°C and 23.67°C respectively.

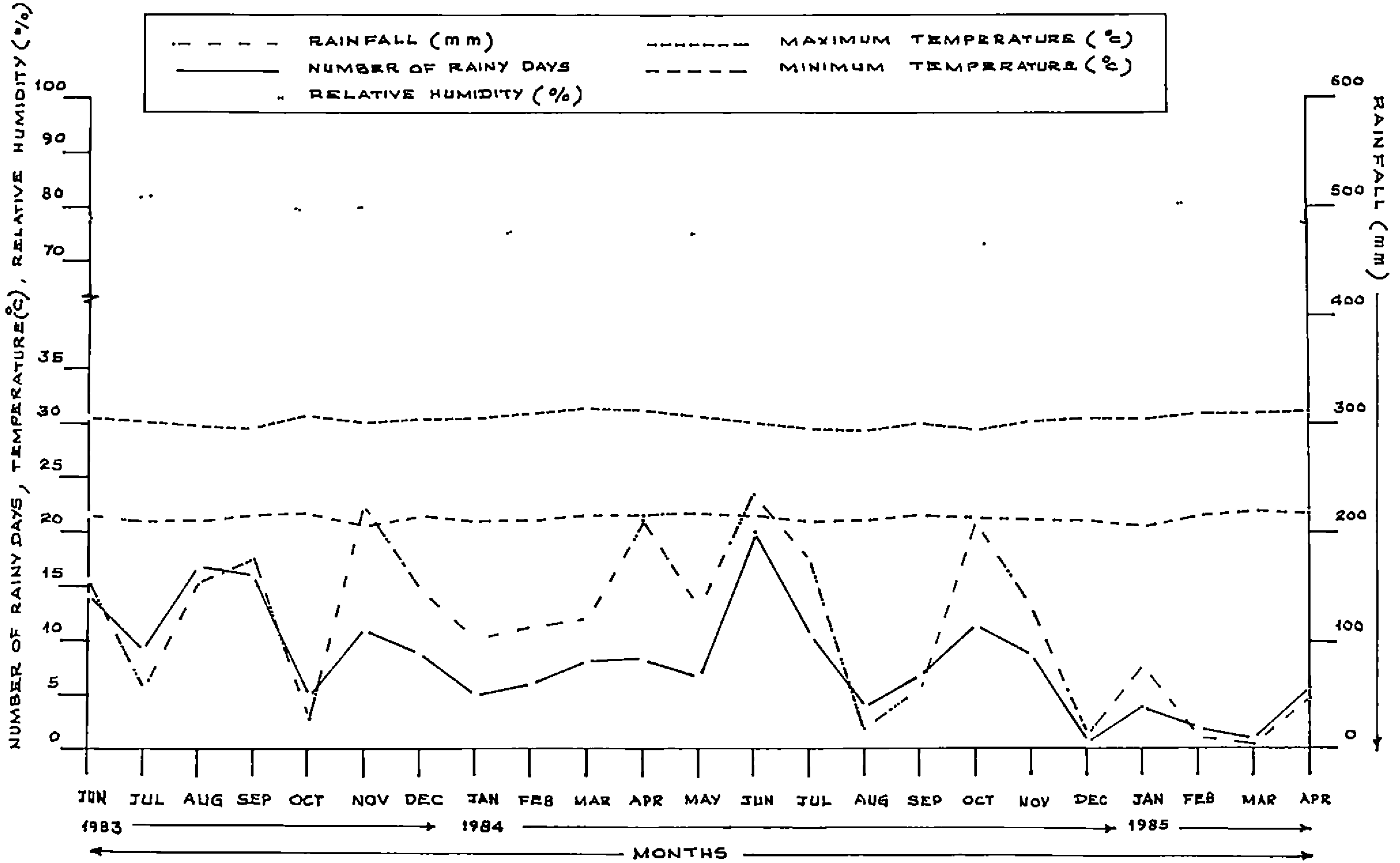
The weather conditions prevailed during the cropping period are shown in Fig. 1 and the normal Weather data (average for 24 years') are given in appendix-I. The light intensity was measured using a Luxmeter. The receipt of solar radiation was 1,15,000 lux and 44,000 lux, in the open and partial shade respectively.

3.4 Materials

3.4.1 Planting material and variety

The planting material of the cassava varieties were obtained from the Central tuber crops research, institute,

FIG 1 WEATHER CONDITIONS DURING THE CROP PERIOD



Trivandrum. The descriptions of the varieties are given below.

3.4.1.1. Malayan-4 (M-4)

Malayan-4 usually known as M-4 is a semi-branching cassava cultivar introduced from Malayasia. Due to its superior cooking quality, it is very popular especially for intercropping in the homestead coconut gardens. Under good management and sole cropping it is capable of yielding 18-20 tonnes of fresh tubers per hectare. M-4 matures in 10 months after planting.

3.4.1.2 Sreevisakham (H-1687)

Sreevisakham is a hybrid cassava variety developed at Central tuber crops research institute by crossing an indigenous type'Cheeni Kappa'and an exotic type introduced from Malagasy republic. It is semi-branching and produces medium sized tubers with good culinary qualities. Sreevisakham is tolerant to cassava mosaic disease and matures in 10 months. Under sole cropping it is capable of yielding 30-35 tonnes of fresh tubers.

3.4.2 Fertilizers

Urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O) were used to supply nitrogen, phosphorus and potassium respectively.

3.4.3 Growth regulators

3.4.3.1 Ethrel

The liquid formulation of ethrel, containing 480 g acid equivalent as Ethephon (2-Chloroethyl phosphonic acid) per litre, was obtained from Messers Agromore limited, Mysore Road, Bangalore-560 026.

3.4.3.2 Cycocel

Cycocel 500 A containing 50% active ingredient of 2-chloroethyl trimethyl ammonium chloride was supplied by the Agricultural Division, Cinamid India Limited, Bombay-540 025.

3.4.3.3 Application of growth regulators

The above growth regulators were diluted in water to the required concentrations and sprayed on cassava plants with a knapsack sprayer at monthly intervals from first month after planting to fourth month.

3.5 Methods

3.5.1 Design and lay out for the field experiments

(A) Effect of different plant populations and growth regulators on cassava intercropped in coconut gardens

This experiment was laid out in split plot design, with six main plot treatments, five subplot treatments and three replications.

Main plot treatments (Variety x spacing)

1.	$v_1 s_1$	4.	$v_2 s_1$
2.	$v_1 s_2$	5.	$v_2 s_2$
3.	$v_1 s_3$	6.	$v_2 s_3$

v_1 - Cassava variety - Malayan-4

v_2 - " " Sreevisakham

	Spacing	No. of cassava plants in one hectare of coconut garden
S-1	60 x 60 cm	20,000
S-2	90 x 90 cm	8,000
S-3	120 x 120 cm	5,000

Subplot treatments

g_1 - Water spray - control

g_2 - Ethrel 500 ppm

g_3 - Ethrel 1000 ppm

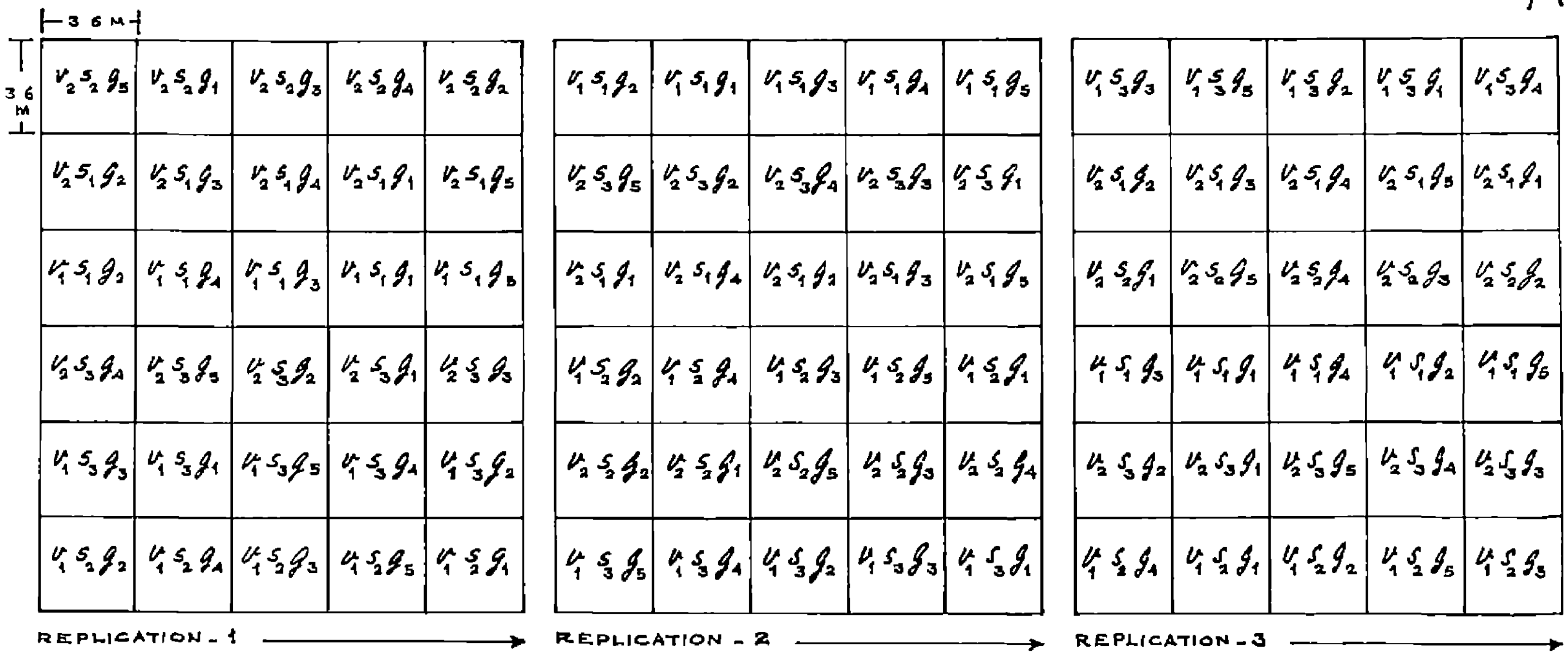
g_4 - Cycocel 1000 ppm

g_5 - Cycocel 1500 ppm

Main plot size - 18 x 3.6 M

Subplot size - 3.6 x 3.6 M

FIG 2 LAY OUT PLAN OF EXPERIMENT - A



TREATMENTS

V_1 - MALAYAN - 4
V_2 - SREEVISAKHAM
S_1 - 60 x 60 cm
S_2 - 90 x 90 cm
S_3 - 120 x 120 cm

g_1 - CONTROL
g_2 - ETHREL - 500 ppm
g_3 - ETHREL - 1000 ppm
g_4 - CYCOCEL - 1000 ppm
g_5 - CYCOCEL - 1500 ppm

(B) Response to different levels of N, P and K by cassava raised as intercrop in coconut gardens.

This experiment was laid out as $3^3 \times 2$ confounded asymetrical factorial design with NPK confounded in replication I and NPKV confounded in replication II.

Treatments

Factorial combinations of three levels each of nitrogen, phosphorus and potassium and two cassava varieties constituted the treatments.

(i) Levels of nitrogen

n_1 - 50 kg N/ha
n_2 - 100 kg N/ha
n_3 - 150 kg N/ha

(ii) Levels of phosphorus

p_1 - 50 kg P_2O_5/ha
p_2 - 75 kg P_2O_5/ha
p_3 - 100 kg P_2O_5/ha

(iii) Levels of potassium

k_1 - 50 kg K_2O/ha
k_2 - 100 kg K_2O/ha
k_3 - 150 kg K_2O/ha

(iv) Cassava varieties

v_1 - Malayan-4
v_2 - Sreevisakham

Treatment combinations

1. $n_1\ p_1\ k_1\ v_1$
2. $n_1\ p_1\ k_1\ v_2$
3. $n_1\ p_1\ k_2\ v_1$
4. $n_1\ p_1\ k_2\ v_2$
5. $n_1\ p_1\ k_3\ v_1$
6. $n_1\ p_1\ k_3\ v_2$
7. $n_1\ p_2\ k_1\ v_1$
8. $n_1\ p_2\ k_1\ v_2$
9. $n_1\ p_2\ k_2\ v_1$
10. $n_1\ p_2\ k_2\ v_2$
11. $n_1\ p_2\ k_3\ v_1$
12. $n_1\ p_2\ k_3\ v_2$
13. $n_1\ p_3\ k_1\ v_1$
14. $n_1\ p_3\ k_1\ v_2$
15. $n_1\ p_3\ k_2\ v_1$
16. $n_1\ p_3\ k_2\ v_2$
17. $n_1\ p_3\ k_3\ v_1$
18. $n_1\ p_3\ k_3\ v_2$
19. $n_2\ p_1\ k_1\ v_1$
20. $n_2\ p_1\ k_1\ v_2$
21. $n_2\ p_1\ k_2\ v_1$
22. $n_2\ p_1\ k_2\ v_2$
23. $n_2\ p_1\ k_3\ v_1$
24. $n_2\ p_1\ k_3\ v_2$
25. $n_2\ p_2\ k_1\ v_1$
26. $n_2\ p_2\ k_1\ v_2$
27. $n_2\ p_2\ k_2\ v_1$
28. $n_2\ p_2\ k_2\ v_1$
29. $n_2\ p_2\ k_3\ v_1$
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41. $n_3\ p_1\ k_3\ v_1$
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43. $n_3\ p_2\ k_1\ v_1$
44. $n_3\ p_2\ k_1\ v_2$
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48. $n_3\ p_2\ k_3\ v_2$
49. $n_3\ p_3\ k_1\ v_1$
50. $n_3\ p_3\ k_1\ v_2$
51. $n_3\ p_3\ k_2\ v_1$
52. $n_3\ p_3\ k_2\ v_2$
53. $n_3\ p_3\ k_3\ v_1$
54. $n_3\ p_3\ k_3\ v_2$

FIG 3 LAYOUT PLAN OF EXPERIMENT – B

N

REPLICATION-1

Block									
B_1	$n_2p_1k_3v_2$	$n_2p_3k_1v_1$	$n_1p_2k_3v_1$	$n_3p_1k_2v_1$	$n_3p_1k_2v_2$	$n_3p_3k_3v_1$	$n_1p_1k_1v_2$	$n_2p_3k_1v_2$	$n_3p_2k_1v_1$
	$n_2p_2k_2v_1$	$n_3p_2k_1v_2$	$n_1p_3k_2v_1$	$n_1p_2k_3v_2$	$n_2p_2k_2v_2$	$n_2p_1k_3v_1$	$n_1p_3k_2v_2$	$n_1p_1k_1v_1$	$n_3p_3k_3v_2$
B_2	$n_2p_1k_1v_2$	$n_1p_2k_1v_2$	$n_3p_3k_1v_2$	$n_1p_1k_2v_2$	$n_1p_1k_2v_1$	$n_3p_1k_3v_1$	$n_3p_2k_2v_1$	$n_2p_3k_2v_2$	$n_3p_3k_1v_1$
	$n_3p_2k_2v_2$	$n_2p_3k_2v_1$	$n_1p_3k_3v_1$	$n_1p_3k_3v_2$	$n_3p_1k_3v_2$	$n_2p_2k_3v_2$	$n_2p_1k_1v_1$	$n_2p_2k_3v_1$	$n_1p_2k_1v_1$
B_3	$n_1p_1k_3v_2$	$n_3p_3k_2v_2$	$n_1p_3k_1v_1$	$n_3p_1k_1v_1$	$n_1p_1k_3v_1$	$n_2p_1k_2v_1$	$n_1p_2k_2v_2$	$n_2p_3k_3v_1$	$n_2p_2k_1v_2$
	$n_3p_2k_3v_1$	$n_1p_2k_2v_1$	$n_2p_2k_1v_1$	$n_3p_1k_1v_2$	$n_3p_3k_2v_1$	$n_2p_1k_2v_2$	$n_1p_3k_1v_2$	$n_1p_3k_3v_2$	$n_3p_2k_3v_1$

3.6 m (plot width); 4.5 m (plot length)

REPLICATION-2

Block									
B_4	$n_3p_2k_3v_2$	$n_3p_3k_2v_2$	$n_1p_1k_1v_1$	$n_1p_1k_3v_2$	$n_2p_1k_3v_1$	$n_3p_1k_2v_1$	$n_3p_2k_1v_1$	$n_3p_3k_3v_1$	$n_2p_2k_1v_2$
	$n_1p_2k_2v_2$	$n_3p_1k_1v_2$	$n_2p_3k_3v_2$	$n_1p_2k_3v_1$	$n_1p_3k_2v_1$	$n_2p_3k_1v_1$	$n_1p_3k_1v_2$	$n_2p_2k_2v_1$	$n_2p_1k_2v_2$
B_5	$n_2p_3k_2v_1$	$n_1p_3k_3v_1$	$n_1p_2k_1v_1$	$n_2p_1k_1v_1$	$n_3p_2k_2v_1$	$n_3p_2k_1v_2$	$n_3p_3k_3v_2$	$n_3p_1k_3v_1$	$n_2p_1k_2v_2$
	$n_2p_1k_3v_2$	$n_1p_2k_3v_2$	$n_2p_3k_1v_2$	$n_1p_1k_2v_1$	$n_1p_1k_1v_2$	$n_2p_2k_2v_2$	$n_2p_2k_3v_1$	$n_1p_3k_2v_2$	$n_3p_3k_1v_1$
B_6	$n_2p_3k_3v_1$	$n_2p_1k_1v_2$	$n_1p_2k_1v_2$	$n_3p_3k_2v_1$	$n_1p_1k_3v_1$	$n_3p_2k_3v_1$	$n_1p_3k_3v_2$	$n_2p_2k_3v_2$	$n_2p_2k_1v_1$
	$n_2p_1k_2v_1$	$n_1p_2k_2v_1$	$n_3p_2k_2v_2$	$n_1p_3k_1v_1$	$n_3p_3k_1v_2$	$n_3p_1k_1v_1$	$n_1p_1k_2v_2$	$n_3p_1k_3v_2$	$n_2p_3k_2v_2$

TREATMENTS

LEVELS OF NITROGEN	LEVELS OF PHOSPHORUS	LEVELS OF POTASSIUM	VARIETIES
n_1 – 50 kg N ha^{-1}	P_1 – 50 kg P_2O_5 ha^{-1}	k_1 – 50 kg K_2O ha^{-1}	V_1 – MALAYAN-4
n_2 – 100	P_2 – 75 " "	k_2 – 100 "	V_2 – SREEVISAKHAM
n_3 – 150	P_3 – 100 " " "	k_3 – 150 "	

No.of blocks per replication	...	3
No.plots per block	...	18
Total no.of treatments per replication	...	54
Plot size	...	4.5 x 3.6 M
Spacing	...	90 x 90 cm

A third replication with the same treatment combinations (as in replication two) was maintained in both the seasons for plant removal at sixty days' interval. Plant removal was carried out for estimation of dry matter production and NPK uptake at various growth stages.

The lay out plan of the experiments A and B are presented in Fig. 2 and 3 respectively.

3.5.2 Land preparation and planting

Experimental plots were formed in the interspaces of coconut trees leaving an area of two metres radius at the base of the palms. Mound method of planting cassava was followed. Previously selected healthy stems of both the varieties were cut into setts of 20 cm length and one sett per mound was planted vertically, at a depth not exceeding 5 cm.

3.5.3 Fertilizer application

For the experiment 'A' fertilizers to provide 100 kg N, 100 kg P_2O_5 and 100 kg K_2O per hectare were applied. For the experiment B fertilizers at the calculated amounts to supply the different levels of N, P_2O_5 and K_2O as per the treatment schedule were applied. In both the cases the whole of P_2O_5, half the dosages of nitrogen and potassium were given as the basal dressing. The remaining dosages of nitrogen and potassium were applied at the time of second weeding and earthing up.

3.5.4 After cultivation

Sprouting and establishment were satisfactory during both the years. Cultivation practices other than the treatment requirements of the experiments were followed as per the package of practices recommendations of the Kerala Agricultural University (1982).

A brief schedule of the cultural operations is provided in Table 2.

3.6 Biometric observations

Following biometric observations were recorded from both the experiments.

Table 2. Schedule of cultural Operations

Year	Operations	Experiment A	Experiment B
1983-84	1. Planting	14.6.1983	16.6.1983
	2. First weeding and earthing up	15.7.1983	17.7.1983
	3. Second weeding and top dressing	12.8.1983	14.8.1983
	4. Harvesting	20.4.1984	22.4.1984
1984-85	1. Planting	10.6.1984	12.6.1984
	2. First weeding and earthing up	9.7.1984	12.7.1984
	3. Second weeding and top dressing	11.8.1984	14.8.1984
	4. Harvesting	11.4.1985	15.4.1985

3.6.1 Pre-harvest observations

Observations on growth characters were recorded from three plants selected at random from each plot in the case of both the experiments. The observations were recorded at 60 day's interval from planting to harvest and the mean values were worked out.

3.6.1.2 Plant height

Height of the tallest stem was measured from the base of the sprout to the terminal bud.

3.6.1.3 Number of nodes per plant

The number of fully opened leaves and the leaf scars were counted from the base to the tip of both the shoots,

3.6.1.4 Number of functional leaves per plant

The number of fully opened leaves or the functional leaves was counted from the base to the tip of the stem on both the stems.

3.6.1.5 Leaf area index

The leaf area was worked out using the linear measurements method suggested by Ramanujam and Indira (1978). The leaf area index was calculated by the following formula developed by Watson (1947).

$$LAI = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Land area occupied by the plant (cm}^2\text{)}}$$

3.6.2 Post harvest observations

The sample plants ear marked for the preharvest observations were harvested on the previous day of the general harvest. The following observations were made and the mean values calculated.

3.6.2.1 Number of tubers per plant

The well developed tubers from the observational plants were separated and counted.

3.6.2.2 Tuber weight

The mean tuber weight was computed by dividing the fresh tuber weight of the selected plants by the number of tubers and expressed in grams.

3.6.2.3 Length of tubers

The length of medium sized tubers was measured and the mean values were taken.

3.6.2.4 Girth of tuber

Girth measurements were made from those tubers from which the length was measured. The girth was recorded at three places of the tuber, one at the middle and the other two at half between the middle and both the ends of tuber. Average of these three was taken as the girth of tuber.

3.6.2.5 Utilization index (U.I.)

The ratio of the root weight to top weight (stems and leaves) which is an important yield determinant of cassava (Obigbesan, 1973) was worked out.

3.6.2.6 Top yield

The total weight of stems and leaves of the plants from the net plot were recorded soon after the harvest.

3.6.2.7 Tuber yield

After carefully pulling out the plants from the net plot, the tubers were separated, cleaned and the fresh weight was recorded.

3.6.2.8 Starch content

Starch content of the tubers in each treatment was determined Calorimetrically; after hydrolysis into glucose and then following Nelson's method (Whistler, 1962).

3.6.2.9 Hydrocyanic acid content

The HCN content of fresh tuber samples were estimated calorimetrically by sodium picrate method (Indira and Sinha 1969).

3.7 Growth analysis

3.7.1 Drymatter production and distribution

Destructive sampling at 60 days interval from the third replication of the experiment 'B' was carried out. At each sampling one plant from each treatment was carefully pulled out and separated out into roots, stem and leaves. Fresh weight of each part was recorded and sub samples were taken for estimating the dry weight. The sub samples were dried in oven at 80°C to constant dry weight. Then the dry weights of each plant part was computed and recorded.

3.7.2 Net assimilation rate (NAR)

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

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

Where

W_2 = total dry weight of plant g m^{-2} at time t_2

W_1 = total dry weight of plant g m^{-2} at time t_1

$t_2 - t_1$ = time interval in days

A_2 = loaf area m^{-2} at time t_2

A_1 = leaf area m^{-2} at time t_1

3.7.3 Crop growth rate (CGR)

Crop growth rate was calculated by the formula of Watson (1958).

CGR = NAR x LAI

This was expressed as g m^{-2} day^{-1}

3.7.4 Tuber bulking rate (B.R.)

It is the rate of increase in tuber weight per unit time and is an important measure of tuber growth. It is expressed as g day^{-1} $plant^{-1}$ (dry wt.).

$$\text{B.R.} = \frac{W_2 - W_1}{T_2 - T_1}$$

Where W_2 = Dry weight of tuber at time T_2

W_1 = Dry weight of tuber at time T_1

3.8 Chemical analysis

3.8.1 Plant analysis

The sample plants uprooted at 60 days intervals from the third replication was separated into leaf, stem and root and the dry weight was recorded as stated earlier. Nitrogen phosphorus and potassium contents of different plant parts were analysed at various growth stages.

3.8.1.1 Nitrogen

Total nitrogen of the plant sample were determined by the modified micro-kjeldahl method (Jackson, 1967).

3.8.1.2 Phosphorus

Phosphorus was determined calorimetrically by the Vanadomolybdo phosphoric acid yellow colour method (Jackson, 1967).

3.8.1.3 Potassium

Potassium was determined flame photometrically using a systronics flame photometer.

3.8.2 Uptake of nutrients

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

3.8.3 Soil analysis

Before commencement of the experiment composite soil samples were taken replication vice and analysed, for various physico-chemical properties. Plotvice analysis of soil samples from experiment 'B', for available nitrogen, phosphorus and potassium was done after the harvest of the experiment.

3.8.3.1 Mechanical analysis

Mechanical analysis of the initial soil samples was carried out by the international pipette method (Piper, 1950).

3.8.3.2 Organic carbon

Walkley and Black's wet oxidation method as described by Jackson (1967) was used for the estimation of organic carbon.

3.8.3.3 Total nitrogen

Modified micro-Kjeldahl method (Jackson, 1967) was adopted for the estimation of total nitrogen content of the soil.

3.8.3.4 Available nitrogen

Available nitrogen was determined by the procedure of Subbiah and Asija (1956).

3.8.3.5 Available phosphorus

The available phosphorus was determined by Bray's I method (Jackson, 1967).

3.8.3.6 Available potassium

Available potassium was extracted by neutral normal ammonium acetate solution and determined by a systronics flame photometer (Jackson, 1967).

3.9 Statistical analysis

The data of the experiment 'A' were analysed by the analysis of variance technique for split plot design and for the analysis of the experiment 'B' analysis of variance technique as applicable to $3^3 \times 2$ confounded asymetrical factorial design was adopted (Cochran and Cox, 1965). Whereever the F test was significant in ANOVA the critical difference (CD) is provided. The results and discussion are based on 5 percent level of significance.

The correlations between the yield and yield attributes were also determined. Path coefficient analysis was also done as per the procedure given by Wright (1921) and Li (1955). A quadratic response surface of applied nutrients on tuber yield was fitted for both the crop years (Das and Giri, 1978). The economics of intercropping cassava at different levels of fertilizer application was also worked out.

RESULTS

4. RESULTS

4.1 Experiment A

The results of the experiment "Effect of different plant population and growth regulators on cassava intercropped in coconut gardens" are presented hereunder.

4.1.1 Growth characters

4.1.1.1 Plant height

The effect of treatments on the height of plants at various stages of crop growth during 1983-84 and 1984-85 are presented in Table 3a.

The differences in plant height between the varieties were not significant during the initial stages of growth. But v_1 had significantly higher plant height at 180th day, 240th day and at harvest in 1983-84. However, in 1984-85 the differences in height between the varieties were not significant at all stages of growth. The influence of plant population on the height of plants was significant at all stages of growth, except on 60th day, during both the years. With increase in planting density significant reduction in plant height was recorded, especially at the later stages of growth. Maximum stunting was

Table 3a. Effect of varieties, spacing and growth regulators on plant height (cm)

	60th day		120th day		180th day		240th day		At harvest	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
V_1 (Malayan-4)	42.06	39.35	129.32	123.85	197.84	188.36	269.38	251.78	270.39	252.56
V_2 (Sreevisakham)	42.20	39.90	129.34	124.12	200.11	190.50	267.66	250.87	268.39	251.70
C.D.	NS	NS	NS	NS	0.74	NS	0.86	NS	0.89	NS
S_1 (60 x 60 cm)	42.21	39.58	124.25	115.65	163.73	154.75	194.56	183.15	195.40	183.88
S_2 (90 x 90 cm)	41.90	39.31	128.98	126.80	210.91	201.83	301.75	278.09	302.61	278.91
S_3 (120 x 120 cm)	42.28	39.98	134.76	129.51	222.28	211.71	309.26	292.75	310.15	293.60
C.D.	NS	NS	0.40	1.83	0.90	2.39	1.06	1.38	1.09	1.55
g_1 (Control)	42.16	39.88	133.02	125.44	204.61	194.33	272.02	255.27	273.16	255.97
g_2 (Ethrel 500ppm)	42.17	39.47	132.52	125.77	202.22	193.72	271.50	254.86	272.22	255.86
g_3 (Ethrel 1000ppm)	41.91	39.50	131.69	127.19	200.55	191.47	269.77	253.37	270.75	254.22
g_4 (Cycocel 1000ppm)	42.13	39.75	125.77	122.13	195.33	185.63	267.30	248.83	268.11	249.50
g_5 (Cycocel 1500ppm)	42.27	39.52	123.63	119.38	192.16	182.00	262.02	244.30	262.69	245.11
CD	NS	NS	0.50	1.37	0.75	1.52	1.36	1.77	1.53	2.39

Table 3b. Effect of V x G interaction on plant height (cm) at the harvest stage

Variety	Growth regulator treatments									
	g_1		g_2		g_3		g_4		g_5	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
V_1	272.88	255.83	272.88	256.05	271.66	254.88	270.88	250.44	263.61	244.61
V_2	273.44	256.11	271.55	255.66	269.83	253.55	265.33	248.55	261.77	244.61

CD for 1983-84 = 2.17

CD for 1984-85 = NS

observed in plants under the treatment s_1. Among the growth regulators, g_4 and g_5 caused significant reduction in plant height at all stages of growth except on 60th day during both years. The effect of g_3 in decreasing the height of plants was also significant in most of the stages. Maximum reduction in plant height was observed in plants treated with g_5 (cycocel 1500 ppm).

The interactions V x S and S x G were not significant in both the years. However the V x G interaction had significant influence on plant height at the final stage during 1983-84 (Table 3b). Maximum reduction in plant height was recorded under the treatment combination v_2 g_5.

4.1.1.2 Number of nodes

The data on number of nodes plant^{-1} at different growth stages of the crop for 1983-84 and 1984-85 are presented in Table 4a.

The variety v_2 had significantly higher number of nodes plant^{-1} at all growth stages except at 60th day during 1983-84. The effect of plant population on number of nodes plant^{-1} was also significant at all stages except at 60th day during 1983-84. Plants at wider spacings in general had higher number of nodes at all the stages of growth. The highest number of nodes was

Table 4a. Effect of varieties, spacing and growth regulators on number of nodes plant^{-1}

Treatments	60th day		120th day		180th day		240th day		At harvest	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
V_1 (Malayan-4)	34.44	30.63	59.57	45.61	101.73	94.60	145.53	126.73	146.15	127.64
V_2 (Sreevisakham)	34.91	31.24	61.24	47.04	111.40	104.48	150.71	129.73	151.28	130.60
CD	NS	0.17	0.93	1.14	1.45	0.85	1.35	0.37	1.23	0.42
s_1 (60 x 60 cm)	35.06	30.65	44.50	43.45	78.20	73.40	134.00	92.76	134.56	93.76
s_2 (90 x 90 cm)	34.56	31.10	62.73	43.81	110.06	105.53	144.83	136.46	145.36	137.36
s_3 (120 x 120 cm)	34.40	31.06	74.00	51.71	131.43	119.70	165.53	155.46	166.23	156.23
CD	NS	0.20	1.40	1.39	1.78	1.07	1.65	0.45	1.50	0.51
g_1 (Control)	34.38	31.52	61.16	47.44	107.61	99.27	148.44	128.88	148.88	129.77
g_2 (Ethrel 500 ppm)	35.61	30.91	60.11	47.38	108.61	99.88	148.61	128.22	149.44	129.11
g_3 (Ethrel 1000 ppm)	34.55	30.77	60.61	46.50	109.11	100.27	149.50	129.66	150.22	130.27
g_4 (Cycocel 1000 ppm)	35.66	30.86	60.05	45.61	104.88	98.88	148.50	127.77	149.00	128.83
g_5 (Cycocel 1500 ppm)	33.66	30.61	59.61	44.69	102.61	99.38	145.55	126.61	146.05	127.61
CD	NS	0.44	1.23	0.98	1.54	NS	1.75	1.55	1.73	NS

Table 4b. Effect of V x S interaction on number of nodes plant^{-1} at the harvest stage

Variety	Spacing					
	S_1		S_2		S_3	
	83-84	84-85	83-84	84-85	83-84	84-85
V_1	131.60	93.60	143.00	136.80	162.86	152.53
V_2	136.53	93.93	147.73	137.93	169.60	159.93

CD For 1983-84 - 2.60

CD For 1984-85 - 0.89

observed in plants under the treatment s_3. In the case of growth regulators, g_5 caused significant reduction on number of nodes plant^{-1} during most of the stages of crop growth. However the effect of other treatments was not significant during both the years.

The V x S interaction effect on the number of nodes plant^{-1} was significant during 1984-85 (Table 4b). Significantly higher number of nodes was produced in plants under the treatment v_2 s_3. The interactions V x G and S x G were not significant at the stage of harvest in both the years.

4.1.1.3 Number of functional leaves

The data on mean number of functional leaves plant^{-1} recorded at 60 days' interval in 1983-84 and 1984-85 are given in Table 5.

During 1983-84, the higher number of functional leaves plant^{-1} recorded for the variety v_2 was significant only at 180th day. However, during the subsequent year the above variety had significantly higher number of functional leaves at all stages of growth except at 240th day. The effect of planting density on number of functional leaves plant^{-1} was significant only during the later stages of growth during both the years. Increase in plant population resulted in significant negative

Table 5. Effect of varieties, spacing and growth regulators on number of functional levels plant^{-1}

Treatments	60th day		120th day		180th day		240th day		At harvest	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-84
v_1 (Malayan-4)	33.73	29.32	50.53	37.00	72.26	68.13	67.44	63.37	45.48	39.66
v_2 (Sreevisakham)	33.97	30.06	51.28	40.53	75.44	70.08	68.57	64.44	46.68	40.75
CD	NS	0.32	NS	1.75	1.26	0.72	NS	NS	NS	0.54
s_1 (60 x 60 cm)	34.50	29.20	35.73	33.13	53.73	48.90	61.06	57.66	33.60	28.23
s_2 (90 x 90 cm)	33.63	30.03	52.46	37.96	81.43	77.96	69.66	63.13	50.73	41.26
s_3 (120 x 120 cm)	33.43	29.83	64.53	45.20	86.40	80.46	73.30	70.76	53.93	51.13
CD	NS	NS	1.17	2.14	1.54	0.88	1.14	1.07	1.53	0.67
g_1 (Control)	33.44	30.33	51.16	35.55	73.88	69.50	68.72	63.66	46.55	39.88
g_2 (Ethrel 500 ppm)	34.83	29.61	50.77	40.22	73.66	69.22	67.88	64.11	45.94	40.83
g_3 (Ethrel 1000 ppm)	33.72	29.50	51.27	40.05	74.66	69.05	68.71	63.66	46.22	40.16
g_4 (Cycocel 1000 ppm)	34.50	29.66	51.11	39.16	73.66	68.33	68.00	63.94	45.55	40.05
g_5 (Cycocel 1500 ppm)	32.77	29.33	50.22	38.83	73.38	68.94	66.72	63.88	46.16	40.11
CD	NS	0.55	NS	2.50	NS	NS	NS	NS	NS	NS

effect on the number of functional leaves. As such plants in the treatment s_1 had lowest number of functional leaves. In general the growth regulator treatments had no significant influence on number of functional leaves $plant^{-1}$.

The interactions V x S, V x G and S x G were also not significant at the harvest stage during both the years.

4.1.1.4 Leaf area index

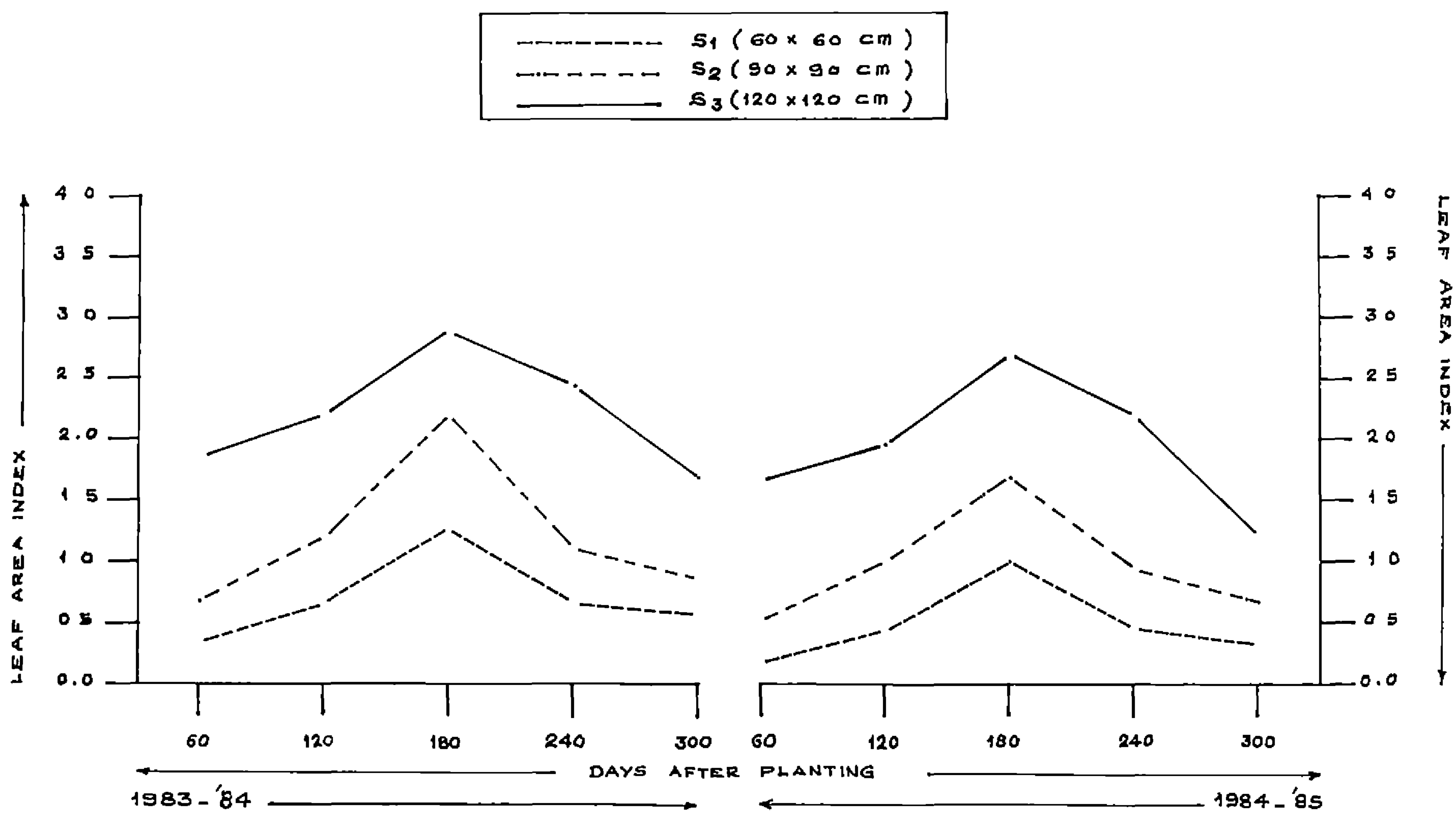
The data on leaf area index at various stages of crop growth for both the years are presented in Table 6.

During both the years, v_2 had significantly higher leaf area index at most of the stages. Increase in plant population resulted in significantly higher leaf area indices at various stages of crop growth during both the years (Fig. 4). Plants at the highest planting density under the treatment s_1 had significantly higher leaf area indices at all the stages. During 1983-84, the effect of growth regulators on leaf area index was significant only at 240th day. Significant reduction in leaf area index due to growth regulator treatments was observed at this stage. In 1984-85 the treatment g_5 was instrumental in significantly lowering the leaf area index, at 120th day. At other stages of crop growth the effect of growth regulators was not significant.

Table 6. Effect of varieties, spacing and growth regulators on leaf area index

Treatments	60th day		120th day		180th day		240th day		At harvest	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
v_1 (Malayan-4)	1.68	1.02	1.52	1.32	2.39	2.17	1.66	1.60	1.32	0.97
v_2 (Sreevisakham)	1.19	1.07	1.53	1.34	2.50	2.24	1.67	1.63	1.33	1.04
CD	NS	0.02	NS	NS	0.05	0.03	0.01	NS	0.01	0.02
s_1 (60 x 60 cm)	2.13	1.83	2.20	2.10	3.30	3.12	2.73	2.71	1.93	1.41
s_2 (90 x 90 cm)	0.92	0.84	1.44	1.15	2.50	2.21	1.35	1.31	1.24	0.96
s_3 (120 x 120 cm)	0.51	0.47	0.94	0.74	1.53	1.28	0.92	0.83	0.81	0.66
CD	0.06	0.02	0.03	0.02	0.06	0.03	0.02	0.03	0.01	0.02
g_1 (Control)	1.16	1.07	1.53	1.33	2.44	2.21	1.69	1.61	1.34	1.00
g_2 (Ethrel 500 ppm)	1.22	1.05	1.53	1.34	2.43	2.22	1.64	1.61	1.32	1.02
g_3 (Ethrel 1000 ppm)	1.20	1.03	1.54	1.35	2.47	2.21	1.67	1.62	1.32	1.02
g_4 (Cycocel 1000 ppm)	1.19	1.05	1.54	1.32	2.44	2.19	1.66	1.62	1.33	1.00
g_5 (Cycocel 1500 ppm)	1.16	1.04	1.50	1.30	2.44	2.18	1.67	1.62	1.32	1.00
CD	NS	NS	NS	0.02	NS	NS	0.02	NS	NS	NS

FIG 4 EFFECT OF PLANTING DENSITY ON LEAF AREA INDEX



The interactions V x S, V x G and S x G on leaf area index were not significant at the harvest stage.

4.1.2 Yield components and yield

4.1.2.1 Number of tubers

The data on mean number of tubers plant^{-1} at harvest during 1983-84 and 1984-85 are presented in Table 7.

The varietal difference in the number of tubers plant^{-1} was significant during both the years. The variety v_2 produced significantly higher number of tubers plant^{-1}. The influence of plant population on tuber number plant^{-1} was significant during 1983-84 and 1984-85. Increase in plant population resulted in significant reduction in the number of tubers plant^{-1}. Highest number of tubers plant^{-1} was obtained from the treatment s_3, followed by s_2. The growth regulators could not exert any influence on the number of tubers plant^{-1}, during both the years.

The interactions V x S, V x G and S x G were also not significant, in the case of number tubers plant^{-1}.

4.1.2.2 Tuber weight

The data on mean weight of the tubers at harvest during 1983-84 and 1984-85 are given in Table 7. During both the years

Table 7. Effect of varieties, spacing and growth regulators on number of tubers plant^{-1} and mean tuber weight

Treatments	Number of tubers plant^{-1}		Mean weight of Tubers (g)	
	83-84	84-85	83-84	84-85
v_1 (Malayan-4)	3.85	3.61	154.12	165.55
v_2 (Sreevisakham)	4.60	4.43	181.36	180.33
CD	0.37	0.28	18.31	15.21
s_1 (60 x 60 cm)	3.68	3.47	74.23	77.44
s_2 (90 x 90 cm)	4.19	4.12	210.26	213.23
s_3 (120 x 120 cm)	4.80	4.46	218.74	228.15
CD	0.45	0.34	22.42	18.63
g_1 (Control)	4.23	4.05	169.41	171.04
g_2 (Ethrel 500 ppm)	4.13	3.94	165.15	175.95
g_3 (Ethrel 1000 ppm)	4.19	3.94	165.37	179.95
g_4 (Cycocel 1000 ppm)	4.16	4.03	175.23	173.49
g_5 (Cycocel 1500 ppm)	4.41	4.14	163.55	164.42
CD	NS	NS	NS	NS

the variety v_2 had significantly higher mean tuber weight. The effect of plant population on mean tuber weight was also significant during both the years. Significantly lower mean tuber weight was registered under the treatment s_1. The difference in mean tuber weight between the treatments s_2 and s_3 was not significant. However, highest mean tuber weight was noticed in the treatment s_3. As regards the growth regulators, their effect on tuber weight was not significant during both the years.

The interactions V x S, V x G and S x G, on mean weight of tubers were also not significant during both the years.

4.1.2.3 Length of tubers

The data pertaining to the length of tubers at harvest during both the years are presented in Table 8.

The variety v_2 produced significantly longer tubers in 1983-84 and 1984-85. The length of tubers was significantly influenced during both the years, by the planting density. Significantly lowest tuber length was recorded in the case of plants under treatment s_1. However, the variation in tuber length between the treatments s_2 and s_3 was not significant. The effect of growth regulators on tuber length was not significant during both the years.

Table 8. Effect of varieties, spacing and growth regulators on length and girth of tubers

Treatments	Mean length of tuber(cm)		Mean girth of tuber(cm)	
	83-84	84-85	83-84	84-85
v_1 (Malayan-4)	14.39	13.89	8.19	8.12
v_2 (Sreevisakham)	15.13	14.85	8.51	8.28
CD	0.52	0.54	0.13	0.10
s_1 (60 x 60 cm)	11.12	10.73	7.15	6.99
s_2 (90 x 90 cm)	16.41	15.72	8.89	8.52
s_3 (120 x 120 cm)	16.76	15.92	8.96	9.10
CD	0.64	0.66	0.16	0.13
g_1 (Control)	14.87	14.24	8.47	8.27
g_2 (Ethrel 500 ppm)	14.72	14.11	8.31	8.19
g_3 (Ethrel 1000 ppm)	14.57	14.00	8.29	8.19
g_4 (Cycocel 1000 ppm)	14.89	14.23	8.33	8.18
g_5 (Cycocel 1500 ppm)	14.77	14.03	8.27	8.18
CD	NS	NS	NS	NS

The interactions V x S, V x G and S x G on tuber length were also not significant during 1983-84 and 1984-85.

4.1.2.4 Girth of tubers

The data on mean girth of tubers for 1983-84 and 1984-85 are presented in Table 8.

The differences in girth of tubers between the varieties were significant during both the years and the variety v_2 had higher tuber girth. The effect of plant population on tuber girth was significant during both the years. Tubers from plants under the treatment s_1 were significantly thinner in size. The variation in tuber girth between the treatments s_2 and s_3 was not significant during 1983-84. However, during 1984-85, the difference between the above treatments was significant and the tuber girth was highest under s_3. The mean tuber girth was not significantly affected by the growth regulators during both the years.

The effects of interactions V x S, V x G and S x G on this yield component were not significant in either of the years.

4.1.2.5 Top yield

The data on top yield for 1983-84 and 1984-85 are presented in Table 9a.

Table 9a. Effect of varieties, spacing and growth regulators on top yield.

Treatments	83-84 t ha^{-1}	84-85 t ha^{-1}
v_1 (Malayan-4)	7.59	7.25
v_2 (Sreevisakham)	8.03	7.77
CD	0.01	0.03
s_1 (60 x 60 cm)	11.18	10.61
s_2 (90 x 90 cm)	7.48	7.32
s_3 (120 x 120 cm)	4.77	4.60
CD	0.01	0.04
g_1 (Control)	7.82	7.53
g_2 (Ethrel 500 ppm)	7.82	7.53
g_3 (Ethrel 1000 ppm)	7.82	7.52
g_4 (Cycocel 1000 ppm)	7.81	7.51
g_5 (Cycocel 1500 ppm)	7.77	7.46
CD	0.01	0.04

Table 9b. Effect of V x S interaction on top yield t ha^{-1}

Variety	Spacing S_1		S_2		S_3	
	83-84	84-85	83-84	84-85	83-84	84-85
V_1	10.90	10.12	7.22	7.12	4.62	4.51
V_2	11.44	11.11	7.33	7.51	4.90	4.69

C.D. for 1983 - 84 - 0.02

C.D. for 1984 - 85 - 0.08

The variety v_2 produced significantly higher top yield during both the years. Among the treatments on plant population, the differences in top yield were significant in 1983-84 and 1984-85. With increase in plant population there was significant increase in top yield. Highest top yields were obtained from s_1. As regards the growth regulator treatments, g_5 had significant depressing effect on top yield during both the years. However the other growth regulator treatments had no significant depressing effect on top yield.

The V x S interaction effect was significant during the above years on top yield (Table 9b). Highest top yield was obtained from v_2 s_3. The V x G interaction on top yield was not significant in either of the years. But the S x G interaction on top yield was significant during 1983-84.

4.1.2.6 Utilization index

The effect of treatments on utilisation index for 1983-84 and 1984-85 are presented in Table 10.

The utilisation index was significantly higher for the variety v_2 during both the years. The influence of planting density on utilisation index was also significant during both the years. With increase in plant population there was significant reduction in utilisation index. Significantly

Table 10. Effect of varieties, spacing and growth regulators on Utilisation index (UI)

Treatments	Utilisation index	
	83-84	84-85
v_1 (Malayan-4)	0.818	0.829
v_2 (Sreevisakham)	1.037	1.046
CD	0.008	0.008
s_1 (60 x 60 cm)	0.508	0.532
s_2 (90 x 90 cm)	1.113	1.120
s_3 (120 x 120 cm)	1.161	1.160
CD	0.010	0.010
g_1 (Control)	0.923	0.941
g_2 (Ethrel 500 ppm)	0.917	0.933
g_3 (Ethrel 1000 ppm)	0.925	0.940
g_4 (Cycocel 1000 ppm)	0.920	0.926
g_5 (Cycocel 1500 ppm)	0.952	0.947
CD	0.018	0.010

lowest utilisation index was recorded for the treatment s_1. The difference in utilisation index between s_2 and s_3 was also significant and the former had lower utilisation index. Among the growth regulators, g_5 had a tendency to increase the utilisation index and this effect was significant in 1983-84.

The interactions V x S, V x G and S x G had no significant influence on utilisation index in either of the years.

4.1.2.7 Tuber yield

The data on treatment effects on tuber yield in tonnes ha^{-1} for 1983-84 and 1984-85 are presented in Table 11a.

The varietal difference in tuber yield was significant during both the years and the variety v_2 gave higher tuber yield. The effect of plant population on tuber yield was also significant in both the years. Significantly higher tuber yield was obtained with a spacing of 90 x 90 cm. In 1983-84 the treatments s_1 and s_3 were on par in production of tubers. However in 1984-85 the tuber yield from s_1 was significantly higher than the yield from s_3. Tuber yield was not significantly influenced by growth regulators in both the years. However, cycocel at the higher concentration (g_5) tended to promote tuber yield.

Table 11a. Effect varieties, spacing and growth regulators on tuber yield of cassava (t ha^{-1})

Treatments	Fresh tuber t ha^{-1}	
	83-84	84-85
v_1(Malayan-4)	5.48	5.58
v_2(Sreevisakham)	7.41	7.27
CD	0.27	0.06
s_1(60 x 60 cm)	5.69	5.67
s_2(90 x 90 cm)	8.12	8.24
s_3(120 x 120 cm)	5.53	5.38
CD	0.34	0.04
g_1(Control)	6.53	6.44
g_2(Ethrel 500 ppm)	6.49	6.40
g_3(Ethrel 1000 ppm)	6.12	6.44
g_4(Cycocel 1000 ppm)	6.49	6.38
g_5(Cycocel 1500 ppm)	6.61	6.47
CD	NS	NS

Table 11b. Effect of V x S interaction on tuber yield (t ha^{-1})

Treat-ment	Spacing					
	S_1		S_2		S_3	
	83-84	84-85	83-84	84-85	83-84	84-85
V_1	5.15	5.16	6.77	7.17	4.54	4.42
V_2	6.23	6.17	9.48	9.31	6.51	6.32

CD for 1983 - 84 - 0.58

CD for 1984 - 85 - 0.07

The V x S interaction effect on tuber yield was significant in both the years (Table 11b). Significantly highest tuber yield was obtained under the treatment v_2 s_2. The interactions V x G and S x G were not significant in either of the years.

4.1.3 Quality Attributes

4.1.3.1 Starch content of tubers

The data on starch content of tubers as influenced by various treatments in 1983-84 and 1984-85 are given in Table 12.

The higher starch content in the tubers recorded for the variety v_1 was significant in the first year. In the second year also the above variety produced tubers with higher starch content. In both the years effect of plant population on starch content of the tubers was significant. At the highest planting density (s_1), significant reduction in starch content of tubers, was observed. But the difference between s_2 and s_3 was not significant. The growth regulator treatments exerted no significant influence on starch content of cassava tubers.

4.1.3.2 HCN content

The data on HCN content of fresh tubers as influenced by the treatments in 1983-84 and 1984-85 are presented in Table 12.

Table 12. Effect of varieties, spacing and growth regulators on starch and HCN content of tubers.

Treatments	Starch % (dry wt. basis)		HCN μ/g	
	83-84	84-85	83-84	84-85
v_1 (Malayan-4)	78.78	79.15	54.91	52.53
v_2 (Sreevisakham)	78.50	79.05	55.49	54.84
CD	0.06	NS	NS	0.62
s_1 (60 x 60 cm)	78.46	78.71	57.27	54.50
s_2 (90 x 90 cm)	78.72	79.26	54.27	53.20
s_3 (120 x 120 cm)	78.75	79.35	54.07	53.36
CD	0.08	0.10	0.63	0.76
g_1 (Control)	78.64	79.10	55.11	53.83
g_2 (Ethrel 500ppm)	78.65	79.09	55.17	53.66
g_3 (Ethrel 1000ppm)	78.63	79.13	55.44	53.27
g_4 (Cycocel1000ppm)	78.62	79.11	55.17	53.77
g_5 (Cycocel 1500ppm)	78.67	79.11	55.11	53.88
CD	NS	NS	NS	NS

During both the years the variety v_1 had lower HCN content in fresh tubers. The varietal difference in HCN content of tubers was significant during the second year. Tubers from plants at highest planting density (s_1) had significantly higher HCN content in both the years. But the difference between s_2 and s_3 was not significant. The effect of growth regulators on HCN content of tubers was not significant.

4.2 Experiment B

The results of the experiment "Response to different levels of nitrogen, phosphorus and potassium by cassava intercropped in coconut gardens" are presented in this section.

4.2.1 Growth characters

4.2.1.1 Plant height

The data on effect of treatments on plant height at various growth stages during 1983-84 and 1984-85 are presented in Table 13a.

The variations in plant height between the varieties were not significant at most of the stages during both the years. But the effect of nitrogen on plant height was significant at all stages of growth during 1983-84 and 1984-85. With

Table 13a. Effect of varieties and NPK on plant height at various growth stages (cm)

Treatments	60th day		120th day		180th day		240th day		At harvest	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
v_1 (Malayan-4)	42.35	37.57	145.39	132.50	205.87	202.19	253.91	246.20	255.70	274.26
v_2 (Sreevisakham)	42.50	38.09	142.78	133.31	205.22	201.70	252.81	246.20	255.17	247.31
CD	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
n_1 (50 kg N)	35.19	35.72	122.06	119.86	173.03	172.50	195.25	189.72	197.03	190.94
n_2 (100 " ")	41.58	37.22	139.69	132.61	208.67	203.53	263.03	257.83	265.53	258.94
n_3 (150 " ")	50.50	40.56	170.50	146.25	234.94	229.81	301.81	291.06	303.75	291.97
CD	1.61	0.61	2.98	1.23	5.51	3.54	4.67	2.15	4.35	2.05
p_1 (50 kg P_2O_5)	42.25	37.89	142.56	131.89	205.19	199.69	252.92	246.56	254.00	247.61
p_2 (75 " ")	42.69	38.00	145.61	132.72	205.11	201.81	248.53	242.89	251.89	244.00
p_3 (100 " ")	42.33	37.61	144.08	134.11	206.33	204.33	258.64	249.17	260.42	250.25
CD	NS	NS	NS	NS	NS	3.54	4.67	2.15	4.35	2.05
k_1 (50 kg K_2O)	42.36	37.47	145.06	132.72	209.17	207.14	259.42	252.67	262.00	253.56
k_2 (100 " ")	43.44	37.89	145.00	133.44	233.33	198.03	250.67	244.39	252.44	245.58
k_3 (150 " ")	41.47	38.14	142.19	132.56	233.30	200.67	250.00	241.56	251.86	242.72
CD	NS	NS	NS	NS	5.51	3.54	4.67	2.15	4.35	2.05

Table 13b. Effect of N x P, N x K and P x K interaction on plant height (cm) at harvest

Treatments	n_1 83-84	n_1 84-85	n_2 83-84	n_2 84-85	n_3 83-84	n_3 84-85	k_1 83-84	k_1 84-85	k_2 83-84	k_2 84-85	k_3 83-84	k_3 84-85
p_1	199.75	198.42	268.42	261.08	293.83	283.33	267.83	255.08	246.17	241.58	248.00	246.17
p_2	193.25	181.92	261.75	257.25	300.67	292.83	253.67	250.25	251.25	247.00	250.75	234.75
p_3	198.08	192.50	266.42	268.50	316.75	299.75	264.50	255.33	259.92	248.17	256.83	247.25
k_1	205.92	200.00	274.67	266.58	305.42	294.08						
k_2	192.58	186.92	262.17	258.42	302.58	291.42						
k_3	192.58	185.92	259.75	251.83	303.25	290.42						

	83-84	84-85
CD N x P	4.75	3.56
CD N x K	NS	3.56
CD P x K	4.75	3.56

increase in levels of nitrogen there was significant increase in plant height. Tallest plants were found under the highest level of nitrogen. The influence of phosphorus on plant height was significant only at the later stages of growth. Plants receiving the highest level of P registered significantly higher plant height at 240th day and at harvest stage, during both the years. The difference between p_1 and p_2 was not significant at most of the growth stages. In the case of potassium also the effect was significant at the later stages of growth. At higher levels of potassium reduction in plant height was recorded especially at the harvest stage.

The interaction N x P on plant height was significant at the harvest stage in both the years (Table 13b). Maximum plant height was observed under the combination $n_3\ p_3$. The interaction P x K also was significant during both the years. In 1984-85 the interaction N x K significantly influenced plant height. The effect of K in depressing plant height was conspicuous at all the levels of nitrogen.

4.2.1.2 Number of nodes

The data on number of nodes $plant^{-1}$ for both the years are presented in Table 14a.

Table 14a. Effect of varieties and NPK on number of nodes plant^{-1}

Treatments	60th day		120th day		180th day		240th day		At harvest	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
v_1 (Malayan-4)	37.80	31.41	61.19	57.17	109.50	102.44	146.74	141.22	149.50	142.46
v_2 (Sreevisakham)	39.18	31.56	63.43	58.59	110.91	103.87	148.87	143.26	151.83	144.43
CD	S	NS	S	NS	NS	S	NS	S	S	S
n_1 (50 kg N)	31.56	28.97	48.50	44.97	77.53	72.22	131.38	123.53	133.33	124.72
n_2 (100 " ")	37.44	31.53	64.64	59.03	144.44	105.89	142.86	136.00	146.28	137.28
n_3 (150 " ")	46.39	34.31	73.68	69.64	138.64	131.36	169.28	167.19	172.39	168.33
CD	1.11	0.72	1.26	1.02	2.24	1.40	3.17	1.65	2.04	1.61
p_1 (50 kg P_2O_5)	38.14	30.92	62.00	57.39	108.44	102.56	147.83	140.53	150.19	141.69
p_2 (75 " ")	38.22	31.61	61.89	57.42	110.33	103.56	149.39	143.33	151.11	144.50
p_3 (100 " ")	39.03	31.92	63.03	58.83	111.83	103.36	146.19	142.86	150.69	144.14
CD	NS	0.71	NS	1.02	2.24	NS	NS	1.65	NS	1.61
k_1 (50 kg K_2O)	38.08	30.86	61.28	56.69	107.75	101.25	147.22	141.25	149.22	142.53
k_2 (100 " ")	38.39	31.53	62.67	58.17	110.39	103.89	146.92	141.22	150.14	142.47
k_3 (150 " ")	38.92	32.06	62.97	58.78	112.47	104.33	149.28	144.25	152.64	145.33
CD	NS	0.72	1.26	1.02	2.24	1.40	NS	1.65	2.04	1.61

Table 14b. Effect of N x K and P x K interactions on number of nodes plant^{-1}

Treatments	k_1		k_2		k_3	
	83-84	84-85	83-84	84-85	83-84	84-85
n_1	130.92	122.25	133.92	124.83	135.17	127.08
n_2	145.75	137.00	145.42	137.00	147.67	137.83
n_3	171.00	168.33	171.08	165.58	175.08	171.08
p_1	149.42	140.92	148.17	139.42	153.00	144.75
p_2	147.83	142.83	150.42	143.25	155.08	147.42
p_3	150.42	143.83	151.83	144.75	149.83	143.83

	83-84	84-85
CD for NxK	NS	2.80
CD for PxK	3.54	2.80

The variety v_2 produced significantly higher number of nodes plant^{-1} at most of the stages except at 180th day and 240th day in 1983-84 and 60th day during 1984-85. Incremental doses of nitrogen produced significantly higher number of nodes plant^{-1} at all growth stages during both the years. Significantly higher number of nodes was recorded in plants under n_3. During the first year the levels of phosphorus had no significant effect on number of nodes plant^{-1}, except at 180th day. At this stage p_3 registered maximum number of nodes plant^{-1}. In the second year, p_3 was instrumental in producing significantly higher number of nodes at most of the stages of growth. The effect of potassium on number of nodes was significant at all stages of growth except at 60th day and 240th day during 1983-84. The increase in number of nodes under k_3 was significant over k_1 at most of the growth stages. The variation in number of nodes between k_2 and k_3 was significant only at later stages of growth.

The effect of N x K interaction on number of nodes plant^{-1} was significant in the second year and maximum number was recorded under n_3 k_3 (Table 14b). P x K interaction on this growth attribute was significant for both the years. Maximum number of nodes plant^{-1} was found under p_2 k_3.

4.2.1.3 Number of functional leaves

The data on mean number of functional leaves plant^{-1} for 1983-84 and 1984-85 are given in Table 15a.

Though the varietal difference was not significant at most of the stages the variety v_2 had a tendency to retain higher number of functional leaves. Increased levels of nitrogen significantly enhanced the number of functional leaves plant^{-1} during both the years. Significantly highest number of functional leaves was registered for n_3 at all the growth stages. The differences in number of functional leaves between n_1 and n_2 at all the stages were also significant. In the first year phosphorus had no significant role on number of functional leaves plant^{-1}. In the second year also the effect of P was not significant except at 120th day. At this stage p_3 produced significantly higher number of functional leaves over p_1. The effect of K on number of functional leaves was significant at 60th day in the first year and at 180th and 240th days in both the years. At the above stages k_2 and k_3 were on par but produced significantly higher number of functional leaves over k_1.

The P x K interaction was significant on number of functional leaves plant^{-1} and maximum number was observed under p_3 k_2 (Table 15b).

Table 15a. Effect of varieties and NPK on number of functional leaves $plant^{-1}$

Treatments	60th day		120th day		180th day		240th day		At harvest	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
v_1 (Malayan-4)	34.94	29.78	51.56	48.85	78.43	75.70	65.74	63.02	53.19	47.70
v_2 (Sreevisakham)	35.81	30.26	52.70	49.76	78.74	76.48	66.37	63.96	53.67	48.06
CD	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
n_1 (50 kg N)	28.75	27.28	38.94	37.28	58.06	56.33	45.08	43.58	35.17	31.44
n_2 (100 " ")	34.75	30.42	53.64	49.94	83.75	80.78	70.89	68.39	56.42	51.44
n_3 (150 " ")	42.64	32.86	63.81	60.69	93.94	91.17	81.75	78.50	68.56	60.75
CD	1.22	0.49	1.64	1.40	2.71	2.14	2.74	2.62	2.80	2.26
p_1 (50 kg P_2O_5)	34.97	29.75	51.58	48.42	77.86	75.31	64.22	62.06	52.44	46.61
p_2 (75 " ")	35.11	30.11	51.94	49.14	78.47	75.92	66.39	64.17	53.44	47.64
p_3 (100 " ")	36.06	30.19	52.86	50.36	79.42	77.06	67.11	64.25	54.25	49.39
CD	NS	NS	NS	1.40	NS	NS	NS	NS	NS	NS
k_1 (50 kg K_2O)	35.11	29.28	51.14	48.17	75.81	73.44	63.50	61.50	51.50	46.28
k_2 (100 " ")	35.56	30.19	52.61	49.86	79.81	77.19	67.17	64.39	54.44	48.89
k_3 (150 " ")	35.47	30.58	52.64	49.89	80.14	77.64	67.06	64.58	54.19	48.47
CD	NS	0.49	NS	1.41	2.71	2.14	2.74	2.68	NS	NS

Table 15b. Effect of P x K interaction on number of functional leaves plant^{-1} at harvest stage

Treatments	k_1		k_2		k_3	
	83-84	84-85	83-84	84-85	83-84	84-85
p_1	52.92	47.25	52.33	46.92	52.08	45.67
p_2	49.83	45.42	53.00	47.42	57.50	50.08
p_3	51.75	46.17	58.00	53.33	53.00	49.67

CD for 83-84 - 4.85

CD for 84-85 - 3.93

4.2.1.4 Leaf area index

The data on leaf area index (LAI) at various growth stages during 1983-84 and 1984-85 are presented in Table 16a.

LAI was not significantly higher for the variety v_2 except for a difference at the earlier stages of growth in 1984-85. Incremental doses of nitrogen significantly enhanced the leaf area index at all stages of growth (Fig. 5) Higher values for LAI at all stages of growth were registered under n_3. Different levels of phosphorus had no significant influence on LAI at most of the stages, except at 60th day and 120th day during the second year. At 60th day p_2 and p_3 had significantly higher LAI over p_1. At 120th day, the increase in LAI with increase in levels of P was significant at all levels. Effect of potassium on LAI was significant at 120th day and 180th day in the first year. At 120th day with increase in levels of K there was significant increase in LAI. At 180th day k_2 and k_3 were on par but significantly superior to k_1. In the second year at all stages of growth k_2 resulted in significantly higher LAI, than that of k_1.

Among the interactions only N x K at the stage of harvest in the second year was significant on LAI (Table 16b). Maximum LAI was observed under the combination n_3 k_3.

Table 16a. Effect of varieties and NPK on leaf area index

Treatments	60th day		120th day		180th day		240th day		At harvest	
	83-84	84-85	83-84	84-85	83-84	83-84	83-84	84-85	83-84	84-85
v_1 (Malayan-4)	0.99	0.82	1.42	1.35	2.50	2.39	1.64	1.65	1.27	1.20
v_2 (Sreevisakham)	0.98	0.83	1.43	1.38	2.52	2.41	1.65	1.66	1.28	1.22
CD	NS	S	NS	S	NS	NS	NS	NS	NS	NS
n_1 (50 kg N)	0.79	0.75	1.06	1.05	1.82	1.78	1.34	1.39	0.84	0.79
n_2 (100 " ")	0.96	0.83	1.46	1.37	2.63	2.54	1.51	1.48	1.27	1.26
n_3 (150 " ")	1.15	0.89	1.76	1.66	3.07	2.89	2.08	2.09	1.73	1.58
CD	0.02	0.01	0.05	0.03	0.07	0.06	0.05	0.05	0.05	0.03
p_1 (50 kg P_2O_5)	0.96	0.82	1.42	1.33	2.48	2.37	1.64	1.63	1.27	1.21
p_2 (75 " ")	0.96	0.83	1.43	1.36	2.53	2.40	1.65	1.65	1.28	1.20
p_3 (100 " ")	0.98	0.83	1.44	1.39	2.52	2.41	1.64	1.68	1.29	1.23
CD	NS	0.01	NS	0.03	NS	NS	NS	NS	NS	NS
k_0 (50 kg K_2O)	0.95	0.80	1.33	1.32	2.41	2.32	1.62	1.60	1.26	1.18
k_1 (100 " ")	0.98	0.83	1.46	1.38	2.55	2.44	1.65	1.68	1.30	1.21
k_2 (150 " ")	0.97	0.84	1.44	1.38	2.56	2.45	1.65	1.68	1.29	1.25
CD	NS	0.01	0.05	0.03	0.07	0.06	NS	0.05	NS	0.03

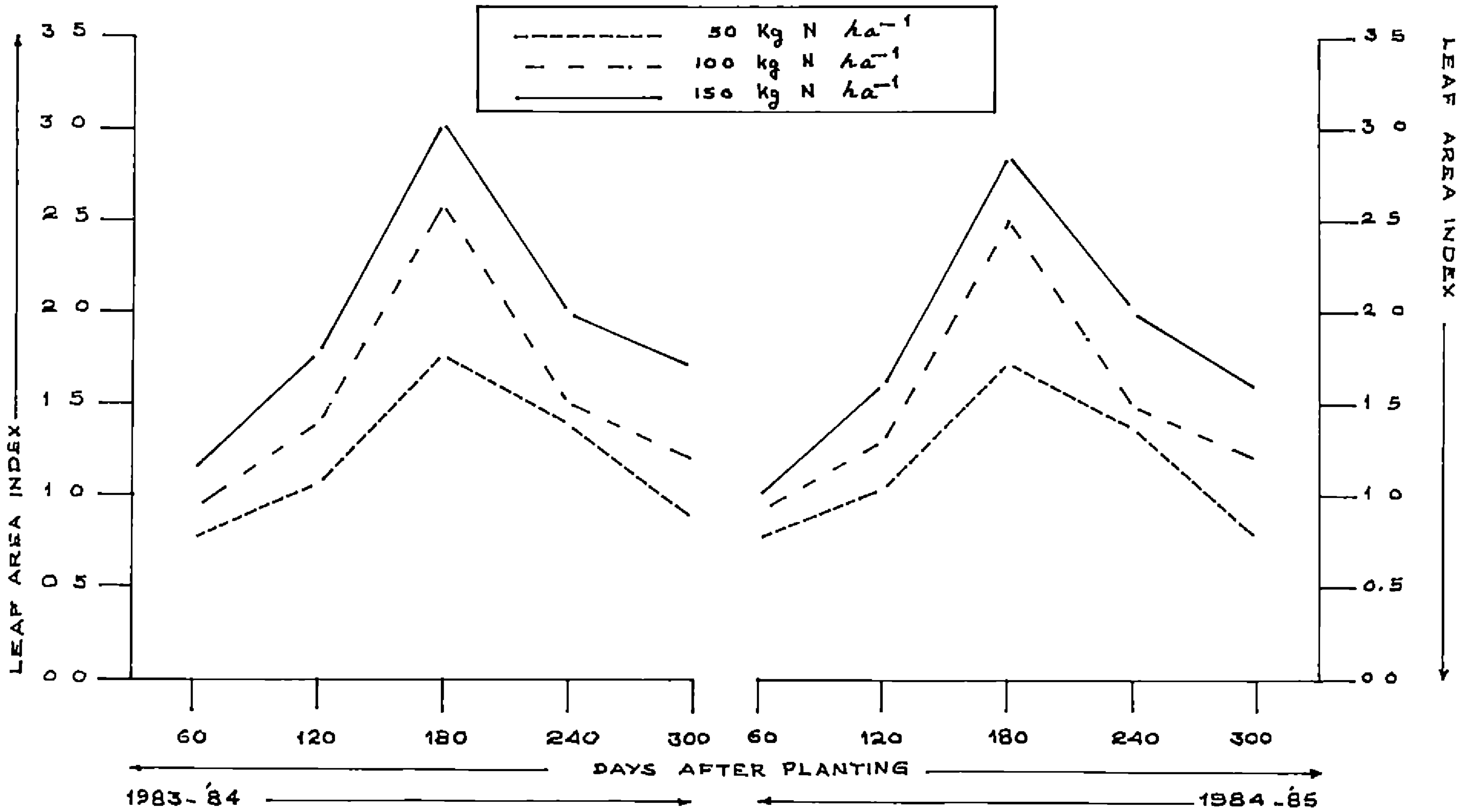
Table 16b. Effect N x K interaction on leaf area index at harvest

	n_1		n_2		n_3	
	83-84	84-85	83-84	84-85	83-84	84-85
k_1	0.81	0.75	1.24	1.24	1.72	1.54
k_2	0.87	0.82	1.26	1.27	1.76	1.53
k_3	0.84	0.80	1.30	1.28	1.72	1.67

C.D for 83-84 - N.S.

C.D. for 84-85 - 0.04

FIG 5 EFFECT OF NITROGEN ON LEAF AREA INDEX



4.2.2 Yield components and yield

4.2.2.1 Number of tubers

The data on mean number of tubers plant^{-1} recorded at harvest stage for 1983-84 and 1984-85 are presented in Table 17a.

The variety v_2 was significantly superior in number of tubers plant^{-1} during both the years. Nitrogen was not found to influence the number of tubers during 1983-84 while it was found to be effective in 1984-85. Application of highest level of N helped to increase the number of tubers. The effect of phosphorus on number of tubers plant^{-1} was significant in both the years. Significantly higher number of tubers plant^{-1} was registered at p_3. The variation in tuber number plant^{-1} between p_1 and p_2 was not significant. Increased rates of potassium significantly increased the tuber number in the first year. The treatment k_3 produced significantly higher number of tubers when compared to k_2 and k_1. The difference in tuber number plant^{-1} between k_1 and k_2 was also significant. In the second year k_2 and k_3 were on par but significantly superior to k_1 in number of tuber plant^{-1}.

Table 17a. Effect of varieties and NPK on number of tubers and tuber weight

Treatments	Number of tubers $plant^{-1}$		Mean weight of tubers (g)	
	83-84	84-85	83-84	84-85
v_1 (Malayan-4)	3.93	3.76	192.20	184.16
v_2 (Sreevisakham)	4.66	4.47	219.44	210.17
CD	S	S	S	S
n_1 (50 kg N)	4.32	4.06	197.80	194.59
n_2 (100 " ")	4.27	4.05	208.22	202.58
n_3 (150 " ")	4.30	4.23	209.44	194.32
CD	NS	0.09	5.83	NS
p_1 (50 kg P_2O_5)	4.20	4.05	204.12	198.70
p_2 (75 " ")	4.27	4.12	205.26	195.94
p_3 (100 " ")	4.42	4.18	208.09	196.86
CD	0.11	0.09	NS	NS
k_1 (50 kg K_2O)	3.75	3.46	170.12	173.19
k_2 (100 " ")	4.50	4.43	220.94	204.87
k_3 (150 " ")	4.63	4.46	226.40	213.44
CD	0.11	0.09	5.83	9.33

Table 17b. Effect of N x P, N x K and P x K interactions on number of tubers $plant^{-1}$

Treat-ments	n_1		n_2		n_3		k_1		k_2		k_3	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
p_1	4.31	3.92	4.24	4.13	4.04	4.09	3.92	3.56	4.37	4.38	4.31	4.20
p_2	4.32	4.12	4.18	4.08	4.31	4.16	3.58	3.40	4.45	4.38	4.77	4.58
p_3	4.32	4.13	4.38	3.96	4.55	4.43	3.74	3.42	4.68	4.52	4.83	4.59
k_1	3.77	3.42	3.81	3.45	3.66	3.51						
k_2	4.55	4.36	4.31	4.26	4.65	4.66						
k_3	4.64	4.39	4.68	4.46	4.59	4.52						

	83-84	84-85
C.D. for N x P	0.19	0.17
C.D. for N x K	0.19	0.17
C.D. for P x K	0.19	0.17

Table 17c. Effect of P x V and K x V interactions on number of tubers plant^{-1}

Treatments	V_1		V_2	
	83-84	84-85	83-84	84-85
P_1	3.79	3.59	4.60	4.50
P_2	3.96	3.78	4.58	4.46
P_3	4.03	3.90	4.81	4.46
k_1	3.54	3.34	3.95	3.58
k_2	4.21	4.06	4.79	4.79
k_3	4.02	3.87	5.25	5.04

	83-84	84-85
CD for P x V	0.13	NS
CD for K x V	0.16	0.13

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was significant only during the first year. The levels n_2 and n_3 were on par but resulted in significantly higher tuber weight when compared to n_1. Increased rates of phosphorus application had no significant effect on tuber weight in any of the years. However incremental dosages of potassium significantly enhanced the tuber weight during both the years. Maximum increase was observed under k_3, which was significantly superior to k_2 and k_1 in 1983-84. The difference in mean tuber weight between k_2 and k_3 was also significant in 1984-85.

The effects of interactions N x P, N x K, P x K, P x V and K x V are given in Table 17d.

The effect of N x P interaction on mean tuber weight was significant in the first year and maximum tuber weight was recorded under the combination n_3 p_1. The N x K interaction on mean tuber weight was also significant in the first year. Highest mean tuber weight was recorded under the treatment n_3 k_3 which was on par with n_2 k_3. In both the years the P x K interaction on mean tuber weight was significant. At all the levels of P the effect of K in increasing tuber weight was conspicous, but significant only upto k_2 level. P x V interaction effect indicated that the response of v_2 was on par at all doses of P, while a significant decrease in mean tuber weight was observed in v_1 at the highest level of P.

Table 17d. Effect of N x P, N x K, P x K, P x V and K x V interactions mean tuber weight

Treat-ments	p_1		p_2		p_3		k_1		k_2		k_3	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
n_1	194.04	195.47	199.70	194.91	205.62	193.41	168.43	173.90	212.18	200.00	218.80	209.86
n_2	201.81	200.51	211.99	199.27	210.87	207.97	168.41	177.41	230.42	210.82	225.84	219.53
n_3	216.45	200.14	204.10	193.63	207.77	189.20	173.53	168.27	220.23	203.78	234.57	210.91
k_1	160.02	163.59	174.74	173.74	175.61	182.25						
k_2	222.12	207.98	221.27	203.11	219.44	203.51						
k_3	230.22	224.54	219.77	210.97	229.21	204.81						
v_1	197.71	191.09	195.68	185.80	183.20	175.59	152.90	151.19	203.44	192.47	220.26	208.83
v_2	210.52	206.32	214.84	206.07	232.77	218.13	187.35	195.20	238.44	217.26	232.54	218.05

		83-84	84-85
C.D.	N x P	10.10	NS
	N x K	10.10	NS
	P x K	10.10	16.16
	P x V	8.25	13.20
	K x V	8.25	13.20

As regards K x V interaction, in both the years, mean tuber weight of v_1 increased with higher rates of K application. In the case of v_2 this effect was seen only upto k_2 level.

4.2.2.3 Length of tuber

The data pertaining to mean length of tubers at harvest, for 1983-84 and 1984-85 are given in Table 18a.

The mean tuber length was significantly higher for the variety v_2 in the above years. The levels of nitrogen exerted no influence on tuber length in either of the years. The rates of applied phosphorus also had no significant effect on tuber length. Incremental dosages of potassium upto k_2 level, significantly increased the tuber length in both the years.

Effects of interactions N x P, P x K, N x V and K x V on mean tuber length are shown in Table 18b.

The N x P interaction was significant only in 1984-85 and maximum tuber length was recorded under the treatment n_3 p_3. The P x K interaction was significant in the second year. At all levels of P, the increased rates of K application significantly enhanced the tuber length. The K x V interaction was significant during the second year indicating

Table 18a. Effect of varieties and NPK on tuber length and tuber girth

Treatments	Tuber length (cm)		Tuber girth (cm)	
	83-84	84-85	83-84	84-85
v_1 (Malayan-4)	15.21	13.80	8.31	8.07
v_2 (Sreevisakham)	15.65	14.21	8.59	8.24
CD	S	S	S	S
n_1 (50 kg N)	15.45	13.92	8.39	8.19
n_2 (100 " ")	15.46	14.12	8.43	8.20
n_3 (150 " ")	15.39	13.97	8.53	8.07
CD	NS	NS	0.07	0.06
p_1 (50 kg P_2O_5)	15.51	13.98	8.51	8.21
p_2 (75 " ")	15.32	13.90	8.44	8.08
p_3 (100 " ")	15.46	14.13	8.40	8.17
CD	NS	NS	0.07	0.06
k_1 (50 kg K_2O)	14.88	13.44	8.08	7.94
k_2 (100 " ")	15.60	14.21	8.53	8.23
k_3 (150 " ")	15.81	14.36	8.73	8.30
CD	0.16	0.21	0.07	0.06

Table 18b. Effect of N x P, P x K, N x V and K x V interactions on length of tubers (cm)

Treat-ments	n_1		n_2		n_3		k_1		k_2		k_3	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
p_1	15.42	13.85	15.48	13.84	15.63	14.24	15.09	13.24	15.61	14.10	15.83	14.58
p_2	15.43	13.91	15.42	13.98	15.13	13.83	14.79	13.36	15.47	14.10	15.72	14.25
p_3	15.50	14.00	15.47	14.55	15.41	13.84	14.78	13.72	15.72	14.41	15.83	14.25
v_1	15.30	13.78	15.10	13.86	15.23	13.76	14.59	13.21	15.34	13.92	15.70	14.27
v_2	15.60	14.06	15.81	14.38	15.54	14.18	15.18	13.67	15.86	14.49	15.92	14.45

	83-84	84-85
C.D. for N x P	NS	0.36
CD for P x K	NS	0.36
CD for N x V	0.23	NS
CD for K x V	NS	0.29

that there was significant increase in tuber length due to higher levels of K in the variety v_1. In v_2 the effect was found only upto k_2.

5.2.2.4 Girth of tuber

The data on mean girth of tubers at harvest for both the years are presented in Table 18a.

In both the years the variety v_2 had significantly higher tuber girth. The girth was found to increase with increase in applied nitrogen in 1983-84. As regards phosphorus, increased levels had no beneficial effect on tuber girth in either of the years. Increased rates of K application significantly enhanced tuber girth in both the years. Maximum tuber girth was recorded at k_3 level.

The effects of interactions N x P, N x K, P x K, P x V and K x V on tuber girth are shown in Table 18c.

The N x P interaction on mean tuber girth was significant in the first year and the positive effect of nitrogen was observed at all the levels of phosphorus, in promoting tuber girth. During both the years N x K interaction was significant and K application enhanced tuber girth in combination with all levels of N. P x K interaction was significant

Table 18c. Effect N x P, N x K, P x K, P x V and K x V interaction on tuber girth (cm)

Treatments	p_1		p_2		p_3		k_1		k_2		k_3	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
n_1	8.48	8.27	8.35	8.06	8.34	8.24	8.11	8.03	8.40	8.19	8.68	8.35
n_2	8.37	8.22	8.41	8.13	8.50	8.26	7.96	7.97	8.60	8.27	8.72	8.37
n_3	8.68	8.15	8.55	8.05	8.37	8.03	8.18	7.83	8.60	8.22	8.82	8.17
k_1	8.08	7.99	8.13	7.93	8.04	7.91						
k_2	8.64	8.22	8.48	8.13	8.49	8.33						
k_3	8.31	8.43	8.70	8.17	8.78	8.29						
v_1	8.46	8.13	8.30	8.01	8.12	8.06	8.03	7.89	8.29	8.12	8.62	8.20
v_2	8.56	8.30	8.52	8.14	8.69	8.29	8.14	8.00	8.78	8.34	8.84	8.40

	83-84	84-85
CD for N x P	0.12	NS
CD for N x K	0.12	0.11
CD for P x K	NS	0.11
CD for P x V	0.10	NS
CD for K x V	0.10	NS

in the second year. Increase in tuber girth was noticed at all the levels of P due to K application upto k_2 level. The effect of P x V interaction on tuber girth was significant in the first year and v_2 p_3 registered the highest tuber girth. Similarly the K x V interaction was also significant in the first year. Both the varieties indicated increase in tuber girth due to increased levels of applied K. Maximum tuber girth was observed under v_2 k_3.

4.2.2.5 Utilisation index (UI)

The data on effect of treatments on utilisation index for 1983-84 and 1984-85 are presented in Table 19a.

Significantly higher UI was registered for the variety v_2 during both the years. Increased levels of nitrogen had depressing effect on UI, in both the years. Significantly lowest UI was found at the highest level of nitrogen. In the first year the increased rates of phosphorus significantly enhanced the UI. Highest value for UI was recorded at p_3. In the second year, the increase in UI with increase in applied P was not significant. Incremental rates of potassium applications significantly enhanced UI during both the years. Treatment k_3 resulted in significantly higher UI. The difference in UI between k_2 and k_1 was also significant.

Table 19a. Effect of varieties and NPK on utilisation index (UI)

Treatments	Utilization index	
	83-84	84-85
v_1 (Malayan-4)	0.82	0.80
v_2 (Sreevisakham)	1.10	1.05
CD	S	S
n_1(50 kg N)	1.07	1.05
n_2(100 " ")	0.94	0.90
n_3(150 " ")	0.88	0.82
CD	0.02	0.02
p_1(50 kg P_2O_5)	0.93	0.91
p_2(75 " ")	0.96	0.93
p_3(100 " ")	1.00	0.94
CD	0.02	NS
k_1(50 kg K_2O)	0.69	0.68
k_2(100 " ")	1.06	1.03
k_3(150 " ")	1.13	1.07
CD	0.02	0.02

Table 19b. Effect of N x V, P x V, K x V and P x K interactions on Utilisation index

Treatments	v_1		v_2		k_1		k_2		k_3	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
n_1	0.92	0.91	1.22	1.19						
n_2	0.80	0.78	1.08	1.03						
n_3	0.74	0.72	1.01	0.93						
p_1	0.80	0.80	1.05	1.02	0.68	0.66	1.04	1.03	1.05	1.05
p_2	0.85	0.82	1.07	1.04	0.68	0.68	1.05	1.01	1.14	1.10
p_3	0.80	0.79	1.19	1.09	0.71	0.69	1.09	1.06	1.19	1.07
k_1	0.58	0.58	0.80	0.78						
k_2	0.92	0.90	1.21	1.17						
k_3	0.95	0.93	1.30	1.21						

	83-84	84-85
CD for N x V	NS	0.03
CD for P x V	0.02	0.03
CD for K x V	0.02	0.03
CD for P x K	0.03	NS

Interaction effects P x K, N x V, P x K and K x V on utilisation index are provided in Table 19b.

The variations in UI due to N x V interaction was significant only during the second year. Both the varieties had lower values of UI at higher levels of nitrogen. Influence of P x V interaction on UI was significant in both the years. In the case of v_1 maximum values of UI were attained at p_2 level. In v_2 significantly higher utilisation indices were recorded at p_3 level. K x V interaction effect on UI was also significant during both the years. The variety v_2 at the highest level of K application registered maximum UI. P x K interaction was significant only in the first year. Highest utilisation index was recorded for the combination $p_3 k_3$.

4.2.2.6 Top yield

The data on effect of treatments on top yield for both the years are presented in Table 20a.

The cassava variety v_2 produced significantly higher top yield in both the years. The influence of nitrogen on top yield was significant during both the years. Significantly higher top yield was obtained at n_3. The top yield at n_2 level was also significantly superior to that of n_1. In the

Table 20a. Effect of varieties and NPK on top yield (t ha^{-1})

Treatments	Top yield t ha^{-1}	
	83-84	84-85
v_1 (Malayan-4)	8.98	8.43
v_2 (Sreevisakham)	9.05	8.49
CD	S	S
n_1 (50 kg N)	7.89	7.33
n_2 (100 " ")	9.22	8.59
n_3 (150 " ")	9.94	9.45
CD	0.04	0.05
p_1 (50 kg P_2O_5)	8.97	8.42
p_2 (75 " ")	9.02	8.45
p_3 (100 " ")	9.06	8.51
CD	0.04	NS
k_1 (50 kg K_2O)	9.01	8.43
k_2 (100 " ")	9.02	8.46
k_3 (150 " ")	9.02	8.48
CD	NS	NS

Table 20b. Effect of interactions N x P, P x K and K x V on top yield (t ha^{-1})

Treatments	p_1		p_2		p_3		v_1		v_2	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
n_1	7.90	7.32	7.88	7.30	7.89	7.37				
n_2	9.13	8.52	9.26	8.61	9.27	8.65				
n_3	9.90	9.41	9.92	9.43	10.01	9.52				
k_1	8.92	8.36	8.97	8.40	9.12	8.46	9.00	8.42	9.01	8.44
k_2	8.97	8.44	9.14	8.55	8.95	8.40	8.99	8.45	9.05	8.47
k_3	9.02	8.46	8.94	8.40	9.10	8.59	8.96	8.43	9.09	8.54

	83-84	84-85
CD for N x P	0.07	NS
CD for P x K	0.07	0.08
CD for K x V	0.05	NS

first year the increased top yield registered with higher rates of P application was significant. Significantly highest top yield was obtained at p_3. The difference in top yield between p_2 and p_1 was also significant. The increased trend in top yield with higher levels of phosphorus observed in the second year was not significant. Incremental rates of potassium application had no significant effect on top yield in either of the years.

The data on effect of interactions N x P, P x K and K x V on top yield are presented in Table 20b.

The N x P interaction on top yield was significant during the first year. Increase in top yield due to combined application of N and P was observed at all the levels. Highest top yield was obtained at n_3 p_3. The influence of P x K interaction on top yield was significant in both the years. In the first year highest top yield was obtained under the combination p_2 k_2. But in the second year highest top yield was recorded under the treatment p_3 k_3. The K x V interaction effect on top yield was significant only during the first year. The treatment v_2 k_3 produced maximum top yield, though on par with v_2 k_2.

4.2.2.7 Tuber yield

The data on the effect of treatments on the yield of fresh tuber for both the years and the results of pooled analysis are presented in Table 21a.

The cassava variety v_2 produced significantly higher fresh tuber yield in both the years. The average yield of the above variety was 9.43 t ha^{-1}.

The effect of increased levels of nitrogen on tuber yield was significant only in the first year. The levels n_2 and n_3 were on par but produced significantly higher tuber yield when compared to n_1. In the second year there was a tendency for increase in yield with increase in nitrogen application. The results of pooled analysis of tuber yield data showed that, the increase in yield, due to nitrogen application was significant only upto n_2 level.

The influence of applied phosphorus on tuber yield was significant during both the years. The yield was found to increase with higher levels of P. Results of pooled analysis also showed that there was significant increase in tuber yield with increase in levels of P. Response to potassium was significant during both years and tuber yield increased with higher rates of application. Pooled analysis of yield data also revealed similar trend.

Table 21a. Effect of varieties and NPK on tuber yield ($t\ ha^{-1}$)

Treatments	Tuber yield $t\ ha^{-1}$		Pooled Mean
	83-84	84-85	
v_1 (Malayan-4)	7.33	6.73	7.03
v_2 (Sreevisakham)	9.94	8.92	9.43
CD	S	S	S
n_1 (50 kg N)	8.45	7.75	8.10
n_2 (100 " ")	8.70	7.82	8.26
n_3 (150 " ")	8.76	7.91	8.34
CD	0.16	NS	0.10
p_1 (50 kg P_2O_5)	8.31	7.66	7.98
p_2 (75 " ")	8.61	7.82	8.21
p_3 (100 " ")	9.00	8.01	8.50
CD	0.15	0.15	0.10
k_1 (50 kg K_2O)	6.19	5.74	5.96
k_2 (100 " ")	9.55	8.70	9.12
k_3 (150 " ")	10.17	9.05	9.61
CD	0.15	0.15	0.10

Table 21b. Effect of interactions N x K, P x K, N x V, P x V and K x V on tuber yield (t ha^{-1})

Treatments	k_1		k_2		k_3		v_1		v_2	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
n_1	6.18	5.71	9.38	8.62	9.80	8.91	7.26	6.68	9.64	8.81
n_2	6.21	5.76	9.63	8.66	10.25	9.05	7.36	6.73	10.04	8.91
n_3	6.20	5.73	9.65	8.81	10.45	9.20	7.38	6.78	10.15	9.05
p_1	6.07	5.50	9.37	8.64	9.49	8.83	7.20	6.69	9.42	8.63
p_2	6.08	5.69	9.54	8.60	10.20	9.17	7.60	6.88	9.62	8.76
p_3	6.44	6.02	9.75	8.86	10.80	9.15	7.21	6.63	10.79	9.38
v_1	5.22	4.84	8.24	7.55	8.54	7.80				
v_2	7.17	6.63	10.86	9.84	11.80	10.31				

	83-84	84-85
CD for N x K	0.26	NS
CD for P x K	0.25	NS
CD for N x V	0.22	NS
CD for P x V	0.22	0.21
CD for K x V	0.22	0.21

The data on interaction effects N x K, P x K, N x V, P x V and K x V on tuber yield are presented in Table 21b.

The N x K interaction significantly influenced the tuber yield in the first year. Effect of K in increasing tuber yield was evident at all the levels of N. Maximum tuber yield was obtained at n_3 k_3 but was on par with n_2 k_2. In the second year the N x K interaction effect was not significant. In the case of P x K interaction also a similar result was observed. In both the years the varieties were found to interact with P and K, while the N x V interaction was seen only in 1984-85. The response of v_1 was similar at all levels of N tried. But v_2 showed an increase in yield with higher rates of nitrogen application. Similarly in the case of P and K also v_2 responded upto the highest level, while v_1 responded only upto the middle level.

4.2.3 Quality Attributes of Tubers

4.2.3.1 Starch content

The data on starch content of the tubers for 1983-84 and 1984-85 are present in Table 22.

Table 22. Effect of varieties and NPK on starch and HCN content of tubers

Treatments	Starch (%)		HCN ($\mu g/g$)	
	83-84	84-85	83-84	84-85
v_1 (Malayan-4)	78.73	79.69	54.30	54.70
v_2 (Sreevisakham)	78.02	78.98	55.24	56.07
CD	S	S	S	S
n_1 (50 kg N)	78.64	79.42	53.06	52.81
n_2 (100 " ")	78.71	79.53	54.67	56.11
n_3 (150 " ")	78.38	79.06	56.58	57.25
CD	0.08	NS	0.32	0.58
p_1 (50 kg P_2O_5)	78.63	79.92	54.83	55.17
p_2 (75 " ")	78.50	79.14	54.67	54.97
p_3 (100 " ")	78.60	78.94	54.81	56.03
CD	0.09	0.48	NS	0.58
k_1 (50 kg K_2O)	78.21	78.53	57.53	57.97
k_2 (100 " ")	78.69	79.53	54.36	55.28
k_3 (150 " ")	78.82	79.54	54.42	52.92
CD	0.08	0.47	0.32	0.58

During both the years, the starch content in variety v_1 was significantly higher than that of v_2. The influence of nitrogen on starch content was significant only during the first year. Nitrogen application at the highest level produced significant depressing effect on starch content of tubers. Increased rates of phosphorus nutrition was found to reduce starch content of tubers during both the years. Effect of potassium on starch content was significant during both the years. In the first year there was significant increase in starch content with increased levels of K application. In the second year k_2 and k_3 were on par but superior to k_1 in starch content of tubers.

4.2.3.2 HCN content of tubers

The data on HCN content of tubers for 1983-84 and 1984-85 are given in Table 22.

The tubers from variety v_1 had significantly lower HCN content when compared v_2 during both the years. Nitrogen application at higher levels significantly increased the HCN content in both the years. Maximum HCN content was recorded at n_3 level. The effect of different levels of phosphorus on HCN content was not significant during the first year. In the second year significantly higher HCN content was found at p_3 level. However, p_1 and p_2 were on par. The influence of potassium on HCN content was significant in both the years. An increase in K was found to decrease the HCN content.

4.2.4 Growth analysis

4.2.4.1 Dry matter production and distribution

4.2.4.2. Leaf dry matter

The data on leaf dry matter during various growth stages in 1983-84 and 1984-85 are given in Table 23.

During the year 1983-84 the variety v_2 produced higher leaf dry matter at all the stages of growth, except at harvest stage. In the year 1984-85 the increase in leaf dry matter registered for the variety v_2 was not significant, except at 240th day. Increased rates of nitrogen application significantly enhanced the leaf dry matter production at all stages of growth during both the years. Leaf dry matter production was significantly high at n_3 level. The increase in leaf dry matter recorded at n_2 level over n_1 was also significant. In the first year, the effect of P on leaf dry matter production was significant only at the initial stages. At 60th day there was significant increase in leaf dry matter with increase in levels of phosphorus. The increase in leaf dry matter noted at p_2 level was significant at 120th day and

Table 23. Effect of varieties and NPK on leaf dry matter (g $plant^{-1}$) at various growth stages.

Treatments	60th day		120th day		180th day		240th day		At harvest	
	83-84	84-85	83-84	84-85	83-84	84-85	83-83	84-85	83-84	84-85
v_1 (Malayan-4)	19.29	17.93	57.68	55.15	75.89	72.74	62.44	59.84	48.54	45.73
v_2 (Sreevisakham)	19.67	18.05	58.84	55.45	76.77	73.30	62.90	60.47	48.86	45.90
CD	S	NS	S	NS	S	NS	S	S	NS	NS
n_1 (50 kg N)	17.18	16.36	39.86	37.46	55.88	52.66	42.42	40.23	29.10	26.18
n_2 (100 " ")	18.98	18.33	62.56	57.01	80.31	76.39	67.54	64.77	53.25	50.53
n_3 (150 " ")	22.27	19.28	72.37	71.41	92.80	90.01	78.05	75.47	63.75	60.73
CD	0.18	0.47	0.27	0.74	0.35	0.73	0.22	0.24	0.44	0.46
p_1 (50 kg P_2O_5)	19.13	17.98	58.12	54.64	76.64	73.21	62.47	60.09	48.60	45.69
p_2 (75 " ")	19.56	17.80	58.64	55.34	76.10	72.91	62.93	60.18	48.56	45.78
p_3 (100 " ")	19.75	18.19	58.02	55.92	76.25	72.94	62.61	60.20	48.93	45.97
CD	0.18	NS	0.27	0.74	0.35	NS	0.22	NS	NS	NS
k_1 (50 kg K_2O)	19.25	17.29	57.47	54.14	75.14	71.73	61.72	59.10	48.08	45.08
k_2 (100 " ")	19.51	18.30	58.55	55.53	76.51	73.86	63.06	60.06	48.95	46.09
k_3 (150 " ")	19.67	18.39	58.76	56.22	77.33	73.98	63.24	60.83	49.07	46.27
CD	0.18	0.47	0.27	0.74	0.35	0.73	0.22	0.24	0.44	0.46

240th day in the same year. In the second year, the effect of phosphorus on leaf dry matter was significant only at 120th day. At this stage maximum leaf dry matter was produced at p_3 level. The influence of potassium on leaf dry matter production was significant at all stages of growth in both the years. At most of the stages highest leaf dry matter was recorded at k_3. However in the later phases of growth, k_3 was on par with k_2, in leaf dry matter production.

In general the leaf dry matter increased considerably after 60th day and attained high values by 180th day. After 180th day leaf dry matter exhibited a tendency to decline, during both the years.

4.2.4.3 Stem dry matter

The data on stem dry matter at different stages of growth for the two years are presented in Table 24.

In both the years the variety v_2 recorded significantly higher stem dry matter, at all the stages of growth. Incremental doses of nitrogen significantly enhanced the stem dry matter production at all the phases of growth during both the years. Highest level of nitrogen resulted in maximum stem dry matter production.

Table 24. Effect of varieties and NPK on stem dry matter (g plant^{-1}) at various growth stages

Treatments	60th day		120th day		180th day		240th day		At harvest	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
v_1 (Malayan-4)	11.84	11.21	103.36	101.39	127.01	124.00	230.80	220.41	232.00	221.50
v_2 (Sreevisakham)	12.00	11.35	107.26	104.14	128.11	125.10	232.04	221.35	233.17	222.45
CD	S	S	S	S	S	S	S	S	S	S
n_1 (50 kg N)	11.03	10.56	95.05	92.38	122.39	119.26	216.89	205.97	218.00	207.19
n_2 (100 " ")	11.91	11.31	103.82	102.39	128.14	125.18	232.47	222.50	233.61	223.49
n_3 (150 " ")	12.81	11.99	117.06	113.51	132.15	129.21	244.89	234.17	246.14	235.25
CD	0.11	0.14	0.87	0.74	0.48	0.51	0.23	0.66	0.63	0.66
p_1 (50 kg P_2O_5)	11.96	11.30	105.15	102.11	126.91	124.06	231.31	220.67	232.22	221.61
p_2 (75 " ")	11.84	11.20	105.36	103.32	127.39	124.27	231.44	220.97	232.94	222.00
p_3 (100 " ")	11.96	11.35	105.42	102.81	128.39	125.32	231.50	221.00	232.58	222.32
CD	NS	NS	NS	0.74	0.48	0.51	NS	NS	NS	NS
k_1 (50 kg K_2O)	11.55	10.98	104.84	102.28	126.44	123.63	229.98	219.39	231.25	220.44
k_2 (100 " ")	12.08	11.42	105.47	102.86	127.98	124.89	231.75	221.03	232.83	222.24
k_3 (150 " ")	12.12	11.45	105.63	103.05	128.26	125.13	232.61	222.22	233.67	223.25
CD	0.11	0.14	NS	NS	0.48	0.51	0.23	0.66	0.63	0.66

The effect of phosphorus on stem dry matter was not significant at most of the stages during both the years. But at 180th day, increased rates of P significantly increased the stem dry matter. At the later phases of growth there was a tendency for increased stem dry matter production at the higher levels of phosphorus application. The influence of potassium, on stem dry matter was significant at all phases, except at 120th day in both the years. At 60th day and 180th day k_2 and k_3 were on par but significantly superior to k_1. At the subsequent phases of growth k_3 produced significantly higher stem dry matter.

4.2.4.4 Root dry matter

The data on root dry matter at various growth stages for 1983-84 and 1984-85 are presented in Table 25.

Significantly higher root dry matter was observed for the variety v_2 at all stages of growth during both the years. The effect of nitrogen on root dry matter was significant only at 60th day during both the years and maximum values were recorded at n_3 level. Increased levels of phosphorus significantly enhanced root dry matter at all phases of growth, except at 60th day in both the years. During the initial phase root dry matter increased only

Table 25. Effect of varieties and NPK on root dry matter (g plant^{-1}) at various growth stages.

Treatments	60th day		120th day		180th day		240th day		At harvest	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
v_1 (Malayan-4)	10.75	10.68	78.45	69.81	113.66	110.49	194.68	190.09	226.47	210.51
v_2 (Sreevisakham)	11.12	10.97	85.13	80.31	153.73	143.89	259.77	248.38	297.79	277.41
CD	S	S	S	S	S	S	S	S	S	S
n_1 (50 kg N)	10.78	10.69	78.59	75.25	131.74	127.39	223.57	217.83	257.88	240.45
n_2 (100 " ")	10.89	10.76	80.79	75.33	134.07	128.29	230.84	221.31	263.17	243.07
n_3 (150 " ")	11.13	11.04	78.50	74.61	135.28	125.87	227.27	218.57	265.33	248.36
CD	0.16	0.19	NS	NS	NS	NS	NS	NS	NS	NS
p_1 (50 kg P_2O_5)	10.88	10.77	78.60	74.97	128.25	123.63	219.35	210.79	251.56	235.62
p_2 (75 " ")	10.92	10.86	82.22	76.96	132.98	126.89	226.10	218.38	260.06	242.65
p_3 (100 " ")	11.01	10.85	77.06	73.26	139.91	131.04	236.23	228.53	274.78	253.61
CD	NS	NS	3.10	2.45	4.10	5.19	9.01	9.33	9.65	11.40
k_1 (50 kg K_2O)	10.52	10.37	58.93	54.73	96.38	95.21	163.56	155.76	187.88	180.38
k_2 (100 " ")	11.29	11.07	87.92	85.92	147.44	140.65	253.03	245.60	290.20	270.68
k_3 (150 " ")	10.99	11.05	91.03	85.25	157.27	145.70	265.09	256.33	308.35	280.62
CD	0.16	0.19	3.10	2.45	4.10	5.19	9.01	9.33	9.65	11.40

upto p_2 level. But at later stages root dry matter increased with increased rates of P application. The effect of potassium in promoting root dry matter production was significant at all stages of growth during both the years. (Fig.6). At 60th day higher root dry matter was recorded at k_2 level. At the subsequent stages root dry matter was found to increase with increase in K application.

4.2.4.5 Net assimilation rate (NAR)

The mean values of NAR recorded at the active growth phases in 1983-84 and 1984-85 are provided in Table 26.

The variety v_2 registered significantly higher NAR at all the phases of growth during the above years. Higher levels of nitrogen had depressing effect on net assimilation rate, at all the phases of growth, during both the years. Similarly increased levels of phosphorus also had no beneficial effect on net assimilation rate at various phases of growth. Higher rates of potassium nutrition significantly enhanced the values of NAR, at all stages of growth during both the years. Highest values of NAR were recorded at k_3 level during the active phases of tuberisation. However the difference between k_3 and k_2 in net assimilation rate was not significant.

FIG 6 SHOOT AND ROOT DRY MATTER PRODUCTION (MEAN OF TWO YEARS)

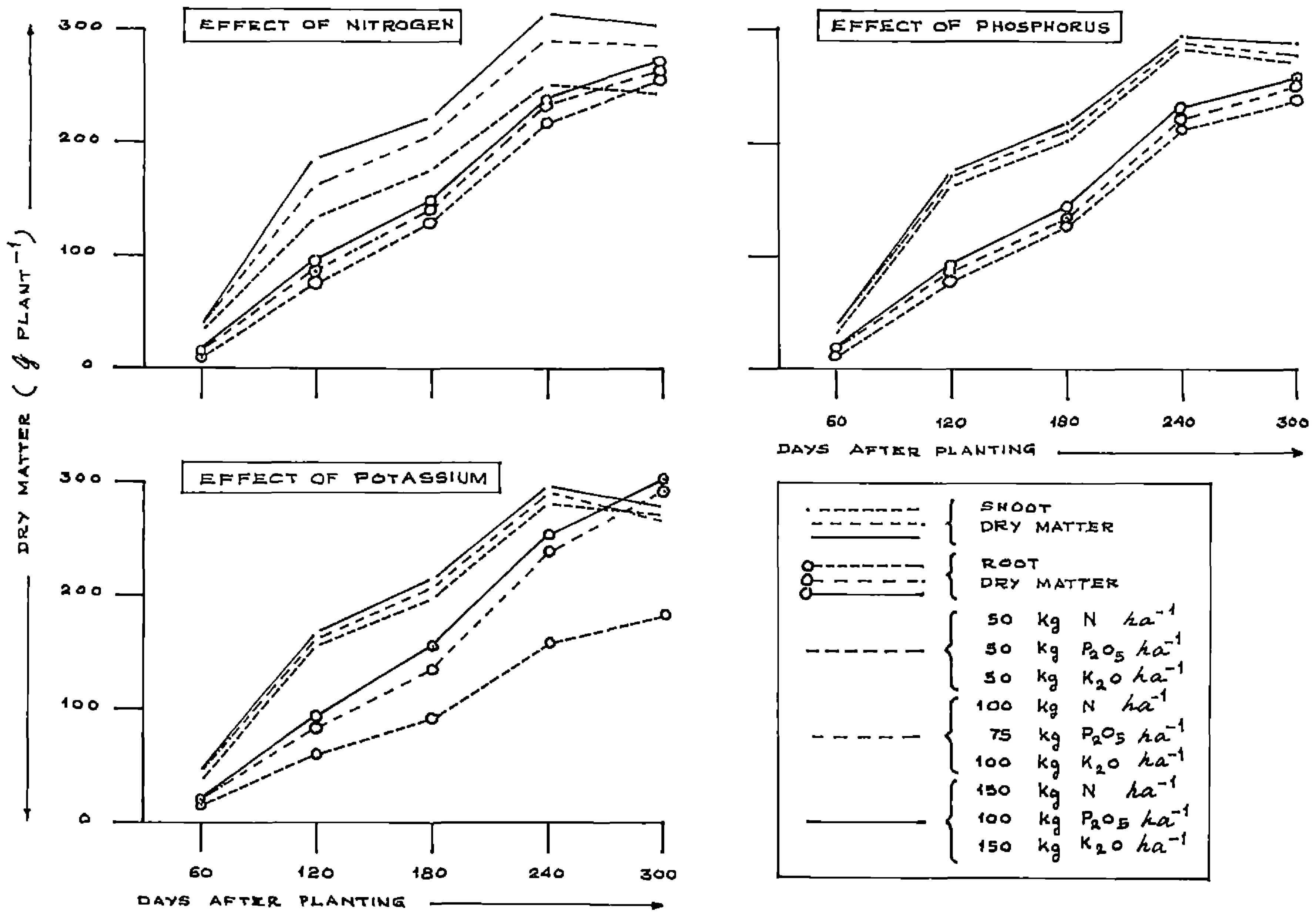


Table 26. Effect of varieties and NPK on net assimilation rate (g m^{-2} day^{-1})

Treatments	I Phase		II Phase		III Phase	
	83-84	84-85	83-84	84-85	83-84	84-85
v_1 (Malayan-4)	4.17	4.01	1.11	1.08	2.14	1.65
v_2 (Sreevisakham)	4.43	4.33	1.38	1.39	2.48	1.73
CD	S	S	S	S	S	S
n_1 (50 kg N)	4.86	4.82	1.68	1.59	2.84	2.55
n_2 (100 " ")	4.23	3.91	1.11	1.21	2.21	1.42
n_3 (150 " ")	3.82	3.77	0.96	0.91	1.88	1.11
CD	0.29	0.35	0.15	0.19	0.19	0.18
p_1 (50 kg P_2O_5)	4.35	4.21	1.29	1.19	2.35	1.60
p_2 (75 " ")	4.36	4.27	1.22	1.25	2.32	1.80
p_3 (100 " ")	4.20	4.01	1.24	1.27	2.26	1.67
CD	NS	NS	NS	NS	0.19	NS
k_1 (50 kg K_2O)	3.99	3.88	1.07	1.08	1.99	1.48
k_2 (100 " ")	4.46	4.28	1.31	1.25	2.44	1.72
k_3 (150 " ")	4.46	4.34	1.37	1.37	2.50	1.88
CD	0.29	0.35	0.15	0.19	0.19	0.18

4.2.4.6 Crop growth rate (CGR)

The mean values of CGR obtained during active growth phases in 1983-84 and 1984-85 are presented in Table 27.

Higher crop growth rate was observed for the variety v_2 at all the phases in the above years. At the first phase, (60 to 120 days) increase in levels of nitrogen significantly increased the CGR during both the years. At the second phase (120 to 180 days) the effect of nitrogen was not significant on crop growth rate. In the subsequent phase (180 to 240 days) during the first year, n_2 and n_3 were on par, but significantly superior to n_1. In both the years at the first phase, the effect of phosphorus on CGR was significant. Significantly higher CGR was recorded at p_2 level at the above phase. At the second phase, the effect of phosphorus was significant, only in the first year. At this phase p_3 resulted in maximum CGR. In the last phase the influence of phosphorus on CGR was not significant. Potassium exerted marked influence on CGR at all the phases during both the years. At k_1 the CGR was significantly lower to that at other levels. At most of the phases, k_3 resulted in higher CGR, but was on par with k_2.

Table 27. Effect of varieties and NPK on crop growth rate (g m^{-2} day^{-1})

Treatments	I phase		II phase		III phase	
	83-84	84-85	83-84	84-85	83-84	84-85
v_1 (Malayan-4)	3.98	3.82	1.66	1.72	3.53	2.27
v_2 (Sreevisakham)	4.32	4.19	2.19	2.16	4.11	2.50
CD	S	S	S	S	S	NS
n_1 (50 kg N)	3.59	3.62	1.98	1.92	3.61	3.40
n_2 (100 " ")	4.30	3.93	1.91	2.07	3.96	1.99
n_3 (150 " ")	4.56	4.46	1.89	1.83	3.89	1.75
CD	0.11	0.13	NS	NS	0.27	0.28
p_1 (50 kg P_2O_5)	4.11	3.96	1.85	1.87	3.86	2.22
p_2 (75 " ")	4.25	4.11	1.84	1.95	3.76	2.46
p_3 (100 " ")	4.10	3.94	2.10	2.00	3.84	2.46
CD	0.11	0.13	0.10	NS	NS	NS
k_1 (50 kg K_2O)	3.70	3.60	1.58	1.61	3.29	2.04
k_2 (100 " ")	4.33	4.20	2.00	2.00	4.11	2.48
k_3 (150 " ")	4.42	4.21	2.21	2.21	4.06	2.63
CD	0.11	0.13	0.10	0.29	0.27	0.28

4.2.4.7 Tuber bulking rate

The data on tuber bulking rate at various growth phases during 1983-84 and 1984-85 are given in Table 28.

The tuber bulking was higher for the variety v_2 at all the phases in the above years. The effect of higher levels of nitrogen on tuber bulking rate was not significant during both the years. However, at the later phases higher bulking rate was observed with increase in nitrogen application. The influence of phosphorus on tuber bulking rate was significant only in the initial phases during both the years. In the first phase maximum bulking rate was noted at p_2. But in the second phase higher bulking rate was obtained at p_3 level. Increased rates of potassium application enhanced the tuber bulking rate at all phases except in the fourth phase of the second year. The treatments k_3 and k_2 were on par but significantly superior to k_1 in tuber bulking rate, at the active phases of tuber development.

4.2.5 Nutrient uptake

4.2.5.1 Nitrogen

The data on plant uptake of nitrogen at different growth stages for 1983-84 and 1984-85 are given in Table 29.

Table 20. Effect of varieties and NPK on bulking rate (g day^{-1})

Treatments	I phase		II Phase		III phase		IV phase	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
v_1(Malayan-4)	1.04	0.98	0.68	0.69	1.36	1.32	0.53	0.34
v_2(Sreevisakham)	1.23	1.15	1.10	1.06	1.78	1.76	0.62	0.48
CD	S	S	S	S	S	S	S	S
n_1(50 kg N)	1.13	1.07	0.85	0.87	1.53	1.49	0.56	0.37
n_2(100 " ")	1.16	1.07	0.88	0.91	1.63	1.57	0.54	0.36
n_3(150 " ")	1.12	1.06	0.95	0.84	1.56	1.57	0.63	0.50
CD	NS	NS	NS	NS	NS	NS	NS	NS
p_1(50 kg P_2O_5)	1.12	1.07	0.82	0.79	1.53	1.49	0.52	0.41
p_2(75 " ")	1.18	1.10	0.79	0.86	1.58	1.52	0.56	0.40
p_3(100 " ")	1.10	1.04	1.00	0.97	1.60	1.62	0.64	0.41
CD	0.06	0.04	0.11	0.10	NS	NS	NS	NS
k_1(50 kg K_2O)	0.80	0.74	0.63	0.67	1.12	1.06	0.39	0.41
k_2(100 " ")	1.27	1.23	0.99	0.93	1.78	1.73	0.63	0.42
k_3(150 " ")	1.33	1.23	1.04	1.02	1.81	1.84	0.72	0.40
CD	0.05	0.04	0.11	0.10	0.13	0.16	0.12	NS

In the above years plant uptake of nitrogen was significantly higher for the variety v_2 than the variety v_1 at all the growth stages. The effect of applied nitrogen on the uptake of this nutrient at various growth stages was significant during both the years. Plant uptake of nitrogen significantly increased with higher rates of N nutrition. Plant uptake of nitrogen was not significantly affected by applied phosphorus in the initial stages during both the years. But at later stages there was a tendency for increased uptake of nitrogen at higher levels of P and this effect was significant at 240th day. An application of K upto k_2 level promoted the plant uptake of N. A further increase in K did not increase the N uptake.

4.2.5.2 Uptake of phosphorus

The data on plant uptake of phosphorus at various growth stages in 1983-84 and 1984-85 are presented in Table 30.

The varietal difference in the uptake of phosphorus was not significant at the initial stages of growth during both the years. The variety v_2 registered significantly higher uptake of phosphorus from 180th day to harvest. Plant uptake of phosphorus was significantly influenced by the levels of applied nitrogen at all stages of growth in the above years.

Table 29. Effect of varieties and NPK on uptake of nitrogen (kg ha^{-1}) at various growth stages

Treatments	60th day		120th day		180th day		240th day		At harvest	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
v_1 (Malayan-4)	9.38	8.90	38.58	36.96	43.80	41.65	49.89	48.76	45.85	43.69
v_1 (Sreevisakham)	9.49	9.04	39.72	38.11	45.77	42.89	52.82	51.34	48.83	46.34
CD	S	S	S	S	S	S	S	S	S	S
n_1 (50 kgN)	8.52	8.28	30.63	29.18	36.14	34.69	43.23	41.26	39.32	36.69
n_2 (100 ")	9.42	9.17	40.82	35.55	45.05	43.68	53.49	51.71	49.01	46.68
n_3 (150 ")	10.37	9.47	45.99	44.89	53.17	48.45	57.33	57.18	53.69	51.67
CD	0.09	0.09	0.61	0.37	0.81	0.71	0.55	0.62	0.51	0.71
p_1 (50 kg P_2O_5)	9.39	8.99	38.98	37.12	44.00	42.34	50.62	49.46	46.61	44.68
p_2 (75 " ")	9.44	8.99	39.10	37.86	44.91	42.11	51.33	50.30	47.27	44.89
p_3 (100 " ")	9.47	8.93	39.37	37.64	45.45	42.35	52.11	50.39	48.14	45.47
CD	NS	NS	NS	0.37	0.81	NS	0.55	0.62	0.51	NS
k_1 (50 kg K_2O)	9.33	8.74	36.98	35.07	42.80	40.52	48.26	46.75	44.13	41.75
k_2 (100 " ")	9.46	9.06	40.04	38.69	45.38	42.86	52.61	51.40	48.30	46.15
k_3 (150 " ")	9.52	9.11	40.43	38.85	46.18	43.44	53.18	52.00	49.59	47.15
CD	0.09	0.09	0.61	0.37	0.81	0.71	0.55	0.62	0.51	0.71

Table 30. Effect of varieties and NPK on uptake of phosphorus (kg ha^{-1}) at various growth stages

Treatments	60th day		120th day		180th day		240th day		At harvest	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
v_1 (Malayan-8)	0.96	0.91	4.21	4.13	4.61	4.67	6.10	6.11	6.14	5.79
v_2 (Sreevisakham)	0.96	0.92	4.27	4.25	5.09	4.97	6.79	6.52	6.91	6.49
CD	NS	NS	NS	S	S	S	S	S	S	S
n_1 (50 kg N)	0.90	0.86	3.62	3.61	4.26	4.26	5.86	5.58	5.87	5.61
n_2 (100 " ")	0.95	0.92	4.34	4.25	4.94	4.91	6.55	6.37	6.65	6.16
n_3 (150 " ")	1.02	0.97	4.75	4.71	5.34	5.25	6.93	7.00	7.05	6.66
CD	0.004	0.01	0.07	0.07	0.16	0.16	0.21	0.40	0.10	0.19
p_1 (50 kg P_2O_5)	0.93	0.91	4.17	4.12	4.70	4.77	6.34	6.18	6.41	6.07
p_2 (75 " ")	0.96	0.91	4.28	4.26	4.90	4.74	6.44	6.19	6.51	6.16
p_3 (100 " ")	0.98	0.93	4.26	4.18	4.95	4.90	6.56	6.57	6.66	6.19
CD	0.004	0.01	0.07	0.07	0.15	NS	NS	NS	0.10	NS
k_1 (50 kg K_2O)	0.95	0.88	4.05	3.93	4.41	4.41	5.75	5.83	5.73	5.48
k_2 (100 " ")	0.96	0.93	4.34	4.30	4.99	4.96	6.67	6.44	6.81	6.37
k_3 (150 " ")	0.96	0.93	4.33	4.33	5.14	5.04	6.93	6.67	7.04	6.58
CD	0.004	0.01	0.07	0.07	0.15	0.16	0.21	0.40	0.10	0.19

Significant increase in uptake of phosphorus was observed with increased rates of nitrogen application and maximum values were recorded at n_3 level. Application of P Significantly influenced the plant uptake of this nutrient in 1983-84 at all stages of growth except at 240th day, while in 1984-85 the effect was evident only at the initial growth phase. Potassium application upto k_2 level enhanced P uptake at all stages of growth; a further increase in K was not effective.

4.2.5.3 Uptake of potassium

The data on plant uptake of potassium at different growth stages in 1983-84 and 1984-85 are presented in Table 31.

During the above years, the variety v_2 registered higher plant uptake of potassium at all the growth stages. Higher rates of nitrogen fertilisation, significantly enhanced plant uptake of potassium at all stages of growth during both the years. Maximum uptake was registered at n_3 followed by n_2. Phosphorus application at higher rates, had a tendency to promote uptake of potassium. At most of the stages the above effect was significant and maximum uptake values were recorded at p_3 level. Increased rates of potassium application significantly influenced the uptake of this nutrient at all stages of growth, during both years. At most of the stages maximum

Table 31. Effect of varieties and NPK on uptake of potassium (kg ha^{-1}) at various growth stages

Treatments	60th day		120th day		180th day		180th day		At harvest	
	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85	83-84	84-85
v_1 (Malayan-4)	8.51	8.02	38.36	34.28	48.26	46.96	59.05	56.95	56.67	52.75
v_2 (Sréevisakham)	8.57	8.11	40.21	36.26	53.26	51.53	66.76	64.28	63.99	60.23
CD	S	S	S	S	S	S	S	S	S	S
n_1 (50 kg N)	7.83	7.54	34.02	31.05	46.78	45.41	57.93	55.10	54.23	52.70
n_2 (100 " ")	8.58	8.13	39.98	35.50	52.13	49.38	64.37	62.13	61.63	56.60
n_3 (150 " ")	9.21	8.52	43.85	39.26	54.24	52.94	66.41	64.61	65.13	60.17
CD	0.04	0.12	0.59	0.38	0.84	2.54	1.38	1.25	1.25	1.40
p_1 (50 kg P_2O_5)	8.53	8.05	39.11	35.06	49.97	48.30	61.95	59.76	59.17	55.54
p_2 (75 " ")	8.53	8.02	39.77	35.64	51.16	50.39	62.79	60.35	59.61	56.68
p_3 (100 " ")	8.56	8.12	38.97	35.12	52.02	49.05	63.97	61.72	62.21	57.25
CD	NS	NS	0.59	0.38	0.84	NS	1.38	1.25	1.25	NS
k_1 (50 kg K_2O)	8.37	7.76	35.55	32.16	45.67	44.98	55.04	52.10	51.54	49.53
k_2 (100 " ")	8.54	8.20	40.61	36.77	52.67	51.48	66.24	64.26	63.75	58.94
k_3 (150 " ")	8.71	8.23	41.69	36.91	54.81	51.34	67.43	65.48	65.70	60.99
CD	0.04	0.12	0.59	0.38	0.84	2.54	1.38	1.25	1.25	1.40

uptake was recorded at the highest level of K application.

4.2.6 Available nutrients in the Soil

4.2.6.1 Available nitrogen

The data on effect of treatments on available nitrogen content of the soil, after each crop year is provided in Table 32.

The cassava varieties did not show any significant effect on the available nitrogen content of the soil in the first year. However, after the second year's crop significantly lower values for available nitrogen content were recorded in plots under v_2. Available N increased with increase in applied N. No significant effect of applied phosphorus was observed in the first year. But in the second year, at higher levels of P significant reduction in available N was observed. In both the years increased rates of K fertilization significantly increased the available N status of the soil. Higher available N content was registered under k_3 during both the years.

4.2.6.2 Available phosphorus

The data on available phosphorus status of the soil, after each years' crop are provided in Table 32.

Table 32. Available nitrogen, phosphorus and potassium (kg ha^{-1})

Treatments	Available nitrogen		Available Phosphorus		Available Potassium	
	83-84	84-85	83-84	84-85	83-84	84-85
v_1 (Malayan-4)	169.89	173.26	29.46	31.48	80.31	82.03
v_2 (Sreevisakham)	170.11	172.57	29.18	31.26	80.46	82.49
CD	NS	S	NS	NS	NS	NS
n_1 (50 kg N)	158.85	163.36	29.30	32.19	81.22	83.73
n_2 (100 " ")	170.44	172.77	29.67	30.87	80.04	82.19
n_3 (150 " ")	180.71	182.62	28.98	31.04	79.89	80.85
CD	0.79	0.46	NS	0.68	NS	1.62
p_1 (50 kg P_2O_5)	170.23	173.57	19.94	22.01	80.53	82.23
p_2 (75 " ")	169.88	172.59	27.88	30.76	80.51	82.25
p_3 (100 " ")	169.89	172.60	40.13	41.33	80.12	82.29
CD	NS	0.46	0.88	0.68	NS	NS
k_1 (50 kg K_2O)	168.17	172.40	29.40	32.08	62.27	64.16
k_2 (100 " ")	170.66	172.65	29.13	31.59	84.58	86.92
k_3 (150 " ")	171.17	173.71	29.42	30.44	94.30	95.68
CD	0.79	0.46	NS	0.68	1.58	1.62

Both the cassava varieties did not exert any influence on available phosphorus content of the soil. In the first year the available P status was not influenced by levels of N. In the second year available P status decreased in plots, under higher levels of nitrogen. In both the years the available P status of the soil enhanced, with increased rates of P fertilizers. The effect of applied potassium on available P was similar to that of nitrogen.

4.2.6.3 Available potassium

The data on available potassium content in the soil after each years crop are furnished in Table 32.

The cassava varieties had no significant effect on the available K status of the soil. Higher rates of applied nitrogen had no effect on the available K status of the soil during the first year. However, in the second year at n_3 level, significantly lower value for available potassium was observed. The available K status of the soil was not influenced by the levels of phosphorus fertilisation during both the years. Significant increase in available K status of the soil was recorded during both the years with increased levels of K application. Maximum content of available K was observed at k_3 level, followed by k_2.

4.7 Correlation studies

4.7.1 Correlation between yield components and yield

Simple correlations were worked out between yield components like number of tubers, mean tuber weight length of tuber, girth of tuber and utilisation index with yield for 1983-84 and 1984-85. The correlation matrices are presented in Tables 33 and 34.

It may be observed that, number of tubers mean weight of tuber, length of tuber, girth of tuber and utilisation index had significant possitive correlation with tuber yields during both the years.

4.7.2 Correlation between uptake of nitrogen, phosphorus, potassium and yield

Simple correlations worked out between plant uptake of nitrogen, phosphorus and potassium (at harvest) and tuber yield are presented in Table 35.

It may be seen that there was significant positive correlation between uptake of the above nutrients and tuber yield.

Table 33. Simple correlations among tuber yield and yield components (1983-84)

	Tuber yield	Number of tuber	Tuber weight	Length tuber	Girth of tuber	Utilisation Index
Tuber yield	1	0.8496**	0.8403**	0.7367**	0.7695**	0.9270**
Number of tubers		1	0.4492**	0.5246**	0.4618**	0.8169**
Tuber weight			1	0.7492**	0.8458**	0.7487**
Length of tuber				1	0.6718**	0.7178**
Girth of tuber					1	0.6758**
Utilisation Index						1

** Significant

Table 34. Simple correlations among tuber yield and yield components (1984-85)

		Number of tubers	Tuber weight	Tuber length	Tuber girth	Utilisation index
Tuber yield	1	0.8603**	0.7196**	0.6687**	0.7010**	0.8974**
Number of tubers		1	0.3620**	0.3552**	0.5083**	0.7506**
Tuber weight			1	0.8539**	0.6845**	0.6445**
Length of tuber				1	0.6889**	0.5917**
Girth of tuber					1	0.7051**
Utilisation index						1

** Significant

Table 35. Simple correlation between tuber yield and uptake of nutrients

1983-84	
N - uptake	0.4782**
P - uptake	0.8514**
K - uptake	0.8673**
1984-85	
N - uptake	0.4151**
P - uptake	0.7980**
K - uptake	0.8861**

** Significant

4.7.3 Path coefficient analysis of yield components on yield

Path coefficient analysis also was carried out by taking yield as the dependent character and the yield components like, number of tubers, mean tuber weight, length of tuber, girth of tuber and the utilisation index as independent characters (causes). The results obtained for 1983-84 and 1984-85 are presented in Tables 35 and 36 respectively. The graphs depicting the cause and effect relationship are also presented in Fig. 7 and 8.

Maximum direct effect on tuber yield was due to the number of tubers (53%) during both the years. The correlation of number of tubers with tuber yield was 85%, of which the direct effect was 53% and the indirect effect via mean tuber weight, tuber length, tuber girth and utilisation index was 32%. The maximum indirect contribution to the number of tubers was through mean tuber weight (23%) in the first year, whereas in the second year it was through the utilisation index (21%). Next to number of tubers, maximum direct effect was exerted by mean tuber weight, though the magnitude was less in the second year. The correlations between mean tuber weight and tuber yield were to the tune of 84% and 72% respectively in the first and second years, but of this the direct contribution was 51% in first year and about 30% in the second year.

Table 36. Direct effects, indirect effects and correlation coefficients of yield components on yield (1983-84)

	No. of tuber XI	Mean weight of tuber X2	Length of tuber X3	Girth of tuber X4	U I X5	
X1	0.5325	0.2282	-0.0119	0.0191	0.0817	0.8496
X2	0.2932	0.5082	-0.0170	0.0350	0.0748	0.8403
X3	0.2791	0.3807	-0.0227	0.0278	0.0718	0.7367
X4	0.2459	0.4298	-0.0152	0.0414	0.0676	0.7695
X5	0.4349	0.3804	-0.0163	0.0279	0.1001	0.9270

Note: The diagonal values show the direct effect and the off diagonal values indicate the indirecc effect.

FIG 7 PATH COEFFICIENT ANALYSIS OF YIELD COMPONENTS ON YIELD (1983-'84)

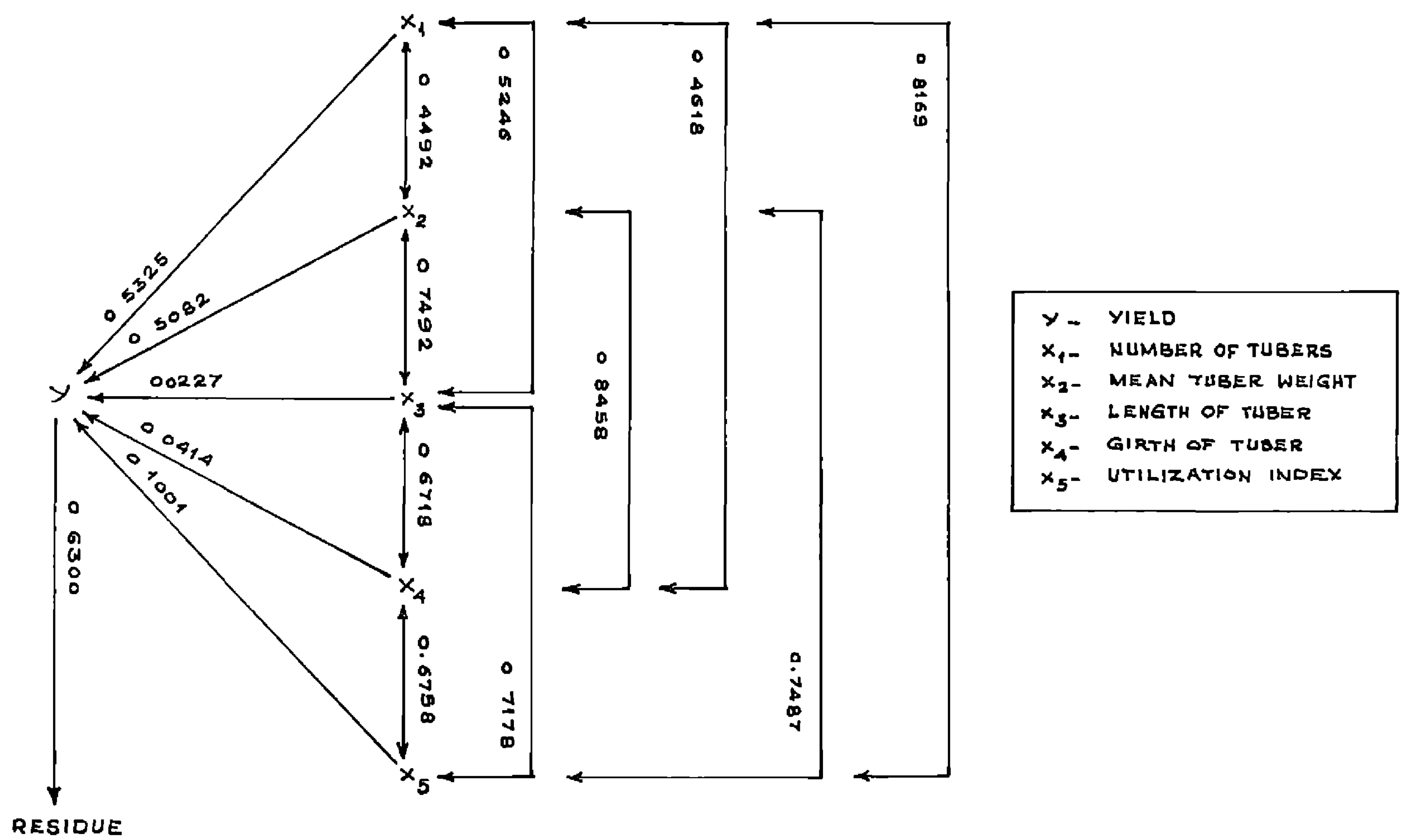
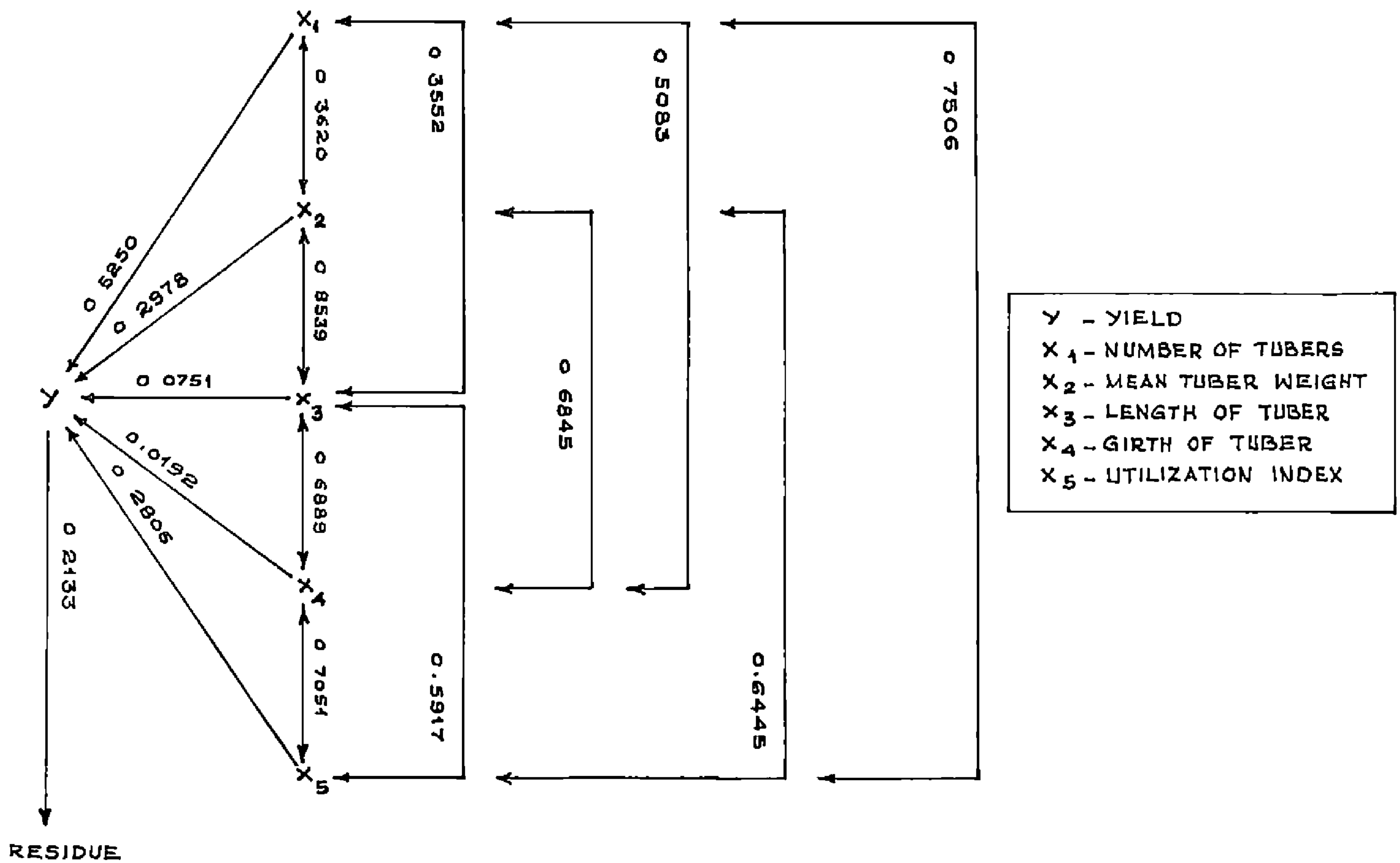


Table 37. Direct effects, indirect effects and correlation coefficients of yield components on yield (1984-85)

	No. of tuber X1	Meant weight of tuber X2	Length of tuber X3	Girth of tuber X4	U I U I X5	
X1	0.5250	0.1078	0.0267	-0.0098	0.2106	0.8603
X2	0.1900	0.2978	0.0641	-0.0131	0.1808	0.7196
X3	0.1865	0.2543	0.0751	-0.0132	0.1660	0.6687
X4	0.2669	0.2038	0.0517	-0.0192	0.1978	0.7010
X5	0.3940	0.1919	0.0444	-0.0135	0.2806	0.8974

Note: The diagonal values shows the direct effect and the off diagonal values indicate the indirect effect.

FIG 8 PATH COEFFICIENT ANALYSIS OF YIELD COMPONENTS ON YIELD (1984-'85)



During both the years the utilisation index showed very high significant positive correlations with tuber yield, though its direct effect was less especially in the first year. Its indirect effect on tuber yield via number of tubers and mean tuber weight was conspicously high. The direct effects of other yield components were very less but they influenced the tuber yield mainly via number of tubers and mean tuber weight. The indirect contribution of Utilisation index via other factors ranged from 17 to 21% in second year while it was only 6 to 8% in first year.

DISCUSSION

5. DISCUSSION

The results of studies conducted to evaluate the production potential of cassava intercropped in coconut gardens are discussed in this chapter.

5.1 Experiment A

Effect of different plant population and growth regulators on cassava intercropped in coconut gardens.

5.1.1 Growth characters

5.1.1.1 Plant height

The cassava variety Malayan-4 was significantly taller than Sreevisakham at the later stages of growth during the first year. This trend was seen during the second year also. This variation in plant height may be due to the inherent morphological differences between them. Increase in planting density significantly reduced the height of cassava plants during both the years. Maximum supression in plant height was observed at the closest spacing of 60 x 60 cm. Reduction in height of cassava plants intercropped in coconut gardens, on account of dense planting was reported earlier also (CTCRI, 1979).

The effect of cycocel in reducing plant height was significant during both the years, particularly at the higher concentration. Supression of vegetative growth due to cycocel treatment has been reported by Humphries and Dyson (1967) in potatoes and by Shashikala Khanna et al. (1980) in sweet potatoes. Foliar treatment with ethrel at 1000 ppm also suppressed the height of cassava (Table 3a), which is in agreement with the findings of Muthukrishnan et al. (1976). The reduction in plant height may be due to inhibition of cell division and elongation of subapical meristem as stated by Sen and Sen (1968).

5.1.1.2 Number of nodes and functional leaves plant^{-1}

The variety Sreevishakham had significantly higher number of nodes during the active stages of growth during both the years (Table 4a). The number of functional leaves plant^{-1} was also higher for the above variety at 180th day in the first year and at all stages of growth in the second year (Table 5). From these observations it is evident that the variety Sreevisakham is capable of producing higher number of leaves and retaining the same during the active stages of growth. The cassava plants under the lowest planting density had significantly higher number of nodes and functional leaves.

This may be due to the increased availability of sun light and relatively less competition for other growth factors at wider spacing. The effect of cycocel at the higher concentration in reducing the number of nodes plant^{-1} which is a measure of total number of leaves plant^{-1}, was significant during both the years. Similar effect of cycocel on sweet potato was reported by Biswas et al. (1980). None of the growth regulator treatments affected the number of functional leaves plant^{-1} at various stages of growth. This indicates that growth regulators had no significant influence on leaf retention in cassava.

5.1.1.3 Leaf area index

The data on leaf area index presented in Table 6 show that the variety Sreevisakham was superior in LAI at most of the stages of growth. The capacity of this variety in maintaining higher leaf area index under intercropping in coconut gardens was already reported by Ramanujam et al. (1984). The higher LAI recorded for this variety highlights the capacity of this variety to produce higher number of functional leaves even under the intercropping situations.

During both the years, significantly higher LAI was observed with increase in planting density. Maximum values of LAI at various stages of growth were recorded by the closest spacing of 60 x 60 cm. This result is in agreement with the findings of Enyi (1973) and CTCRI (1979). The growth regulators had no significant effect on LAI at most of the stages. However, at 240th day during the first year and 120th day during the second year, cycocel at higher concentration significantly lowered the LAI. This reduction in LAI may be due to the suppressing effect of cycocel on leaf production.

5.1.2 Yield components and yield

5.1.2.1 Number of tubers plant^{-1}

The data on number of tubers plant^{-1} presented in Table 7 clearly show that the variety Sreevisakham produced significantly higher number of tubers during both the years. In cassava, number of tubers plant^{-1} is reckoned as one of the important yield attributes. Superiority of the above variety over Malayan-4 in producing higher number of tubers plant^{-1} was observed by Ramanujam et al. (1984). From the data on mean number of tubers plant^{-1} it is obvious that increase in plant population significantly reduced the number of tubers plant^{-1}, during both the years. Reduction in number of tubers plant^{-1} at higher planting densities, observed in this study is in conformity with the reports of Gurnah (1973), Mohankumar et al. (1975) and Godfrey-Sam-Aggrey(1978). However, the growth regulators could not exert significant influence on number of tubers plant^{-1}, during both the years. Indira and Sinha (1970) also observed that growth regulators like IAA and CCC had no significant effect on number of tubers plant^{-1} in cassava.

5.1.2.2 Tuber Weight

During both the years, the variety Sreevisakham was significantly superior to Malayan-4 in mean tuber weight (Table 7). The ability of Sreevisakham in producing large sized tubers suggests the higher sink capacity of the storage organs of this variety. It is seen that mean tuber weight was significantly lowest at the closest spacing. However, there was no significant difference in tuber weight between plants at 90 x 90 cm and 120 x 120 cm spacings. Reduction in mean tuber weight due to increase in plant population in cassava was also reported by Williams (1972) and from CIAT (1973). The effect of cycocel and ethrel was not significant on mean weight of tubers. This clearly indicated that, these growth regulators, at the concentrations tried were not effective in promoting translocation of assimilates to the storage organs. Muthukrishnan et al. (1976) also could not get any improvement in tuber size of cassava due to application of growth regulators.

5.1.2.3 Length and girth of tubers

From the data on mean length and girth of tubers presented in Tables 8 and 9, it is evident that the variety Sreevisakham was significantly superior to Malayan-4 in respect of length and girth of tubers. The tubers under the highest planting density registered significantly lower length and girth, during both the years. Enyi (1973) reported that the reduction in tuber size of cassava associated with plant populations beyond the optimum, was due to the decreased rate of bulking. The growth regulators cycocel and ethrel had no beneficial effect on size of tubers in cassava and this result is in agreement with the observations of Mustafa et al. (1980) in sweet potato.

5.1.2.4 Top yield

The variety Sreevisakham produced significantly higher top yield over Malayan-4 during both the years (Table 9a). Ramanujam et al. (1984) also reported higher shoot drymatter production for the above variety under inter cropping in coconut gardens. Increase in planting density significantly enhanced the top yield during both the years and maximum top yield was obtained at the closest spacing of 60 x 60 cm. Gunasena *et al.* (1980) also got maximum drymatter yield from dense planting of cassava in the interspaces of coconut palms.

Among the growth regulators, cycocel at the higher concentration reduced the top yield significantly. This reduction in top yield was due to the negative effect of cycocel on plant height and number of leaves. Inhibitory effect of cycocel on growth of aerial parts in many crop plants has been well documented (Lindly, 1973).

5.1.2.5 Utilisation index

During both the years the variety Sreevisakham had significantly higher utilisation index (Table 10). The higher utilisation index (root: shoot ratio) recorded for this variety suggests its ability for better accumulation of photosynthates in storage organs, even in the partially shaded conditions prevalent in coconut gardens.

Utilisation index was significantly lower at the highest density of planting. Such fall in utilisation index was due to decreased size of storage roots associated with higher plant population. This is in agreement with the findings of Cock *et al.* (1977).

Among the growth regulator treatments, cycocel at higher concentration enhanced the utilisation index, especially during the first year. This may be due to the significantly lower shoot growth observed in plants treated with cycocel.

5.1.2.6 Tuber yield

From the data on tuber yield presented in Table 11 a it is seen that the variety Sreevisakham produced significantly higher tuber yield over Malayan-4 during both the years. This result is in conformity with the observations of Jos et al. (1980).

Significantly higher tuber yield was obtained during both the years from the spacing of 90 x 90 cm. The yield increase was about 43% and 47% respectively as compared to 60 x 60 cm and 120 x 120 cm spacings. The variety x spacing interaction was also significant during both the years (Table 11b). Sreevisakham planted at 90 x 90 cm spacing, produced maximum tuber yields of 9.48 t ha^{-1} during the first year and 9.31 t ha^{-1} during the second year. The variety Malayan-4 also produced maximum quantity of tubers at the spacing 90 x 90 cm.

The effect of cycocel and ethrel was not significant though the former at the higher concentration tended to enhance the tuber yield. The beneficial effects of cycocel and ethrel in promoting the yield of tuber crops are attributed to their antigibberellin properties (Melis and Van Standen, 1983). In cassava grown under partially shaded conditions (as in the present study) most of the photosynthates are used for shoot growth adversely affecting the tuber growth. Excess shoot growth can be due to high levels of gibberellins in the leaves, (Menzel, 1980). The occurrence of microorganisms capable of producing indole acetic acid and gibberellin like substances has been reported to be present within the rhizosphere of coconut palms, by Nair and Rao (1977). So in cassava intercropped in coconut gardens a very high level of gibberellin like substances might have been present which would have combated the favourable effect of cycocel and ethrel treatments.

5.1.3. Quality of tubers

From the data on quality attributes (Table 12) it may be seen that the variety Malayan-4 produced tubers with higher starch content and low HCN. However the differences between Malayan-4 and Sreevisakham in starch and HCN content, were of very low magnitude. In both the years, the quality of tubers under the highest planting density was poor as they had significantly lower starch % and higher HCN. This poor quality of tubers is attributed to the insufficient filling of storage translocation of assimilates to the storage organs. Muthukrishnan et al. (1976) also could not get any improvement in tuber size of cassava due to application of growth regulators.

5.1.2.3 Length and girth of tubers

From the data on mean length and girth of tubers presented in Tables 8 and 9, it is evident that the variety Sreevisakham was significantly superior to Malayan-4 in respect of length and girth of tubers. The tubers under the highest planting density registered significantly lower length and girth, during both the years. Enyi (1973) reported that the reduction in tuber size of cassava associated with plant populations beyond the optimum, was due to the decreased rate of bulking. The growth regulators cycocel and ethrel had no beneficial effect on size of tubers in cassava and this result is in agreement with the observations of Mustafa et al. (1980) in sweet potato.

5.1.2.4 Top yield

The variety Sreevisakham produced significantly higher top yield over Malayan-4 during both the years (Table 9a). Ramanujam et al. (1984) also reported higher shoot drymatter production for the above variety under inter cropping in coconut gardens. Increase in planting density significantly enhanced the top yield during both the years and maximum top yield was obtained at the closest spacing of 60 x 60 cm. Gunasena et al. (1980) also got maximum drymatter yield from dense planting of cassava in the interspaces of coconut palms.

Among the growth regulators, cycocel at the higher concentration reduced the top yield significantly. This reduction in top yield was due to the negative effect of cycocel on plant height and number of leaves. Inhibitory effect of cycocel on growth of aerial parts in many crop plants has been well documented (Lindly, 1973).

5.1.2.5 Utilisation index

During both the years the variety Sreevisakham had significantly higher utilisation index (Table 10). The higher utilisation index (root: shoot ratio) recorded for this variety suggests its ability for better accumulation of photosynthates in storage organs, even in the partially shaded conditions prevalent in coconut gardens.

Utilisation index was significantly lower at the highest density of planting. Such fall in utilisation index was due to decreased size of storage roots associated with higher plant population. This is in agreement with the findings of Cock et al. (1977).

Among the growth regulator treatments, cycocel at higher concentration enhanced the utilisation index, especially during the first year. This may be due to the significantly lower shoot growth observed in plants treated with cycocel.

5.1.2.6 Tuber yield

From the data on tuber yield presented in Table 11 a it is seen that the variety Sreevisakham produced significantly higher tuber yield over Malayan-4 during both the years. This result is in conformity with the observations of Jos *et al.* (1980).

Significantly higher tuber yield was obtained during both the years from the spacing of 90 x 90 cm. The yield increase was about 43% and 47% respectively as compared to 60 x 60 cm and 120 x 120 cm spacings. The variety x spacing interaction was also significant during both the years (Table 11b). Sreevisakham planted at 90 x 90 cm spacing, produced maximum tuber yields of 9.48 t ha^{-1} during the first year and 9.31 t ha^{-1} during the second year. The variety Malayan-4 also produced maximum quantity of tubers at the spacing 90 x 90 cm.

The effect of cycocel and ethrel was not significant though the former at the higher concentration tended to enhance the tuber yield. The beneficial effects of cycocel and ethrel in promoting the yield of tuber crops are attributed to their antigibberellin properties (Melis and Van Standen, 1983). In cassava grown under partially shaded conditions (as in the present study) most of the photosynthates are used for shoot growth adversely affecting the tuber growth. Excess shoot growth can be due to high levels of gibberellins in the leaves, (Menzel, 1980). The occurrence of microorganisms capable of producing indole acetic acid and gibberellin like substances has been reported to be present within the rhizosphere of coconut palms, by Nair and Rao (1977). So in cassava intercropped in coconut gardens a very high level of gibberellin like substances might have been present which would have combated the favourable effect of cycocel and ethrel treatments.

5.1.3. Quality of tubers

From the data on quality attributes (Table 12) it may be seen that the variety Malayan-4 produced tubers with higher starch content and low HCN. However the differences between Malayan-4 and Sreevisakham in starch and HCN content, were of very low magnitude. In both the years, the quality of tubers under the highest planting density was poor as they had significantly lower starch % and higher HCN. This poor quality of tubers is attributed to the insufficient filling of storage cells, as most of the photosynthates were utilized for shoot growth in plants at the highest planting density. The effect of cycocel and ethrel on quality attributes of cassava tubers was not significant. Similar results in coleus were reported by Indira _et al._ (1980).

5.2 Experiment B

The results of the experiment B - "Response to different levels of nitrogen, phosphorus and potassium by cassava intercropped in coconut gardens" are discussed in this section.

5.2.1 Growth characters

5.2.1.1 Plant height

Increased levels of nitrogen significantly enhanced plant height at all the stages of growth, during both the years (Table 13a). Tallest plants were found at the highest level of nitrogen application. Influence of nitrogen in promoting the vegetative growth of plants is a well established fact. Increase in height of cassava plants due to higher levels of nitrogen nutrition have been documented earlier by Ngongi (1976), Pillai and George (1978) and Nair (1982). Significant increase in plant height at the later stages of growth was observed with increased rates of applied phosphorus and maximum height was recorded at highest level, during both the years. Krochmal and Samuels (1970) also reported increase in height of cassava at higher levels of P. The role of phosphorus in promoting shoot growth of cassava was further emphasised by Edwards et al. (1977). The effect of K on plant height was also more conspicous at the later stages of growth. Potassium at higher levels had significant depressing effect on height of cassava. This may be due to the role of K in the translocation of photosynthates more to the roots, rather than to the shoot. In this regard, it may be noted that Malavolta et al. (1955) and Obigbesan (1973) reported increased root/top ratio with higher rates of potassium application.

5.2.1.2 Number of nodes and functional leaves

The variety Sreevisakham had higher number of nodes plant^{-1} at most of the stages during both the years (Table 14a). This indicates that the above variety has an inherent capacity to produce more number of leaves plant^{-1}. Nitrogen at higher rates of application significantly enhanced the number of nodes and number of functional leaves plant^{-1} (Table 14a and 15a). Maximum number of nodes and number of functional leaves plant^{-1}, were found at the highest level at all the stages of growth during both the years. Number of nodes actually represents the total number of leaves produced plant^{-1} and in cassava, it is an important measure of vegetative growth. Natarajan (1975) and Nair (1982) also found similar positive effect of nitrogen on the vegetative growth of cassava.

The effect of phosphorus in enhancing the number of nodes plant^{-1} was significant at 180th day during the first year and maximum number of nodes was recorded at the highest level. In the second year also the highest level of P produced maximum number of nodos plant^{-1}, though the difference between 75 kg P_2O_5 and 100 kg P_2O_5 was not significant, at most of the stages. This positive effect of phosphorus on node number indicates that, at higher levels of phosphorus there was increase in total number of leaves plant^{-1}. Reports from CIAT (1978) also support the above finding. In both the years, the influence of potassium in promoting the number of nodes plant^{-1} was significant, and maximum number of nodes was observed at the highest level. Similarly K had significant positive effect on number of functional leaves at active stages of growth. But the beneficial effect of K on number of functional leaves was seen only upto 100 kg K_2O ha^{-1}. The influence of K in promoting leaf retention was reported by Nair (1983).

5.2.1.3 Leaf area index

Increased rates of nitrogen application was instrumental in maintaining significantly higher leaf area indices at various growth stages, in both the years (Table 16a). Maximum values of LAI were registered at the highest level of N (Fig. 5). The positive effect of nitrogen on LAI is attributed to the higher number of functional leaves retained per plant, at higher levels of nitrogen as evident from Table 15a. Similar increase in LAI due to nitrogen nutrition in cassava was reported earlier by Ngongi (1976), Nair (1982) and CTCRI (1983a). The influence of phosphorus on LAI was not significant except at the initial stages during the second year. However, at most of the stages LAI at 75 kg P_2O_5 ha^{-1} was higher than 50 kg P_2O_5 ha^{-1}. The beneficial effect of phosphorus on this character may be due to its role in better absorption and utilisation of applied nitrogen. Increase in foliage growth as a result of higher rates of P application to cassava was observed at CIAT (1977).

In the first year the positive effect of K on LAI was significant only in the initial stages. In the second year 100 kg K_2O ha^{-1} and 150 kg K_2O ha^{-1} were on par, but maintained significantly higher LAI over 50 kg K_2O ha^{-1}. The higher number of functional leaves found at the above levels of K, might have contributed such increase in LAI. Ngongi (1976) and Ramanujam (1982) also observed increase in LAI of cassava due to K nutrition.

5.2.2 Yield components and yield

5.2.2.1 Number of tubers

The variety Sreevisakham had significantly higher number of tubers plant^{-1} over Malayan-4 during both the years. (Table 17a). In cassava number of tubers plant^{-1} is considered as an important yield determinant. Higher number of tubers plant^{-1} for the variety Sreevisakham over Malayan-4 under intercropping in coconut garden was reported by Ramanujam et al. (1984). Increased rate of nitrogen application exerted no influence on tuber number in the first year. In the second year also there was no significant difference between 50 kg N ha^{-1} and 100 kg N ha^{-1}. However at the highest level there was a marginal increase in tuber number. Natarajan (1975) and Asokan et al.(1980) did not find any significant effect on tuber number due to higher rates of nitrogen. The influence of phosphorus on number of tubers plant^{-1} was significant in both the years. Significantly higher tuber number was recorded at the highest level. Favourable effect of phosphorus on the root system of cassava was reported by Howeler (1976) and Thampan (1979).

Higher levels of potassium significantly enhanced the number of tubers plant^{-1} during both the years. In the first year maximum number of tubers plant^{-1} was observed at the highest level. In the second year 100 kg K_2O and 150 kg K_2O ha^{-1} produced significantly higher number of tubers over the lowest level of potassium, although the former two levels were on par. Beneficial effect of potassium in increasing tuber number in cassava is well documented (Mandal and Mohan Kumar, 1972; Asokan et al. 1980). Further increase in number of tuberous roots due to higher rates of potassium in shade grown cassava was reported by Kasele et al.(1983)

5.2.2.2 Tuber weight

The variety Sreevisakham was significantly superior to Malayan-4 in mean tuber weight during both the years (Table 17a). The higher mean tuber weight of this variety may be due to higher rate of bulking of tubers, which was evident from Table 28.

The effect of nitrogen on mean tuber weight was significant during the first year. The levels 100 kg N and 150 kg N ha^{-1} were on par, but significantly superior to the lowest level of N in this character. In the second year also there was marked increase in tuber weight at 100 kg N ha^{-1} over 50 kg N ha^{-1}. Increased rate of nitrogen nutrition was helpful in maintaining higher leaf area index during the tuber bulking phase (Table 16a). This higher LAI might have favoured higher rate of photosynthesis and production of assimilates which in turn would have been responsible for increased mean tuber weight. Nair (1982) also observed increase in mean tuber weight at higher rates of nitrogen application to cassava.

The influence of higher levels of phosphorus on mean tuber weight was not significant during both the years. Similar results were reported by Thampan (1979) and from CTCRI (1981). In both the years higher rates of potassium significantly enhanced mean tuber weight and maximum tuber weight was observed at the highest level. Such increase in mean tuber weight is attributed to the higher tuber bulking rate observed at higher levels of potassium (Table 28a). Tuber enlargement is through synthesis and accumulation of starch (Hunt et al. 1977). The role of potassium in translocation of assimilates to the roots is well known (Tunso and Fujise 1964). At the higher levels of K it may be noted that there was severe suppression of vegetative growth (Table 13a). This facilitated plants to utilise much of the photosynthates for tuber bulking at higher levels of K. Several earlier workers have reported increase in mean tuber weight in cassava due to K nutrition. (Ngongi, 1976; Nair 1982). Kasele *et al.* (1983) also found increase in mean tuber weight due to higher levels of potassium, in cassava grown under artificial shade.

5.2.2.3 Length and girth of tuber

The variety Sreevisakham had significantly higher mean length and girth of tubers during both the years (Table 18a). This indicates the above variety's inherent capacity to produce large sized tubers. Though higher levels of nitrogen had no effect on tuber length, there was significant increase in tuber girth. Maximum tuber girth was registered at the highest level of N in the first year and at the middle level in the second year. The enhancement in girth found at higher levels of N may be due to the increased bulking of tubers. Improvement in size of tubers due to nitrogen at higher rates of application was reported by Mohankumar and Mandal (1972). Higher rates of P application exerted no influence on length and girth of tubers. Thampan (1979) stated that P applied alone or in combination with N and K had no effect on tuber size in cassava. Incremental dosages of potassium significantly enhanced the length and girth of tubers, during both the years. Maximum length and girth of tubers were found at the highest level of K. Kasele *et al.* (1983) demonstrated the beneficial effect of higher levels of K in increasing the number and size of storage cells in shade grown cassava. Similar increase in number and size of storage cells might have contributed towards the better size of tubers observed at higher levels of K in this study.

5.2.2.4 Utilisation Index

The variety Sreevisakham was superior in utilisation index (U.I.) when compared to Malayan-4 during both the years (Table 19a). The U.I. for the variety Malayan-4 was less than unity in both the years indicating its poor tuber yield. Varietal difference in U.I. was observed by Obigbesan (1973). Increased rates of nitrogen application significantly reduced U.I. and lowest values were recorded at the highest level. Such reduction in U.I. was due to the very high top yields obtained with increase in applied nitrogen (Table 20a). CIAT (1977) also reported decrease in harvest index due to application of nitrogen at higher levels as it stimulated top growth at the expense of root growth. The favourable effect of phosphorus on U.I. was significant in the first year. With increase in levels of P there was enhancement in U.I. This may be due to the higher tuber yield obtained with increase in P levels. Positive effect of phosphorus on tuber yield of cassava was reported by Howeler (1976). Application of potassium at higher rates resulted in significant enhancement of U.I. during both the years. This can be attributed to the reduction in vegetative growth and increase in tuber yield found at higher levels of K. Considerable increase in U.I. due to application of K at higher levels was reported by Obigbesan (1973).

5.2.2.5 Top yield

During both the years the variety Sreevisakham produced significantly higher top yield over Malayan-4 (Table 20a). Ramanujam et al. (1984) also observed higher shoot production for Sreevisakham over Malayan-4 under intercropping in coconut gardens.

Significant increase in top yield with increase in nitrogen application was observed in both the years. Maximum top yield was obtained at the highest level. As the availability of nitrogen increases, most of the carbohydrates are used for the synthesis of protein leading to enhanced top growth (Russel, 1973). Plant height and number of functional leaves, which are the contributing factors for top yield, increased at higher rates of nitrogen application in the present study (Table 13a and 15a). Similar increase in top yield due to higher doses of nitrogen has been reported from CIAT (1975) and by Kasele et al. (1983). In the first year the highest and middle levels of phosphorus were on par, but significantly superior to the lowest level in top yield. In the second year also higher levels of P tended to enhance top yield. This may be due to the beneficial effect of P in promoting the vegetative growth in cassava, as stated by Krochmal and Samuels (1970) and Howeler (1976). The effect of increased rates of potassium application on top yield was not significant in both the years. This may be due to the inhibitory effect of higher levels of Potassium on the vegetative growth of cassava, especially plant height. Pushpadas and Aiyer (1976) also found that higher levels of potassium exerted no significant effect on vegetative growth of cassava.

5.2.2.6 Tuber yield

The data on effect of treatments on fresh tuber yield for 1983-84, 1984-85 and the results of pooled analysis are presented in Table 21a.

In the both the years the cassava variety Sreevisakham produced significantly higher tuber yield. Results of pooled analysis revealed that the above variety was capable of yielding an average of 9.43 t ha^{-1}, where as the yield from Malayan-4 was only 7.03 t ha^{-1}. This difference in yield can be attributed to the varietal character. Significantly higher number of tubers, mean tuber weight and length and girth of tubers observed for Sreevisakham might have contributed for higher yield.

Influence of nitrogen on tuber yield was significant only in the first year. The results of pooled analysis showed that the increase in tuber yield due to enhancement of nitrogen from 50 kg ha^{-1} (n_1) to 100 kg ha^{-1} (n_2) was only to the tune of 0.16 t ha^{-1}. And the effect of further increase in nitrogen dosage was not significant. The poor response to applied nitrogen by cassava observed under the partially shaded conditions, must be due to the profuse vegetative growth, at higher levels of nitrogen, which is evident from the data on plant height, number of nodes, number of functional leaves and LAI. It may also be noted from the Table 26 that at higher rates of nitrogen fertilisation, there was significant inhibitory effect on NAR. Further from the data on dry matter accumulation presented in Tables 23, 24 and 25 it may be observed that at higher levels of nitrogen there was significant increase in leaf and stem dry matter production at the expense of root dry matter accumulation. This makes it obvious that the shoot (stem + leaves), acted as an intermediate sink, restricting the tuber enlargement, at higher levels of nitrogen. Gunasena et al. (1980) from Sri Lanka also reported that cassava intercropped in coconut garden did not respond to higher levels of applied nitrogen. Kasele et al. (1983) observed that under artificial shade higher levels of nitrogen had no beneficial effect on tuber yield, but significantly increased the shoot yield.

Response to phosphorus was significant in both the years and maximum yield was obtained at the highest level. It may be noted from Table 17a that at higher levels of phosphorus there was significant increase in number of tubers produced plant^{-1}. Such increase in number of tubers might have contributed for enhancement in tuber yield at higher levels of phosphorus. Increase in tuber yield due to higher rates of phosphorus application was reported by several workers. (Vijayan and Aiyer 1969; Edwards et al. 1977; Sittibusaya and Kurmarohita, 1978).

Tuber yield increased significantly with incremental doses of potassium in both the years and maximum yield was obtained at the highest level. From the results of pooled analysis, it may be seen that by enhancing potassium application, from 50 kg ha^{-1} (k_1) to 100 kg ha^{-1} (k_2) tuber yield increased by 3.16 t ha^{-1}. But a further increase from 100 kg ha^{-1} to 150 kg ha^{-1} produced only a marginal increase of 0.29 t ha^{-1}. From the data on number of functional leaves plant^{-1}, LAI, NAR and CGR (Table 15a, 16a, 26 and 27) it is obvious that potassium exerted significant positive influence on these parameters. This in turn reveals that cassava plants well supplied with K had more efficient photosynthetic activity, resulting in production of more assimilates. It may also be noted that potassium at higher levels enhanced, the number of tubers plant^{-1} and mean tuber weight (Table 17a). At higher levels of potash nutrition there was higher bulking rate (Table 28) and significant increase in tuber dry matter (Table 25). Potassium application also enhanced the uptake of nitrogen and potassium. Such uptake of N and K might have played a favourable role in the growth and development of cassava. The influence of Potassium on tuber yield is also evident from the significant positive correlation between uptake of K and tuber yield (Table 35). Combined effect of all the above factors must have favourably influenced the tuberisation, tuber enlargement and final tuber yield of cassava at higher levels of K. Kasele *et al.* (1983) also reported the positive effect of higher levels of potassium in tuber production of cassava grown under artificial shade.

Interactions N x K and P x K were significant only in the first year (Table 21b). At all the levels of N, the effect of K in enhancing the tuber yield was evident and maximum tuber yield was obtained at the highest levels of N and K, though it was on par with 100 kg N and 150 kg K_2O ha^{-1}.

In the Second Year also similar trend was observed. This reveals that for cassava intercropped in coconut gardens, an N:K ratio of 1:1.5 may be ideal to get maximum tuber yield. At all the levels of phosphorus also the influence of potassium in promoting tuber yield was conspicuous. In both the years P x V and K x V interactions were significant and the variety Sreevisakham produced higher yields at the highest levels of P and K. This may be due to the high fertilizer responsive character of the above variety.

5.2.3 Quality of tuber

5.2.3.1 Starch content

During both the years significantly higher starch content was found in the tubers of variety Malayan-4 (Table 22). This observation is in agreement with the findings at CTCRI (1976).

Nitrogen at the highest level reduced the starch content of tubers and the effect was significant during the first year. As the availability of nitrogen increases there is a tendency for decrease in carbohydrates in plants (Black 1973). This may be due to increased rate of protein synthesis and consequent increase in vegetative growth triggered by higher nitrogen supply; with corresponding decrease in starch content. Vijayan and Aiyer (1969) also found decrease in starch content of cassava tubers with increase in nitrogen application. Increased rate of phosphorus also had an inhibitory effect on starch content of tubers. It may be noted that at higher levels of phosphorus, there was significant enhancement in vegetative growth of cassava plants in the present study. Further the role of phosphorus in better absorption and utilisation of nitrogen and consequent increased shoot growth is well known. So at higher levels of phosphorus, good amount of the photosynthates might have been diverted for increased top growth resulting in reduced starch content in the storage roots. In this connection it may also be noted that the effect of higher levels of phosphorus in promoting shoot growth at the expense of root growth was reported from CIAT (1977). Starch content of tubers increased significantly with higher rates potassium and maximum starch content was observed at the highest level in the first year. In the second year starch content increased only upto the middle level of K application. The positive effect of potassium in this quality trait can be attributed to its role in synthesis and translocation of carbohydrates. Increase in starch content of tubers at higher levels of potassium, is in conformity with the reports of Pushpadas and Aiyer (1976);, Gomes and Howeler (1980) and Nair and Kumar (1982).

5.2.3.2 HCN content of tubers

The tubers of the variety Malayan-4 had significantly lower HCN content during both the years (Table 25). The HCN content of tubers is an important quality parameter, as it decides to a large extent the value of the tubers for human consumption and it is mostly a varietal character. Nitrogen application at higher rates significantly increased the HCN content of tubers during both the years and maximum values were recorded at the highest level. A high level of nitrogen application results in a high content of cyanogenic glycosides in the tuber (Sinha, 1969), which upon hydrolysis releases the toxic hydrocyanic acid. Several investigators have earlier reported increase in HCN content due to higher rates of nitrogen fertilisation. (Indira et al. 1972; Mohankumar and Maini, 1977; Nair, 1982). Phosphorus fertilisation had no significant beneficial effect on HCN content of tubers. Muthuswamy et al. (1974) also reported similar results.

Effect of potassium in reducing HCN content of tuber was significant during both the years. In the first year lowest HCN content was registered at 100 kg K_2O ha^{-1} whereas in the second year, it was at 150 kg K_2O ha^{-1}. According to Clark (1936) the content of glucosides reduced as the dry matter content increased. In the present study also the root dry matter content increased with incremental doses of K (Table 25). This high content of root dry matter might have reduced the HCN content of tubers. Beneficial effect of potassium alone or in combination with nitrogen in reducing the HCN content of cassava tubers was observed by Indira et al. (1972); Obigbesan (1973) and Ramanujam (1982).

5.2.4 Growth analysis

5.2.4.1 Drymatter production and distribution

The variety Sreevisakham produced significantly higher quantity of leaf and stem dry matter during both the years (Tables 23 and 24). At all stages of growth the root dry matter production was higher for the above variety (Table 25). Ramanujam et al. (1984) also reported similar dry matter production pattern for the variety Sreevisakham when compared to Malayan-4.

Higher rates of nitrogen application significantly enhanced the leaf and stem dry matter production at all stages of growth during both the years. Maximum shoot dry matter production (stem and leaves) was observed at the highest level. But higher rates of nitrogen exerted no significant influence on root dry matter production except in the initial stages of growth (Fig. 6). This suggests the possibility that most of the photosynthates produced by increased nitrogen nutrition was diverted for shoot growth, rather than for enlargement of tubers. Increase in shoot dry weight due to higher rates of nitrogen application to cassava grown under shaded conditions was observed by Kasele et al. (1983). The positive effect of higher levels of phosphorus on leaf dry matter production was significant only in the initial stages of growth. Similarly the effect of higher rates of phosphorus on stem dry matter production, was significant only at 180th day during both the years. But the root dry matter production enhanced with higher levels of phosphorus application. In this connection it may be recalled that there was significant increase in the number of tubers $plant^{-1}$ at higher levels of P (Table 17a), which inturn contributed to higher root dry matter production. The influence of potassium in promoting leaf dry matter production was significant only upto 100 kg K_2O ha^{-1} at all stages of growth during both the years. However, significantly higher stem dry matter production at the final stage was observed at the higher levels of K. Root dry matter production also increased with higher doses of potassium and the effect was significant at all stages in both the years.

The differences in root dry matter production between 100 kg K_2O and 150 kg K_2O ha^{-1} were negligible in the initial phase of growth, but the difference became very conspicuous at the later stages of growth, and the highest level of K producing maximum root dry matter (Fig. 6). The above dry matter distribution pattern indicates that potassium was helpful in the translocation and accumulation of photosynthates to the roots. In this context it may be noted that, increase in tuber dry matter content by potassium application upto 200 kg ha^{-1} has been observed at CIAT (1980). Kasele et al. (1983) also found increase in root dry matter production due to higher rates of potassium, in cassava under artificial shade.

5.2.4.2 Net assimilation rate and crop growth rate.

The variety Sreevisakham had significantly higher NAR and CGR in both the years at all the stages of growth (Tables 26 and 27). These varietal differences in these physiological parameters can mostly be accounted to genetic variability, which influences the growth attributes. Increase in levels of nitrogen had no beneficial effect on net assimilation rate. But significant increase in crop growth rate was observed at higher levels of nitrogen, especially at the initial stages in both the years. Similar results due to increased nitrogen nutrition in cassava, were reported by Ramanujam (1982). Higher rates of phosphorus also had no significant effect on NAR. The positive effect of phosphorus on CGR was significant only in the initial phase and maximum CGR was recorded at 75 kg $P_2O_5 ha^{-1}$. As regards to potassium, at the highest level maximum values of NAR and CGR, especially in the tuber development phase, were recorded though the differences between 100 kg K_2O and 150 kg K_2O ha^{-1} were not significant. From this it is obvious that potassium exerted a favourable role in enhancing the photosynthetic efficiency in cassava.

5.2.4.3 Tuber bulking rate

Higher tuber bulking rate was observed for the variety Sreevisakham during both the years (Table 28). This may be due to more efficient synthesis and translocation of carbohydrates to the storage roots, evidenced by the higher values of NAR and CGR recorded for this variety.

Increase in levels of nitrogen exerted no significant influence on tuber bulking rate. It may be noted that at higher levels of nitrogen there was significant increase in vegetative growth. Such vegetative growth might have inhibited tuber bulking rate. The favourable effect of phosphorus on tuber bulking rate was significant only in the initial phases. Howeler (1976) also observed enhanced tuber growth in cassava due to phosphorus nutrition. Increased rates of potassium promoted tuber bulking rate especially in the active tuber development phase. The beneficial effect of potassium in synthesis and translocation of starch to the storage organs in tuber crops is a well established fact. The higher values of NAR and CGR found at higher levels of K nutrition in this study also corroborates the above result.

5.2.5 Uptake of nutrients

From the Tables 29, 30 and 31 it may be seen that the variety Sreevisakham removed higher amounts of nitrogen, phosphorus and potassium, when compared to Malayan-4. Total dry matter production also was higher for the above variety. This clearly suggests that the variety Sreevisakham was more efficient in absorption and utilisation of applied nutrients, under partially shaded conditions.

Plant uptake of nitrogen increased with higher rates of application of this nutrient. Increase in uptake of nitrogen due to higher rates of application, is a well known fact, Pushpadas *et al.* (1976) also recorded similar observations in cassava. The effect of Phosphorus on uptake of nitrogen was conspicuous only at the later stages. The influence of potassium in promoting the uptake of nitrogen was significant only upto 100 kg K_2O ha^{-1}. This is in conformity with the findings of Nair (1982).

At higher levels of nitrogen, significant enhancement in phosphorus uptake was recorded. This may be due to the formation of new tissues as a result of increased protein synthesis caused by higher rates of nitrogen nutrition. Vijayan and Aiyer (1969) also documented similar results. The positive effect of potassium on P uptake was not significant beyond 100 kg K_2O ha^{-1}. Reduced rate of phosphorus uptake due to higher level of K application was reported by Thampan (1979) in cassava.

Nitrogen fertilisation at higher levels, significantly enhanced plant uptake of potassium at all the stages of growth. Rajendran *et al.* (1976) reported similar results in this crop. There was a tendency for increased uptake of potassium coupled with higher levels of P application. This may be attributed to the better root system, that developed at higher levels of phosphorus nutrition. Significant increase in uptake of potassium with increase in dosages of this nutrient was recorded at all the stages of growth. This enhanced rate of uptake with increased rate of application, was effectively utilised by the plant as there was significant positive effect on yield components and tuber yield in this study. Kumar et al. (1971) and Nair (1982) also reported higher uptake of potassium due to increased rates of application to cassava.

5.2.6 Soil nutrients

5.2.6.1 Available nitrogen

Available nitrogen content of the soil increased with higher levels of nitrogen fertilisation (Table 32). Such increase in available nitrogen status, consequent to nitrogen application was reported by several workers (Rajendran et al. 1971; Mohankumar and Maini, 1977). The available N content of the soil was not influenced by the rates of applied phosphorus in the first year. In the second year there was slight reduction in available nitrogen status due to higher rates of phosphorus nutrition. This may be due to the higher total dry matter production and consequent removal of nitrogen, promoted by phosphorus nutrition. Increased rates of potassium fertilisation significantly enhanced the available nitrogen content. Nair (1982) also recorded similar results.

5.2.6.2 Available phosphorus

There was significant reduction in available phosphorus status of the soil due to increased rate of nitrogen application (Table 32). This might be due to crop removal of phosphorus, associated with enhanced dry matter production at higher levels of nitrogen. Available phosphorus content of the soil recorded significant increase with higher levels of application of this nutrient. Build up of phosphorus in soil due to higher rates of application was reported by Chan (1980) and from CTCRI (1983b). Potassium exerted no influence on available P in the first year. In the second year there was significant reduction in available phosphorus, at the highest level of K application. Such reduction in available phosphorus can be attributed to crop removal, resulted by higher dry matter production at the highest level of K.

5.2.6.3 Available potassium

In general the available K status of the soil was not influenced by levels of nitrogen and phosphorus (Table 32).

But there was significant increase in available K in the soil due to higher rates of potassium application. Maximum build up of available K was found at the highest level of application. Build up of available K due to higher rates of application was observed by Kumar et al. (1977).

5.2.7 Correlation Studies

5.2.7.1 Relationship between yield components and yield

It may be observed from the Table 33 and 34 that, among the characters studied, utilisation index was correlated to the maximum extent with tuber yield. Mean number of tubers plant^{-1} and mean tuber weight was also found to have significant correlation with tuber yield.

Path coefficient analysis (Fig. 7 and 8) also revealed that number of tubers exerted maximum direct effect on tuber yield. Mean tuber weight also had considerable direct effect on tuber yield. Utilisation index, though showed very high significant correlation with tuber yield, its direct effect was much less, when compared to tuber number and tuber weight. However the utilisation index had maximum indirect effect via number of tubers and mean tuber weight. The importance of number of tubers plant^{-1} and mean tuber weight on yield of cassava was reported by Williams (1974); Pillai and George (1978) and Ramanujam and Indira (1980).

5.2.7.2 Relationship between uptake of nutrients and tuber yield

The correlation coefficients between uptake of N, P and K at harvest and tuber yield are presented in Table 35. There were significant positive correlation between uptake of the above nutrients and tuber yield in both years. Higher correlation was observed between tuber yield and uptake of phosphorus and potassium.

5.2.8 Response studies

As the cassava varieties Malayan-4 and Sreevisakham exhibited differential response to the levels of NPK fertilization, the relationship between applied nutrients and yield of fresh tubers were estimated separately by fitting a quadratic response surface as given below:

$$
\begin{aligned}
Y = {} & b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + \\
& b_{11} x_1^2 + b_{22} x_2^2 + b_{33} x_3^2 + \\
& b_{12} x_1 x_2 + b_{13} x_1 x_3 + b_{23} x_2 x_3
\end{aligned}
$$

Where $x_1 = \frac{N - 50}{50}$

$x_2 = \frac{P - 50}{25}$

$x_3 = \frac{K - 50}{50}$

The fitted surfaces for Malayan-4 and Sreevisakham for both the years were found to be significant. The relevant regression coefficients and the coefficient of determination (R^2) are presented in Table 38. The higher values of R^2 clearly revealed the reliability of the fitted surface.

From the response surface the physical optimum levels of N, P_2O_5 and K_2O for Malayan-4 and Sreevisakham for both the years were estimated and the values are presented in Table 39. During the second year, there was no significant response to increased rates of applied nitrogen. The linear response of N was negative, while the quadratic response was positive. However the regression coefficients were found to be not significant (Table 38). In the case of P, the linear response was negative and the quadratic response was positive for the variety Sreevisakham during second year; but the quadratic response was not significant. With regard to K the optimum levels for both the cassava varieties were clearly determinable during the years of the study. It may also be noted that within the explored region of the response surface an economic optimum combination of NPK was not determinable.

Table 38. Regression of yield on NPK

Regression coefficients	Malayan-4		Sreevisakham	
	1983-84	1984-85	1983-84	1984-85
b_0	4.9813	4.8546	7.0217	6.3181
b_1	0.4225	-0.0106	0.1500	-0.1650
b_2	0.9544*	0.3318*	-0.7020*	-0.1032
b_3	4.4761**	3.8704**	4.5287**	4.6179**
b_{11}	-0.1203	-0.0008	0.1447	0.0192
b_{22}	-0.4786*	-0.2192*	0.4845	0.2475
b_{33}	-0.4461**	-1.2342**	-1.3822**	-1.3708**
b_{12}	-0.1363	0.0308	0.1296	0.1329
b_{13}	-0.0704	0.0283	0.2629	0.1096
b_{23}	0.0588	0.0471	0.2879*	-0.1467
R^2	92%	98%	96%	95%
F	61.74*	113.36*	108.39*	90.91*

* Significant

Table 39. Physical optimum levels of NPK

Variety	1983-84			1984-85		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Malayan-4	87	50	127	0	46	120
Sreevisakham	186	34	155	0	131	105

5.2.9 Economics of fertilizer application

From the economics of fertilizer application presented in Table 40, it is evident that the variety Sreevisakham at 50 kg N, 50 kg P_2O_5 and 100 kg K_2O per hectare, produced the maximum net return of Rs. 2280.00. Higher rates of fertilizer application beyond the above levels of nutrients decreased the net return. The net return from the variety Malayan-4 was substantially lower than Sreevisakham at all levels of fertilizer treatments, probably due to its low yield potential.

Table 40. Economics of fertilizer application

Sl. No.	Treatments N	P_2O_5	K_2O kg ha^{-1}	Cost of cultivation Rs ha^{-1}	Yield t ha^{-1} V_1	V_2	Value of tuber Rs ha^{-1} V_1	V_2	Profit/Loss Rs ha^{-1} V_1	V_2
1	50	50	50	2740.00	5.14	6.21	2570.00	3105.00	170.00	365.00
2	50	50	100	2840.00	7.60	10.24	3800.00	5120.00	960.00	2280.00
3	50	50	150	2940.00	7.88	10.25	3940.00	5125.00	1000.00	2185.00
4	50	75	50	2877.50	4.98	6.83	2490.00	3415.00	-387.50	537.50
5	50	75	100	2977.50	8.22	9.63	4110.00	4815.00	1132.50	1837.50
6	50	75	150	3077.50	8.31	10.70	4155.00	5350.00	1077.50	2272.50
7	50	100	50	3015.00	4.94	7.57	2470.00	3785.00	-545.00	770.00
8	50	100	100	3115.00	7.63	10.68	3815.00	5340.00	700.00	2225.00
9	50	100	150	3215.00	8.02	10.73	4010.00	5365.00	795.00	2150.00
10	100	50	50	2990.00	5.25	6.43	2625.00	3215.00	-365.00	225.00
11	100	50	100	3090.00	7.66	10.42	3830.00	5210.00	740.00	2120.00
12	100	50	150	3190.00	8.01	10.05	4005.00	5025.00	815.00	1835.00
13	100	75	50	3127.50	5.02	6.76	2510.00	3380.00	-617.50	252.50
14	100	75	100	3227.50	8.34	9.89	4170.00	4945.00	942.50	1717.50
15	100	75	150	3327.50	8.46	10.97	4230.00	5485.00	902.50	2157.50

Cond....

Sl. No.	Treatments			Clst of cultivation Rs ha^{-1}	Yield t ha^{-1}		Value of tuber Rs ha^{-1}		Profit/Loss Rs ha^{-1}	
	N	P_2O_5	K_2O kg ha^{-1}		V_1	V_2	V_1	V_2	V_1	V_2
16	100	100	50	3265.00	4.88	7.54	2440.00	3770.00	-825.00	505.00
17	100	100	100	3365.00	7.66	10.91	3830.00	5455.00	465.00	2090.00
18	100	100	150	3465.00	8.11	11.29	4055.00	5645.00	590.00	2180.00
19	150	50	50	3240.00	5.25	6.41	2625.00	3205.00	-615.00	-35.00
20	150	50	100	3340.00	7.65	10.41	3828.00	5205.00	485.00	1865.00
21	150	50	150	3440.00	8.02	10.58	4010.00	5290.00	570.00	1850.00
22	150	75	50	3377.50	4.94	6.75	2470.00	3375.00	-907.00	-2.00
23	150	75	100	3477.50	8.36	9.96	4180.00	4980.00	703.00	1503.00
24	150	75	150	3577.50	8.48	11.16	4240.00	5580.00	603.00	2003.00
25	150	100	50	3515.00	4.87	7.54	2436.00	3770.00	-1080.00	255.00
26	150	100	100	3615.00	7.93	11.03	3965.00	5515.00	350.00	1900.00
27	150	100	150	3715.00	7.47	11.74	3735.00	5870.00	20.00	2155.00

Cost of fertilizer N @ Rs.5.00 kg^{-1} P_2O_5 @ Rs.5.50 kg^{-1} K_2O Rs.2.00 kg^{-1}
Value of Cassava Rs.500 t^{-1}

SUMMARY

6. SUMMARY

An investigation was undertaken at the coconut research station, Balaramapuram during the years 1983-84 and 1984-85, to study the production potential of cassava intercropped in coconut gardens. The above investigation was carried out in two field experiments. In the experiment 'A' the performance of cassava varieties Sreevisakham and Malayan-4 intercropped in coconut gardens as influenced by different planting density and growth regulators was studied, adopting a split plot design with 3 replications. In the experiment-'B' the response to different levels of NPK fertilizers, by the above cassava varieties, raised as intercrop in coconut gardens was assessed. This experiment was conducted in $3^3 \times 2$ partially confounded, factorial design with 2 replications. The salient findings of the above study are summarised below:

(1) The cassava hybrid Sreevisakham was superior to the popular cultivar Malayan-4 in number of nodes $plant^{-1}$, number of functional levels $plant^{-1}$, LAI, NAR, CGR and total dry matter production.

(2) Higher values with respect to number of tubers plant^{-1}, mean tuber weight, length and girth of tubers and utilisation index were also registered for the variety Sreevisakham.

(3) Consistently higher tuber yield was obtained from Sreevisakham in both the experiments.

(4) The tubers from Malayan-4 had higher starch content and lower HCN content, when compared to Sreevisakham.

(5) Increase in planting density caused reduction in plant height, number of nodes and number of functional leaves plant^{-1}.

(6) Reduction in number of tubers plant^{-1}, size of tubers and utilisation index was observed in both varieties with increase in planting density. Maximum reduction was recorded in plants under the closest spacing of 60 x 60 cm.

(7) For maximum fresh tuber yield from cassava inter-cropped in coconut gardens, a plant population of 9000 (per hectare of coconut garden) was found to be optimum.

(8) Cycocel and ethrel at the higher concentrations tried, reduced plant height.

(9) The yield attributes and yield of cassava were not influenced by cycocel and ethrel treatments.

(10) Increased rates of nitrogen fertilisation, enhanced plant height, number of nodes $plant^{-1}$, number of functional leaves $plant^{-1}$ and LAI. Maximum values with respect to these parameters were recorded at 150 kg N ha^{-1}.

(11) Phosphorus nutrition at 100 kg ha^{-1} resulted in maximum plant height and number of nodes $plant^{-1}$, but had no effect on number of functional leaves and LAI.

(12) Potassium at higher rates reduced plant height. Increase in LAI due to potassium application was observed only upto 100 kg K_2O ha^{-1}.

(13) Phosphorus and potassium application was effective in enhancing number of tubers $plant^{-1}$.

(14) Potassium at higher levels increased the mean tuber weight and maximum tuber weight was recorded at 150 kg K_2O ha^{-1}.

(15) Top yield increased with higher rates of NPK application

(16) Increased rates of nitrogen application reduced the utilisation index whereas phosphorus and potassium were beneficial in enhancing the utilisation index.

(17) Higher rates of potassium resulted in substantial increase in tuber yield. By increasing application of potassium from 50 kg K_2O ha^{-1} to 100 kg K_2O ha^{-1}, the tuber yield increased from 5.96 t ha^{-1} to 9.12 t ha^{-1}.

(18) Nitrogen at higher levels enhanced the HCN content of tubers and maximum HCN content was observed at 150 kg N ha^{-1}.

(19) Potassium nutrition was beneficial in reducing the HCN content of tubers.

(20) Leaf and stem dry matter production increased with higher levels of nitrogen and maximum values were recorded at 150 kg N ha^{-1}.

(21) Root dry matter production was promoted by higher levels of potassium.

(22) Nitrogen at higher levels had depressing effect on NAR, whereas potassium enhanced the NAR at all stages of growth.

(23) Phosphorus nutrition promoted tuber bulking rate at the initial stages of crop growth.

(24) Higher rates of potassium enhanced tuber bulking rate at all the stages of growth.

(25) Plant uptake of N and K increased with higher levels of application.

(26) Available N, P and K status of the soil was found to increase with levels of application of these nutrients.

(27) Correlation studies revealed that tuber number, utilisation index and mean tuber weight were highly correlated with tuber yield.

(28) Similarly tuber yield was highly correlated with plant uptake of potassium and phosphorus.

(29) Path coefficient analysis showed that mean tuber number followed by mean tuber weight exerted maximum direct effect on tuber yield.

(30) Quadratic response surface was found to be significant to define the relationship between NPK nutrition and tuber yield.

(31) The economics of fertilizer application worked out revealed that intercropping cassava variety Sreevisakham in coconut garden, with application of 50 kg N, 50 kg P_2O_5 and 100 kg K_2O gave the maximum net profit of Rs. 2280 ha^{-1}.

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* Original not seen

APPENDICES

APPENDIX - I

Weather data average value for the past 24 years (1958-1982)

Month	Rainfall mm	Temperature (c) Max.	Min.	Humidity %
January	36.62	30.93	22.46	79.88
February	36.00	31.34	22.87	82.05
March	35.06	32.17	24.00	81.36
April	89.16	32.27	25.02	83.29
May	197.70	31.75	24.92	85.07
June	292.20	30.42	23.95	85.13
July	220.90	29.72	23.46	87.18
August	138.63	29.77	23.22	86.02
September	150.28	30.12	23.76	85.77
October	264.14	29.70	23.76	86.41
November	208.05	29.91	23.81	86.97
December	71.05	30.66	23.26	84.78

PRODUCTION POTENTIAL OF CASSAVA (*MANIHOT ESCULENTA* CRANTZ) INTERCROPPED IN COCONUT GARDENS

By

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ABSTRACT OF A THESIS
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ABSTRACT

Field experiments were conducted at the coconut Research Station, Balaramapuram, during 1983-84 and 1984-85 to study the production potential of cassava varieties Sreevisakham and Malayan-4, intercropped in coconut gardens, as influenced by planting density, growth regulators and different levels of NPK fertilizers.

The cassava hybrid Sreevisakham was superior to the popular cultivar Malayan-4 in number of nodes plant^{-1}, number of functional leaves plant^{-1}, leaf area index, net assimilation rate, crop growth rates, dry matter production, utilisation index, tuber bulking rate and in fresh tuber yield.

For intercropping one hectare of coconut garden in which coconuts are spaced at 7.5 x 7.5 m, cassava plant population of 8000 (spacing 90 x 90 cm) was found to be optimum to produce maximum fresh tuber yield. Cassava plants at higher planting density, were stunted in growth and produced poor quality tubers.

The growth regulators cycocel and ethrel though decreased the plant height, could not influence either the yield attributes or yield and quality of cassava tubers.

Nitrogen application at higher levels enhanced plant height, number of nodes plant^{-1} number of functional leaves plant^{-1}, leaf area index, and leaf and stem dry matter production. Higher rates of nitrogen nutrition also caused significant depressing effect on net assimilation rate. Phosphorus at higher levels, also promoted the vegetative growth of cassava plants, but was beneficial in increasing the number of tubers plant^{-1}. The increase in tuber yield due to higner rates of nitrogen and phosphorus nutrition was of lower magnitude. Potassium at higher rates of application resulted in substantial increase tuber yield. Physiological parameters like, NAR, CGR, tuber bulking rate and utilisation index were also promoted by higher rates of potash nutrition. Nitrogen at higher rates of application increased the HCN content of tubers while potassium at higher rates improved the quality of tubers by lowering the HCN content. Plant uptake of nitrogen and potassium increased with higher levels of application. of the above nutrients.

Tuber number plant^{-1} mean tuber weight and utilization index were found to be highly correlated with tuber yield.

Intercropping the cassava variety Sreevisakham in coconut garden with application of 50 kg N, 50 kg P_2O_5 and 100 kg K_2O per hectare gave maximum net profit.