INTERCROPPING TAPIOCA (*Manihot esculenta* Crantz.) WITH PULSES AND GROUNDNUT

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Intercropping tapioca (*Manihot esculenta* Crantz.) with pulses and groundnut" 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.

Place: Vellayani.
Date: 26-7-1978.

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CERTIFICATE

Certified that this thesis, entitled "Intercropping tapioca (*Manihot esculenta* Grantz.) with pulses and groundnut" is a record of research work done independently by Shri. H. RAMAKRISHNA BHAT 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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INTRODUCTION

Tuber crops form an important group that produces abundant food materials at low cost and hence they have become favourite articles of food in the developing countries of the world. Recently published figures indicate that global production of tuber crops is of the order of 170 million tons per annum of which tapioca alone accounts for more than 105 million tons which is about two-third of the total tuber crop production (FAO, 1973).

Tapioca, which is also called as cassava, manioc, aipi, mandioca, yucca etc. in different parts of the world, has a pivotal role in the economy of the State of Kerala with an annual production of about 53.9 lakh tons from an area of about 3.29 lakh hectares. In Kerala, majority of the farmers belong to the group of marginal farmers and farming is a means of subsistence rather than business for them. Tapioca being a subsidiary food crop for the middle and lower class people of the State, requires much attention in the improvement of its production.

Tapioca is mainly a carbohydrate rich crop with very low content of proteins. It has been suggested that one of the several reasons for the protein deficiency of people in the tropics is the large scale consumption of

tapioca by them (Courcey and Haynes, 1970). Therefore it is emphasised that some protein rich food items should also be included along with tapioca. As evidenced by the fact that legumes are rich sources of protein (Jain, 1975) it is nutritionally sound to supplement tapioca with some grain legumes like pulses.

As already stated, bulk of the tapioca growers are subsistence farmers and cannot afford to go in for the cultivation of pulses on a large scale in fresh land. So suitable agro-techniques have to be adapted in order to enable the cultivators to grow pulses without any additional land or expenditure so as to enable them to include pulses also along with tapioca in their daily diet.

Intercropping is a term that is being widely used by agricultural scientists in recent years. In reality, intercropping is a practice of intensive land use to take two or more crops simultaneously each year. This system not only increases the production from unit area per unit time but also provides additional work to the agricultural labourers besides giving an additional income. Again, intercropping systems involve growing together two or more species of crops with the assumption that two species could exploit the environment better than one.

The intercrops selected should ensure maximum production or maximum returns per unit input to the farmer and should be compatible and able to co-exist with the main crop. It should be able to utilize and harness efficiently the light that is filtered through the leaf canopy of the main crop. The rooting patterns of the intercrops should be such that they can utilize the water and nutrients which are not utilized by the main crop.

Tapioca, being a ten months duration crop, the initial growth rate of the crop is comparatively slow and it generally takes 2½ to 3 months to develop the full canopy (Mohankumar and Mrishi, 1974). It has also been reported that most of the tubers develop only by the third month after planting. Further tapioca is planted at a spacing of 75 - 90 cm on both ways which results in leaving a considerable area unutilized during the early part of crop growth.

Based on the above facts intercropping in tapioca will be an economically and practically feasible venture. It not only gives an additional income but also utilizes the natural resources of sunlight, water and nutrients to the fullest extent. Experiments conducted at C.T.C.R.I., Trivandrum (Singh et al. 1967) have showed that a combination of tapioca and pulses will be beneficial with regards

to income and soil fertility.

A wide variety of pulses has been found to co-exist with other field crops in intercropping systems. They were also found to be beneficial to the main crop. Among the pulses, cowpea, greengram and blackgram were used in large scale by the people of Kerala. Besides, groundnut is another leguminous oilseed crop which has high potential for growing in Kerala as an intercrop.

The manurial recommendations for the crop raised as intercrop will be different from that recommended for the same crop when raised as a pure crop. This was necessitated due to a decrease in plant population when it was grown as an intercrop. Detailed studies regarding the effect of intercropping tapioca with different pulses and groundnut were lacking in Kerala. The fertiliser recommendations for the intercrops were also not worked out. Hence the present investigation was taken up with the following objectives:-

(1) To study the effect of intercropping, with different pulses and groundnut, on the growth, yield and quality of tapioca.

(2) To study the comparative efficiency of different leguminous crops as intercrops in tapioca and to select the most suitable intercrop for tapioca.

(3) To find out the optimum and economic dose of fertilizers for the intercrops.

(4) To study the economics of intercropping tapioca with different leguminous crop supplied with different fertilizer doses.

(5) To study the effect of intercropping on the fertility status of the soil.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Much experimental evidence is not available on the performance of tapioca grown in association with legumes, in India or abroad. However, different legumes are being grown in association with different field crops by the cultivators. Although different legumes have been tried as intercrops with tapioca, the comparative performance of tapioca with these intercrops supplied with different fertilizer doses have not been studied very extensively. Literature available on the above aspects has been reviewed here. Since information pertaining to the above work is limited, similar works on related crops are also reviewed.

I. Effect of intercropping on the growth and yield of tapioca

The practice of intercropping in tapioca has been reported from Brazil as early as in 1935 (Marcus, 1935). The practice of intercropping tapioca with cotton was reported by Velasquez (1953) in Colombia. Reports from Tanganyika indicated that when early sown groundnuts were intercropped with late planted tapioca, the yield of cassava was reduced to less than one-fifth of what it produced when grown alone (Anon., 1960).

Singh and Mandal (1963) noted that growing groundnut

as intercrop in tapioca did not substantially affect the growth and yield of tapioca but on the contrary provided an additional gross income of Rs.1150/ha. In their experiment, tapioca was planted 3' x 3' apart and groundnut was sown in the centre of 2 rows of tapioca at one foot apart.

The tuber yield of tapioca was not much affected by growing legumes like groundnut and cowpea as intercrops but on the other hand gave an additional income (Singh et al., 1969). Singh and Mandal (1970) reported that horsegram and sesamum reduced the tuber yield of tapioca considerably.

Mohankumar and Mrishi (1973) tried cowpea, sunflower, greengram, soybean, groundnut and maize as intercrops in tapioca. They found that tuber yield in the plot without intercrop was significantly higher than that in the intercropped plots. Tuber yield was reduced significantly when intercropped with greengram, maize, soybean, sunflower and groundnut. The differences were on par in the greengram, maize and soybean plots. Though groundnut plots recorded the lowest tuber yield of tapioca, it was found superior to other intercrops from the net return point of view. Intercropping with greengram and soybean were found to be uneconomic as the net returns were less than that of the control plot (Mohankumar and Mrishi, 1974).

Beets (1975) reviewed the intercropping practice with tapioca in Indonesia and noted that intercropping in tapioca was more profitable than monoculture. In Nigeria, when tapioca was intercropped with yams, the tuber yield was increased. This was attributed to the residual effect of manures and fertilizers applied to the yam (Irving, 1975).

Growing of groundnut and cowpea in between tapioca rows did not affect the normal yield of the main crop and was found to be very profitable (Katyal and Dutta, 1976). Tuber length of tapioca undersown with Stylosanthes guyanensis was 16.03 per cent more than that of tapioca grown alone. Tapioca/stylo mixture produced 180 per cent greater top yields than tapioca alone (Nitis and Sumatra, 1976).

Sintuprama (1976) reported the practice of intercropping in tapioca in Thailand and found it profitable without affecting the growth and yield of the main crop. Growth and yield of tapioca was reduced considerably when intercropped with crops such as lab lab, small onion, Bellary onion, cowpea, bhindi, groundnut and bengal gram (Thamburaj and Muthukrishnan, 1976). They also noted that the growth of tapioca was affected by intercropping as adjudged by the height of the plants. However, it was found that the tuber yield of tapioca was not seriously affected by growing groundnut as intercrop (Anon., 1978).

II. Effect of intercropping on the growth and yield of other tuber crops

Among the other tuber crops, intercropping studies have been undertaken in potatoes, sweet potatoes and yams. Koregave (1964) studied the economic aspects of suran (elephant footyam) mixed with various other field crops and found that intercropping suran with radish and methi gave better money returns followed by groundnut and cluster beans.

Potato yields were increased from 2.94 to 6.7 t/ha when maize was grown in alternate single or double rows (Lungu et al., 1972). Intercropping had no significant effect on the chemical composition of the potato tubers.

Intercropping studies in sweet potatoes showed that total annual production was increased when sweet potatoes were grown in association with maize (Anon., 1973). It was also found that intercropping systems had a more efficient light utilization pattern and a higher efficiency of utilization of applied N.

Yield of potatoes intercropped with sugarcane was increased from 10.8 to 27.9 t/ha of tubers (Kathi et al., 1974). Akhade et al. (1975) also noted that intercropping of potatoes in irrigated sugarcane gave good yields of potatoes without adversely affecting sugarcane yields.

On the other hand the yield of potato tubers was reduced considerably when grown in association with maize (Fisher, 1975). Kar et al. (1975) got maximum cane yields and the highest net returns when potatoes were grown with autumn planted sugarcane. The beneficial effects of intercropping potatoes with sugarcane were reported by Agarwal and Mathur (1976) and Mathur (1976). Singh et al. (1976) successfully intercropped potatoes with wheat without any adverse effect on the potato yield.

Fisher (1977) compared the productivity of potato/maize mixture with pure stands of the component crops in four cropping seasons and found that yield from the mixtures fell short of that from pure stands in low rainfall seasons, whereas in high rainfall seasons there was not much reduction in the maize yield.

III. Effect of legume intercropping on the dry matter content of main crop

Tewari and Schmid (1960) found that Timothy or smooth brome grass mixed with lucerne in adjacent rows 6" away yielded more dry matter than grown in rows 12" away from the lucerne plant. There was a loss in the quantity of dry matter produced in the mixed cropping of sorghum and cowpea (Singh and Sogani, 1968). Prasad and Chaudhury (1975) found an increase in the dry matter yields of Cenchrus setigerus by growing greengram varieties in the interspaces.

Nitis and Sumatra (1976) observed an increase in the dry matter content of the tapioca tuber when undersown with Stylosanthes guyanensis. The tuber dry matter yield for mixed tapioca/stylo was 16.8 per cent greater than for tapioca grown alone.

IV. Effect of legume intercropping on the starch content

Growing jowar in association with legumes like cowpea increased significantly the starch equivalent as compared to growing jowar alone (Dey et al., 1958).

When maize was grown with potatoes in alternate single or double rows, the starch equivalent yield was increased. The starch equivalent yield was highest with one row of maize alternating with two rows of potatoes (Lungu et al., 1972).

V. Effect of legume intercropping on crude protein

Increase in the crude protein content of crops when intercropped with legumes was recorded by several authors. Churchill (1947) found that a mixture of brome grass and alfalfa yielded higher content of crude protein from bromegrass when compared to its pure stand. Growing jowar and cowpea in 3:1 ratio increased crude protein content significantly as compared to their pure stand (Dey et al., 1958).

The crude protein content of Timothy grass or

smooth bromegrass was higher when grown in association with lucerne than grown alone (Tewari and Schmid, 1960). Growing of legumes and non-legumes alternately in double rows produced better fodder yield and an increase in the crude protein content of 7.5 per cent in the mixture as compared to 4.5 per cent in pure M.P. Chari variety of sorghum was noted (Manitkar and Shukla, 1974).

VI. Effect of leguminous intercrops on the growth and yield of main crop

(a) Blackgram

Pathak and Sahani (1960) observed that blackgram as an intercrop with redgram gave higher profit. Blackgram was found to be the most common intercrop with cotton in Tirunelveli District of Tamil Nadu (Guruswamyraja, 1962). Singh and Premchand (1969) noted that growing blackgram in between the rows of maize after the final earthing up, did not affect the grain yield of maize. On the contrary, in cotton, the seed cotton yield was significantly reduced when it was intercropped with blackgram (Verma and Kanke, 1969).

Experiments conducted at I.A.R.I., New Delhi showed that an additional yield of 7 to 8 q/ha of pulse grain from urd could be obtained by intercropping with pigeon-pea without any adverse effect on the yield of the latter (Anon., 1971). Sobti and Saini (1972) reported that

blackgram intercropped in maize depressed the maize yields, but the total grain yield in the intercropped field was higher than their pure stands.

Morachan et al. (1977) noted that the yield of sorghum was not affected by growing blackgram as an intercrop. Further, the intercropped plots gave a net return of Rs.1436/ha as compared to Rs.789/ha from pure sorghum.

(b) Cowpea.

Experiments conducted at I.A.R.I., New Delhi, showed higher yield of maize when cowpea was grown as an intercrop with it (Anon., 1951). Gupta (1952) and Malik (1952) also reported the feasibility of growing cowpea as an intercrop with other crops.

Dey et al. (1958) observed a suppression of growth of sorghum due to the intertwining effect of intersown cowpea. A 25 per cent increase in yield of bajra was noted when cowpea was intercropped with it (Misra, 1958). Panickar (1960) reported higher profits when cowpea was used as an intercrop with sorghum.

Maturity and seed production in cowpea were affected under conditions of intercropping it in maize (Gautam et al., 1964). Reddy et al. (1965) found that cowpea when grown as an intercrop with castor, reduced the yield of the latter significantly. Cowpea, grown in the same row as

sugarcane or at 20 cm from it gave higher yields than grown at a greater distance. Cowpea yielded 520 kg/ha of seed and there was no bad effect on the main crop or vice versa (Krutman, 1968).

Singh and Sogani (1968) got higher yields by growing cowpea in association with jowar while Singh et al. (1969) and Singh and Mandal (1970) found that cowpea can be profitably grown as an intercrop with tapioca without much affecting the tuber yield. Saxena and Yadav (1971) observed no significant reduction in arhar yield by growing cowpea as an intercrop.

Cowpea as an intercrop reduced the tuber yield of tapioca significantly (Mohankumar and Krishi, 1973; Thamburaj and Muthukrishnan, 1976). Intercropping cowpea in cotton was found not profitable (Singh and Singh, 1973) whereas Dayal and Kale (1975) found no significant difference in the yield of cotton due to growing cowpea as an intercrop. Katyal and Dutta (1976) reported that growing cowpea in between tapioca rows did not affect the normal yield of the latter.

Intercropping of cowpea in arhar did not prolong the maturity of arhar but cowpea did not show any promise and reduced the net return by 16.8 per cent (Singh et al., 1976). Morachan et al. (1977) reported that cowpea as an

intercrop with sorghum did not affect the main crop yield and this practice fetched a net return of Rs.2003/ha compared to Rs.739/ha in sorghum alone.

(c) Greengram.

Misra (1958) reported the possibility of growing greengram in association with jowar and bajra. Mung when grown as an intercrop with hybrid maize did not affect the yield of maize (Gautam et al., 1964). Bains et al. (1970) reported mung as the most suitable intercrop with sugarcane which fetched an additional net return of Rs.698/ha.

From the trials conducted at I.A.R.I., New Delhi, it was found that an additional yield of 7.8 q/ha of pulse grain from mung could be obtained by intercropping with pigeon-pea, without any adverse effect on yield of the latter (Anon, 1971). Similar results were reported by Saxena and Yadav (1971).

Trials conducted at the I.R.R.I., Manila showed that the Philippine mung bean cv. MG-50-10A and CES-55 when intercropped with maize, did not affect the flowering time, but caused the plants to grow taller, to have heavier infestation of leaf diseases, to have fewer pods and to senesce earlier. Seed size was also reduced slightly (Anon., 1973). Singh and Singh (1973) found a slight

reduction in cotton yield when greengram cv.G-63 was grown as an intercrop.

Devotta and Choudappan (1975) reported an increase in the seed cotton yield when cotton cv.MCU-6 was intercropped with greengram. An additional income of about Rs.400-500/ha could be realised by intercropping greengram in arhar (Saraf et al., 1975). Intercropping mung in sugarcane did not show any visible repercussion on the productivity of sugarcane crop (Anon., 1976). Similar results were obtained by Dayanand and Goswami (1976).

Greengram as an intercrop in arhar did not prolong the maturity period of the latter (Singh et al., 1976). Morachan et al. (1977) found that growing greengram along with sorghum was profitable and did not affect the main crop yield.

(d) Groundnut.

Seshadri et al. (1956) reported that yield of groundnut was reduced when grown with cotton. But when the economics was worked out, the mixture gave the maximum returns. It was most profitable to raise groundnut as an intercrop with ragi than growing ragi alone (Pillai et al., 1957). Ghawghwar (1958) reported that groundnut and sorghum grown in alternate rows was more economical than pure crop.

Intercropping groundnuts in maize or sorghum resulted in higher yields than when either was grown alone. The presence of weeds in the row caused the same percentage reduction in yields of pure stands of groundnuts as when another crop was grown (Evans, 1960). Groundnut sown in alternate rows with castor reduced castor yield least when compared to other legumes (Reddy et al., 1965). Schilling (1965) reported that cereal yield was considerably higher with groundnut as intercrop.

An overall increase in profit inspite of a decrease in sugarcane yield due to groundnut intercropping was observed by Tse and Shive (1965). Singh and Mandal (1968), Singh et al. (1969) and Singh and Mandal (1970) found that groundnut grown with tapioca did not affect the latter much. On the contrary, Mohankumar and Krishi (1973) reported a significant reduction in tuber yield of tapioca by intercropping groundnut. However, they found from the economics of intercropping, that groundnut had recorded the maximum net return which was significantly more than all the crops tried.

Chandrasekharan et al. (1974) observed that groundnut when raised as intercrop with sesamum, reduced the yield of the latter. Groundnut could be intercropped in cotton in order to utilize the interspace area for economic return (Dayal and Kale, 1975).

Katyal and Dutta (1976) reported that groundnut when grown with tapioca did not affect the normal yield of the latter. On the other hand, Thamburaj and Muthukrishnan (1976) noted a significant reduction in the yield of tapioca by groundnut intercropping.

VII. Effect of fertilizer application to the intercrops.

When cowpea was intercropped in maize, the nitrogen dose could be reduced from 300 to 50 kg of ammonium sulphate, whereas an additional dose of 188 kg superphosphate per hectare was required to get better yields from both the main and intercrops (Bains, 1961). Francis and Dover (1965) reported that the losses caused in the yield of cereals due to intercropping could be minimised by applying nitrogen to the intercrops. The grain yield of rye grown as an intercrop with bermuda grass, increased with increased nitrogen application to the former (Welch et al., 1967).

Bains et al. (1970) observed that there was no need of additional fertilizers for the short duration intercrops such as mung, urd, cowpea etc. when grown with sugarcane. The intercrops matured with the fertilizers and irrigation applied to the main crop. Maize intercropped with legumes gave no response to application of nitrogen upto 50 kg/ha. Maize with legumes but no fertilizers yielded almost as

well as maize grown with fertilizers but no legumes (Agboola and Fayemi, 1971).

The need of additional fertilizers for the intercrops, in order to get economic yields from arhar mixed with cowpea, mung and groundnut, was stressed by Saxena and Yadav (1972). Singh et al. (1972) recommended the same fertilizer dose for intercrops as was used for the respective pure crops. Higher phosphate level to the leguminous intercrops in maize increased the gross and net income over lower dose (Sobti and Saine, 1972).

Mohankumar and Krishi (1973) reported that application of fertilizers to both the main as well as intercrops produced higher yield which was significantly superior to application of fertilizers to main crop only. Separate application of fertilizers was required for chillies when it was grown as an intercrop with cotton (Sheelavanthar et al., 1974). But Meenakshi et al. (1975) observed that there was no need of extra fertilizers for the short duration vegetables like bhindi, cowpea, radish, cluster bean, beetroot, carrot etc., when grown as intercrops with maize. They applied the recommended dose of fertilizers for the maize crop only.

The effects of intercropping in sugarcane with extra dose of fertilizers to the potato intercrop was studied by

Akhade et al. (1975). They found that application of fertilizer to the intercrops was beneficial as compared to no fertilizer to the intercrops. The additional quantity of fertilizers to intercrops in order to get profitable returns from the intercropping system was also stressed by Devotta and Choudappan (1975). Dayal and Kale (1975) found no beneficial effect by application of additional fertilizers to the intercrops.

Growing one row of greengram either with or without extra dose of fertilizers did not adversely affect the sugarcane yield; rather, 30 to 40 q/ha more yield of sugarcane was obtained in addition to 4 q/ha of greengram. However, two rows of greengram without extra fertilizer reduced the yield of sugarcane which could be sustained by the application of extra fertilizer to greengram, which gave additional grain yield of 6.3 q/ha (Dayanand and Goswami, 1976).

VIII. Effect of intercropping on the fertility status of the soil.

Mirchandani et al. (1958) observed that blackgram was grown as an intercrop in the Damodar Valley area to reduce soil loss. It was also grown as an intercrop in various parts of India to improve soil fertility (Misra, 1958). Roy and Sahani (1969) and Singh (1969) noted that

greengram when grown as intercrop not only increased the monetary return but also left behind a reserve of nitrogen for the use of the succeeding crop.

Groundnut and cowpea as intercrops with tapioca enriched the soil fertility by adding nitrogen through the organic matter added to the soil (Singh et al., 1969). Bhagyaraj and Chalapathy (1970) found that growing of potatoes in association with sorghum resulted in small increases of bacterial population and reduced actinomycetes and azetobacter population. The beneficial effects of cowpea as an intercrop with maize in reducing losses of water, soil, nitrogen and phosphorus in Udaipur were reported by Jain and Jain (1971).

Groundnut helped to cover the soil and prevented run off in slopes when grown with shallow rooted and low water requiring short duration crops like jowar or bajra (Lakshminarayana and Reddy, 1972). Thosar and Mahalle (1973) found that soil fertility was increased without loss of crop by intercropping Phaseolus mungo as a green manure crop in sorghum and by ploughing at the flowering stage.

Morachan et al. (1977) observed a reduction of 30 kg/ha in the nitrogen requirement for sorghum when intercropped with pulses, thus saving an appreciable amount

in the fertiliser cost. They also found a slight increase in total and available nitrogen content of the soil due to legume intercropping.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was undertaken to find out the comparative performance of tapioca with four different leguminous intercrops namely blackgram, cowpea, greengram and groundnut with and without fertilizer application to the intercrops. The legumes were grown in between tapioca rows.

Experimental site

The experiment was carried out in the Instructional Farm attached to the College of Agriculture, Vellayani. The soil of the experimental area was red loam. The chemical analysis of the soil before starting the experiment was as follows:

pH	- 5.00
Total nitrogen	- 0.045%
Available nitrogen	- 0.0046%
Total P_2O_5	- 0.115%
Available P_2O_5	- 0.00146%
Total K_2O	- 0.078%

Season

The experiment was conducted during the period from May 1977 to March 1978. All the crops were raised as rainfed.

Weather conditions

The maximum and minimum temperature, rainfall and relative humidity during the entire crop period were recorded from the meteorological observatory of the Farm and presented as weekly averages in Appendix I.

Cropping history

The experimental area way lying fallow for the previous 3 months and before that vegetables were raised.

Planting materials

Tapioca

The variety used was M-4, an introduction from Malayasia. It is a tall-growing, non-branching variety with moderate yields and matures in ten months. It shows resistance to mosaic disease and produces medium sized tubers with low HCN content. The planting material required for this investigation was obtained from the College Farm.

Blackgram

Blackgram CO-2, a short duration variety with lesser foliage due to determinate growth habit and which has 2-3 productive branches and fair amount of tolerance to pests and diseases was used. This variety has also got uniform maturity due to synchronised flowering. There was

also no tendril formation.

Cowpea

The variety of cowpea used was PLS-370 which was short in stature and semi-spreading. It was a vegetable cum grain variety with a high yield potential and comes to harvest in 70 to 80 days. The green pods as vegetables would be ready for picking in 60 days. The variety was photoinsensitive.

Greengram

Greengram CO-2, the variety under study, was a short duration one, maturing in 65 to 75 days. The plants were short with erect habit. It has got 80% synchronous fruiting and could be harvested in two pickings. The variety was photoinsensitive and suited for companion cropping.

Groundnut

TMV-2, a short duration high yielding variety with a bunch type habit, was used. It was also photoinsensitive and comes to harvest in 110 to 115 days.

The planting material required for all the four leguminous intercrops for this study was obtained from the Pulses and Oilseeds Research Station, Coimbatore.

Fertilizers and manures

Ammonium sulphate analysing 20.1 per cent N, superphosphate analysing 16 per cent P_2O_5, muriate of potash analysing 60 per cent K_2O and farm yard manure (dry basis)

analysing 0.46 per cent N, 0.3 per cent P_2O_5 and 0.27 per cent K_2O were used.

Experimental details

The treatments consisted of tapioca alone and tapioca with four intercrops at three different fertiliser combinations.

Crops

T	=	Tapioca
B	=	Blackgram
C	=	Cowpea
G	=	Greengram
Gn	=	Groundnut

Fertiliser combinations for the interorops

		N	P	K
Blackgram, Cowpea, Greengram	m1 =	0	0	0
	m2 =	10	15	5
	m3 =	20	30	10
Groundnut	m1 =	0	0	0
	m2 =	10	15	20
	m3 =	20	30	40

Treatments

T1 = T - Tapioca alone

T2 = T + Bm1 = Tapioca + Blackgram (0:0:0)

LAY OUT PLAN – RANDOMISED BLOCK DESIGN

← 6.3 M →

↓ 4.5 M

REP. I

REP. II

REP. III

T + G m_1	T + B m_1	T	T + B m_2	T + B m_3	T + G m_3	T + C m_1
T + G m_2	T + C m_3	T + Gn m_2	T + Gn m_1	T + Gn m_3	T + C m_2	
T + B m_2	T + C m_1	T + G m_1	T + G m_3	T + G m_2	T	T + C m_3
T + B m_1	T + B m_3	T + Gn m_3	T + Gn m_1	T + C m_2	T + Gn m_2	
T + Gn m_3	T + C m_3	T + B m_3	T + Gn m_2	T + Gn m_1	T + C m_2	T + C m_1
T + B m_1	T + B m_2	T + G m_3	T	T + G m_2	T + G m_1	

T – TAPIOCA.

INTERCROPS

B – BLACKGRAM.
C – COWPEA.
Gn – GROUNDNUT.
G – GREENGRAM.

FERTILISERS TO INTERCROPS

m_1 – NO. FERTILISER.
m_2 – ½ RECOMMENDED DOSE.
m_3 – FULL RECOMMENDED DOSE

FIG: 1.

T3 = T + Bm2 = Tapioca + Blackgram (10:15:5)

T4 = T + Bm3 = Tapioca + Blackgram (20:30:10)

T5 = T + Cm1 = Tapioca + Cowpea (0:0:0)

T6 = T + Cm2 = Tapioca + Cowpea (10:15:5)

T7 = T + Cm3 = Tapioca + Cowpea (20:30:10)

T8 = T + Gm1 = Tapioca + Greengram (0:0:0)

T9 = T + Gm2 = Tapioca + Greengram (10:15:5)

T10 = T + Gm3 = Tapioca + Greengram (20:30:10)

T11 = T + Gnm1 = Tapioca + Groundnut (0:0:0)

T12 = T + Gnm2 = Tapioca + Groundnut (10:15:20)

T13 = T + Gnm3 = Tapioca + Groundnut (20:30:40)

Layout and design

The experiment was laid out in Randomised Block Design with three replications. The layout plan of the experiment is shown in Fig.1.

Spacing and plot size

A spacing of 90 cm x 90 cm was given for tapioca. The gross plot size was 6.3 m x 4.5 m and net plot size was 4.5 m x 2.7 m with 35 plants per gross plot and 15 plants per net plot.

The intercrops were sown in two rows at a spacing of 15 cm x 15 cm in between the tapioca mounds.

Details of cultivation

Land preparation.

The experimental area was dug twice, stubbles were removed, clods were broken and the field was laid out into blocks and plots. Mounds were raised at a distance of 90 cm on both ways. Lime at the rate of 1 t/ha in the form of $CaCO_3$ was applied at the time of land preparation and well incorporated into the soil.

Manuring

An uniform basal dose, at the rate of 12.5 t/ha of farm yard manure was applied and well incorporated into the field.

Fertilizer application

Tapioca.

An uniform dose of 50 kg N, 50 kg P_2O_5 and 50 kg K_2O/ha was applied to the main crop tapioca. The different nutrients were supplied in the form of ammonium sulphate, superphosphate and muriate of potash respectively. Half the dose of N and full dose of P and K were applied as basal. The remaining half N was applied as top dressing in bands on the sides of the mounds 120 days after planting.

Intercrops.

For blackgram, cowpea and greengram three different NPK combinations were given to each namely 0:0:0, 10:15:5

and 20:30:10 kg/ha in the form of ammonium sulphate, superphosphate and muriate of potash respectively. The fertilisers were applied as basal in lines in between the tapioca mounds.

For groundnut the fertiliser combinations were 0:0:0, 10:15:20 and 20:30:40 kg/ha of N, P and K respectively. The fertilisers were applied as in the case of other intercrops.

Planting.

Planting of tapioca as well as the sowing of intercrops was done on 24-5-1977. Tapioca setts of 20 cm length were planted on the top of the mounds inserting 4 cm below soil. The seeds of intercrops were sown at the rate of 2 to 3 seeds/hole. The seeds were pressed in the soil by hand to a depth of 1.5 cm and covered with soil.

After cultivation.

Germination of setts was satisfactory. Ungerminated setts were replaced by fresh setts one week after planting. Excess sprouts were removed after retaining one healthy and vigorous sprout. Germination of the intercrops was good. On seventh day after sowing, thinning and gap filling were done.

The first earthing up for tapioca was given on 12-9-1977 along with the top dressing of N. A light raking and weeding was given on 24-10-1977. The crop received

one more earthing up on 24-11-1977. The soil was slightly stirred in groundnut plots at 3 weeks after sowing.

Plant protection

Prophylactic sprayings of 0.1 per cent Ekalux and 1 per cent Bordeaux mixture were given to the intercrop on 25-6-1977. There was no incidence of any pest or disease.

Harvest.

Cowpea and greengram were harvested on 1-8-1977, blackgram on 6-8-1977 and groundnut on 10-9-1977. The haulms were allowed to decompose and incorporated into the soil in situ. The main crop tapioca was harvested on 24-3-1978, ten months after planting. The plants selected for biometric studies were harvested on 23-3-1978 and necessary observations recorded.

Observations recorded

Main crop (Tapioca)

Sampling techniques for biometric studies

Three plants standing diagonally in the same direction were selected at random from each plot for taking the observations. Averages of the observations were used for statistical analysis.

Growth characters

(a) Number of leaves per plant.

The total number of leaves was recorded by counting

the number of fully opened leaves as well as the leaf scars from the base to the tip of the stem on the shoot. This observation was recorded at monthly interval from the first month after planting to harvest.

(b) Height of plant

Cumulative height of the shoot of each plant, including branches, was measured from the base of the sprouts to the top of the unopened bud at monthly interval starting from the first month after planting to harvest.

Yield attributes and yield

(a) Total number of roots per plant.

The total number of roots including productive and unproductive ones were recorded.

(b) Number of tubers per plant.

The total number of fully developed tubers from the net plot was recorded and average per plant worked out.

(c) Percentage of productive roots.

The percentage of productive roots in each plot was worked out using the number of tubers per plant and corresponding total number of roots per plant.

(d) Length of tubers.

The average length of tuber was worked out by measuring the length of medium sized tubers from the observation plants and expressed in cms.

(e) Girth of tubers.

Girth measurements were recorded from the same tubers that were used for length measurements. Girth values were recorded at three places, one at the centre, and the other two at half way between the centre and both ends of the tubers. The average was taken as the tuber girth and expressed in cms.

(f) Rind to flesh ratio.

A random sample of fresh tubers were taken from each plot. The tubers were peeled and the rind weight and flesh weight were found separately. Then the rind to flesh ratio was worked out.

(g) Percentage of edible portion.

A random sample of fresh tubers (1000 g) were weighed from each plot. The tubers were peeled, the weight of fleshy edible portion recorded and expressed as percentage on the total weight of the tubers.

(h) Tuber yield.

After the harvest of the plants, the yield of tuber per net plot was recorded after removing the soil adhering to the tubers and converted to tonnes of tubers per hectare.

(i) Top yield.

The total weight of the stem and leaves of the plants per net plot was recorded at the time of harvest and converted to tonnes per hectare.

(j) Utilization index.

This is the ratio of the tuber weight to top (stem and leaves) weight and is an important yield determinant (Obigbesan, 1973). This was found out from the three observation plants and averaged.

Quality attributes

(a) Dry matter content of tuber flesh.

Uniform quantity of flesh from the tubers were taken from each plot and chopped into small pieces and dried to constant weight in an air oven at 105°C. The weight of the dry matter obtained was expressed as percentage of the fresh weight (A.O.A.C., 1969).

(b) Starch content of tubers.

Starch content of the flesh was estimated by using Potassium ferricyanide method (Ward and Pigman, 1970). The values were expressed as percentage of the fresh weight.

(c) Crude protein content of tubers.

The total nitrogen of oven dried samples from each plot was estimated using Modified microkjeldahl method (Jackson, 1964). The nitrogen values were multiplied by the factor 6.25 to get the crude protein content of the tubers (A.O.A.C., 1969).

(d) Hydrocyanic acid content of tubers.

The hydrocyanic acid (HCN) content of fresh tuber

samples were estimated by calorimetric method suggested by Indira and Sinha (1969) and expressed in mg per kg of fresh tuber.

(e) Cooking quality.

Cooking quality of the tubers was assessed by judging the bitterness. The sensory method of analysis by a taste panel was used in differentiating cooking quality (Jellinek, 1964). Since the sensitivity in taste determination test is likely to be affected by increasing the number of samples, only five treatments (Tapioca with no intercrop, tapioca with blackgram, tapioca with cowpea, tapioca with greengram and tapioca with groundnut) were tested for cooking quality (Prema et al., 1975).

Fresh tubers from the above five treatments were combined over replications. A random sample of about 3 kg of fresh tubers was taken from each of the five treatments. These samples were used for quality evaluation test. The samples were derinded, cut into pieces of 5 to 8 cm long, washed clean and cooked in five different earthern pots till the flesh became soft.

The members of the taste panel were served with samples in random order. Taste was assessed on a discrete scale. The best taste was described as sweet and was allotted a score of (2). The other scores in the decreasing

order of taste were watery sweet (1), starchy (0), bitter (-1) and watery bitter (-2). The results were statistically analysed.

Intercrops.

For recording growth and yield observations, ten plants of each intercrop from each plot was selected randomly and observations recorded. The average of the observations was used for statistical analysis.

Observations.

(a) Height of plant at harvest.

In the intercrops, the height of plant was recorded on the day of harvest. The height was measured from the base of the plant to the growing tip of the tallest branch and expressed in cm.

(b) Seed yield.

The seed yield from each plot was recorded and converted to yield in kg/ha.

(c) Weight of organic matter (haulms).

The weight of the haulms in each of the observation plant was recorded, averaged and converted to kg/ha.

(d) Amount of nitrogen incorporated into the soil by haulm.

The amount of nitrogen incorporated into the soil by means of haulms of the legumes in each treatment was

found out using the corresponding dry matter percentage and total nitrogen percentage of the plant sample. The dry matter percentage was worked out using the A.O.A.C. (1969) method and the total nitrogen percentage was found out by Modified microkjeldahl method (Jackson, 1964).

(e) Response curve and economics of fertilizer application.

Quadratic response curves were fitted to the yield data of intercrops obtained from the three fertilizer levels m1, m2 and m3 (F.A.O. 1966). The optimum and economic doses of fertilizers were worked out from the response curve. Using the expected yield at different combinations the economics of fertilizer application was worked out.

Soil chemical analysis

Soil samples.

Soil samples were taken from each plot before starting the experiment and analysed for total and available N, P_2O_5 and K_2O and pH.

Soil samples from each plot were taken after the experiment and analysed for total nitrogen using the Modified microkjeldahl method (Jackson, 1964) and compared.

Statistical analysis

Statistical analysis of the data was performed by using the analysis of variance technique suggested by Snedecor and Cochran (1967).

RESULTS

RESULTS

The observations recorded were statistically analysed and the analysis of variance tables are given in Appendices II to XI and the meteorological data are given in Appendix I. The mean values of observations are given in Tables 1 to 25 and the results are presented below.

TAPIOCA

Growth characters

(a) Number of leaves.

The mean values of the observation are given in Table 1 and the analysis of variance table in Appendix II.

From the results it is seen that there was no significant difference between the treatments with respect to the number of leaves throughout the stages of growth as well as at the time of harvest. It is observed that maximum number of leaves was recorded by pure crop of tapioca followed by intercropping with greengram, cowpea, blackgram and groundnut, at the time of harvest.

(b) Height of plant.

The mean height of plants as influenced by the treatments is presented in Table 2 and the analysis of variance table in Appendix III.

Table 1. Effect of intercropping on number of leaves per plant at different stages of growth in tapioca

Stage of growth (days after planting)	Treatments													F test	S.Em.
	T	T+Bm1	T+Bm2	T+Bm3	T+Cm1	T+Cm2	T+Cm3	T+Gm1	T+Gm2	T+Gm3	T+Gnm1	T+Gnm2	T+Gnm3		
30	15.9	13.4	14.1	13.3	14.1	13.2	13.5	13.2	13.9	13.6	13.0	13.8	14.8	N.S.	0.79
60	30.6	27.4	30.3	28.2	28.6	28.2	27.2	23.3	29.2	26.7	27.6	29.3	30.9	N.S.	1.25
90	51.6	41.8	48.0	46.9	45.3	40.0	44.1	39.8	49.1	46.7	41.1	41.3	49.0	N.S.	2.79
120	85.8	72.4	79.7	78.4	79.8	72.3	74.2	74.3	84.8	86.3	68.8	74.0	84.2	N.S.	4.96
150	124.1	97.6	114.5	100.4	113.8	96.2	103.1	98.2	119.2	116.9	98.5	96.3	122.0	N.S.	8.62
180	172.8	123.1	144.0	134.0	153.8	127.0	126.7	112.1	155.4	161.8	124.4	126.6	145.4	N.S.	15.01
210	219.9	150.9	172.6	161.0	204.7	158.7	165.0	134.5	199.9	220.3	158.8	153.1	184.0	N.S.	20.98
240	230.2	161.0	192.7	171.0	214.4	169.0	174.9	144.6	209.6	230.4	168.8	163.0	194.0	N.S.	20.93
270	237.2	167.7	223.2	178.2	221.4	175.6	181.9	151.2	216.7	236.3	175.9	169.7	200.7	N.S.	21.13
At harvest	241.3	171.7	226.6	182.1	225.2	179.8	185.5	155.2	220.4	240.2	180.2	174.3	204.8	N.S.	21.00

T = Tapioca B = Blackgram C = Cowpea G = Greengram Gn = Groundnut
N.S. = Not significant

		N	P_2O_5	K_2O kg/ha
Blackgram Cowpea Greengram	m1	0	0	0
	m2	10	15	5
	m3	20	30	10

		N	P_2O_5	K_2O kg/ha
Groundnut	m1	0	0	0
	m2	10	15	20
	m3	20	30	40

Table 2. Effect of intercropping on height of plants (cm) at different stages of growth in tapioca

Stage of growth (days after planting)	Treatments													F test	S.Em
	T	T+Bm1	T+Bm2	T+Bm3	T+Cm1	T+Cm2	T+Cm3	T+Gm1	T+Gm2	T+Gm3	T+Gnm1	T+Gnm2	T+Gnm3		
30	23.6	20.4	21.2	19.3	19.7	16.0	18.7	16.3	17.2	20.2	18.3	18.4	20.7	N.S.	1.48
60	56.0	49.9	52.2	51.1	44.5	41.0	47.2	43.7	49.6	45.0	45.1	50.8	53.9	N.S.	3.71
90	76.3	62.7	66.6	66.4	58.0	53.6	60.1	58.0	67.1	64.5	54.2	57.9	68.5	N.S.	4.86
120	104.0	87.6	94.4	92.2	89.0	81.1	90.0	94.2	93.8	95.2	72.8	82.1	85.5	N.S.	6.97
150	192.6	142.4	163.1	152.8	169.5	135.3	146.4	121.6	176.0	126.8	170.2	135.0	135.9	N.S.	14.74
180	214.9	164.9	185.9	172.7	201.0	156.8	158.1	142.8	203.0	203.7	147.4	161.1	190.7	N.S.	38.17
210	343.7	198.2	255.7	237.6	302.1	232.8	242.0	179.1	301.4	318.0	204.8	218.3	266.0	N.S.	37.92
240	363.4	218.6	271.5	257.7	322.0	251.9	262.0	199.3	321.0	339.8	225.0	237.9	286.3	N.S.	37.54
270	373.3	229.0	281.8	267.5	331.5	262.3	272.0	209.5	330.8	347.8	235.4	248.2	296.0	N.S.	37.44
At harvest	378.4	234.1	286.9	272.7	336.6	267.4	277.0	214.6	335.8	350.9	240.5	252.8	300.3	N.S.	37.28

T = Tapioca B = Blackgram C = Cowpea G = Greengram Gn = Groundnut
N.S. = Not significant

		N	P_2O_5	K_2O kg/ha
Blackgram, Cowpea, Greengram	m1	0	0	0
	m2	10	15	5
	m3	20	30	10

		N	P_2O_5	K_2O kg/ha
Groundnut	m1	0	0	0
	m2	10	15	20
	m3	20	30	40

The results showed no significant difference between the treatments with regard to the height of tapioca plants. However, it was observed that pure crop of tapioca recorded maximum height when compared to the intercropped treatments.

Yield attributes and yield

(a) Total number of roots per plant.

The mean values of the observation are presented in Table 3 and the analysis of variance table in Appendix IV.

It is seen from the results that there was no significant difference between treatments with respect to the total number of roots per plant. Among the intercrops groundnut recorded the highest number of tapioca roots per plant followed by blackgram, greengram and cowpea.

(b) Number of tubers per plant.

The mean number of tubers per plant is given in Table 4. and the analysis of variance table in Appendix IV.

It is seen from the data that the treatments differed significantly in their effect on the number of tubers per plant. Pure crop of tapioca was on par with the groundnut intercrop receiving the highest fertilizer dose (m3) with respect to the number of tubers per plant. However, the other intercrops at all their fertilizer combinations showed a significantly lower number of tubers

Table 3. Effect of intercropping on total number of roots per plant in tapioca

Treatment	Intercrops				No intercrop
	Blackgram	Cowpea	Greengram	Groundnut	
m1	29.4	30.6	27.1	30.6	-
m2	26.3	26.7	27.6	28.4	-
m3	31.6	25.8	29.4	32.3	-
Mean	29.1	27.7	28.0	30.4	27.3

Table 4. Effect of intercropping on number of tubers per plant in tapioca

Treatment	Intercrops				No intercrop
	Blackgram	Cowpea	Greengram	Groundnut	
m1	6.7	7.4	7.9	8.9	-
m2	7.3	7.4	7.3	7.7	-
m3	9.9	7.0	8.6	11.0	-
Mean	8.1	7.3	7.9	9.2	15.5

C.D. (0.05) for comparison between treatments = 2.868

C.D.(0.05) for comparison between intercrops and pure tapioca = 2.342

C.D.(0.05) for comparison between intercrops = 1.656

		N	P_2O_5	K_2O kg/ha
Blackgram, Cowpea, Greengram	m1	0	0	0
	m2	10	15	5
	m3	20	30	10
Groundnut	m1	0	0	0
	m2	10	15	20
	m3	20	30	40

per plant as compared to the pure crop of tapioca. Blackgram, greengram, and cowpea were on par in their effect on the number of tubers per tapioca plant.

In all the intercrops the highest fertilizer dose (m3) gave the maximum number of tubers per plant except in cowpea wherein the middle dose (m2) gave the maximum number of tubers per plant.

(c) Percentage of productive roots.

The mean values of the observation are given in Table 5 and the analysis of variance table in Appendix IV.

The results showed that there was significant difference between the treatments with regard to the percentage of productive roots in tapioca. Pure crop of tapioca recorded the highest percentage of productive roots which was significantly higher than all other intercropped treatments.

Among the intercropped plots there was not much difference in the percentage of productive roots. But the plots with groundnut as intercrop at the highest fertilizer dose (m3) recorded the next highest percentage of productive roots after pure crop of tapioca. All the intercrops except cowpea recorded the maximum percentage of productive roots at the highest fertilizer dose of m3.

Table 5. Effect of intercropping on percentage of productive roots in tapioca

Treatment	Intercrops				No intercrop
	Blackgram	Cowpea	Greengram	Groundnut	
m1	23.4	24.5	29.1	29.1	-
m2	30.9	26.9	26.4	26.5	-
m3	32.1	26.4	29.3	35.2	-
Mean	28.8	25.9	28.3	30.3	50.3

C.D.(0.05) for comparison between treatments = 10.370
C.D.(0.05) for comparison between intercrops and pure tapioca = 8.469
C.D.(0.05) for comparison between intercrops = 5.989

Table 6. Effect of intercropping on length of tubers (cm)

Treatment	Intercrops				No intercrop
	Blackgram	Cowpea	Greengram	Groundnut	
m1	24.2	25.6	22.6	22.8	-
m2	25.7	22.9	25.0	25.2	-
m3	23.3	25.4	24.7	25.1	-
Mean	24.4	24.6	24.1	24.4	24.5

		N	P_2O_5	K_2O kg/ha
Blackgram, Cowpea, Greengram	m1	0	0	0
	m2	10	15	5
	m3	20	30	10
Groundnut	m1	0	0	0
	m2	10	15	20
	m3	20	30	40

(d) Length of tubers.

The mean length of the tubers is given in Table 6 and the analysis of variance table in Appendix IV.

There was no significant difference in the length of tubers between treatments. However, most of the intercropped plots recorded a slightly higher length of tubers.

(e) Girth of tubers

The mean girth of tubers is presented in Table 7 and the analysis of variance table in Appendix IV.

There was no significant difference between the treatments with regard to the tuber girth. However, all the intercropped plots recorded a slightly higher girth for the tubers as compared to the pure crop of tapioca.

Among the intercrops blackgram recorded the maximum girth for the tubers followed by greengram, cowpea and groundnut.

In all the intercrops except cowpea, the highest fertilizer dose (m3) given to intercrops recorded the maximum girth as compared to the middle (m2) and lower (m1) doses.

(f) Rind to flesh ratio.

The results of the observations are presented in Table 8 and the analysis of variance table in Appendix V.

Table 7. Effect of intercropping on girth of tubers (cm)

Treatment	Intercrops				No intercrop
	Blackgram	Cowpea	Greengram	Groundnut	
m1	10.9	10.2	10.4	10.1	-
m2	10.3	10.9	10.5	10.4	-
m3	11.3	10.3	11.1	10.4	-
Mean	10.8	10.5	10.7	10.3	9.9

Table 8. Effect of intercropping on rind to flesh ratio of tubers

Treatment	Intercrops				No intercrop
	Blackgram	Cowpea	Greengram	Groundnut	
m1	0.190	0.208	0.209	0.212	-
m2	0.199	0.210	0.205	0.188	-
m3	0.199	0.207	0.191	0.210	-
Mean	0.196	0.208	0.202	0.203	0.218

C.D.(0.05) for comparison between treatments = 0.0133
C.D.(0.05) for comparison between intercrops and pure tapioca = 0.0110
C.D.(0.05) for comparison between intercrops = 0.0077

		N	P_2O_5	K_2O kg/ha
Blackgram, Cowpea, Greengram	m1	0	0	0
	m2	10	15	5
	m3	20	30	10
Groundnut	m1	0	0	0
	m2	10	15	20
	m3	20	30	40

The treatments differed significantly in their effect on the rind to flesh ratio. Pure crop of tapioca recorded the highest ratio. The lowest ratio was recorded from the plots with groundnut as intercrop at the m2 level of fertilizers.

Pure crop of tapioca recorded significantly higher rind to flesh ratio than when it was intercropped with groundnut, greengram and blackgram. There was no significant difference between the pure crop of tapioca and intercropping it with cowpea as regard to the rind to flesh ratio.

The highest dose of fertilizers (m3) recorded the lowest ratio in cowpea and greengram whereas in groundnut the middle dose (m2) recorded the lowest rind to flesh ratio. In blackgram the rind to flesh ratio was not reduced by applying fertilizers to it.

(g) Percentage of edible portion.

The mean values of the observation are given in Table 9 and the analysis of variance table in Appendix V.

There was significant difference between the treatments in their effect on the percentage of edible portion in tubers. Pure crop of tapioca recorded the lowest percentage of edible portion and groundnut intercrop at m2 level of fertilizers recorded the highest

Table 9. Effect of intercropping on percentage of edible portion in tubers

	Intercrops				
Treatment	Blackgram	Cowpea	Greengram	Groundnut	No intercrop
m1	84.0	82.8	82.8	82.6	-
m2	83.5	82.7	83.0	84.2	-
m3	83.4	82.9	84.0	82.6	-
Mean	83.6	82.8	83.3	83.1	82.1

C.D.(0.05) for comparison between treatments = 0.938
C.D.(0.05) for comparison between intercrops and pure tapioca = 0.767
C.D.(0.05) for comparison between intercrops = 0.542

Table 10. Effect of intercropping on tuber yield (t/ha) of tapioca

	Intercrops				
Treatment	Blackgram	Cowpea	Greengram	Groundnut	No intercrop
m1	14.31	13.86	14.16	12.17	-
m2	18.66	14.87	16.57	14.31	-
m3	20.70	16.50	17.43	17.86	-
Mean	17.89	15.08	16.07	14.78	17.90

		N	P_2O_5	K_2O kg/ha
Blackgram, Cowpea, Greengram	m1	0	0	0
	m2	10	15	5
	m3	20	30	10
Groundnut	m1	0	0	0
	m2	10	15	20
	m3	20	30	40

percentage of edible portion.

Among the intercrops, blackgram, greengram and groundnut recorded significantly higher percentage of edible portion in tubers as compared to pure crop of tapioca. Cowpea was found to be on par with the pure crop of tapioca in this aspect. There was no significant difference between greengram, groundnut and cowpea in their effect on the edible portion in tapioca tubers.

The highest fertilizer dose (m3) recorded the maximum percentage of edible portion with cowpea and greengram whereas the middle dose (m2) recorded the maximum percentage of edible portion with groundnut intercrop. In blackgram the percentage of edible portion was not increased by applying fertilizers to it.

(h) Tuber yield.

The mean tuber yield per hectare is given in Table 10 and the analysis of variance table in Appendix V.

There was no significant difference in tuber yield between the treatments. However, intercropping with blackgram at m2 and m3 levels of fertilizers recorded a slightly higher tuber yield as compared to pure crop of tapioca. Intercropping of groundnut at m3 level of fertilizers gave a tuber yield which was almost equal to that obtained from pure crop of tapioca. The tuber yield

was found to increase with increased fertilizer application from m1 to m3, to the intercrops.

(i) Top yield.

The mean top yield per hectare is given in Table 11 and the analysis of variance table in Appendix V.

There was no significant difference between the treatments in their effect on the top yield. However, intercropping of groundnut at the m3 level of fertilizers recorded the maximum top yield. Intercropping of blackgram recorded the maximum top yield in tapioca among the intercrops followed by groundnut, greengram and cowpea.

The highest fertilizer dose (m3) recorded the maximum top yield of tapioca with blackgram and groundnut whereas the middle dose (m2) showed the maximum top yield with cowpea and greengram.

(j) Utilisation index.

The mean values of the observation are given in Table 12 and the analysis of variance table in Appendix V.

The results showed that there was no significant difference between treatments with respect to the utilization index. Among the intercrops blackgram recorded the highest utilization index followed by greengram, cowpea and groundnut. The highest fertilizer dose (m3) recorded maximum index with

Table 11. Effect of intercropping on top yield (t/ha) of tapioca

Treatment	Intercrops				
	Blackgram	Cowpea	Greengram	Groundnut	No intercrop
m1	6.21	6.03	5.73	5.58	-
m2	7.00	6.42	7.18	6.71	-
m3	8.10	5.69	6.80	8.15	-
Mean	7.10	6.05	6.57	6.18	7.61

Table 12. Effect of intercropping on utilization index of tapioca

Treatment	Intercrops				
	Blackgram	Cowpea	Greengram	Groundnut	No intercrop
m1	2.31	2.30	2.48	2.19	-
m2	2.66	2.33	2.39	2.13	-
m3	2.55	2.74	2.56	2.33	-
Mean	2.51	2.46	2.48	2.22	2.35

		N	P_2O_5	K_2O kg/ha
Blackgram, Cowpea, Greengram	m1	0	0	0
	m2	10	15	5
	m3	20	30	10
Groundnut	m1	0	0	0
	m2	10	15	20
	m3	20	30	40

cowpea, greengram and groundnut whereas in blackgram the middle dose (m2) recorded the maximum index.

Quality attributes

(a) Percentage of dry matter in tubers.

The mean dry matter percentage of tubers is given in Table 13 and the analysis of variance table in Appendix VI.

The treatments differed significantly in their effect on the dry matter percentage. The highest percentage of dry matter in tubers was recorded by groundnut and cowpea intercrops at their highest level of fertilizers (m3). The lowest percentage of dry matter in tubers was recorded by the pure crop of tapioca.

Among the intercrops groundnut recorded the highest percentage of dry matter in tubers which was significantly higher than that obtained from the blackgram intercrop as well as from the pure crop of tapioca. Greengram and cowpea were on par with groundnut in their effect on the dry matter percentage of tubers.

The highest fertilizer dose (m3) recorded the maximum dry matter percentage of tubers with greengram whereas the middle dose (m2) was found to record the maximum dry matter percentage of tubers with blackgram, cowpea and groundnut.

Table 13. Effect of intercropping on dry matter content (%) of tubers

Treatment	Intercrops				No intercrop
	Blackgram	Cowpea	Greengram	Groundnut	
m1	33.0	36.6	38.5	38.1	-
m2	36.7	40.2	38.5	40.2	-
m3	32.5	35.3	39.4	40.1	-
Mean	34.1	37.4	38.8	39.5	29.6

C.D.(0.05) for comparison between treatments = 3.88
C.D.(0.05) for comparison between intercrops and pure tapioca = 3.17
C.D.(0.05) for comparison between intercrops = 2.24

Table 14. Effect of intercropping on starch content (%) of fresh tubers

Treatment	Intercrops				No intercrop
	Blackgram	Cowpea	Greengram	Groundnut	
m1	28.8	30.0	28.4	25.8	-
m2	27.2	30.2	30.3	31.3	-
m3	23.9	29.5	29.3	32.5	-
Mean	26.6	29.9	29.3	29.9	21.1

C.D.(0.05) for comparison between treatments = 2.259
C.D.(0.05) for comparison between intercrops and pure tapioca = 1.840
C.D.(0.05) for comparison between intercrops = 1.301

		N	P_2O_5	K_2O kg/ha
Blackgram, Cowpea, Greengram	m1	0	0	0
	m2	10	15	5
	m3	20	30	10
Groundnut	m1	0	0	0
	m2	10	15	20
	m3	20	30	40

(b) Percentage of starch in tubers.

The mean values of the observation are given in Table 14 and the analysis of variance table in Appendix VI.

There was significant difference in the percentage of starch in tubers between the treatments. Intercropping of groundnut at the highest dose of fertilizers (m3) recorded the highest percentage of starch in tapioca tubers and the lowest percentage of starch was shown by the pure crop of tapioca.

Groundnut and cowpea were found to record the highest percentage of starch in tubers among the intercrops followed by greengram and blackgram. All the intercrops recorded significantly higher percentage of starch in tubers as compared to the pure crop of tapioca. Cowpea, groundnut and greengram were on par in their effect on starch percentage of tubers.

The highest fertilizer dose (m3) recorded the maximum starch content in tubers with groundnut whereas the middle fertilizer dose (m2) recorded the maximum starch content with cowpea and greengram. With blackgram, the starch content of tubers was not increased with fertilizer application.

(c) Percentage of crude protein in tubers.

The mean values of the observation are given in Table 15 and the analysis of variance table in Appendix VI.

There was no significant difference between treatments with regard to crude protein content of the tubers. However all the four intercrops recorded a slightly higher crude protein content in tapioca tubers as compared to the pure crop of tapioca. Intercropping of groundnut recorded the highest percentage of crude protein in tapioca tubers among the four legumes.

(d) Hydrocyanic acid content of tubers.

The mean values of the observation are presented in Table 16 and the analysis of variance table in Appendix VI.

The treatments differed significantly in their effect on the hydrocyanic acid content of tubers. The maximum hydrocyanic acid content was recorded from the plots with groundnut as intercrop at the lowest level of fertilizers (m1) which was significantly higher than all other treatments. The lowest hydrocyanic acid content was shown by blackgram intercrop at the m2 level of fertilizers.

Among the intercrops groundnut recorded the highest content of hydrocyanic acid in tapioca tubers which was significantly higher than that recorded by all other intercrops as well as by pure crop of tapioca. Cowpea and

Table 15. Effect of intercropping on crude protein content (%) of tubers

Treatment	Intercrops				No intercrop
	Blackgram	Cowpea	Greengram	Groundnut	
m1	2.58	2.17	2.38	2.58	-
m2	2.43	2.35	2.48	2.44	-
m3	2.49	2.96	2.35	2.52	-
Mean	2.50	2.49	2.40	2.51	2.32

Table 16. Effect of intercropping on HCN content (mg/kg) of tubers

Treatment	Intercrops				No intercrop
	Blackgram	Cowpea	Greengram	Groundnut	
m1	37.0	54.0	44.7	91.1	-
m2	24.7	51.7	47.3	47.7	-
m3	59.7	41.0	41.5	59.4	-
Mean	40.5	48.9	44.5	66.1	40.5

C.D.(0.05) for comparison between treatments = 7.79
C.D.(0.05) for comparison between intercrops and pure tapioca = 6.36
C.D.(0.05) for comparison between intercrops = 4.50

		N	P_2O_5	K_2O kg/ha
Blackgram, Cowpea, Greengram	m1	0	0	0
	m2	10	15	5
	m3	20	30	10
Groundnut	m1	0	0	0
	m2	10	15	20
	m3	20	30	40

greengram, greengram and blackgram and blackgram and pure crop of tapioca did not show any significant difference between them with respect to the hydrocyanic acid content of tubers.

The highest fertilizer dose (m3) recorded the lowest hydrocyanic acid content of tubers with cowpea and greengram whereas the middle dose (m2) recorded the lowest hydrocyanic acid content with blackgram and groundnut.

(c) Cooking quality of tubers.

The summary scores obtained in the organo-leptic test is given in Table 17 c and the mean scores in Table 17 b and the analysis of variance table in Appendix VII.

There was no significant difference between the treatments. All the legumes reduced the cooking quality of tubers, though not significantly as compared to pure crop of tapioca. Among the intercrops groundnut reduced the cooking quality of tubers most and blackgram least. Groundnut, cowpea and greengram were on par in their effect on the cooking quality of tubers. Blackgram and greengram were also on par in their effect on the cooking quality.

Total nitrogen content of the soil after the experiment.

The mean values of the total nitrogen content of the soil in kg/ha, after the experiment, are given in Table 18 and the analysis of variance table in Appendix VI.

Table 17a. Summary scores obtained in the organoleptic test of tapioca tubers

Treatment	Intercrops					Total
	Black-gram	Cow-pea	Green-gram	Groundnut	No inter-crop	
Sweet (2)	3	2	3	2	5	15
Watery sweet (1)	4	4	3	5	4	20
Starchy (0)	4	5	5	4	2	20
Bitter (-1)	-	-	-	-	-	-
Watery bitter (-2)	-	-	-	-	-	-
Total	11	11	11	11	11	55

Table 17b. Mean scores obtained in the organoleptic test of tapioca tubers

Treatment	Intercrops				No inter-crop
	Black-gram	Cowpea	Greengram	Groundnut	
Mean	0.91	0.73	0.82	0.82	1.27

The treatments differed significantly in their effect on the total nitrogen content of the soil after the experiment. The plots with groundnut as intercrop at m3 level of fertilizers recorded the maximum amount of total nitrogen in the soil (1336.5 kg/ha). The pure crop of tapioca recorded the lowest amount of total nitrogen in the soil (1003.5 kg/ha).

The highest dose of fertilizers (m3) recorded the maximum amount of total soil nitrogen in all the four leguminous crops.

Intercrops

(a) Height of plant at harvest.

The result of the observation is given in Table 19 and the analysis of variance table in Appendix VIII.

It is observed that in blackgram, cowpea and greengram, the treatment m3 has recorded maximum height followed by m2 and m1 which were all significantly different from one another.

In groundnut m2 has recorded maximum height and was found to be on par with m3. The height was significantly lower with m1 as compared to m2 and m3.

(b) Seed yield.

The mean values of the observation are given in Table 20 and the analysis of variance table in Appendix IX.

Table 18. Effect of intercropping on total nitrogen content (kg/ha) of soil

Treatment	Intercrops				No inter-crop
	Blackgram	Cowpea	Greengram	Groundnut	
m1	1234.5	1237.5	1236.8	1246.5	-
m2	1239.0	1307.3	1241.3	1323.0	-
m3	1239.0	1311.8	1287.0	1336.5	-
Mean	1237.5	1285.5	1255.0	1302.0	1003.5

C.D.(0.05) for comparison between treatments = 73.36
C.D.(0.05) for comparison between intercrops and pure tapioca = 59.90
C.D.(0.05) for comparison between intercrops = 42.35

Table 19. Mean height of plants (cm) at harvest (intercrops)

Treatment	Blackgram	Cowpea	Greengram	Groundnut
m1	31.10	71.37	21.63	53.50
m2	42.83	108.63	33.93	62.57
m3	55.57	131.47	45.90	60.73
C.D.(0.05)	3.13	10.37	5.12	4.91

		N	P_2O_5	K_2O kg/ha
Blackgram, Cowpea, Greengram	m1	0	0	0
	m2	10	15	5
	m3	20	30	10
Groundnut	m1	0	0	0
	m2	10	15	20
	m3	20	30	40

In blackgram m3 has recorded the highest seed yield followed by m2 and m1 which were all significantly different from one another.

In cowpea, greengram and groundnut, eventhough m3 gave the maximum seed yield, it was found to be on par with m2, both being significantly superior to m1.

(c) Organic matter (haulm) yield.

The mean values of the observation are presented in Table 21 and the analysis of variance table in Appendix X.

It was observed that in blackgram and greengram, m3 recorded significantly higher organic matter (haulm) yield followed by m2 and m1.

In cowpea and groundnut m3 gave the maximum organic matter (haulm) yield which was on par with m2, both being significantly superior to m1.

(d) Amount of N incorporated by haulms.

The mean values of the observation are given in Table 22 and the analysis of variance table in Appendix XI.

It was seen that in blackgram the treatment m3 recorded the maximum amount of nitrogen incorporated into the soil followed by m2 and m1, all the three being significantly different from one another.

In cowpea, greengram and groundnut m3 recorded the

Table 20. Seed yield of intercrops (kg/ha)

Treatment	Blackgram	Cowpea	Greengram	Groundnut
m1	32.55	196.14	56.53	441.41
m2	114.48	684.28	116.48	972.37
m3	245.06	701.82	118.59	1002.92
C.D.(0.05)	62.07	16.90	38.50	126.29

Table 21. Organic matter (haulm) yield of intercrops (kg/ha)

Treatment	Blackgram	Cowpea	Greengram	Groundnut
m1	1086.67	9850.33	608.22	9843.33
m2	3050.00	24010.33	1659.24	17446.67
m3	6036.67	25191.67	3689.20	18123.33
C.D.(0.05)	1441.16	3552.30	745.19	3210.47

		N	P_2O_5	K_2O kg/ha
Blackgram, Cowpea, Greengram	m1	0	0	0
	m2	10	15	5
	m3	20	30.	10
Groundnut	m1	0	0	0
	m2	10	15	20
	m3	20	30	40

Table 22. Amount of nitrogen (in kg/ha) incorporated by the haulms

Treatment	Blackgram	Cowpea	Greengram	Groundnut
m1	4.06	47.56	2.34	42.64
m2	13.76	136.69	7.46	84.37
m3	26.58	147.01	16.79	90.32
C.D. (0.05)	6.25	19.73	3.41	18.37

		N	P_2O_5	K_2O kg/ha
Blackgram Cowpea Greengram	m1	0	0	0
	m2	10	15	5
	m3	20	30	10
Groundnut	m1	0	0	0
	m2	10	15	20
	m3	20	30	40

Table 23. Optimum and economic doses of fertilizers for intercrops

	Optimum dose (kg/ha)			Economic dose (kg/ha)		
Intercrops	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Blackgram						
Cowpea	15.37	23.00	7.69	14.55	21.83	7.28
Greengram	15.37	23.00	7.69	12.79	19.19	6.40
Groundnut	18.03	27.05	36.06	17.56	26.34	35.12

maximum value but was on par with m2, both being significantly superior to m1.

(e) Response curve and economics of fertilizer application.

The linear function in blackgram and the quadratic response curves fitted to the equation in cowpea, greengram and groundnut are given below:-

Blackgram

Yield = $301.8x + 371.3$

Net profit = $648.85x + 641.95$

Cowpea

Yield = $972.06 + 359.15x - 334.28x^2$

Net profit = $1657.82 + 612.5x - 668.56x^2$

Greengram

Yield = $330.89 + 88.2x - 82.135x^2$

Net profit = $540.93 + 114.7x - 205.34x^2$

Groundnut

Yield = $2637.23 + 854.01x - 531.81x^2$

Net profit = $6286.28 + 2008.73x - 1329.53x^2$

The optimum dose and economic dose of fertilizers for the intercrops cowpea, greengram and groundnut are given in Table 23. For blackgram the economic dose of fertilizers could not be found out since the response to fertilizers was linear.

Table 24. Economics of fertilizer application to intercrops

Levels of $N:P_2O_5:K_2O$ (kg/ha)	Yield of seed (kg/ha)	Value of produce (Rs/ha)	Increase over zero level (Rs/ha)	Extra cost of fertilizers (Rs/ha)	Profit due to the fertilizer application (Rs/ha)
Blackgram					
0:0:0	32.55	91.14	-	-	-
10:15:5	114.48	320.57	229.43	104.50	124.93
20:30:10	245.06	686.17	595.03	209.00	386.03
Cowpea					
0:0:0	196.14	392.28	-	-	-
10:15:5	684.28	1368.56	976.28	104.50	871.78
14.55:21.83:7.28	1066.23	2132.46	1740.18	152.09	1588.10
20:30:10	701.82	1403.64	1011.36	209.00	802.36
Greengram					
0:0:0	56.53	141.33	-	-	-
10:15:5	116.48	291.20	149.87	104.50	45.37
12.79:19.19:6.4	349.11	872.78	731.45	133.69	597.76
20:30:10	118.59	296.48	155.15	209.60	-53.85
Groundnut					
0:0:0	441.41	1103.53	-	-	-
10:15:5	972.37	2430.93	1327.40	125.50	1201.90
17.56:26.34:35.12	2478.66	6196.65	5093.12	220.38	4872.74
20:30:40	1002.92	2507.30	1403.77	251.00	1152.77

Cost of fertilizers: N @ 4.5/kg. P_2O_5 @ Rs.3.5/kg K_2O @ Rs.1.4/kg

Value of produce: Greengram and Groundnut @ Rs.2.5/kg. Cowpea @ Rs.2.00/kg. Black gram @ Rs.2.8/kg

The economics of fertilizer application was worked out and presented in Table 24.

Economics of intercropping

The economics of intercropping over pure cropping was worked out and is presented in Table 25. It was seen that the net profit from the intercropped plots was more than that from pure crop of tapioca when the intercrops were given additional fertilizers except in the case of greengram. The highest net profit of Rs.5489.70/ha was recorded by intercropping groundnut at m3 level of fertilizers.

Among the crop associations, intercropping with groundnut recorded the highest net profit of Rs.4193.62/ha as compared to Rs.3427.50/ha obtained from pure crop of tapioca. In terms of net profit, groundnut was followed by blackgram with Rs.3505.16/ha as net profit. Intercropping tapioca with cowpea and greengram recorded a net profit which was less than that obtained from pure crop of tapioca.

In all the intercrops application of fertilizers to the intercrops resulted in an increase in the net profit.

Table 25. Economics of intercropping

Treatments	Cost of cultivation Rs./ha			Yield		Value of produce (Rs./kg)			Additional profit obtained by intercropping (Rs/ha)	Net profit (Rs./ha)	Mean net profit from the intercrops (Rs./ha)
	Tapioca	Intercrop	Total	Tapioca kg/ha	Intercrop kg/ha	Tapioca	Intercrop	Total			
T	1942.50		1342.50	17.90		5370.00		5370.00	-	3427.50	
T+Bm1	"	180.50	2123.00	14.32	32.55	4296.00	91.14	4387.14	-982.86	2264.14	
T+Bm2	"	286.30	2228.80	18.66	114.48	5598.00	320.57	5918.57	+548.57	3689.77	3505.16
T+Bm3	"	392.10	2334.60	20.70	245.06	6210.00	686.17	6986.17	+1526.17	4561.57	
T+Cm1	"	180.50	2123.00	13.86	196.14	4158.00	392.28	4550.28	-818.72	2427.28	
T+Cm2	"	286.30	2228.80	14.87	684.28	4461.00	1368.56	5829.56	+459.56	3600.76	3349.00
T+Cm3	"	392.10	2334.60	16.50	701.82	4950.00	1403.56	6353.56	+983.56	4018.96	
T+Gm1	"	180.50	2123.00	14.16	56.53	4248.00	141.33	4389.33	-930.67	2266.33	
T+Gm2	"	286.30	2228.80	16.57	116.48	4971.00	291.20	5262.20	-107.80	3033.40	2835.20
T+Gm3	"	392.10	2334.60	17.48	118.59	5244.00	296.48	5540.48	+170.48	3205.88	
T+Gnm1	"	180.50	2123.00	12.17	441.41	3651.00	1103.53	4754.53	-615.47	2631.53	
T+Gnm2	"	306.80	2249.30	14.31	972.37	4293.00	2430.93	6723.93	+1355.93	4474.63	4193.62
T+Gnm3	"	433.10	2375.60	17.86	1002.92	5358.00	2507.30	7865.30	+2495.30	5489.70	

T = Tapioca B = Blackgram C = Cowpea G = Greengram Gn = Groundnut

Value of tapioca @ Rs.30/qm, Greengram and Groundnut @ Rs.2.5/kg. Cowpea @ Rs.2.00/kg
- = Loss + = Profit Black gram @ Rs.2.8/kg

		N	P_2O_5	K_2O kg/ha
Blackgram	m1	0	0	0
Cowpea	m2	10	15	5
Greengram	m3	20	30	10

		N	P_2O_5	K_2O kg/ha
Groundnut	m1	0	0	0
	m2	10	15	20
	m3	20	30	40

DISCUSSION

DISCUSSION

An investigation was carried out at the College of Agriculture, Vellayani during 1977-1978 to study the performance of tapioca intercropped with different legumes (blackgram, cowpea, greengram and groundnut) supplied with different fertilizer doses (no fertilizer, half the recommended dose and full recommended dose). The experiment was conducted under rainfed conditions. The results obtained from the study are discussed below:

TAPIOCA

Growth characters

(a) Number of leaves.

From the Table 1 and Fig.2 it was seen that intercropping tapioca with crops such as blackgram, cowpea, greengram and groundnut did not affect the leaf production in the main crop of tapioca significantly. This shows that there was no deleterious effect of growing leguminous intercrops on the leaf production in tapioca. This may be due to the enrichment of soil nitrogen by the legumes. This observation is in agreement with the findings of Prasad and Choudhary (1975) who noticed no adverse effect to the principal crop due to legumes in grass-legume association.

(b) Height of plant.

It was observed from the Table 2 and Fig.2 that different intercropping treatments did not show any significant difference in plant height as compared to the pure tapioca. This shows that there was no harmful effect on the height of tapioca plants by growing the leguminous intercrops. This again may be due to the beneficial effect of legumes through enrichment of soil nitrogen. Similar results were obtained by Prasad and Choudhary (1975).

Yield attributes and yield

(a) Total number of roots per plant.

The results (Table 3 and Fig.3) indicated that the total number of roots per plant in tapioca was not affected by growing leguminous intercrops such as blackgram, cowpea, greengram and groundnut. However, there was an increasing trend in the number of roots per plant in tapioca due to legume intercropping. This may be attributed to the stimulation of the root primordia by the nitrogen excreted from the legumes (Russel, 1961) or the enrichment of soil nitrogen by the incorporation of haulms into the soil (Singh et al., 1969). This shows that the leguminous intercrops were helpful in increasing the number of roots in tapioca. This finding is in line with the observation of Nitis and Sumatra (1976).

EFFECT OF INTERCROPPING ON THE HEIGHT, NUMBER OF LEAVES, TUBER YIELD, TOP YIELD AND UTILIZATION INDEX OF TAPIOCA

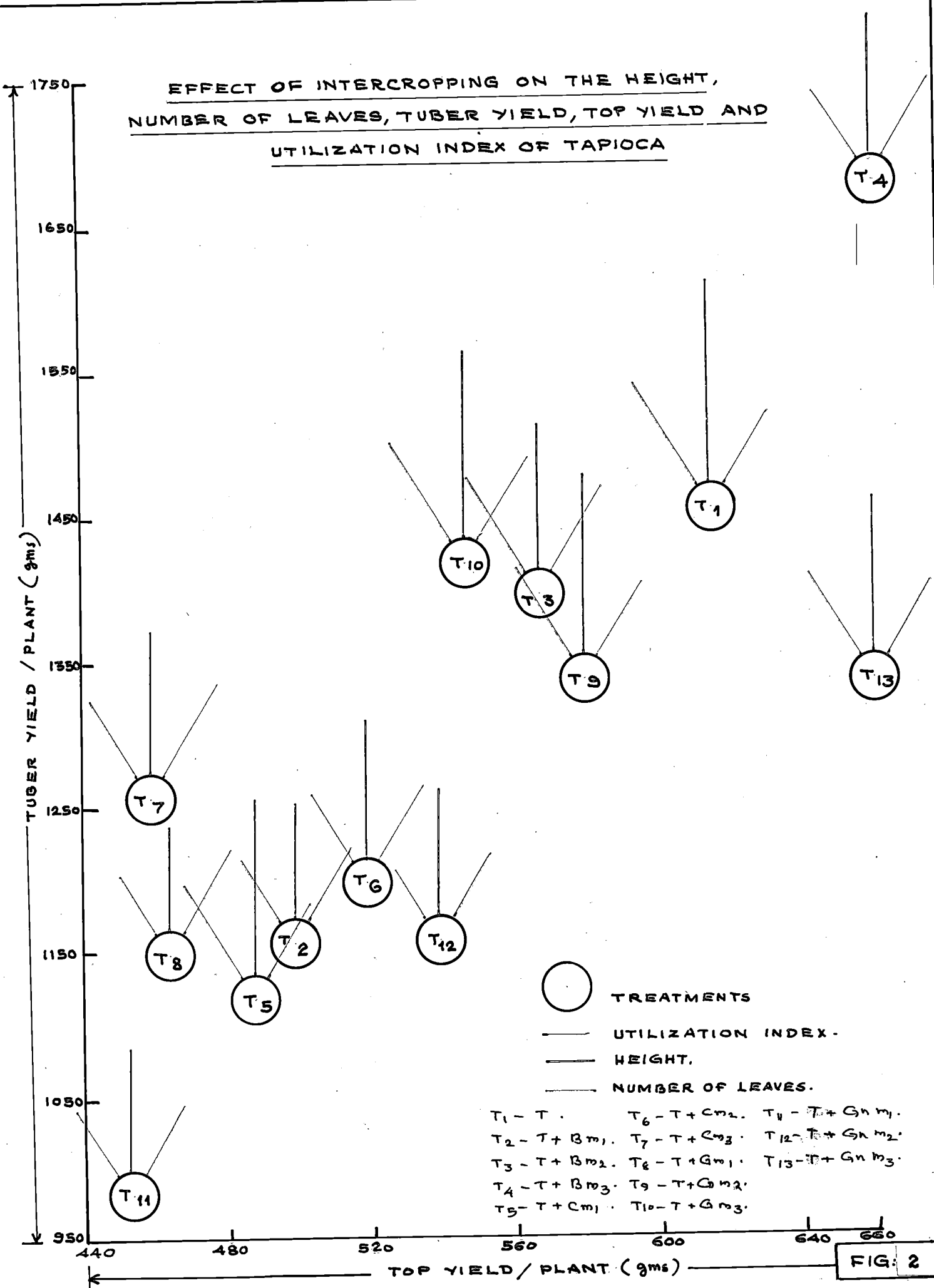


FIG: 2

(b) Number of tubers per plant.

From the results (Table 4 and Fig.3) it was observed that intercropping tapioca with groundnut receiving 20:30:40 level of fertilizers was on par with pure crop of tapioca with respect to the number of tubers per plant. However, all the other treatments recorded a significantly lower number of tubers per plant as compared to the pure tapioca. The increase in the number of tubers per plant in the pure crop may be attributed to the larger unit area obtained by the crop as compared to the intercropped plots (Mohankumar and Krishi, 1973). However groundnut at 20:30:40 level of fertilizers showed an almost equal number of tubers per plant. This may be attributed to the adequate amount of nutrients applied to the groundnut which would have avoided the competition for nutrients with the tapioca, resulting increased number of tubers in tapioca.

Similarly all the remaining intercrops namely blackgram, cowpea and greengram showed an increased number of tapioca tubers per plant with increased fertilizer application (20:30:40). It might be even possible to avoid a reduction in the number of tubers in intercropped plots by applying higher amounts of fertilizers to the intercrops than that added in this experiment. This is in agreement with the findings of Saxena and Yadav (1972) in arhar;

Singh et al. (1972) in sesamum and Mohankumar and Hrishi (1973) in tapioca.

(c) Percentage of productive roots.

The result presented in Table 5 and Fig.3 shows that pure crop of tapioca was more efficient in converting the roots into tubers. The results also indicated that the intercrops interfered with the tuberization of the roots resulting in a lower percentage of productive roots. The reason for the higher percentage of productive roots in pure crop of tapioca may be due to the higher land area available per plant of tapioca and also the lack of competition from intercrops.

Though the percentage of productive roots was lower in intercropped plots, it was compensated by the size of the tubers. The tubers in the intercropped plots showed more length and girth (Tables 6 and 7) as compared to the tubers in the pure tapioca.

The plots with groundnut as intercrop recorded the next lower percentage of productive roots than pure tapioca. This shows that the competition was less between tapioca and groundnut as compared to other intercrops, probably due to the adequate amount of nutrients received by groundnut and its root distribution character.

The highest fertilizer dose given to most of the intercrops increased the number of tubers (Table 4) which resulted in a higher percentage of productive roots. The increase in the percentage of productive roots by adequate nutrients has been stressed by Mohankumar and Mrishi (1973) leading to less competition by intercrops.

(d) Length of tubers.

From the Table 6 and Fig.3 it was observed that the length of tubers in most of the intercropped plots was showed an increasing trend as compared to the pure crop of tapioca. This may be due to the stimulating effect of the legumes on the root primordia of tapioca by means of the nitrogen excretion (Sen, 1958). This is in agreement with the findings of Nitis and Sumatra (1976) who reported an increase in the length of tubers in tapioca-stylosanthes mixture.

(e) Girth of tubers.

The data (Table 7 and Fig.3) revealed that the girth of tubers tended to increase by intercropping tapioca with all the four legumes namely blackgram, cowpea, greengram and groundnut as compared to the pure crop of tapioca. Thus legume intercropping was found beneficial in increasing the girth of tapioca tubers.

Among the intercrops blackgram recorded the maximum girth for tapioca tubers. This may be due to the poor performance of blackgram as evidenced from the Table 20

EFFECT OF INTERCROPPING ON TOTAL NUMBER OF ROOTS, NUMBER OF TUBERS, PERCENTAGE OF PRODUCTIVE ROOTS AND LENGTH AND GIRTH OF TUBERS.

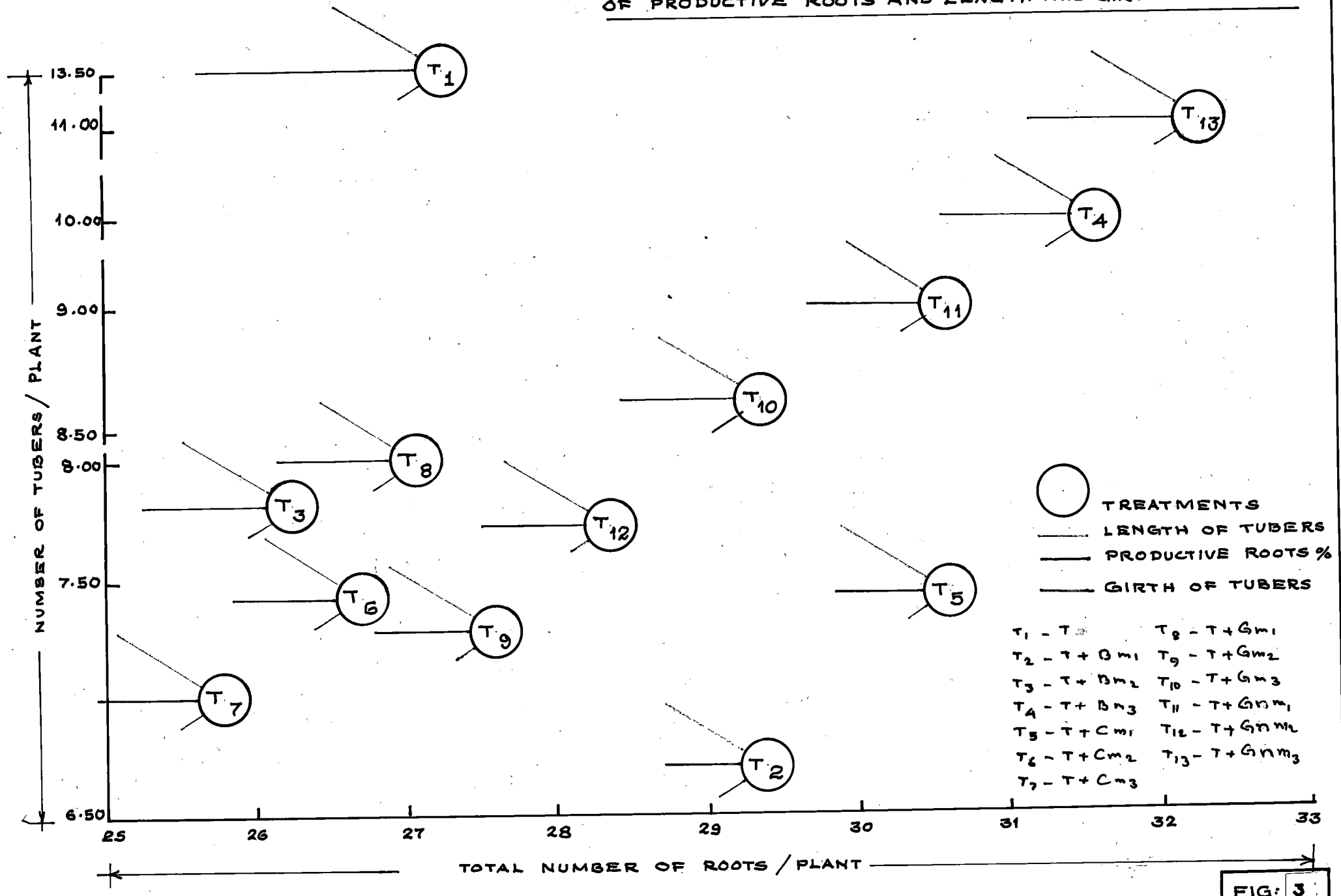


FIG: 3

resulting in the utilisation, of the nutrients applied to the intercrop, by tapioca in addition to the nutrients received by the same. Increase in the girth of tubers by application of NPK was reported by Natarajan (1975).

The increase in the girth at the highest level of fertilisers (20:30:10 for blackgram, cowpea and greengram and 20:30:40 for groundnut) for the intercrops may be due to the application of adequate amount of fertilisers to the intercrops.

(f) Rind to flesh ratio.

From the results (Table 8) it was observed that all the intercropped treatments showed a considerably lower rind to flesh ratio as compared to the pure crop of tapioca. Groundnut, greengram and blackgram reduced the rind to flesh ratio of tubers significantly. Cowpea also reduced the ratio considerably though not significantly.

The low rind to flesh ratio obtained from the legume intercropped plots was due to the production of higher proportion of flesh than the rind. This shows that the legumes (groundnut, greengram, blackgram and cowpea) were helpful in reducing the proportion of rind to flesh, which is a desirable character. In otherwords the legumes were found to increase the quantity of flesh per unit weight of the tuber.

The reduction in the rind to flesh ratio by increased fertilizer application to the intercrops may be due to less competition for nutrients by the intercrops which would have enabled tapioca to produce more of flesh rather than rind per unit weight of tuber. Similar increase in the flesh portion due to nutrient application was reported by Natarajan (1975).

(g) Percentage of edible portion.

As in the case of rind to flesh ratio, the leguminous intercrops showed a considerable increase in the percentage of edible portion in tapioca tubers as shown in Table 9 and Fig.4. The percentage of edible portion was least in pure crop of tapioca. Since the rind to flesh ratio and the percentage of edible portion were related aspects, the results were also similar.

Similarly, blackgram was found to be the most efficient intercrop in increasing the percentage of edible portion followed by greengram, groundnut and cowpea. Also, higher rates of fertilizer application to the intercrops gave higher percentage of edible portion, as observed in the rind to flesh ratio.

(h) Tuber yield.

From the Table 10 and Fig.2 it was seen that intercropping tapioca with the four legumes (blackgram, cowpea, greengram and groundnut) at different fertilizer levels (m1, m2 and m3) to the intercrops did not depress the tuber yield as compared to the pure crop of tapioca. On the other hand, intercropping tapioca with blackgram with additional fertilizers to the intercrop, recorded higher tuber yield than that obtained from pure tapioca. Similarly intercropping of groundnut with its recommended dose of fertilizers (20:30:40) gave a tuber yield (17.86 t/ha) which was almost equal to that obtained from pure tapioca (17.9 t/ha).

The yield of tapioca tubers was not reduced in the intercropped plots when compared to non-intercropped plots. This was made possible by the increased length and girth of tubers (Tables 6 and 7) in intercropped plots. As already noted the reduction in the number of tubers per plant was compensated by the size of the tubers. Besides the length and girth, the dry matter content of tubers (Table 13) might have also contributed to maintain the tuber yield in intercropped plots.

It was also observed that the tuber yield was increased by increasing the fertilizer application to the intercrops in all the four legumes. All these show that by applying

adequate fertilizers to the intercrops as well as to the main crop, it might be possible to maintain tuber yield in tapioca-legume association as that in pure tapioca.

Singh et al. (1969) and Katyal and Dutta (1976) reported that growing leguminous intercrops such as groundnut and cowpea did not affect the tuber yield of tapioca.

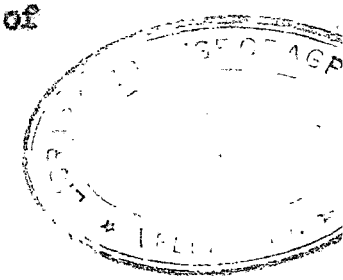
(i) Top yield.

The mean top yields presented in Table 11 and Fig.2 showed that intercropping tapioca with the legumes did not depress the top yield in tapioca. On the other hand intercropping of groundnut at the recommended dose of fertilizers (20:30:40) recorded a higher top yield (8.15 t/ha) as compared to that in pure crop of tapioca (7.61 t/ha).

As in the case of tuber yield, the top yield of tapioca was also increased with increased fertilizer application to the intercrops. This shows that the top yield of tapioca in tapioca-legume association could be maintained by applying adequate fertilizers to the main crop as well as the intercrops.

(j) Utilization index.

The data presented in Table 12 and Fig.2 pointed out that the utilization index of tapioca was not reduced by the intercropping treatments at different levels of



fertilizers to the intercrops. However, blackgram intercropped plots found to give the highest utilization index in tapioca as compared to pure tapioca. This might be due to the higher production of tubers from blackgram intercropped plots (Table 10) consequent of poor performance of blackgram (Table 20).

Application of fertilizers to the intercrops also increased the index in tapioca. This again might be due to the increased tuber yield as seen from the Table 10.

Quality attributes

(a) Percentage of dry matter in tubers.

The results (Table 13 and Fig.4) showed that legume intercropping increased the dry matter content of tapioca tubers significantly. It was observed that groundnut and cowpea at their recommended dose of fertilizers (20:30:40 and 20:30:10 respectively) recorded the maximum dry matter content in tapioca tubers as compared to pure tapioca.

Growing groundnut, cowpea, greengram and blackgram as intercrops with tapioca increased the dry matter content of the tubers over growing tapioca alone. The increase in the dry matter content of tubers in intercropped plots might be due to the nutrients added by means of the incorporation of haulms in to the soil (Misra and Misra, 1975).

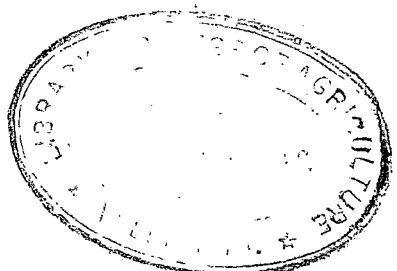
Similar increase in the dry matter content of tubers by nutrient application was reported by Pillai (1967) in tapioca.

The maximum dry matter content in tapioca tubers recorded by groundnut and cowpea might be due to the larger quantity of haulms added by them (Table 21) to the soil and thereby addition of nutrients (Table 22). The nutrients in the haulms would have been utilized by the tapioca in dry matter production. Similar increase in the dry matter content of tubers due to legume intercropping has been reported by Nitis and Sumatra (1976).

The increase in the dry matter content of tubers by the application of fertilizers to the intercrops might be due to the higher quantity of haulms produced at increased fertilizer levels (Table 21). This would have contributed to an increase in the dry matter content of tubers as discussed above.

(b) Percentage of starch in tubers.

From the results (Table 14 and Fig.4) it was observed that the percentage of starch in tapioca tubers was significantly increased by intercropping legumes. Intercropping tapioca with groundnut at the recommended dose of fertilizers (20:30:40) recorded the maximum percentage



of starch in tapioca tubers when compared to all other treatments.

Pure crop of tapioca showed the lowest percentage of starch in its tubers. Among the intercrops groundnut and cowpea recorded the highest percentage of starch in tapioca tubers followed by greengram and blackgram. This would have been due to the enrichment of soil nitrogen by the legumes which might have resulted in the increased top yield in tapioca (Table 11) enabling more carbohydrate synthesis (Russel, 1961). The increased starch content due to nitrogen enrichment was reported by Pillai (1967) in tapioca. Increase in starch content by leguminous intercrops has also been obtained by Dey et al. (1958) in jowar.

In most of the intercrops, the starch content of tapioca tubers was increased by application of fertilizers to the intercrops. This might be due to the beneficial effects of NPK added to the intercrops.

(e) Percentage of crude protein in tubers.

As seen from the Table 15 and Fig.4 the crude protein content of tapioca tubers was slightly increased by the leguminous intercrops. Among the intercrops, groundnut recorded the highest percentage of crude protein in the tubers. All these show that the enrichment of soil

EFFECT OF INTERCROPPING ON EDIBLE PORTION, DRY MATTER CONTENT, CRUDE PROTEIN CONTENT, HCN AND STARCH CONTENT OF TAPIOCA TUBERS.

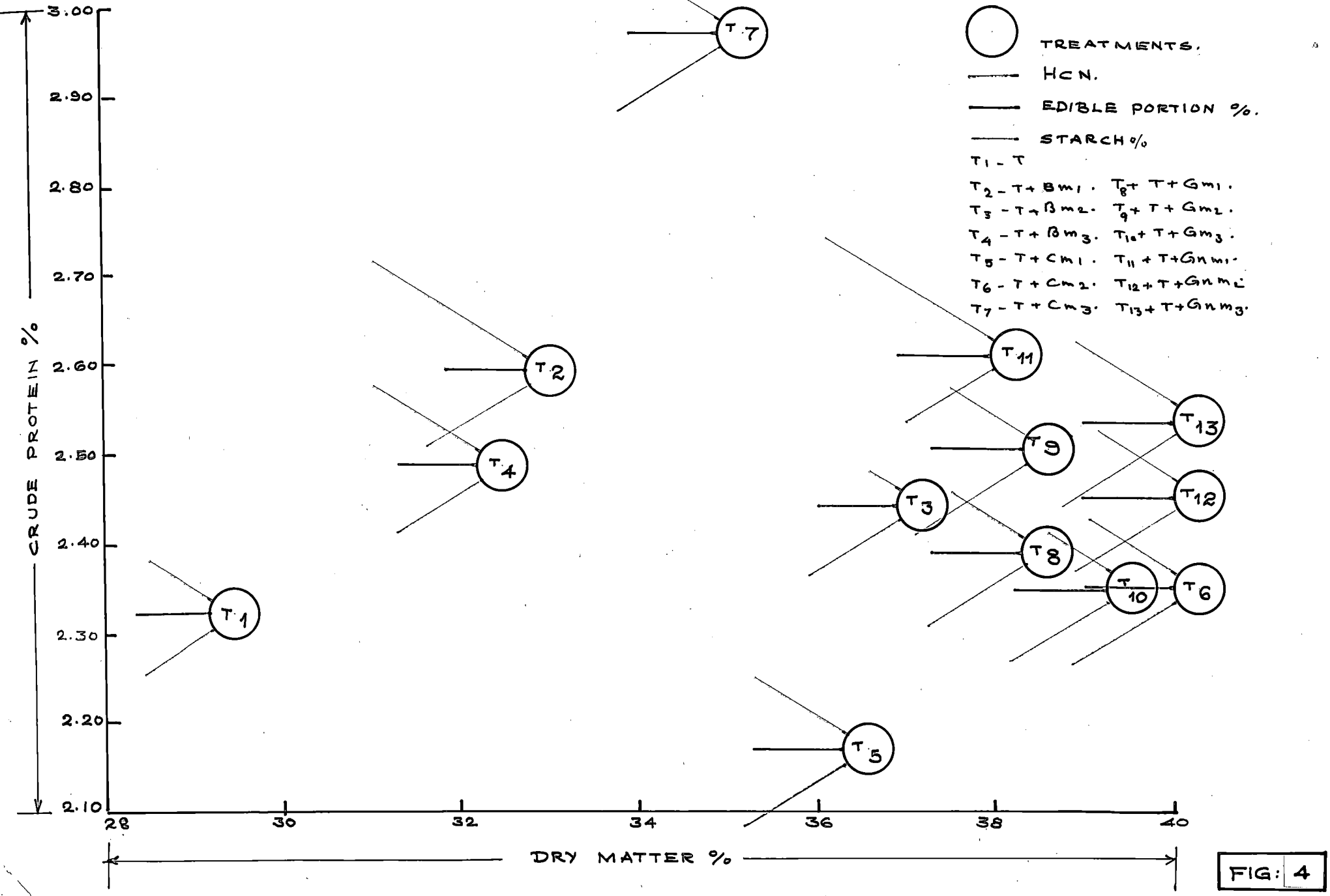


FIG: 4

nitrogen by the legumes would have increased the nitrogen uptake by the plants which in turn would have resulted in an increase in the crude protein content of the tubers (Malavolta, 1955).

Increased crude protein due to legume intercropping has been reported by Dey et al. (1958) in jowar, Tewari and Schmid (1960) in Timothy grass and Manitkar and Shukla (1974) in fodder sorghum.

(d) Hydrocyanic acid content of tubers.

The results presented in Table 16 and Fig.4 indicated that the hydrocyanic acid content of the tubers increased significantly by the legume intercropping. Intercropping tapioca with groundnut resulted in the highest hydrocyanic acid content in tapioca tubers followed by intercropping with cowpea, greengram and blackgram. Pure tapioca showed the lowest hydrocyanic acid content.

Nitrogen application to tapioca was found to increase the hydrocyanic acid content of tubers (Indira et al., 1972). Since the legumes have enriched the soil nitrogen by symbiotic fixation (Kumar and Pandey, 1962) and incorporation of the haulms in situ (Singh et al., 1969), the thus added nitrogen would have caused an increase in the hydrocyanic acid content of the tubers.

The application of fertilizers to the intercrops was found to reduce the hydrocyanic acid content of the tapioca tubers. Application of potash either alone or in combination with nitrogen and phosphorus has been found to reduce the hydrocyanic acid content of tubers in tapioca (Indira et al., 1972). So in this case the potash added in combination with nitrogen and phosphorus to the intercrops would have been made available to the main crop after the incorporation of their haulms into the soil thereby reducing the hydrocyanic acid content. Thus application of fertilizers to the intercrops was also found beneficial to tapioca by means of a reduction in the hydrocyanic acid content of tubers.

(e) Cooking quality of tubers.

It was observed from the Tables 17a and 17b that intercropping with legumes did not affect the cooking quality of tapioca as measured by the bitterness of tubers. However, a slight reduction in cooking quality of tubers was noted in the intercropped plots, but not significant. The reduction in the cooking quality of tubers due to increase in bitterness may be due to the nitrogen uptake, by the tubers, enriched by legumes through their haulms.

Reduction in the cooking quality of tubers due to higher levels of nitrogen was reported by Prema et al.(1975).

Total nitrogen content of the soil after experiment.

The total nitrogen content of the soil after the experiment (Table 18) revealed that the treatments increased the total nitrogen content of the soil significantly as compared to the pure crop of tapioca. Among the intercrops groundnut and cowpea recorded the maximum total soil nitrogen (1302 kg/ha and 1285.5 kg/ha respectively). The increase in the total soil nitrogen in the intercropped plots may be due to the enrichment of soil nitrogen by the legumes. Enrichment of soil nitrogen by growing these leguminous intercrops in tapioca had been earlier reported by Singh et al. (1969).

Similar increase in the soil nitrogen by legume intercropping was also reported by Morachan et al. (1977).

Intercrops

(a) Height of plant at harvest.

The results (Table 19) revealed that there was significant difference in the height of all the legumes under different fertilizer treatments. The highest fertiliser dose 20:30:10 produced maximum height in blackgram, cowpea, and greengram whereas in groundnut the middle dose 10:15:20 produced the tallest plants eventhough it was on par with the highest dose 20:30:40.

In the case of leguminous crops it takes some time for the plants to obtain nitrogen by symbiotic fixation (Jain, 1975). During this initial stage of growth the plants have to depend on fertilizer nitrogen for growth (Schandert, 1943). In the case of the other two nutrients namely phosphorus and potassium, the plants have to depend mostly on the applied source. The height being a nutrient dependent character, the amount of nutrients applied through fertilizers would have encouraged a higher rate of nutrient absorption resulting in an increase in the plant height. However, in the case of groundnut the middle dose 10:15:20 seems to be sufficient for producing the maximum height. Similar increase in height due to fertilizer application was obtained by Sen and Bains (1955) in cowpea; Deshpande and Bathkal (1965) in greengram; Kurup and Kaliappan (1969) in sunnhemp and Mahatanya (1976) in beans.

(b) Seed yield.

From the results (Table 20) it was seen that the recommended dose of fertilizers (20:30:10 for blackgram, cowpea and greengram and 20:30:40 for groundnut) has given the maximum seed yield in all the four legumes. However, in the case of cowpea, greengram and groundnut the middle dose (10:15:5 for cowpea and greengram and 10:15:20 for groundnut) was on par with the recommended dose.

The increase in seed yield obtained with the application of fertilizers can be attributed to the beneficial effect of the nutrients N, P and K. The beneficial effect of N in increasing the seed yield may be due to its relation to carbohydrate utilization and its relation to phosphorus metabolism. Phosphorus also helps in root growth, flowering, pod formation and seed setting. Moreover, phosphorus might have stimulated the rhizobial activity in the root nodules leading to larger fixation of atmospheric nitrogen (Mercer, 1948), in addition to its effect in the uptake of other nutrients from the soil (Robert and Olsen, 1944). Potassium might have contributed to the yield by means of its influence on photosynthesis (Tisdale and Nelson, 1975). Increase in grain yield with increased fertilizer application was reported by Rao et al. (1954) in cowpea and Deshpande and Rathkal (1965) in greengram.

The influence of nutrients in enhancing the yield was also observed by Moolani and Jana (1965) in greengram; Rajendran et al. (1974) and Subramanian et al. (1977) in blackgram and Pande et al. (1971) in groundnut.

(c) Organic matter (haulm) yield

As evidenced from the results (Table 21), the organic matter (haulm) production was maximum at the highest fertilizer dose in all the four intercrops. In all these

intercrops the highest fertilizer dose (20:30:10 for blackgram, cowpea and greengram; 20:30:40 for groundnut) produced significantly higher quantity of green matter (haulm) when compared to the lower doses of fertilizers except in cowpea and groundnut wherein the middle dose (10:15:5 and 10:15:20 respectively) of fertilizers was on par with the highest dose.

The increase in the organic matter (haulm) production due to fertilizer application may be due to the effect of the nutrients on vegetative growth of the plants. This may be due to the increase in available nitrogen (Singh and Sahasrabudhe, 1957) and the stimulatory effect of phosphorus on the nitrogen fixing bacteria (Parr and Bose, 1945; Sen and Bains, 1952; Rao et al., 1954). The beneficial effect of potassium in increasing haulm production may be attributed to its role in the growth and meristematic tissues and activation of various enzymes (Tisdale and Nelson, 1975).

(d) Amount of nitrogen incorporated into the soil by haulms.

The data (Table 22) showed that the highest fertilizer dose (20:30:40 for groundnut and 20:30:10 for others) for all the four legumes resulted in the incorporation of more nitrogen in the soil through the haulms, as compared to

the lower fertilizer doses. Among the intercrops blackgram showed significant difference between the fertilizer doses with respect to the amount of nitrogen incorporated into the soil by the haulms. In the remaining intercrops the middle dose (10:15:20 for groundnut; 10:15:5 for others) of fertilizers was on par with the highest dose. When no fertilizer was given to the intercrops, all the four intercrops were not efficient in adding nitrogen by means of incorporation of haulms.

Among the four legumes tried, cowpea was found to be more efficient in enriching the soil nitrogen by means of incorporation of the haulms into the field after harvest. Groundnut came next in this aspect followed by blackgram and greengram. The higher amount of nitrogen added by the haulms of cowpea may be attributed to the larger quantity of haulm production (Table 21) by it. The superiority of cowpea over the other leguminous intercrops with regard to the enrichment of soil nitrogen was reported by Singh et al. (1969). The increased rate of enrichment of soil nitrogen at higher doses of fertilizers may be attributed to the increased production of organic matter (haulm) at the higher fertilizer doses as seen from the Table 21.

(e) Response curve and economics of fertilizer application.

It is evident from the Figures 5, 6, 7 and 8 and Tables 23 and 24 that the four leguminous intercrops chosen for the present investigation responded differently under

YIELD AND NET PROFIT FUNCTIONS OF THE INTERCROPS

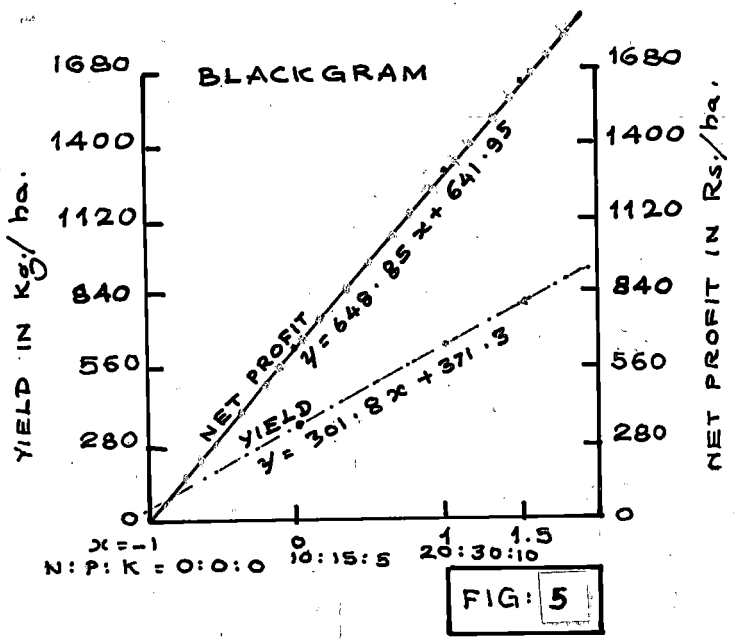


FIG: 5

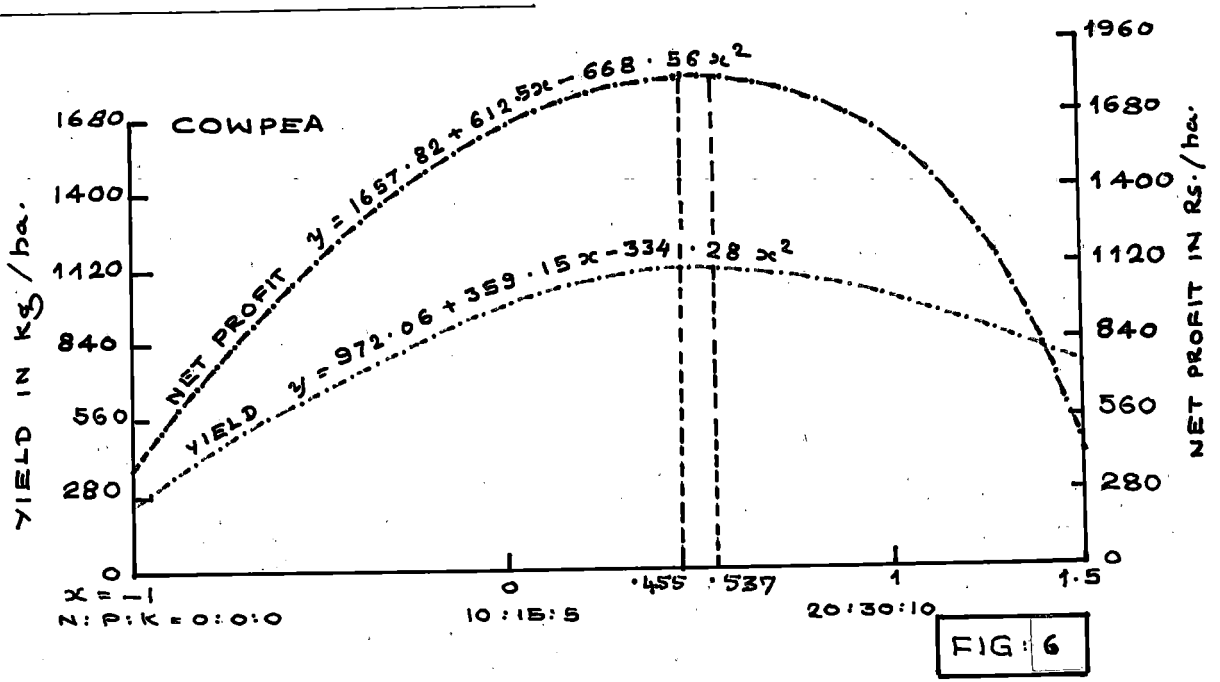


FIG: 6

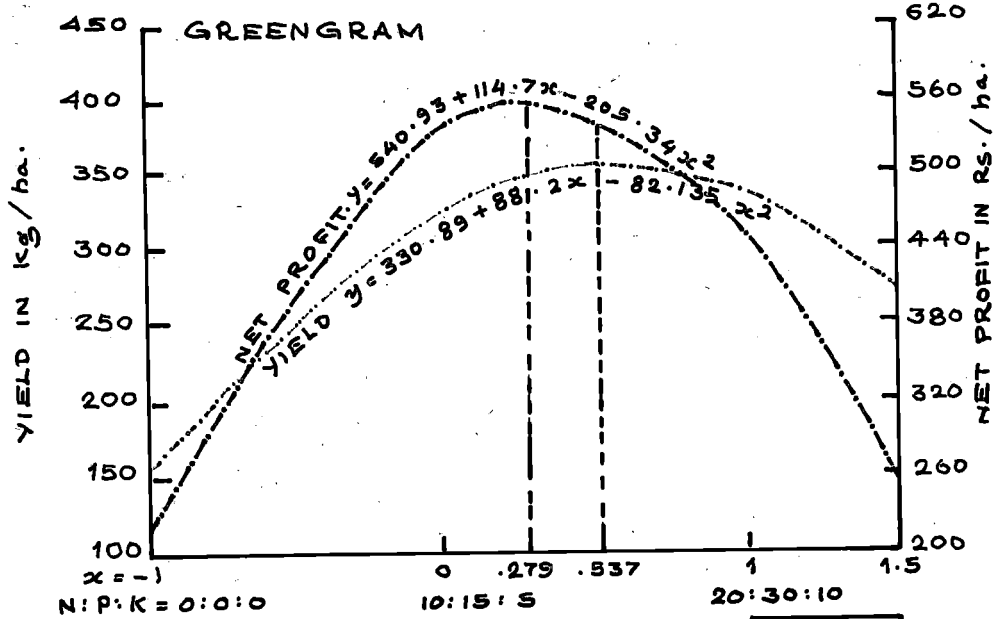


FIG: 7

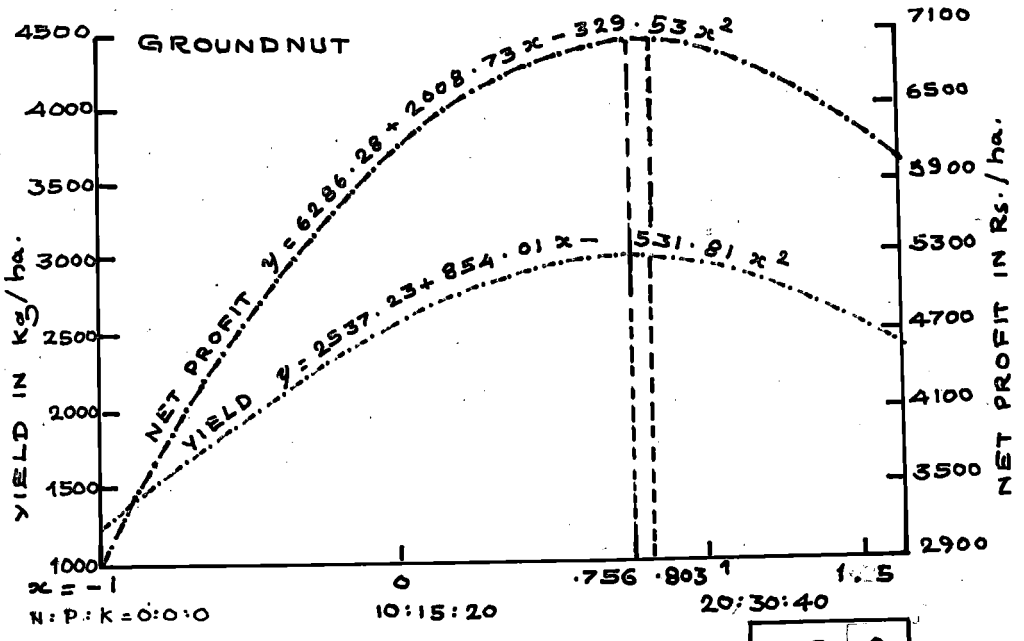


FIG: 8

different fertilizer treatments. In blackgram it was found that the response to fertilizer application was linear and the yield and profit increased with increasing fertilizer application (Fig.5) and the optimum fertilizer dose was not obtained. In cowpea, greengram and groundnut the optimum dose and economic dose of fertilizers were worked out (Table 23). Cowpea produced maximum grain yield with a fertilizer dose of 15.37: 23.0: 7.69 kg/ha of N, P_2O_5 and K_2O whereas the economic dose was only 14.55:21.83:7.28 kg/ha of N, P_2O_5 and K_2O. In greengram 15.37:23.0:7.69 kg/ha and 12.79:19.19:6.4 kg/ha of N, P_2O_5 and K_2O were found to be the optimum and economic doses respectively. In groundnut maximum yield was obtained with 18.03:27.05:36.06 kg/ha of N, P_2O_5 and K_2O whereas maximum profit was obtained with 17.56:26.34:35.12 kg/ha of N, P_2O_5 and K_2O.

Economics of intercropping

The study on the expenditure and income of tapioca alone and in intercropped situations is given in Table 25. The net profit and benefit/cost ratio from each treatment is shown in Fig.9. It was found that intercropping of groundnut, blackgram and cowpea with additional fertilizers recorded an additional income over tapioca alone.

Among the intercrops, groundnut intercropped plots recorded the maximum net profit (Rs.4198.62/ha) as well as

additional profit (Rs.1077.92/ha) over pure tapioca and blackgram came next to groundnut in this respect. Intercropping tapioca with greengram resulted in a loss at all the three fertilizer doses as compared to pure tapioca. This is in agreement with the findings of Mohankumar and Mrishi (1973) wherein intercropping with greengram resulted in a net loss showing that it was not an economic intercrop with tapioca in Trivandrum District.

It was conclusively proved that intercropping tapioca with groundnut, blackgram and cowpea with additional fertilizers (both half and full recommended doses) to the intercrops was more profitable than growing tapioca alone. The maximum net profit of Rs.5489.7/ha was obtained by intercropping tapioca with groundnut at its recommended fertilizer dose of 20:30:40.

Future line of work

In the present investigation, it was seen that three intercrops namely groundnut, blackgram and cowpea can be successfully raised with tapioca by giving additional fertilizers to the intercrops. The optimum dose of fertilizers for cowpea and groundnut has been worked out whereas a linear response for fertilizers was obtained in blackgram. So similar experiment can be taken up with

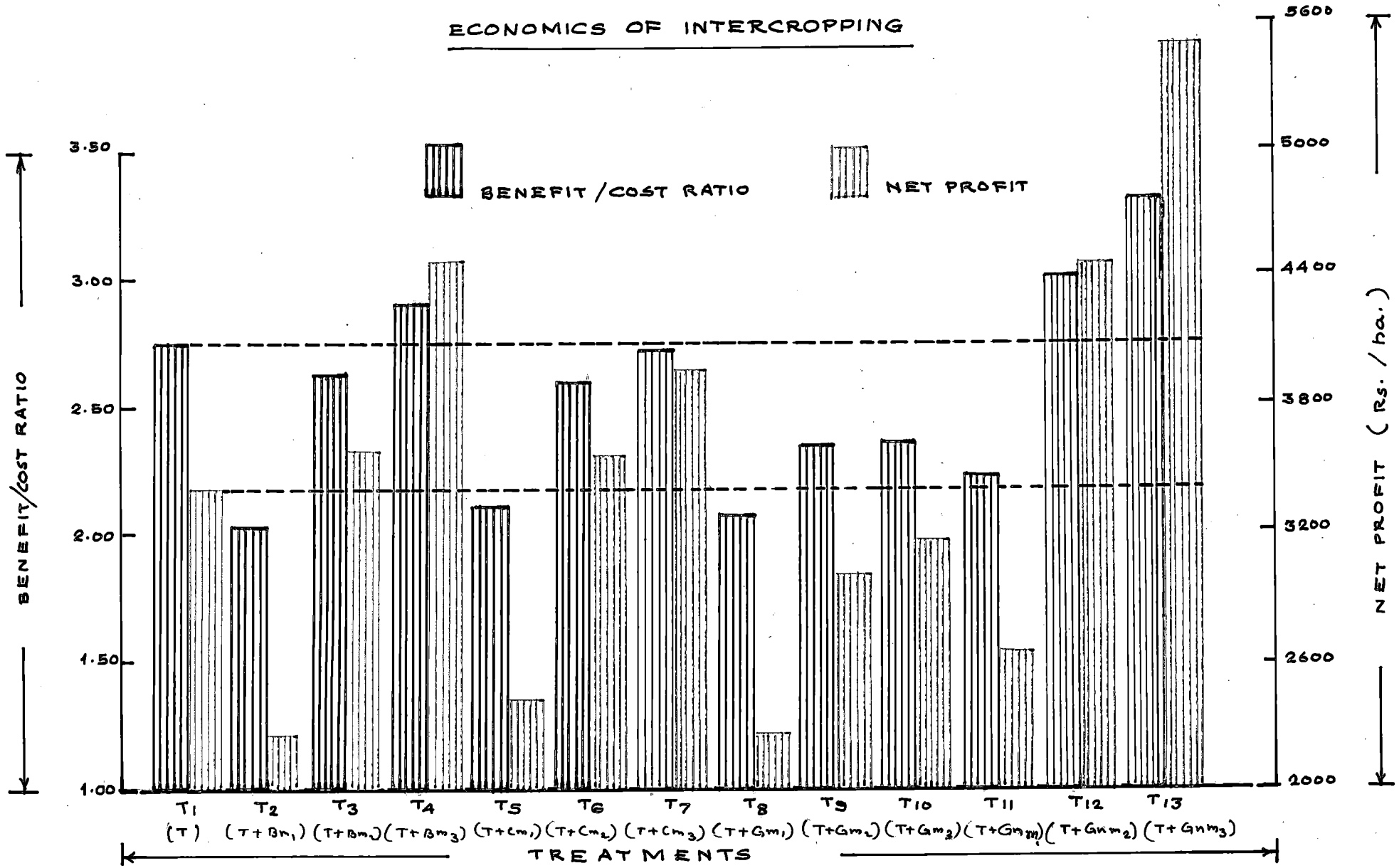
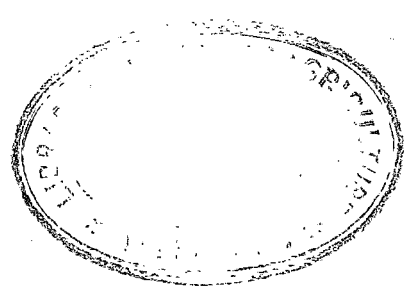

ECONOMICS OF INTERCROPPING
BENEFIT/COST RATIO
NET PROFIT
BENEFIT/COST RATIO
NET PROFIT (Rs./ha.)
3.50
3.00
2.50
2.00
1.50
1.00
5600
5000
4400
3800
3200
2600
2000
T1 (T)
T2 (T+Bm1)
T3 (T+Bm2)
T4 (T+Bm3)
T5 (T+Cm1)
T6 (T+Cm2)
T7 (T+Cm3)
T8 (T+Gm1)
T9 (T+Gm2)
T10 (T+Gm3)
T11 (T+Gnm1)
T12 (T+Gnm2)
T13 (T+Gnm3)
TREATMENTS

FIG: 9

blackgram as intercrop to work out the optimum dose of fertilizers for growing this as an intercrop with tapioca. The optimum fertilizer requirement for tapioca in these type of associations should also be worked out. Similarly the optimum season of planting the intercrops and optimum spacing for the intercrops and tapioca may also be found out by suitable experiments.



SUMMARY

SUMMARY

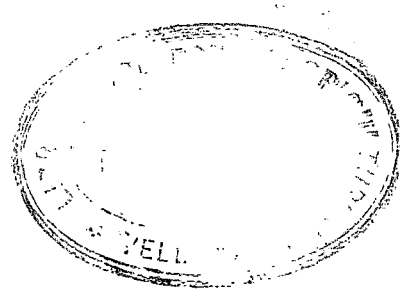
An experiment was conducted at the College of Agriculture, Vellayani to study the performance of tapioca intercropped with different legumes (blackgram, cowpea, greengram and groundnut) supplied with different fertilizer doses. The experiment was carried out, in a randomised block design with three replications, under rainfed conditions. The results obtained are summarised below.

1. The growth of tapioca plant was not suppressed by legume intercropping as adjudged from the height and production of leaves.

2. Legume intercropping in tapioca slightly increased the number of tapioca roots per plant. Among the intercrops, groundnut recorded the maximum number of tapioca roots.

3. Intercropping of legumes with tapioca tended to reduce the number of tapioca tubers, but the size of tubers were increased. Increased dose of fertilizers to the intercrops, increased the number of tubers.

4. Intercropping of legumes such as blackgram, cowpea, greengram and groundnut with tapioca reduced the percentage of productive roots in tapioca.



5. A tendency to increase the length and girth of tapioca tubers was noticed due to growing legume with tapioca.

6. Intercropping of the legumes lowered the rind to flesh ratio of tapioca tubers as compared to the pure tapioca. Growing of blackgram as intercrop with tapioca gave the lowest rind to flesh ratio of tapioca tubers. Application of fertilizers to the intercrops reduced the rind to flesh ratio.

7. The percentage of edible portion in tapioca tubers was increased due to growing the legumes as intercrops. Blackgram with tapioca caused the highest percentage of edible portion in tubers. Application of fertilizers to the intercrops also increased the percentage of edible portion in tubers.

8. The tuber yield, top yield and utilization index of tapioca were not affected by growing the intercrops.

9. The dry matter content of tapioca tuber was increased due to legume intercropping. Intercropping of groundnut recorded the highest dry matter content in tapioca tubers. Application of fertilizers to the intercrops increased the dry matter content of tapioca tubers.

10. Higher percentage of starch was recorded by tapioca tubers when grown in association with the legumes. Among the intercrops groundnut and cowpea were found to record the highest percentage of starch in tubers. Application of fertilizers to groundnut, cowpea and greengram increased the starch content of tapioca tubers.

11. Higher crude protein content in tapioca tubers was obtained by legume intercropping. Groundnut recorded the highest percentage of protein in tapioca tubers.

12. Legume intercropping was found to increase the hydrocyanic acid content of tubers. Intercropping of groundnut recorded the highest content of hydrocyanic acid in tapioca tubers whereas application of fertilizers to the intercrops reduced the hydrocyanic acid content.

13. Cooking quality of tapioca tubers was not affected by growing the legumes as intercrops.

14. There was an improvement in the fertility status of the soil due to legume intercropping in tapioca. The total nitrogen content of soil was significantly increased by growing leguminous intercrops and incorporating their haulms into the soil. Groundnut intercrop was superior to other intercrops with respect to the soil fertility.

15. In blackgram, cowpea and greengram the recommended dose of fertilizers gave the maximum plant height when they are grown as intercrops whereas in groundnut half the recommended dose gave the maximum height of plants.

16. The recommended dose of fertilizers produced the highest seed yield in all the intercrops, though it was on par with half the recommended dose in cowpea, greengram and groundnut.

17. The organic matter (haulm) yield was maximum with the recommended dose of fertilizers in all the four intercrops. But in cowpea and groundnut half the recommended dose of fertilizers was on par with the recommended dose in this respect.

18. The amount of nitrogen incorporated into the soil through haulms in the case of the four intercrops was maximum with the recommended dose of fertilizers. In cowpea, greengram and groundnut half the recommended dose of fertilizers was on par with the recommended dose.

19. The optimum doses of N, P_2O_5 and K_2O for cowpea, greengram and groundnut, when grown as intercrops with tapioca, were 15.37:23:7.69; 15.37:23:7.69 and 18.03:27.05:36.06 kg/ha respectively and the economic doses of the nutrients were 14.55:21.83:7.28; 12.79:19.19:6.4 and

and 17.56:26.34:35.12 kg/ha respectively.

20. Intercropping was found to be profitable than pure cropping. Additional profit of Rs.548.57 and Rs.1526.17 by intercropping blackgram (from 10:15:5 and 20:30:10 kg/ha of N, P_2O_5 and K_2O) Rs.459.56 and Rs.983.56 by intercropping cowpea (from 10:15:5 and 20:30:10 kg/ha of N, P_2O_5 and K_2O) and Rs.1353.93 and Rs.2495.30 by intercropping groundnut (from 10:15:20 and 20:30:40 kg/ha of N, P_2O_5 and K_2O) were obtained over the pure crop of tapioca.

Maximum net profit from the crop was obtained (Rs.5489.70) when tapioca was intercropped with groundnut supplied with 20:30:40 kg/ha of N, P_2O_5 and K_2O.

From the results of the above experiment it has been conclusively proved that intercropping legumes in the inter-row spaces of tapioca would increase the income from unit land area per unit time without reducing the normal growth, yield and quality of tapioca.

Groundnut was found to be the most suitable leguminous intercrop for growing with tapioca. To obtain maximum tuber yield from tapioca and seed yield from the intercrops, separate application of fertilizers to the intercrops, was found necessary.

An improvement in the fertility status of the soil was noticed due to intercropping tapioca with legumes.

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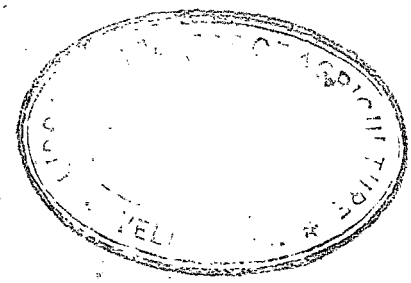

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*Originals not seen.

APPENDICES

APPENDIX I

Weather data for the period from May 1977 to March 1978 (Weekly averages) recorded at Vellayani

Period	Rain fall (in mm)	Temperature (^{o}C)		Relative humidity (%)
		Maximum	Minimum	
22-5-77 to 28-5-77	6.7	31.1	23.9	86.6
29-5-77 to 4-6-77	9.3	29.9	23.4	89.4
5-6-77 to 11-6-77	15.7	30.6	23.5	81.4
12-6-77 to 18-6-77	3.4	29.4	23.0	87.6
19-6-77 to 25-6-77	8.9	29.6	23.2	88.7
26-6-77 to 2-7-77	1.3	30.3	24.1	85.4
3-7-77 to 9-7-77	7.0	29.7	23.0	86.3
10-7-77 to 16-7-77	0.0	31.1	23.6	83.1
17-7-77 to 23-7-77	5.1	29.0	22.6	90.1
24-7-77 to 30-7-77	1.4	30.1	23.6	85.6
31-7-77 to 6-8-77	0.0	30.4	24.0	99.6
7-8-77 to 13-8-77	0.0	30.9	24.1	82.3
14-8-77 to 20-8-77	6.9	31.4	24.0	84.7
21-8-77 to 27-8-77	7.4	29.0	23.3	89.7
28-8-77 to 3-9-77	5.0	29.9	23.1	85.0
4-9-77 to 10-9-77	1.1	29.7	23.4	88.4
11-9-77 to 17-9-77	0.0	30.3	23.3	84.0
18-9-77 to 24-9-77	0.0	31.3	23.6	75.1
25-9-77 to 1-10-77	16.9	31.1	23.9	85.7
2-10-77 to 8-10-77	0.0	30.4	23.3	86.7
9-10-77 to 15-10-77	7.1	30.3	23.9	88.7
16-10-77 to 22-10-77	62.9	28.6	23.3	92.9
23-10-77 to 29-10-77	44.0	28.9	23.6	90.0
30-10-77 to 5-11-77	25.7	31.2	23.4	86.4

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APPENDIX I (CONTINUED)

Period	Rain fall (in mm)	Temperature (°C)		Relative humidity (%)
		Maximum	Minimum	
6-11-77 to 12-11-77	6.4	30.0	23.1	89.9
13-11-77 to 19-11-77	4.0	30.6	23.3	89.4
20-11-77 to 26-11-77	9.6	30.6	22.9	85.0
27-11-77 to 3-12-77	0.0	31.4	23.4	81.1
4-12-77 to 10-12-77	0.0	31.6	23.1	81.7
11-12-77 to 17-12-77	0.0	31.6	21.7	71.1
18-12-77 to 24-12-77	0.0	32.3	23.0	74.7
25-12-77 to 31-12-77	0.0	32.0	22.4	78.4
1-1-78 to 7-1-78	0.0	31.0	20.7	73.3
8-1-78 to 14-1-78	0.0	31.6	22.3	68.1
15-1-78 to 21-1-78	0.0	31.7	22.4	76.4
22-1-78 to 28-1-78	3.6	31.6	20.9	71.0
29-1-78 to 4-2-78	1.4	31.3	23.1	78.7
5-2-78 to 11-2-78	0.3	31.2	21.8	87.6
12-2-78 to 18-2-78	0.0	31.0	21.9	84.3
19-2-78 to 25-2-78	0.0	30.7	22.7	83.1
26-2-78 to 4-3-78	0.0	31.6	22.3	84.6
5-3-78 to 11-3-78	0.0	31.4	21.2	84.7
12-3-78 to 18-3-78	0.0	32.5	23.2	84.1
19-3-78 to 25-3-78	0.0	33.2	24.4	85.0

APPENDIX II

Abstract of analysis of variance table for number of leaves per plant at different stages of growth in tapioca

Source	df	Mean square									
		30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	180 DAP	210 DAP	240 DAP	270 DAP	At harvest
Block	2	25.37**	2.99	97.04	212.30	205.78	214.61	320.95	326.86	505.21	489.61
Treatment	12	1.83	5.39	46.05	102.89	346.72	969.28	2296.59	2293.59	2495.02	2472.53
Error	24	1.83	4.68	23.36	73.66	333.73	675.97	1319.92	1313.91	1359.44	1323.39

D.A.P = Days after planting

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX III

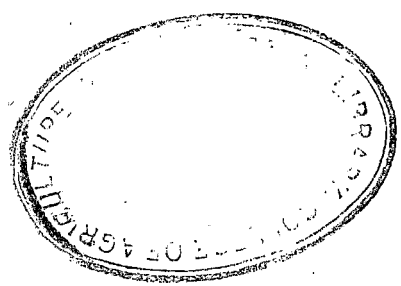
Abstract of analysis of variance table for height of plants (cm) at different stages of growth in tapioca

Source	df	Mean square									
		30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	180 DAP	210 DAP	240 DAP	270 DAP	At harvest
Block	2	89.03**	543.86**	443.59**	778.78*	858.96	739.95	6067.66	6008.02	5895.44	5768.55
Treatment	12	13.01	58.70	124.73	184.90	1391.06	1723.28	7541.89	7496.70	7436.58	7375.19
Error	24	6.54	41.24	70.85	145.62	651.90	4369.95	4314.10	4227.40	4205.92	4168.34

DAP = Days after planting

*Significant at 5 per cent level

**Significant at 1 per cent level



APPENDIX IV

Abstract of analysis of variance table for total number of roots per plant, number of tubers per plant, percentage of productive roots, length of tuber, and girth of tuber

Source	df	Mean square				
		Total number of roots per plant	Number of tubers per plant	Percentage of productive roots	Length of tuber (cm)	Girth of tuber (cm)
Block	2	79.98*	10.68	26.97	0.77	7.15**
Treatment	12	13.22	11.11*	141.52*	3.73	0.50
Error	24	18.19	4.21	55.13	5.71	0.72

*Significant at 5 per cent level

**Significant at 1 per cent level

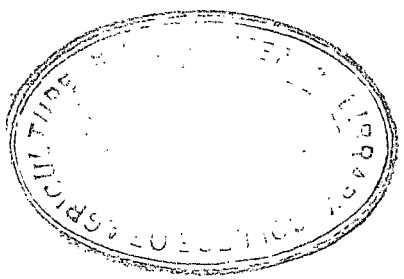
APPENDIX V

Abstract of analysis of variance table for rind to flesh ratio, percentage of edible portion in tubers, tuber yield, top yield and utilisation index in tapioca

Source	df	Mean square				
		Rind to flesh ratio	Percentage of edible portion in tubers	Tuber yield (t/ha)	Top yield (t/ha)	Utilisation index
Block	2	0.005**	21.45**	31.79	7.03*	0.001
Treatment	12	0.0003*	1.23*	17.10	2.30	0.095
Error	24	0.00009	0.45	11.31	2.02	0.054

*Significant at 5 per cent level

**Significant at 1 per cent level



APPENDIX VI

Abstract of analysis of variance table for dry matter percentage of tubers, starch content of tubers, crude protein content of tubers hydrocyanic acid content of tubers in tapioca and the total nitrogen content of the soil after the experiment

Source	df	Mean square				
		Dry matter percentage of tuber flesh	Starch content of tubers (%)	Crude protein content of tubers (%)	Hydrocyanic acid content of tubers (mg/kg)	Total N content of the soil (kg/ha)
Block	2	40.29*	0.03	3.12**	224.16**	26739.40**
Treatment	12	33.66**	29.54**	0.11	786.70**	20734.01**
Error	24	7.72	2.60	0.06	31.13	2757.44

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX VII

Analysis of variance table for cooking quality of tapioca tubers

Source	S.S.	df	M.S.	F
Total	34.550	54	-	-
Treatments	2.005	4	0.501	0.770
Error	32.545	50	0.651	-

APPENDIX VIII

Abstract of analysis of variance table for height of plants in intercrops (cm)

		Mean square			
Source	df	Blackgram	Cowpea	Greengram	Groundnut
Block	2	123.13**	37.72	3.88	65.34*
Treatment	2	449.23**	2761.09**	441.69**	69.13*
Error	4	3.23	35.49	8.64	7.94

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

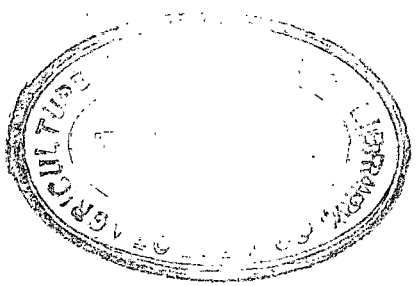
APPENDIX IX

Abstract of analysis of variance table for grain or seed yield of intercrops (kg/ha)

Source	df	Mean square			
		Blackgram	Cowpea	Greengram	Groundnut
Block	2	2711.50	1080.29*	347.76	154.28
Treatment	1	34462.90**	247143.27**	3747.38*	249072.96**
Error	4	1271.25	94.26	489.17	5262.27

*Significant at 5 per cent level

**Significant at 1 per cent level



APPENDIX X

Abstract of analysis of variance table for haulm yield of intercrops (kg/ha)

Source	df	Mean square			
		Blackgram	Cowpea	Greengram	Groundnut
Block	2	13086677.78	10525148.45	479386.97	154.28
Treatment	2	18533677.79**	218628328.45**	7348705.09**	249072.96**
Error	4	685394.44	4164272.78	183253.55	5262.27

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX XI

Abstract of analysis of variance table for the amount of nitrogen incorporated by haulms (kg/ha)

Source	df	Mean square			
		Blackgram	Cowpea	Greengram	Groundnut
Block	2	23.42	329.90	9.12	615.77
Treatment	2	382.56**	8970.22**	161.16**	2024.97**
Error	4	12.92	128.50	3.83	111.34

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

ABSTRACT

An experiment was conducted in the College of Agriculture, Vellayani during the year 1977-1978 to study the performance of tapioca intercropped with different legumes (blackgram, cowpea, greengram and groundnut) supplied with different fertilizer doses (no fertilizer, half the recommended dose and full recommended dose). The experiment was laid out in a randomised block design with three replications. The experiment was conducted under rainfed conditions.

The results revealed that the growth as measured from height and number of leaves and yield of tapioca as adjudged by the various yield attributes was not depressed by growing the four legumes at the three levels of fertilizers. On the other hand the quality and size of tapioca tubers were improved due to legume intercropping. The dry matter content, starch content and the HCN content of tapioca tubers were increased significantly due to growing of legumes in association with tapioca. The crude protein content of tubers as well as the length and girth of tubers were also increased slightly due to the legume intercropping.

Though the hydrocyanic acid content of the tapioca tubers was found to increase significantly due to legume

intercropping, the cooking quality of tubers was not affected.

The fertility status of the soil was improved by growing the legumes as intercrops. The total nitrogen content of the soil after the experiment was considerably higher in the intercropped plots when compared to the non-intercropped plot.

Application of additional fertilizers to the intercrops in addition to that applied to the main crop was found beneficial to the intercrops as well as for the main crop. The growth, yield and quality of tapioca were higher when fertilizers were applied to intercrops.

Intercropping in tapioca was found to be profitable when blackgram, cowpea and groundnut were raised as intercrops with additional fertilizers to them. Intercropping of groundnut with the recommended dose of fertilizers gave the highest net profit of Rs.5489.70/ha from the association as compared to Rs.3427.50/ha from pure tapioca. Greengram was not a promising intercrop with tapioca. Among the intercrops groundnut was the best.

The fertilizer requirement of the legumes when grown as intercrops was found to be slightly less than that required for their pure stands.