CROP GEOMETRY STUDIES IN TAPIOCA BASED INTERCROPPING SYSTEM

By
ANILKUMAR A S.

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DECLARATION

I hereby declare that this thesis entitled "CROP GEOMETRY STUDIES IN TAPIOCA BASED INTERCROPPING SYSTEM" 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 any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellayani,

(ANIL KUMAR, A.S.)

CERTIFICATE

Certified that this thesis entitled "CROP GEOMETRY STUDIES IN TAPIOCA BASED INTERCROPPING SYSTEM" is a record of research work done independently by Sri ANIL KUMAR. A.S. 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.

(Dr. V.K. SASIDHAR)
Chairman,
Advisory Committee,
Professor of Agronomy,
College of Agriculture, Vellayani.

Vellayani,

APPROVED BY:

Chairman:

Dr. V.K. SASIDHAR

Members:

1. Shri. V. RAMACHANDRAN NAIR

2. Shri. P. CHANDRASEKHARAN

3. Shri. P.R. RAMASUBRAMONIAN

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ANIL KUMAR. A.S.

Vellayani,

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Introduction

INTRODUCTION

Tapioca, (*Manihot esculenta* Crantz.) is one of the most important subsidiary food crops of Kerala and forms an integral part of the farming systems throughout the state. In Kerala it grows easily and yields heavily even on poor laterite soils. It is grown even on hill tops and slopes where the yield from other annual crops would be extremely low.

The cultivation of tapioca increased considerably as a result of the increase in the world's population, the scarcity of other sources of nutritional energy, and its high potential for production of carbohydrates per unit of land or labour. Moreover, as a root crop tapioca is biologically more efficient than grain since it does not require an elaborate structure to support its edible portion. Hydrocyanic acid content of tapioca makes it subject to minimal animal and pest attacks and hence it is a good risk aversion crop. Besides its easy method of propagation, drought resistance and flexibility of harvesting time make tapioca well suited to small scale subsistence agriculture (Phillips, 1973). But the pity is that the tapioca grower who contributes substantially for averting starvation in the state is himself in a semi-starved condition since tapioca has no comparable spell or prosperity as other money crops like rubber. It is very often argued that being the food of the common man, tapioca should be sold at low price (Anon., 1972). This may not be possible unless tapioca is made more remunerative by generating more income from tapioca fields. In this respect intercropping is considered as one of the few measures for higher economic returns from unit land area. The growth cycle of tapioca permits successful intercropping in early stages of its growth also (Mohankumar, 1976).

The principle of intercropping is in line with ecological systems in nature where the niches created by the larger species are successively utilized by the ecologically smaller ones; this progressive accommodation ensures a high and efficient utilization of the energy in the ecosphere and leads to maximum production (Panje, 1973). In fact, it is a system of cropping where in between the spaces of widely spaced principal crops short duration companion crops are grown to make maximum use of solar energy, water and soil in the periods while principal crop is still in the growing stage or have little growth (Mahabal Ram, 1980). Both the crops are usually 'simultaneous' for a significant part of their growing periods (Willey, 1979). Farmers intercrop for a variety of reasons, namely, to (1) insure against total crop failures under aberrant weather conditions or pest epidemics (2) increase total productivity per unit land area, and (3) equitably and judiciously utilize land resources and farming inputs including labour(Rajat and Singh, 1979).

Tapioca plants have large canopies and are planted in wider rows. They are slow growing during the early stages and usually take more than three months from the time of planting to the time when leaves from adjacent rows overlap. During the pre-overlapping period solar energy either goes to waste or is used by weeds growing between the rows of tapioca. Several fast growing crops can be accommodated in between the rows of developing tapioca plants. These intercrops should be capable of germinating quickly and developing its own leaf area index so fast that weeds are not able to overtake it. Secondly, it should have temperature and photoperiod requirements corresponding to the season of intercropping. Thirdly, there should be no antibiosis between crops. Fourthly, its photosynthesis for seed development should not be largely or entirely confined to the reproductive phase or to the late stages of its life cycle; actually it could be better if the intercrop sheds its leaves during the flowering and seed setting stages (Panje, 1973). Besides the above characteristics, the intercrops should be selected to fit in the expected rainfall pattern of the area since both crops are planted simultaneously. The planting time of tapioca always coincides with the onset of monsoon rains. Considering the above aspects two short duration leguminous crops, namely, groundnut and cowpea were selected for the present study.

Main crop is usually the main source of income whereas the fast maturing intercrop is used only to supplement the food needs of the farm household while waiting for the main crop. Therefore, it is essential that productivity of the slow maturing main crop is neither disrupted nor substantially reduced by the fast maturing intercrop. But several experiments conducted in tapioca based intercropping system revealed a reduction in the productivity of the main crop when it was planted in the uniform row distances (Singh and Mandal, 1970). The growth of the companion crop is depressed substantially if it is interplanted between the normal rows of a base crop (Singh, 1979).

Spatial arrangement of crops can have a direct effect on yield, on the absorption of radiant energy and on evaporation and thus an indirect effect on water use efficiency (Arnon.,1979). In fact, the spatial arrangement decides the extent of utilization of available space, time, nutritional factors and light to boost production from an intercropping situation. Tapioca border rows produce considerably higher yields than inside rows probably because of their relative position favouring to receive more light and nutrients (Mattos et al., 1980a). Planting tapioca in double rows brings two rows of tapioca more closer and leaves a greater space between the double rows into which the intercrop can be accommodated. With this background, the present investigation was undertaken with the following objectives.

1. To study the effect of intercropping of cowpea and groundnut with tapioca.
2. To identify the most suitable spatial arrangement of crops in tapioca based intercropping system.
3. To investigate the possibilities of introducing paired row system of planting pattern in tapioca.
4. To work out the economics of intercropping in tapioca.

Review of literature

REVIEW OF LITERATURE

Tapioca based scientific intercropping system is only of recent origin. Various short duration crops like cereals, millets, minor tubers, pulses and legumes, oil seeds, leafy vegetables, fruits medicinal plants and forages are grown along with tapioca. Thampan (1979) reported that the morphological features as well as the ecophysiological requirements of intercrops influenced the productivity of tapioca. Various management practices like crop compatibility, planting geometry, planting time and technique, fertilizer management, water balance, weed control and plant protection decide the production potential of a tapioca based intercropping system. Research works on the above practices and other related aspects are reviewed hereunder.

A. Influence of crop compatibility on the productivity of a tapioca based intercropping system.

The success of intercropping largely depends upon selection of a suitable companion crop for the main crop. According to Mahabal Ram (1980) it is essential to know the prerequisites of companion crops before selecting any companion crop such as, (1) soil requirement compatibility (2) water requirement compatibility (3) competition for space, sunshine and air (4) compatibility for pests and diseases (5) duration and yield potential and (6) time of sowing and harvesting. Growing crops of dissimilar growth patterns, such that, peak periods of growth do not coincide, would ensure optimum productivity of the two crops growing in association. For long duration crops with an initial slow growth rate solar energy utilization can be optimized by interplanting a quick maturing crop (Rajat and Singh, 1979).

The practice of intercropping in tapioca has been reported from Brazil as early as 1935 (Marcus, 1935). Lan (1908) who was a pioneer in this field could not find significant influence of a legume crop, Macuna utilis when intercropped with cassava. Rotenhan et al., (1966) observed the practice of intercropping sorghum, maize, rice, groundnut, Bambara groundnut, cowpeas, mungbeans, chickpeas, sweet potatoes, cotton and sisal with tapioca.

Both harmful and beneficial effects of intercropping have been reported by several workers. In an experiment carried out by Singh and Mandal (1970) with different intercrops like horsegram, sesamum, coleus, bhindi, groundnut and cowpea, it was found that horsegram and sesamum considerably reduced the tuber yield of tapioca. Mohankumar (1975) noted maximum reduction in tuber yield when maize was intercropped with cassava and it was significantly inferior to greengram, groundnuts and soybeans but was on par with sunflower.

The vigorous growth of cassava resulted in reduced yield of mungbean due to shading effect caused from its early development onwards (Anon., 1978a).

At CIAT cassava was planted with various legumes like beans, perennial peanuts, soybeans, cowpea, stylo, kudzu etc. (Anon., 1978a). It was found that beans, perennial peanuts and soybeans grew poorly because of toxic levels of aluminium and manganese in the soil and thus competed little with cassava. But cowpea grew very vigorously and competed for light during the critical early growth phase of cassava. Although cowpea yields were very low, the cassava never recouped from this early competition. Like cowpea, kudzu and velvet bean grew vigorously and climbed over the cassava canopy and thus competed seriously for light. Stylosanthes guyanensis reduced cassava yields because of its strong competition for water during the dry period. Kudzu, cowpea and especially the extremely vigorous Indigofera competed heavily with cassava, reducing yields upto 50 to 60% of normal. Desmodium ovalifolium produced a dense but low soil cover and did not compete much with cassava until the latter began to lose its leaves at the end of the growth period. D. ovalifolium combines the favourable characteristics of early establishment, good ground cover and minimal competition with cassava. Lira et al., (1979) showed that intercropping pearl millet for the second cassava year (cassava was harvested after 18 months) was not profitable. Studies on intercropping of tapioca at Nileswar revealed that growing of pulses and vegetables as intercrops with tapioca was not a worthwhile proposition in areas where south west monsoon starts straight away with intensive downpour (Anon., 1979). Prabhakar et al., (1979) noted that all the intercrops (groundnut, cowpea, maize, fodder maize, horsegram, greengram, blackgram and redgram) had their deleterious effects on the main crop, which resulted in the reduction of cassava tuber yield. Maximum tuber yield of 31.3 t/ha was produced in the control plot which was on par with cowpea intercropping, but was significantly superior to other intercrops tried. The reduction in yield in the intercropped plots was mainly due to the crop competition in the early growth stage of cassava which resulted in comparatively lesser number of tubers per plant as well as reduction in the size of the tuber.

The possibilities of raising a second intercrop in cassava was assessed by Prabhakar et al., (1979) which showed that under the agroclimatic conditions prevailing in Kerala and considering the growth habit of cassava it was not possible to raise a second intercrop in cassava holdings. This was probably due to the fact that at the time of harvest of the first series of intercrops, cassava developed enough canopy to cover the entire field and the sunlight infiltration into the ground was less than 10%. Another probable reason may be that the subsequent growth period of cassava (October-December) continued with the dry period, with the result there was considerable moisture stress in the soil; thus reducing the possibility for a second series of intercrops. According to Prabhakar *et al.*, (1979) the tuber yield was significantly superior when cassava was grown as a pure crop and intercropping with any vegetable crop (cowpea, french beans, amaranthus, cucumber or bhindi) has reduced the tuber yield significantly. Among the different intercrops tried, beans recorded the maximum tuber yield; but was on par with other intercrops. The possibilities of growing some of the short duration, drought tolerant medicinal plants like Senna (*Cassia angustifolia*) and *Vinca rosea* along with cassava plants during its early stages of growth were also attempted. Out of the two medicinal plants tried, only *Vinca rosea* established and yielded (Prabhakar *et al.*, 1979). Prabhakar *et al.*, (1979) again reported significant reduction in cassava yield due to intercropping of pigeonpea. The highest tuber yield of 23.1 t/ha was obtained in pure crop of cassava which was significantly superior to intercropped cassava yield obtained with pigeonpea. There was no significant difference among different pigeonpea varieties with respect to cassava yield. Prabhakar and Nair (1979) reported that planting a row of pigeonpea at a spacing of 75 cm between two rows of cassava decreased tuber yield from 24.42 to 17.49 t/ha.

Howler (1980) suggested that intercrops should be carefully chosen so as to tolerate the same soil and climatic conditions as cassava and not to compete excessively for light (climb on the cassava plant), water or plant nutrients. Although intercropping increased the combined yields of both crops expressed as land equivalent or area - time equivalent ratios, it seldom had a direct beneficial effect on cassava yields. Depending on the competition from the intercrop, cassava yields were reduced from 0 to 50%. Bean yield, relative to monoculture, was negatively correlated with cassava top growth three months after planting. When the same cassava cultivar was intercropped with soybean, cassava and soybean yields were negatively correlated. But when simultaneous planting of cassava and soybean was done, there was only slight reduction in the yield of soybean (Anon., 1981a).

The different varieties of cowpea and groundnut were evaluated as intercrops with cassava and concluded that all the cowpea varieties tried except H 42-1 had affected cassava growth to some extent as compared to control. Maximum fodder yield was recorded by Kanakamani which was almost equalled by H 42-1. All the groundnut varieties affected the cassava growth but maximum effect was seen with TG-17. However, TG-17 recorded highest yield as intercrop and TMV-2 the lowest (Anon., 1981b).

In trials at CIAT (Anon., 1982a) some or all the 61 Vigna unguiculata, 66 V. radiata, 14 Cajanus cajan, 9 Psophocarpus tetragonolobus, 8 Glycine max, 3 Phaseolus lunatus, 2 Stizolobium deeringianum, 1 Canavalia ensiformis, 1 C. gladiata and 1 Arachis hypogaea cultivars were tested for qualities suitable for simultaneous cultivation in cassava such as non-aggressive growth, rapid ground cover and maturity in less than 100 days. The reduction in cassava root and legume seed yield due to intercropping were in the ranges 1 to 68 and 10 to 81%, respectively with C. ensiformis, C. gladiata causing the greatest reduction in cassava yields and giving little or no seed yield in compensation. V. unguiculata and A. hypogaea suffered seed reductions of 10 and 15% from intercropping with cassava and reduced cassava root yields by 36 and 18% respectively.

Contrary to the above observations, beneficial effects due to intercropping in tapioca have been reported from several tapioca growing centres in the world. An attempt was made by the Agronomy Department of Agricultural College, Vellayani, Kerala during 1961 in which the role of legumes as intercrops was studied in the coastal regions of Kerala. The yield of tapioca grown mixed with blackgram and groundnut was found to be more as compared to several legume intercrops cultivated along with tapioca (Anon., 1965). Singh and Mandal (1968) observed no substantial reduction in the yield of cassava when it was intercropped with groundnut. Singh (1969) even proved the superiority of groundnut and cowpea as intercrops in cassava as compared to ragi, jowar and sesamum. Mohankumar (1973) revealed that among several cultural practices, intercropping in cassava was an economic proposition and crops like groundnut and maize can be introduced profitably in between tapioca rows during its early stages of growth. It was revealed that cassava grown alone gave tuber yields of 12.9 t/ha while it was 13.2 t/ha and 11.0 t/ha when intercropped with beans and maize respectively. These yields did not differ significantly also (Anon., 1975 a).

Gonzalez (1976) evaluated the morphological characteristics of the plants that affected radiation within the crop and has revealed that non-intercepted solar radiation within the crop decreased progressively as the plant became older. Morphological characteristics correlated best with this microclimatic factor were plant height, leaf area and total biomass. Significant effect of the association of beans or cowpea on cassava plant height was also noticed. When cassava was intercropped with Bellary onion, cowpeas, peanuts, mungbeans and field beans, it was found that Bellary onion was the most suitable intercrop causing only slight yield reduction in cassava (1.1% reduction) (Thamburaj and Muthukrishnan, 1976).

Wilson and Adenigan (1976a) recommended intercropping of vegetables with cassava. Cassava was intercropped with a sequence of three vegetables (tomatoes, okra and French beans). Okra and French bean yields were suppressed but land equivalent ratios (L.E.Rs) showed that this system was more efficient than any of the crops alone. Wilson and Adeniran (1976b) also made records on land productivity under maize and cowpea in pure stands and mixed cropping with cassava and reported that total yield/ha/year was 28% higher in mixed cropping. The possibility of raising crops like blackgram, greengram, cowpea and bhendi as intercrops in tapioca was studied at Coconut Reseafch Station, Pilicode, Kerala. The tapioca yield in all the intercropped plots was more than that of the control having no intercrops. The maximum yield increase of tapioca was seen in plots intercropped with cowpea and greengram (Anon., 1977a). Patanothai et al., (1977) revealed that there were no significant yield differences between cassava in monoculture and those obtained from intercropping with peanuts, soybeans, mung beans, maize and upland rice. Among the field crops used, peanuts produced the best yields also. In general, mung beans and peanuts, appeared to be the most suitable crops for intercropping in cassava.

It was also indicated that the yield of the main crop tapioca was not affected by growing intercrops like groundnut, cowpea and maize (Anon., 1978b). At CIAT a black bean of indeterminate growth habit was intercropped with 20 cassava genotypes of widely varying morphological characters and noted a strong negative correlation between bean yield relative to monoculture and cassava top growth, three months after planting. In this experiment there was a non-significant, but positive correlation between bean yield and cassava fresh root yield. The <u>Phaseolus</u> bean completed its growth cycle (100 days) before cassava covered the ground and hence could yield well with cassava. On the otherhand, the soybean had a growth cycle of 125 days and its grain filling period occurred only when cassava completely covered the ground. Therefore there occurred severe competition between cassava and soybean and therefore it was difficult to select a cassava variety combining the high yield potential as well as ability to tolerate full development of the component crop (Anon., 1978b).

Moreno and Hart (1979) concluded that ecological studies and identification of socio-economic determinants in specific locations were required to evaluate the production potential of a tapioca based intercropping system. Nitis (1978) reported that cassava/stylo produced 5 to 180% more green feed immediately after the harvest of cassava than cassava/volunteer spp. Intercropping with stylo increased cassava tuber yield from 6.75 to 6.81 t drymatter/ha. But intercropping with native grass decreased tuber yields to 3.24 t/ha. Intercropping did not affect protein content or in vitro digestibility of either crop or starch or hydrocyanic acid content of cassava. Ramakrishna Bhat (1978) opined that the tuber and top yields of tapioca were not affected by growing groundnut, cowpea, blackgram and greengram as intercrops. On the otherhand tapioca tuber dry matter content, percentage starch content and crude protein content were increased by legume intercropping. Correa and Rocha (1979) recommended intercropping of cassava with cowpea, maize, rice, soybeans, grain sorghum, <u>Phaselus vulgaris</u> and <u>Crotalaria spp</u> for maximum land use and productivity. Maximum quantity of marketable cassava tubers was harvested by Escalda and Javier (1979) when it was intercropped with inoculated bush beans. Among root crops (sweet potato, cassava and gabi) - legume (mung beans, soybeans and bush beans) combinations, cassava gave the highest yields. Yields of legumes when grown in association with root crops were low compared to those of monoculture, however, they were considered economically favourable as extra crops.

A new intercropping technology for cassava/grain associations was developed at CIAT by Leihner (1979). According to this high yielding cassava cv. with an erect, late branching growth habit with minimum intercrop competition should be used. Legume crops, preferably <u>Phaseolus vulgaris</u>, <u>Vigna unguiculata</u> or <u>Arachis hypogaea</u> which are early maturing, rapidly covering the ground and with determinate growth habits should be used as companion crops. The associated crops should be planted simultaneously, each at its normal, monocropping density.

An array of crops with duration not exceeding four months have been tested at the Cassava Experimental Plots of the Tamil Nadu Agricultural University, Coimbatore for their suitability as intercrops under irrigated conditions. The intercrops tested were (1) bulb crops like onion (Allium cepa, var. cepa L.) and Aggregate onion (Allium cepa. var aggregatum) (2) leguminous crops like greengram (Phaselous aureus, L.) cowpea (Vigna sinensis, L. savil) and Co-8 Lablab (Lablab niger, L) (3) fruit vegetable crops like Okra (Abelmoschus esculentus (L) Meench) and (4) oil seed crops like groundnut (Arachis hypogaea L.) and sunflower (Helianthus annuus L.). It was concluded that onion (Allium cepa L.) was the most suitable intercrop with cassava because bulb formation and maturity were completed within 85 days before root bulking in cassava. Neither growth nor tuber yield of cassava was affected by onion (Muthukrishnan and Thamburaj, 1979). According to Thomas and Nair (1979) cassava grown in pure stands yielded 10.37 t tuber/ha and when intercropped with groundnuts yielded 10.86 t/ha, in addition, groundnut yielded 1.86 t of unshelled nuts/ha.

Zandstra (1979) pointed out some considerations for the design of cassava intercropping patterns: (1) cassava variety should be tolerant to early shading (2) during maximum production period the cassava canopy should be superior to that of the intercrop (3) if possible, cassava should remain below the canopy of the intercrop during the first 120 days (4) cassava planting should be delayed 20 to 30 days to prevent excessive shading of the intercrop and (5) plant density should be kept low and row spacing wide without yield reductions. De and Frazao (1980) concluded that for total crop returns the best system was maize/cassava intercropping followed by cowpea. An experiment conducted at Khonkaen University, Thailand produced higher yields of cassava (26.76 t/ha) when intercropped with groundnuts compared to sole culture (Anon., 1980a). According to Burgos (1980) reduced soil and nutrient losses as well as maintenance of good physical properties were the reasons for increased yields in simultaneous intercropping.

Mohankumar (1980) noticed significant difference in tuber yield when cassava was intercropped with greengram, groundnut, maize, soybeans and sunflower. Control plot in which no intercrop was raised recorded the maximum yield which was significantly superior to intercropped fields. Experiments conducted at CIAT (Anon., 1981c) showed that cassava could be successfully intercropped with beans at later stages of development without modifying the cassava canopy. In this case, cassava yields were not affected by intercropping and a low yield of 500 to 800 kg/ha of dry beans was feasible.

Sheela (1981) concluded that the growth of tapioca plant as observed from the height, total number of leaves and girth of stem was suppressed by legume intercropping in the early stage, but later the suppressing effect was overcome and no difference was noticed in the characters due to intercropping. Intercropping tapioca with cowpea and groundnut reduced the percentage of productive roots in the main crop. Length of tapioca tubers was unaffected by the systems of cropping. Although the drymatter content of tapioca tuber was not influenced by any of the treatments, starch, protein and hydrocyanic acid contents of tubers were increased by intercropping. Cooking quality of tuber was also not affected by growing legumes. This experiment once again confirmed the superiority of groundnut as an intercrop with tapioca. While screening cowpea varieties suitable for mixed cropping with tapioca it was observed that V-37 produced the highest yield (1175 kg/ha) at Peechi command area and Kanakamani yielded maximum (615 kg/ha) at Chalakudy command area. At Malampuzha, C-152 gave the highest yield (505 kg/ha) and was superior to all other varieties tried (Anon., 1982b). Groundnut varieties like JL-24, Pollachi-1, Pollachi-2, FSB-7-2 and TMV-2 were evaluated for mixed cropping with tapioca at Kodassery

(Chalakkudy). Though the difference in pod yield was found to be nonsignificant, highest yield was recorded by TMV-2 (482 kg/ha)(Anon., 1982c). The intercropping trials conducted at Vellanikkara identified cowpea as the most profitable intercrop in cassava in the high rainfall regions with laterite soil. The yield of cassava was not reduced due to intercropping (Anon., 1982d).

Beans planted in association with cassava had no significant reductions in yields whereas, yields of soybeans were severely reduced. Yields of beans and soybeans were negatively correlated with vegetative vigour of the associated cassava genotype, but were not correlated with yield or inter-genotypic competitive ability of the cassava genotype. Cassava could be planted in association with short duration crops without sacrificing much on the yields of either crop. High yielding cassava genotypes with low vegetative vigour would bring about high combined yields of cassava and the associated crop (Kawano and Thung, 1982).

B. Influence of the time of planting on the productivity of a tapioca based intercropping system.

By changing the time of planting both favourable and unfavourable effects on the growth and yield of tapioca and companion crops have been observed. It was reported that when early sown groundnuts were intercropped with late planted cassava, the yield of groundnut was not seriously affected, but the yield of cassava was reduced to less than one fifth of what was produced when grown alone (Anon., 1959). In field trials Phaseolus vulgaris was sown on dates relative to a single planting date of cassava, either in monoculture or intercropped. Seed yields in monoculture decreased slightly with delay in sowing date, the mean yield being 2.9 t/ha, but were reduced severely when sown as intercrops after cassava. Cassava planted six weeks before P. vulgaris reduced seed yield to 53% of what was obtained in monoculture. Leaf area index in P. vulgaris was markedly depressed when cassava canopy was higher than that of P. vulgaris (Anon., 1976). When cassava and phaseolus beans were intercropped (Anon., 1977b), cassava root yield was little affected by the planting date of the beans compared with monoculture cassava harvested at 340 days. When intercropped cassava was harvested earlier at 260 days, the effects were pronounced with cassava yields being markedly reduced when the beans were planted four weeks before the cassava. Bean yields were not reduced by intercropping with cassava when beans were planted from four to six weeks before cassava. However, bean yields showed a marked decline when beans were planted from three weeks before to six weeks after cassava. According to Gerodetti (1979) simultaneous planting reduced total production of cassava by 40% in cassava/maize associations. Another experiment on cassava/maize association (Maurya and Lal, 1980) revealed that a second maize intercrop was not possible during the second season.

Improvements on the growth and yield of tapioca and associated crops by changing the time of planting have been reported by many workers. Hart (1975) investigated the effect of interspecific competition on crop yield by designing a bean, corn and cassava polyculture system. Systems like (1) succession polyculture (in which bean, maize and cassava were all planted at the same time and harvested after 9, 18 and 36 weeks respectively) (2) reverse polyculture (in which cassava was planted alone and then interplanted with maize after 18 weeks and beans after 27 weeks and all crops harvested after 36 weeks and an (3) intensive polyculture in which four bean crops, two maize crops and one cassava crop were all interplanted during a 36 week period and concluded that interspecific competition in the succession polyculture resulted in a dynamic interaction between bean and maize yields. Experiments on intercropping cassava with maize, melons and vegetables were conducted at Ibadan, Nigeria (Anon., 1975b). Results indicated that it was essential to plant cassava one to two months before maize to ensure a relay crop prior to the harvesting of cassava. When intercropped with maize and melons, cassava yielded 34 t fresh weight/ha as compared to 28 t when planted alone.

Mung beans were planted 40, 20 and 0 days before cassava to determine the proper time of intercropping and concluded that planting time had no effect on mung bean yields although planting cassava 40 days after mung beans gave higher income than at 20 and 0 days (Kanchanahut, 1976a). An experiment on similar line was conducted by Kanchanahut et al., (1976) with groundnuts and revealed that simultaneous planting peanuts and cassava was the best. Planting cassava, 0, 20 and 40 days after soybeans yielded nearly the same amount of roots, but at 40 days, soybeans gave more income (Kanchanahut, 1976b). When beans were planted six weeks before cassava, total land use time for the two crops was 382 days. However, when they were planted at the same time or later, total land use time was 340 days when the cassava was harvested 340 days after planting. The Land Equivalent Ratio (L.E.R.) of the various planting dates was calculated as the ratio of the land area needed in intercropping/monoculture for both crops. The most efficient biological land use measured by the L.E.R. was 1.7 when crops were planted at the same time. This very high L.E.R. suggested that there was great potential for intercropping with cassava. Yields indicated that one hectare of land produced 34 t of fresh cassava and 2.9 t of beans in less than one year (Anon., 1977b).

Chew (1979) tried various annual crops in matured and immatured cassava and concluded that relay cropping of cassava following peanuts, sorghum, chillies, tobacco and asparagus beans was more likely to succeed than relaying these after cassava.

Studies on the effect of time of planting cassava on upland cropping pattern performance (Anon., 1978b) revealed that the optimum planting date for cassava was 20 days after sowing maize and 40 days after sowing upland rice. Thung and Cock (1979) emphasized the importance of planting date and reported that simultaneous planting appeared preferable for obtaining higher yields from both the crops of a cassava field bean association. An L.E.R. of 1.5 was obtained resorting to simultaneous planting. Simultaneous planting of both maize and cassava was found to be profitable (Anon., 1980c). The different dates of sowing groundnut as intercrop in tapioca did not influence the yield of groundnut also (Anon., 1980d).

According to Lazarte (1980) planting date affected both cassava and bean production. The shade produced by bean plants affected cassava growth during the initial stages. Root weight did not vary due to planting or intercropping date. Cassava planted 60 days after bean planting gave greater land use efficiency, productivity and total profit/ha, there was a difference of 8844 kg as compared with beans and cassava in monoculture.

Moreno and Meneses (1980) analysed the yields of some legumes intercropped with cassava at the end of its growth cycle. Cowpea, lima beans and common beans (both climbing and bunch type) were intercropped after 240 days of cassava planting. Cowpea and lima bean yields decreased 33 and 35% in respect to monoculture. Reduction in the yield of bush variety of common beans to the tune of 17% was observed due to competition with cassava while 14% increase was noted with climbing variety as compared to its respective monoculture. Cassava both in monoculture and in association with beans presented a similar yield (25.40 and 25.61 t/ha respectively).

Phaseolus sp. was sown upto six weeks before or six weeks after cassava planting. Phaseolus seed yield declined with lateness of sowing. Yields of cassava roots harvested at 260 days were reduced by early Phaseolus sowing but at 340 days were not affected. The most efficient biological land utilization as measured by the L.E.R. (ratio of land area needed in intercropping/monoculture for both crops) was 1.7 when the crops were sown or planted at the same time as Phaseolus one week earlier (Anon., 1981a). Wilaipon et al., (1981) carried out field trials to study the effect of sowing time of stylo on cassava-stylo production and concluded that planting cassava and stylo at the same time significantly reduced cassava yield as compared with monocropping of cassava.

However, planting stylo six weeks after cassava caused only very little and insignificant reduction in cassava yield.

C. Influence of planting geometry on the productivity of a tapioca based intercropping system.

According to Mahabal Ram (1980) the geometry of planting plays a very important role in the success of intercropping. Efforts should therefore be made to create a favourable environment so that both the companion crops may adjust themselves properly. The effect of cassava/peanut intercropping on the yield of cassava was reported by Ekmahachai et al., (1976). Among the various planting patterns tried, cassava intercropped with two rows of peanuts (30 cm between rows and 20 cm between hills) between cassava rows, 35 cm apart from the cassava row was found to be remunerative when compared to cassava monocrop, peanut intercropped within the cassava rows or cassava intercropped with three rows of peanuts between its rows.

Methods of intercropping cassava with mung beans were investigated by Kanchanahut (1976a). Planting two rows of mung beans at a spacing of 30 x 20 cm between cassava rows was found to be superior to cassava monoculture, planting in the cassava rows (four hills of mung beans between two cassava plants) or planting three rows of mung beans. Kanchanahut et al., (1976) while making a comparative evaluation of the various methods of growing peanuts as an intercrop in cassava observed that planting peanuts in the cassava row ie., four hills of peanuts at a spacing of 20 cm between two hills of cassava planted at a spacing of 1 x 1 m was superior to cassava monoculture, planting two rows of peanuts between the cassava rows (30 x 20 cm) or planting three rows of peanuts between the cassava rows. Intercropping soybeans between the cassava rows (two rows of soybeans at 30 x 20 cm) was found to be better than growing cassava in monoculture, intercropping in the cassava row (four hills of soybeans between two hills of cassava at 20 cm spacing or three rows of soybeans (Kanchanahut, 1976b). Tongham (1976) evaluated various methods of intercropping cassava with mung beans and concluded that highest yield was obtained when three rows of mung beans were sown between the cassava rows (four hills of mung beans between two hills of cassava + 2 rows of mung beans between the cassava rows). This was contrary to the observation made by Kanchanahut (1976a).

Spatial arrangements were studied with both cowpea and peanuts for finding the planting pattern which caused leaf competition with cassava. Grain yields of both legumes were highest in a pattern of three rows between two rows of cassava spaced 1.8 m apart. Outside rows of legumes were 0.55 m from the cassava with o.35 m spacing between rows of legumes. Cassava yields were highest when two rows of legumes were planted 0.7 m from cassava rows spaced 1.8 m apart (Anon., 1980b).

Effect of spatial arrangements in cassava on the interspecific competition of cassava intercropped with cowpea was studied by Rego (1981). He evaluated different spatial arrangements as to the rate of soil cover and light interception and identified the spatial arrangement that minimized interspecific competition and maximized the productivity of the system. Cassava in monoculture exhibited a slow initial growth; at two months cassava had an average of 33% soil cover while in association with cowpea the average was 75%. The result of the experiments conducted at Mannuthy, Kerala indicated that high yields from groundnut and tapioca could be obtained when one row of groundnut was raised at a spacing of 30 cm apart in tapioca grown at a spacing of 75 cm^2 (Anon., 1982c).

D. Influence of planting density on the productivity of a tapioca based intercropping system.

Experiments conducted at Turrialba in Costa Rica by Meneses and Moreno (1979) to establish optimum planting density in maize/cassava association revealed very strong effect of competition by maize over cassava wherein cassava yields varied from 75% (with 10,000 maize plants/ha) to 46% (with 50,000 plants/ha). Maize planting density had a highly significant effect on cassava with parameters like height of the plant, height at the first branching, number, weight and length of commercial roots and stem diameter. Hagewald (1980) while making a study on intercropping grain legumes with cassava on acid sulphate soils revealed that cowpea and groundnut yielded maximum with 100 000 and 200 000 plants/ha respectively. Spatial arrangement influenced inter and intra specific competition both being minimized in a 60-30-60 cm triple row arrangement of legumes between cassava. The effect of maize plant population on maize/cassava intercropping was investigated by Kang and Wilson (1980) and reported that increasing maize population from 10 to 30 x 10^3 plants/ha significantly increased maize grain yield and at the same time had no significant effect on cassava root yield. Higher populations (maximum tried 70 x 10^3 plants/ha) however, had no effect on grain yield but significantly depressed root yield. Three maize plants/cassava hill were found to be optimum.

In trials in which Vigna unguiculata or groundnuts were sown at various populations and spaced at three different ways among cassava planted at 9259 plants/ha in rows 180 cm apart, seed yields were highest at 110 000 and 222 000 plants/ha respectively and when sown in three rows 30 cm apart, with the outer row 60 cm distant from a row of cassava. Legumes reduced cassava root yields with least and greatest effect when rows of legumes were placed 70 and 45 cm respectively distant from cassava rows (Anon., 1981d). In field trials, seed yield of groundnuts grown at 50000 - 60000 plants/ha spaced in three different ways among cassava planted in rows 180 cm apart increased with increasing population to a density of 250000 plants/ha with no further increase at higher populations. Cassava root yield was related negatively to groundnut seed yield, but not to groundnut population.

E. Influence of paired row planting pattern on the productivity of a tapioca based intercropping system.

Sowing crops in the normally recommended uniform row distances would afford little or no opportunity for accommodating a companion crop. On the other hand, modification of a planting pattern of the base crop would make intercropping feasible and often remunerative. Keeping the plant population per unit area of the base crop constant, no deviation in its yield has been noted by altering the orentation of rows (De et al., 1978). This planting geometry may provide additional space for the intercrop component. It will thus augment the utilization of available space, time, nutritional factors and light to boost the production per unit of natural and applied inputs (Singh, 1979).

Paired row system of tapioca cultivation, a modification of the traditional planting pattern has been reported from many research centres. In many experiments cassava border rows produce higher yields than inside rows probably because they receive more light and nutrients. The double (paired) row system tried to make use of this advantage. The use of the double row system for cassava offers the advantage of allowing other crops to be planted between the double rows and produces higher yields than conventional cassava cropping systems (Mattos *et al.*, 1980a). Planting cassava in double rows brings together two rows of cassava and leaves a greater space between these double rows than with the traditional method. This paired row system can improve crop production by (1) allowing easy use of mechanical equipments (2) decreasing production costs due to a reduction of labour (3) presenting the possibility of continuous use of the same area by alternating rows (4) allowing the possibility of multiple cropping (5) making crop inspection easy (6) increasing productivity due to a border effect (7) making the application of pesticides to control pests and diseases easy (8) allowing the possibility of mulching with plants in the free spaces for enriching the soil with organic material (9) reducing the amount of fertilizer used (10) reducing soil preparation to only the planting areas and (11) making better use of the land (Mattos et al 1980a). He also reported that cassava planting in double rows was an advisable practice because besides increasing root and starch yields and profitability, it allowed the free space to be used for growing other species such as beans, soybeans, rice, peanut, millet, sweet potatoes and tobacco. According to him 2.0 x 0.6 x 0.6 m spacings brought out the highest productivity and the greatest income return rate. Ezumah and Okigbo (1980) reported favourable effects on peanut productivity especially at high peanut populations by adopting double row planting technique for cassava.

Mattos *et al.*, (1980b) while conducting an experiment to utilize the free space between double rows of cassava by *Crotalaria juncea* revealed that the highest cassava root yields of 34.12 t/ha in CV BGM-116 and 39.72 t/ha in BGM-001 were given by double rows 2.0 m apart with 0.6 m between the two rows of each double row and between plants in the row and these yields were 57 and 16% respectively higher than a control with rows 1 m apart and 0.6 m between plants in a row. Yields with 2.5 or 3.0 m between rows were not significantly different from the control and differences in starch yields were not significant. Fresh matter yield of *C. juncea* ranged from 14.7 t/ha with 2.0 m between cassava rows and 0.5 m between plants in the row and between the two rows of each double row to 22.6 t with 3.0 m between cassava rows and 0.7 m between plants in the row and between the two rows of each double row.

Instances of reduced yield of cassava due to paired row system were also reported in the literature. For instance Mohankumar (1976) tried the possibilities of growing various intercrops like green gram, groundnut, maize, soybeans and sunflower under ordinary and paired row method of planting cassava and concluded that tuber yields were reduced in intercropped plots. He noticed no significant difference in tuber yield for the different methods of planting also. However, Patanothai and Laohasiriwong (1977a) while comparing single and double row planting patterns for cassava/legume (peanuts, soybeans and mung beans) association recorded no significant differences in yields.

When cassava was planted in double rows Souza *et al.*, (1981) recorded 25.8, 27.9 and 32.0 t/ha of tuber for the treatments (a) annual ploughing of the whole area and mechanical cultivation between the double rows (b) as in (a) but sowing *Canavalia ensiformis* between the rows instead of mechanical cultivation and (c) minimum ploughing of only the two area and then as (a), respectively. Above ground parts yielded 8.5, 8.4 and 12.6 t/ha in a, b and c respectively. Starch yield, number of tubers per plant and height of 6 and 12 month old plants were also greater. Ternes (1981) reported that although total roots per plant were higher with cassava in single rows, commercial root production was 13% greater in double rows. Associations of maize with cassava in double rows were the most efficient in land use in time (28% higher). The best agronomic and economic cropping system was cassava in double rows intercropped with maize.

F. Influence of fertilizer elements on the productivity of a tapioca based intercropping system.

Singh *et al.*, (1969) reported that cowpea added more organic matter (29.8 t/ha) and thereby more nitrogen (188.7 kg/ha) and groundnut ranked next in this respect from the results of an experiment involving groundnut and cowpea as intercrops in between cassava rows. Deeratikasikorn and Wickham (1977) studied the response of cassava to inorganic fertilizer application and the effect of oversowing Townswille stylo on cassava yield at different rates of fertilizer application. Yields of Townswille stylo tended to be higher in the fertilized plots; however, oversowing stylo resulted in a decrease in cassava yield in both fertilized and nonfertilized plots. According to Mohankumar (1976) application of fertilizers to cassava and intercrops like greengram, groundnut, soybean and sunflower produced maximum tuber yields, and was significantly superior to the application of fertilizers to cassava alone. Ekpete (1976) indicated that fertilizers recommended for sole crop of cassava would be more profitable when applied to cassava alone than when applied to mixed crops of cassava, maize and okra.

Changes in nutrient absorption in different stages of physiological development of the crops and its effects on a bean, maize and cassava production agrosystem were investigated by Lacharme (1976). The greatest need of the crops for soil nutrients was between 25 to 75 days. The need was of the order of cassava > maize > beans. Cassava and maize were great biomass producers and soil nutrient extractors. Fertilizer efficiency was of the order of K > N > P > S. According to the Equivalent Land Use, the polycultural systems were efficient in yield and biomass production than monocrop. But Patanothai and

Laohasiriwong (1977b) noted no response to fertilizer application by cassava when it was intercropped with peanuts, soybeans and mung beans. On similar soils it was also found that fertilization in cassava/legume intercropping was not profitable.

Nitis (1977) revealed that as a companion crop, stylo was beneficial because of the increased N supply for cassava, equivalent to about 20 kg urea/ha. With P and K fertilizers, the N supply by stylo reached the equivalent of 160 kg urea. In association, cassava shoot and root yields increased 0.39 and 0.43 t drymatter/ha respectively. The extra green feed produced by stylo ranged from 0.14 - 0.39 t drymatter/ha. Measured in terms of protein, starch, hydrocyanic acid and in vitro digestibility (organic matter and drymatter), the nutritive values of cassava and stylo were not significantly affected by the association.

Field experiments conducted in Philippines comparing monoculture plantings of maize, rice and cassava with intercrop combination at different nitrogen levels, Palada and Harwood (1977) revealed that when the three crops were sown or planted together at the same date, maize and cassava had a better competitive ability than rice in terms of light and nutrients. Growth balance between the three crops was best at low nitrogen level (60 kg/ha) but total productivity was lower. Higher total productivity was obtained at 180 kg nitrogen/ha with a land equivalent ratio (L.E.R) value of 1.9 for the three crop combination. According to Ramakrishna Bhat (1978) the intercrops should be fertilized separately in addition to the fertilization of main crop of tapioca. He found improvement in the fertility status of soil due to intercropping tapioca with legumes. Nitis (1978) revealed the effect of cassava/stylo combination on cassava/stylo production and land productivity after two years of intercropping. It was found that the residual effect of fertilizers was still beneficial for the natural pasture after the companion cropping. The effect of nitrogen derived from the stylo root nodule seemed to be greater than that from urea. The carry over effect of the companion cropping increased the quality and quantity of livestock feed, gave better water and soil conservation and more efficient land utilisation.

Pinto and Cepeda (1978) indicated that the nutritional requirements were different for each crop in a maize/cassava/yam association. This should be taken into account in fertilizer recommendations for associated crops. According to Meneses and Moreno (1979) the level of fertilization had a highly significant effect on the number and weight of commercial roots of cassava in a maize/cassava association. But Lira et al., (1979) concluded that intercropping increased production with or without fertilizers. Porto et al., (1979) obtained best cassava yields when single superphosphate, potassium chloride and amonium sulphate were applied at 300, 100 and 150 kg/ha respectively to an association of cassava with beans, soybeans, rice, peanuts, sorghum or maize. Sheela (1981) recommended a common fertilizer dose of 50:62.5:62.5 and 93.75:75:93.75 kg of N, P_2O_5 and K_2O/ha for tapioca/ cowpea and tapioca/groundnut combination, respectively to get maximum returns. She also found an improvement in the fertility status of soil due to intercropping tapioca with legumes.

But from an experiment at CIAT (Anon., 1978a) highest yields were obtained without any cover crop and cassava yields declined as the competition of the cover crop increased. The cover crop neither increased the nitrogen levelnor decreased the phosphorus level in cassava leaves indicating that the nitrogen contribution and nutrient competition of the legumes were minimal.

From an experiment on nitrogen economy and soil conservation in tapioca/stylo intercropping system Anil Kumar (1983) concluded that growth characters and yield attributing characters were not influenced by intercropping and nitrogen levels. Even though numerically the tuber and top yields were lower in intercropped plots, these reductions were not statistically significant. Similarly the utilization index was also not influenced by intercropping and nitrogen levels.

G. Economics of tapioca based intercropping system.

The economic analysis of various intercropping systems in tapioca has been done in India and elsewhere. At CTCRI, Trivandrum it was found that growing groundnut as an intercrop in cassava holdings provided an additional gross income of Rs.1150/ha (Singh and Mandal, 1968). Groundnut was found to be the best intercrop while considering the economics of intercropping with tapioca (Singh and Mandal, 1970). Sintuprama et al., (1973) revealed that intercropping cassava with soybeans and peanuts gave better income than cassava monoculture. As reported earlier Mohankumar and Hrishi (1974, 1976) also obtained maximum returns from groundnut intercropped plots. The next best treatment was maize which also increased the net returns/ha over other treatments. However, intercropping with soyoeans and greengram were found to be uneconomic as the net returns were less than that of the control plots.

Hart (1975) recorded the economic return from bean, corn and cassava monoculture and polyculture cropping systems and revealed that the economic return was significantly higher from the polyculture than from the monoculture system. The net economic return from the succession polycultures which had been designed as an analog to leaf, stem and root biomass compartmentalisation during natural succession was higher than from the two other polycultures. The net economic return was 54% higher than from the monoculture rotation cropping system.

Tongham (1975) reported that intercropping of cassava with sweet corn, soybeans and peanuts gave 14 to 41.7% more income than cassava monoculture. Mohankumar (1978) obtained 25% more returns from cassava/peanut intercropping when compared to cassava monoculture. Again groundnut plots recorded maximum returns (Prabhakar _et al._, 1979). Prabhakar _et al._, (1979) reported that among different vegetables, maximum net return was obtained for the crop combination of cassava/beans with an additional income of Rs.712/ha over control, followed by cowpea and cucumber. Cultivation of bhindi and amaranthes was found uneconomical. Sonlaksup _et al._, (1978) reported 33.7% higher income from cassava intercropping.

Mohankumar _et al._, (1980) proved the superiority of groundnut from the point of view of maximum returns. However, the next best intercrop was french beans.

Net income calculations (excluding land and management costs) at varying cassava:maize price ratios demonstrated that the improved intercropping system without fertilizer was the most profitable upto the very highest price ratios. At low cassava prices the income gain was substantial with only very marginal increases in costs (Anon., 1980b).

Materials and methods

MATERIALS AND METHODS

The present investigation was undertaken to study the effect of intercropping of cowpea and groundnut with tapioca and to identify the most suitable spatial arrangement of crops in tapioca based intercropping system. The materials used and the methods adopted are detailed below.

Materials

Experimental site.

The experiment was conducted in the Instructional Farm attached to the College of Agriculture, Vellayani. The college is located at 8°N latitude and at an altitude of 29 metres above mean sea level.

Soil.

The soil of the experimental area is red loam with the following physico-chemical properties.

A. Mechanical composition

Coarse sand	(%)	..	13.70
Fine sand	(%)	..	33.40
Silt	(%)	..	28.00
Clay	(%)	..	24.90

B. Chemical composition

pH	..	5.3
Total nitrogen	..	0.077 per cent
Available P_2O_5	..	43.410 kg/ha
Available K_2O	..	40.000 kg/ha

Cropping history of the field

The experimental area was lying fallow for three months prior to the present investigation and before that it was under a bulk crop of tapioca.

Season.

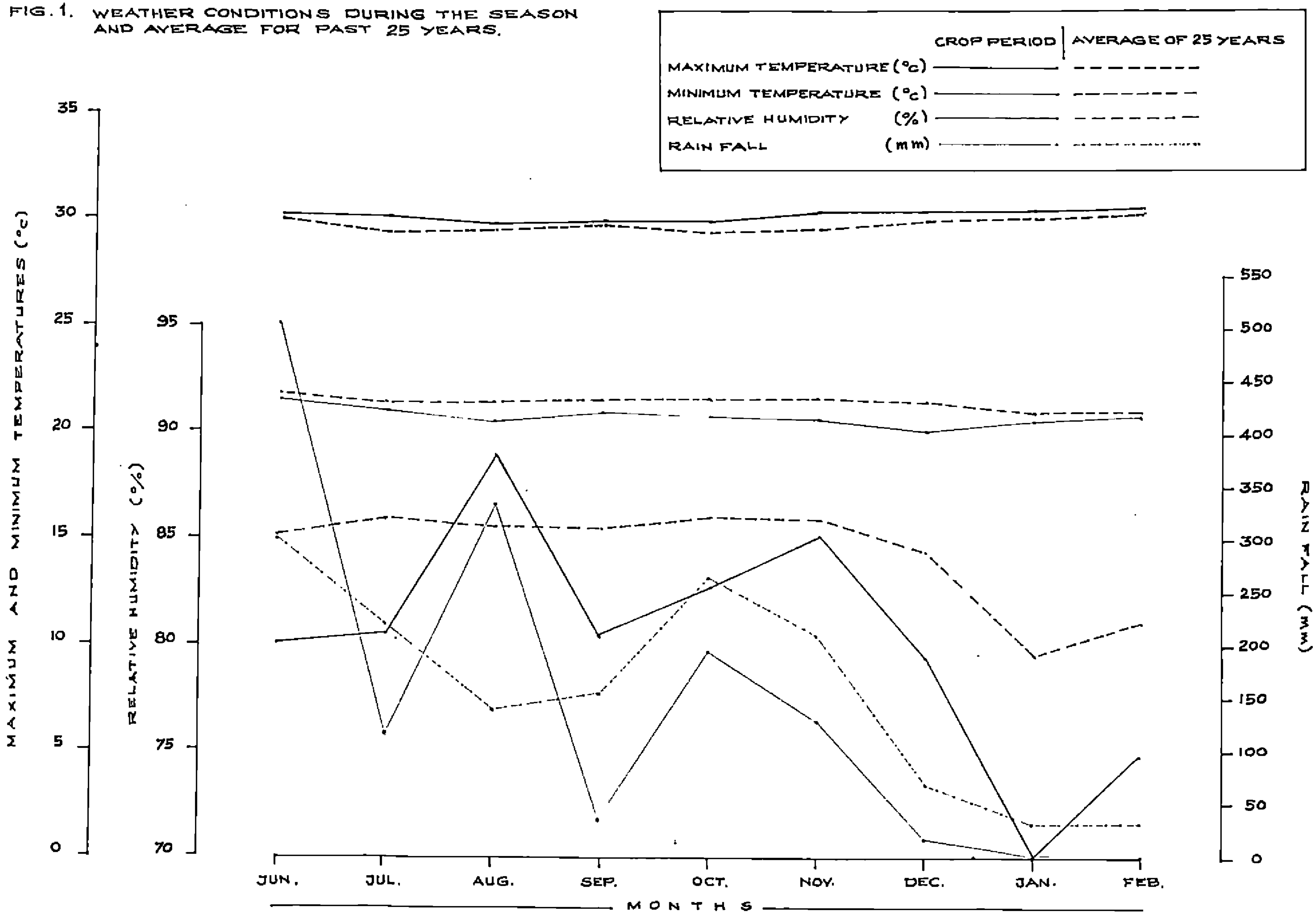
The experiment was conducted during the regular planting season (during the period from June 1982 to February 1983) of tapioca in Kerala. All the crops were raised as rainfed.

Weather conditions.

The meteorological parameters recorded were rainfall, maximum and minimum temperature and relative humidity. The average monthly values and their variation from the average for the past 25 years (1956-1981) from planting to harvest were worked out and presented in Appendix I and illustration given in Fig. 1.

In general the weather conditions were favourable for the satisfactory growth of the crops.

FIG. 1. WEATHER CONDITIONS DURING THE SEASON AND AVERAGE FOR PAST 25 YEARS.



Planting material.

Tapioca.

The variety M_4, a popular variety in the state was used for the trial. It is a tall growing, non-branching variety with moderate yields and matures in ten months. It produces medium size tubers with low hydrocyanic acid content. The planting material required for this study was obtained from the Instructional Farm attached to the College of Agriculture, Vellayani.

Cowpea.

'Kanakamani' a medium duration variety of cowpea recently released by the Kerala Agricultural University was used for the present investigation. It is bushy, moderately high yielding and matures within 70 to 80 days during kharif and 65 to 70 days during rabi and summer seasons. The average number of days taken for 50% flowering is 48. This variety is photoinsensitive and to a certain extent drought tolerant. It is excellent as a green vegetable and equally good as a grain pulse. The protein content is 22.41%. It can yield upto 1100 kg/ha of grain and 2500 to 3500 kg/ha of green pods.

The seeds of this variety for this investigation was obtained from the Command Area Research Centre for Intensification of Pulses and Oilseeds, Trichur.

Groundnut.

TMV-2, a selection from Spanish bunch was used. It is a short duration type with bunch habit of growth. It matures in 100-115 days. The pods are small and one to two seeded. The shell is thin and kernels are light rose in colour. The seeds are nondormant. The kernels have an oil content of 49%. This variety is popular among groundnut growers in Kerala. It is suited for both rainfed and irrigated conditions.

The planting material was obtained from the Command Area Research Centre for Intensification of Pulses and Oilseeds, Trichur.

Manures and fertilizers.

Farm yard manure with the following nutrient values was used for the trial.

0.46 per cent N

0.30 per cent P_2O_5 and

0.27 per cent K_2O

Fertilizers with the following nutrient analysis were used for the trial.

Urea	46 per cent N
Superphosphate	16 per cent P_2O_5
MMuriate of potash	60 per cent K_2O
Quick lime (CaO)	Neutralising value 163.1

Methods

Design and layout

The experiment was laid out in a Randomised Block Design with three replications. The layout plan of the experiment is given in Fig. 2.

The treatment details are furnished below:

T_1	Tapioca in paired row with groundnut in interspaces of paired row.
T_2	Tapioca at normal spacing with groundnut on mounds
T_3	Tapioca at normal spacing with groundnut in interspaces
T_4	Tapioca as in T_1 with cowpea as intercrop
T_5	Tapioca as in T_2 with cowpea as intercrop
T_6	Tapioca as in T_3 with cowpea as intercrop
T_7	Tapioca in paired row without intercrop
T_8	Tapioca at normal spacing without intercrop

Number of replications	:	3
Total number of plots	:	24
Methods of planting tapioca	:	Normal and pairdd row
Spacing for tapioca	:	Normal method 90 x 90cm
		Pairdd row method 45/135 x 90
		45 cm between two rows making up a pair
		135 cm between two such pairs
		90 cm between plants within the row

FIG. 2. LAY-OUT PLAN RANDOMISED BLOCK DESIGN.

REPLICATION I	T_1	T_6	T_4	T_2	T_7	T_5	T_3	T_8
REPLICATION II	T_6	T_7	T_8	T_1	T_2	T_5	T_4	T_3
REPLICATION III	T_7	T_6	T_1	T_4	T_2	T_5	T_8	T_3

TREATMENTS

- T_1 TAPIOCA IN PAIRED ROW WITH GROUND NUT IN INTERSPACES OF PAIRED-ROW.
- T_2 TAPIOCA AT NORMAL SPACING WITH GROUND NUT ON MOUNDS.
- T_3 TAPIOCA AT NORMAL SPACING WITH GROUND NUT IN INTERSPACES.
- T_4 TAPIOCA AS IN T_1 WITH COW PEA AS INTERCROP.
- T_5 TAPIOCA AS IN T_2 WITH COW PEA AS INTERCROP.
- T_6 TAPIOCA AS IN T_3 WITH COW PEA AS INTERCROP.
- T_7 TAPIOCA IN PAIRED ROW WITHOUT INTERCROP.
- T_8 TAPIOCA AT NORMAL SPACING WITHOUT INTERCROP.

Methods of planting intercrop.

(1) Paired row planting.

Planted four rows of intercrops in the interspaces of paired row at a spacing of 30 (rows) cm x 20 (plants) cm.

(2) Ring method of planting.

Planted intercrops as two rings over tapioca mounds. The distance between two rings was 30 cm. 20 cm was given between plants in a ring.

(3) Alternate row planting.

Planted two rows of intercrops in the interspaces of normal rows at a spacing of 30 (rows) cm x 20 (plants) cm.

Plot size.

Gross plot size : 4.5 m x 9.9 m

Net plot size : 2.7 m x 8.1 m

Net area of a plot: 21.87 m^2

Number of tapioca plants in the gross plot : 55

Number of tapioca plants in the net plot : 27

Intercrop population in paired and alternate row planting.

Length of one row : 440 cm (left 5 cm on both sides)

Number of plants per row : 440 ÷ 20 = 22

Number of rows : 20

Plant population : 22 x 20 = 440

Intercrop population in ring method of planting.

Number of plants per tapioca mound	:	8
Number of mounds	:	55
Plant population	:	8 x 55 = 440

Plant population was kept constant in all treatments.

Field culture.

Preparation of field.

The experimental area was dug twice, stubbles removed, clods broken and the field was laid out into blocks and plots. Mounds were raised as per the treatments.

Manuring.

A uniform basal dose of 12.50 t/ha of farm yard manure was applied and well incorporated into the soil before taking mounds.

Fertilizer and lime application.

The fertilizer nutrients were applied in the form of urea, superphosphate and muriate of potash for N, P_2O_5 and K_2O respectively. A fertilizer dose of 35:70:45 kg/ha of N, P_2O_5 and K_2O (ie. 25:50:25 for tapioca and 10:20:20 for intercrops) was applied on the 20th day of planting. Another dose of 25:25 kg/ha of N and K_2O was applied to tapioca after the harvest of intercrops.

Lime at the rate of 1000 kg/ha was applied on the 40th day of planting.

For tapioca, top dressing was done over the mounds and raked well into the soil. For intercrops, the fertilizers and lime were thoroughly mixed with the soil.

Planting.

Planting of tapioca and sowing of intercrops were done on 2-6-1982. Tapioca setts of 20 cm length were planted upright on the top of the mounds to a depth of 3 to 4 cm. The seeds of intercrops were sown as per the technical programme. Cowpea seeds were sown at the rate of two seeds per hole and that of groundnut at the rateof one seed per hole. The seeds were pressed into the soil by hand to a depth of 1.5 cm and covered with soil.

After cultivation.

Germination of setts was good. Unsprouted setts were replaced by fresh ones ten days after planting. Excess sprouts were removed, retaining only two healthy and vigorous shoots. Germination of intercrops was also good. Gap filling was done wherever found necessary. Thinning was done one week after sowing and the population was maintained uniform.

The soil was slightly stirred in groundnut plots at the time of flowering in order to facilitate pegging of groundnut which was combined with the application of lime. The first earthing up for tapioca was done at the time of harvest of intercrops (on 14-8-1982 for cowpea intercropped plots and on 20-9-1982 for groundnut intercropped plots. One more earthing up was given on 15-11-1982 for tapioca.

Plant protection.

Plant protection measures were adopted against termite attack by dusting 10 per cent B.H.C. Prophylactic spraying of 0.05% Malathion was effected on 5-7-1982 for the intercrop cowpea. Ekalux (0.1%) was sprayed on 10-8-1982 to groundnut as a prophylactic measures against the incidence of red hairy caterpillar.

General condition of the crops.

The general condition of the crops was good throughout the period of growth.

Harvest.

Cowpea was harvested on 14-8-1982 and groundnut on 20-9-1982. The bhusa of the intercrops was incorporated into the soil <u>in situ</u> and allowed to decompose. The main crop of tapioca was harvested on 14-2-1983 when indications of maturity were observed.

Observations recorded.

Sampling technique for biometric studies.

Ten plants each were tagged alternately from the net plot area for detailed biometric observations.

A. Observation on growth characters.

The following growth characters of tapioca were studied and data recorded.

a. Height of the plant.

Cumulative height of the shoot of each plant including branches were measured from the base of the sprouts to the tip of the terminal bud at monthly intervals commencing from the first month after planting till harvest.

b. Total number of leaves per plant.

The total number of leaves was recorded at monthly intervals by counting the number of fully opened leaves as well as fallen leaves as indicated by the leafscars on the stem.

c. Number of functional leaves per plant.

The number of fully opened leaves retained in the plants was recorded at monthly intervals from the first month after planting till harvest.

d. Leaf area index.

The method evolved by Ramanujam and Indira (1978) was followed in this experiment for determining the leaf area index of tapioca at monthly intervals from the first month after planting till harvest.

e. Girth of the stem.

This was recorded by measuring the girth at the base of the shoot of each plant, taken at monthly intervals starting from the second month after planting to harvest.

B. Observation on yield attributes and yield

a. Total number of roots per plant.

The total number of roots including productive and unproductive ones was recorded at the time of harvest from plants under observation and the average per plant worked out.

b. Number of tubers per plant.

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

c. Percentage of productive roots.

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

d. Length of tubers.

The average length of tuber was worked out by measuring the length of ten tubers taken at random from the observation plants and expressed in cm.

e. Girth of tuber.

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 tubers. The average was taken as the tuber girth and expressed in cm.

f. Rind to flesh ratio.

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

g. Tuber yield.

At the time of harvest the tubers were separated and cleaned to remove the adhering soil and the fresh weight of the tuber from the net plot was recorded. The per hectare yield was then worked out from this.

h. Top yield.

The total weight of the stem and leaves of the plants from net plot was taken at the time of heavest and converted to t/ha.

i. Utilisation index.

This is the ratio of the root weight to top (stem and leaves) weight and is an important yield determinant factor (Obigbesan, 1973). This was worked out from the already recorded observations.

C. Observations on quality attributes.

a. Drymatter content of the tuber flesh.

A uniform quantity of flesh from fresh tuber was taken and dried to constant weight in an air oven at 105°C. The weight of drymatter expressed as percentage of fresh weight gave the drymatter content of the tuber flesh (A.O. A.C., 1969).

b. Starch content of tuber.

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

c. Crude protein content of tuber.

The total nitrogen content of oven dried samples from each plot was estimated by modified micro-kjeldahl method (Jackson, 1967). To get the crude protein content of the tuber, the nitrogen values were multiplied by the factor 6.25 (A.O.A.C., 1969).

D. Plant analysis.

Separate samples of tuber, stem and leaves were collected for chemical studies, dried at 80°C ±5and were ground in a Willey mill. The nitrogen, phosphorus and potassium contents of tuber, stem and leaves were separately analysed.

a. Nitrogen content.

The total nitrogen content of the sample was determined by the modified micro-kjeldahl method (Jackson, 1967).

b. Phosphorus content.

Phosphorus was determined by Vanado-molybdo-phosphoric yellow colour method (Jackson, 1967).

c. Potassium content.

Potassium content was determined by using 'EEL' flame photometer.

Intercrops.

Ten plants were selected at random from both cowpea and groundnut plots for recording detailed biometric observations. The observations recorded are given below.

A. Observations on growth, yield attributes and yield

a. Height of the plant.

The height of the observation plants was measured at twenty days interval. The measurement was from the base to the growing tip of the plants and mean height worked out.

b. Number of branches per plant.

The number of branches on each of the observation plants was counted and the average number worked out and recorded at twenty days interval starting from the 40th day of sowing.

c. Number of functional leaves per plant.

The total number of green leaves present in the observation plants was counted at twenty days interval and the average worked out and recorded.

d. Leaf area index.

The general graph paper method was followed for determining the leaf area index at twenty days interval.

e. Number of mature pods per plant.

The number of mature pods in the observation plants at the time of harvest was counted and the average number of pods per plant recorded.

f. Grain yield of cowpea.

Pods were harvested, dried, threshed and winnowed for recording the grain yield of cowpea from each plot. The yield (kg/ha) was then worked out from this.

g. Pod yield of groundnut.

The pod yield from each plot was recorded after separating and drying the pods and converted to kg/ha.

h. Bhusa yield.

The weight of bhusa obtained from each plot after separating the pods was taken and recorded. The yield in kg/ha was calculated from this data.

i. Quantity of nitrogen, phosphorus and potassium incorporated into the soil by bhusa.

The quantity of nitrogen, phosphorus and potassium incorporated into the soil by means of bhusa of the legumes in each treatment was found out from the corresponding drymatter yield and nitrogen, phosphorus and potassium content of the plant sample.

The drymatter percentage was found out by A.O.A.C. (1969) method. Percentage of nitrogen was found out by modified micro-kjeldahl method (Jackson, 1967). Vanado-molybdo-phosphoric yellow colour method (Jackson, 1967) was followed for phosphorus estimation and 'EEL' flame photometer was used for potassium determination.

Soil analysis.

Mechanical composition of the soil before starting the experiment was determined by the International pipette method. A composite soil sample collected blockwise prior to the experiment and soil samples collected from individual plots after the experiment were analysed for total nitrogen, available phosphorus and available potassium. Total nitrogen was determined by modified micro-kjeldahl method, available phosphorus by Bray's method and available potassium by Ammonium acetate method (Jackson, 1967).

Statistical analysis.

Data relating to different observations were statistically analysed using the analysis of variance technique for Randomised Block Design and significance was tested by using the 'F' test (Snedecor and Cochran, 1967). The data were analysed with the help of a Casio Scientific Calculator.

Results

RESULTS

The observations recorded were statistically analysed and the analysis of variance tables are given in Appendices II to XV. The mean values of observations are given in Tables 1 to 25 and the important results are presented below.

Observations on main crop (Tapioca)

A. Growth characters

1. Height of the plant.

The height of tapioca was recorded at monthly intervals. The mean values are presented in Table 1 and the analysis of variance in Appendix II.

It is seen that the treatments exerted significant influence on plant height after second, third and fourth month of planting tapioca. Maximum height was recorded by the treatment T_7 which was on par with T_8, T_1 and T_3 at the above growth stages. Minimum height was recorded by the treatment T_6 during the above growth stages, but was on par with T_5 and T_4 after second and third month of planting and with all intercropped treatments after fourth month of planting.

No significant difference was observed between treatments with regard to the height of plants after first, fifth, sixth and seventh month of planting and at the time of harvest.

Table 1. Height of tapioca as influenced by planting patterns, intercrops and spatial arrangements (cm).

M.A.P.	Treatments								C.D. (0.05)	S.E.
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8		
I	9.433	8.567	9.467	8.567	8.833	7.933	9.367	9.467	-	0.628
II	36.300	29.167	35.500	25.700	19.133	18.400	40.800	39.433	9.786	3.219
III	56.400	44.233	55.2	34.833	29.200	27.033	67.300	62.366	15.069	4.956
IV	59.033	47.933	56.7	48.233	42.766	41.100	79.00	75.966	24.854	8.174
V	85.000	79.000	92.433	77.166	83.933	74.800	106.700	105.3	-	10.740
VI	114.333	106.767	128.467	99.200	121.267	112.733	130.633	130.967	-	7.514
VII	131.200	127.933	145.067	114.467	126.900	116.600	144.967	143.900	-	10.167
At harvest	141.900	134.700	157.900	128.833	147.33	129.1	155.666	155.266	-	10.128

M.A.P. - Months After Planting

2. Total number of leaves produced per plant.

The mean values of the observation taken at monthly intervals are given in Table 2 and the analysis of variance in Appendix III.

It is seen that there was significant differences between treatments with regard to the total number of leaves throughout the stages of growth except at first month after planting.

The treatment T_8 recorded the maximum number of leaves which was on par with T_7, T_1 and T_3 at two months after planting whereas the treatment T_6 showed the minimum number of leaves, but was not statistically different from T_5 and T_4 at that stage. Though the treatments T_7 and T_8 were on par after third and fourth month of planting, T_7 recorded more number of leaves at both stages. As in the previous case, here also T_6 showed minimum number of leaves. After fifth and sixth month of planting also the highest number of leaveswas recorded by T_8 and T_7. T_7 after seventh month of planting and T_8 at the time of harvest recorded maximum number of leaves. But T_6 showed the minimum number of leaves seven months after planting and at the time of harvest.

3. Functional leaves per plant.

The mean number of functional leaves per plant taken at monthly intervals are given in Table 3 and the analysis of variance in Appendix IV.

Table 2. Total number of leaves of tapioca as influenced by planting patterns intercrops and spatial arrangements.

M.A.P.	Treatments								C.D. (.05)	S.E.
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8		
I	8.567	7.267	7.833	7.333	6.967	7.367	7567	7.533	-	0.556
II	23.000	17.400	21.967	16.667	13.500	12.700	24.333	24.833	4.409	1.450
III	35.433	28.867	33.800	26.800	22.267	21.300	42.633	40.333	6.895	2.268
IV	43.933	36.570	42.400	38.267	34.300	32.100	60.234	56.133	9.105	2.994
V	68.533	51.500	60.433	56.233	48.020	51.300	88.400	91.967	21.259	6.992
VI	104.000	83.800	101.700	70.433	80.600	74.900	138.977	139.067	39.337	12.937
VII	140.900	105.367	117.167	107.667	95.567	87.400	190.133	184.067	54.876	18.048
At harvest	160.217	129.900	134.467	128.133	122.433	104.233	220.833	221.600	81.083	26.667

M.A.P. Months After Planting.

Table 3. Number of functional leaves of tapioca as influenced by planting patterns, intercrops and spatial arrangements.

M.A.P.	Treatments								C.D. (.05)	S.E.
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8		
I	8.567	7.267	7.833	7.333	6.967	7.367	7.567	7.533	-	0.559
II	23.000	17.400	21.967	16.200	11.967	10.933	24.167	24.600	5.089	1.674
III	26.367	20.200	24.700	18.800	14.967	14.067	36.167	33.233	5.411	1.779
IV	17.633	13.800	17.567	20.900	21.433	19.333	34.933	33.333	7.662	2.519
V	29.500	20.400	24.000	27.267	27.253	26.733	43.233	47.167	14.391	4.732
VI	47.200	39.067	45.400	38.300	38.833	36.066	64.410	64.733	-	7.434
VII	42.667	30.067	34.300	31.300	28.233	27.600	57.933	56.433	-	8.250
At harvest	34.367	25.600	27.967	26.567	27.467	23.167	50.600	51.733	-	7.074

M.A.P. - Months After Planting.

The data on mean values showed that the treatments differed significantly in their effect on the number of functional leaves produced per plant after second, third, fourth and fifth month of planting tapioca. However, no significant difference could be observed at any other growth stage.

There was significant reduction in the number of functional leaves per plant in the intercropped treatments after third, andfourth month of planting as compared to two pure cropped treatments of tapioca. However, T_1 and T_3 were on par with the pure cropped plots at second month after planting. At fifth month after planting, T_1 again was on par with T_7. The treatment T_6 after second and third month of planting and T_2 after fourth and fifth month of planting recorded the lowest number of functional leaves per plant.

4. Leaf area index.

The leaf area index was recorded at monthly intervals and the mean values are presented in Table 4 and the analysis of variance in Appendix V.

The results indicated that there was significant difference in leaf area index values at second, third and fourth month after planting tapioca. However, no significant difference was observed at any other stages of crop growth.

The treatment T_8 recorded the maximum leaf area index at the above three stages of crop growth and it was on par with

Table 4. Leaf area index of tapioca as influenced by planting patterns, intercrops and spatial arrangements.

M.A.P.	Treatments								C.D. (.05)	S.E.
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8		
I	0.043	0.031	0.042	0.036	0.028	0.026	0.036	0.043	-	0.008
II	0.537	0.231	0.411	0.195	0.095	0.078	0.530	0.577	0.333	0.109
III	0.763	0.561	0.755	0.352	0.138	0.173	1.233	1.233	0.468	0.153
IV	0.345	0.305	0.415	0.347	0.365	0.308	1.084	1.186	0.393	0.129
V	0.506	0.457	0.504	0.477	0.819	0.737	0.559	0.720	-	0.094
VI	1.526	1.192	1.682	1.083	1.301	1.030	1.630	1.451	-	0.192
VII	0.797	0.626	1.069	0.516	0.591	0.567	0.925	0.912	-	0.139
At harvest	0.287	0.209	0.322	0.198	0.357	0.222	0.291	0.260	-	0.066

M.A.P. - Months After Planting

T_1, T_7 and T_3 after second month of planting and with only T_7 after third and fourth month of planting tapioca. The lowest values at second, third and fourth month of planting were recorded by the treatments T_6, T_5 and T_2 respectively.

5. Girth of the stem.

The data on mean stem girth taken at monthly intervals from second month after planting to harvest are presented in Table 5 and the analysis of variance inAppendix VI.

The results revealed that there was significant difference in mean stem girth after second, third and fourth month of planting although significance could not be observed at any other stage of crop growth.

Although the treatment T_8 recorded the maximum stem girth after second month of planting, it differed significantly from all the cowpea intercropped treatments. Though the treatment T_8 was on par with T_7 and T_1 it differed significantly from other treatments after third month of planting. The same treatment recorded the maximum value after fourth month of planting but was on par with T_7. Both the above treatments differed significantly from all other intercropped treatments. T_6 after second and third month of planting and T_5 after fourth month of planting recorded minimum stem girth values.

B. Yield attributes and yield

1. Yield attributes

The mean values of yield attributes are presented in Table 6 and the analysis of variance in Appendix VII a.

Table 5. Girth of tapioca stem as influenced by planting patterns, intercrops and spatial arrangements.

M.A.P.	Treatments								C.D. (.05)	S.E.
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8		
II	3.133	3.167	3.133	2.333	1.933	1.880	3.367	3.667	0.662	0.217
III	4.000	3.600	3.933	2.933	2.867	2.500	4.467	5.00	1.053	0.346
IV	4.200	3.750	4.137	3.250	2.967	2.983	5.067	5.217	0.825	0.271
V	4.633	4.283	4.833	4.550	4.200	3.900	5.083	5.267	-	0.387
VI	5.330	4.967	5.667	4.967	5.200	4.817	5.950	5.900	-	0.349
VII	5.700	5.250	5.833	5.33	5.283	5.283	6.167	6.150	-	0.315
At harvest	5.800	5.333	6.150	5.383	5.633	5.383	6.467	6.233	-	0.275

M.A.P. - Months After Planting.

a. Total number of roots per plant.

It is seen from the results that there was no significant difference between treatments with regard to the total number of roots per plant. However, T_8 recorded the maximum number of roots per plant. The minimum number of roots per plant was recorded by T_5.

b. Number of tubers per plant.

It is seen from the data that the treatments differed significantly in their effect on the number of tubers per plant. T_3 recorded the maximum number of tubers per plant and it was on par with T_1 and T_8, but differed significantly from other treatments. T_4 recorded the minimum number of tubers per plant which was found to be on par with T_5 and T_6.

c. Percentage of productive roots.

The results showed that there was no significant difference between treatments with regard to the percentage of productive roots in tapioca. The treatment T_1 recorded the highest percentage of productive roots, whereas T_6 recorded the lowest percentage of productive roots.

d. Length of tuber.

The data revealed no significant difference in length of tuber due to treatment effects. T_7 recorded the maximum length and T_2 the minimum.

Table 6. Yield attributes of tapioca as influenced by planting patterns, intercrops and spatial arrangements.

Treatments	Number of roots per plant	Number of tubers per plant	Percentage of productive tubers	Length of tuber (cm)	Girth of tuber (cm)	Rind to flesh ratio
T_1	6.433	6.067	93.840	26	10.237	0.155
T_2	7.000	5.033	74.357	25.39	10.413	0.174
T_3	7.667	6.633	86.310	27.343	10.113	0.169
T_4	6.160	3.627	59.193	29.037	11.583	0.168
T_5	5.867	3.667	64.580	31.857	12.843	0.162
T_6	7.400	4.033	57.690	27.900	12.867	0.157
T_7	7.067	4.900	71.837	35.620	11.513	0.177
T_8	7.700	5.500	71.553	27.920	11.873	0.156
C.D. (.05)	-	1.259	-	-	-	-
S.E.	0.813	0.414	8.461	3.321	0.906	0.008

e. Girth of tuber.

The results indicated that there was no significant variation between treatments with regard to the tuber girth. However, the maximum girth was recorded by T_6 and the minimum by T_3.

f. Rind to flesh ratio.

It is seen from the results that there was no significant difference in the rind to flesh ratio of tapioca tubers between treatments. The highest ratio was obtained for the treatment T_7 and the lowest ratio for T_1.

2. Tuber yield.

The mean tuber yield per hectare is given in Table 7 and the analysis of variance in Appendix VII a.

The data revealed that there was significant variation between treatments with regard to the tuber yield per hectare.

The highest tuber yield was obtained from the treatment T_7 which differed significantly from all other treatments except T_8. The treatment T_8 in turn did not statistically differ from T_3 and T_1. The treatment T_4 recorded the lowest tuber yield.

3. Top yield.

Table 7 shows the mean values of top yield and Appendix VII a furnishes the corresponding analysis of variance.

There was no significant difference between treatments with regard to the top yield of tapioca. However, maximum top

Table 7. Yield and utilization index of tapioca as influenced by planting patterns, intercrops and spatial arrangements.

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	C.D. (.05)	S.E.
Tuber yield (t/ha)	13.392	10.890	14.630	10.324	11.833	11.521	20.423	17.956	5.776	1.899
Top yield (t/ha)	6.439	4.846	7.059	4.256	5.935	6.450	7.056	7.495	-	0.986
Utilization index	2.057	2.247	2.153	2.420	2.063	1.780	2.993	2.423	0.534	0.175

yield was recorded by the treatment T_8 followed by T_3. T_4 recorded the minimum top yield in tapioca.

4. Utilisation index.

The mean values on utilisation index are presented in Table 7 and the analysis of variance in Appendix VII a.

The results showed that there was significant difference between treatments with regard to the utilisation index values. The treatment T_7 recorded the highest utilisation index value and it was significantly different from all other treatments. T_8 was the next best superior treatment but it was on par with T_4, T_2, T_3, T_5 and T_1. The lowest value was recorded by the treatment T_6.

C. Quality attributes

1. Drymatter content of tuber.

The mean values on drymatter percentage of tuber are given in Table 8 and the analysis of variance in Appendix VII b.

The data revealed that the treatments did not significantly influence the drymatter percentage of tuber. The highest percentage of drymatter was recorded by T_3 followed by T_6 whereas, the lowest percentage of drymatter was recorded by T_1.

2. Starch content of tuber.

Table 8 shows the mean values of the starch content of tuber and Appendix VII b shows the corresponding analysis of variance.

Table 8. Quality attributes of tapioca tuber as influenced by planting patterns intercrops and spatial arrangements.

Quality attributes	Treatments T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	C.D. (.05)	S.E.
Drymatter content (per cent)	33.110	35.590	37.770	35.033	35.167	36.760	35.990	35.103	-	0.925
Starch content (per cent)	24.983	24.642	24.008	24.495	24.703	24.943	25.809	24.642	-	0.596
Protein content (per cent)	2.224	2.005	1.932	2.297	2.370	2.260	1.896	1.969	-	0.157

Though no significant difference was observed between treatments, T_7 recorded a slightly higher starch content followed by T_1. The lowest value was recorded by the treatment T_3.

3. Crude protein content of tuber.

Table 8 furnishes the mean values of crude protein content and Appendix VII b gives the corresponding analysis of variance.

The treatments could not register any significant influence on crude protein content of tuber. However, T_5 recorded the highest value and T_7 recorded the lowest content of crude protein as compared to other treatments.

D. Plant analysis.

1. Nitrogen content.

The mean values on nitrogen content (per cent) of leaves and stem are given Table 9 and the analysis of variance in Appendix VIII.

a. Nitrogen content of leaves.

The data revealed no significant difference in leaf nitrogen content due to any of the treatments. The highest leaf nitrogen content was recorded by T_1 and the lowest by T_4.

b. Nitrogen content of stem.

No significant difference in the nitrogen content of stem was recorded due to any of the treatments. However,

Table 9. Distribution of nitrogen (per cent) in tapioca as influenced by planting patterns, intercrops and spatial arrangements.

Treatments	Plant parts	
	Leaf	Stem
T_1	1.995	0.700
T_2	1.823	0.636
T_3	1.756	0.677
T_4	1.651	0.735
T_5	1.925	0.671
T_6	1.721	0.630
T_7	1.808	0.735
T_8	1.733	0.641
C.D. (.05)	-	-
S.E.	0.128	0.040

T_6 recorded the lowest nitrogen content.

2. Phosphorus content.

The mean values of phosphorus content in tapioca as influenced by different treatments are furnished in Table 10 and the analysis of variance in Appendix VIII.

a. Phosphorus content of leaves.

The treatments did not exert any significant influence on the phosphorus content of tapioca leaves. The treatment T_8 recorded the maximum phosphorus content in the leaves and T_5 recorded the minimum content.

b. Phosphorus content of stem.

Phosphorus content of stem also did not differ significantly due to the influence of treatments. Maximum content of phosphorus in the stem was recorded by T_4 T_5 and T_8

c. Phosphorus content of tuber.

No significant difference was observed in the phosphorus content of tuber due to any of the treatments. The highest phosphorus content of tuber was recorded by T_5 T_6 and the lowest value by T_7.

3. Potassium content.

Table 11 gives the mean values of potassium content in tapioca as influenced by various treatments. Appendix VIII gives the corresponding analysis of variance.

Table 10. Distribution of phosphorus (per cent) in tapioca as influenced by planting patterns, intercrops and spatial arrangements.

Treatments	Plant parts		
	Leaf	Stem	Tuber
T_1	0.452	0.286	0.152
T_2	0.443	0.276	0.143
T_3	0.448	0.286	0.152
T_4	0.448	0.290	0.142
T_5	0.429	0.290	0.157
T_6	0.462	0.276	0.152
T_7	0.452	0.281	0.138
T_8	0.471	0.290	0.157
C.D. (.05)	-	-	-
S.E.	0.026	0.008	0.013

a. Potassium content of leaves.

There was no significant difference in the potassium content of leaves due to various treatments. However a higher potassium content was recorded by T_7. T_4 showed the lowest level of potassium.

b. Potassium content of stem,

The results showed no significant difference in the potassium content of stem due to different treatments. The highest potassium content was given by the treatment T_5

c. Potassium content of tuber.

The different treatments had no significant influence onnthe potassium content of tuber. The maximum and minimum levels of potassium in the tuber were recorded by T_5 and T_8 and T_7 respectively.

Observations on Intercrop (Groundnut and cowpea)

A. Growth characters.

1. Height of the plant at different stages.

The mean values are presented in Tables 12 and 13 and the analysis of variance in Appendix IX.

The results revealed that there was no significant difference on the height of groundnut plants after 20, 40, 60 and 80 days of planting. However, significant difference was

Table 11. Distribution of potassium (per cent) in tapioca as influenced by planting patterns, intercrops and spatial arrangements.

Treatments	Plant parts		
	Leaf	Stem	Tuber
T_1	0.722	0.467	0.733
T_2	0.722	0.456	0.733
T_3	0.689	0.489	0.678
T_4	0.656	0.478	0.744
T_5	0.689	0.511	0.811
T_6	0.667	0.500	0.633
T_7	0.756	0.489	0.622
T_8	0.744	0.456	0.622
C.D. (.05)	-	-	-
S.E.	0.082	0.058	0.054

noticed at the 100th day after planting and at the time of harvest. Maximum height was recorded by T_3 at 100th day after planting and was found to be superior to T_1 and T_2. Similarly at the time of harvest also T_3 recorded the maximum height and was on par with T_1.

Unlike groundnut no significant difference between treatments could be observed at any growth stage of cowpea. However, T_4 recorded the maximum values at all growth stages. The minimum values after 20 and 60 days of planting and at the time of harvest were recorded by T_6 whereas T_5 showed the minimum height at 40th day of planting.

2. Number of branches per plant at different stages.

The data are given in Tables 14 and 15 and the analysis of variance in Appendix X.

Significant difference between treatments could be observed in groundnut only at the time of harvest. At that stage T_3 recorded the maximum number of branches and T_2 the minimum number.

The number of branches per plant of cowpea could be affected only at 40 days after planting. At that stage T_4 recorded the maximum number and T_5 the minimum. The same trend was observed after 60 days of planting and at the time of harvest also.

Table 12. Height of groundnut at different growth stages as influenced by the main crop and spatial arrangements (cm).

Treatments	Days after planting					
	20	40	60	80	100	At harvest
T_1	3.350	8.967	35.033	45.167	46.867	48.553
T_2	3.703	10.367	31.067	41.867	43.633	44.593
T_3	3.237	10.167	35.733	48.467	50.800	51.433
C.D. (0.5)	-	-	-	-	3.138	4.406
S.E.	0.376	0.609	1.249	1.497	0.798	1.121

Table 13. Height of cowpea at different growth stages as influenced by the main crop and spatial arrangements (cm).

Treatments	Days after planting			
	20	40	60	At harvest
T_4	11.567	22.133	114.167	115.833
T_5	10.670	17.800	97.900	113.7
T_6	10.083	21.000	91.533	109.667
C.D. (.05)	-	-	-	-
S.E.	0.473	1.369	10.813	9.507

Table 14. Number of branches of groundnut at different growth stages as influenced by the main crop and spatial arrangements.

Treatments	Days after planting					
	20	40	60	80	100	At harvest
T_1	0.500	3.400	4.667	4.733	4.737	4.833
T_2	0.600	3.800	4.167	4.600	4.767	4.800
T_3	0.267	3.667	4.467	4.833	5.050	5.500
C.D. (0.5)	-	-	-	-	-	0.537
S.E.	0.0161	0.323	0.467	0.306	0.218	0.137

Table 15. Number of branches of cowpea at different growth stages as influenced by the main crop and spatial arrangements.

Treatments	Days after planting			
	20	40	60	At harvest
T_4	-	3.067	3.100	3.133
T_5	-	2.200	2.767	2.900
T_6	-	2.400	2.967	2.967
C.D. (.05)	-	0.633	-	-
S.E.	-	0.161	0.129	0.233

3. Number of functional leavesper plant at different stages.

The data on the mean number of functional leaves at different stages are furnished in Tables 16 and 17 and the corresponding analysis of variance in Appendix XI.

The treatments did not have any significant influence on the total number of functional leaves in groundnut at any of the growth stages. Though T_3 recorded the maximum number of functional leaves at 20, 60 and 100 days after planting T_2 recorded the same during all the other growth stages. T_1 showed the minimum number of functional leaves at all growth stages of groundnut except at 60 days after planting.

Significant difference in the number of functional leaves in cowpea was observed at 40 and 60 days after planting. At both stages T_4 was the superior treatment which differed significantly from T_5 and T_6 which were on par. But at the time of harvest T_5 showed the maximum number of functional leaves. T_6 recorded the lowest value at all stages of growth.

4. Leaf area index of the plant at different stages.

The mean leaf area index values are presented in Tables 18 and 19 and the analysis of variance in Appendix XII.

The results indicated that there was no significant difference between treatments with regard to the leaf area index values at any of the growth stages of groundnut from planting till harvest. Even then T_3 recorded the maximum

Table 16. Number of functional leaves in groundnut at different growth stages as influenced by the main crop and spatial arrangements.

Treatments	Days after planting					
	20	40	60	80	100	At harvest
T_1	4.100	18.300	53.733	63.400	64.800	39.053
T_2	4.233	21.900	52.833	74.033	75.767	46.957
T_3	4.467	20.900	59.567	73.067	79.867	44.100
C.D. (0.05)	-	-	-	-	-	-
S.E.	0.125	3.091	2.239	7.529	3.397	2.371

Table 17. Number of functional leaves in cowpea at different growth stages as influenced by the main crop and spatial arrangements.

Treatments	Days after planting			
	20	40	60	At harvest
T_4	2	12.467	33.300	13.600
T_5	2	11.067	26.267	14.367
T_6	2	10.167	25.067	12.133
C.D. (.05)	-	1.261	4.867	-
S.E.	-	0.320	1.238	1.427

leaf area index at 20, 80 and 100 days after planting and at the time of harvest. T_2 at 40 days after planting and T_1 at 60 days after planting produced maximum leaf area index. T_2 at 20 and 60 days after planting and T_1 at other growth stages recorded the minimum leaf area index.

As mentioned above, no significant difference could be observed between treatments with regard to the leaf area index values of cowpea also. T_4 at all growth stages except at the time of harvest and T_5 at the time of harvest showed maximum leaf area index and the minimum was recorded by T_6 at 20 days after planting and at the time of harvest and T_5 at other growth stages.

B. Yield and yield attributes.

1. Pod number per plant.

The data on the mean number of pods per plant are given in Tables 20 and 21 and the analysis of variance in Appendix XIII.

Though no significant difference could be observed between treatments with regard to the number of pods per groundnut, T_3 recorded the maximum number followed by T_2 and T_1.

As in the case of groundnut, cowpea also showed no significant variation between treatments with regard to the number of pods per plant. Still T_4 recorded the maximum number and T_5 the minimum.

Table 18. Leaf area index of groundnut at different growth stages as influenced by the main crop and spatial arrangements.

Treatments	Days after planting					
	20	40	60	80	100	At harvest
T_1	0.163	1.271	5.533	7.872	7.372	4.913
T_2	0.156	1.444	3.038	8.870	8.963	5.725
T_3	0.187	1.437	5.360	9.090	9.257	5.889
C.D. (.05)	-	-	-	-	-	-
S.E.	0.008	0.199	0.799	0.691	0.647	0.265

Table 19. Leaf area index of cowpea at different growth stages as influenced by the main crop and spatial arrangements.

Treatments	Days after planting			
	20	40	60	At harvest
T_4	0.047	3.089	6.453	3.077
T_5	0.045	2.393	4.090	3.330
T_6	0.044	2.570	5.591	2.907
C.D. (.05)	-	-	-	-
S.E.	0.002	0.230	0.947	0.357

2. Pod yield of groundnut and grain yield of cowpea

The mean values of pod yield of groundnut and grain yield of cowpea are given in Tables 20 and 21 and the analysis of variance in Appendix XIII.

No significant influence could be found either on the pod yield of groundnut or on the grain yield of cowpea due to various treatments.

The highest yield of groundnut was recorded by the treatment T_1 while T_2 produced the lowest yield.

Maximum grain yield of cowpea was recorded by the treatment T_4 and the minimum by T_5.

3. Bhusa yield

The mean values of the observation are presented in Tables 20 and 21 and the analysis of variance in Appendix XIII.

Bhusa yield of groundnut differed significantly between treatments. T_3 recorded the maximum yield and it was significantly different from the other two treatments (T_1 and T_2) which were on par.

There was no significant difference between treatments with regard to the bhusa yield of cowpea. However, T_5 recorded the maximum value and T_4 the minimum.

Table 20. Pod number and yield of groundnut as influenced by the main crop and spatial arrangements.

Treatments	Pod number per plant	Pod yield kg/ha	Bhusa yield kg/ha
T_1	30.270	2008.667	7608.333
T_2	33.320	1741.667	7354.000
T_3	34.670	1889.667	9757.000
C.D. (.05)	-	-	1546.363
S.E.	3.798	237.875	393.326

Table 21. Pod number and yield of cowpea as influenced by the main crop and spatial arrangements.

Treatment	Pod number per plant	Grain yield kg/ha	Bhusa yield kg/ha
T_4	8.930	1585.000	10629.000
T_5	7.670	1335.330	12918.333
T_6	8.030	1478.670	11185.333
C.D. (.05)	-	-	-
S.E.	0.261	86.147	1262.273

C. Plant analysis.

Bhusa of cowpea and groundnut were analysed for nitrogen phosphorus and potassium contents. The mean nitrogen, phosphorus and potassium contents of the *bhusa* are given in Table 22 and the respective analysis of variance in Appendix XIV.

1. Nitrogen content of *bhusa*.

The different treatments had no significant influence on the nitrogen content of *bhusa*.

T_1 and T_2 among groundnut intercropped treatments and T_4 among cowpea intercropped treatments recorded higher values of nitrogen in the *bhusa*. Lowest values were recorded by T_3 and T_5 respectively.

2. Phosphorus content of *bhusa*.

The phosphorus content of the *bhusa* was not significantly influenced by various treatments.

Similar to the above observation on nitrogen content here also T_1 among groundnut intercropped treatments and T_4 among cowpea intercropped treatments recorded higher values of phosphorus in the *bhusa*. Lowest values were recorded by T_2 and T_6 respectively.

3. Potassium content of *bhusa*.

Similar to nitrogen and phosphorus contents, potassium content was also not influenced by the various treatments.

Table 22. Distribution of nitrogen, phosphorus and potassium (per cent) in the bhusa of intercrops as influenced by the main crop and spatial arrangements.

Treatments	Nitrogen		Phosphorus		Potassium	
	Groundnut	Cowpea	Groundnut	Cowpea	Groundnut	Cowpea
T_1	1.033	-	0.129	-	1.100	-
T_2	1.033	-	0.114	-	1.111	-
T_3	1.027	-	0.124	-	1.100	-
T_4	-	1.493	-	0.157	-	1.167
T_5	-	1.225	-	0.152	-	1.144
T_6	-	1.330	-	0.152	-	1.155
C.D. (.05)	-	-	-	-	-	-
S.E.	0.011	0.115	0.004	0.008	0.024	0.063

T_2 and T_4 among groundnut and cowpea intercropped treatments respectively recorded higher potassium contents inthe bhusa.

D. Quantity of nutrients incorporated by the intercrops.

The mean values of nitrogen, phosphorus and potassium incorporated to the soil through the intercrops are given in Table 23 and the analysis of variance in Appendix XIV.

1. Quantity of nitrogen incorporated by the intercrops.

Significant difference was observed between the two intercrops with regard to the quantity of nitrogen incorporated. Cowpea bhusa incorporated more quantity of nitrogen when compared to groundnut bhusa. T_4 was the superior treatment.

2. Quantity of phosphorus incorporated by the intercrops.

The quantity of phosphorus incorporated through bhusa was also significantly influenced by the intercrops. Cowpea added more phosphorus than groundnut bhusa.

3. Quantity of potassium incorporated by the intercrops.

Similar to the quantity of nitrogen and phosphorus incorporated quantity of potassium incorporated was also found to be significantly influenced by the intercrops. T_5 which was on par with T_6 and T_4 incorporated maximum quantity of potassium.

Table 23. Quantity of nitrogen, phosphorus and potassium incorporated by the intercrops (kg/ha) as influenced by the main crop and spatial arrangements.

Treatments	Nitrogen	Phosphorus	Potassium
T_1	25.381	3.475	27.091
T_2	24.954	2.700	26.557
T_3	32.411	3.908	34.654
T_4	56.129	5.683	42.317
T_5	52.126	6.320	49.134
T_6	49.724	5.670	43.323
C.D. (.05)	21.225	1.740	13.857
S.E.	6.730	0.552	4.394

Soil analysis after the experiment.

The mean values of the chemical properties of soil after the experiment are presented in Table 24 and Appendix XV gives the analysis of variance.

1. Total nitrogen content of the soil.

The various treatments had no significant effect on the total nitrogen content of the soil. However, maximum content was recorded by T_4 and minimum value by T_5.

2. Available phosphorus content of the soil.

Available phosphorus content of the soil did not show any significant difference due to different treatments. But T_4 recorded the maximum content and T_5 recorded the lowest value.

3. Available potassium potassium content of the soil.

The results revealed that there was no significant difference in the final available potassium content of the soil. T_1 recorded the highest available potassium content. The lowest value was recorded by T_8.

Table 24. Soil analysis after the experiment

Treatments	Total nitrogen content (per cent)	Available phosphorus content (kg/ha)	Available potassium content (kg/ha)
T_1	0.096	39.693	76.400
T_2	0.086	37.834	76.800
T_3	0.093	39.295	76.800
T_4	0.112	43.145	67.200
T_5	0.072	33.852	65.600
T_6	0.082	40.092	67.200
T_7	0.091	34.383	65.600
T_8	0.086	38.100	64.000
C.D. (.05)	-	-	-
S.E.	0.008	4.169	3.771

Table 25. Economics of intercropping in tapioca as influenced by planting patterns, intercrops and spatial arrangements.

Treatments	Cost of cultivation Rs/ha	Yield		Value of produce		Total income	Profit	Gain over T_8
		Tapioca t/ha	Intercrop kg/ha	Tapioca Rs.	Intercrop Rs.			
T_1	6471.8	13.392	2008.667	5356.80	9039.00	14395.80	7924.00	5971.6
T_2	6471.8	10.890	1741.667	4356.00	7837.50	12193.5	5721.7	3769.3
T_3	6471.8	14.630	1889.667	5852.00	8503.50	14355.5	7883.7	5931.3
T_4	6191.8	10.324	1585.000	4129.60	7291.00	11420.6	5228.8	3276.4
T_5	6191.8	11.833	1335.330	4733.2	6142.52	10875.72	4683.92	2731.52
T_6	6191.8	11.521	1478.670	4608.4	6801.88	11410.28	5218.48	3266.08
T_7	5230.0	20.423	-	8169.2	-	8169.2	2939.2	986.8
T_8	5230.0	17.956	-	7182.4	-	7182.4	1952.4	-

Price of tapioca - Rs. 40/quintal

Price of groundnut- Rs. 4.50/kg

Price of cowpea - Rs. 4.60/kg

Discussion

DISCUSSION

An investigation was carried out at the College of Agriculture, Vellayani during 1982-83 to study the effect of intercropping of groundnut and cowpea with tapioca and to identify the most suitable spatial arrangement of crops in the tapioca based intercropping system. The observations on growth characters, yield attributes and yield were recorded. Chemical analyses on soil and plant samples were done and the data recorded. The results obtained from the study are discussed hereunder.

Main crop (Tapioca)

A. Growth characters

1. Height of the plant

It is seen that (Table 1) there was significant influence of treatments on the height of plants after second, third and fourth month of planting. The plants in the two control treatments recorded maximum height. In the control plots there were no intercrops and as such the reduced population density resulted in comparatively lesser competition for ecophysiological requirements like water, nutrients, light etc. On the other hand in the intercropped plots there existed a tight competition for these requirements resulting in an unfavourable situation for rapid vegetative growth thereby causing a reduction in the height of tapioca.

The treatment in which groundnut was planted on mounds and all the cowpea intercropped plots were significantly inferior with regard to the height of tapioca as compared to the two control treatments after second, third and fourth month of planting. There was not much difference between the heights of the main crop of tapioca and the groundnut intercropped on the mounds with the result that the two crop canopies might have attained the same level and a certain amount of mutual suppression might have existed. But when groundnut was planted in the interspaces of both in the paired rows and normal rows, the two canopies never attained the same level because of the difference in vertical distance of planting of tapioca and groundnut as the tapioca setts were planted on the top of mounds and groundnut seeds in the interspaces. So the height of the mounds always helped the tapioca plants to hold its canopy at a higher level above the canopy of groundnut crop resulting in lesser competition by groundnut and cowpea. The luxurient vegetative growth of cowpea intercrop might have smothered the main crop of tapioca in the initial stages resulting in severe reduction in the height of tapioca in all the cowpea intercropped treatments.

After the fifth month of planting no significant difference in the height of tapioca plants was observed.

As all the intercrops were harvested and the stubbles incorporated into the soil there was no competition for the tapioca plants. The <u>bhusa</u> of the intercrops incorporated also released plant nutrients to the standing crop of tapioca. In addition the total population density was also reduced in the intercropped plots after the harvest of intercrops. All these factors were responsible for the uniform growth of tapioca plants observed after the fifth month of planting.

2. Total number of leaves per plant.

The results revealed that there was significant influence of treatments on the total number of leaves at all stages of growth of the plant except after first month of planting (Table 2). The two pure cropped treatments recorded higher values than the intercropped ones except that the intercropped treatments T_1 and T_3 were on par with the control treatments at certain stages of growth. As stated earlier there existed zero competition from the intercrop in the pure cropped treatments and as such there was absence of competition for light, space, nutrients and water for the main crop of tapioca resulting in higher leaf production per plant. Prabhakar and Nair (1979) also obtained higher leaf number in plots where no intercrop was raised.

Although significant difference was observed on the total number of leaves per plant even after sixth month of planting, no such difference was observed on the number of functional leaves after that stage. So the difference in total leaf number was due to the difference in the number of leaves produced before that stage of growth which in turn might have been influenced by the various treatments.

Considering the two intercrops, groundnut intercropped plots recorded higher values on the total number of leaves over cowpea intercropped ones. This is because of the fact that the interference caused by groundnut was minimum when planted in the interspaces of paired and normal rows. But this was not the case with groundnut planted on mounds which caused considerable shade to the tapioca resulting in lesser production of leaves over the other two methods of planting intercrops. Regarding the other intercrop cowpea, its growth rate was very high and as such the interference on tapioca was also more and thus affected the total leaf production in tapioca.

But the situation seemed to have changed after the harvest of intercrops. The incorporated bhusa released nutrients in the intercropped plots for the benefit of the standing tapioca crop which might have helped the plants to come on par with the pure cropped plants with regard to this very important growth parameter.

3. Functional leaves per plant.

A critical analysis of the data on functional leaves (Table 3) revealed that there was significant difference regarding the functional leaf number per plant on account of treatment effects after second, third, fourth and fifth month of planting. Plants in the two pure cropped plots and in paired rows with groundnut in interspaces were significantly superior to other treatments after second month of planting because plants in these treatments might have experienced little competition for light, nutrients, water and other growth inputs as compared to other treatments. Plant population was also less in the two pure cropped fields. As the intercrops were sown only in the interspaces of paired rows and the intra-paired row interspace was kept free of intercrops, tapioca might have experienced little competition from groundnuts of paired row interspaces. This might be the reason for getting higher leaf number from those treatments. Since cowpea had an initial vigorous vegetative growth it might have smothered tapioca at this stage resulting in reduced functional leaf number even in paired rows.

The two control plots registered maximum number of functional leaves per plant after third and fourth month of planting and was significantly superior to all other inter-cropped treatments possibly because of less intercrop competition in the control plots. At this stage groundnut produced excellent vegetative growth and thus might have reduced the functional leaf number in tapioca by way of competition for resources. Though there was no cowpea crop at the above two stages of growth, the smothering effect caused by cowpea crop during the earlier stages might have influenced the leaf number even at later stages.

Pure crop of tapioca also recorded higher leaf number even after fifth month of planting. But there was no significant difference between tapioca alone in paired rows and tapioca in paired rows with groundnut in the interspaces. Tapioca in the second category recouped earlier set back since the deleterious effects caused by the intercrop might have been minimum and as such could produce higher leaf number.

With regard to the number of functional leaves no significant difference was observed after fifth month of planting between the different treatments, because a much more favourable condition was created in the intercropped fields after the harvest of intercrops. The intercrops after the harvest of economic produce were uprooted and incorporated into the soil and by the decomposition of bhusa the nutrients were released and made available to the standing crop. Again, the total plant population was reduced in the intercropped treatments after the harvest of intercrops.

4. Leaf area index.

The mean values of leaf area index (Table 4) indicated that there was significant difference due to treatment effects after second, third and fourth month of planting. The two control plots and the two groundnut intercropped treatments (in the interspaces of paired and normal rows) were on par after second month of planting. The two pure cropped treatments recorded higher values of leaf areas index when compared to cowpea intercropped treatments. The smothering effect of cowpea was evident in the form of yellowing of the older leaves of tapioca in cowpea intercropped plots. This might have reduced the leaf area duration in addition to the number of functional leaves thereby causing a reduction in the leaf area index of tapioca in cowpea intercropped plots. The two pure cropped plots also showed their superiority over other intercropped treatments after third and fourth month of planting. However, no significant difference in the leaf area index was observed after fifth month of planting. Here also the reasons attributed for the higher functional leaf production of pure cropped tapioca are applicable.

5. Girth of the stem.

From the results obtained (Table 5) it is seen that there was significant influence of treatments on stem girth after second, third and fourth month of planting. The tapioca in the two control plots and in all the groundnut intercropped plots after 2nd month of planting and in groundnut intercropped in the paired rows in addition to the control plots after 3rd month of planting recorded significant variation from the cowpea intercropped plots. Vegetative growth of tapioca in treatments other than intercropped cowpea was more and the activity of photosynthetic apparatus was maximum thereby the cambium might have been more active and formed a thicker stem by secondary growth. In cowpea intercropped plots, the canopy coverage was sparse and activity was minimum and so there was less demand for the transport of sap, as such cambium was less active resulting in a thinner stem by secondary growth. After fourth month of planting also tapioca in the two control treatments recorded significantly higher stem girth values.

No significant variation in stem girth was noticed after fifth month of planting onwards possibly because of zero competition in the intercropped treatments due to the harvest of intercrops and release of nutrients by the incorporated bhusa to the standing tapioca crop which might have helped tapioca even in the cowpea intercropped treatments for recoupment.

B. Yield attributes and yield.

1. Total number of roots per plant.

The total number of roots per plant (Table 6) was not significantly influenced by the different treatments. However, T_8 recorded the maximum number of roots per plant. The minimum number of roots per plant was recorded by T_5. Indira and Kurien (1977) observed that root formation in cassava took place within a few days of planting. So root formation might have completed well before the commencement of interference from intercrops and hence intercropping had no effect on the number of roots per plant. Therefore tapioca plants in the intercropped treatments behaved in a similar fashion as that of pure cropped plants with regard to this character.

2. Number of tubers per plant.

A critical analysis of the data on number of tubers per plant (Table 6) revealed that there was significant difference due to treatment effects. T_3 produced the maximum number of tubers per plant and was on par with T_1 and T_8. This might be due to the fact that tapioca in all the above three treatments did not experience much severe competition from the intercrop components unlike the other treatments on mounds in which the intercrops depleted nutrients and moisture from the root zone of tapioca. The depletion of nutrients and moisture might have adversely interfered with tuber development. During the earlier stages of growth all the cowpea treatments considerably retarded above ground growth of tapioca due to intense competition for resources (Tables 1 to 5). This resulted in poor development of the photosynthetic apparatus which in turn might have reduced the carbohydrate supply for initiating secondary thickening of roots for tuber development. T_7 recorded lower values since the spacing between rows was less (Mattos et al., (1980). Ramakrishna Bhat (1978) and Sheela (1981) reported that groundnut intercropped plots showed higher tuber number per plant.

3. Percentage of productive roots.

The results (Table 6) showed that there was no significant difference between treatments with regard to the percentage of productive roots in tapioca. However, groundnut intercropping recorded a higher percentage of productive roots of tapioca than cowpea intercropping suggesting that groundnut was the best intercrop with tapioca. This might be due to a variety of factors like lesser competition for nutrients and the root distribution character of groundnut which would have provided favourable condition for greater bulking of roots. Ramakrishna Bhat (1978) reported that groundnut intercropping increased the percentage of productive roots than cowpea intercropping.

4. Length of tuber.

The data (Table 6) revealed no significant difference in length of tuber due to treatment effects. However, it could be seen that length of tuber was maximum in paired row without any intercrop. While working on relative water loss between crop rows, Larson and Willis (1957) found that soil moisture increased from within the row to the middle point between the rows. This clearly indicated that sufficient moisture would have been available in the paired row interspaces into which tapioca roots traversed in search of moisture resulting in an increase of tuber length in T_7. Between groundnut and cowpea, cowpea produced longer tubers. This is in conformity with the findings of Sheela (1981) also. She reported that cowpea intercrops grown on mounds might have put forth their tap roots to deeper layers and the uprooting of intercrops resulted in a loosened soil condition around the tapioca plant. This condition would have helped the growing tubers to penetrate easily through the loose soil at the time of tuberisation resulting in an increase in the length of tubers incowpea intercropped plots.

5. Girth of tuber.

The data (Table 6) showed that there was no difference in tuber girth due to treatment effects. However, the data revealed that the treatment which showed the lowest percentage of productive roots (T_6) recorded the highest tuber girth possibly due to more availability of assimilates for storage, and lesser number of productive roots when compared to other treatments. This is in conformity with the findings of Magoon et al. (1972) that the storate root size was inversely related to the number.

6. Rind to flesh ratio,

No significant variation was observed in the rind to flesh ratio of tubers. However, tapioca in paird row without intercrop recorded the highest value. This may be due to the fact that as the treatment T_7 produced longer tubers (Table 6) it could register higher value of rind to flesh ratio.

7. Tuber yield.

The data (Table 7 and Fig. 3) brought out clearly that there was significant difference in tuber yield due to treatment effects. Tapioca in paired row without intercrop not only recorded the highest yield but differed significantly from all other intercropped treatments also. However, tapioca at normal spacing without intercrop was on par with the above treatment and also with T_3 and T_1. T_7 recorded higher yields, may be because of the fact that in that treatment tapioca was planted in paired rows. Mattos et al. (1980a) explained the principle of "border effect". According to them "Cassava border rows produce higher yields than inside rows because they receive more light and nutrients". The paired row system tries to use this principle (Mattos et al., 1980a) which has been successfully demonstrated by producing higher yields from the paired row treatment. Moreover there was no competition from intercrops in this treatment.

The importance of border effect is further revealed in the behaviour of treatment T_8, which also lacked competition from intercrop but ranked only next to T_7 since it could not get the benefit of border effect. It is seen that the two intercrops did not differ significantly between themselves in influencing the tuber yield of tapioca. This is in conformity with the findings of Sheela (1981). The treatment T_4 recorded the lowest tuber yield.

8. Top yield.

The mean values of top yield (Table 7 and Fig. 4) revealed that the treatments did not have any significant effect although pure crop of tapioca at normal spacing recorded the highest value. The free growth of tapioca due to wider planting and without competition from intercrop might have encouraged better utilization of the various growth factors particularly sunlight resulting in more vegetative growth and thus highest top yield.

9. Utilization index.

The data presented in Table 7 revealed that there was significant difference in the utilization index due to treatment effects. The significant variation observed in the tuber yield may be responsible for inducing variation in utilization index. T_7 produced maximum tuber yield and hence it recorded the highest value and it differed significantly from all other treatments also. The lowest utilization index was recorded by the treatment T_6.

C. Quality attributes.

1. Drymatter, starch and crude protein contents of tuber.

From the results (Table 8) it is observed that quality attributes like drymatter, starch and crude protein contents of tapioca tuber were not significantly influenced by treatment effects. Though significant variations in biometric observations were noticed due to competition and interference with intercrops, such features had little impact on the quality attributes and hence the above results. This is quite natural as the treatments did not include variation in nutrients and varieties which would have influenced the above quality attributes.

D. Plant analysis.

Nitrogen content of leaf and stem and phosphorus and potassium contents of leaf, stem and tubers.

No significant difference was observed in the nitrogen (Table 9) content of tapioca leaf and stem. Phosphorus (Table 10) and potassium (Table 11) contents of leaf, stem and tuber were not influenced by the treatments. Thus it has also been brought out clearly that the two intercrops did not have any influence on the N, P and K contents of tapioca. Since tapioca has been given uniform doses of N, P and K in all the treatments according to package of practices and intercrops have been adequately fertilized significant variation on the N, P and K contents of plant parts need not be expected also.

Intercrops

A. Growth characters and yield

a. Groundnut

1. Height of plant.

It is seen that there was significant difference in the height of groundnut at 100th day of planting and at the time of harvest (Table 12). Groundnut planted in the interspaces of normal rows recorded the highest values. Vigorous vegetative growth of tapioca might have shaded groundnut which in turn produced longer internodes for intercepting more of sunlight with the result the height increased considerably. On the other hand groundnut planted in the interspaces of paired rows might not have experienced so much shading from tapioca since ample space was available for groundnut to put forth its canopy and hence it recorded a lower height.

2. Number of branches per plant.

Mean values of the number of branches of groundnut (Table 14) at the time of harvest indicated that there was significant difference between treatments. T_3 differed significantly from the other two treatments because T_3 at the time of harvest recorded maximum height (Table 12) and hence it might have intercepted more sunlight resulting increased production of branches.

3. Number of functional leaves per plant.

The results (Table 16) revealed no significant difference between treatments with regard to the number of functional leaves per groundnut plant. The increase in height of plant happened due to elongation of internodes and not due to more number of nodes. As such the leaf number remained the same although the height was different in different treatments.

4. Leaf area index.

The mean values of leaf area index of groundnut (Table 18) indicated that there was no significant difference due to treatment effects at any stage of plant growth. As there was no significant difference between treatments with regard to functional leaf number (Table 16) the leaf area index also did not differ significantly between treatments.

5. Pod number, pod yield and bhusa yield.

From the results obtained (Table 20 and Fig. 3 and 4) it is seen that pod number, pod yield
of groundnut were not significantly influenced due to treatment effects. This clearly indicated the fact that the above characters could not be influenced by spatial arrangements.

b. Cowpea.

1. Height of plants.

Though no significant difference in the height of cowpea was observed (Table 13), T_4 at all stages of growth recorded the maximum height. Since there were four rows of intercrop in one paired row interspace, intercrop might have experienced little competition from main crop and hence the result. Mahabal Ram (1980) reported that paired row technique was most suitable for growing intercrops. According to him this system prevented a tall crop shading on the companion crop and thereby improved companion crop development. The present result is in conformity with the above finding.

2. Number of branches per plant.

Mean values on the number of branches of cowpea (Table 15) at 40th day of planting recorded significant difference between treatments with T_4 recording the maximum number. The reasons attributed for the greater height of cowpea can be attributed to the more number of branches also.

3. Number of functional leaves per plant.

Significant difference in cowpea leaf number (Table 17) was recorded by T_4 after 40 and 60 days of planting. Unlike groundnut where elongation of internodes due to shading was the main reason for increase in height, the cowpea intercrop increased in height in T_4 due to increased availability of space and less competition from the main crop and as such the number of functional leaves also increased in that treatment.

4. Leaf area index.

In the case of cowpea no variation in the leaf area index was observed (Table 19) although there was significant variation between treatments with regard to functional leaf number which may probably be because of poor leaf retention capacity and shorter leaf area duration in plants producing more number of leaves.

5. Pod number, grain yield and bhusa yield.

From the results obtained (Table 21 and Fig. 3 and 4) it is seen that pod number, grain yield and bhusa yield of cowpea were not significantly influenced due to treatment effects. This clearly indicated the fact that the above characters could not be influenced by spatial arrangements.

FIG. 3. YIELD OF TAPIOCA, GROUND NUT AND COW PEA AS INFLUENCED BY PLANTING PATTERNS, INTERCROPPING AND SPATIAL ARRANGEMENTS.

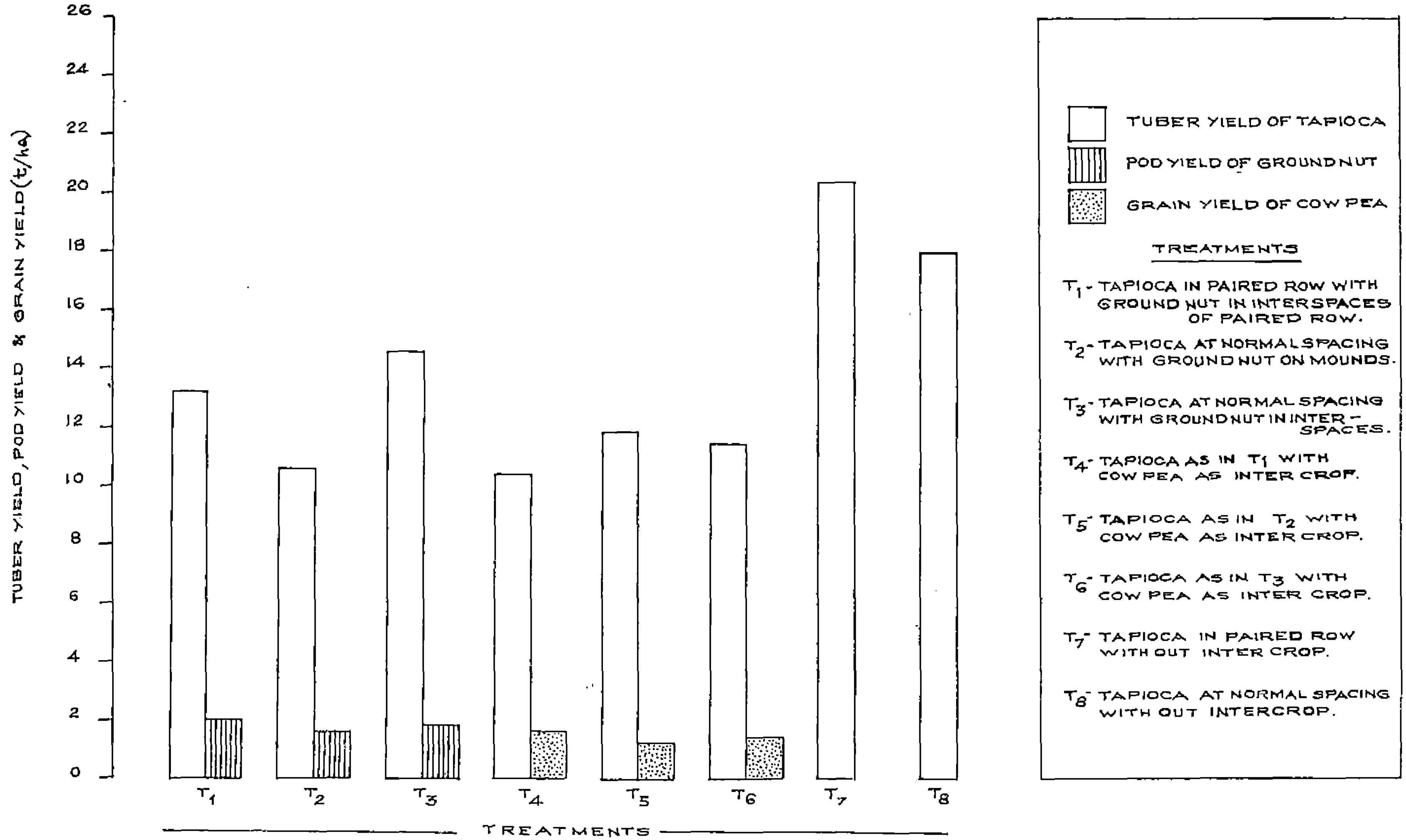
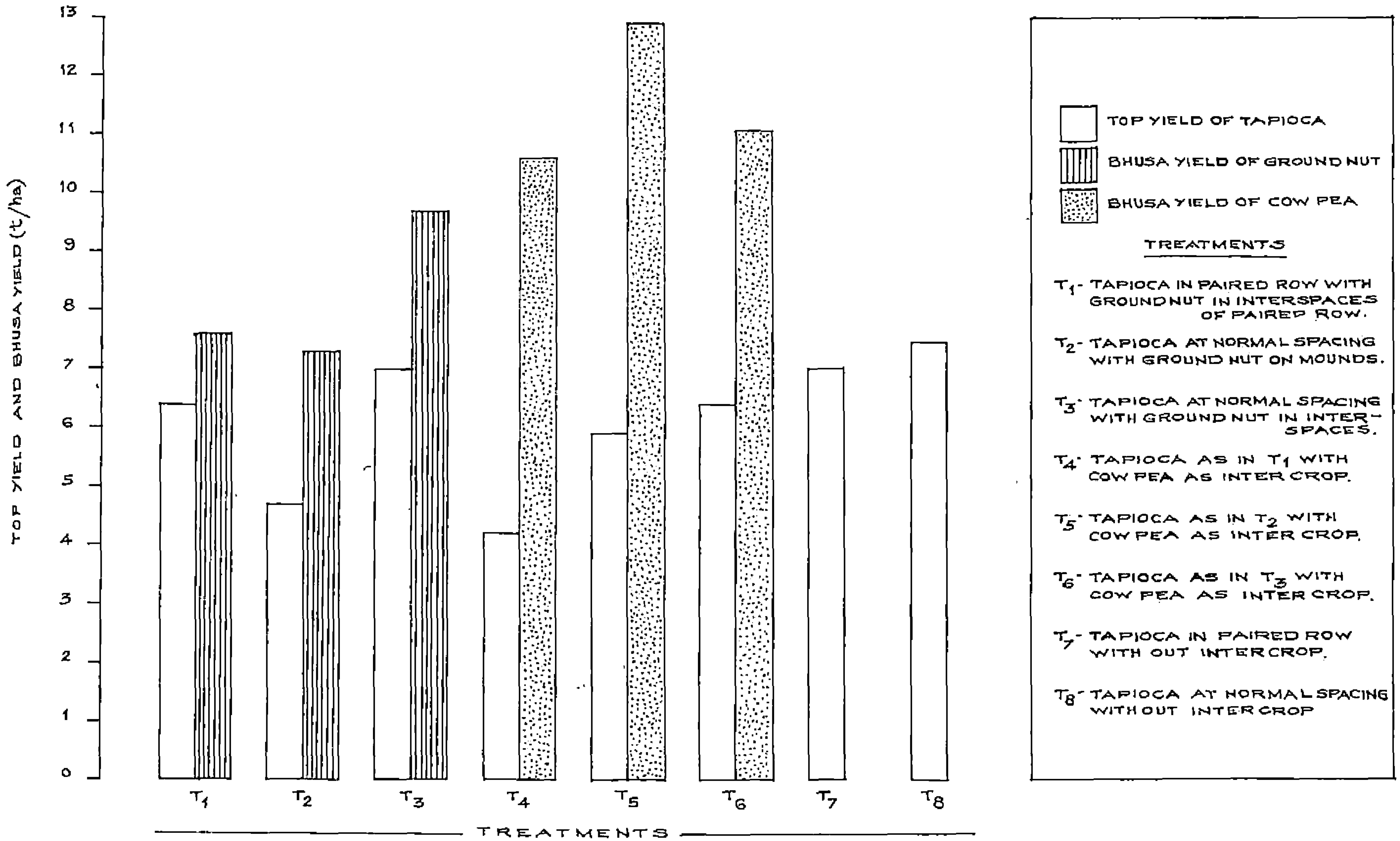


FIG.4. TOP YIELD OF TAPIOCA AND BHUSA YIELD OF INTERCROPS AS INFLUENCED BY PLANTING PATTERNS, INTERCROPPING AND SPATIAL ARRANGEMENTS.



B. Plant analysis.

Nitrogen, phosphorus and potassium contents of <u>bhusa</u>.

From the results obtained (Table 22) it is seen that nitrogen, phosphorus and potassium contents of bhusa were not significantly influenced due to treatment effects indicating that the distribution of nutrients in groundnut and cowpea <u>bhusa</u> could not be influenced by spatial arrangements.

C. Enrichment of soil nutrients by the intercrops.

The data on the amount of nitrogen, phosphorus and potassium incorporated into the soil by the intercrops (Table 23) revealed significant difference due to various treatments.

Cowpea bhusa incorporated large quantities of nitrogen, phosphorus and potassium into the soil while groundnut ranked only next to cowpea. All the cowpea intercropped treatments produced large quantities of vegetative material (Table 21) when compared to groundnut. In addition, cowpea <u>bhusa</u> was rich in nitrogen, phosphorus and potassium than groundnut <u>bhusa</u> (Table 22). Large quantities of vegetative material coupled with higher percentage of nitrogen, phosphorus and potassium have helped cowpea <u>bhusa</u> to incorporate more quantities of these nutrients into the soil.

Nutrient content of soil after the experiment.

Chemical analysis of soil for major plant nutrients (Table 24) revealed that there was no significant difference in nitrogen, phosphorus and potassium content of soil after the experiment. However, cowpea intercropped plot registered maximum value for nitrogen followed by groundnut intercropped ones. Enrichment of soil nitrogen by growing leguminous intercrops in tapioca was reported earlier by Singh _et al._ (1969) and Ramakrishna Bhat (1978). Similar increase in soil nitrogen by legume intercropping was also shown by Morachan _et al._ (1977).

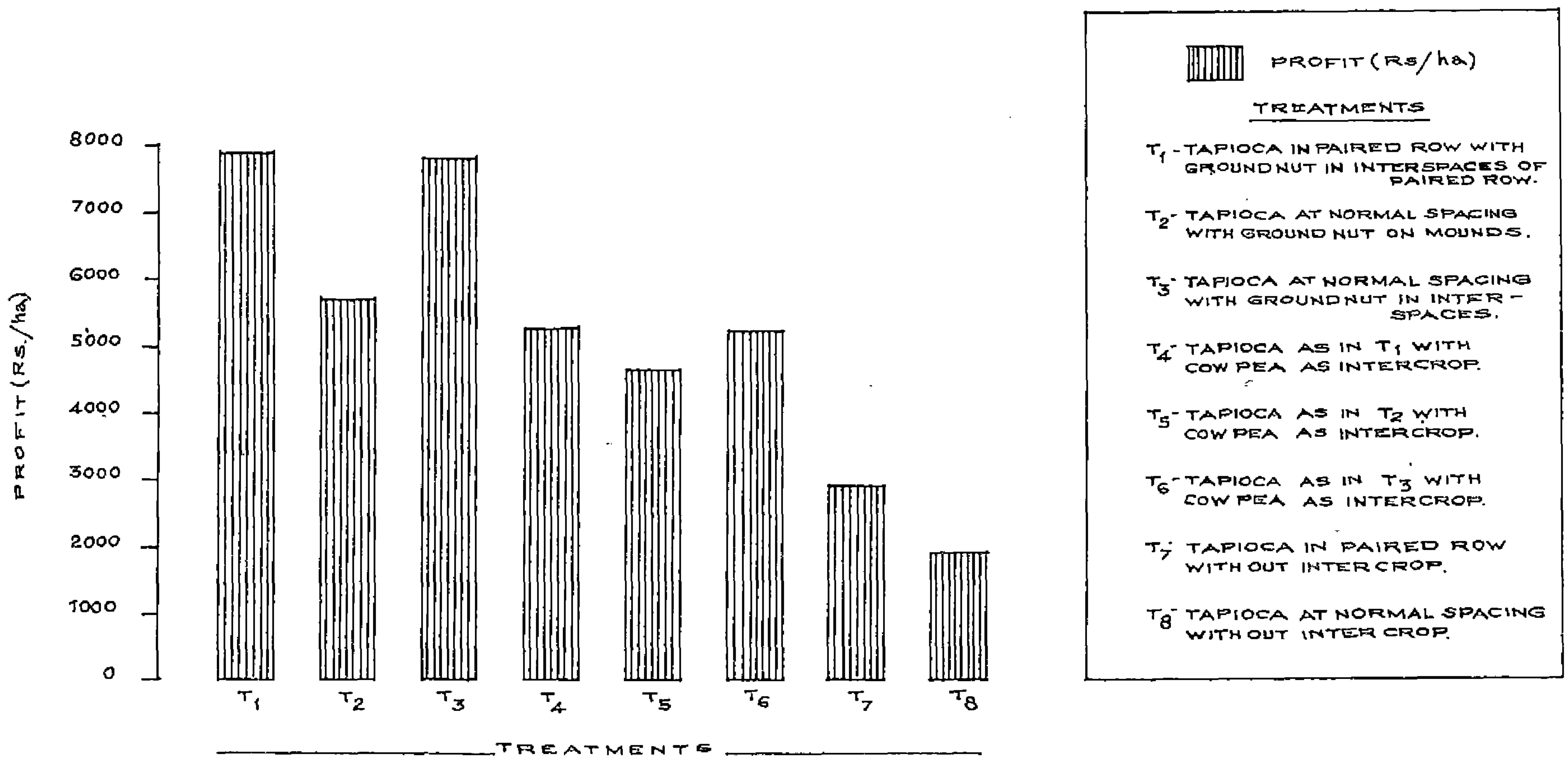
The different treatments showed no significant influence on the available phosphorus content of the soil after the experiment (Table 24). However, T_4 recorded the maximum phosphorus content while T_5 recorded the lowest value.

The treatments showed no significant influence on the available potassium content of the soil after the experiment (Table 24). T_1 recorded the highest available potassium content. The lowest value was recorded by T_8.

Economics of tapioca based intercropping system.

The results (Table 25 and Fig. 5) indicated that groundnut was the most profitable intercrop in tapioca. Singh and Mandal(1968, 1970), Sintuprama _et al._ (1973), Mohankumar and Hrishi (1974, 1976), Tongham (1975), Ramakrishna Bhat (1978), Mohankumar (1978, 1980) and Sheela (1981) obtained similar results showing groundnut as the most profitable intercrop in tapioca.

FIG. 5. ECONOMICS OF INTERCROPPING IN TAPIOCA AS INFLUENCED BY PLANTING PATTERNS, INTERCROPS AND SPATIAL ARRANGEMENTS.



The highest return was obtained from the treatment where tapioca was planted in paired rows and groundnut in the interspaces of paired rows. The next best system was tapioca in normal rows with groundnut in the interspace of normal rows. Tapioca at normal spacing with groundnut on mounds recorded the lowest returns among the groundnut intercropped treatments.

When considering the economy of intercropping system all the cowpea intercropped treatments recorded only lower returns as compared to groundnut and has proved to be inferior to groundnut intercropping system. When tapioca is considered as a pure crop without intercropping paired row of tapioca without intercropping recorded a higher profit than the control treatment.

Future line of work.

From the present study, it is seen that the highest economic return was obtained from the treatment where tapioca was planted in paired rows and groundnut in the interspaces of paired rows. Under the above system of spatial arrangement since the space between the paired rows of tapioca was very wide, even at its rank growth stage tapioca was not able to attain the filled in condition which was quite common in normal row planting. Even the plants showing luxuriant vegetative growth caused only partial shade in the paired row interspaces. This provides an opportunity to investigate the possibilities of raising a second intercrop immediately after the harvest of the first in the same area.

Summary

SUMMARY

An experiment was conducted at the College of Agriculture, Vellayani during 1982-83 to study the effect of intercropping groundnut and cowpea with tapioca and to identify the most suitable spatial arrangement of crops in the tapioca based intercropping system. The study also helped to find out the possibilities of changing the geometry of planting of tapioca from the normal method to the paired row pattern. The experiment with eight treatments was carried out in randomised block design with three replications under rainfed conditions. The results obtained are summarised below.

1. Competition for ecophysiological requirements in intercropped treatments during the early stages of growth caused unfavourable environment for rapid growth of tapioca unlike the pure cropped treatments as reflected in the growth habit of tapioca. Most of the growth characters like height, number of functional leaves, total number of leaves, leaf area index and stem girth of tapioca showed lower values in intercropped treatments. But later, the suppressing effect of intercrops was nullified and as such no significant difference was observed in these characters except on the total number of leaves produced.

2. The total number of roots per plant was not significantly influenced by the different treatments due to the fact that

the roots were formed very early in the growth cycle of tapioca, i.e., earlier than the vigorous growth of intercrops.

3. Among the various treatments tapioca at normal spacing with groundnut in the interspaces recorded the maximum number of tubers per plant.

4. Intercropping with groundnut recorded higher percentage of productive roots than with cowpea.

5. Maximum length of tuber was produced by tapioca in paired row without intercrop. Between the two intercrops tried, cowpea produced longer tubers.

6. There was no difference in tuber girth due to treatment effects. However, the treatment which showed the lowest percentage of productive roots recorded the highest tuber girth.

7. No significant variation was observed in the rind to flesh ratio of tubers.

8. Tapioca in paired row without intercrop recorded the highest tapioca yield and it differed significantly from all other intercropped treatments. However, tapioca at normal spacing without intercrop was on par with the above treatment.

9. The mean values of top yield revealed the fact that the treatments did not have any significant effect though pure crop of tapioca at normal spacing recorded the highest value.

10. There was significant difference in the utilisation index values due to treatment effects. Tapioca in paired row without intercrop recorded the highest value and it differed significantly from all other treatments.

11. Quality attributes like drymatter, starch and crude protein contents of tapioca tuber were not significantly influenced by treatment effects.

12. No significant difference was observed in the nitrogen content of tapioca leaf and stem. Phosphorus and potassium contents of leaf, stem and tuber also showed no significant variation.

13. Grountnut planted in the interspaces of normal rows produced more height after 100 days of planting and at the time of harvest. But no significant difference could be observed in the height of cowpea.

14. When groundnut was planted in the interspaces of normal rows of tapioca, more number of branches were produced at the time of harvest. Cowpea planted in the paired row interspaces recorded the maximum number of branches after 40 days of planting.

15. No significant difference between treatments with respect to the number of functional leaves per groundnut was observed. However, cowpea planted in the paired row interspaces recorded significantly higher values than the other two treatments at 40 and 60 days after planting.

16. The mean values of leaf area index of intercrops indicated that there was no significant difference due to treatment effects at any stage of plant growth.

17. Groundnut planted in the interspaces of normal rows of tapioca recorded the maximum pod number whereas the same was recorded by cowpea in the paired row interspaces of tapioca.

18. The maximum pod yield of groundnut and grain yield of cowpea were recorded by the intercrops in the paired row interspace of tapioca.

19. Maximum bhusa yield was recorded by groundnut in the interspace of normal rows of tapioca. The same was recorded by cowpea on mounds.

20. From the results obtained it is seen that nitrogen, phosphorus and potassium contents of bhusa were not significantly influenced by the treatment effects.

21. Cowpea bhusa was rich in nitrogen, phosphorus and potassium when compared to groundnut bhusa.

22. Cowpea bhusa incorporated large quantities of nitrogen, phosphorus and potassium into the soil. Groundnut ranked only next to cowpea in this respect.

23. Cowpea intercropped plots registered maximum values for soil nitrogen after the experiment followed by groundnut intercropped plots.

24. The different treatments did not show any significant difference in the available phosphorus and potassium contents of the soil after the experiment.

25. The highest economic return was obtained from the treatment where tapioca was planted in paired rows and groundnut in the interspaces of paired rows.

26. The next best system was tapioca in normal rows with groundnut in the interspace of normal rows.

27. Tapioca in paired row without intercrop recorded a higher profit than tapioca at normal spacing without intercrop.

28. The results indicated that groundnut was the most profitable intercrop in tapioca.

29. The results also indicated that paired row planting of tapioca with groundnut in the interspaces was the most profitable system worth popularising.

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Appendices

APPENDIX - I

Weather data during the crop period in comparison with the corresponding average values for the past 25 years

Month	Rainfall (mm)		Average temperature °C				Average R.H. (per cent)	
	Crop period (total)	Past 25 years (average)	Maximum		Minimum		Crop period	Past 25 years
			Crop period	Past 25 years	Crop period	Past 25 years		
June	500.50	299.01	30.12	30.38	23.07	23.89	80.00	85.26
July	120.00	217.08	30.16	29.73	22.51	23.44	81.00	87.45
August	335.00	143.82	30.04	29.77	21.23	23.21	89.00	86.3
September	66.50	156.75	30.48	30.09	22.11	23.29	81.00	86.12
October	190.50	266.97	30.95	29.70	22.50	23.68	83.00	87.68
November	129.00	209.87	31.03	29.95	22.02	23.77	85.00	87.24
December	19.50	69.44	31.31	30.62	20.70	23.19	79.00	84.76
January	-	33.24	31.58	30.97	21.17	22.37	70.00	79.86
February	-	34.56	31.79	31.27	22.08	22.73	75.39	82.07

APPENDIX - II

Abstract of analysis of variance table for the height of tapioca at different growth stages.

Source	df	Mean squares			
		I M.A.P	2 M.A.P.	3 M.A.P.	4 M.A.P.
Block	2	1.525	137.824*	723.746*	1084.881*
Treatment	7	0.978	230.858*	717.846*	625.264*
Error	14	1.184	31.078	73.695	200.456

Source	df	Mean squares			
		5 M.A.P	6 M.A.P.	7 M.A.P.	8 M.A.P.
Block	2	1445.026*	2834.133	3215.751	3943.723
Treatment	7	456.051	415.790	456.499	432.899
Error	14	346.071	169.366	310.087	307.724

M.A.P. - Months after planting

* - Significant at 0.05 level

APPENDIX - III

Abstract of analysis of variance table for the total number of leaves of tapioca at different growth stages.

Source	df	Mean squares			
		1 M.A.P.	2 M.A.P.	3 M.A.P.	4 M.A.P.
Block	2	1.858	22.576*	106.858*	355.782*
Treatment	7	0.692	70.071*	189.008*	312.408*
Error	14	0.927	6.308	15.426	26.899

Source	df	Mean squares			
		5 M.A.P.	6 M.A.P.	7 M.A.P.	8 M.A.P.
Block	2	1166.693*	2445.389*	5136.946*	15179.717*
Treatment	7	874.964*	2229.410*	4676.363*	6071.470*
Error	14	146.650	502.127	977.179	2133.410

M.A.P. - Months after planting

* - Significant at 0.05 level

APPENDIX - IV

Abstract of analysis of variance table for the number of functional leaves of tapioca at different growth stages.

Source	df	Mean squares			
		1 M.A.P.	2 M.A.P.	3 M.A.P.	4 M.A.P.
Block	2	1.858	26.032*	92.795*	254.881*
Treatment	7	0.692	88.888*	196.969*	175.391
Error	14	0.927	8.405	9.502	19.050

Source	df	Mean squares			
		5 M.A.P.	6 M.A.P.	7 M.A.P.	8 M.A.P.
Block	2	486.225*	845.155*	898.346*	1415.480
Treatment	7	265.739*	404.084	463.457	389.939
Error	14	67.203	165.813	203.940	150.136

M.A.P. - Months after planting

* - Significant at 0.05 level

APPENDIX - V

Abstract of analysis of variance table for the leaf area index of tapioca at different growth stages.

Source	df	Mean squares			
		1 M.A.P.	2 M.A.P.	3 M.A.P.	4 M.A.P.
Block	2	0.0005	0.1142*	0.2400*	0.1514*
Treatment	7	0.0001	0.1271*	0.5525*	0.4044*
Error	14	0.0002	0.0359	0.0709	0.0499

Source	df	Mean squares			
		5 M.A.P.	6 M.A.P.	7 M.A.P.	8 M.A.P.
Block	2	0.2440*	0.4577*	0.3373*	0.1194*
Treatment	7	0.0583	0.1842	0.1242	0.0095
Error	14	0.0267	0.1103	0.0585	0.0133

M.A.P. - Months after planting

* - Significant at 0.05 level

APPENDIX - VI

Abstract of analysis of variance table for the girth of tapioca stem at different growth stages.

Source	df	Mean squares			
		1 M.A.P.	2 M.A.P.	3 M.A.P.	4 M.A.P.
Block	2	-	0.900*	0.747	1.804
Treatment	7	-	1.388*	2.204*	2.306
Error	14	-	0.142	0.360	0.221

Source	df	Mean squares			
		5 M.A.P.	6 M.A.P.	7 M.A.P.	8 M.A.P.
Block	2	4.037*	0.785	2.634	2.378*
Treatment	7	0.637	0.585	0.462	0.577
Error	14	0.451	0.365	0.299	0.227

M.A.P. - Months after planting

* - Significant at 0.05 level

APPENDIX - VII

a. Abstract of analysis of variance table for yield attributes and yield of tapioca

Source	df	Mean squares								
		Number of roots per plant	Number of tubers per plant	Percentage of productive roots	Length of tuber	Girth of tuber	Tuber yield	Top yield	Utilization index	Rind to flesh ratio
Block	2	0.0820	3.8643*	601.5712*	103.7107*	2.3839	125.2720*	29.6129*	0.0460	0.0002
Treatment	7	1.4347	3.6979*	475.7035	33.8702	3.6341	39.2424*	3.8357	0.3838*	0.0002
Error	14	1.9828	0.5143	214.7620	33.0818	2.4620	10.8268	2.9173	0.0923	0.0002

b. Abstract of analysis of variance table for quality attributes of tapioca

Source	df	Mean square		
		Drymatter content	Starch content	Crude protein content
Block	2	2.071	0.289	0.139
Treatment	7	5.637	0.792	0.105
Error	14	2.569	1.066	0.074

* - Significant at 0.05 level

APPENDIX - VIII

Abstract of analysis of variance table for the distribution of nutrients in tapioca.

Source	df	Mean square							
		Nitrogen		Phosphorus			Potassium		
		Leaf	Stem	Leaf	Stem	Tuber	Leaf	Stem	Tuber
Block	2	0.0046	0.0105	0.0001	0.0026*	0.00006	0.0532	0.0034	0.0684
Treatment	7	0.0383	0.0054	0.0004	0.0001	0.00015	0.0039	0.0005	0.0144
Error	14	0.0491	0.0049	0.0020	0.0002	0.00046	0.0204	0.0101	0.0089

* - Significant at 0.05 level

APPENDIX - IX

a. Abstract of analysis of variance table for the height of groundnut at different growth stages.

Source	df	Mean squares					
		20 D.A.P.	40 D.A.P.	60 D.A.P.	80 D.A.P.	100 D.A.P.	At harvest
Block	2	0.559	0.243	5.580	46.063	45.123*	21.045
Treatment	2	0.109	1.720	19.002	32.67	38.643*	35.381*
Error	4	0.425	1.113	4.678	6.723	1.912	3.768

b. Abstract of analysos of variable table for the height of cowpea at different growth stages.

Source	df	Mean squares			
		20 D.A.P.	40 D.A.P.	60 D.A.P.	At harvest
Block	2	1.362	1.268	1365.963	222.063
Treatment	2	1.675	15.151	408.703	29.423
Error	4	0.672	5.628	350.772	271.127

D.A.P. - Days After Planting

* - Significant at 0.05 level

APPENDIX - X

a. Abstract of analysis of variance table for the number of branches of groundnut at different growth stages.

Source	df	Mean squares					
		20 D.A.P.	40 D.A.P.	60 D.A.P.	80 D.A.P.	100 D.A.P.	At harvest
Block	2	0.058	0.688	0.903	1.727	0.509	0.532*
Treatment	2	0.088	0.125	0.190	0.043	0.090	0.468*
Error	4	0.078	0.313	0.655	0.280	0.142	0.056

b. Abstract of analysis of variance table for the number of branches of cowpea at different growth stages.

Source	df	Mean squares			
		20 D.A.P.	40 D.A.P.	60 D.A.P.	At harvest
Block	2	-	0.528	0.618*	0.480
Treatment	2	-	0.618*	0.085	0.043
Error	4	-	0.078	0.050	0.163

D.A.P. - Days After Planting

* - Significant at 0.05 level.

APPENDIX - XI

a. Abstract of analysis of variance table for the number of leaves of groundnut at different growth stages.

Source	df	Mean squares					
		20 D.A.P.	40 D.A.P.	60 D.A.P.	80 D.A.P.	100 D.A.P.	At harvest
Block	2	0.003	29.560	43.318	178.427	42.266	12.492
Treatment	2	0.103	10.360	78.825	103.723	182.041	48.046
Error	4	0.047	28.655	15.046	170.070	34.625	16.871

b. Abstract of analysis of variance table for the number of leaves of cowpea at different growth stages.

Source	df	Mean squares			
		20 D.A.P.	40 D.A.P.	60 D.A.P.	At harvest
Block	2	÷	5.583*	47.861*	1.803
Treatment	2	-	4.030*	59.348*	3.863
Error	4	-	0.308	4.598	6.107

D.A.P. - Days After Planting

* - Significant at 0.05 level

APPENDIX - XII

a. Abstract of analysis of variance table for the leaf area index of groundnut at different growth stages.

Source	df	Mean squares					
		20 D.A.P.	40 D.A.P.	60 D.A.P.	80 D.A.P.	100 D.A.P.	At harvest
Block	2	0.00006	0.1623	3.0504	4.7160	0.8913	0.3850
Treatment	2	0.0008	0.0289	5.8222	1.2645	3.0848	0.5625
Error	4	0.0002	0.1197	1.9176	2.3807	1.2556	0.2114

b. Abstract of analysis of variance table for the leaf area index of cowpea at different growth stages.

Source	df	Mean squares			
		20 D.A.P.	40 D.A.P.	60 D.A.P.	At harvest
Block	2	0.000021	0.4725	3.0352	0.2666
Treatment	2	0.000007	0.3932	4.2978	0.1357
Error	4	0.000008	0.1590	2.6894	0.3825

D.A.P. - Days After Planting.

APPENDIX - XIII

a. Abstract of analysis of variance table for the number of pods and yield of groundnut.

Source	df	Mean square		
		Number of pods	Pod yield	Bhusa yield
Block	2	5.526	1892358.300*	285268.100
Treatment	2	15.248	53677.000	5228000.000*
Error	4	43.277	169753.850	464115.950

b. Abstract of analysis of variance table for the number of pods and yield of cowpea

Source	df	Mean square		
		Number of pods	Grain yield	Bhusa yield
Block	2	3.741*	22977.000	31960000.000
Treatment	2	1.275	47092.330	4280000.000
Error	4	0.204	22263.835	4780000.000

* - Significant at 0.05 level

APPENDIX - XIV

a. Abstract of analysis of variance table for the distribution of nutrients in the bhusa of intercrops.

Source	df	Mean square					
		Nitrogen		Phosphorus		Potassium	
		Groundnut	Cowpea	Groundnut	Cowpea	Groundnut	Cowpea
Block	2	0.13233*	0.04699	0.00016	0.00016	0.00790*	0.10930*
Treatment	2	0.00003	0.05485	0.00016	0.00002	0.00012	0.015568
Error	4	0.00034	0.03949	0.00006	0.00019	0.00179	0.011848

b. Abstract of analysis of variance table for the quantity of nutrients incorporated into the soil by bhusa.

Source	df	Mean square		
		Nitrogen	Phosphorus	Potassium
Block	2	716.455*	3.472*	259.824*
Treatment	5	600.553*	6.835*	256.883*
Error	10	135.887	0.914	57.923

* - Significant at 0.05 level

APPENDIX - XV

a. Abstract of analysis of variance table for total nitrogen, available phosphorus and available potassium content of the soil after the experiment.

Source	df	Mean square		
		Total nitrogen	Available phosphorus	Available potassium
Block	2	0.00006	27.46618	54.72000
Treatment	7	0.00040	27.85526	108.48000
Error	14	0.00019	52.13469	42.65143

CROP GEOMETRY STUDIES IN TAPIOCA BASED INTERCROPPING SYSTEM

By

ANILKUMAR A S.

ABSTRACT OF A THESIS
SUBMITTED IN PARTIAL FULFILMENT OF THE
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COLLEGE OF AGRICULTURE
VELLAYANI, TRIVANDRUM

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ABSTRACT

An experiment was conducted at the College of Agriculture, Vellayani, during 1982-83 to study the effect of intercropping groundnut and cowpea with tapioca and to identify the most suitable spatial arrangement of crops in the tapioca based intercropping system. The study also helped to find out the possibilities of changing the geometry of planting of tapioca from the normal method to the paired row pattern. The experiment with eight treatments was carried out in randomised block design with three replications under rainfed conditions.

The results revealed that competition for ecophysiological requirements in intercropped treatments during the early stages of growth caused unfavourable conditions for the vigorous growth of tapioca. Most of the growth characters were severely affected due to intercropping and spatial arrangements during the early stages although no such suppressing effect was observed at later stages of growth.

Among the yield attributes number of roots, percentage of productive roots, length of tuber, girth of tuber and rind to flesh ratio were not influenced by the various treatments. But tuber number per plant was influnnced by planting patterns, intercrops and spatial arrangements. Though the above

practices influenced tuber yield and utilisation index, top yield was unaffected by treatments.

Quality attributes like drymatter, starch and crude protein contents remained unaffected by the treatments. Similarly intercropping had no significant influnnce on the distribution of nutrients in tapioca.

Spatial arrangements influenced height and number of branches in groundnut and number of branches and the number of functional leaves in cowpea at certain stages of growth.

Pod number, an important yield attribute of intercrop was not affected by spatial arrangements. The same had no effect either on the pod yield of groundnut and grain yield of cowpea or on the bhusa yield of intercrops.

Spatial arrangements had no effect on the distribution of nutrients in the bhusa of intercrops. Cowpea bhusa incorporated large quantities of nutrients into the soil.

Cowpea intercropped plots registered maximum values for soil nitrogen after the experiment though no significant difference on the available phosphorus and potassium contents of the soil was observed.

The highest economic return was obtained from the treatment where tapioca was planted in paired rows and groundnut in the interspaces of paired rows. The next best system was tapioca in normal rows with groundnut in the interspaces of normal rows. Tapioca in paired row without intercrop recorded a higher profit than tapioca at normal spacing without intercrop.

The results indicated that groundnut was the most profitable intercrop in tapioca.