NITROGEN ECONOMY AND SOIL CONSERVATION IN TAPIOCA-STYLO INTERCROPPING SYSTEM

BY

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THESIS

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

MASTER OF SCIENCE IN AGRICULTURE

FACULTY OF AGRICULTURE

KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE

VELLAYANI, TRIVANDRUM

1983

DECLARATION

I hereby declare that this thesis entitled "NITROGEN ECONOMY AND SOIL CONSERVATION IN TAPIOCA-STYLO 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.

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CERTIFICATE

Certified that this thesis, entitled "NITROGEN ECONOMY AND SOIL CONSERVATION IN TAPIOCA-STYLO INTERCROPPING SYSTEM" is a record of research work done independently by Sri. ANIL KUMAR, P. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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ACKNOWLEDGEMENT

I wish to express my deep sense of gratitude and indebtedness to my guide and Chairman, Shri.K.Pushpangadhan, Associate Professor of Agronomy, College of Agriculture, Vellayani, for his valuable guidance, critical suggestions and constant encouragement throughout the course of this investigation.

I wish to place on record my heartfelt thanks to Dr. C. Sreedharan, Professor and Head of Department of Agronomy, College of Horticulture, Vellanikkara, and Dr. R.S. Aiyer, Professor and Head of Department of Soil Science and Agriculture Chemistry, College of Agriculture, Vellayani for their constant encouragement, critical suggestions and valuable advice during the conduct of the study.

I am deeply indebted to Sri. G. Raghavan Pillai, Associate Professor of Agronomy, College of Agriculture, Vellayani, whose inspiration, encouragement and valuable suggestions helped me a lot in the preparation of my thesis.

I am greatly obliged to Dr. V.K. Sasidhar, Professor of Agronomy, College of Agriculture, Vellayani, Shri K.P. Madhavan Nair, Associate Professor of Agronomy and Dr. V. Muraleedharan Nair, Associate Professor of Agronomy for their timely help and suggestions.

The suggestions and help given by Smt.P.Saraswathi, Associate Professor of Agriculture Statistics, in the preparation of my thesis will be remembered with gratitude.

My sincere thanks are due to Shri. Viswambharan, K., Lecturer, Extension Training Centre, Thaliparamba., Shri. P. Rajendran, Assistant Professor of Agriculture Chemistry and Shri Koshy Abraham, Assistant Professor of Plant Pathology for their valuable suggestions and timely help in the conduct of my experiment and preparation of my thesis.

I am indebted to Smt. Meera Bai. M; Smt.Lekha Radhakrishnan and Smt. Sheela, K.R., Junior Assistant Professors of Agronomy and my friends Shri.D. Padmakumar, Research Assistant, Soil Conservation Research Station, Konni, Shri. Ravikumar, P.K. and Sathiyanathan K.M., for their constant help, co-operation and encouragement during the course of the study.

My heartfelt thanks are also due to all the members of the staff and students of the Department of Agronomy for their co-operation and encouragement during the course of the research work.

I am deeply indebted to the Dean, College of Agriculture, Vellayani for providing necessary facilities during the course of investigation.

I wish to acknowledge with gratitude the award of fellowship by the Kerala Agricultural University during the tenure of the M.Sc. (Ag) programme.

Vellayani,
18-4-1983.

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Introduction

INTRODUCTION

Tapioca, (*Manihot esculenta* Crantz.) is widely used as a supplement to rice or even exclusively replaces it in the diet of a large section of the people of Kerala. It is one of the most important food crops of the tropics and has been described as the "tropical staff of life", (Schery, 1947). Kerala State accounts for 80 per cent of the area under tapioca in India.

There has been a tremendous increase in the cultivation and production of tapioca in the past three decades. This increase has occurred very largely through the initiative of subsistence farmers, as the crop has many advantages for the small farmers. It is high yielding, adaptable to poor or exhausted soils, relatively free of pests and diseases, reliable as a food producer, drought resistent, needs the use of only stems for planting materials, and above all gives an extremely high return of food per unit of energy input in its cultivation. This last factor is of prime importance to the subsistence farmer who has neither the access to mechanised implements nor to draught animal power. Further more, even in those areas where tapioca is not a popular food, staggered harvesting from slightly immature to mature stage over a period of two months usually enables the subsistence farmer to tide over the lean months. It is often planted as a reserve against

Zemine on account of its great reliability. (Cock and Howeler, 1978).

Fertilizer nitrogen constitutes an important and costly input in crop production. In the developing tropical and subtropical countries where the oil crisis is acute, high costs of fertilizer nitrogen precludes its use or substantially reduces its application.

Tapioca is universally considered as an erosion permitting crop. It is therefore essential to develop a well planned cropping system which include intercropping of legumes so as to supply part of the nitrogen needs, and for their possible effect in improving soil productivity by preventing soil erosion.

Livestock forms the back-bone of Indian agriculture. Rearing livestock with nutritious and balanced feed is a major problem. As far as the state is concerned the availability of land for pure culture of forage is very limited. Incorporation of forage crops along with the existing food and plantation crops is the solution for this.

Brazilian lucerne, _Stylosanthes guianensis_ is a leguminous fodder-cum-cover crop which was introduced into our state during this decade by the Kerala Livestock Development and Milk Marketing Board. It is found to be the best and most promising type of cover crop (Bourke, 1975., Lal et al., 1979). Its suitability for growing under the agroclimatic conditions of this region has been well established, (Anon. 1980). It is estimated that the nitrogen contribution of stylosanthes by symbiotic fixation to be equivalent to 20 kg urea per hectare (Nitis, 1978).

Intercropping, that is growing two or more crops simultaneously on the same field, is the main crop production system in subsistence agriculture (Willey, 1979). Better use of resources above and below the soil surface results in a greater combined crop yield than when the crops are grown in two monoculture plots, (Andrews, 1972; Osiru and Willey, 1972; Willey and Osiru, 1972; Remison, 1978; Fisher, 1979). Besides this, intercropping and mixed cropping reduces soil losses and in this way helps to maintain the soil in good condition (Ives, 1951).

At present the area under tapioca cultivation in Kerala comes to about 2.88 lakh hectares with an annual production of around 42 lakh tonnes. Of this more than 50 per cent of the area is confined to the eastern hilly tract of the state. The mean annual rain fall of about 3000 to 3200 mm received in the state is spread over six to seven months of the year. Since cultivation has to be done mostly on these slopy areas, the situation has aggravated and the worst form of soil erosion is seen in these areas.

Tapioca is usually planted with the onset of monsoon in June-July or September-October. Generally the soil is loosened and is heaped to small mounds or ridges and tapioca setts are planted on these. As a result of this during the rainy periods substantial amount of loose soil that is heaped up is washed down. Its wide spacing and slow initial growth, leaves considerable area unutilized during the early part of the crop growth and is subjected to severe erosion hazards. So it becomes highly necessary that the land between mounds or ridges, that are left bare, should be protected with some kind of cover crop so as to prevent or reduce the run off and soil loss.

Preliminary observational studies conducted at Vellayani and also in farmers fields have proved the possibility of growing stylosanthes as intercrop in tapioca fields. But detailed information on the efficiency of stylosanthes in reducing the soil and nutrient loss from tapioca plots and thereby improving the soil productivity has not been worked out. With this back ground the present investigation was undertaken with the following objectives.

1. Effect of stylosanthes, in reducing the nitrogenous fertilizer dose of tapioca when grown as intercrop.

2. Effect of intercropping tapioca with stylosanthes on the total edible food materials produced for human and animal consumption; and

3. The efficiency of stylosanthes in preventing the erosion from tapioca plots when cultivated along slopy areas.

Review of literature

REVIEW OF LITERATURE

Tapioca can be considered as an efficient utiliser of plant food elements, when grown as a monocrop or in association with other crops. Agronomic practices other than manuring also assume importance in tapioca culture because the problem in tapioca nutrition is not only to replenish the soil of its nutrient losses consequent on crop removal but also to build up the fertility status to a higher level and increase the efficiency of utilization of added nutrients.

Tapioca tends to enhance erosion and hence nutrient loss. So the observed decline in soil fertility may be due to nutrient loss by erosion as well as by crop removal. Intercropping practice with legumes can be considered as a means of overcoming these problems. The performance of different leguminous intercrops with tapioca has been studied but their effectiveness in economising the nitrogen dose for tapioca and in conserving the soil has not been studied. Research works on these lines and related topics are reviewed herewith. Similar works on closely related topics are also incorporated in the review, wherever information on the above line is rather meagre.

1. Effect of fertilizers on growth, yield and quality of tapioca.

Nitrogen is associated with vigorous vegetative growth, the supply of which is controlled by man. Differential response of tapioca to nitrogen had been observed in many experiments conducted in India and abroad.

Once established cassava resists drought and has a remarkable capacity to extract nutrients (De geus, 1967). Nijholt (1935) observed that the absorption of nutrients during the growth was fairly regular and took place without interruption except in case of nitrogen. This has been attributed to the loss of nitrogen in abscissed leaves. At an early stage of growth the absorption of nutrients took place somewhat rapidly, than at the formation of dry matter.

According to Jacoby (1965) with its well developed root system cassava extracts large amounts of soil nutrients especially those located deep in the soil which are unavailable.

a. Growth characters.

Doop (1937) reported that nitrogen fertilization had no effect on growth and yield and that it may even be detrimental when it interferes with the uptake of soil P. It has been reported that responses to nitrogen fertilizers were observed only when soil organic matter content was less than one per cent (Anon., 1968).

Forno (1977) found that cassava was not better than most of the other crops in the ability to take up nitrogen from low nitrate or ammonium concentration. Even when cassava growth was greatly retarded by low nitrogen supply, severe deficiency symptoms did not develop. The ability of cassava to grow better than most crops on low fertility soils is due in part to its superior ability to regulate its growth rate according to the rate of nutrient supply.

Acosta and Pinto (1978) concluded that there was no direct relationship between fertilizer application and plant height or number of roots per plant.

By raising the nitrogen levels for tapioca Malavolta et al. (1955) found that the weight of shoots and roots increased. Krochmal and Samuel (1970) in an experiment to determine the effect of different levels of N, P and K in a nutrient solution revealed that high levels of nitrogen increased top growth but reduced root growth.

A high rate of nitrogen tended to increase the weight of stem and leaves, total dry weight, top/root ratio and plant height. At a low rate of nitrogen the top/root ratio and the plant height did not increase, but stem and leaf weight and total dry weight tended to be higher than in unfertilized plots (Choo-Samut, 1974).

According to Fox et al. (1975) the top growth responded strongly and root growth moderately to applied nitrogen. Ngongi (1976) reported that plant height, leaf number, leaf area, leaf area duration and leaf size were increased by N, K, Mg and S. High rates of fertilization however may lead to excessive top growth and also result in a decrease in harvest index, indicating that proportionately less dry matter produced is transported to the roots (CIAT 1977, 1978).

Pillai and George (1978) concluded that the application of N and K increased the plant height and weight. In case of total number of leaves produced per plant Prabhakar et al. (1979 a) found that the treatments which had nitrogen as one of the nutrients produced higher number of leaves per plant, also the maximum plant height was recorded for NPK + FYM treatment.

In an experiment, Ramanujam and Indira (1979) found that the treatments beyond 100 kg N/ha. did not change significantly the height of plants in tapioca. Nitrogen significantly affects the leaf growth (number of leaves produced per plant) upto 150 kg N/ha level. The average leaf size was less under no nitrogen plot. The plant growth was high under high levels of nitrogen application.

Asokan et al. (1980) reported that the application of nitrogen increases the canopy weight per plant. Magalhães and Acevedo (1980) also reported that application of fertilizers increased the yield of aerial parts and tubers.

The leaf characters are important factors contributing to yield in cassava (Singh and Nair, 1971). Bernuy (1975) observed that during the first five months there was a slow growth of the leaf area, from the fifth and sixth month there was marked increase equal to 76.5 per cent of the maximum leaf area. Maximum leaf area index was 0.6 observed five months after planting.

According to the results obtained by Cock (1975) cassava has an optimum leaf area index of 2.5 to 3.5 and high rates of fertilization may lead to excessive top growth and a leaf area index of more than four.

Gallegos (1976) reported that cassava in monoculture reached its peak leaf area production before any of the cropping systems tried. However it shed leaves sooner than in the other system. The highest leaf area index measured for cassava was 1.44 for monocrop at the age of six months. The leaf area index for cassava showed a progressive leaf area increase upto six months, when the leaf area began to diminish.

Ramanujam and Indira (1979) observed that leaf area was highly influenced by nitrogen upto 190 kg N/ha. The maximum value of leaf area index was recorded between third and sixth month stage of the crop.

b. Yield and yield attributes.

With respect to fertilization on yield and yield attributes of tapioca both positive and negative results have been obtained due to the varying effect of nitrogen.

When cassava was grown as a monocrop Greenstreet and Lambourne (1933) showed that there was increased yield with fertilization and no sign of decline in yield was obtained. De gous (1967) found that in high nitrogen plots cassava produced many tubers. There was only slight increases in root yield with high rates of nitrogen in areas where the organic matter content is more than one per cent (Anon., 1968).

Chew (1970) reported that N, P and K each resulted in yield increases. A strong linear response of 23 per cent was obtained for nitrogen. P and K interacted with N enhancing the response to it.

On an undisturbed (unplowed) silt loam forest savanna Ochrosol, Takyi (1972) observed that K and lime had little effect on cassava yields but N and P used as basal dressing increased yields by 46.7 per cent.

According to Mohankumar and Mandal (1977) the yield and number of thickened roots per plant increased with increased nitrogen fertilization. Obigbesan et al. (1977)

recorded a significant increase in yield by the application of N and P.

In an experiment the treatment combination of FYM + NPK was found to be significantly superior to all other treatments with respect to tuber yield per hectare. Among the individual nutrients nitrogen was found to be superior which register significantly higher tuber yield per hectare as compared to FYM alone and control treatments. With regard to number of tubers per plant, treatment combination with FYM resulted in markedly higher tuber number per plant when compared to those treatment without the combination of FYM (Prabhakar et al., 1979).

Asokan et al. (1980) recorded increases in tuber yield with higher levels of nitrogen.

Vijayan and Aiyer (1969) reported that an increase of nitrogen from 0 to 75 kg/ha increased the number of tubers but further increases in nitrogen decreases this number. The nutrient treatments had no significant effect on the percentage of edible portion of the tubers.

Ratananukul (1976) noted that there was response and yield increased as the nitrogen fertilizer application increased. Highest yield was obtained at 150 kg N/ha. Above this, yield decreases were noted. Application of N and P at above 50 kg increased the fresh weight of stems but not of roots.

Pillai and George (1978) concluded that the tuber yield was significantly increased by application of N, P, K and Ca and by combined N and K. Application of nitrogen increased tuber yields — number of tubers per plant increased with increasing levels of N, K and Ca application. The application of nitrogen decreased the edible portion of the tuber significantly.

According to Ramanujam and Indira (1979) the tuber yield and tuber number were increased significantly by nitrogen application. Beyond 150 kg level nitrogen has little effect on tuber yield and tuber number.

Contrary to the above observations and reports Krochmal and Samuel (1970) noticed no tuber formation with nitrogen and low phosphorus and potassium levels. High nitrogen levels reduced tuber growth per plot by 41 per cent. They also observed that greater tuber production was associated with a 1:1 top to tuber ratio.

Gomez et al. (1973) in their studies with N, P and K in oxisols in Bahía concluded that nitrogen fertilization had no effect on yield. A similar result was obtained for Cheo-Samut (1974) in which he reported that fertilizer application did not increase fresh or dry weight of the roots. Bermuy (1975) also noticed no significant differences in yield between the different rates of nitrogen fertilizers.

Ocleligle (1975) also reported that tuber yield was not affected by fertilizer rates.

Gomez and Howeler (1980) from the research carried out has concluded that although nitrogen uptake by cassava is high, it does not always result in yield increases.

Ramanathan et al. (1980) also noted no significant influence by application of nitrogen at higher levels on the fresh tuber yield, although there was a numerical increase in yield.

Yield depressions were noted by Ngongi (1976) at high rates of fertilization and these yield depressions were directly related to depressions in TDM or total fresh weight production.

Pillai and George (1978) also recorded a positive correlation between a tuber yield and the number of tubers per plant and between weight of above ground parts and amount of branching.

c. Quality aspects.

There are contradicting reports regarding the effect of fertilizers on starch, HCN, crude protein content of tubers and also dry matter content of tubers.

i) Starch.

Malavolta et al. (1955) reported that by raising the nitrogen levels, the starch content of the roots fell from 32 to 24 per cent, and that the increase in root yield did not compensate for such a drop. Jacob and Uexkull (1966) noted that when K content is low the starch content is low and De geus (1967) obtained a decrease in starch:protein ratio by increasing nitrogen levels.

Vijayan and Aiyer (1969) concluded that starch content of tubers increased with an increase of nitrogen upto 75 kg/ha but decreased with further increases in nitrogen.

Jong (1977) found that there was little influence of manuring on the percentage of dry matter and hence it follows that the percentage of starch does not change much either. A regular correlation was found between percentage of dry matter and percentage of starch.

Pillai and George (1978) recorded significant influence on starch content by increased NPK application, but Ramanathan et al. (1980) noted the same result with only NK application.

ii) Hydrocyanic acid content.

With regard to HCN content of tubers there are varying reports. When K application was low Jacob and Uexhull (1966) noticed high HCN content in tubers. According to Vijayan and Aiyer (1969) the HCN content is increased with increases in nitrogen application. Kurian et al. (1976)

found that application of nitrogen and NP increased HCN content but K alone and in combination with N and or P decreased it. Application of FYM according to Muthuswamy et al. (1976) markedly decreased HCN content of tubers. Kailasam et al. (1977) and Obigbesan et al.(1977) recorded no significant effect on HCN content of tubers with fertilizer application. Prabhakar et al. (1979 a) reported that HCN content of tubers were found to increase when N or FYM alone or in combination were applied.

iii) Crude protein content.

The crude protein of tubers increased with an increase in nitrogen application (Vijayan and Aiyer, 1969; Pillai and George, 1978) and the extent of increase was about 50 per cent when higher doses were given (Malavolta et al. 1955).

iv) Dry matter content of tuber.

Oelsligle (1975) observed that tuber dry matter accumulation was most rapid in nineth and tenth month of growth. Both Prabhakar et al. (1979 a) and Ramanujam and Indira (1979) concluded that there was no marked differences among different nutrient combinations and nitrogen fertilization respectively on the dry matter content of tubers.

2. Effect of fertilizers on growth and yield of stylosanthes.

Stylosanthes guianensis is a potentially valuable forage crop for the low fertility ultisols of the humid regions (Vélez Santiago et al., 1981) and was found to be more persistent and high in leaf yield (David Lamboll, 1982).

It was found to be the most suitable legume which remained green and retained its leaf further into the dry season; tolerated acid and phosphorus deficient soils (Savory and Thomas, 1977). Pure stand of *Stylosanthes guianensis* showed excellent performance and was found to be suitable for sands (Van Rensburg, 1969). *Stylosanthes guianensis* cv. Schoefield was found to be suitable and best errect type of cover crop (Bourke, 1975; Okigbo and Lal, 1977; Lal 1979).

Tewari (1968) noted a rather erratic effect with PK and NPK fertilizers and found that in general NPK fertilizers has no effect on the yield of *Stylosanthes gracilis* in pure stand.

According to Fayemi et al. (1970) the dry matter yield of *Stylosanthes gracilis* was generally not affected by nitrogen levels or soil types.

Wendt (1970) reported increased yields with P, K and S. Olsen and Moe (1971) concluded that phosphate fertilizer accelerated the rate of establishment of the legumes and significantly increased their dry matter production.

Bruce (1972) recorded increased yield by application of super phosphate.

Jones (1974) recorded increased height of _Stylosanthes gracilis_ with increasing dose of phosphorus fertilizer.

Mufandaedza (1976) recorded increase in herbage dry matter yield, digestable dry matter and crude protein with increase in harvest intervals in _Stylosanthes gracilis_ cv. Schoofield.

Mariyappan (1978) observed that increasing the phosphorus fertilizer dose increased the height, leaf:stem ratio and green matter yield of _Stylosanthes gracilis_.

Lekha Sreekantan (1981) reported significant increase in plant height, green and dry matter yields, leaf:stem ratio and spread with high doses of phosphorus fertilizers.

3. Effect of stylosanthes on soil fertility.

According to Fayemi et al. (1970) the nodule number of the legumes significantly decreased with increased nitrogen levels. The nitrogen fixation consistently decreased with increased nitrogen levels. The legumes fixed more nitrogen in sandy loam than in loamy sand soils.

Wendt (1970) found that nitrogen fixation was stimulated by P and S. Bruce (1972) failed to detect any increase in total soil nitrogen as a result of fertilizer treatment.

Significant difference for available N, P and K as well as for Cation exchange capacity of the soil was noted when grown with stylosanthes (Bruce, 1974; Singh and Singh, 1975).

Gillard and Edye (1979) reported a significant increase in soil nitrogen when grown with stylosanthes but noted a decrease in K content which was ascribed to an increased uptake of K by pasture.

There was significant increase in soil nitrogen content, and cation exchange capacity also showed a similar trend (Lal, 1979).

4. Effect of intercropping on growth, yield and quality of tapioca.

The practice of intercropping in tapioca has been reported from almost all tapioca growing centres in the world. Probably the first report regarding this was from Brazil as early as 1935. (Marcus, 1935).

Tapioca is frequently intercropped with maize, common beans (Krantz, 1974; CIAT, 1975; Tobon et al., 1975) yams (CATIE, 1978) potatoes, tomatoes and several other species according to traditional practices based on little understood agronomic criteria (CIAT, 1976).

Both harmful and beneficial effects of intercropping have been reported by several workers. In a trial Singh and Mandal (1970) revealed that horsegram and sesamum as intercrops reduced the tuber yield of cassava. It has been noted in cases when intercropped with maize and soybean, the yield of cassava was 50 per cent less than those of the monocrop (CIAT, 1971).

According to Mohankumar and Krishi (1973) when tapioca was intercropped with cowpea, sunflower, green gram, soybean, groundnut and maize the yield of pure crop of tapioca was found to be significantly higher than intercropped ones.

Deeratikasikorn and Wickham (1977) noted a decrease in cassava yield when over sown with stylo. When cassava was intercropped with bush bean, the yields were lowered by 12 to 18 per cent when compared to monoculture (Anon, 1978 b). Similarly high yields were obtained for cassava without any cover crop and cassava yields were depressed as the competition of the cover crop increased. Stylosanthes guianensis reduced cassava yields because of its strong competition for water during the dry season. Cassava seldom benefits directly from the presence of cover crops, however the benefits of the cover crops for erosion and weed control and establishment of a cash or pasture crop would compensate the reduced cassava yield (Anon, 1978 c).

Although intercropping has greatly increased the combined yield of both crops, it seldom has a direct beneficial effect on cassava yields. Depending upon competition from intercrops the yield of cassava were depressed from 0 to 50 per cent (CIAT, 1978). Results of intercropping peanuts and mungbeans indicated that the root yield of cassava was lower for cassava/peanut than for cassava monoculture (Sonlaksup, 1978).

A comparision of cassava intercropping pattern to sole crop cassava showed a decrease in the total dry matter production of root nearly 7 t/ha for sole crop to 3.5 t/ha when intercropped with maize (Zandstra, 1978).

From an experiment to find out the possibility of raising two intercrops in cassava during its growth phase, Prabhakar et al.(1979 b) saw that all the intercrops had their effect on the main crop which resulted in the reduction of tuber yield. This reduction in yield was ascribed to the crop competition in the earlier growth stages of cassava which resulted in comparatively, lesser number of tubers per plant, as well as reducing size of tubers.

It was also noticed that the tuber yield was significantly superior when cassava was grown as a pure crop and intercropping with any vegetable crop (Prabhakar et al., 1979 c) or pigeon pea (Prabhakar, 1979) significantly reduced yield.

Sheela (1981) observed that tuber yield, yield attributes and total dry matter production of tapioca were reduced by intercropping with cowpea and groundnut.

Contrary to the above reports Singh and Mandal (1968) observed that intercropping tapioca with groundnut did not substantially affect the growth and yield of tapioca. Singh et al. (1969) reported that tuber yield of tapioca was not affected by intercropping with cowpea and groundnut.

According to CIAT reports (1975) the yield of cassava intercropped with either maize or common beans are sometimes similar to those of the monocrop. Growing of groundnut and cowpea in between tapioca rows according to Katyal and Dutta (1976) did not affect the normal yield of the main crop.

Nitis and Sumatra (1976) observed that the root length of cassava inter sown with stylo was 16.08 per cent longer than that of cassava planted alone, but root number and circumference were not significantly affected. In the cassava and stylo treatment root dry matter was 16.8 per cent heavier than that of cassava alone. Cassava treated with nitrogen fertilizers produced 21.09 per cent more root dry matter than in cassava + stylo treatment. Cassava + stylo combined produce 180 per cent more top dry matter than cassava alone.

Lal et al. (1977) reported that stylosanthes contributed to excellent cassava yield when grown under no tillage among the various grasses and leguminous cover crops tried.

Nitis (1977) found that when stylo was grown as a companion crop with tapioca, the tapioca root and shoot yields increased 0.39 and 0.43 t DM/ha respectively. Measured in terms of protein, starch, HCN, the nutritive values of cassava and stylosanthes were not significantly affected by the association.

When climbing bean were intercropped with cassava there was no reduction in yields (Anon, 1978 b).

Ramakrishna Bhat (1978) concluded that the tuber and top yield of tapioca were not affected by growing groundnut, cowpea, blackgram and green gram as intercrops. Tapioca tuber dry matter content, percentage starch content and crude protein content were increased by legume intercropping.

From the experiments conducted in Turrialba, Moreno and Hart (1978) found that none of the legumes tried lowered cassava yields when they were raised during the last three months of growth period of cassava. Intercropping cassava with stylosanthes increased the tuber yield of cassava but native grasses decreased yield of tuber (Nitis, 1978).

Nambiar et al. (1979) noted an increase in cassava yield when short duration crops were raised in the interspace in cassava during early stages, irrespective of the intercrops.

Moreno and Meneses (1980) concluded that cassava both in monoculture and in association with beans presented a similar yield. Viswambharan (1980) recorded that growth and yield of tapioca were not significantly reduced by groundnut intercropping.

Sheela (1981) noted that the quality attributes like tuber dry matter, starch, crude protein and HCN content were improved by intercropping.

5. Effect of legumes on intercropping system.

Experiments conducted all over the world reveal that most of the leguminous crops can be raised profitably as intercrops and its combination is also helpful in improving soil fertility.

In a legume intercropping, yields of either or both of the component crops have been lowered than in sole crops and this is attributed to competition for nutrients, water, light or space (Kurtz et al., 1952; Pendleton et al.,.1963; Enyi, 1973).

Guljaev and Ronsal (1962) found that growth of maize was stimulated by the secretion from roots of intercrop, cowpea.

An increase in cereal yield when intercropped with legume has also been recorded (Agboola and Fayemi, 1971; Keswani et al., 1977) in which case the contributing factor has been assumed to be the supply of biologically fixed nitrogen from the legume (Agboola and Fayemi, 1972) and perhaps the influence of rhizosphere microflora (Keswani et al., 1977).

Kanapathy (1974) reported that the fertilizer requirement might be reduced by sowing leguminous crops in rotation or during the early stages of growth of the crop.

The nitrogen contribution and nutrient competition of the legumes were minimal (Anon, 1978 c). But Nitis (1978) found that under sowing cassava with _Stylosanthes guianensis_ increased the productivity of land after the cassava by a factor of 7 to 13.

Ahlawat et al. (1981) found that legumes increased nitrogen and phosphorus status of the soil compared with cereal or fallow. Maize following legumes recorded increases in growth, yield attributes, yield and nitrogen uptake. The winter legumes reduced the need for fertilizer nitrogen in maize to the extent of 18 to 68 kg/ha compared with cereal or fallow.

Pigeon pea was intercropped with maize to study its utility in economizing nitrogen for maize. Results indicate that pigeon pea increased the soil nitrogen content due to the substantial nodulation, but as an intercrop did not increase the yield of maize at any level of nitrogen (Yadav, 1981).

6. Effect of stylosanthes on growth and yield of main crop.

Shelton and Humphreys (1975) observed that the growth and nitrogen yield of Stylosanthes guianensis under sown with upland rice were negatively related to levels of urea application. Stylo was initially dominated by rice but exploited environmental growth factors more effectively in the latter part of the growing season, accentuating competition for water and phosphorus. Simultaneous stylo and rice sowing reduced rice grain yield by 12 per cent, the greatest reduction occurring at low levels of urea, mainly due to abortion of spikelet after panicle exertion.

According to Kenyama and Edje (1976) under sowing maize with stylosantheshad no significant effect on maize yields, but the dry matter yield of stylo was significantly reduced when compared to pure stand.

Nitis and Sumatra (1976) found that the root length of cassava intersown with stylo was 16.08 per cent longer than that of cassava planted alone; but root number and circumference were not significantly affected. In the cassava and stylo treatment, root dry matter was 16.8 per cent heavier than that of cassava alone. Top dry matter yield of stylo sown with cassava was 20.8 per cent lower than stylo alone. In terms of livestock feed supply, under sowing cassava with stylo could produce five to six tons more feed dry matter/ha/yr even though stylo growth and yield were depressed by the more competitive cassava.

When stylo was over sown on cassava during the first year, results showed no response of cassava to fertilizer application. The yield of stylo tended to be higher in fertilized plots, however oversowing stylo resulted in a decrease in cassava yield in both fertilized and unfertilized plots. (Deeratikasikorn and Wickham, 1977).

Results of Lal et al. (1977) reveal that stylosanthes contributed to excellent cassava yields when grown under no tillage. As a companion crop stylo was beneficial because of the increased nitrogen supply for cassava equivalent to about 20 kg urea per hectare. With P, K and trace element fertilizers, the nitrogen supplied by stylosanthes reached the equivalent of 160 kg urea. In association cassava shoot and root yields increased and the nutritive values of cassava and stylosanthes were not significantly affected (Nitis, 1977).

Stylosanthes guianensis reduced cassava yields because of its strong competition for water during dry season (Anon, 1978 c). Nitis (1978) observed that soil fertility is important in the root nodule nitrogen utilization by cassava; decreases in successive cassava/stylo cropping can be minimised by fertilization. The effect of nitrogen derived from the stylo root nodule seemed to be greater than that from urea. Under sowing cassava with Stylosanthes guianensis increased the productivity of land after the cassava crop by a factor of 7 to 13. 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 utilization.

7. Effect of fertilizers on intercropping system.

When two crops of dissimilar nutrient requirements are grown together it sometimes become operationally difficult to meet the nutrient needs of the two crops simultaneously. A cereal/legume intercropping system is a case in point where heavy nitrogen fertilization of the cereal is often not conducive to the growth of the legume components (Rajat and Singh, 1978).

When maize was intercropped with cowpea, Bains (1961) reported that the nitrogen dose could be reduced from 300 to 50 kg ammonium sulphate. Bains et al. (1970) again found that there was no need of additional fertilizers for the short duration intercrops such as mung, urd, cowpea etc. when grown with sugar cane. The intercrops matured with the fertilizers and irrigation applied to the main crop.

Mohankumar and Hrishi (1973) found that application of fertilizers to both the main and intercrops produced higher yields which was significantly superior to application of fertilizers to main crop only.

Experiments conducted at CIAT reveal that small amounts of nitrogen appeared to be optimal both for cassava root production and grain legume production (CIAT, 1976).

In cassava-stylo intercropping system Nitis (1977) found an increased nitrogen supply for cassava equivalent to about 20 kg urea per hectare and with P, K and trace element fertilizer the nitrogen supply reached 160 kg urea.

Ramakrishna Bhat (1978) reported that the intercrops should be fertilized seperately in addition to the fertilization of main crop of tapioca.

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.

8. Effect of intercropping on fertility status of soil.

It is a well established fact that legume intercropping in general is beneficial for improving the fertility status of the soil. It was reported by Misra (1958) that blackgram was grown in various parts of India with a view to improve the fertility of the soil. An increase in soil nitrogen percentage was recorded by Koregave (1964) by intercropping *Amorphophallus campanulatus* with leguminous crops. Singh (1967) found that when green gram was grown as an intercrop, it left behind a reserve of nitrogen for the use of the succeeding crop.

Singh et al. (1969) observed an improvement in the fertility status of the soil when tapioca was intercropped with groundnut and cowpea by way of organic matter addition to the soil.

Kass (1976) proposed the reduction of nutrient losses as one of the reasons for increased yields from intercropped plots. However reduced soil losses may not affect yield of crops in the same growing season, but will conserve soil fertility in the long run.

Ravichandran (1976) and Morachan et al. (1977) observed a slight increase in soil nitrogen by intercropping with legumes.

Ramakrishna Bhat (1978) and Sheela (1981) found an improvement in the fertility status of soil due to intercropping tapioca with legumes. Nitis (1978) recorded an increase in productivity of land by a factor of 7 to 13 by under sowing cassava with *Stylosanthes guianensis*.

9. Effect of management on erosion, soil loss and run off.

Ives (1951) recorded that soil losses from plots planted with cassava were 101 and 111 t/ha for 16 and 45 per cent slope plots respectively. Accordingly the plots covered with grass showed zero loss. He attributed the high losses for cassava to the early growth stage of cassava and to the fact that they had been freshly cultivated just before the storm.

Ellison (1952) Rose (1960) and Hudson (1961) reported that energy of falling raindrops is a significant factor in erosion. Thus interception of high energy raindrops by the canopy can be an important factor in soil erosion.

The amount of soil removed during each torrential rainfall was enormous and might be another factor contributing to the rapid decline of soil fertility. Hongsapan (1962) suggested that for growing cassava in sandy soils, measures should be taken to prevent soil erosion and that organic manures be applied as much as is economically feasible.

Complete removal of the native vegetation for commercial cassava production either as a sole crop or in association with other crops can aggravate soil erosion (Mouttappa, 1973; Tourte and Moomaw, 1977; Lal, 1979).

Gil (1974) observed that the most serious erosion was under root crops. There was rather more run off from pasture than from cereals, but the soil loss is lower. The run off from root crops was 400 times that from forests.

Bhola et al. (1975) found that run off and soil loss were significantly reduced under natural covers. On a volcanic ash soil with 60 per cent slope a cassava crop lost 10 tonnes per hectare of soil in 28 months due to erosion and that 30 per cent of the soil was lost only five days shortly after harvest (Gomez, 1975).

According to Singh and Verma (1975) water run off and soil loss increased with fineness of soil texture. Cultivated lands had higher intake rates and less soil loss than the uncultivated ones. Run off and soil losses increased with increase in the rainfall intensity. Loamy sands seem to be resistant to soil erosion at rainfall intensities greater than 4 cm/hr.

Gee et al. (1976) reported that maximum erosion potential occurs prior to and during the period of vegetation establishment when the ground cover is sparse or non-existent.

Natural grass-lands, vetch and oats-corn rotations according to Moto (1976) gave the minimum soil erosion losses. Strongly eroded soils should be used only for pastures.

Pabat et al. (1976) reported that perennial grasses protect the soil from erosive action of water because of their dense root and top mass.

Aina et al. (1977) compared the effect of cassava alone and cassava and maize grown simultaneously on run off and soil loss. The mean soil loss was higher for monoculture of cassava when compared to maize-cassava mix. Similarly the mean water run off decreased in case of maize + cassava when compared to monoculture. In general soil loss and water run off decreases exponentially with an increase in vegetative cover.

According to CIDIAT reports (1977) rotations that included cassava showed higher soil losses and mean annual run off in tropical region of Africa and Madagascar. This was probably due to cassava's delay in developing an effective ground cover.

Eltz et al. (1977) found that erosion losses in plots under native grassland and cultivated pastures were insignificant in comparison with that in the bare soil.

Lal (1977) concluded that crops and soil management systems that provided early ground cover controlled run off and erosion better than those that did not. He also found that soil erosion and run off losses were less with mixed crops than with monoculture. He pointed out that soil depleting crops grown with proper soil conserving techniques could result in less run off and soil losses than a soil conserving crop grown without conservation practices.

Morgan (1977) recorded erosion rates more than 2.5 t/ha/yr on bare ground with a maximum value of 17.69 t/ha/yr on a 11° slope. A grass cover reduced the erosion rates less than 2.4 and a woodland cover to less than 0.2 t/ha/yr. Most erosion took place in infrequent but moderate storms. Soil losses were related to the quantity of run off, the detachment of soil particles by rain drops and slope steepness.

It was observed that plot under grass cover did not permit any run off and any soil loss and hence nutrient loss where as cultivated fallow gave maximum run off, soil and nutrient loss (Anon, 1978 a).

Hong Ling (1978) showed that run off and soil loss on a soil of 10 per cent slope under natural cover, legumes and bare soil were considerably reduced under natural cover and legumes.

Ling ah Hong (1978) reported that soil loss and run off was higher in soils left bare. In areas sown with legumes the difference increasing with time as the leaf canopy developed. Loss from plots of legume were greater than from plots allowed to establish with natural cover at first but became equallylow as the canopy developed.

Luis Calabuig and Puerto Martin (1978) found that at the top of the slope severe erosion was associated with less soil nitrogen and organic matter levels and sparse plant cover. Little erosion occurred towards the base of the slope.

According to Messer (1978) the grass cover provided best protection against erosion. Zero tilled plots appear to be more liable to erosion than cultivated plots, seasonal variations in soil surface roughness.

Cover shape or distribution of inter cover shape appeared to be important in affecting sediment loss. Run off volume was significantly reduced by high cover levels which protected the soil from sealing. The cover percentage was related to sediment in surface run off by a parabolic relationship (Singer and Blackard, 1978).

Singh and Verma (1978) reported that soils with a grass cover produced more run off but much less soil loss per unit of run off than bare cultivated soils.

Sittibusaya and Kurmarohita (1978) noted that besides nutrient extraction by the crop, soil fertility may decline due to erosion.

Crop residues were shown to be important in reducing soil loss (Griffin, 1979).

Jozefaciuk et al. (1979) found that the quantity of soil lost by erosion was proportional to the volume of water flow in run off. Moist soils were more susceptible to water erosion than dry soils and loess and silt soils were more susceptible than light carbonate loam and loose sand soils.

A significant improvement in the physical and chemical characteristics of an alfisol under legume and grass cover was reported by Lal et al. (1979) in Nigeria. Both organic matter and nutrient levels were higher under sod because of erosion control.

In a study Mishra et al. (1979) made an attempt to give numerical values of various vegetative covers in terms of leaf area index and to relate the same with run off under controlled situations. The run off varied from 74.5 per cent to 2.1 per cent depending primarily on leaf area index values. The average run off in the best cover having leaf area index of 6.7 varied from two to four per cent. This shows wide possibilities of increasing/decreasing water yield by manipulating plant cover complex.

Moore et al. (1979) noted that run off and soil loss were high from a eroding subsoil but low on a recently ploughed and grassed site. A heavily grazed but well grassed site produced very high run off but lost little soil.

Berg and Carter (1980) recorded a sediment loss ranging from 0.5 to 141 t/ha from furrow erosion on irrigated crop land. They found that erosion increased sharply on row cropped fields where slopes exceeded one per cent.

Burgos (1980) suggested that in regions of high rainfall intensity, the soil surface be kept covered for as long as possible.

Costin (1980) foundthat surface run off and soil losses were inversely related to cover. Cover values less than 70 per cent were associated with some large increases in run off and soil loss whereas at high cover values there was relatively little reduction in run off and soil loss. Most soil losses were small when run off were less than 15 per cent but increased rapidly with increasing run off. When the top soil is mostly wet run off were greater, reflecting the much lower infiltration capacities of the subsoil. Soil losses were related to runoff.

According to De Coursey (1980) the row spacing, land slope and tillage operations affected run off and sediment yields more than factors such as plant population and levels of fertilizers.

Gilley (1980) reported that soil losses were greatest on the bare treatment and least on the undisturbed plots. Application of straw mulch reduced erosion by 66 per cent over the bare condition.

Cassava, according to Howeler (1980) tends to enhance erosion and hence nutrient loss. The observed decline in soil fertility may be due to nutrient loss by erosion as well as by crop removal.

Erosion was marked where the soil surface was soft, the gradient steep, or mechanical reclamation had been carried out, but was less on surface sown sites (Ishida et al. 1980).

Ramos and Marinho (1980) noted that soil losses from bare ground in Ceará, Brazil due to rainfall erosion amounted to 115.4 t/ha during a six month period. On ground with herbaceous vegetation cover or shrubs andtrees, soil losses were reduced.

Singer et al. (1980) reported that soil loss from bare tilled plots was 75 times greater than from plots under natural cover.

Viswambharan (1980) observed that maximum run off and soil loss occurred in uncultivated bare fallow plot which was significantly higher than other treatments. Among the agrotechniques tried maximum run off was observed in the plot where tapioca alone was planted on mounds without inter crop. Run off was low in other treatments. Groundnut intercropping significantly reduced run off and soil loss.

Ground covers of weeds, and especially under sowings of clover and mulch covers were the most effective treatments for reducing soil erosion according to Zwack et al. (1980).

The range of soil loss due to erosion noted by Lal (1981) was 0.42 to 524 t/ha on the least and most eroded plots respectively.

After the ground cover was cleared a prior study conducted by Lewis (1981) indicated that loss increases as slope gradient increases. Results also indicate that losses of soil materials are greatest not on the steepest slopes but on the five per cent slopes. No relation was found between plot length and loss.

Quansah (1981) reported that soil type, intensity of rain and slope steepness significantly influence the amount of soil detached and transported.

Greenland and Nye (undated) observed that on moderate slopes planted very closely, soil losses may not be important. Mounding or ridging of the soil for root crops such as yams, sweet potato and cassava, accelerates soil erosion in forest environments. Soil losses vary in magnitude depending upon rainfall intensity, percentage of slope, soil type and soil and crop management.

10. Nutrient losses through erosion.

Middleton et al. (1934) and Rogers (1941) reported that eroded soils are sometimes richer than the original soil in respect of nutrients.

Bobko (1943) observed that loss of nutrients by erosion are considerable and in some cases exceeded the annual crop removal.

Goel et al. (1968) found that nutrient losses in general were increased on steeper and longer slopes but the concentration of nutrients in the run off is thereby decreased.

Burke et al. (1974) recorded that losses of P in run off was low; K losses were also low and were associated with heavy rainfall soon after fertilizers were applied. Substantial losses of nitrate nitrogen occurred when heavy rain followed soon after nitrogen was applied in the off growth season.

Hanway and Laflen (1974) found that total phosphorus concentration in surface run off were closely related to sediment concentrations and were much higher in surface run off. Annual losses averaged less than 1 kg/ha soluable inorganic phosphorus concentration in surface run off were low and were independent of sediment concentration, but were directly related to the available phosphorus in surface soils. Losses of inorganic nitrogen varied from less than 1 to 30 kg/ha/yr.

Total nutrients discharged in run off according to

Olness et al. (1975) ranged from 2 to 15 kg/ha of nitrogen and 1 to 11.5 kg/ha of phosphorus. Run off losses of soluble inorganic nitrogen were generally less than qualities received in rainfall.

From an estimated losses of applied fertilizers Mc Coll et al. (1975) and Mc Coll (1978) found that phosphorus was the least mobile fertilizer component.

Grodeev et al. (1976) noted that melt water run off on moderately eroded sod podzolic soils usually removed 227 kg humus, 24 kg N, 9 kg P and 97 kg K/ha from autumn ploughed fields and 127 kg humus, 17 kg N, 5 kg P and 46 kg K/ha respectively from fields under winter crops.

The loss of nitrates varied considerably depending upon events before each run off producing storms. Concentrations of nitrates were usually highest just after fertilizer applications when the soil was near field capacity and lowest when large amounts of water infiltrated into dry soil immediately before run off. During run off producing storms just after fertilizer application the concentration were lowest in the initial run off and highest near the end of the run off event. For entire five years study the mean concentration of nitrate nitrogen in run off was 2.9 and 2.3 ppm nitrate. The mean total loss of nitrate was 3.2 kg/ha/yr. Losses of sediment associated nitrogen were about 5 kg N/ha/yr (Kissel et al., 1976).

Lal (1976 a) observed that nutrient loss in run off and eroded soil was significant only for unmulched treatments. The maximum annual loss of nitrate nitrogen in run off was about 15 kg/ha. The maximum annual loss of total nitrogen in eroded soil from unmulched plot was about 180 kg/ha that of P, 5 kg/ha and that of K about 14 kg/ha.

Lal (1976 b) also noted that total loss of nutrient elements in run off and eroded soil materials was significantly affected by slope and by soil and crop management treatments. The nutrient losses in eroded soil materials from the mulched and no till treatments were negligible. From the plowed treatments greatest losses were of organic matter and total nitrogen.

The highest nutrient losses in run off water was reported by Lal (1976 c) to be from a 15 per cent bare slope, in Nigeria, and values were 13.4 kg N 2.5 kg P, 20 kg K, 14 kg Ca and 2.7 kg Mg/ha respectively during one season. In addition nutrient losses in sediments of 27 to 126 kg N, 3.5 kg P, 12 kg exchangeable K, 8.4 kg exchangeable Ca and 11 kg exchangeable Mg/ha.

The movement of nitrogen according to Hoyt et al. (1977) generally increased as the quantities of solids, run off and leachate increased. Where discrepancies occurred they could be explained by differences in structure, crusting of soils or clogging of pores by manure or by effect of straw on soil permeability or microbial activity. In general almost all the mineral nitrogen moving in the leachate and about half of that moving in the run off was in the form of nitrate.

Timmons and Holt (1977) pointed out that 68 to 88 per cent of the average annual nutrients losses were transported by run off. Average nitrogen losses were 0.8 kg and phosphorus losses 0.1 kg/ha/yr.

Fletcher et al. (1978) reported that nitrogen because of its concentration in lighter surface material is selectively eroded from a soil by water with the result that total nitrogen content of eroded material is several times greater than that of the original soil.

Howeler et al. (1979) found that losses of phosphorus are relatively small. He attributed this to the low level of available phosphorus and high fixing capacity of the soil.

Mc Dowell and Mc Gregor (1980) reported that solution phosphorus concentration and losses were related to crop management practices. The losses of phosphorus is attributed to insufficient sediment to absorb P from solution, the limited sorption of fertilizer phosphorus by soil caused by decreased fertilizer incorporation, release of phosphorus from crop residues and possibly a greater phosphate supplying capacity of sediments in run off.

Viswambharan (1980) recorded the maximum losses of nutrients (107.47 kg N, 28.47 kg P and 82.479 kg K/ha respectively) from the uncultivated bare fallow plots during the entire cropping season. Among the agrotechniques maximum losses of nutrients were recorded by tapioca alone in mounds (44.01 kg N; 14.845 kg P and 39.09 kg K/ha respectively) during the entire season.

11. Mechanical composition of eroded sediments.

Middleton et al. (1934) and Rogers (1941) found that eroded soils are richer than the original soil in respect of colloidal clay. Fine sand being the least resistant to splash action, detachment increases as the fine sand content of soil increases (Ellison, 1947, Baver, 1966).

Tamhane et al. (1959) while studying the intensity of rainfall on soil loss and run off observed that soil lost in run off is much more clayey as compared to the original soil and that clay and silt were the main constituents carried away by run off water.

Clay enhances aggregate formation and stability (Baver, 1966; Greenland 1977; Luk 1979).

Wischmeier et al. (1971) reported that the particle size distribution of the soil is a major determinant of the susceptibility of soils to erosion.

Solid transport in surface run off according to Cha a bouni (1977) takes place in such a way that particles of clay and coarse sand are selected preferentially over loam.

According to Jozefaciuk et al. (1979) erosion resulted in an increased sand content and a decreased colloidal fraction content of soil.

Costin (1980) noted that most of the soil was in fine suspension, little as bed load or coarse floating debris. The presence of crop canopy according to Meyer et al. (1980) did not affect the sediment size distribution of eroded particles from crop row side slopes.

Viswambharan (1980) recorded that under high intensity of rainfall conditions the content of sand in run off was found to be higher.

Quansah (1981) reported that graded sand and three soil tested are significantly different in their mean weight of soil detached and transported. They can be placed in rank order of graded sand, sand, clay and clay loam, with increasing resistance to splash detachment. The amount of material transported is in the order graded sand > clay > sand > clay loams. For each soil there was significant increase in splash detachment and splash transport with increasing rainfall intensity.

Materials and methods

MATERIALS AND METHODS

The present investigation was undertaken with a view to study the possibilities of reducing the fertilizer nitrogen dose for tapioca by intercropping with stylosanthes, a perennial leguminous fodder-cum-cover crop and also to study its efficiency in reducing soil erosion when intercropped with tapioca in slopy areas. The materials used and methods adopted are detailed below.

Materials

Location.

The experiment was conducted in the Instructional Farm attached to the College of Agriculture, Vellayani. The college is located at an altitude of 29 metres above mean sea level. The area having uniform slope of 13.4 per cent lying east-west was selected for the conduct of the experiment.

Soil.

The soil of the experimental area was deep, well drained, moderately acidic, sandy loam of lateritic origin with the following physico-chemical properties.

Percentage of coarse sand	..	40.6
Percentage of fine sand	..	24.6
Percentage of silt	..	18.0
Percentage of clay	..	13.5

Percentage total nitrogen	..	0.066 (Micro-Kjeldahl method)
Available phosphorus	..	16.75 kg/ha (Bray's method)
Available potash	..	182 kg/ha (Neutral normal Ammonium acetate method)
Cation exchange capacity	..	2.76 Meq/100 g of soil
pH	..	4.7 (1:2 soil solution ratio using glass electrode)

Cropping history of the field.

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

Season.

The experiment was conducted during the period from June 1981 to April 1982. The crops were planted on 26.6.1981 and was harvested on 20.4.1982. Both 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 24 years (1956-1980) 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.

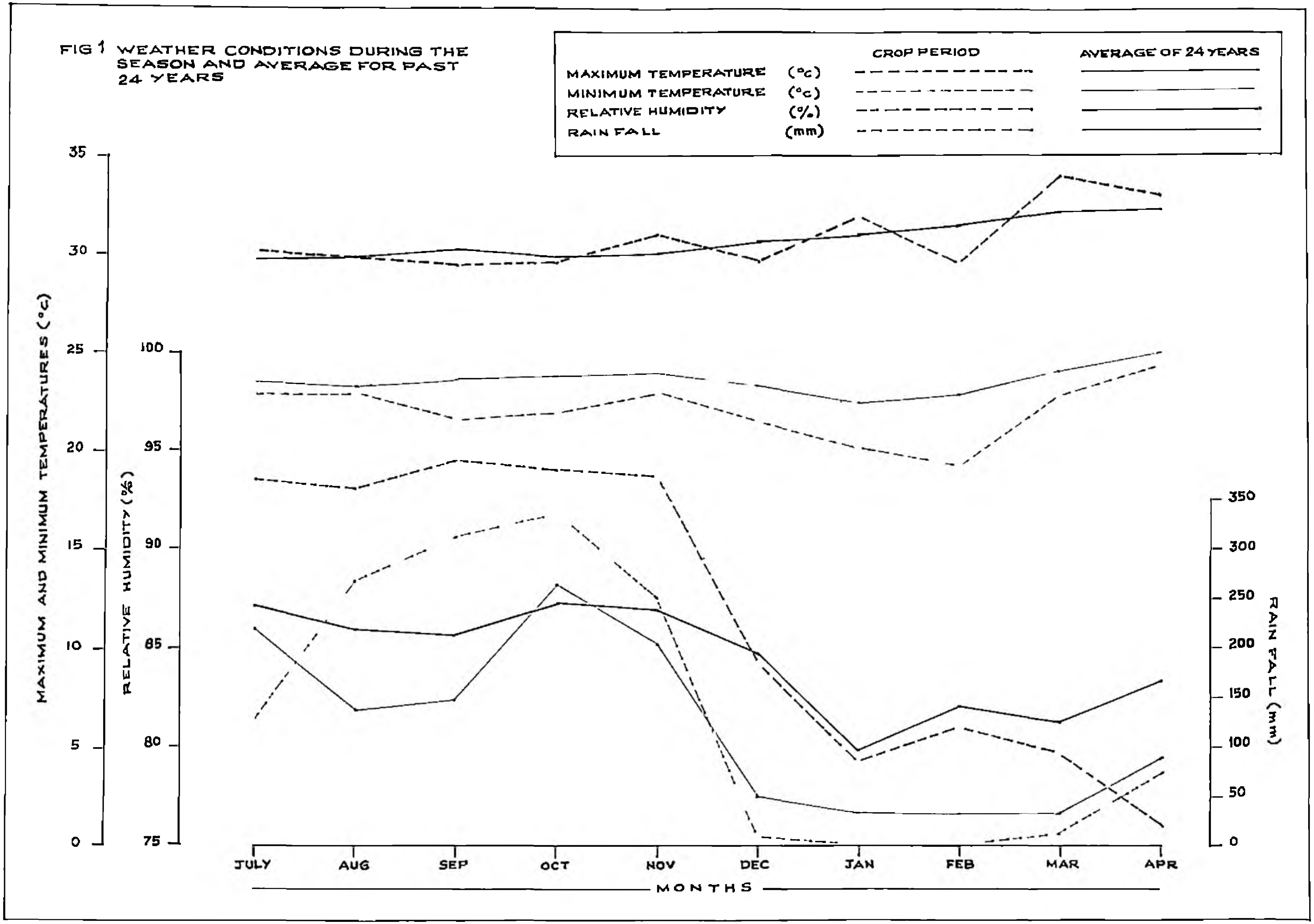


FIG 1 WEATHER CONDITIONS DURING THE SEASON AND AVERAGE FOR PAST 24 YEARS
CROP PERIOD
AVERAGE OF 24 YEARS
MAXIMUM TEMPERATURE (°c)
MINIMUM TEMPERATURE (°c)
RELATIVE HUMIDITY (%)
RAIN FALL (mm)
MAXIMUM AND MINIMUM TEMPERATURES (°c)
RELATIVE HUMIDITY (%)
RAIN FALL (mm)
35
30
25
20
15
10
5
0
100
95
90
85
80
75
350
300
250
200
150
100
50
0
JULY
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MONTHS

Planting material.

Tapioca.

The variety M_4 an introduction from Malaysia was used for the trial. It is a tall growing, non-branching variety with moderate yields and matures in ten months. The tubers are medium sized with low HCN content. Disease free, medium sized planting material required for the study was obtained from the Instructional Farm, Vellayani.

Stylosanthes.

The cultivar Schoefield was used for the study. Stylosanthes is a perennial leguminous fodder-cum-cover-crops which is vigorous and thick stemmed and capable of yielding 25 to 30 tonnes of fodder per hectare. Disease free, uniform sized seeds were procured from the Kerala Livestock Development and Milk Marketing Board. Prior to sowing, the seed was tested for its viability after scarification using concentrated sulphuric acid and was found to give 96 per cent germination.

Manures and fertilizers.

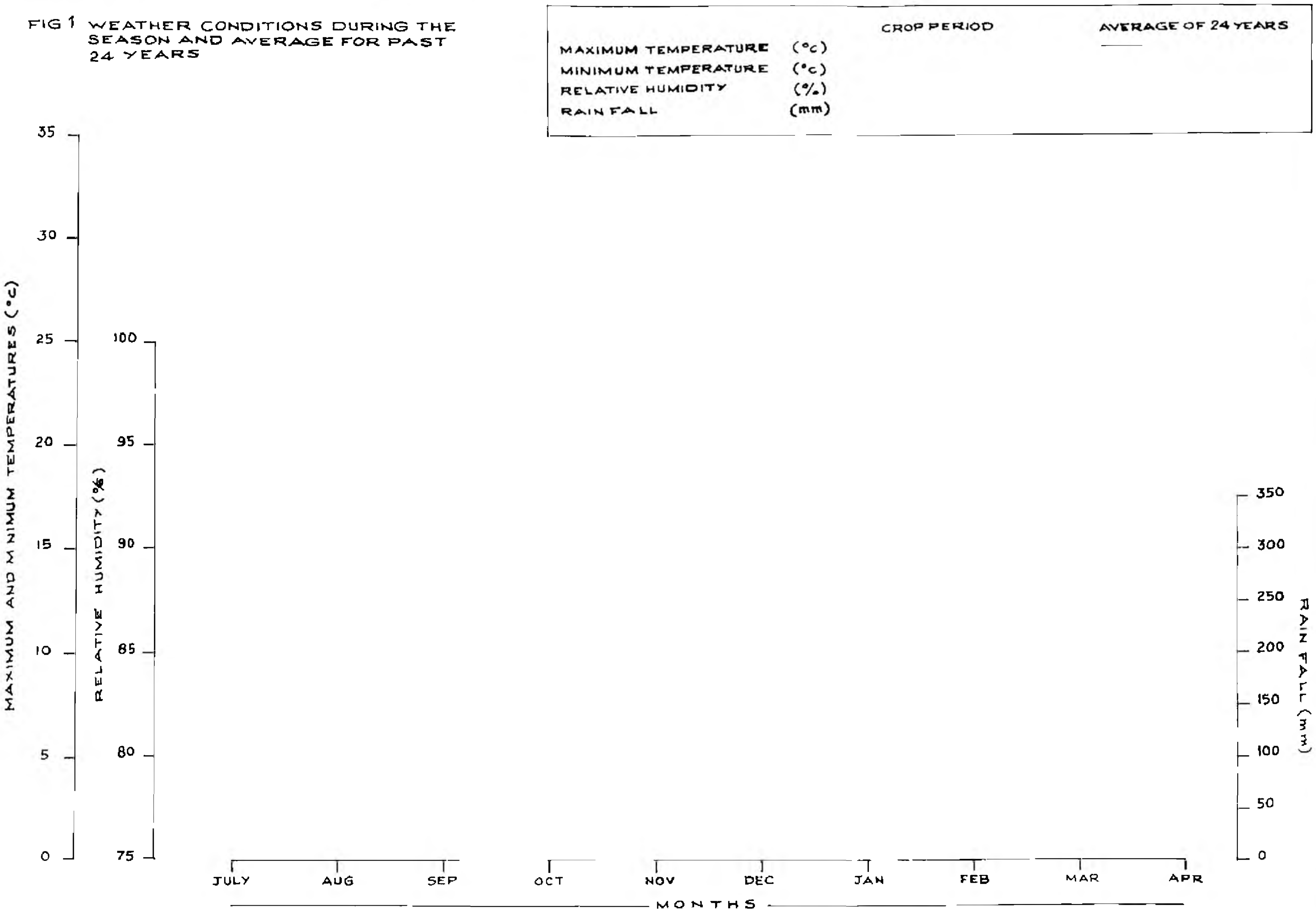
Organic manure used in the experiment included farm yard manure with the following nutrient values.

0.46 per cent N

0.3 per cent P_2O_5 and

0.27 per cent K_2O

FIG 1 WEATHER CONDITIONS DURING THE SEASON AND AVERAGE FOR PAST 24 YEARS



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0.3 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
Muriate of Potash	60 per cent K_2O
Quick Lime (CaO)	Neutralising value 164.1

Design and layout.

The experiment was laid out in a Randomised Block Design. The lay out plan of the experiment is given in Fig. 2.

The experiment was conducted in a field of uniform slope (13.4 per cent) each plot measuring a length of 20 metres and width of 3 metres. The plot edgings were done with embedded polythene sheets. The runoff water and soil from each plot was collected directly in trenches (1 metre length, 1 metre width and 1 metre depth) excavated and lined with water proof polythene sheets at the bottom of each plot.

Treatments.

The treatment details are furnished below.

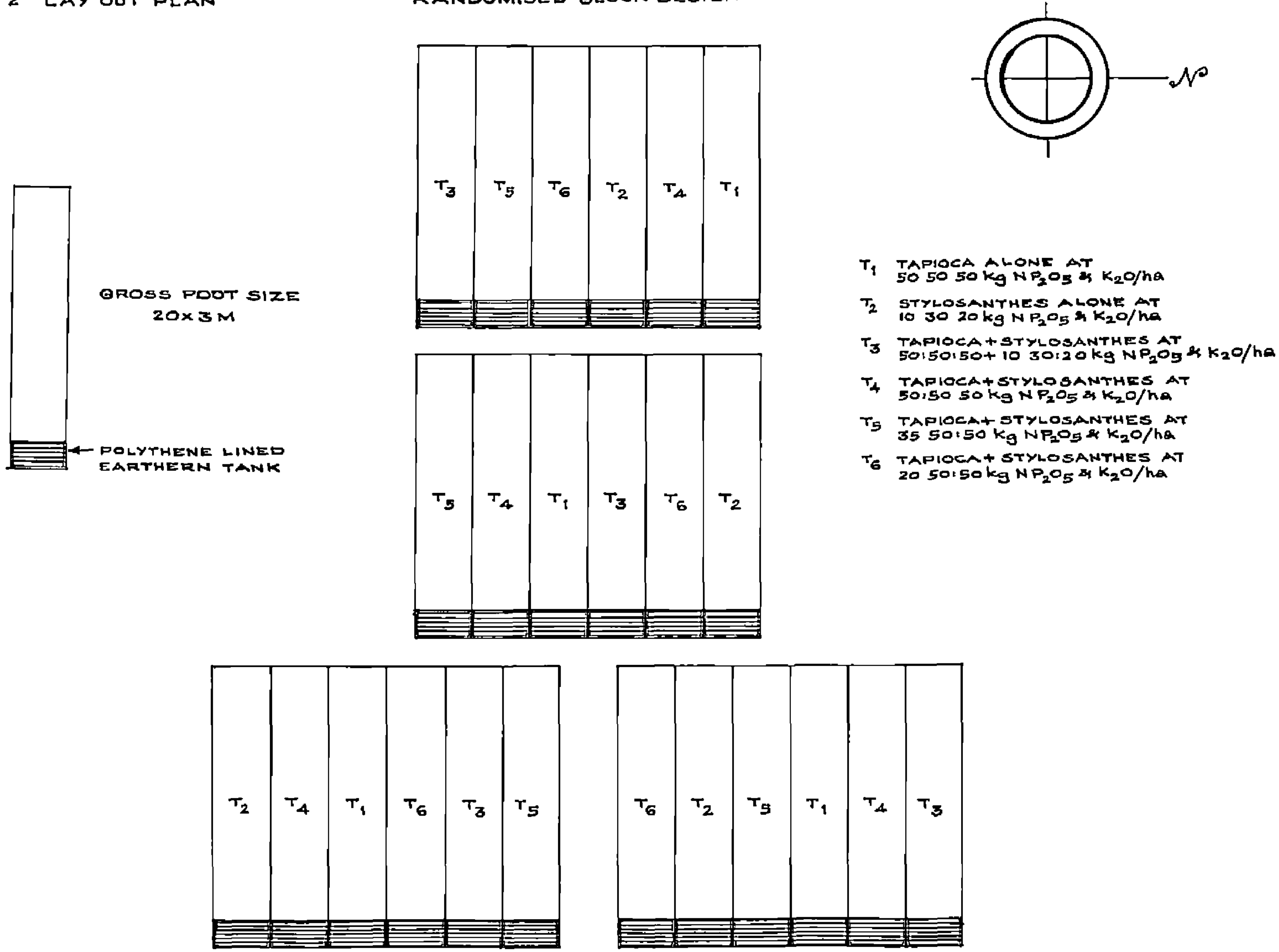
T_1 Tapioca alone at 50:50:50 kg N, P_2O_5 and K_2O/ha

T_2 Stylosanthes alone at 10:30:20 kg N, P_2O_5 and K_2O/ha

T_3 Tapioca + Stylosanthes at 50:50:50 + 10:30:20 kg N, P_2O_5 and K_2O/ha

FIG 2 LAY OUT PLAN

RANDOMISED BLOCK DESIGN



T_4	Tapioca + Stylosanthes at 50:50:50 kg N, P_2O_5 and K_2O/ha	
T_5	Tapioca + Stylosanthes at 35:50:50 kg N, P_2O_5 and K_2O/ha	
T_6	Tapioca + Stylosanthes at 20:50:50 kg N, P_2O_5 and K_2O/ha	

Number of replications : 4

Total number of plots : 24

Plot size.

Gross plot size : 20 m x 3 m

Net plot size : 18 m x 1 m

Net area of a plot : 18 sq.m

Number of tapioca plants in the gross plot : 60

Number of tapioca plants in the net plot : 18

Stylosanthes seeds were sown broadcast around the tapioca mounds adopting a seed rate of 2.5 kg/ha. In the plot where only stylosanthes was grown it was broadcasted uniformly at the rate of 2.5 kg/ha after mixing the seeds with soil for uniform distribution in the field.

Field culture.

Preparation of field.

The experimental area was dug, stubbles removed, clods broken and the field was laid out into blocks and plots.

Manuring.

A uniform basal dose of farm yard manure at the rate of 12.5 t/ha was applied and incorporated well into the soil before taking mounds.

Fertilizer and lime application.

The fertilizer nutrients as per the treatment schedule were applied in the form of urea, superphosphate and muriate of potash for N, P_2O_5 and K_2O respectively. Nitrogen was applied in two splits—half basal and the remaining half applied as top dressing over the mounds and raked in about 60 days after planting. P_2O_5 and K_2O were applied in full as basal dose before taking the mounds.

A uniform dose of lime at the rate of 500 kg/ha was applied in all the plots and incorporated prior to the application of fertilizers.

Seed treatment.

The hard seeds of stylosanthes were subjected to scarification by treating with concentrated sulphuric acid for two minutes. The seeds were treated with sulphuric acid just enough to soak the seeds. The time was standardized to two minutes so as to provide maximum percentage of germination. The acid was decanted and seeds repeatedly washed with water till it was free from acid as tested with litmus paper. The scarified seeds were then treated with rhizobium culture obtained from State Soil Testing Laboratory, Pattambi.

Planting.

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 stylosanthes were sown broadcast and covered with a very thin layer of soil.

After cultivation.

Germination of setts was good. Gaps found were replaced with fresh setts ten days after the planting. Excess sprouts were removed, retaining only two healthy and vigorous shoots. Germination of stylosanthes was also uniform. Thinning and gap filling were done 20 days after sowing and the population was maintained uniform in all the plots.

The first earthing up for tapioca was done 60 days after planting, combined with the top dressing of fertilizer in bands over the mounds.

Plant protection.

Plant protection measures were adopted as a prophylactic measure against termite attack by dusting 10 per cent B.H.C.

Harvest.

The initial cut of stylosanthes was taken from all the plots on the 116th day of sowing and the second was taken on the 59th day after the first cut. The third and final cut was taken on the 115th day after the second cut.

The main crop of tapioca was harvested on 20.4.1982; ten months after planting.

Observations recorded.

Main crop (Tapioca)

Sampling technique for biometric studies.

Ten plants each were tagged alternately from the net plot area for detailed biometric observations. The averages of the observations were used for statistical analysis.

A. Observation on growth characters.

The following growth factors 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 leaf scars on the stem.

c. Number of functional leaves per plant.

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

d. Leaf area index.

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

B. Observation on yield attributes and yield.

a. Total number of roots per plant.

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

d. 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.

o. 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 of the same tubers which were used for length measurements were taken at three places, one at the middle of the tuber and the other two at half way between the middle and distal ends on either sides. The average was taken as the tuber girth and expressed in cm.

f. Tuber yield.

At the time of harvest, tuber yield per net plot was recorded after cleaning the tubers. The per hectare yield was then worked out from this.

g. Top yield.

After removing the tubers the total weight of the stem and leaves were recorded plot wise and also in tonnes per hectare.

h. Utilisation index.

According to Obigbesan (1973) utilisation index is an important yield determining factor and is defined as the ratio of the tuber weight to the top weight - both stem and leaves. This was found out from the observations already recorded.

C. Observations on quality attributes.

a. Dry matter content of the tuber flesh.

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

b. Starch content of tuber.

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

c. Hydrocyanic acid content of tubers.

The HCN content of fresh tuber was estimated by the colorimetric method as outlined by Indira and Sinha (1969) and expressed in $\mu g/g$ of fresh tuber.

d. Crude protein content of tuber.

The total nitrogen content of oven dried samples from each plot was estimated using 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 collected for chemical studies were dried at 80°C ± 5; ground in a Willey mill and used for chemical analysis. The nitrogen, phosphorus and potassium contents of tuber, stem and leaves were seperately analysed.

a. Nitrogen content.

The total nitrogen content of the samples were determined by 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.

Intercrop (Stylosanthes)

Sampling technique for biometric studies.

For recording detailed biometric observations, ten plants were selected randomly from each plot and the growth characters were recorded. The average of the observations was used for statistical analysis. The observations recorded are given below.

A. Observations on growth and yield attributing characters.

a. Height

The height of the plant was measured from the base to the growing tip of the tallest branch.

b. Spread.

The spread was measured as the maximum lateral diameter from the main stem of each plant.

c. Leaf:stem ratio.

Plant samples from each plot were seperated into leaf and stem and from their dry weights the leaf:stem ratios were computed at each harvest.

d. Green matter yield.

At each harvest the yield of green fodder per plot was recorded and from this the per hectare yield was calculated.

e. Dry matter yield.

Sample plants were cut into small pieces and dried in shade and then to constant weight in an air oven at 105°C. Dry matter content was recorded and the dry matter yields computed from the respective green matter yields.

B. Plant analysis.

The oven dried plant samples were powdered in a Willey grinder and used for chemical analysis.

a. Crude protein content.

Total nitrogen content of the samples were determined by modified micro-kjeldahl method (Jackson, 1967) and crude protein percentage worked out by multiplying the nitrogen by the factor 6.25 (A.O.A.C., 1969).

b. Phosphorus content.

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

c. Potassium content.

Potassium content was estimated by using EEL flame photometer.

Observations on run off and soil loss.

Eroded soil and run off water were channelled into the collecting tanks specially made for the purpose at the lower end of each plot. Soil and water lost by run off due to rains were measured on the next day itself. The measurements were taken as follows. The total volume of water lost by run off and collected in each tank was first measured with a dipstick (meter scale). Then a representative sample of the run off water thus collected from each tank was taken for analysis. The water and soil collected in the tank was allowed to settle. The supernatant water was then drained off. The sludge in the tank was transferred to large containers and further allowed to settle and then again the supernatant water was completely drained off. The containers were then weighed with the sludge and samples were drawn from each lot. These samples were weighed, dried and percentage dry weights calculated. From these dry weights the quantity of dry soils in each tank was determined and then the quantity of soil eroded from each plot was computed which was expressed as kg/ha (Othieno and Laycock, 1977).

Analysis of rainfall.

Rainfall exceeding 12.5 mm per day was taken for the study of run off losses as the run off losses are negligible, under lower rainfalls (Viswambharan, 1980). Since a simple expression of relationship between rainfall and erosion was desired, only those data which can be taken directly from a self recording raingauge chart were considered. For this purpose a self recording raingauge was installed. The raingauge chart observations were counter checked with a 122 mm ordinary raingauge. The self recording raingauge chart was used for studying the following characters of rainfall.

i) Quantity of rainfall in mm.

ii) Maximum intensity of rainfall in mm/hr.

The quantity and intensity of rainfall received during the experimental period are presented in Appendix II.

Chemical analysis of run off water.

The nitrogen, phosphorus and potassium contents of run off water were determined by standard analytical techniques as outlined by Jackson (1967) for soils with modifications. The phosphorus content in run off water was found to be in traces.

Chemical analysis of eroded soil.

The eroded soil lots were dried under shade and samples were taken for the analysis of nitrogen, phosphorus and potassium.

a. Nitrogen content.

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

b. Phosphorus content.

The phosphorus content in the sediment was extracted with Bray's No. 1 extractant and was colorimetrically estimated by the amino-naphthol sulphonic acid reduced molybdo-phosphoric blue colour method in HCl system using red filter (640-660 nm.).

c. Available potassium content.

The available potassium in the soil was determined as per the method suggested by Jackson (1967).

Mechanical analysis of eroded soil.

The mechanical analysis of a composite sample of the eroded soil was conducted by International pipette method (Piper, 1942).

Soil chemical analysis.

Soil samples were collected from individual plots prior to and after the experiment and were analysed for total nitrogen, available phosphorus; and available potassium.

Nitrogen.

Total nitrogen content of soil samples were determined by modified micro-kjeldahl method (Jackson, 1967).

Phosphorus.

The phosphorus content of soil samples were determined by extracting the soil with Bray's No. 1 extractant and colorimetrically estimating P, by the amino-naphthol-sulphonic acid reduced molybdo-phosphoric blue colour method in HCl system, using red filter (640-660 nm).

Potassium.

The available potassium content of soil was determined by neutral normal ammonium acetate method as outlined in Jackson (1967).

Cation exchange capacity.

The cation exchange capacity of the initial and final soil samples were estimated by displacement technique using neutral normal ammonium acetate.

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 Micro 2200 Hindustan Computer.

Results

RESULTS

The growth characters, yield and quality of both main crop and intercrop along with run off and soil losses and the results of chemical analysis are presented in this chapter. The observations recorded were analysed statistically and the mean values are given in tables 1 to 10. The corresponding analysis of variance are given in Appendices III to XI.

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 anlysis of variance in Appendix III.

The treatments did not show any significant difference on plant height at any growth stage of the crop either due to intercropping or to varying nitrogen levels.

2. Total number of leaves produced per plant.

The data regarding the mean values of the total number of leaves produced per plant revealed that there was no significant difference either due to intercropping or to varying levels of nitrogen.

Table 1. Height of tapioca as influenced by intercropping and nitrogen levels (cm).

	T_1	T_3	T_4	T_5	T_6	
I month	12.250	12.950	11.725	11.925	11.950	N.S.
II month	36.300	38.500	35.875	36.650	32.700	N.S.
III month	68.925	70.975	68.350	62.800	65.675	N.S.
IV month	130.550	120.475	124.375	104.750	114.050	N.S.
V month	165.575	151.900	159.325	134.550	144.050	N.S.
VI month	198.600	179.425	186.825	159.250	168.850	N.S.
VII month	210.250	188.100	194.625	166.650	176.600	N.S.
VIII month	216.375	192.675	195.725	171.225	180.925	N.S.
IX month	222.100	198.725	202.775	175.575	184.075	N.S.
Harvest	225.800	202.200	205.300	178.150	187.025	N.S.

N.S. = Non Significant.

3. Functional leaves per plant.

The mean values of the number of functional leaves, taken at monthly intervals till harvest also revealed that the treatment effects were not significant.

4. Leaf area index.

The leaf area index was taken at monthly intervals and the mean values are presentdd in table 2 and the analysis of varience in Appendix IV.

The results indicated that there was significant difference in leaf area index values, due to intercropping and varying doses of nitrogen fertilization, at all stages of the crop from planting till harvest.

The treatment T_3 (Tapioca + Stylosanthes at 50:50:50 + 10:30:20 kg N, P_2O_5 and K_2O/ha) recorded the maximum leaf area index at all the growth stages. But after the second month of planting it was seen that the values of leaf area index of T_1 (Tapioca alone at 50:50:50 kg N, P_2O_5 and K_2O/ha) came on par with T_3. The lowest value was recorded by T_6 (Tapioca + Stylosanthes at 20:50:50 kg N, P_2O_5 and K_2O/ha) at all stages.

B. Yield attributes and yield.

1. Yield attributes.

The mean values of yield attributes are presented in table 3 and the analysis of varience in Appendix V.

Table 2. Leaf area index of tapioca as influenced by intercropping and nitrogen levels.

	T_1	T_3	T_4	T_5	T_6	C.D. (.01)
I month	0.272	0.325	0.222	0.212	0.188	0.049
II month	1.032	1.225	0.892	0.825	0.683	0.183
III month	1.796	1.904	1.184	1.047	0.907	0.262
IV month	2.199	2.346	1.607	1.438	1.135	0.292
V month	1.837	2.034	1.453	1.284	0.891	0.467
VI month	1.257	1.455	1.018	0.947	0.831	0.204
VII month	1.019	1.107	0.761	0.697	0.608	0.096
VIII month	0.873	0.916	0.666	0.526	0.478	0.054
IX month	0.789	0.848	0.640	0.520	0.475	0.092
Harvest	0.796	0.832	0.615	0.553	0.498	0.074

a. Total number of roots per plant.

The results showed no significant difference with regard to the total number of roots produced per plant due to treatment effects. However, T_1 (Tapioca alone at 50:50:50 kg N, P_2O_5 and K_2O/ha) recorded the maximum number of roots and the minimum number was recorded by T_6 (Tapioca + Stylosanthes at 20:50:50 kg N, P_2O_5 and K_2O/ha).

b. Number of tubers per plant.

There was no significant difference with regard to the number of tubers produced per plant due to treatment effect. Even though there was no significant difference, T_1 (Tapioca alone at 50:50:50 kg N, P_2O_5 and K_2O/ha) recorded the highest number of tubers per plant while T_6 (Tapioca + Stylosanthes at 20:50:50 kg N, P_2O_5 and K_2O/ha) recorded the lowest number.

c. Percentage of productive tubers.

The effect of intercropping and levels of nitrogen did not show significant difference on the percentage of productive tubers. However the percentage was maximum for T_6 (Tapioca + Stylosanthes at 20:50:50 kg N, P_2O_5 and K_2O/ha) while the minimum percentage was recorded for T_1 (Tapioca alone at 50:50:50 kg N, P_2O_5 and K_2O/ha).

d. Length of tubers.

No significant difference in length of tuber was observed due to intercropping and nitrogen levels. The maximum length was recorded by T_4 (Tapioca + Stylocanthes at 50:50:50 kg N, P_2O_5 and K_2O/ha) where as the tuber length was minimum in T_5 (Tapioca + Stylocanthes at 35:50:50 kg N, P_2O_5 and K_2O/ha).

e. Girth of tuber.

There was no significant variation in girth of tuber either due to intercropping or to nitrogen levels. However, the maximum girth was recorded by T_1 (Tapioca alone at 50:50:50 kg N, P_2O_5 and K_2O/ha) and the minimum recorded by T_5 (Tapioca + Stylocanthes at 35:50:50 kg N, P_2O_5 and K_2O/ha).

2. Tuber yield.

The mean values of tuber yield obtained from statistical analysis are presented in table 3 and the analysis of variance in Appendix V.

There was no significant difference in yield due to intercropping and varying levels of nitrogen. Still, the highest tuber yield was recorded by T_1 (Tapioca alone at 50:50:50 kg N, P_2O_5 and K_2O/ha). The lowest yield was recorded by T_6 (Tapioca + Stylosanthes at 20:50:50 kg N, P_2O_5 and K_2O/ha). Among the intercropped plots, T_4 (Tapioca + Stylosanthes at 50:50:50 kg N, P_2O_5 and K_2O/ha) recorded maximum yield.

Table 3. Yield attributes and yield of tapioca as influenced by intercropping and nitrogen levels.

	Number of roots per plant.	Number of tubers per plant.	Percentage productive tubers.	Length of tuber(cm)	Girth of tuber(cm)	Tuber yield (kg/ha)	Top yield (Kg/ha)	Utilization index.
T_1	19.186	13.077	67.784	34.50	12.51	32847.2	13263.8	2.535
T_3	18.269	12.797	70.487	32.15	12.19	26388.9	9305.5	2.807
T_4	18.175	12.625	69.504	38.20	11.74	29236.1	10763.8	2.751
T_5	17.636	12.372	70.331	31.55	10.90	21874.9	8055.5	2.719
T_6	15.443	11.425	74.071	34.80	11.83	20972.2	7986.1	2.648
	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

N.S. = Non Significant.

3. Top yield.

Table 3 shows the mean values of top yield and Appendix V furnishes the corresponding analysis of variance.

Intercropping and nitrogen levels did not have any significant influence on the top yield of tapioca. T_1 (Tapioca alone at 50:50:50 kg N, P_2O_5 and K_2O/ha) recorded the highest yield and T_6 (Tapioca + Stylosanthes at 20:50:50 kg N, P_2O_5 and K_2O/ha) recorded the minimum yield. Among the intercropped plots, T_4 (Tapioca + Stylosanthes at 50:50:50 kg N, P_2O_5 and K_2O/ha) recorded the highest yield.

4. Utilisation index.

The mean values on utilisation index are presented in table 3 and the analysis of variance in Appendix V.

There was no significant difference in utilisation index due to intercropping and nitrogen levels. The maximum value was recorded by T_3 (Tapioca + Stylosanthes at 50:50:50 + 10:30:20 kg N, P_2O_5 and K_2O/ha). The minimum value was recorded by T_1 (Tapioca alone at 50:50:50 kg N, P_2O_5 and K_2O/ha).

C. Quality attributes.

1. Dry matter content of tuber.

The dry matter content of tuber was not influenced by intercropping and nitrogen levels.

2. Starch content of tuber.

The mean values of the starch content of tuber under different treatments are presented in table 4 and the analysis of variance in Appendix V.

Intercropping and nitrogen levels significantly influenced the starch content of tuber. T_1 (Tapioca alone at 50:50:50 kg N, P_2O_5 and K_2O/ha) recorded a significantly higher starch content when compared to other treatments excepting T_3 (Tapioca + Stylosanthes at 50:50:50 + 10:30:20 kg N, P_2O_5 and K_2O/ha) which was on par with it. The lowest value of starch content was recordedby the treatment T_6 (Tapioca + Stylosanthes at 20:50:50 kg N, P_2O_5 and K_2O/ha) but was on par with T_4 and T_5 (Tapioca + Stylosanthes at 50:50:50 kg N, P_2O_5 and K_2O/ha and Tapioca + Stylosanthes at 35:50:50 kg N, P_2O_5 and K_2O/ha respectively).

3. Hydrocyanic acid content.

The mean values are given in table 4 and analysis of variance in Appendix V.

The results revealed that there was significant effect due to intercropping and nitrogen levels on the hydrocyanic acid content in tuber. The maximum value was recorded by T_3 (Tapioca + Stylosanthes at 50:50:50 + 10:30:20 kg N, P_2O_5 and K_2O/ha) which was significantly higher than other treatments. The lowest value was recorded

Table 4. Starch and HCN contents of tuber as influenced by intercropping and nitrogen levels.

	T_1	T_3	T_4	T_5	T_6	C.D. (.01)
Percentage starch content of tuber	28.675	28.400	28.025	27.850	27.550	0.551
Hydrocyanic acid content of tuber. (µg/g of fresh weight)	29.750	31.750	29.000	28.375	26.750	1.071

by T_6 (Tapioca + Stylosanthes at 20:50:50 kg N, P_2O_5 and K_2O/ha).

4. Crude protein content of tuber.

Intercropping and nitrogen levels had no significant influence on the crude protein content of tubers.

D. Plant analysis.

1. Nitrogen content.

a. Nitrogen content of leaves.

The data revealed no significant difference in nitrogen content of leaves due to intercropping and nitrogen levels.

b. Nitrogen content of stem.

There was also no significance in the nitrogen content of stem due to any of the treatments.

2. Phosphorus content.

a. Phosphorus content of leaves.

There was no significant difference in the phosphorus content of tapioca leaves due to intercropping and nitrogen levels.

b. Phosphorus content of stem.

Phosphorus content of stem also did not differ significantly due to influence of intercropping and nitrogen levels.

c. Phosphorus content of tuber.

No significance was observed in the phosphorus content of tuber also due to intercropping and nitrogen levels.

3. Potassium content.

a. Potassium content of leaves.

There was no significance in the potassium content of leaves due to different treatments.

b. Potassium content of stem.

The results revealed no significant difference in the potassium content of stem due to intercropping and nitrogen levels.

c. Potassium content of tuber.

Intercropping and nitrogen levels had no significant influence on potassium content of tapioca tuber.

Observations on intercrop. (Stylosanthes)

A. Growth characters.

1. Height of plants.

The mean height of plants at first, second and third cuts are presented in table 5 and the related analysis of variance are presented in Appendix VI.

During the first cut there was significant difference in the height of plants due to intercropping and nitrogen levels. The plants in T_2 (Stylosanthes alone at 10:30:20 kg N, P_2O_5 and K_2O/ha) recorded a significantly lower height when compared to intercropped plants. The height of plants in the intercropped treatments were on par and significantly higher than the pure crop. The maximum height was recorded in T_4 (Tapioca + Stylosanthes at 50:50:50 kg N, P_2O_5 and K_2O/ha).

In the second and third cut the treatments did not show any significant difference in the height of plants. However during the second cut the maximum height was recorded in T_3 (Tapioca + Stylosanthes at 50:50:50 + 10:30:20 kg N, P_2O_5 and K_2O/ha) and minimum height in treatment T_5 (Tapioca + Stylosanthes at 35:50:50 kg N, P_2O_5 and K_2O/ha). During the third cut maximum height was recorded in T_6 (Tapioca + Stylosanthes at 20:50:50 kg N, P_2O_5 and K_2O/ha).

2. Spread of plants.

The mean spread of plants at the time of first, second and third cuts are presented in table 5 and analysis of variance in Appendix VI.

The results revealed that there was no significant difference due to treatments on the spread of plants. However the maximum values were recorded during the first and third cuts by T_3 (Tapioca + Stylosanthes at 50:50:50 + 10:30:20 kg N, P_2O_5 and K_2O/ha) whereas T_2 (Stylosanthes

Table 5. Height and spread of stylosanthes as influenced by intercropping and nitrogen levels.

	I cut		II cut		III cut	
	Height	Spread	Height	Spread	Height	Spread
T_2	70.700	100.950	69.400	98.575	58.525	70.150
T_3	98.725	132.887	70.225	87.812	61.975	77.150
T_4	101.200	126.150	65.925	84.675	59.675	71.125
T_5	90.375	118.450	65.450	86.625	54.225	68.250
T_6	89.975	119.200	69.050	96.375	67.150	75.075
C.D. (.01)	12.311	N.S.	N.S.	N.S.	N.S.	N.S.

N.S. = Non Significant.

alone at 10:30:20 kg N, P_2O_5 and K_2O/ha) recorded the maximum spread in the second cut. In all the three cuts, the minimum values were recorded by T_2, T_4 and T_5 for first, second and third cuts respectively. (Stylosanthes alone at 10:30:20, kg N, P_2O_5 and K_2O/ha; Tapioca + Stylosanthes at 50:50:50 kg N, P_2O_5 and K_2O/ha; and Tapioca + Stylosanthes at 35:50:50 kg N, P_2O_5 and K_2O/ha respectively).

3. Leaf:stem ratio.

The leaf:stem ratio values at the time of each cut showed no significant difference due to treatments in any of the cuts.

B. Yield.

1. Green matter yield.

The mean green matter yields at each cut and the total green matter production are furnished in table 6 and analysis of variance in Appendix VII.

There was significant difference between the yield of pure crop T_2 (Stylosanthes alone at 10:30:20 kg N, P_2O_5 and K_2O/ha) and the yield from the intercropped treatments in all the three cuts. The yield of pure crop was always significantly higher when compared to that from intercropped plots which were on par.

Table 6. Yield of stylosanthes as influenced by intercropping and nitrogen levels (kg/ha).

	I cut		II cut		III cut		Total	
	Green matter	Dry matter	Green matter	Dry matter	Green matter	Dry matter	Green matter	Dry matter
T_2	13062.5	3087.2	11500.0	2924.2	4270.8	3841.6	28833.3	9913.1
T_3	4333.3	1031.7	4083.3	1287.2	1625.0	1490.6	10041.6	3809.6
T_4	3645.8	878.7	3250.0	1063.2	1458.3	1336.0	8354.1	3278.1
T_5	4166.6	1015.5	4624.9	1423.0	1583.3	1460.3	10374.9	3898.9
T_6	4249.9	991.7	5166.6	1478.8	2333.3	2125.8	11749.9	4596.4
C.D. (.01)	3758.9	994.7	2694.3	633.7	1144.7	1046.0	6724.6	2271.2

2. Dry matter yield.

The mean values for dry matter yields in the three cuts and the total dry matter production are presented in table 6 and the analysis of variance in Appendix VII.

Significant difference was noted between the treatments with regard to the dry matter yield. The treatment T_2 (Stylosanthes alone at 10:30:20 kg N, P_2O_5 and K_2O/ha) recorded the maximum dry matter yield in all the three cuts, which were significantly higher than other intercropped treatments. The yields from the intercropped plots were on par in all the three cuts.

With respect to the total dry matter yield from all the three cuts, the pure crop recorded a significantly higher total dry matter production when compared to intercropped treatments which were on par.

C. Plant analysis.

1. Crude protein content.

The mean values of crude protein content in each cut and total crude protein yield are furnished in table 7 and the analysis of variance in Appendix VIII.

Results revealed that there was significant difference in crude protein content in the first cut due to treatment effects. The pure crop of stylosanthes at 10:30:20 kg N, P_2O_5 and K_2O/ha registered a significantly

Table 7. Crude protein content of stylosanthes as influenced by intercropping and nitrogen levels (per cent).

	I cut	II cut	III cut	Total
T_2	15.619	13.124	10.391	39.133
T_3	12.533	12.687	9.734	34.955
T_4	12.054	12.687	9.078	33.819
T_5	12.227	13.234	9.625	35.086
T_6	11.265	12.578	9.844	33.686
C.D. (.01)	1.999	N.S.	N.S.	2.571

N.S. = Non Significant.

higher protein content as compared to other treatments which were on par. The lowest protein content was obtained from treatment T_6 (Tapioca + Stylosanthes at 20:50:50 kg N, P_2O_5 and K_2O/ha).

In the second and third cuts there was no significant difference in crude protein content due to treatments. However, the highest yield was recorded by T_5 (Tapioca + Stylosanthes at 35:50:50 kg N, P_2O_5 and K_2O/ha) during the second cut and the minimum recorded in T_6 (Tapioca + Stylosanthes at 20:50:50 kg N, P_2O_5 and K_2O/ha). In the third cut pure crop registered a maximum protein content, eventhough there was no statistical significance. In this cut, the treatment T_4 (Tapioca + Stylosanthes at 50:50:50 kg N, P_2O_5 and K_2O/ha) recorded the minimum protein content.

With regard to total protein yield there was significant difference between pure crop and that of inter-cropped ones. The pure crop established a significantly higher total crude protein content as compared to intercropped ones which were on par. Among the intercropped treatments, T_5 (Tapioca + Stylosanthes at 35:50:50 kg N, P_2O_5 and K_2O/ha) recorded a higher total protein content, and treatment T_6 (Tapioca + Stylosanthes 20:50:50 kg N, P_2O_5 and K_2O/ha) recorded the lowest protein content.

2. Phosphorus content.

The results showed that there was no significant difference in the phosphorus content, among treatments in all the three cuts.

3. Potassium content.

There was no significant difference among treatments in the potassium content also in all the three cuts.

Observations on run off.

1. Quantity of run off.

The table 8 presents the mean values of the total quantity of run off water collected during the observation period and the analysis of variance presented in Appendix IX.

There was significant difference in the total quantity of run off water due to intercropping. The treatment T_2 (Stylosanthes alone at 10:30:20 kg N, P_2O_5 and K_2O/ha) recorded significantly higher quantity of run off as compared to other treatments excepting T_1 (Tapioca alone at 50:50:50 kg N, P_2O_5 and K_2O/ha), which was on par with T_2. The treatment T_4 (Tapioca + Stylosanthes at 50:50:50 kg N, P_2O_5 and K_2O/ha) recorded the lowest quantity of run off water but was on par with other treatments except the pure crop of Stylosanthes.

2. Nitrogen content of run off water.

The mean values of total quantity of nitrogen lost through run off water are presented in table 8 and the respective analysis of variance given in Appendix IX.

With regard to the total nitrogen lost in run off water, there was no significant difference due to treatment effects. Even though there was no significant difference, the highest and the lowest values were recorded by T_2 (Stylosanthes alone at 10:30:20 kg N, P_2O_5 and K_2O/ha) and T_1 (Tapioca alone at 50:50:50 kg N, P_2O_5 and K_2O/ha) respectively.

3. Potassium content in run off water.

Table 8 furnishes the mean total values of potassium lost through run off water. The analysis of variance is given in Appendix IX.

The total potassium lost through run off water showed no significant difference in any of the treatments. However, T_2 (Stylosanthes alone at 10:30:20 kg N, P_2O_5 and K_2O/ha) recorded the highest value whereas T_1 (Tapioca alone at 50:50:50 kg N, P_2O_5 and K_2O/ha) recorded the lowest value.

Observations on soil loss.

1. Quantity of soil eroded.

The mean values regarding the total soil loss are presented in table 8 and 8 (i) and the corresponding analysis of variance are furnished in Appendix IX and X respectively.

Table 8. Runoff, soil and nutrient loss as influenced by intercropping and nitrogen levels.

	T_1	T_2	T_3	T_4	T_5	T_6	C.D.
Total runoff (litres)	13279.250	13495.000	13090.500	13036.500	13040.250	13111.000	(.05) 254.758
Total soil loss (kg/ha)	30849.500	29476.250	22313.350	21532.500	21193.850	22241.500	(.01) 405.472
Nitrogen loss through runoff (kg/ha)	42.980	51.780	51.640	48.770	49.580	47.340	N.S.
Available potassium loss through runoff (kg/ha)	2.485	2.851	2.715	2.778	2.739	2.734	N.S.
Nitrogen content in eroded soil (kg/ha)	17.850	20.510	13.220	12.270	11.490	11.800	(.01) 1.066
Available phosphorus content in eroded soil (kg/ha)	0.181	0.193	0.119	0.116	0.105	0.121	(.01) 0.039
Available potassium content in eroded soil (kg/ha)	3.077	3.808	2.018	2.240	1.977	1.900	(.01) 0.487

(contd..)

	T_1	T_2	T_3	T_4	T_5	T_6	C.D.
Total nitrogen lost both through runoff and eroded soil (kg/ha)	60.834	72.303	64.861	61.049	61.084	59.153	(.05) 7.340
Total potassium lost both through runoff and eroded soil (kg/ha)	5.561	6.658	4.732	5.014	4.715	4.633	(.01) 0.685

N.S. = Non Significant.

Table 8 (i) Quantity of soil eroded as influenced by intercropping and nitrogen levels (kg/ha).

	T_1	T_2	T_3	T_4	T_5	T_6	C.D. (.01)
I	452.025	506.175	427.025	428.675	437.675	460.800	49.694
II	570.775	974.925	572.850	543.725	541.700	576.975	70.733
III	2016.625	2499.975	2008.300	1929.150	1970.800	1912.500	200.460
IV	2477.050	3660.375	2454.175	1879.150	2454.150	2437.450	677.494
V	1016.675	816.225	674.975	666.675	677.025	666.600	62.645
VI	883.325	893.725	684.525	656.200	666.700	679.125	90.475
VII	1562.450	1537.500	1045.800	1020.800	1033.325	1033.300	100.600
VIII	3095.800	2600.950	2191.625	2185.275	2204.125	2208.275	91.336
IX	4329.150	3320.825	2674.950	2704.175	2658.325	2695.800	84.219
X	3216.625	3237.475	2570.825	2554.125	2541.600	2533.300	98.232

(contd...)

	T_1	T_2	T_3	T_4	T_5	T_6	C.D. (.01)
XI	1370.800	1345.825	708.325	712.500	695.850	712.475	87.944
XII	1008.300	983.525	575.000	558.300	566.650	558.325	59.313
XIII	1874.975	1783.300	1325.025	1320.825	1316.625	1345.800	56.215
XIV	2579.125	2028.175	1724.975	1700.300	1729.150	1737.475	77.989
XV	4395.800	3287.475	2674.975	2666.625	2699.950	2683.300	73.067

The results of all the observations taken recorded a significant difference between treatments regarding the quantity of soil washed by runoff. Accordingly T_1 (Tapioca alone at 50:50:50 kg N, P_2O_5 and K_2O/ha) recorded the maximum quantity of soil loss which was significantly higher than other treatments. T_4 (Tapioca + Stylosanthes at 50:50:50 kg N, P_2O_5 and K_2O/ha) recorded significantly lower soil loss as compared to other treatments. It was also noted that in the pure crop of stylosanthes the quantity of soil loss was considerably high, but significantly lower than T_1 (Tapioca alone at 50:50:50 kg N, P_2O_5 and K_2O/ha) and significantly higher than T_4 (Tapioca and stylosanthes at 50:50:50 kg N, P_2O_5 and K_2O/ha).

2. Nitrogen content of eroded soil.

The mean values of the nitrogen loss through the eroded sediments are presented in table 8 and analysis of variance in Appendix IX.

The total loss of nitrogen through sediment was found significantly higher in T_2 (Stylosanthes alone at 10:30:20 kg N, P_2O_5 and K_2O/ha) as compared to other treatment whereas T_5 (Tapioca + Stylosanthes at 35:50:50 kg N, P_2O_5 and K_2O/ha) recorded a significantly lower value as compared to other treatments.

3. Phosphorus content of eroded soil.

The mean values of available phosphorus lost through eroded sediments are presented in table 8 and analysis of variance in Appendix IX.

In the case of total available phosphorus content in eroded soils, there was significant difference between treatments. The maximum content was recorded from T_2 (Stylosanthes alone at 10:30:20 kg N, P_2O_5 and K_2O/ha) which was significantly higher than intercropped plots but was on par with pure crop of tapioca. The intercropped plots were on par.

4. Potassium content of eroded soil.

Table 8 furnishes the mean values of the total potassium loss through eroded sediment. The corresponding analysis of variance are presented in Appendix IX.

The total potassium content in eroded sediment showed that the treatment T_2 (Stylosanthes alone at 10:30:20 kg N, P_2O_5 and K_2O/ha) recorded a significantly higher potassium loss through eroded sediments as compared to other treatments which were on par. The lowest value was recorded by T_6. (Tapioca + Stylosanthes at 20:50:50 kg N, P_2O_5 and K_2O/ha).

Total nitrogen loss both through run off and eroded soil.

The mean values of total nitrogen loss both through run off and eroded sediments are presented in table 8 and the analysis of variance furnished in Appendix IX.

The total nitrogen loss was significantly higher from treatment T_2 (Stylosanthes alone at 10:30:20 kg N, P_2O_5 and K_2O/ha) as compared to other treatments, which were on par. Even then T_6 (Tapioca + Stylosanthes at 20:50:50 kg N, P_2O_5 and K_2O/ha) recorded the lowest total loss of nitrogen both through run off and eroded soil.

Total potassium loss both through run off and eroded soil.

Table 8 furnishes the mean total values regarding the potassium loss both through run off and eroded soil. The related analysis of variance are presented in Appendix IX.

The data revealed that there was significant difference in the total values due to treatment effect. The treatment T_2 (Stylosanthes alone at 10:30:20 kg N, P_2O_5 and K_2O/ha) recorded the maximum loss which was significantly higher than other treatments. The intercropped plots were on par with respect to the potassium loss, but however T_6 (Tapioca + Stylosantes at 20:50:50 kg N, P_2O_5 and K_2O/ha) recorded the lowest value.

Mechanical composition of eroded soil.

The mean values of mechanical composition of the eroded soils are presented in table 9 and the corresponding

Table 9. Mechanical composition of eroded soil as influenced by intercropping and nitrogen levels.

	Percentage coarse sand	Percentage fine sand	Percentage silt	Percentage clay
T_1	58.282	15.485	2.312	23.125
T_2	53.955	15.115	2.375	27.625
T_3	53.525	17.305	2.437	24.375
T_4	55.097	17.140	3.250	23.875
T_5	54.187	18.167	3.375	23.375
T_6	52.827	18.875	3.312	24.125
	N.S.	N.S.	N.S.	N.S.

N.S. = Non Significant.

analysis of variance presented in Appendix XI.

The data revealed that there was no significant effect due treatments in the percentage of different soil components eroded in each treatment. However it is evident from the table that sand faction constitute about 73 per cent of the material of the eroded sediment.

Soil analysis after the experiment.

1. Total nitrogen content of the soil.

The mean values of total nitrogen content of soil after the experiment are presented in table 10 and Appendix XI gives the analysis of variance.

The total nitrogen content of soil recorded a significant difference due to intercropping and different levels of nitrogen. T_2 (Stylosanthes alone at 10:30:20 kg N, P_2O_5 and K_2O/ha) recorded a significantly higher soil nitrogen content as compared to other treatments but was on par with T_4 (Tapioca + Stylosanthes at 50:50:50 kg N, P_2O_5 and K_2O/ha). The lowest value was recorded in T_1 (Tapioca alone at 50:50:50 kg N, P_2O_5 and K_2O/ha) but was on par with other treatments including T_4 but excluding T_2.

2. Available phosphorus content of soil.

The mean values are presented in table 10 and the analysis of variance in Appendix XI.

Intercropping at different fertility levels had no effect on the available phosphorus content of the soil. However, maximum content was recorded by T_5 (Tapioca + Stylosanthes at 35:50:50 kg N, P_2O_5 and K_2O/ha) and T_6 (Tapioca + Stylosanthes at 20:50:50 kg N, P_2O_5 and K_2O/ha) recorded the minimum value.

3. Available potassium content of soil.

The mean values of available potassium content of the soil after the experiment are presented in table 10 and the analysis of variance in Appendix XI.

The results revealed that there was significant difference in final available potassium content of the soil. T_1 (Tapioca alone at 50:50:50 kg N, P_2O_5 and K_2O/ha) recorded the highest available potassium content and was significant as compared to other treatments. The lowest value was recorded by T_2 (Stylosanthes alone at 10:30:20 kg N, P_2O_5 and K_2O/ha) which was on par with T_3 (Tapioca + Stylosanthes at 50:50:50 + 10:30:20 kg N, P_2O_5 and K_2O/ha) T_6 (Tapioca + Stylosanthes at 20:50:50 kg N, P_2O_5 and K_2O/ha) and T_5 (Tapioca + Stylosanthes at 35:50:50 kg N, P_2O_5 and K_2O/ha) respectively.

4. Cation exchange capacity.

The mean values of cation exchange capacity of the soil after the experiment are given in table 10 and the analysis of variance in Appendix XI.

Table 10. Soil chemical properties after the experiment.

	Total nitrogen content (per cent)	Available phosphorus content (kg/ha)	Available potassium content (kg/ha)	Cation exchange capacity (meq/100g soil)
T_1	0.061	13.500	72.500	2.625
T_2	0.085	9.625	50.000	4.525
T_3	0.071	13.250	60.000	3.800
T_4	0.073	11.625	65.000	3.350
T_5	0.063	15.375	55.000	3.500
T_6	0.063	9.125	57.500	3.700
C.D.	0.013 (.05)	N.S.	10.410 (.01)	0.736 (.01)

N.S. = Non Significant.

The treatments had significant effect on the cation exchange capacity of the soil. T_2 (Stylosanthes alone at 10:30:20 kg N, P_2O_5 and K_2O/ha) recorded a significantly higher value but was on par with T_3 (Tapioca + Stylosanthes at 50:50:50 + 10:30:20 kg N, P_2O_5 and K_2O/ha). The lowest value was recorded by T_1 (Tapioca alone at 50:50:50 kg N, P_2O_5 and K_2O/ha) which was on par with T_4 (Tapioca + Stylosanthes at 50:50:50 kg N, P_2O_5 and K_2O/ha).

Discussion

DISCUSSION

An experiment was conducted at the College of Agriculture, Vellayani, to find out the possibilities of reducing the fertilizer nitrogen requirement of tapioca by intercropping with stylosanthes, a perennial leguminous fodder-cum-cover crop. The effect of stylosanthes in reducing soil erosion when intercropped with tapioca in slopy areas was also determined. The observations on growth characters, yield and quality of both the main crop and intercrop; run off; nutrient and soil losses were recorded. Supporting chemical data was collected. The results obtained from the study are discussed below.

Main crop. (Tapioca)

A. Growth characters.

1. Height of the plant.

From the results obtained (table 1) it was revealed that there was no significant influence of treatments on the height of plants at any stage of growth of the plant. There was no direct relationship between fertilizer application and plant height. This result is in confirmation of the findings reported by Acosta and Pinto (1978).

2. Leaf area index.

The mean values of leaf area index (table 2) indicated that there was significant difference due to intercropping and varying levels of nitrogen at all stages of the crop from planting till harvest. It can be seen that when tapioca was intercropped with stylosanthes with a fertilizer dose applied for both the crops, the leaf area index was minimum and was significantly higher than other treatments in the first month. This might be due to the fact that major portion of the nutrients applied might have been utilized by tapioca during the early stage of establishment and also since the initial competition between the crops for nutrients was less.

From the second month onwards the leaf area index of pure crop of tapioca was on par with that of T_3 (Tapioca + stylosanthes at 50:50:50 + 10:30:20 kg N, P_2O_5 and K_2O/ha). By this time stylosanthes might have started competing with the main crop. In the pure crop of tapioca the growth was not hindered and hence light, space, nutrients and water were utilized which might have contributed for higher leaf area index. However, the higher leaf area index in the treatment where tapioca and stylosanthes were intercropped with the recommended doses of fertilizer for both the crops revealed the fact that when both the crops were adequately fertilized, the competition for nutrients was the minimum. This was conspicuous from the other treatments where lower levels of fertilizers, especially nitrogen was applied wherein the leaf area index was correspondingly reduced.

This result is in confirmation with the findings of Cock (1975) and Ramanujam and Indira (1979) that leaf area index was highly influenced by high rates of fertilization especially nitrogen.

B. Yield attributes and yield.

1. Total number of roots per plant.

The total number of roots per plant (table 3) was not significantly influenced by intercropping and levels of nitrogen. However the pure crop of tapioca treated with the recommended dose of fertilizers recorded the maximum number of roots per plant. The increased root number in the pure crop of tapioca might be due to the fact that there was adequate space and fertilizer for the pure crop compared to the main crop with the intercrop.

2. Number of tubers per plant.

A critical analysis of the mean values (table 3) revealed that there was no significant difference regarding the tuber number per plant due to treatment effects. In this case also the pure crop recorded a numerically higher number of tubers over the other treatments. This also might be due to the larger unit area obtained by the pure crop as compared to the intercropped ones. This finding is in agreement with the results obtained by Mohankumar and Hrishi (1973).

3. Percentage of productive tubers.

The results (table 3) showed that intercropping and nitrogen levels did not significantly affect the development of productive tubers. It can be seen that the percentage of productive tubers was the maximum in intercropped plot given the lowest level of nitrogen, though it did not influence the production of more tubers per plant. From this it can be assumed that stylosanthes might have contributed substantially to the level of nitrogen in the soil at later stages of development and consequent thickening of tubers and that it did not interfere with the tuberisation of roots thus lowering the percentage productive roots. Mohankumar and Mandal (1977) also reported similar results in development and thickening of tubers in tapioca.

4. Length of tuber.

From the data presented in table 3 it could be seen that there was no significant difference on the length of tuber between the pure crop and intercropped ones. The maximum length was however recorded in the intercropped plot given only 50:50:50 kg N, P_2O_5 and K_2O/ha for both crops(T_4). This might be due to effective competition for nutrients and the search for the same in the deeper layers resulting in increase of tuber length in intercropped plot. Nitis and Sumatra (1976) and Ramakrishna Bhat (1978) obtained increases in tuber length due to legume intercropping.

5. Girth of tuber.

Girth of tuber was not influenced significantly by intercropping and different levels of nitrogen (table 3).

However, the data revealed that the pure crop recorded the maximum girth of tubers which is attributed to adequate nutrients, lesser competition and effective synthesis and accumulation of starch in the tubers.

6. Tuber yield.

The data (table 3 and Fig.3) showed that there was no significant difference in yield due to intercropping and varying nitrogen levels. It is evident from this that intercropping tapioca with stylosanthes did not significantly affect the tuber yield. This is in line with the results reported by Singh and Mandal (1968); Singh (1969); Katyal and Datta (1976); Mitis and Sumatra (1976); Patanothai et al. (1977); Ramakrishna Bhat (1978); Lira et al. (1979) and Moreno and Meneses (1980); that intercropping tapioca produced yields similar to that of pure crop.

Even though statistically no significant difference was observed the pure crop recorded the maximum tuber yield which might be due to the contributing effect of the yield attributes namely number of roots per plant, number of tubers per plant and girth of tubers as compared to intercropped plots. The absence of competition for nutrient absorption and also the possibilities for better utilisation of the applied nutrients might have also resulted in higher yields. The vegetative growth character discussed earlier might have also favoured higher yields in the pure crop by enhancing the photosynthate production, its translocation and accumulation in the tubers.

The finding that tapioca intercropped with stylosanthes and supplied with a fertilizer dose of 50:50:50 kg N, P_2O_5 and K_2O/ha recommended for a pure crop of tapioca relatively increased the yield of tapioca with legume can be attributed to the fact that lower levels of nutrients were sufficient enough for tapioca to evince its normal performance when intercropped. The legume stylosanthes might have also contributed sufficient nitrogen. The results as reported by Nitis and Sumatra (1976); Nitis (1977, 1978), also makes clear the fact regarding the nitrogen contribution of stylosanthes when grown in association with tapioca.

7. Top yield.

The mean values of top yield (table 3) revealed the fact that intercropping and nitrogen levels did not have any significant effect, even though pure crop of tapioca recorded the highest value. The free growth of tapioca without competition and interference might have encouraged the better utilisation of the applied nutrients and sunlight resulting in more vegetative growth and top yield. Similar results have been reported by Asokan et al. (1980) and Magalhaes and Azevedo (1980).

B. Utilisation index.

The data on mean values presented in table 3 revealed that there was no significant difference in the utilisation index due to intercropping and nitrogen levels. The non significance of tuber and top yield values might have resulted in the non significant values of utilisation index. Further, intercropped treatment with fertilizer does for both the crops recorded relatively higher value.

C. Quality attributes.

1. Starch and hydrocyanic acid contents of tubers.

Intercropping at different nitrogen levels significantly influenced the percentage of starch in tubers (table 4). In this case the pure crop of tapioca (T_1) recorded significantly higher starch content as compared to other treatments except for T_3, which was on par with T_1. The higher levels of nitrogen might have contributed to ensure a higher starch content in both the treatments. In the pure crop the high availability of nutrients especially nitrogen might have contributed to a higher content of starch. This is in line with the findings of Vijayan and Aiyer (1969) and Pillai and George (1978) who obtained an increase in starch content by increasing levels of nitrogen.

Hydrocyanic acid content of tuber also showed significant difference (table 4) due to legume intercropping at different levels of nitrogen. The maximum value was recorded in T_3 (Tapioca + Stylosanthes at 50:50:50 + 10:30:20 kg N, P_2O_5 and K_2O/ha) which was significantly higher than other treatments. The comparatively higher level of fertilizer nitrogen together with nitrogen contributed by stylosanthes might have induced the increased hydrocyanic acid content of tubers. This was in confirmation with the reports of Vijayan and Aiyer (1969); Kurian et al. (1976) and Prabhakar et al. (1979); that hydrocyanic acid content of tuber was increased with nitrogen application.

Observation on intercrop. (Stylosanthes)

A. Growth characters.

1. Height of plants.

From the results obtained (table 5) it was observed that there was significant difference in the height of plants during the first cut. The pure crop recorded a significantly lower plant height as compared to intercropped plants which were on par. The competition of intercropped stylosanthes for light might have resulted in the production of larger internodes resulting in increased plant height.

However, during the subsequent cuts taken after 175 days and 290 days after sowing, the treatments did not show significant difference in the plant heights. By this period adequate penetration of light sufficient enough for the proper growth of stylosanthes might have been obtained, since the density of tapioca canopy was reduced due to senescence of old leaves, reduced leaf area and the crop attaining height in growth.

2. Spread of plants.

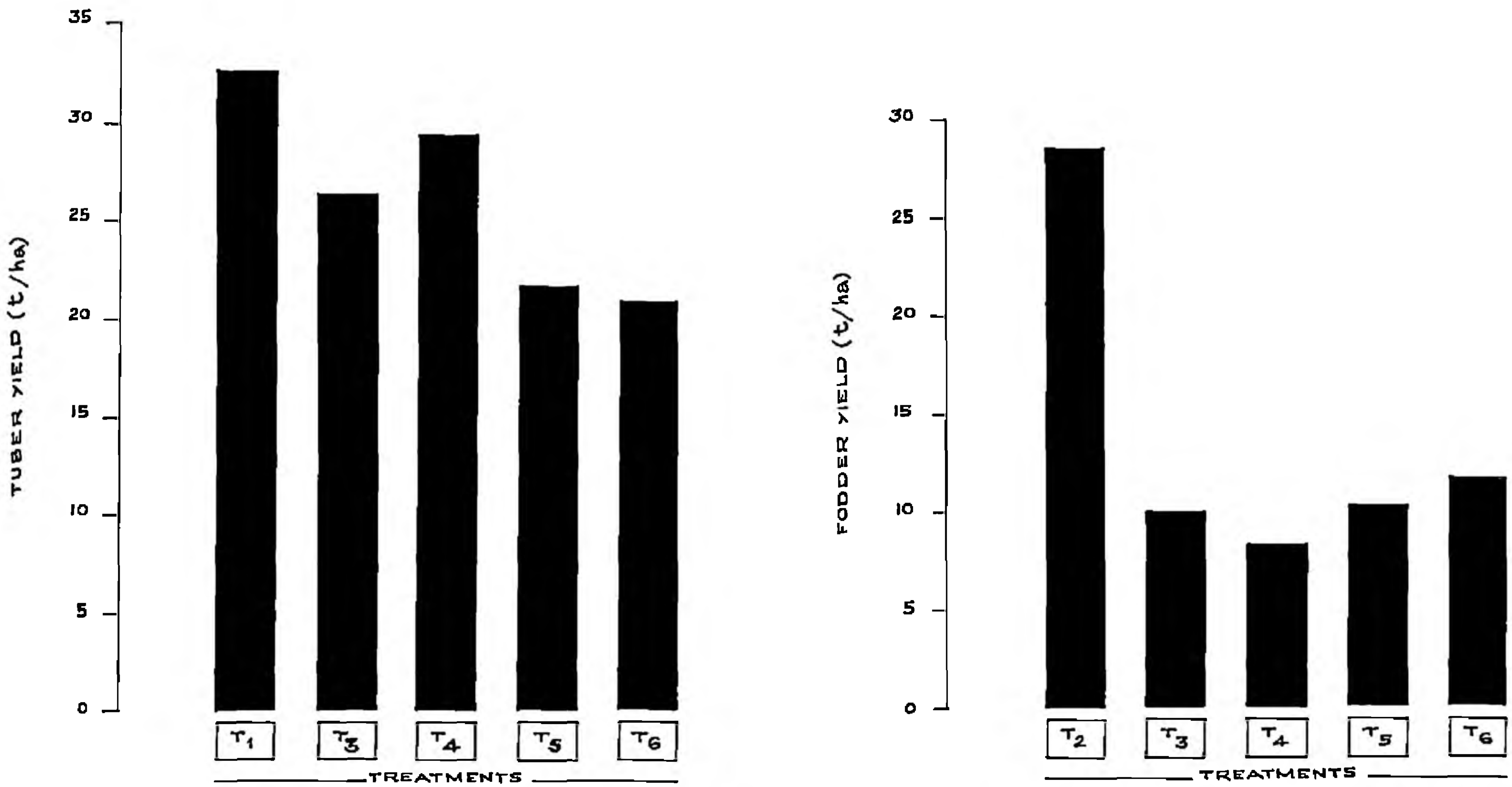
The mean values of spread of plants (table 5) revealed that there was no significant difference in the values in any of the cuts taken. From the table it can however be observed that during the first and third cuts the maximum values were recorded by the treatment T_3. The increased supply of fertilizers might have helped in increasing the meristematic activity, thereby producing longer and more number of secondary and tertiary growth thereby increasing the spread of plants.

B. Yield.

1. Green matter yield.

Mean values on the green matter yield of stylosanthes (table 6 and Fig.3) from each cut and the cumulative yield indicated thatthere was significant difference between the

FIG 3 YIELD OF TAPIOCA AND STYLOSANTHES AS INFLUENCED BY INTERCROPPING AND LEVELS OF NITROGEN



- T1 TAPIOCA ALONE AT 50 50 50 kg N P_2O_5 & K_2O/ha
- T2 STYLOSANTHES ALONE AT 10:30 20 kg N P_2O_5 & K_2O/ha
- T3 TAPIOCA + STYLOSANTHES AT 50 50 50 + 10 30 20 kg N P_2O_5 & K_2O/ha
- T4 TAPIOCA + STYLOSANTHES AT 50 50:50 kg N P_2O_5 & K_2O/ha
- T5 TAPIOCA + STYLOSANTHES AT 35 50 50 kg N P_2O_5 & K_2O/ha
- T6 TAPIOCA + STYLOSANTHES AT 20:50 50 kg N P_2O_5 & K_2O/ha

yield of pure crop and that from intercropped plots. It can be seen that the yield from pure crop was significantly higher in all cuts and in cumulative yield also. The yield from intercropped plots were on par in all the three cuts independently and collectively.

The higher yield of stylosanthes as pure crop might be due to more land area and canopy development. Among the intercropped treatments, T_6 - the one which received the lowest level of nitrogen recorded the highest yield which is a common feature for legume crop supplied with lower levels of nitrogen.

2. Dry matter yield.

The dry matter yield (table 6) from the three cuts and cumulative dry matter production revealed that the pure crop has registered a significantly higher yield as compared to intercropped plots which were on par. This also follows the same trend as shown in the case of green matter production.

C. Plant analysis.

1. Crude protein content.

The data on crude protein content (table 7) showed that intercropping and nitrogen levels significantly influenced the crude protein content of stylosanthes in treatment T_2 during the first cut, whereas in subsequent cuts the treatments did not show any significant difference.

The low level of nitrogen applied to the pure crop might have accelerated the nitrogen fixation process which might have increased the availability of nitrogen for assimilation by plants and thereby the increase in crude protein. The lower crude protein content in the intercropped plots might be due to the reason that a comparatively higher nitrogen levels at the initial stages of the plant growth might have inhibited nitrogen fixation in the intercropped plots and thereby nitrogen assimilation, and crude protein content.

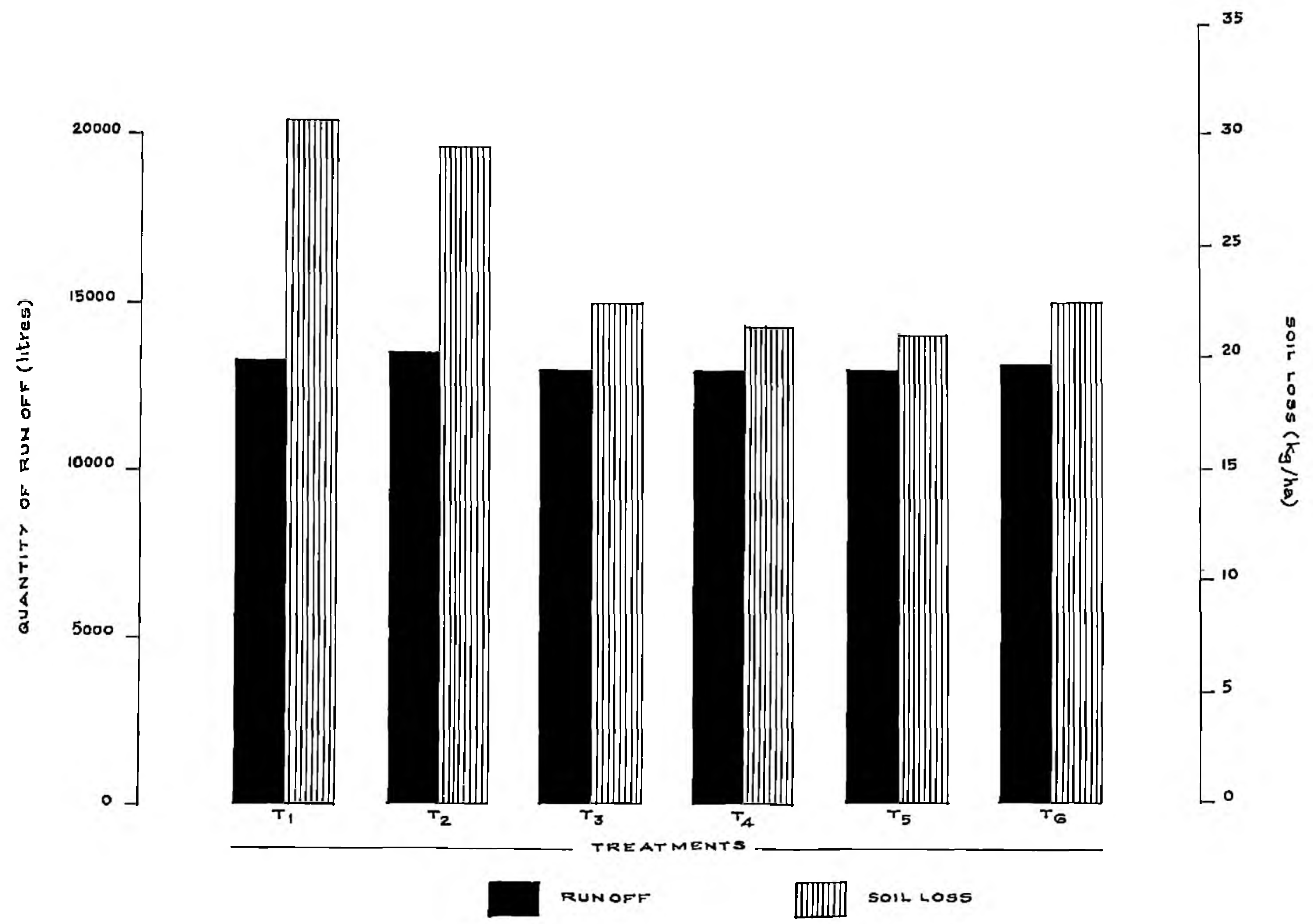
With regard to total protein yield significant difference was exhibited between pure crop and intercropped treatments. The pure crop recorded the higher total crude protein content as compared to intercropped treatments which were on par. The above explanation offered in the case of crude protein holds good in this case also.

Observations on run off, soil and nutrient loss.

1. Quantity of run off.

A critical study of the mean tables on the quantity of run off water (table 8 and Fig.4) revealed that there was significant difference in the quantity of run off from the different treatments. It was observed that the quantity of run off was significantly higher in T_2, where

FIG 4 RUN OFF AND SOIL LOSSES AS INFLUENCED BY INTERCROPPING AND LEVELS OF NITROGEN



stylo anthes was grown as a pure crop. This might be due to the fact that the direct penetration of rain water is obstructed by the coverage of the crop, stylosanthes, thus permitting a higher quantity of water received by rain and lost by run off. This result is in line with the reports of Gil (1974) that there was more run off from pasture than from cereals; that of Singh and Verma (1978) that soils with grass cover produced more run off than bare cultivated soil. Moore et al. (1979) also reported that well grassed site produced very high run off.

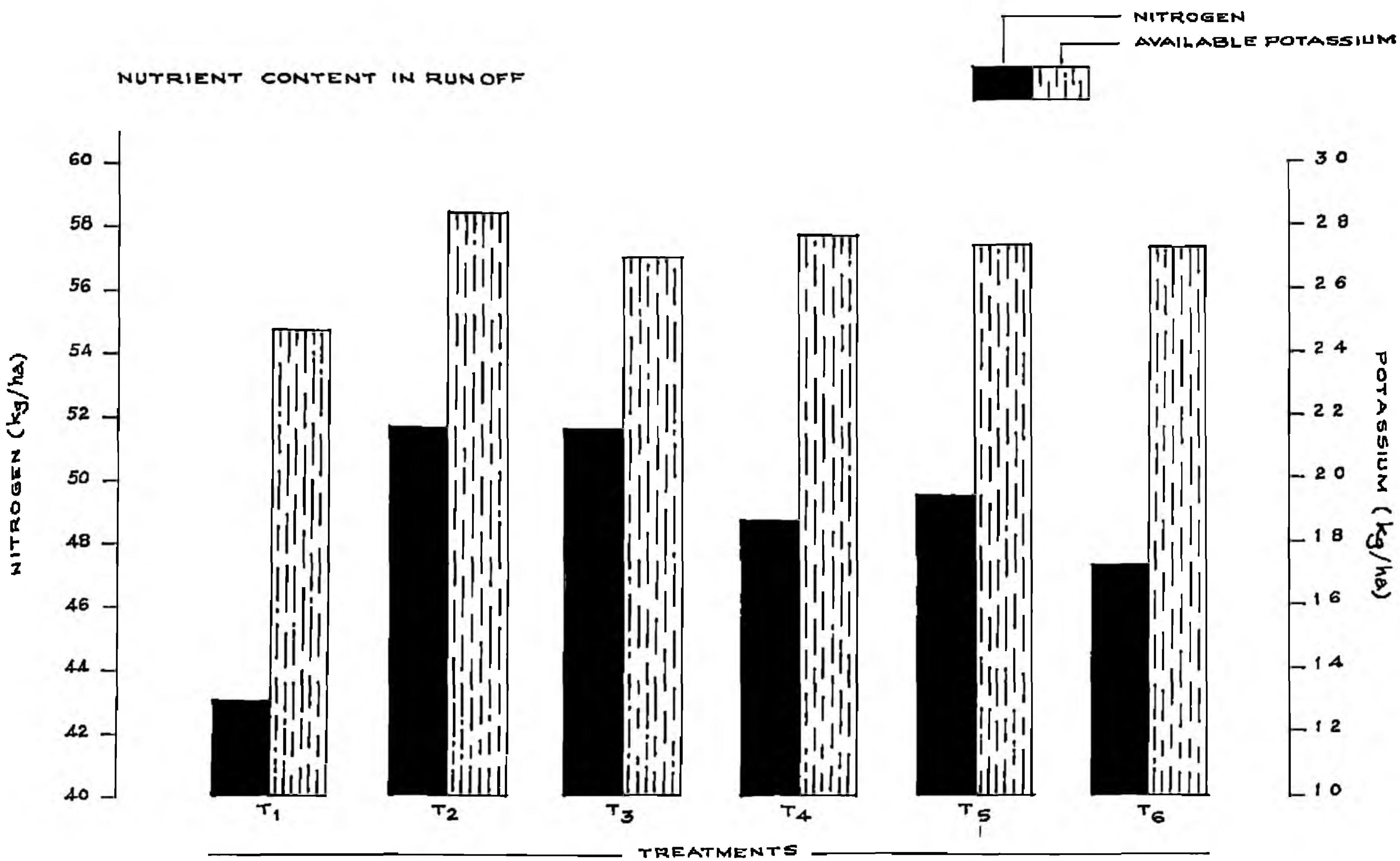
The quantity of run off from pure crop of tapioca was statistically on par with that of pure crop of stylosanthes. This can be attributed to the open nature of the soil and the high intensity of rainfall. This is supported by the findings reported by Viswambharan (1980). The quantity of run off from intercropped plots (T_3, T_4, T_5 and T_6) were on par with that in pure crop of tapioca.

2. Nitrogen, phosphorus and potassium content in run off.

From the data (table 8 and Fig.5) it can be seen that there was no significant difference in the total content of nitrogen in the run off water due to the treatments. However a slight increase in the nitrogen content was recorded for the treatment T_2.

The phosphorus content in the run off water was only

FIG 5 NUTRIENT LOSS AS INFLUENCED BY INTERCROPPING AND LEVELS OF NITROGEN



in traces. Burke et al. (1974); Mc Coll et al. (1975); Mc Coll (1978) and Howeler et al. (1979) reported that the loss of phosphorus was little or very low under high rainfall conditions.

The mean values (table 8 and Fig.5) of total potassium content in run off also did not exhibit any significant difference due to treatments. The possible reason that can be attributed is that though there is variation in the dose of potassium fertilizer applied to individual plots, the potassium applied to the soil in the available form immediately brings about an equilibrium with that of partly available and non available forms.

3. Quantity of soil eroded.

From the results obtained (table 8 and Fig.4) it was observed that there was significant difference in the quantity of soil lost through erosion. It can be seen from the total quantity of soil eroded, that the pure crop of tapioca has recorded a significantly higher quantity of soil loss, as compared to other treatments. This was in line with the reports of Howeler (1980) and Viswambharan (1980).

The soil loss from pure crop of stylosanthes was significantly higher when compared to intercropped treatments but was significantly lower to the pure crop of tapioca. This might be due to the fact that the initial growth of stylosanthes was very slow and hence the soil coverage during this period was also not effective. Thus the high intensity of rainfall together with the erosive action of the run off water might have carried large quantities of soil particles. Gee et al. (1976) also reported that maximum erosion potential occurs prior to and during the period of vegetation establishment when ground cover is sparse or non existent. It was also seen (table 8 (i) that when once the plant has established and canopy fully developed, the erosion was less. Again when the stylosanthes was harvested the ground was left exposed directly to the splash action of rain drop which, when coupled with run off might have carried substantial quantities of soil.

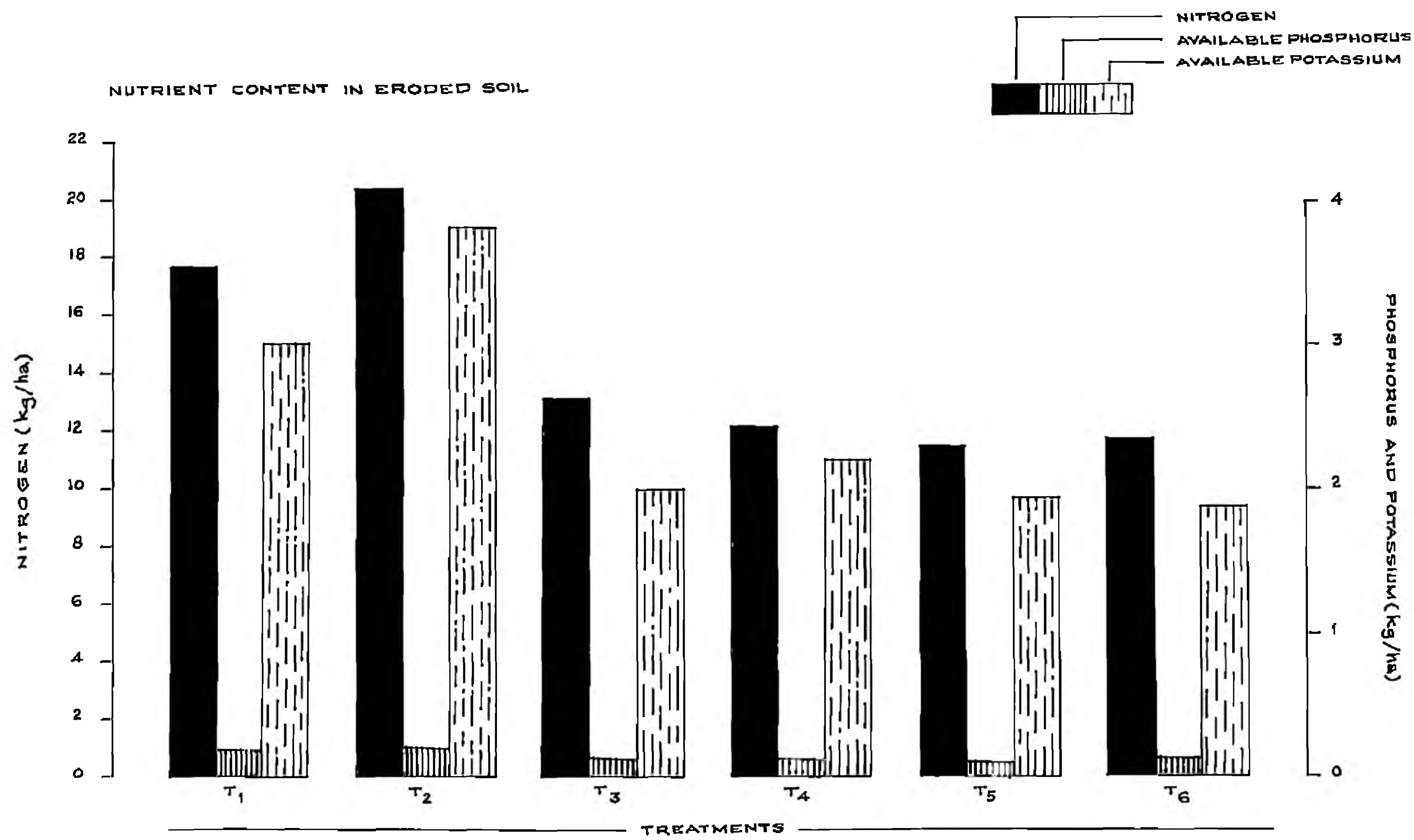
It is clearly evident from all the observations that the soil loss from intercropped plots was significantly lower as compared to other treatments. This can be ascribed to the protective cover of stylosanthes in reducing soil loss. The soil and run off losses were less when tapioca and maize were grown simultaneously (Aina et al., 1977). Lal (1977) reported that soil erosion and run off losses were less with mixed crops than with monoculture. Viswambharan (1980) also reported that groundnut intercropping significantly reduced run off and soil loss in tapioca.

4. Total nitrogen, available phosphorus and available potassium content in eroded soil.

The data (table 8 and Fig.6) revealed that the pure crop of stylosanthes recorded a significantly high content of nitrogen in eroded soil. Legumes are well known for their capacity of nitrogen fixation and part of the nitrogen thus fixed might have been excreted to the soil and later subjected to erosion. The nitrogen loss from the pure crop of tapioca was also significantly higher as compared to intercropped plots, but was significantly lower than pure crop of stylosanthes. This can be attributed to the highest quantity of soil loss recorded in the treatment T_1, resulting in the higher loss of nitrogen. This was in confirmation with the result of Viswambharan (1980) wherein the maximum losses of nutrients were noticed when tapioca alone was grown on mounds. Even though lowest loss of nitrogen was noted in T_5 it was observed that the nitrogen loss from intercropped plots was less.

The mean values of available phosphorus content (table 8 and Fig.6) revealed that there was significant difference in its content in eroded soil. Even though phosphorus is a less mobile element as reported by Mc Coll et al. (1975) and Mc. Coll (1978), it can be seen that the loss from the pure crop of stylosanthes was higher which was on par with pure crop of tapioca. The intercropped plots were on par. The higher quantity of run off coupled with the removal of large quantities of soil from T_1 and T_2

FIG 6 NUTRIENT LOSS AS INFLUENCED BY INTERCROPPING AND LEVELS OF NITROGEN



might be the reason for obtaining such significant difference in its contents.

With regard to the available potassium content (table 8 and Fig.6) it was observed that there was significant difference between treatments in its content in eroded sediment. The pure crop of stylosanthes recorded a significantly higher content of potassium in eroded soil. This also might be due to the higher quantity of soil loss from the pure crop of stylosanthes. The pure crop of tapioca also recorded a significantly higher potassium content than intercropped plots, but it was significantly lower than pure crop of stylosanthes. The loss from intercropped plots were on par.

5. Total nitrogen and potassium lost both through run off and soil.

The data (table 8) revealed that the pure crop of stylosanthes recorded a significantly higher total loss of nitrogen both through run off and eroded soil. This might have been due to the excretion of fixed nitrogen to the soil which in turn might have been subjected to erosion loss. The total loss of nitrogen from T_6 was found to be the lowest even though statistically it was on par with other treatments except T_2, which can be attributed to the lower dose of nitrogen to this treatment.

The mean values (table 8) on total potassium loss both through run off and eroded soil indicated that there was a significant higher loss of potassium from the pure crop of stylosanthes. This might be due to the higher quantities of run off and soil loss from this treatment which might have resulted in the high potassium losses. Here also T_6 recorded a lower loss of potassium, even though it is on par with intercropped plots. This can be attributed to the lower content of potassium both in run off and eroded soil from this treatment.

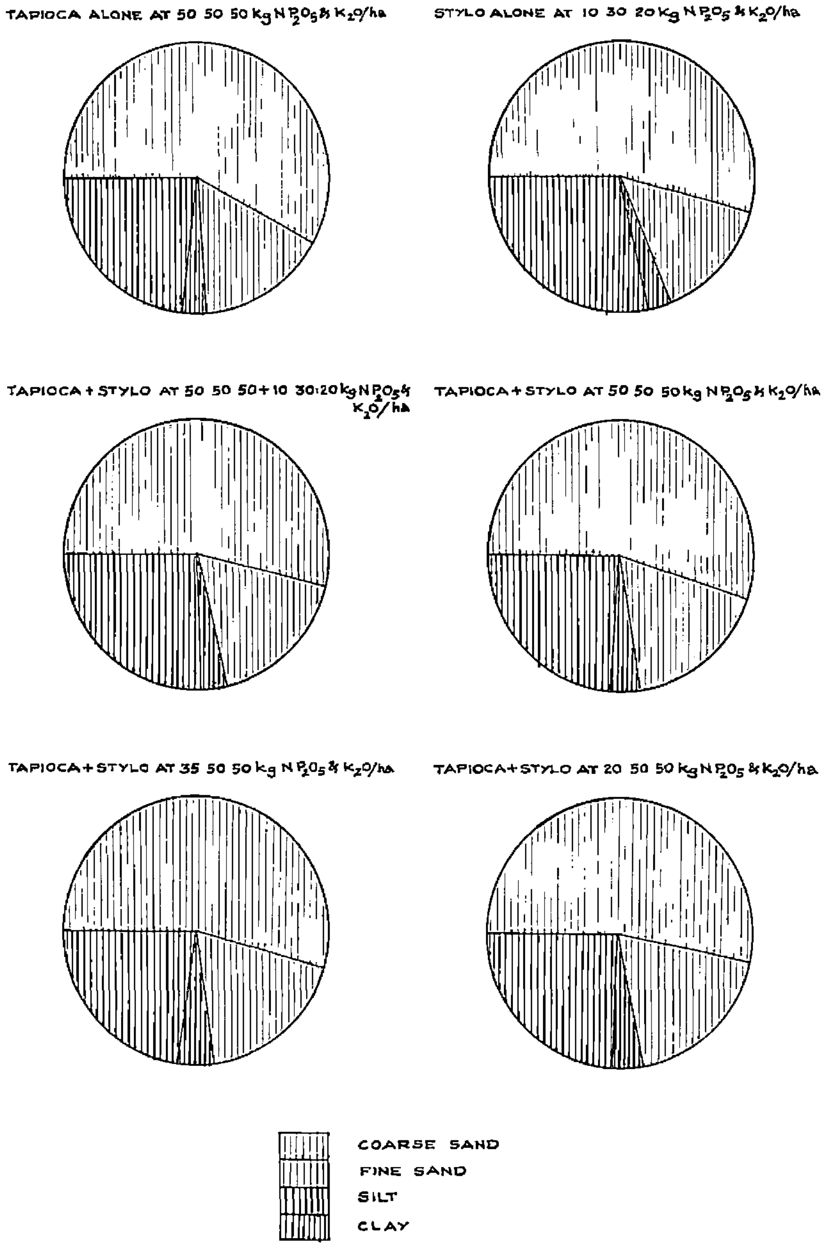
Mechanical composition of eroded soil.

A critical analysis of the data (table 9 and Fig.7) revealed that there was no significant effect due to treatments on the size distribution of particles in the eroded soil. This was in confirmation with the results reported by Meyer et al. (1980) that the presence of crop canopy did not affect the sediment size distribution of eroded particles. It is however evident that sand fraction (Coarse and fine) constitute about 75 per cent of the material eroded. This is in line with the reports of Cha a bouni (1977) Jozefaciuk et al. (1977) and Viswambharan (1980) that sand content in eroded material is higher.

Soil analysis after the experiment.

The total nitrogen content of the soil (table 10) established a significant difference due to intercropping

FIG 7 MECHANICAL COMPOSITION OF ERODED SOIL



and different nitrogen levels. The pure crop of stylosanthes registered a significantly higher total nitrogen content in the soil after the experiment. This was in confirmation with the reports of Bruce (1974); Singh and Singh (1975); Nitis (1978) and Lal (1979). Similarly it was seen that the intercropped plots under T_3 and T_4 have recorded increase in total nitrogen content as compared to pure crop of tapioca which recorded the lowest value. Increase in total nitrogen content by intercropping with legumes was reported earlier by Ravichandran (1976) and Morachan et al. (1977). The low content of nitrogen in other two intercropped plots, T_5 and T_6 might be due to the triple effects of lower dose of applied nitrogen, crop removal and erosion loss. The low content of nitrogen in plots of pure crop of tapioca might be attributed to removal by tapioca plants and lack of nitrogen fixation, as it was not intercropped.

The intercropping and levels of nitrogen showed no significant influence on the available phosphorus content of the soil after the experiment (table 10). This might be due to the uniform pattern of removal of phosphorus by crops as well as erosion.

The available potassium content of soil (table 10) recorded a significant difference due to intercropping and fertility levels. It was seen that pure crop of tapioca recorded a significantly higher level of available potassium content as compared to other treatments where stylosanthes was grown. The low level of available potassium content in stylosanthes intercropped plots might be due to increased uptake of potassium by stylosanthes. This is in line with the findings of Bruce (1974); Singh and Singh (1975) and Gillard and Edye (1979).

The mean values of cation exchange capacity (table 10) of the soil after the experiment revealed that the pure crop of stylosanthes recorded a significantly higher value when compared to other treatments except T_3 which was on par. This can be ascribed to the ability of stylosanthes in improving the cation exchange capacity of the soil as reported by Bruce (1974); Singh and Singh (1975) and Lal (1979).

Summary

SUMMARY

An experiment was conducted at the College of Agriculture, Vellayani, during the year 1981-82 to study the possibilities of reducing the fertilizer nitrogen dose for tapioca by intercropping with stylosanthes and also to study its efficiency in reducing soil erosion when intercropped with tapioca in slopy areas. The experiment with six treatments was carried out in randomised block design with four replications, under rainfed conditions. The results obtained are summarised below.

1. The growth characters of tapioca plants as observed from height, number of leaves produced per plant and functional leaves produced per plant were not influenced by intercropping and nitrogen levels at any growth stage of the crop.

2. The values of leaf area index of tapioca was significantly higher in intercropped plots where recommended dose of fertilizer was given for both the crops. But this was on par with the leaf area index of pure crop of tapioca.

3. The yield attributes of tapioca like number of roots per plant, number of tubers per plant, percentage of productive tubers, length and girth of tubers were not influenced by intercropping and nitrogen levels.

4. The tuber yield was not affected by intercropping and nitrogen levels. Even then the pure crop recorded the highest yield followed by intercropped plot supplied with 50:50:50 kg N, P_2O_5 and K_2O/ha.

5. The top yield and utilisation index were also not affected by intercropping and nitrogen levels.

6. The dry matter content of tubers were not affected by intercropping and varying doses of nitrogen application. The starch content of tuber was found to be higher in pure crop of tapioca and in intercropped treatment receiving the fertilizer dose for both the crops. Hydrocyanic acid content of tapioca tubers were increased due to intercropping and levels of nitrogen. The intercropped treatment receiving recommended fertilizer dose for both the crops recorded the maximum HCN content.

7. The nitrogen, phosphorus and potassium contents of tapioca leaves, stem and tubers were not significantly affected by intercropping and nitrogen levels.

8. The spread of stylosanthes was not influenced by intercropping and levels of nitrogen.

9. Green and dry matter yields from pure crop of stylosanthes was higher as compared to intercropped plots.

Among intercropped plots the one which received the lowest level of nitrogen gave the maximum green and dry matter yields.

10. The total crude protein yield from pure crop of stylosanthes was higher as compared to intercropped plots. The treatment that received 35:50:50 kg N, P_2O_5 and K_2O/ha recorded the highest protein yield from among intercropped plots.

11. The total quantity of run off from pure crop of stylosanthes was higher as compared to other treatments. The pure crop of tapioca also recorded the same quantity of run off as compared to pure crop of stylosanthes. The minimum quantity of run off was recorded from the intercropped plots.

12. The nitrogen and potassium contents in run off were not influenced by intercropping and nitrogen levels. Even then the highest and lowest quantities of nitrogen and potassium in run off were recorded by pure crop of stylosanthes and tapioca respectively.

13. The phosphorus content in run off was found to be in traces.

14. The pure crop of tapioca recorded a higher soil loss, followed by pure crop of stylosanthes. The

intercropped treatments recorded lower soil loss.

15. The nitrogen, phosphorus and potassium losses through eroded sediment were higher in the case of pure crop of stylosanthes.

16. Mechanical composition of eroded soil was not influenced by intercropping and nitrogen levels.

17. Total nitrogen and potassium losses both through run off and eroded soil were higher in pure crop of stylosanthes.

18. The nitrogen content in the soil after the experiment was enhanced in pure crop of stylosanthes and intercropped plots which received the higher fertilizer doses.

19. The cation exchange capacity of stylosanthes intercropped plots were found to be increased as compared to initial values.

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* Originals not seen.

Appendices

APPENDIX - I

Weather data during the crop period in comparison with the corresponding average values for the past 24 years.

Month	Rainfall (mm)		Average temperature °C				Average R.H.(per cent)	
			Maximum		Minimum			
	Crop period (total)	Past 24 years (average)	Crop period	Past 24 years	Crop period	Past 24 years	Crop period	Past 24 years
July	125.50	220.90	30.00	29.72	22.90	23.46	93.50	87.19
August	268.50	130.63	29.73	29.77	22.90	23.22	93.00	86.02
September	312.00	150.28	29.35	30.12	21.60	23.66	94.50	89.77
October	335.00	264.13	29.60	29.70	21.90	23.76	94.10	87.41
November	253.50	208.05	30.90	29.91	22.80	23.81	93.70	86.97
December	11.50	71.85	29.60	30.66	21.60	23.26	84.38	84.78
January	-	34.62	32.01	30.93	20.33	22.46	79.31	79.88
February	-	36.00	29.65	31.34	19.26	22.87	81.12	82.05
March	16.50	35.06	33.88	32.17	22.82	24.00	79.93	81.36
April	73.00	89 .16	32.99	32.27	24.42	25.02	76.15	83.29

APPENDIX - II

Quantity and maximum intensity of rainfall during the experimental period.

Sl.No.	Quantity of rain received (mm)	Maximum intensity at 15 minutes interval (mm/hr)
1	20.00	14
2	24.00	35
3	30.50	28
4	74.00	55
5	20.00	18
6	24.00	40
7	29.00	22
8	54.00	52
9	86.50	40
10	52.25	78
11	21.50	11
12	21.50	24
13	38.50	34
14	33.25	26
15	85.25	64

APPENDIX - III

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

Source	df	Mean square				
		I month	II month	III month	IV month	V month
Block	3	8.601*	147.201**	42.352	760.982*	1046.550*
Treatment	4	0.920	17.668	40.129	391.905	601.419
Error	12	2.100	22.969	37.386	185.291	291.906

Source	df	Mean square				
		VI month	VII month	VIII month	IX month	Harvest
Block	3	1144.903	1309.896	1148.599	1052.195	1035.256
Treatment	4	945.851	1121.895	1194.077	1291.810	1343.878
Error	12	524.120	569.424	591.715	504.357	559.700

* - Significant at 0.05 level

** - Significant at 0.01 level.

APPENDIX - IV

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

Source	df	Mean square				
		I month	II month	III month	IV month	V month
Block	3	0.019**	0.037	0.043	0.225**	0.075
Treatment	4	0.012**	0.170**	0.819**	1.051**	0.817**
Error	12	0.001	0.014	0.020	0.035	0.091

Source	df	Mean square				
		VI month	VII month	VIII month	IX month	Harvest
Block	3	0.065*	0.019*	0.016**	0.017*	0.012*
Treatment	4	0.252**	0.183**	0.156**	0.106**	0.087**
Error	12	0.017	0.003	0.001	0.003	0.002

* - Significant at 0.05 level

** - Significant at 0.01 level.

APPENDIX - V

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

Source	df	Mean square							
		Number of roots per plant.	Number of tubers per plant.	Percentage productive tubers.	Length of tuber	Girth of tuber,	Tuber yield	Top yield	Utilization index
Block	3	10.091	4.327	14.077	23.109	1.077	47051100.2	14911625.3	0.164
Treatment	4	7.043	1.601	21.129	27.667	1.463	99454401.4	19477187.3	0.044
Error	12	7.307	4.292	32.214	22.257	1.183	72864372.4	9989141.2	0.090

b. Abstract of analysis of variance table for starch and HCN content of tapioca tubers.

Source	df	Mean square	
		Starch	HCN
Block	3	0.352	7.379**
Treatment	4	0.791**	13.500**
Error	12	0.120	0.483

* - Significant at 0.05 level

** - Significant at 0.01 level.

APPENDIX - VI

Abstract of analysis of variance table for height and spread of stylosanthes.

Source	df	Mean square					
		I cut		II cut		III cut	
		Height	Spread	Height	Spread	Height	Spread
Block	3	199.157	174.901	136.648	240.245	316.080**	391.899**
Treatment	4	574.006**	568.738	18.820	155.401	90.174	53.616
Error	12	63.850	180.165	60.297	152.054	35.729	33.832

** - Significant at 0.01 level.

APPENDIX - VII

Abstract of analysis of variance table for yield of stylosanthes.

a. Green matter.

Source	df	Mean square			
		I cut	II cut	III cut	Total
Block	3	5143056.210	3905092.410	562384.193	17044791.300
Treatment	4	64563715.600**	43693064.900**	5552431.450**	285691356.600**
Error	12	5950057.860	3057871.380	551967.807	19048269.500

b. Dry matter

Source	df	Mean square			
		I cut	II cut	III cut	Total
Block	3	475828.268	570058.838	489983.221	2572210.310
Treatment	4	3568509.400**	2336800.470**	4386215.250**	29846957.700**
Error	12	416849.390	169176.685	460922.369	2172889.350

** - Significant at 0.01 level.

APPENDIX - VIII

Abstract of analysis of variance for crude protein content of stylosanthes.

Source	df	Mean square			
		I cut	II cut	III cut	Total
Block	3	0.033	0.739	0.566	1.973
Treatment	4	11.240**	0.348	0.885	19.651**
Error	12	1.683	0.795	0.693	2.784

** - Significant at 0.01 level.

APPENDIX - IX

Abstract of analysis of variance table for runoff, soil and nutrient losses.

Source	df	Mean square						
		Total runoff	Total soil loss	Nitrogen content in runoff	Potassium content in runoff	Nitrogen content in eroded soil	Phosphorus content in eroded soil	Potassium content in eroded soil
Block	3	16294.946	176592.166	5.007	0.0046	1.163	0.00200	0.080
Treatment	5	129474.468*	70924381.900**	42.816	0.0606	56.224**	0.00560**	2.382**
Error	15	28583.910	72407.746	25.974	0.1330	0.500	0.00067	0.104

Source	df	Mean square	
		Total nitrogen loss	Total potassium loss
Block	3	10.107	0.0791
Treatment	5	93.357*	2.4510**
Error	15	23.783	0.2070

* - Significant at 0.05 level

** - Significant at 0.01 level.

APPENDIX - X

Abstract of analysis of variance table for quantity of soil eroded (individual observation).

Source	df	Mean square				
		I	II	III	IV	V
Block	3	176.707	1471.562	64095.806	276443.923	842.878
Treatment	5	3503.710*	115032.995**	506571.778**	3801586.640**	80239.174**
Error	15	1087.670	2203.475	34642.249	202150.301	1728.401
		VI	VII	VIII	IX	X
Block	3	3720.374	2589.631	1312.349	1697.099	1459.756
Treatment	5	50607.340**	285242.038**	558847.759**	1845812.030**	489824.649**
Error	15	3605.159	4465.596	3674.070	3123.841	4249.684
		XI	XII	XIII	XIV	XV
Block	3	73.318	215.987	586.729	1142.098	1251.760
Treatment	5	452487.399**	198771.889**	272642.095**	484008.316**	1969977.370**
Error	15	3406.263	1549.433	1391.785	2678.785	2351.298

* - Significant at 0.05 level

** - Significant at 0.01 level

APPENDIX -- XI

a. Abstract of analysis of variance table for mechanical composition of eroded soil

Source	df	Mean square			
		Per cent coarse sand	Per cent fine sand	Per cent silt	Per cent clay
Block	3	60.692**	2.976	2.224	66.527**
Treatment	5	14.943	8.670	1.067	10.741
Error	15	6.171	5.083	2.589	5.936

b. Abstract of analysis of variance table for soil chemical properties after the experiment.

Source	df	Mean square			
		Total nitrogen	Available phosphorus	Available potassium	Cation exchange capacity
Block	3	0.00002	6.250	211.10*	0.132
Treatment	5	0.00030*	23.366	250.00**	1.541**
Error	15	0.00007	19.616	47.77	0.239

* - Significant at 0.05 level

** - Significant at 0.01 level.

NITROGEN ECONOMY AND SOIL CONSERVATION IN TAPIOCA-STYLO INTERCROPPING SYSTEM

BY

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ABSTRACT OF A THESIS
SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE DEGREE
MASTER OF SCIENCE IN AGRICULTURE
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

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VELLAYANI, TRIVANDRUM

1983

ABSTRACT

An experiment was conducted at the College of Agriculture, Vellayani, during 1981-82 to study the possibilities of reducing the fertilizer nitrogen dose for tapioca and the efficiency of reducing soil erosion in slopy areas when intercropped with stylosanthes. The experiment was carried out in a randomised block design with four replications under rainfed condition.

The results revealed that growth characters and yield attributing characters were not influenced by stylosanthes intercropping and nitrogen levels. Even though numerically the tuber and top yields were lower in intercropped plots, statistically no significance was observed due to intercropping and levels of nitrogen. The utilisation index also was not influenced by intercropping and nitrogen levels.

Among the quality attributes of tapioca, starch content of tuber was adversely affected by intercropping at low levels of nitrogen, whereas hydrocyanic acid content was influenced by intercropping at higher levels of nitrogen.

The spread of stylosanthes was not affected by intercropping and nitrogen levels. The maximum fodder and crude protein yields were obtained from pure crop of stylosanthes.

The nutrient contents in tapioca and stylosanthes were not affected due to intercropping and levels of nitrogen.

The pure crop of stylosanthes recorded a maximum quantity of run off as compared to intercropped plots, which recorded minimum run off. The nutrient content in run off was not influenced by intercropping and nitrogen levels.

The soil loss was maximum in pure crop of tapioca whereas intercropped plots recorded the minimum loss. The loss of nutrients through eroded sediment was higher from plots of pure crop of stylosanthes as compared to intercropped plots.