STUDIES ON THE EFFECT OF MULTIPLE CROPPING ON SOIL FERTILITY AND CROP YIELDS IN WET LAND

By

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THESIS

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D E C L A R A T I O N

I hereby declare that this thesis entitled "Studies on the effect of multiple cropping on soil fertility and crop yields in wet land" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar titles of any other University or Society.

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Place: Vellayani,

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INTRODUCTION

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The economic life of a nation is dependent upon the quantum of material resources and their judicious exploitation. This is true both in Agriculture and in Industry.

Indian Agriculture enjoys rich endowments of vast soil and water resources, favourable temperature and abundance of sunshine all the year round and a large farm labour force. India has the highest percentage of cultivated land in the world. Even with all these resources, we are unable to produce sufficient food to feed the entire people. This situation is further aggravated by the ever increasing population in the country.

The increase in food production can be achieved by (1) increasing the area under cultivation (2) increasing the yield per unit area and (3) utilising the time factor. With the limitation of land and increasing population, the most suitable strategy seems to be to increase the yield potential of the crop per unit area per unit time. The technique of multiple cropping makes use of this time factor by increasing the area per year and by increasing the yield per year.

Multiple cropping is a system under which two or more annual crops are grown and harvested in the same piece of land in an year. Multiple cropping therefore, utilises the available land to its utmost; but calls for skillful and careful farming to avoid exhausting the land. Multiple cropping not only helps to increase the income of small farmers but also generates considerable additional employment. Multiple cropping in essence is a philosophy of maximum crop production per unit area of land within a calender year or other relevant time span with minimum soil deterioration. The concept has been developed from the revaluation of modern principles of soil management evolved from the experience of short and long term studies on crop rotation. In its simplest form, multiple cropping is a one year cropping system in which two or more crops are grown in succession on the same area. It is a unique asset of tropics and sub-tropics and can be an effective instrument in increasing the income potential of small holdings, banishing unemployment and under-employment, achieving stability of production in both irrigated and unirrigated areas, improving human nutrition and improving animal husbandry.

Unlike the temperate zones where climatic conditions permit crop production only during summer months, the tropical and sub-tropical climates allow an year round crop growth. Because of this fact, the tropical and sub-tropical regions contain the World's greatest potential reserves which still remain to be fully exploited. India is thus fortunate enough to have abundant solar energy all the year round, favourable temperature and a great variety of soil, climate and crops. Even the high population and small sized farms can be a blessing from the point of view of labour-intensive farming. Greatest potentialities for increased agricultural production exist in India through wide use of cropping systems which keep the photosynthetic factory operating at high efficiency throughout the year.

No other country of the size of India has so much of irrigation potential available for raising crops. But this irrigation potential has not so far contributed significantly to the intensity of cropping. There is considerable scope for better utilisation of existing irrigation potential for multiple cropping. The average cropping intensity in our country is just about 115 per cent. This is very low as compared to the cropping intensities of other Asiatic countries like Taiwan (180 per cent), South Korea (151 per cent), Pakistan (137 per cent) and Japan (120 per cent). But India is planning to attain an average cropping intensity of 150 per cent by 1980-81 in all the irrigated areas. This is possible only by bringing more and more irrigated area under multiple cropping. Multiple cropping is not only the method of increasing the production and productivity per unit area per unit time but also is a means of absorbing the additional rural man power. In the context of land ceiling in India, the emphasis on multiple cropping programme will be still greater.

Multiple cropping is a triple edged sword. If it works well, it can solve the problem of deficit production, poverty and unemployment. Extension of irrigation, evolution of short duration photo-insensitive varieties of crops and credit facilities are definite catalysts for adopting multiple cropping. It is an index of assessing the efficiency of farmer. (Minimum tillage, judicious fertilisation, timely and quick field operations and sowing, and scientific knitting of crops constitute bases for multiple cropping.)

As enunciated by Melsted (1954) the philosopy of multiple cropping is one of maximum crop production with minimum soil deterioration. This philosophy is based on the concept that high production is good for soil, that minimum tillage promotes soil tilth and conserve soil organic matter, that high fertility promotes high yields and lessens the loss of soil humus and that large amounts of decomposable organic matter in the soil are essential for good tilth and soil physical condition. Soil is no more considered as a source of fertility; but is regarded as the medium of plant growth.

Precise scientific information on high intensity cropping is of vital importance. As the intensity of cropping increases, the crop yield is likely to go down unless adequate quantities of plant nutrients are added to the soil. It is therefore highly essential to carry out research work on the cultural and manurial requirements of high intensity crop rotations taking into account the preceding and suceeding crop. These research activities are to be carried out in different agro-climatic conditions in order to find out the most economic cropping pattern to be recommended to the cultivators of a particular agro-ecological situation. The applicability of research findings on multiple cropping pattern will depend upon the biological possibility, economic desirability and practical feasibility which in turn indicate what could be aspired, what could be gained and what could be adopted by the farmers with the help of current technology.

Of all the food crops grown in India, rice is the most important one. Till recently a single crop of rice was grown in most of the rice growing tracts on account of the long duration of the varieties and lack of irrigation facilities. But with the introduction of short duration, photo insensitive, fertiliser responsive dwarf varieties of rice, coupled with the recent concept of minimum tillage in crop production and with increase in irrigation facilities multiple cropping is being recommeded to the rice farmers.

It hardly needs to be emphasised that continuous intensive cropping following a multiple crop rotation is not an unmixed blessing. These changes in cropping systems will undoubtedly affect the fertility status of the soil after each crop and this require fertiliser management for the crops involved including rice. It also leads to numerous problems of plant protection and energy shortage. Real technical help is needed to ensure continuous maximum productivity per unit land per unit time without any impairment of soil fertility and without build up of any pests and diseases. It has changed the basic concept of farming from subsitence farming to business farming based on sound principles of economics and technology. Yet another important consideration should be of soil exhaustion and consequently, devising suitable cropping patterns and manurial practices which replenish the soil. These cropping pattern should be developed taking into account various agro-ecological situations in India.

The present study entiled 'Studies on the effect of multiple cropping on soil fertility and crop yields in wet land' was undertaken in the field and laboratory with the following objectives:

i) to find out the most suitable and efficient cropping pattern which produce the maximum yield and dry matter production per unit area per unit time with optimum utilisation of various inputs and natural energy source.,

ii) to determine the effects of various crops in a cropping pattern on the fertility status of the soil.,

iii) to find out the uptake of major plant nutrients by different crops in various cropping patterns.,

iv) to work out the balance sheet of plant nutrients in various treatments as an index of soil fertility maintenance.,

v) to find out the changes in soil physical properties due to multiple cropping., and

vi) to work out the economics of various cropping patterns.

Further, valuable information on the problems to be tackled and prospects to be aspired are expected to emanate from this study. Such findings will help in further refinement of the agro-techniques and in transforming the concept into strategy of practical feasibility for the future.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A detailed review on the various aspects of multiple cropping from the point of view of its effects on soil fertility, crop yields and economic feasibility under the wet land conditions is presented hereunder.

A. Physico-chemical properties of rice soil.

No other crop in India is cultivated under so much diverse soil and climatic conditions as rice. It is grown in low valleys very near to or even lower than the sea level (as in Kuttanad) up to an altitude of 1600 m above the sea level (as in Kashmir).

The bulk of the rice crop is grown under submerged soil where anaerobic conditions exist. Flooding differentiates rice soils physically, chemically and biologically from all other soils (Pearsall, 1950, Mitsui, 1955 and Ponnamperuma, 1965). This condition affects the nutrient absorption by the rice plant as well as its growth. The availability and loss of nutrients are also influenced by submerged conditions. Majority of rice soils in India are low in nitrogen and phosphorus, but are generally well supplied with potassium.

I. Nutrient transformations in rice soils.

(a) Nitrogen.

In aerobic soils, the product of mineralisation of organic nitrogen is nitrate (NO_3), whereas in submerged soils it is ammonium (NH_4). This ammonium accumulates in submerged soils. Concentration of total ammoniacal nitrogen upto 300 ppm have been reported in submerged soils within 20 days of flooding (Ponnamperuma, 1965).

Ammonium from fertilizers broadcast on the soil surface or that diffusing upwards to the zone in which the pE is high, is rapidly converted to nitrate by nitrifying bacteria. The nitrate moves by mass flow and diffusion into the anaerobic zone and is denitrified. Ponnamperuma (1965) further reported that nitrate is extremely unstable in mineralised condition and within a few days of submergence, the bulk of native or added nitrate is lost as nitrogen (N_2) by denitrification. The loss of nitrogen by denitrification in flooded soil can be minimised by keeping the soil continuously flooded (Castro and Lantin, 1976). This is one reason why submerged soils are more fertile than upland soils (Ponnamperuma, 1975).

(b) Phosphorus.

It is known that rice grown under submerged conditions does not respond to phosphorus in some soils, whereas upland crops show a response to this nutrient. The lack of response is due to increase in the availability of phosphorus following soil submergence. The main reactions involved in the change of availability are: reduction of ferric phosphate to more soluble ferrous phosphate and hydrolysis of iron and aluminium phosphates at the dissolving of apatite because of higher carbon di oxide pressure in the soil solution. Among these reactions, the reduction of ferric phosphate to ferrous phosphate appeares to be dominant (Patrick and Mahapatra, 1968, Chang,1971 and Ponnamperuma,1972). Chang (1965) demonstrated that iron phosphate was the main source of phosphate absorbed by the rice plant under submergence in acidic and calcarious soils by directly measuring the quantity of phosphorus absorbed from each chemical form of inorganic phosphate.

Ponnamperuma (1972) studied the kinetics of water soluble phosphorus in submerged soils and found that under submergence the concentration of water soluble phosphorus increased with time upto six to eight weeks, after which it showed some decrease. The increase of soluble phosphorus was markedly affected by the properties of soils. The rate of increase and the peak values were the lowest in acidic clays rich in iron. This phenomenon could possibly be the result of a secondary reaction between the dissolved phosphate and the iron compound. If insoluble phosphates are added to acidic soil, small particles will dissolve first and behave like soluble phosphates in the transformation process. The insoluble phosphates of the larger particles will remain as such for a long time (Gachon, 1973).

Contrary to the above, Primavesi and Primavesi, (1971) reported that the level of phosphorus was not affected or remained practically constant under submerged conditions in rice soils.

(c) Potassium.

For a fast growing crops, the intensity of potassium supply is of primary importance. This depends on the concentration of potassium in the soil solution which is in equilibrium with the potash reserve in the interchangeable form. The release of exchangeable potassium to the soluble form is enhanced under the flooded conditions. Clark and Resnicky (1956) observed an almost doubled potassium concentration in the soil solution. Increases of this order were obtained at the International Rice Research Institute, Philippines (I.R.R.I.) in several soils which were kept submerged (Anonymous, 1963 and Ponnamperuma, 1965). The increase in dissolved potassium reached a maximum at the peak of reduction and was highest in the sandy soils rich in organic matter.

Sturgis (1957) reported that the availability of soil potassium increased by flooding particularly as the temperature of water increased. Ponnamperuma (1965) also observed a slight increase in the exchangeable potassium after submergence, the increase being highest in strongly acid, latosolic soils rich in active Fe^{++}. He attributed this phenomenon to the increased efficiency of extraction due to the dispersion of soil particles which were previously bound by ferric compounds before their reduction and solubilization. The increase in the solubility of potassium under flooded conditions should result in its greater availability as well as in higher leaching loss.

Part of the potassium added to the soil over a period of years is converted to soluble, available form. Drying of soil as well as the nature and particle size of clay are responsible for potassium fixation (Volk,1934). The fixation of potassium applied to Taiwan soils was studied by Chang and Feng (1960). They found that there was little fixation in two acid latosolic soils, more in a slightly acid sandstone and shale alluvial soil and considerable fixation in calcareous slate and alluvial soils. These soils had textures ranging from silty clay loam to silt loam.

Wu (1960) showed in pot culture studies that rice plants under submerged conditions can absorb a larger percentage of their total potassium requirement from the non-exchangeable form than that under upland conditions. In other words, the rate of replacement from non-exchangeable to exchangeable potassium is more rapid under submerged conditions than under upland conditions. According to Mahapatra and Rajendraprasad (1970) an exchangeable potassium content of about 0.2 m.e./100 g of soil is considered to be a satisfactory level for rice.

Results reported from I.R.R.I.(1963) showed that the concentration of potassium in the soil solution could be almost doubled as a result of displacement of potassium from the clay complex. The increases were highest in the sandy soil rich in organic matter and seemed to be associated with the amount of soluble iron and manganese.

However, Primavesi and Primavesi (1971) reported irregular increase in potassium levels under submerged conditions in dry soils.

(d) Calcium.

Nambiar (1947) studied the percentage of total bases in the exchangeable form in some typical rice soils of Kerala and found that the percentage of calcium was much higher in wet land soils than in dry cultivated soils. As in the case of potassium, submergence increased the availability of calcium due to its displacement from the soil complex and due to exchange with Fe^{++} (Pearsall,1950; Chatterjee,1964; Thenabalu,1966; Mahapatra,1968 and Islam and Islam,1973). Mahapatra (1968), studying the effects of flooding on the mobilization of nutrients, found that water soluble calcium increased by water logging.

According to Kabeerathumma (1975), flooding resulted in an increase of exchangeable calcium in most cases which reached a peak in about 30 to 50 days afterwhich there was a decrease. Primavesi and Primavesi (1971) reported irregular increase in calcium under submerged conditions in dry soils.

(e) Magnesium.

The behaviour of magnesium in submerged soils is similar to that of potassium and calcium. Submergence increases the availability of magnesium due to its displacement from the soil complex and due to exchange with Fe^{++} (Pearsall,1950; Chatterjee,1964; Thenabalu,1966; Mahapatra,1968 and Islam and Islam,1973). However, Ghosh *et al*. (1973) found that *Kari* soils of Kerala which are also submerged have a low amount of calcium and magnesium.

II Soil pH.

One of the important physico-chemical properties or processes that control fertility is soil pH. The pH of a submerged soil exerts a marked influence on its capacity to supply nutrients through direct effect on nutrient absorption, direct effect on the concentrations of nutrients or toxic substances in the soil solutions, indirect effect on chemical equilibria and sorption and desorption, and the influence on microbiological processes connected with the release as well as loss of plant nutrients. Singly or in combination, these effects profoundly influence the absorption by the rice plant of both macro- and micronutrients in submerged soils.

The pH of a soil has a marked direct influence on the concentrations of iron, manganese and aluminium in submerged soils. The practical implications of pH - Fe^{++} relationships on the fertility of submerged soils are: (i) at high pH values, rice suffers from iron deficiency and (ii) at low pH values it is affected by iron toxicity (Ponnamperuma,1955 and Tanaka and Yoshida,1970), and potassium and phosphorus deficiencies induced by excess Fe^{++} (Yamada,1959). High concentration of aluminium and manganese are common causes of crop failure in acid, aerobic soils. Except in certain acid sulphate soils, aluminium toxicity disappears within a few weeks of soil submergence because of an increase in pH.

As a result of submergence, pH of acid soils increase and pH of calcarious and sodic soils decrease resulting in an increase in the availability of phosphorus. This is one of the benefits of flooding rice soils (Ponnamperuma,1965). Cation absorption by root reaches its maximum at pH 5 to pH 7, while anion absorption decreases above pH 6 (Moore,1972). Increasing the pH of a submerged soil decreases the concentration of Mg^{++}, Ca^{++} and Mn^{++} apparently through carbonate equilibria involving these ions.

It is difficult to study the effect of pH on microbial processess in submerged soils, because of the spontaneous pH changes occuring in them. But the increase in the rate of ammonification brought about by liming some acid sulphate soils of Thailand seems to confirm the adverse effect of low pH on ammonification. Denitrification also is slow below pH 5.5 (Alexander,1961). This may account for the persistance of nitrate for several weeks in submerged acid soils (Ponnamperuma,1955).

From the stand point of soil fertility, the optimum pH for rice (measured in the solution of submerged soil) is about 6.6. At this pH, the microbial release of nitrogen and phosphorus from soil organic matter as well as the availability of phosphorus are high, the supplies of copper, zinc and molybdenum are adequate, and the concentrations of substances that interfere with nutrient uptake (such as aluminium, manganese, iron, carbondioxide and organic acids) are below the toxic level. Soil and water management practices should therefore be directed towards attaining a pH of 6.6 at planting and maintaining this level at least until panicle primordia initiation.

III <u>Cation exchange capacity</u>.

Submerging a soil brings into solution large amounts of ions through soil reaction, NH_4^+ production and the solvent action of carbon dioxide production on carbonates. These ions increase specific conductance and the toxic strength of the soil solution.

Nambiar (1947) on a study of some typical rice soils of Kerala observed that calcium formed the principal releasable base followed by magnesium, sodium and potassium. The low level of exchangeable calcium on the surface soil was attributed to the continuous leaching by heavy rains as shown by the increase in the exchangeable calcium in the subsurface soils. He also reported that cation exchange capacity showed vide variations ranging from 3.04 to 73.4 m.e./100 g.

In aerobic soils, ion exchange plays an important role in the replenishment of the soil solution, with anions and cations absorbed by plant roots. It also plays an important role in increasing the fertility of acid soils by liming and of saline and sodic soils by leaching. In submerged soils, the large amounts of Fe^{++} and Mn^{++} brought into solution displace cations from the clay complex increasing the concentrations of NH_4^+, K^+, Ca^{++} and Mg^{++} in soil solution. The slight increase in the concentrations of water soluble potassium brought about by cation exchange may not be significant in rice nutrition. But, the loss from the soil of Ca^{++} and Mg^{++} displaced from the soil colloids into the solution may lead to soil acidification by ferrolysis (Brinkman,1970).

Sreedevi and Aiyer (1974) reported that Kari soils had the highest cation exchange capacity among the different acid rice soil types of Kerala.

IV <u>Exchangeable hydrogen</u>.

Acidity in soils is associated mostly with the presence of hydrogen in an exchangeable form. The exchangeable hydrogen not only indirectly controls the pH of soil solution, but also determines the quantity of lime or acidic constituents necessary to bring about a given pH change.

According to Kawaguchi and Kawachi (1969), during flooding and drying of soil, corresponding movements of Fe^{++} into and away from the soil exchange complex occurred. Some of the cations previously desorbed from the soil particles then returned to the original sites; the remainder were occupied by Al^{+++} and H^{+}.

Kabeerathumma and Nair (1973) reported that the soils of Kuttanad are highly acidic and have a high concentration of exchangeable hydrogen and aluminium.

V <u>Organic carbon</u>.

The two main transformations of carbon in nature are photosynthesis and respiration. In submerged soils, respiration (decomposition of organic matter) is the main transformation.

In submerged soils, decomposition of organic matter is almost entirely the work of facultative and obligate anaerobes. Since anaerobic bacteria operate at a much lower energy level than aerobic organisms, both decomposition and assimilation are much slower in submerged soils than in aerobic soils. The accumulation of plant residues in marshes and in under-water sediments (Degens, 1965) illustrates this point.

Koshy and Varghese (1971) reported that the Kari soils contained a high percentage of organic carbon. Ghosh et al. (1973) found a high percentage of organic carbon in Kari soils of Thottapalli and swamp soils of Kattampally. Santhakumari (1975) studying the morphological and physico-chemical properties of Karapadam soils of the Kuttanad region of Kerala State reported that the organic carbon content varied from 0.79 to 4.09 per cent and nitrogen varied from 0.11 to 0.5 percent. Carbon - nitrogen ratio varied between 6.58 and 18.33. Menon (1975) observed significant negative correlation between organic carbon and pH in Kayal soils of Kuttanad of Kerala. He got a significant positive correlation between organic carbon and electrical conductivity.

Pearsall (1950) observed that the reducing conditions prevailing in water logged soils accelerate ammonification as a result of which nitrogen escapes from the soil. Further, the oxidation of carbonacious materials is at a very low pace and thus the C/N ratio of the soil widens. Koshy (1970) found that the ratio of carbon to nitrogen in four typical rice soils of Kerala ranged from 12.17 in a submerged soil to 23.67 in Kari soil.

VI Soil structure.

Experiments conducted in India and abroad have clearly indicated that the continuous cultivation of rice under submerged conditions brings about a distortion in soil structure. Sturgis (1936) observed that continued practice of irrigation to rice causes the development of deflocculation of soil colloids and of other poor physical conditions. The structure and mottling patterns in the drained field and flooded soils were studied by Grant (1964). He observed that puddling dispersed the particles and they were coated with a thin film of water which acted like a cushion. The coating acted as a buffer between rhizosphere and actively reducing minerals. A seperate 'particle structure' (not identical to single grain structure as described in the USDA manual by the United States Department of Agriculture) is formed in the lower ploughed layer. The finer particles were held in suspension and this platy or laminar horizon was observed at the surface. Kumar and Ghildyal (1969) from a pot culture study, observed the effect of soil types and organic matter on the regeneration of puddled structure in lateritic sandy clay loam. Soil aggregation was observed to be a function of the nature of organic material and not of organic carbon content of soil.

VII Bulk density.

Bulk density of soil is closely related to soil structure. Better the structure, lower the bulk density and hence a negative correlation.

Ghosh *et al*.(1973) reported that the bulk density of waterlogged *Kari* soils of Kerala varied from 1.24 to 1.46.

B. Effect of monoculture of rice on soil fertility and crop yields

Long term experiments have revealed that every soil is exhausted by continuous cropping and as such, yields decline appreciably. This is also true with rice cultivation. Continuous cultivation of rice with the addition of fertilizers produces good yields for few years, but later on causes deterioration in soil fertility and depression in yield. Deliterious after-effects of monoculture of rice can increase the soil acidity and cause appreciable deterioration in soil fertility (Lin,1955). In an experiment on multiple cropping with five cropping patterns, Sadanandan and Mahapatra (1972 f) reported decrease in soil pH in rice-jute and rice-rice cropping patterns. They further observed significant increase in the exchangeable hydrogen status of soil after *dalua* and *kharif* rice (Sadanandan and Mahapatra, 1973a)

Mohant and Singh (1969) showed that continuous cultivation of rice decrease the water stable aggregates and organic matter content of soil. Such deteriorating effect on soil structure was reported by Padmaraju and Deb (1969) also. In a field experiment at Cuttack, Sadanandan and Mahapatra (1974 a) observed that continuous cropping of rice (rice-rice rotation) had deteriorating effect on soil structure. Sadanandan and Mahapatra (1970) reported increase in bulk density after the rice crops. This was explained as due to reorientation of soil particles during puddling operations, resulting in decrease in porosity and increase in bulk density.

In an experiment with continuous crops of dwarf rice, Prasad and Jha (1973) observed that there was little change in C/N ratio; but organic carbon was significantly reduced by cropping. Sadanandan and Mahapatra (1975) reported maximum decrease in organic carbon content of soil in continuous cultivation of rice as compared to other cropping patterns.

According to Sadanandan and Mahapatra (1972 a), the potash content of soil decreased after the completion of each crop cycle, the maximum decrease being noticed in the monoculture of rice. On the other hand, there was an increase in the total phosphorus content of soil after the first year; but no change after the second year (Sadanandan and Mahapatra,1972 b). With regard to the available phosphorus content of soil, Sadanandan and Mahapatra (1972 c) observed a slight decrease after dalua rice and an increase after kharif rice, in a rice-rice cropping pattern continuously for two years.

Experiment conducted for two years revealed that exchangeable calcium status of soil decreased with continuous cultivation of rice (Sadanandan and Mahapatra,1972 d). However, a slight gain in exchangeable potassium status was observed in rice-rice rotation for two years (Sadanandan and Mahapatra, 1974 b)

To monitor changes in the capacities of rice soils to NPK over a period of intensive cropping, fertilizer trials were conducted for ten consecutive cropping seasons (1968 to 1972) at three experiment stations of the Philippine Bureau of Plant Industry. At all locations, the efficiency of nitrogen use was highest in the first crop and declined with successive croppings. For phosphorus, the trend was opposite. Phosphorus responses were greater with potash application especially in dry seasons. In areas where one crop per year is grown with adequate nitrogen supply, responses to phosphorus and/or potash may be marginal. However, responses may become marked under intensive rice cultivation (De Datta and Gomez,1975). Pagel and Insa (1975) opined that response to nitrogen increased with duration of usage of soil.

Although deleterious effects of continuous cropping of rice on soil fertility have been reported by several workers, there are instances where soil fertility showed marginal improvement. Sethi *et al.*(1952) reported that their experimental findings did not show bad after-effects of continuous cultivation of rice with fertilizers. The results of an eight year experiment at Central Rice Research Station, Cuttack confirmed the above finding. There was no deleterious effect on the fertility status of soil at the end of eight years (Vachhani *et al.*, 1963; Chaudhry and Vachhani,1965). Continuous cultivation of rice with organic manures increased the organic carbon and total nitrogen content of soil and thus built up soil fertility. Ample evidences are available to show that the chemical properties and microbial population of soil tend to remain at different equlibrium levels depending on the cropping sequences (Singh,1969). By proper management practices, physical properties of soil also could be maintained under intensive cropping (Prabhakaran,1970).

C. Growing more than one crop during an year.

History reveals that double cropping was practiced in India as early as 1000 B.C. In Vedas we find words like 'Purvavaha' (first sown) and 'Aparvaha' (later sown) indicating the existance of the practice of double cropping. In China, mention of double cropping is seen during 530 - 580 A.D. Double cropping in North China centered around wheat, whereas in South, rice was the principal crop. In Japan, planting of a second grain crop on rice fields dates back to 18th centuary.

The old series of permanent manurial trial of Tamil Nadu Agricultural University, Coimbatore which started in 1909 under irrigated conditions has a cropping system comprising of three crops a year. While the practice of double cropping is not new to Indian Agriculture particularly in irrigated areas, scientific multiple cropping has comparatively recent history. It was only towards the early nineteen sixties, the preparatory phase of the third five year plan, that double and multiple cropping received due recognition in national planning. The practice of multiple cropping is becoming more and more popular in other countries like Taiwan, Indonesia, Korea, Laos, Malaysia, Vietnam, Nepal, Ceylon, Egypt, Burma, Iran, Iraq, Philippines and Mexico.

'How would soil physical factors be affected in a multiple cropping system?' was often the question raised by Agronomists and farmers. Bullen (1967) has indicated certain reduction in yields when cereals were grown intensively, which could be restored by soil management practices. Singh (1969) stated that any damage from intensive cropping is temporary and can be corrected by changing the soil management system which provides greater return of organic residues, less frequent tillage and perhaps, more deep rooted crops.

D. Cropping patterns suited to rice areas.

Rice is the staple food crop of India. Currently, rice is grown in 39.69 million hectares of land. The low lying rice fields which remain submerged for six to eight months during the year, limit the possibility of growing any crop other than rice. Till recently, in most of these areas only a single crop of rice was being taken. But with the introduction of short duration, high yielding varieties of rice, cultivators have started raising more number of rice crops from the same piece of land within a period of one year.

Several experiments have been conducted in India to find out rice-based cropping sequences suited to different agro-ecological situations. According to Sadanandan and Mahapatra (1972 e) the maximum net profit per hectare was obtained from potato-rice-rice during the years 1967-68 and 1968-69 at the Central Rice Research Station, Cuttack. Trials conducted for three years by Misra *et al*.(1973) revealed that from economic point of view, the pattern rice-maize-green gram was the best, followed by rice-chillies, for the irrigated medium lands of Orissa. Sahu (1973 a) recommended the following rice-based multiple cropping patterns for the different soil and climatic conditions of Orissa:

For coastal tracts	: Jute-rice.
For central table land	: Rice-mustard-rice.
For eastern ghat region	: Rice-potato-wheat/sesamum.
For Hirakud irrigated area	: Rice-mustard-groundnut; rice-hybrid maize-groundnut-wheat; Rice-potato-onion/ groundnut.
For low land under well drained condition	: Jute-rice-rice/mung; Green manure-rice-rice/ pumpkin/pulse; Arum-rice-follow under water logged condition rice-mung/sesamum.

A field trial conducted on the irrigated *mal* land in Sambalpur revealed that four high intensity one year crop rotations, namely rice-tomato-rice-mung, rice-potato-rice-mung, rice-potato-rice, and rice-radish-wheat-mung were the most profitable cropping patterns (Panda,1973). For the laterite tract of West Bengal, a pattern paddy-wheat-maize has been accepted as the most suitable crop rotation (Tripathi *et al.*, 1973).

The results from six Model Agronomic Centres located in two agro-climatic regions and three major soil groups of eastern India showed that rice-rice rotation was the best under medium to low land conditions for slightly moist, hot zone and rice-wheat rotation was the best under upland to medium land conditions for slightly dry, hot zone irrespective of soil groups with a yield potential of 12-14 tonnes/ha. In addition, a summer crop of early variety of rice or fodder cowpea could be taken successfully under irrigated conditions (Mahapatra *et al.*, 1973).

The production potential experiments conducted in seven Model Agronomic Centres located in the four southern states revealed that the highest production figures of 143.4 q/ha. (rice-rice-rice), 131.2 q/ha. (rice-rice-maize), 120.9 q/ha. (rice-mung-rice), 108.1 q/ha. (rice-rice-urad), 97.91 q/ha. (rice-rice-rice) 82.4 q/ha. (Sorghum-wheat-pearl millet) and 79.2 q/ha. (rice-maize-mung) were obtained at Tirupathi, Bavanisagar, Maruteru, Karaiyiruppu, Mangalore, Siruguppa and Nandyal respectively (Leeu wrik *et al.*, 1973).

The results of national demonstration trials conducted at the farmers fields in the state of Punjab revealed that the two crop rotation of paddy-wheat gave the highest aggregate yield of 130.6 and 150.1 quintals per hectare during 1969-70 and 1970-71, respectively (Chela,1973).

Results of field trials conducted during 1969 and 1970 revealed that rotations rice-wheat-mung at Rudrur and rice-groundnut-mung at Tirupathi were the best under the existing conditions (Sreeramamurthy and Reddy, 1973). At Mangalore, three rice crops produced 7.5 tonnes of grain in 266 days. Besides, ragi (Finger millet) and cowpea were also adoptable for summer (Krishnamurthy and Raghunatha, 1973).

According to Raghavulu and Sreeramamurthy (1975) the pattern rice-wheat-green gram was the best under the agro-climatic conditions of Nizamabad district of Andhra Pradesh.

In Kerala, in the low lying back water areas only one single crop of rice locally called punja is taken from January to April-May. In other areas, the cropping patterns are rice-rice or rice-pulses. The first crop of rice locally called virippu is taken from May to August and the second crop mundakan from September to January. In areas where shortage of water limits the cultivation of the summer paddy and where the soil is loose and well drained, crops like cowpea, sesamum, groundnut, sweet potato, cucumber, bhindi, etc. are cultivated. However, no systematic study has been undertaken under the various agro-climatic conditions of Kerala to identify the most profitable cropping sequence and to find out the effect of various rotations on soil fertility.

E. Soil physico-chemical properties as effected by cropping patterns

Long term experiments have revealed that the constituent crops in a rotation and their management have a marked effect on the various physico-chemical properties of soil.

(a) Soil organic matter and nitrogen.

Organic matter status of a soil is considered as an index of its fertility. Under tropical humid conditions, cultivation and cropping exhaust the soil organic matter more rapidly than it is returned and the productive capacity of the soil greatly declines. Various workers have shown that crop rotations including legumes maintained organic matter in the soil at an optimum level (Salter and Green, 1933). Experiments conducted over thirty seven years in Kansas (USA) indicated that fertilizer treatment and cropping systems had no effect on the trend of nitrogen or carbon but influenced the speed at which equilibrium is reached at their ultimate level (Dodge and Jones, 1947). According to Mirchandani and Khan (1953) judicious inclusion of legumes in crop rotations is desirable for the maintenance of soil fertility.

Sharma and Saxena (1970) studied the balance of nitrogen in the soil under four cropping sequences and found that under double cropped sequences a positive balance of nitrogen could be maintained. Singh and Ramamoorthy (1974) observed that available nitrogen was maintained better in mung-rice-wheat than under fallow-bajra-wheat or fallow-rice-wheat. According to Clark and Mack (1974) soil nitrogen increased under continuous cropping for four years with out the addition of fertilizers. According to Paeth and Azizi (1974) organic matter and nitrogen increased under rotations including alfalfa, a perennial forage. In field experiment consisting of five rice based multiple cropping patterns, Nair et al.(1973 b) found that available nitrogen and organic matter content of soil slightly improved after leguminous crops were grown. They found that changes in the soil fertility were temporary and the soil reverted to near initial status after the subsequent crops.

There are reports in which the different cropping patterns had no effect on the nitrogen and organic matter balance of soil and in some cases, even severe reduction in organic matter and nitrogen. In cropping systems where rice is cultivated year after year, Sturgis (1936) reported that the nitrogen content of soil was reduced from 0.20% to 0.08%.

Haas, et al. (1957) made a study on the effect of cropping patterns on the carbon and nitrogen content of soil at 14 locations in the Great plains (USA). The period of cropping ranged from 30 to 43 years and the nitrogen loss varied from 24 per cent to 60 per cent, with an average loss of 39 per cent over a period of 36 years. Reporting the results of continuous cultivation of groundnut for more than five years, Nijhawan (1963) observed no change in the total nitrogen content of soil. The total nitrogen of soil remained unchanged after continuous cultivation of rice (Chaudhry and Vachhani, 1965).

(b) Soil phosphorus.

Cultivation of crops singly or in rotation seems to have no effect on the total phosphorus content of soil. Sadanandan and Mahapatra (1973 b) reported that there was no noticeable gain or loss of total phosphorus in all cropping patterns tried by them.

However, changes in the available phosphorus status of soil were reported by continuous cultivation and addition of organic matter. Sturgis (1936) reported that by continuous cultivation of rice, the available phosphorus in the soil was reduced from 12.5 ppm to 4.5 ppm. According to Sadanandan and Mahapatra (1973 b) the balance sheet of available phosphorus of soil showed a loss in all the treatments. The maximum loss was observed in rice-rice cropping pattern. Clark and Mack (1974) observed that Na HCo_3 extractable phosphorus was not affected by continuous cropping for four years without the addition of fertilizers.

In a continuous cropping system a higher status of available phosphorus in soil was reported in plots receiving super phosphate and organic manure (Ghosh and Kanzaria, 1964). Hedlin and Ridley (1964) also reported similar results. According to Nair et al. (1973 b) the available phosphorus slightly improved after leguminous crops were grown in a multiple cropping experiment. Singh and Ramamoorthy (1974) found that available phosphorus status was maintained better under mung-rice-wheat than under fallow-bajra-wheat or fallow-rice-wheat. Raghavulu and Sreeramamoorthy (1975) observed slight increase in available phosphorus at the end of three years in all the rotations involving cereals and pulses.

(c) Soil potassium.

Sturgis (1936) reported reduction in the exchangeable potassium content of soil by continuous cultivation of rice. Sadanandan and Mahapatra (1972 a) reported that after completion of each rotation cycle, the total potassium content of soil decreased, the maximum decrease being observed in continuous cultivation of rice. According to

Lal (1973) the available potash decreased where cropping intensity increased from 130 per cent to 300 per cent. The decrease was found to be maximum under 400 per cent cropping intensity. Clark and Mack (1974) found that exchangeable potassium decreased under continuous cropping for four years without fertilizers. In all the rotations involving cereals and pulses, the available potassium status decreased at the end of three years (Raghavulu and Sreeramamoorthy, 1975).

Evidences are also available to show that there is no change in the potassium status of soil due to various cropping systems. (Blair and Prince, 1936 and Hoffmann et al., 1950). Ghosh and Kanzaria (1964) reported no change in total potash in soil by continuous cultivation with the addition of potassic fertilizers. Nair et al., (1973 b) found that available potassium slightly improved after leguminous crops were grown in a field experiment consisting of 5 rice-based multiple cropping patterns. Sadanandan and Mahapatra (1974 b) reported that in the cropping pattern rice-rice, there was a slight gain in exchangeable potassium. Singh and Ramamoorthy (1974) found that available potassium was maintained better under mung-rice wheat than under fallow-bajra-wheat or fallow-rice-wheat.

(d) Soil calcium.

A lowering of exchangeable calcium following addition of ammonium sulphate in continuous cultivation of rice was observed by Lin and Lian (1960). Sadanandan and Mahapatra (1972 d) reported that there was variation in exchangeable calcium status of soil after each crop and crop cycle. In continuous cultivation rice, ie. rice-rice treatment there was decrease after every crop during the two year period of their study.

(e) Soil magnesium.

Generally magnesium does not occur in such large quantities as calcium. Fine textured soils contain more magnesium than sandy soils. The sources of exchangeable magnesium in the soil are crop residues, manures and fertilizers applied to the soil. Exchangeable magnesium is lost from the soil by erosion, crop removal and by leaching.

Sadanandan (1970) reported that the cropping pattern rice-rice-showed a decrease in exchangeable magnesium after both rice crops during the first year, but a slight increase after *dalua* rice and a heavy decrease (0.44 me/ 100 g of soil) after *kharif* rice during the second year.

(f) Soil pH.

A change in the biotic conditions can be brought about by the differential absorption of nutrients by plants and by their excreations in to the soil. The preferential absorption of cations and anions by growing plants may cause a shift in the pH of soil.

Lowering of soil pH by continuous cultivation of crops that use ammonium sulphate was observed by Kanwar and Prihar (1962). Sadanandān and Mahapatra (1972 a) found that maximum decrease in soil pH was in the cropping pattern rice-jute-rice and rice-rice. Lal (1973) found that soil pH decreased with increase in crop intensity from 100 to 400 per cent. Raghavulu and Sreeramamoorthy (1975) reported slight reduction in pH at the end of three years in all crop rotations involving rice, wheat, green gram, maize, bengal gram, bajra, barley and black gram. Juo and Lal (1975) reported that continuous cropping for three years resulted in decrease in soil pH.

Chaudhry and Vachhani (1965) and Bains (1967) observed no change in soil pH due to the continuous cultivation of rice. According to Clark and Mack (1974) the pH value was not affected by continuous cropping for four years with out the addition of fertilizers.

(g) Exchangeable hydrogen.

Acidity of soil is associated mostly with the presence of hydrogen in an exchangeable form. The exchangeable hydrogen not only indirectly controls the pH of soil solution, but also determines the quantity of lime or acidic constituents necessary to bring about a change in pH. In multiple cropping where a very high intensity of cropping with heavy fertilization is adopted, the exchangeable hydrogen status of the soil is likely to be severely affected. Sadanandan and Mahapatra (1973 a) reported that after completion of two crop rotation cycles the maximum increase in exchangeable hydrogen was in the cropping pattern rice-jute-rice, followed by groundnut-jute-rice.

(h) Cation exchange capacity.

Investigation by Nambiar (1947) on the effect of cropping on exchangeable bases revealed that continuous cropping brought about a significant decrease in exchangeable potassium, but showed no measurable change in the other exchangeable bases. A lowering of exchangeable calcium, magnesium and soil pH following addition of ammonium sulphate in continuous cultivation of rice was observed by Lin and Lian (1960). Sadanandan and Mahapatra (1972 d)found that exchangeable calcium decreased with continuous cultivation of rice. According to Juo and Lal (1975) continuous cropping for three years decreased the cation exchange capacity and exchangeable bases in soil. However, in an experiment with five cropping patterns, Sadanandan and Mahapatra (1973 a) found significant increase in exchangeable hydrogen status of soil after dalua and kharif rice.

(i) Organic carbon.

Evidences indicate that continuous cropping brings about significant changes in the carbon and hydrogen status of soil. Poyser *et al.* (1957) oberved that there was an overall decrease of 27.9 per cent organic carbon during 25 years of cropping. Doyle and Hamlyn (1960) also reported a reduction in organic carbon content by continuous cropping. According to Prasad and Jha (1973) the organic carbon content of soil was significantly reduced by continuous crops of rice. Sadanandan and Mahapatra (1975) also reported that there was decrease in organic carbon content of soil, the maximum decrease being in continuous cultivation of rice.

On the other hand Osborn and Mathews (1955) observed that C/N ratio did not vary significantly with cropping system. Kanwar and Prihar (1962) did not find any increase in organic carbon content of soil under continuous cropping with the use of fertilizers. Similarly no change in the organic carbon content of soil was observed even after five years of continuous cropping of groundnut (Nijhawan, 1963). No change in the carbon content of soil due to continuous cropping of rice was reported by Chaudhry and Vachhani (1965). However, Prabhakara (1970) observed that in the case of organic carbon, the values were comparatively higher in the four crop relays all through the year.

(j) Soil structure.

Influence of cropping patterns on soil structure is a reflection of continued effect of physical, chemical and biological agencies (Harris *et al.*, 1966). The relative contribution of these agencies in the formation and degradation of soil structure varies with different cropping systems. In a comparative study of different cropping systems at Kansas, Olmstead (1946) showed that soils under different cropping systems of continuous small grain and continuous row crops lost approximately 80 per cent of their initial aggregates in the surface tilled zone since they were broken from grass land. Islam and Islam (1961) reported that paddy and jute had no significant effect on aggregation.

According to Harris, *et al.* (1966) grain and root crops are the best effective in maintaining an adequate state of soil aggregation. Mohant and Singh (1969) studied the effect of continuous cultivation of maize and paddy on the water stable aggregate status of the acidic soil and found a detrimental effect on water stable aggregates. Padmaraju and Deb (1969) reported that continuous cultivation of rice or rice in rotation with other crops like potato, tomato or chillies had a deteriorating effect on soil structure. Sadanandan and Mahapatra (1974 a) reported that continuous cultivation of rice (Rice-rice rotation) and rice-jute-rice rotation had deteriorating effect on soil structure.

There are evidences to show that different crops and cropping systems can improve the aggregate stability of soil. Continuous cultivation of groundnut has been reported to bring about a slight increase in the water stable aggregates (Mohant and Singh, 1969). Peyer (1969) found that cereals and root crops provided relatively slight soil cover due to their superfical root thus resulting in less aggregation where as under clover grass system the aggregation was better. In a long term experiment on black clay soil, the rotation giving highest percentage of water stable aggregation (70%) was groundnut-gram, followed by groundnut-wheat rotation. Bavaskar and Zende (1973) found that cotton-groundnut showed a better effect on aggregation in the surface soil. Sadanandan and Mahapatra (1974 a) also found that inclusion of groundnut in the cropping pattern improved the structure of the soil slightly. However, according Cary and Hayden (1974) the pore size distribution and hardness were not particularly affected by cropping sequences.

Prabhakara and Dakshinamoorthy (1975) indicated that soil aggregation status was maintained throughout the year in four-crop relay plots with least variation in magnitude, as compared to that in two and three-crop rotations. Deleterious effects of potato on soil aggregation were not seen when included in a relay sequence. Inclusion of a legume crop in the sequence showed improvement in soil structure. Paeth and Azizi (1974) observed improvement in aggregation under rotations including alfalfa and perennial forages.

Carreker et al. (1968) reported that the eight cropping systems studied by them had no effect on aggregate size distribution and on total porosity. However, crust strength decreases and aggregate stability and infiltration rates increase as the quantity of plant materials returned to the soil was increased.

(k) Bulk density

Bulk density of soil is closely related to soil structure. Better the structure, lower the bulk density and hence a negative correlation. Page and Willard (1946) reported that continuous cultivation resulted in loss of pore space and a corresponding increase in weight per unit volume of soil. The adverse effect of cropping systems that included sorghum, on pore space and bulk density had been reported by Khan (1966). Prabhakara (1970) observed a slightly higher bulk density in four crop relays with potato. Sadanandan and Mahapatra (1970) reported that there was an increase in bulk density in continuous cropping of rice during the first year by 0.05 g/cc.

Sharma et al. (1974) found that mechanised way of cultivation and irrigation under a paddy-wheat rotation increased the bulk density, decreased the total and non-capillary prosity, and hydraulic conductivity of soil. Paeth and Azizi (1974) observed improvement in bulk density under rotations including alfalfa and perennial forage.

However, Mohant and Singh (1969) observed that continued cropping of maize, paddy and groundnut did not have any effect on the bulk density of soil.

F. Nutrient requirement of crops included in the cropping pattern

1. Rice.

In pot experiments, it was found that between 59 per cent and 84 per cent of nitrogen, phosphorus, potash, calcium and magnesium present in the ripe plants were absorbed between tillering and flowering. More than 90 per cent of N and K, 80 per cent of P and Ca and 65 per cent of Mg were absorbed prior to flowering and the remainder after heading. More than 60 per cent of the carbohydrate present at the ripe stage was produced after flowering (Ramanathan and Krishnamoorthy, 1973).

(i) Nitrogen nutrition of rice plant.

Nitrogen plays an important physiological role at an early stage in the growth of rice plant (Izhizuka and Tanaka, 1954) during which the rice plant absorbs more NH_4-N than NO_3-N (Ishizuka, 1952).

Nitrogen is absorbed by the rice plant continuously from the time of establishment of seedlings in the field to grain maturity. During the vegetative stage, the plant vigorously absorbs nitrogen to build up the plant body. Some excess nitrogen is stored within the plant, to be translocated to the panicles after fertilization. There is also some absorption of nitrogen after flowering which contributes to the development of panicles. However, the amount of nitrogen absorbed at this stage is small as compared to the amount absorbed during the vegetative stage. According to Matsushima (1965), nitrogen absofbed immediately after establishment of seedlings increased the tillering capacity of the plants, whereas nitrogen applied during reproductive stage was absorbed and translocated into rapidly growing parts such as new leaves and panicles (Patnaik, 1965). By grain formation stage the plants would have absorbed 75 per cent of total nitrogen required. At grain maturity, two-thirds of the nitrogen is stored in the grains and the rest in leaves and culms (Mikkelsen and Patrick, 1968).

Generally, response to nitrogen application has been obtained under a large variety of soil and climatic conditions in India (Ghose *et al*., 1956; Relwani, 1959 and 1961).

Results of experiments with dwarf *indica* varieties showed very high response to the application of nitrogen. Evatt *et al*. (1960) and Chandler (1966) obtained linear response to nitrogen up to 120 kg. per hectare. Varieties with improved plant types were reported to respond to higher level of added nitrogen (De Datta *et al*., 1966). Summarising the results of Co-ordinated Model Agronomic Trials, Mahapatra (1969) concluded that as the level of nitrogen increased from zero to 200 kg. per hectare for the high yielding varieties of rice, there was corresponding increase in yield.

Lakhdive and Prasad (1970) observed that the benefical effect of nitrogen was mainly due to an increase in the number of panicles per m^2 and spikelets per panicle. Maiti and Chatterjee (1971) found that higher levels of nitrogen up to 200 kg. per hectare gave significantly higher yields. But according to Sumbali and Gupta (1972), highest grain yield was obtained at 155 kg. nitrogen per hectare for *I.R.8* and *Jaya* varieties of rice.

Alexander *et al*. (1974) revealed that plant height, number of fertile tillers, panicle length, grain number per panicle and thousand grain weight were enhanced by increasing levels of nitrogen up to 120 kg./ha. Grain and straw yields were also increased up to the highest level tried. Sharma and Rajat De (1975) reported significant increase in yield of rice up to 150 kg.N/ha. Virendrakumar et al. (1975) also reported that the application of 150 kg. N/ha. gave significantly higher grain yield over 50 kg.N. Tewari and Thakur (1976) worked out the optimum dose of nitrogen to be 166.83 kg.N/ha.

(ii) Phosphorus nutrition of rice plant.

Phosphorus is one of the three major nutrients essential for plant growth. The amount of phosphatic fertilizers required for and applied to rice is, in general, second only to that of nitrogen in most soils. As in the case of other nutrients, the uptake of phosphorus and its utilisation by the plant varies according to the growth stage of the plant.

The units of plant materials produced per unit of nutrient are termed the "partial efficiency" of the nutrient. The partial efficiency of phosphorus is found to be different from those of nitrogen and potash with only one very marked peak two to four weeks after transplanting (Mitsui, 1960). The practical significance of this finding is that phosphorus should be supplied to rice at a rather early stage of growth and that a top dressing of phosphatic fertilizer at or around the heading stage may not be necessary, unless the soil is extremely deficient in available phosphorus.

Fertilizer phosphorus applied to rice plant is mostly utilized during the initial eight to ten weeks of its growth (Mitsui 1955). Plants accumulate about two thirds of the total phosphorus at heading stage. Before flowering, the rice leaves contain more than one third of the total accumulated phosphorus (Mikkelsen and Patrick, 1968). During ripening stage, phosphorus accumulates in grain. About 80 per cent of the phosphorus of the entire plant is stored in the grain at maturity.

The phosphorus absorbed by a rice plant can translocate from the older to younger leaves. Ishizuka and Tanaka (1958) found that the mobility of phosphorus from the older to younger leaves takes care of phosphorus requirement of rice during the later stages of plant growth. This characteristic further supports the importance of an adequate supply of phosphatic fertilizers during the early growth stage of rice plant.

Distinct response to phosphate application has been obtained in Madhya Pradesh, Bihar and certain parts of Bombay, Madras and Orissa (Sethi _et al_., 1952). A fertilizer dose of 20 to 30 lb of P_2O_5 per acre increased the rice yields in most of the soil (Karunakar and Rajagopalan, 1948 and Rao, 1952).

The response to phosphorus increases according to Sahu and Lenka (1966), when phosphorus is applied in conjuction with nitrogen. De Datta (1970) postulated that rice responded well to phosphorus and in its absence, the grain yield response to higher levels of nitrogen was negligible. Khatua and Sahu (1970) observed similar response of dwarf <u>indica</u> rice to the application of phosphorus under <u>kharif</u> and <u>rabi</u> seasons. According to Tewari and Thakur (1976), phosphorus significantly influenced grain yield, limiting the response up to 50 and 100 kg. P_2O_5/ha., respectively, in first and second seasons.

(iii) <u>Potassium nutrition of rice plant</u>.

Rice plants absorb much more potassium than nitrogen and phosphorus. The amounts of potash absorbed are generally much higher than those of nitrogen, sometimes reaching more than double the amount. For any given variety, as the yield level rises, the uptake of potassium also increases considerably. Modern varieties with their increased production remove substantially more nutrients, especially potassium, than the conventional tall <u>indicas</u>. Variation in nutrient uptake among different soils are also considerable (Chin and Li, 1965 and Chin, 1971).

Rice plant absorbs nearly ten times potassium as compared to calcium. It takes up potassium even from potassium deficient soils during the early stages of growth when its requirement is low (Mahapatra and Rajendraprasad, 1970). Potassium is absorbed by the plant till the late period of growth.

The percentage of plant potassium is high at transplanting, decreases with the growth of the plant and increases again after flowering until ripening (Ishizuka and Tanaka, 1952). Pot culture studies also showed continuous absorption of potassium during the growth period (Chiu et al., 1960 and 1961). It was also shown that high temperature greately increased potassium absorption by rice plant (Takahashi, et al., 1955; Chiu et al., 1960 and Chiu et al., 1961). According to Chiu (1962), the absorption of potassium is considerably reduced in poorly drained paddy soil where suffocation disease of rice occurs. Lian (1969) and Lian and Tanaka (1972) found that high carbonic acid concentrations in soil solution coupled with high soil calcium supply resulted in a decreased potassium uptake and aggrevated the deficiency of the nutrient in some slate alluvial soils in Southern Taiwan where the yield of the second crop rice is very low.

The absorption of potassium from applied fertilizer was examined in Taiwan by Lin et al. (1973) who used long term fertilizer trial plots set up in 1924. The potassium recovered from the fertilizer which had been applied over a period of 48 years to the acid sand stone/shale alluvial soil (pH 5.2, C.E.C. about 10 m.e./100 g of soil) was found to be about 40 per cent of the total applied. According to John (1958), response to potassium fluctuates depending upon soil type, time and method of application, presence of adequate moisture and quantity and availability of other nutrients. Field trials in 1960 showed that potassium responses in rice are higher in soils with low available potassium. According to Relwani (1961), Satisfactory response to potassium has been obtained in light sandy soils. On average soils, the potash requirement of rice ranges from 30 to 60 kg./ha. On badly drained soils 80 to 120 kg./ha. were found to be more profitable than the lower rates (Huang, 1969). In India, average response in grain yield to potassium application in the 1967-68 experiments on different soil groups, ranged from 472 to 1353 kg. for high yielding varieties (Mahapatra and Rajendraprasad, 1970). According to Tanaka (1971), response of rice to potash have generally been small on the average alluvial soils of Asian countries, although marked responses are frequently observed in soil types such as peaty soils, sandy degraded soils, poorly drained soils prone to _Akagari_ disease, lateritic soils (especially derived from granite) and calcarious soils with low K/Ca ratios. The response of high yielding varieties to potassium in the presence of nitrogen and phosphorus was confirmed in experiment conducted in Burma, Sri Lanka, Madagascar and India (Kemmler, 1971).

According to Kanwar (1974) yield increases of high yielding varieties (mostly I.R.8) obtained from the application of 60 kg. K_2O per hectare averaged 357 kg. of grain (or 6 kg. per kg. of K_2O). Ali et al. (1976) obtained response of rice up to 84 kg. K_2O. Sethi _et al_. (1976) found that in order to produce one quintal of grain the requirement of potassium was 3.22 kg. in the case of dwarf varieties.

(iv) _Nutrient removal by the rice crop_.

The nutrient removal by rice crop depends upon variety, yield, soil and climatic conditions. A crop of rice producing 4000 kg. dry matter removed about 35 kg nitrogen, 9 kg. phosphorus and 42 kg. potash from a hectare of land (Desai, 1959). A rice crop yielding about 3000 kg. of grain and 3500 kg. of straw removed on an average 40 kg. nitrogen, 30 kg. phosphorus and 75 kg. potash from every hectare (Ghose _et al_., 1956).

The average nitrogen, phosphorus and potash uptake of _japonica_ variety in Taiwan was in the order of 84, 41 and 101 kg. per hectare respectively (Chiu et al., 1963). In Lousiana, (U.S.A.) a crop producing 4000 kg. of grain per hectare generally removed 40 to 80 kg. of nitrogen, 8 to 12 kg. of phosphorus and 50 to 90 kg. of potash (Mikkelson and Patrick, 1968). While a rice crop producing only 1000 kg. of grain removed 20.6 kg. of nitrogen, 10.3 kg. of phosphorus and 29.3 kg. of potash from one hectare. (Grist, 1969) a good crop of rice producing 8 tonnes each of grain and straw removed 192 kg. of nitrogen, 80 kg. of phosphorus and 240 kg. of potash per hectare (Mahapatra, 1969). In general, the high yielding varieties of rice removed from soil 150 kg. of nitrogen, 80 kg. of phosphorus and 240 kg. of potash to produce 7000 to 8000 kg. of grain per hectare.

2. Sweet potato.

(i) Nitrogen nutrition of sweet potato.

Sweet potato, as other field crops, is found to respond more often to nitrogen than to any other essential mineral nutrient. Growth of the plant is limited more often by the deficiency of nitrogen than by the deficiencies of any other element. Favourable effect of applied nitrogen on tuber yield of sweet potato has been reported by Johnson and Ware (1948) and Leonard et al. (1949). A fairly close relationship between nitrogen concentration in the whole plant and leaf area index was observed in sweet potato by Tsuno and Fujise (1964). Favourable effect of split application of nitrogen once at planting and again 30 days after planting, on moderating top growth during tuber forming period and enhancing top growth during development period has been reported by Morita (1967).

Mandal et al. (1968) observed a significant increase in sweet potato yield up to 75 kg. nitrogen per hectare. Maximum yield of tuber was obtained by Mandal et al. (1971) by the application of 100 kg. nitrogen in red loam soils of Kerala. Mandal and Mohankumar (1971) reported that size of tuber was not influenced by nitrogen, but higher levels of nitrogen resulted in an increase in the number of tubers per plant. According to Dasharathi and Padmanabhan (1972) there was significant response of sweet potato to application of nitrogen up to 80 kg. of nitrogen. According to Nair et al. (1976) tuber yield and total nitrogen uptake were increased with nitrogen application.

Significant increase in vine yield as a result of nitrogen application was reported by Stuckey (1919). Black (1968) found that an increase in the supply of nitrogen enhanced growth of the above ground portion of plant than of the root. Yuan et al. (1964) showed that heavy application of nitrogen caused excessive vine growth and resulted in dense shading. Thomas (1965) observed significant increase in the yield of vine by nitrogen application. According to him maximum number of shoots were noticed in plants receiving 88 kg. of nitrogen and 88 kg. of potash per hectare. Morita (1967) reported that nitrogen when applied in excessive quantity resulted in excessive top growth.

(ii) Phosphorus nutrition of sweet potato.

Morgan (1939) showed that the inclusion of super phosphate in the fertilizer mixture and an increase in the percentage of it in the mixture gave significant increase in the tuber yield. Landran and Samuels (1951) observed an increase in the carotene content of tubers whenever there was an increase in yield due to phosphate application.

(iii) Potassium nutrition of sweet potato.

Potassium is required for the formation of carbohydrate such as sugars and starches and for their movement from one part of the plant to another. It is also essential for the synthesis of protein in the plant. The crop quality is also improved by potash. It helps in the development of healthy root system and counteracts the undesirable effects due to excessive supply of other nutrients particularly that of nitrogen.

Scott (1950) found that potash fertilizers influence the size and shape of sweet potatoes. The potash content of roots was also increased by potash application.

Landran and Samuels (1951) observed increase in the yield of marketable sweet potatoes with increasing potash application. Uriyo (1973) also reported that potash application significantly increased the yield of sweet potato tubers. According to Godfrey-Sam-Aggrey (1976) fertilizers containing higher potash rates (448 kg./ha. of sulphate of potash) and N:K ratio of 3:4 gave maximum tuber and lower vine yields with low vine/tuber ratio in intensively cropped areas.

(iv) Nutrient removal by sweet potato.

Studies revealed that sweet potato removed larger quantities of potash as compared to nitrogen and phosphorus. A crop producing 40 tonnes per hectare removed 190 kg. nitrogen, 75 kg. Phosphorus and 390 kg. potash per hectare (Dahiya and Restogi, 1976). According to Yawalkar (1969) a crop of sweet potato yielding 120 cwt of tubers removed 63 lb of nitrogen, 18 lb of phosphorus and 120 lb of potash per acre. It has been observed that a mixture of about 60 kg. nitrogen, 60 kg. phosphorus and 120 kg. potash per hectare may yield good response.

3. Cowpea.

(i) Nitrogen nutrition of cowpea.

Waber (1930) and Schanderl (1943) held the view that small quantities of nitrogen were beneficial to encourage early growth of legumes and that the practice of adding nitrogen did not endanger the capacity of legumes to fix atmospheric nitrogen. Russel (1961) opined that nitrogen supply was beneficial for rapid establishment of leguminous crops particularly if the seed was small and the land was worn out. Ezedinma (1964) observed that cowpea seeds grown in sterile soil inoculated with rhizobium strains responded well to light dressings of nitrogen. Ebong (1965) reported that cowpea responds well to fertilizers including a small dosage of nitrogen at the seedling stage. Nitrogenous substances are usually concentrated in leaves during vegetative growth and then transported to the seeds during the grain filling stage.

According to Kudrekri _et al_. (1973) increase in nitrogen level beyond 11 kg./ha. did not produce any increase in yield in cowpea. Cowpea responded to applied nitrogen and the response was to the tune of 3.6 kg. of grain per kg. of nitrogen at the 20 kg./ha. level and 6 kg. per kg. of nitrogen at the 40 kg./ha. level (Anonymous 1976).

(ii) _Phosphorus nutrition of cowpea_.

Phosphorus has a defenite stimulatory effect on the multiplication of rhizobia which in association with leguminous plants fix atmospheric nitrogen. Robert and Olsen (1944) as well as Parr and Sen (1948) observed that the uptake of nitrogen by leguminous crop depended on phosphorus supply. Studies of Parr and Bose (1944, 1945) revealed that cowpea responded highly to phosphate application. Sen and Bains (1955) reported that increasing rates of phosphorus increased the nodulation in cowpea. Sharma and Garg (1973) showed that the green and dry matter production of cowpea increased significantly due to phosphorus application up to 70 kg. phosphorus per hectare. Trials conducted at the Rice Research Station, Pattambi revealed that application of 20 kg. phosphorus per hectare through soil plus 20 kg. phosphorus through foliage gave the maximum yield of 1022 kg./ha. (Anonymous 1976). But according to Subramanian *et al*. (1977 a), 25 kg./ha. recorded the maximum grain yield of 1863 kg./ha.

Kudrekri *et al*. (1973) did not find any increase in the yield of cowpea when phosphorus was increased beyond 22 kg./ha.

(iii) Potassium nutrition of cowpea.

Very little information is available about the response of cowpea to potash application. Response of cowpea to potassium has been low in Africa although potash application of 40 kg./ha. had increased nodulation in eastern Nigeria (Tewari 1965). This element is transported mainly to the stem in the early stages of the growth and later to the seeds (Jacquinot, 1967). In the southern United States, Worley *et al*. (1971) recommended that the level of elemental potassium should not exceed 42 kg./ha.

(iv) Nutrient removal by cowpea.

The requirements of nitrogen, phosphorus, potassium, calcium, megnesium and sulphur have been partially established under certain conditions and for specific genotypes. It is estimated that about 40 kg. nitrogen are removed by each tonne of cowpea seeds harvested from one hectare of land (Jacquinot, 1967). Rachie and Robertst (1974) observed that each tonne of cowpea seeds removes from the soils the mineral nutrients at the rate of 40 kg. nitrogen, 17 kg. phosphorus, 48 kg. potash, 16 kg. calcium, 15 kg. magnesium and 4 kg. of sulphur.

4. Sesamum.

Comparatively less information is available on the physiology of nutrition, on manurial requirements under different soil and climatic conditions and on the effect of fertilizing elements on the chemical composition of the seed of sesamum. Work on the physiology of nutrition of sesamum in India is of very recent origin.

(i) Nitrogen nutrition of sesamum.

Stewart (1947) in his report on soil fertility investigations in India with special reference to manuring, stated that for a crop like sesamum consideration should be given to experiments in nitrogen at 15 to 20 kg./ha. Zanini (1949) observed sesamum to be very sensitive to nitrogen and that yield increases from eight to sixteen quintals per hectare could be obtained as a result of judicious manuring. Seshadri (1967) opined that sesamum is an exhausting crop and unless the soil is adequately manured its depressing effect on the succeeding crop will be felt severely. Sing et al. (1960) found the response of sesamum up to 25 kg. nitrogen and 40 kg. phosphorus per hectare. Gopalakrishna et al. (1971) have also reported that application of fertilizers especially nitrogen and phosphorus increased the yield of sesamum significantly. According to Tilak Raj et al. (1971) application of nitrogen in general increased the grain yield of sesamum. Gaur and Trehan (1973) reported that when compared to control, application of 30 kg. N/ha. increased sesamum yield by 78.53 per cent. Application of 15 kg. nitrogen per hectare in the form of urea in two equal splits, through soil as basal dressing and through foliage 20 days after sowing was found to be beneficial from the point of yield in sandy coastal areas of Kerala (Nair et al., 1975).

(ii) Phosphorus nutrition of sesamum.

Stewart (1947) observed that numerous experiments of broadcast dressings of phosphatic fertilizers failed to show response in yield. Many conflicting results obtained showed that shallow rooted crops responded to phosphorus better than deep rooted crops. He observed phosphorus deficiency to be a factor in many red soils especially of the lighter texture. He also recorded that in many instances where phosphate alone had little effect on yield, its combination with nitrogen was markedly superior to nitrogen alone. Simons (1949) recommended 80 kg. phosphorus per hectare for sesamum in Texas, South Carolina and neighbouring states of U.S.A. Kostrinsky (1959) observed an yield increase of 13.5 per cent over control in sesamum with 18 kg. phosphorus; response was better than that for nitrogen.

(iii) Potassium nutrition of sesamum.

The effect of potassium in sesamum is mostly towards depression of flowering, yield, etc. Stewart (1947) reported reduction in the yield of sesamum due to potash application. There was no response to potash application to sesamum for four years at Rajahmandry (Anonymous, 1958). According to Sivappah and Mariakulandai (1963) application of increased levels of nitrogen and potash influenced flowering positively. However, they found that application of potassium at 30 kg./ha. tended to depress the yield, dry matter and flowering. It has been reported by Sivappah and Raj (1971) that potassium depressed flower production. According to them seed yield analysis also indicated significant depressing effect of potassium. Potassium significantly suppressed flowering and reduced the yield of seed and straw. Simons (1949) recommended 48 kg. potash per hectare for sesamum in U.S.A. Kostrinsky (1959) recorded an yield increase of six per cent, the response being less than that due to individual levels of nitrogen or phosphorus, or combination of these elements. However, in India, there was no response to potassium up to 50 kg./ha. over all four seasons of the trial at Rajahmandry (Anonymous, 1958).

(iv) Nutrient removal by sesamum.

Mineral nutrition of sesamum is rather complex considering the extraordinary uptake of nutrients (Gopalakrishna *et al.*, 1971). The uptake of nitrogen varies with varieties. While in some varieties the nitrogen uptake was gradual and uniform throughout, in some other varieties it was not uniform. However, the uptake of phosphorus and potash was gradual and strikingly similar in all varieties. An overall evaluation of nutrient uptake indicated that 50 per cent of phosphorus and potash intake takes place exclusively during the post-flowering phase. Regarding dry matter production, increasing fertilizer levels had a positive effect during early stages of crop growth, but fluctuations were noted as the crop attained maturity. The lowest fertilizer level effected a 16.3 per cent increase of seed yield over the control and any further increase in fertility level tended to decrease the same.

5. Groundnut.

There are three distinct stages in the growth, nutrition and development of the groundnut plant. In the first stage the development of root system takes place and during the second stage the majority of the nutrients are absorbed by the plants. The third stage is characterised by a decrease in the rate of vegetative growth and development of pods.

(i) Nitrogen nutrition of groundnut.

The absorption of nitrogen through the gynophores has been an established fact (Thornton and Broadbent (1948). When there is ample supply of nitrogen in the root zone, absorption through gynophore is negligible where as, at near nitrogen starvation, considerable absorption takes place through gynophores. The nitrogen which is absorbed by the plant is freely translocated from vegetative parts to the fruits (Thornton and Broadbent, 1948; Bunting and Anderson, 1960). During the first two months most of the nitrogen goes to the vegetative parts; but in the final stages about 70 to 80 per cent of nitrogen absorbed goes to the formation of pods. The remaining quantity of absorbed nitrogen stay in the haulms. Nitrogen is also translocated to the shells. Deficiency of nitrogen results in general chlorosis of leaves and in an insufficient development of root nodules.

Field experiments conducted in Bihar showed adverse effect of nitrogen application on the yield of groundnut (Singh, 1958). Manurial trials on groundnut conducted on red sandy and sandy loam soils of Mysore State for over 30 years revealed that the response of this crop to nitrogen alone or in combination with other nutrients was not significant (Venkita Rao and Govindarajan, 1960). Goldsworthy and Heath Cote (1963) reported no benefit by the application of nitrogen on groundnut, because the plant appeared to be capable of fixing all the nitrogen it required. In many parts of Africa, considerable response has been reported both to the application of nitrogen at sowing and to top dressing (Pretorius and Thomas, 1953). Puntamkar and Bathkal (1967) reported that the application of nitrogen increased the number of branches, pod-bearing capacity and yield of groundnut. According to Georgiev (1974) 200 kg. N/ha. increased the yield of unshelled groundnuts from 1.89 tonne per hectare for control to 3.24 tonne per hectare. According to Chesney (1975), 15 kg. N/ha. gave optimum production; but up to 48 kg./ha. was required in a dry season on the coarser textured soils and during all the seasons on a fine textured soil. Saini and Tripathi (1975) reported that a dose of

15 kg. N/ha. produced maximum pod yield, slightly improved the shelling out turn and gave the highest total oil yield. However, an increase in the nitrogen dose decreased these values.

(ii) Phosphorus nutrition of groundnut.

Well nodulated groundnut plants tolerate high concentrations of phosphate in fertile soils which stimulate symbiotic nitrogen fixation in nodules resulting in luxuriant vegetative growth. The degree of nodulation is an important factor in the utilization of phosphate by groundnut plant. Lack of phosphorus makes the leaves dark blue-green and reduced in size with characteristic deep purple colouration of the stem.

Singh (1958) reported favourable effects to phosphate application in Bihar. Response to phosphate was also observed in red sandy and sandy loam soils of Mysore State (Venkita Rao and Govindarajan, 1960). According to Seshadri (1962), phosphorus has been found to be a limiting factor in the yield; its deficiency retarded flowering and affected the size of pods. Nijhawan (1962) reported that application of 25 lb phosphorus in the form of superphosphate gave significant increase in yield. Studies revealed that the average groundnut crop takes up about 22 lb of phosphorus only. Phosphorus requirement is thus very low as compared to that of nitrogen and other nutrients. Phosphorus is, however, considered very important for the development of legumes and for high nitrogen fixation. Response of groundnut to phosphate application was also noticed by Goldsworthy and Heathcote (1963) and Puntamkar and Bathkal (1967). Increased yield of groundnut pods due to phosphate manuring was reported by Naidu (1968) and Patel (1968). Punnoose (1968) observed that phosphorus significantly increased the number and weight of pods per plant. Puri (1969) reported that phosphorus deficiency reduced the size of pods and that phosphorus was often found to be a limiting factor in yield. Jayadevan (1970) reported that groundnut showed significant response to phosphorus in the red loam soils of Vellayani up to 75 kg. P_2O_5/ha. Nair et al. (1970 and 1971) found that lack of phosphorus reduced the yield of dry matter per plant. They further reported that the growth of groundnut crop was better in soils where available phosphorus was significantly higher. According to Saini and Tripathi (1975) the maximum pod and oil yield were produced by 30 kg. P_2O_5/ha. According to Goudreddy, et al. (1973) foliar application of 20 kg. P_2O_5/ha. or soil application of 60 kg. P_2O_5/ha. increased the yield and gave high economic returns. However, field investigations carried out at Regional Research Station, Dharvar during *kharif* season of 1968 and 1969, to study the response of groundnut to levels and methods of application of phosphorus revealed that the differences in pod yield due to different levels of phosphorus and their application were not significant during both the years (Joshi *et al.*,1975).

(iii) *Potassium nutrition of groundnut*.

According to Bouger (1949), by two-third the length of growing period, complete requirement of potassium is absorbed by the plant. At maturity, only one fifth of the total potassium absorbed by the plant is found in the pods. Rest is found in the vegetative parts.

Deficiency of potassium resulted in stunted plant growth and drying up of leaf margins. The tips of branches turned reddish. Lack of potassium led to a reduction in number of flower forming pods (York and Reed, 1953). Economic response of groundnut to direct application of potash is uncommon. Even in soils where potassium is so deficient that other crops failed, the yield of groundnut was found to be satisfactory (York and Colwell, 1951). Hence,York (1952) recommended that potassium should be applied entirely to the previous crop in the rotation rather than to each crop separately. On soils very low in potassium, groundnut responds to the direct application of it.

Singh (1958) also reported favourable effect of potassium on groundnut in Bihar soils. According to Hickey et al. (1974), application of 100 kg./ha. of potassium at planting over the base rate of 110 kg./ha. significantly increased the yields.

(iv) Nutrient removal by groundnut crop.

It is observed that groundnut crop removes large amounts of nutrients from the soil.

A crop yielding 4000 lb of hay and 2000 lb of pods per acre removed 137.9 lb of nitrogen, 24.3 lb of phosphorus and 103 lb of potash in addition to calcium and magnesium (Collins and Morris, 1942). Bouger (1949) reported that a crop yielding 1500 kg./ha. of pods required 94 kg. of Nitrogen, 13 kg. of phosphorus, 37 kg. of potash, 24 kg. of Cao and 16 kg. of Mgo. Nijhawan (1963) studying the amount of nutrients removed by the groundnut crop found that an average crop yielding 2120 lb of pods per acre removed from the soil 163 lb of nitrogen, 22 lb of phosphorus, 48 lb of potash, 87 lb of Cao and 30 lb of Mgo. According to Sreeramulu (1964), groundnut crop removed 80 lb nitrogen, 22 lb phosphorus, and 54 lb potash per hundredweight of crop. But Raheja (1966) pointed out that a groundnut crop yielding 14 hundredweights of kernels removed 80 lb of nitrogen, 22 lb of phosphorus and 54 lb of potash per acre. According to Puntamkar and Bathkal (1967), groundnut crop removed a maximum of 51.09 lb of nitrogen and 14.25 lb of phosphorus from an acre. Sichmann *et al*. (1970) reported that nutrients (in kg./ha.) removed in fruits and green material (shown in brackets) of a groundnut crop of 16000 plants on a fertile latosol were as follows: N-142(201), P-15(16), K-30(140), Ca-5(113), Mg-10(20), S- 15(16). According to Dahiya and Rastogi (1976), groundnut yielding two tonnes per hectare removed 170, 30 and 110 kg. per hectare of nitrogen, phosphorus and potash, respectively.

From the above findings it can be observed that groundnut crop removes large quantities of nutrients, especially nitrogen and potassium from the soil.

G. Yield of crops as affected by cropping patterns.

Recent break through in Agriculture in our Country is characterised by the maximisation of production per unit of land per unit of time brought about by multiple cropping and by the introduction of high yielding varieties which utilize higher level of fertilizers than older ones. This new strategy in Agriculture could produce still higher yields from unit land area per unit of time by the adoption of appropriate cropping patterns suited to each situation.

According to Gautam and Singh (1970) wheat yields were 24 per cent higher in a guar-wheat rotation than in a maize-wheat rotation. Maize also showed higher yields when grown after other legumes. At many experiment stations, the yield of crops in three or four crop rotations amounted to 10 to 15.3 tonnes per hectare per year. The average grain production in these works out to 40 to 48 kg./day. (Ramamoorthy _et al_., 1971). Sadanandan and Mahapatra (1972 e) reported that the production was doubled in Cuttack by growing potato-rice-rice, instead of the normal practice of growing only two crops in a year and that the net income was Rs.8755/ha. According to Raghavulu and Sreeramamoorthy (1975), rice-wheat-green gram rotations seemed to be the best under the agro-climatic conditions of Nizamabad district of Andhra Pradesh which produced an yield of 9.5 tonnes per hectare per year. With four crops a year, 15 tonnes of food materials were produced during a period of 342 days. This worked out to 44 kg. per day (Mishra _et al_., 1975). Sahoo and Patro (1975) reported that on the basis of dry weight recovery in kg./ha., the treatment rice (_Jaya_)-potato (_Up-to-date_)-rice (_Jaya_) was found to be the best. In trials with five crop rotations on well drained light textured soils in Orissa, potato-rice-rice, groundnut-jute-rice and rice-jute-rice rotations gave the highest net profit and stable yield (Padalia, 1976).

Contrary to the above findings, Sandor (1975) reported yield decrease with continuous cropping.

H. <u>Economic feasibilities of multiple cropping sequences</u>.

Multiple cropping offers extended opportunities in the use of the same land resources within a calendar year through repeated croppings. In this system, more can be produced from the same land effectively, attaining as much increased production as if both land and capital were increased under conventional cropping patterns (Agarwal and Heady, 1970). Bains (1968) found that in relay cropping systems of 400 per cent intensity, the farmers can get a profit of about Rs.11,500 per hectare per year. They studied the economics of two cropping patterns: mung-maize-toria-wheat and mung-maize-potato-wheat. From the first relay cropping sequence they got a net profit of about Rs.10,000/- per hectare, where as, from the second relay cropping sequence they got a net profit of about Rs.11,500/- Mahapatra (1969) reported that the cultivators in Cuttack district of Orissa State obtained a net profit ranging from Rs.2860/- to Rs.5698/- by adopting the cropping pattern, rice-potato-rice.

In a study with five high intensity crop rotations with rice, Nair and Singh (1971) found that the maximum gross return of Rs.12692.36 and net profit of Rs.7367.36 were obtained from the rice-potato-wheat rotation.

At Pant Nagar, Nair (1971) obtained a net return of Rs.1.75 per rupee invested from rice-lahi-soybean rotation. Very high net returns per hectare per year under multiple cropping have also been reported by Gupta (1972), Sambathkumar and Thangabelu (1972), Mitra et al. (1972) and Venkataratnam (1972). According to Sadanandan and Mahapatra (1972 e), the cropping pattern potato-rice-rice has shown the maximum production potentiality during 1967-68 and 1968-69, the net income from the cropping pattern being Rs.8775/- in the first year and Rs.7789/- in the second year. The cropping pattern rice-potato-potato was the best with an approximate profit of Rs.5700 per hectare in Punjab in the studies conducted by Shahi (1973). At Sholapur where annual rainfall ranges between 500-700 mm, short duration and fertilizer responsive crops of maize and wheat could produce fabulous yields and high income of about Rs.4900 per hectare from two crops within 225 days (Deshpande et al., 1973). In Sambalpur district of Orissa, Panda et al. (1973) studied ten high intensity single year crop rotations involving cereals, pulses and vegetables. They found that the rotation rice-tomato-rice-mung recorded the highest production with a net profit of Rs.11025/- per hectare. Pillai (1973) suggested that a suitable crop rotation should not give less than Rs.1000/- per acre net income, although in dry land conditions such a large income can not be expected. Under assured irrigation and 400 per cent relay cropping, it can go up to Rs.2000/- per acre. Studies in the scarcity zone of Maharashtra revealed that double cropping gave gross money returns from two to four times than that of the monoculture which hardly yielded about Rs.500/- per hectare (Pharande *et al.*, 1973). According to Sandhu *et al.* (1973) the cropping pattern maize-potato-wheat-cowpea produced the highest net income of Rs.10,464/- per hectare at Ludhiana in Punjab. Sahoo and Patro (1975) reported that the cropping pattern rice-cauliflower-maize recorded the maximum net profit of Rs.8398.74 per hectare. According to Singh and Singh (1975), increased cropping intensity and increased area under high yielding varieties resulted in higher employment and higher level of income per unit area.

I Effect of a crop on succeeding crop in a given cropping pattern.

It has been known for many centuries that crops play a decided influence on the growth and production of crops which follow (Ripley, 1941). The principle involved in the rotation of crops is based on the above observation and is not an idea of modern age; but dates back far into antiquity. However, to Boussingault (1834) goes the honour of having introduced the concept of rotation in Agricultural Science (Russel, 1961). Various crops when grown on soils leave certain aftereffects which exert a marked influence on the growth of subsequent crops. In some cases the effect is beneficial and in some other cases it may be injurious.

Sturgis (1936) reported that upland crops do not make satisfactory growth when planted immediately after rice. He observed that continued practice of irrigation to rice causes defloculation of soil colloids and development of other poor physical conditions.

Seshadri *et al*. (1954) reported that there was no benefit derived by groundnut following cereals. Crops following rice are not benefited in any way by heavy fertilization of rice. Racho and De Dutta (1968) reported that application of fertilizers to rice, irrespective of rates of application had no residual value for the succeeding crop. Hence it is clear that rice crop in cropping patterns has no beneficial effect on succeeding crop.

Tiwari and Tiwari (1967) reported that when legume fodders such as cowpea, soybean, etc. were grown before sowing rainfed wheat, the yield of succeeding wheat significantly increased as compared to that sown after *kharif* fallow. Verkoc *et al.* (1969) obtained highest yield of winter wheat when the preceding crop was pea. Bains and Sadaphal (1971) obtained an increase in returns by 13 to 15 per cent when jowar, bajra or paddy was taken as a <u>kharif</u> crop after the inclusion of an unfertilized legume (cowpea) in the rotation.

There is a general belief that sesamum crop will supress the yield of the succeeding crop. But according to Viswanathan *et al*. (1973), during 1969-70 and 70-71 growing a gingelly crop increased the bright leaf production of cigarette tobacco. This is a desirable feature as the average value of tobacco per unit area increases with higher production of bright grades. The bright leaf production was enhanced from 43 per cent for fallow to 46,60 and 65 per cent in the various fields grown with gingelly. An experiment conducted to find out the most suitable and remunerative crop rotation involving the sesamum crop indicated that adopting rotational cropping fetches higher yield from sesamum than by cropping it repeatedly. Contrary to the popular belief, sesamum crop did not depress the yield of the succeeding crop, be it a cereal or legume; but increased their yields. The groundnut and sesamum crops have behaved in a manner mutually helpful to each other. It may be noted that no crop, especially the millets, suffered a reduction in yield when sown in rotation with sesamum (Chandrasekharan et al., 1974).

The beneficial effects of groundnut on the succeeding crops have been reported by many workers. In Malaya, growing rice after groundnut recorded an increased yield of 24 per cent over rice grown after rice (Hartley and Keeping, 1950). According to Seshadri et al. (1954), groundnut crop is very valuable in many crop rotations for the role it plays in fetching enhanced yields from crops rotated with it. Dalal and Nagi (1958) working in Punjab reported that the grain yield of wheat was always higher after groundnut than when it was grown alone or grown in rotation with maize or cotton. They found that groundnut enriches the soil leaving a beneficial residual effect on the following rabi crop. Magne (1960) reported that inclusion of rice in a rotation along with groundnut allowed continuous cropping without soil depletion and brought high returns. The beneficial effects to cotton following groundnut in rotation have been reported by many workers(Bederkar and Joshi, 1954; Phillips, 1959; Divakar and Kurta Koti, 1960 and Abraham and Agarwal, 1964). The yield of ragi was better when grown after groundnut. It is seen that ragi in rotation with groundnut produced an yield increase of the order of 40 per cent over the usual practice of ragi year after year (Shivashankar *et al*., 1972). According to Sandor (1975), the preceding leguminous crop increased the yield of rice by 12.8 to 137.7 per cent.

MATERIALS AND METHODS

MATERIALS AND METHODS

The experiment entitled 'Studies on the effect of multiple cropping on soil fertility and crop yields in wet lands' consisted of four parts:

A. Field experiment for seven seasons continuously.

B. Studies on changes in physico-chemical properties of soil due to multiple cropping.

C. Studies on the uptake of plant nutrients by individual crops in each cropping pattern.

D. Economics of the cropping patterns studied.

A. Field experiment.

I Experimental site:

The field experiment was conducted continuously for seven seasons starting from July, 1974 (*Virippu*, 1974) to October, 1976 (*Virippu*,1976) at the Instructional Farm, College of Agriculture, Vellayani situated 12 km. away from Trivandrum. There was controlled irrigation and drainage in the wet land used for this experiment. During the year previous to the experiment, the field was used for raising two bulk crops of rice and the field was kept fallow during the summer season. The soil of the experimental site is sandy clay loam type and is typical of the wet land rice fields of the surrounding area. The physico-chemical properties of the soil are presented in Table 1.

Table-1: Physico-chemical properties of the soil

Physical properties		Chemical properties	
Coarse sand	35.5%	Soil pH	4.91 to 5.08
			(Oven dry basis)
Fine sand	15.6%	Organic carbon (%)	1.616 to 1.756
		Nitrogen (%)	0.1207 to 0.1302
		C/N ratio	13.071 to 13.919
Silt	10.3%	Total phosphorus (ppm)	354 to 388
		Extractable phosphorus (ppm)	17 to 22
Clay	36.2%	Total potash(m.e./100g.)	2.69 to 3.12
		Exchangeable potash (m.e./100g.)	0.2086 to 0.2214
Textural class	Sandy Clay Loam	Exchangeable calcium (m.e./100g.)	3.16 to 3.40
		Exchangeable Magnesium (m.e./100g.)	0.846 to 0.884
Bulk density	1.18 g./cc	Exchangeable hydrogen (m.e./100g.)	1.1823 to 1.2167
		C.E.C. (m.e./100g.)	7.246 to 7.453

II Season and weather conditions:

The weather conditions recorded at the Meteorological unit attached to the Instructional Farm for the various crop seasons from July, 1974 to October, 1976 are presented in Table 2 and Fig.1.

Table 2.

Meteorological data from 1st July 1974 to 31st October 1976

Sl.No.	Month	Rain fall (m.m.)	Temperature °C		Relative humidity (%)
			Maximum	Minimum	
1	July 1974	439.3	29.99	23.63	90.20
2	August 1974	348.7	29.62	22.59	90.00
3	September 1974	287.5	30.84	23.69	89.00
4	October 1974	..	30.00	23.18	82.50
5.	November 1974	64.5	30.03	22.82	83.13
6	December 1974	..	30.49	22.49	77.73
7	January 1975	40.0	30.60	22.34	72.60
8	February 1975	63.0	30.62	20.49	75.16
9	March 1975	66.1	32.50	23.45	78.03
10	April 1975	130.3	32.41	24.19	79.00
11	May 1975	235.5	32.16	23.74	88.60
12	June 1975	433.9	29.16	23.01	90.00
13.	July 1975	249.2	30.44	23.56	89.40
14.	August 1975	128.6	29.97	22.97	89.00
15	September 1975	168.4	30.81	23.13	85.00
16	October 1975	295.9	28.90	22.80	87.00
17	November 1975	308.3	28.80	22.90	85.00
18	December 1975	93.0	30.15	22.95	78.30
19	January 1976	..	30.80	22.45	73.50
20	February 1976	..	31.10	23.50	72.60
21	March 1976	49.0	32.60	23.80	75.40
22	April 1976	76.0	33.25	24.75	86.00
23	May 1976	6.0	31.90	24.90	87.00
24	June 1976	111.0	31.10	23.85	89.10
25	July 1976	104.0	30.90	23.75	89.00
26	August 1976	74.0	30.40	24.30	89.00
27	September 1976	96.0	30.10	23.60	86.90
28	October 1976	256.0	29.2	22.80	88.00

III Experimental details:

a. Statistical design:

Design of experiment	- Randomised Block Design
Number of treatments	- Five
Number of replications	- Five
Total number of plots	- 25
Plot size	- 10m x 5m
Width of bunds	- 50 cm
Width of irrigation channel	- 50cm

Irrigation channels were provided on all sides so that each plot could be irrigated or drained as required, independently of the other plots.

b. Treatments:

The following five cropping patterns were included in the experiment:

Treatment No.	Virippu	Mundakan	Punja (summer)	Intensity
1.	Rice	Rice	Sweet potato	300%
2.	Rice	Rice	Cowpea	300%
3.	Rice	Rice	Sesamum	300%
4.	Rice	Rice	Groundnut	300%
5.	Rice	Rice	Rice	300%

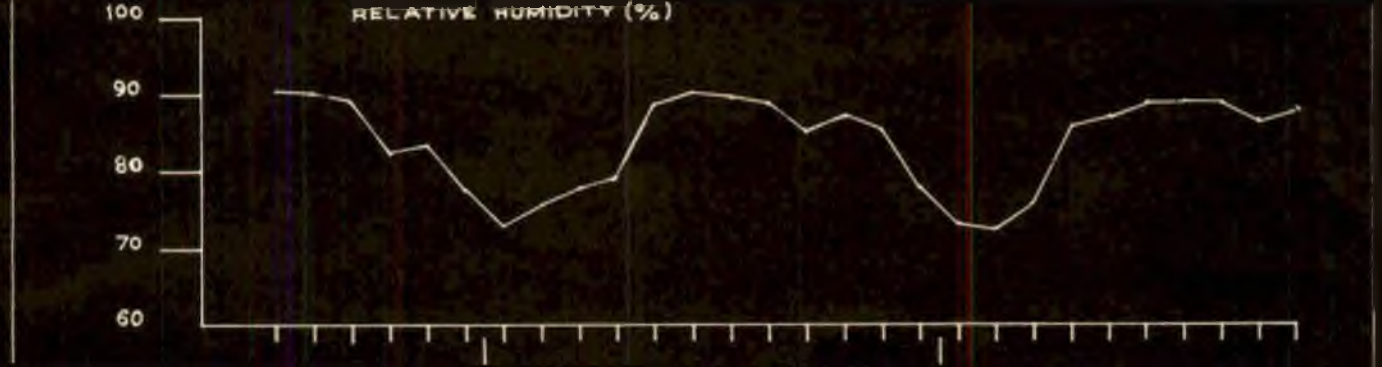
The plan of lay out is given in Fig.2.

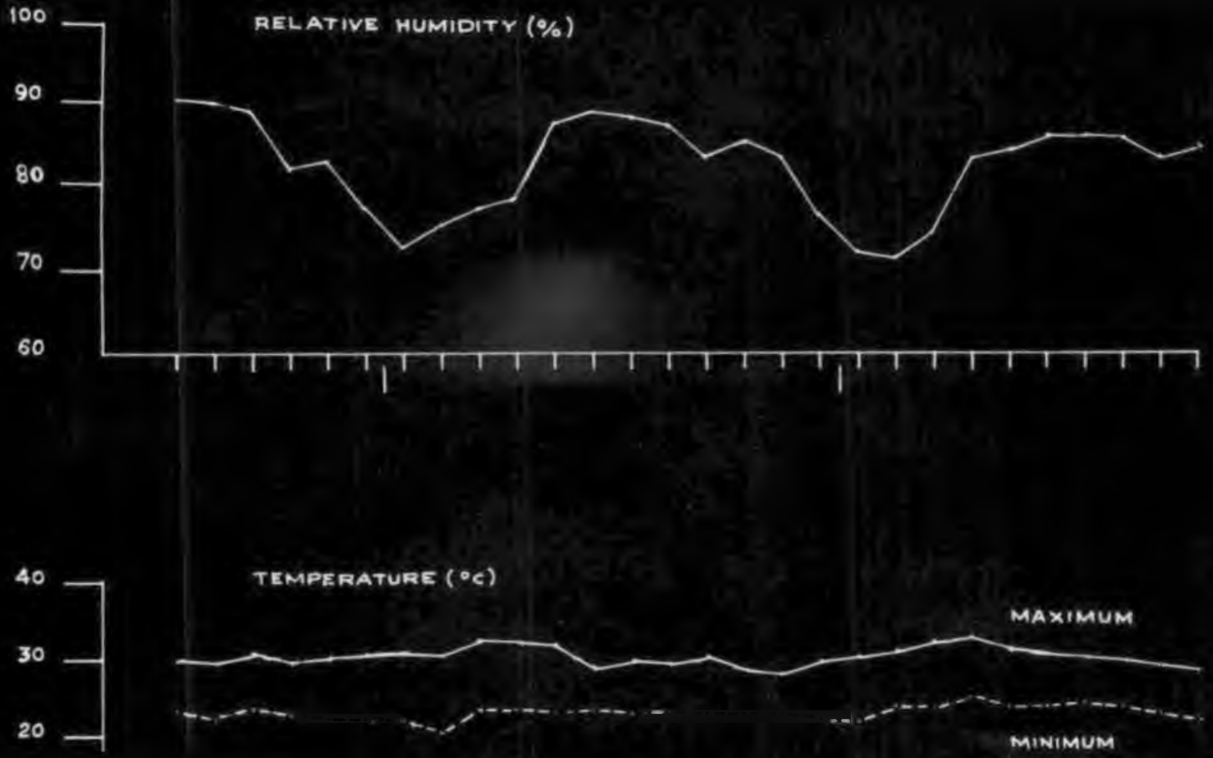
c. Brief description of the varieties used in the experiment:

(i) Rice. *Oryza sativa* Linn. (Graminae)

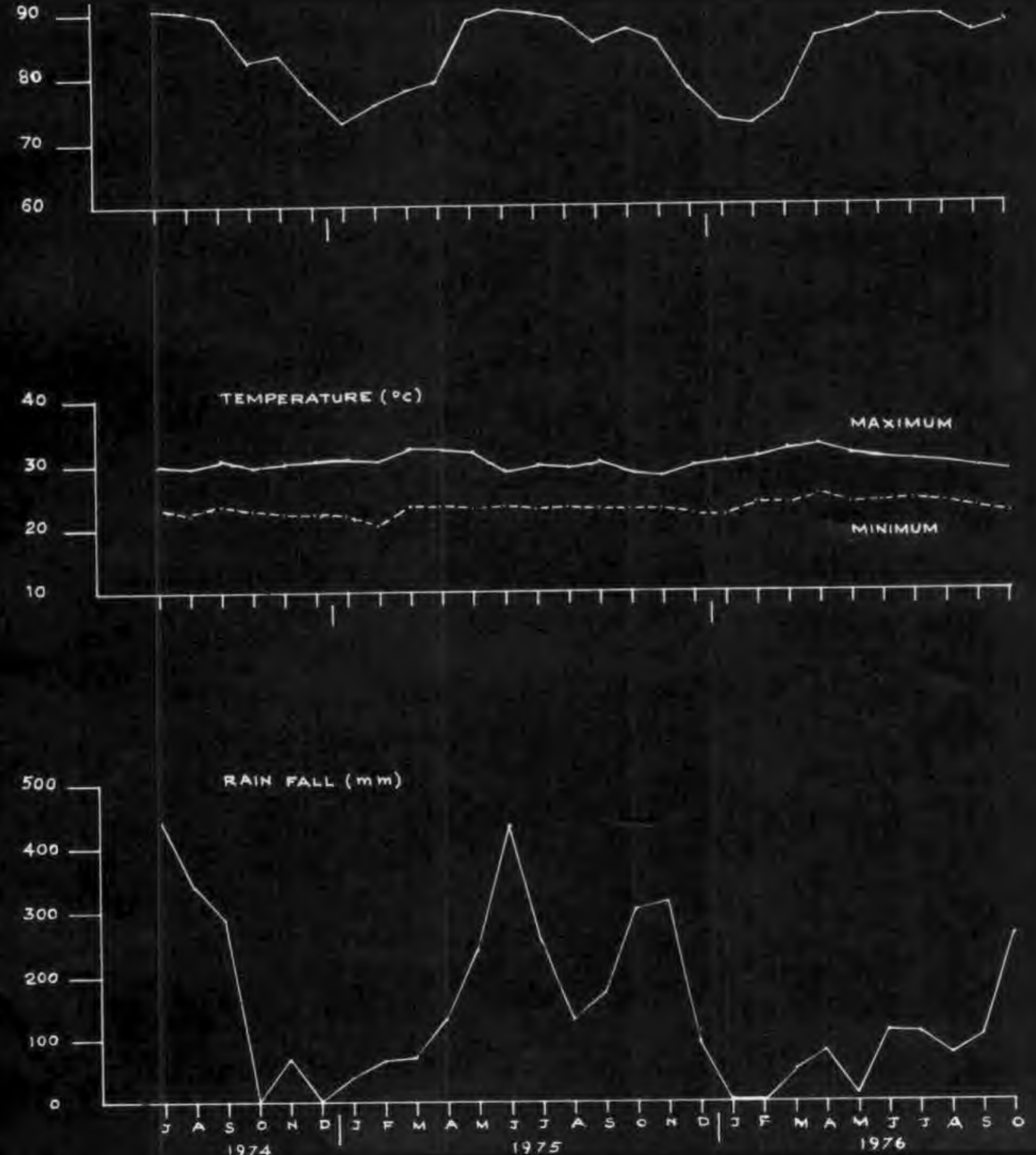
Two varieties, namely, Triveni and Jaya were used

90
80


RELATIVE HUMIDITY (%)
100
90
80
70
60



RELATIVE HUMIDITY (%)
100
90
80
70
60
TEMPERATURE (°C)
40
30
20
MAXIMUM
MINIMUM



90
80
70
60
TEMPERATURE (°C)
MAXIMUM
MINIMUM
40
30
20
10
RAIN FALL (mm)
500
400
300
200
100
0
J A S O N D J F M A M J J A S O N D J F M A M J J A S O
1974
1975
1976


90
80
70
60

FIG. 2. PLAN OF LAY OUT

in the study. Triveni is a high yielding, short duration (about 100 days), short statured and photo-insensitive variety evolved by a cross between Annapurna and Ptb 15. Jaya is a high yielding, medium duration (about 125 days), short statured and photo-insensitive variety evolved by a cross between T (N) 1 and T 141. It is a stable yielder with wide adaptability.

(ii) Sweet potato. Ipomoea batatas (L.) (Lam.) (Convolvulaceae)

The hybrid H-42 evolved by a cross between Velladamph (a local variety) and Triumph (an American variety) was used in the experiment. It produces medium sized, pink skinned tubers having yellowish white flesh.

(iii) Cowpea. Vigna sinesis Savi. (Leguminosae)

The local type Kozhinjil payar, grown extensively in the southern parts of Kerala was used in the experiment. The plants are bushy in nature and profusely branching. Leaves are small and pale green. Flowers are yellow. Pods are small and the seeds red.

(iv) Sesamum. Sesamum indicum (L.) (Pedaliaceae)

Kayamkulam 1 used in the experiment is an improved variety having a duration of 80 to 90 days and is suitable for low land cultivation in Onattukara region of Kerala State and similar areas.

(v) Groundnut. *Arachis hypogaea* Linn. (Leguminosae) The strain T.M.V. 2 suitable for both rainfed and irrigated cropping was used in the experiment. It is bunchy in growth with small two-seeded pods. The kernels are small, rounded, light rose and non dormant. This is popular among the groundnut growers of Kerala.

IV Details of cultivation:

(i) Rice.

Nursery: Wet nurseries were raised in all the three seasons, namely, *Virippu* (July to October), *Mundakan* (November to February) and *Punja* or summer (February-March to May-June). Sprouted seeds were sown and 20 to 25 day-old seedlings were transplanted to the main field.

Cultural practices: The field preparation for rice consisted of four ploughings and puddling. The bunds were trimmed and plastered, after which leveling of each plot was done.

Manures and manuring: Fertilisers were applied as per the "Package of Practices Recommendations" of the Kerala Agricultural University. This consisted of 70-35-35 kg./ha. of N, P and K, respectively for Triveni and 90-45-45 kg./ha. of N, P and K, respectively for Jaya. Nitrogen (as ammonium sulphate) was applied in two split doses for Triveni, half at planting and the rest one month after transplanting and in three split doses for Jaya, half at planting, one-fourth 30 days after transplanting and the rest 45 days after transplanting. Phosphorus (as single superphosphate) and potash (as muriate of potash) were applied as basal dose to both the varieties.

Transplanting: The two varieties Triveni and Jaya were transplanted during the Virippu and Mundakan seasons, respectively, at a distance of 15 cm between rows and 10 cm between plants. During the Punja (summer) season the variety Triveni was planted at a spacing of 10 cm x 10 cm on account of its very short duration during the summer. Two seedlings per hill were planted in all the cases.

Intercultivation and weeding: Gap filling was done one week after transplanting. Plots were hand-weeded twice, first 30 days after transplanting and second 45 days after transplanting.

Irrigation and water management: All the plots were irrigated whenever necessary to maintain about 5 cm water level throughout the growing period. The water was drained out from the plots 15 days before harvest.

Plant protection: As a precautionary measure, seedlings were dipped in parathion 0.05 per cent solution before transplanting. Prophylactic plant protection measures were taken against the attack of pests and diseases whenever necessary according to the "Package of Practices Recommendations".

Harvesting and threshing: Two border rows of plants from all the four sides of plots were harvested and removed. The net plots from all the treatments were then harvested and threshed separately.

(ii) Sweet potato.

Preparatory tillage: The land, after the harvest of mundakan rice, was drained out completely and the soil was allowed to dry. Then the soil was brought to a fine tilth by digging to a depth of 25cm. Ridges of 35cm height were made 75cm apart for planting the vine cuttings.

Planting: Good quality vine cuttings of 'H-42' obtained from the Central Tuber Crops Research Institute, Trivandrum, were used for the study. The vines were cut into 25cm length and planted on the ridges at a spacing of 20cm between vines, using single vine cutting per hole. Vine cuttings were planted with the middle portion burried in the soil and the two cut ends exposed to the surface.

Manuring: Farm yard manure was applied at the rate of 10 tonnes/ha. at the time of preparation of the land. In addition, fertilisers were also applied at the following rates:

Nitrogen	:	75 kg./ha. as ammonium sulphate.
Phosphorus	:	50 kg./ha.as single superphosphate.
Potash	:	75 kg./ha. as muriate of potash.

The full dose of phosphorus and potash were applied at the time of planting, whereas, nitrogen was applied in two equal split doses, the first one at the time of planting and the second one four weeks after planting.

Intercultivation: Weeding and earthing operations were conducted four weeks after planting, that is, at the time of application of second dose of nitrogen. The development of small slender tubers at the nodes were prevented by disturbing the vine occassionally during the active growth period.

Irrigation and water management: At the time of planting sufficient moisture was ensured in the soil for early establishment of the cuttings. Adequate drainage was provided to prevent water logging. Irrigation was provided once in two days for a period of 15 days after planting and thereafter, once in seven days.

Plant protection: Sumithion at 0.1 per cent was sprayed at 30 days interval after planting as a prophylactic measure against the attack of sweet-potato weevil. Against the attack of minor pests like leaf feeders, parathion was sprayed at 0.5 per cent.

Harvesting: Two border rows of plants from all the four sides were harvested and removed. The remaining experimental area was then harvested and the sweet potato tubers and vines immediately weighed and recorded.

(iii) Cowpea.

Preparatory tillage: The land, after the harvest of Mundakan rice, was drained fully and the soil was allowed to dry. The soil was then brought to a fine tilth by digging. The plots were then levelled, using levelling boards.

Seeds and sowing: Seeds of the local variety, Kozhinjil payar were sown in small furrows at a spacing of 15cm x 15cm and the furrows were then covered with soil.

Manuring: Farm yard manure at the rate of two tonnes per hectare was applied at the time of land preparation and incorporated into the soil. In addition, fertilisers were also applied at the following rates:

Nitrogen : 10 kg./ha. as ammonium sulphate.
Phosphorus: 50 kg./ha. as single superphosphate.
Potash : 50 kg./ha. as muriate of potash.

The entire dose of nitrogen, phosphorus and potash was applied as basal dressing at the time of planting.

Intercultivation and weeding: Gap filling was done ten days after sowing. Weeding and hoeing operations were conducted three weeks and six weeks after sowing.

Irrigation and water management: A light irrigation was given four days after sowing. Subsequent irrigations were given once in seven days.

Plant protection: As a prophylactic measure, 0.2 per cent Sevin at 600 litres/ha. was applied at an interval of two weeks, starting from one month after transplanting.

Harvesting: Two border rows of plants were first harvested and removed. The remaing experimental area was then harvested by cutting and removing the plants at the ground level along with the pods. The pods were then separated and shelled. The grains were dried in the sun, cleaned and weight recorded.

(iv) Sesamum.

Preparatory tillage: The land, after the harvest of Mundakan rice, was drained and the soil was allowed to dry. The soil was then brought to a fine tilth by digging properly at the correct moisture level. The clods were broken and the plots were levelled using levelling boards.

Seeds and sowing: Seeds of the variety *Kayamkulam*-1 (at the rate of five kg./ha.) were broadcast after mixing with three times its volume of sand to ensure uniform coverage. A harrow was worked, followed by a woodden plank to cover the seeds in the soil.

Manuring: A basal dose of five tonnes of farm yard manure per hectare was applied at the time of land preparation. The following fertilisers were also applied to the sesamum crop:

Nitrogen	: 30 kg./ha. as ammonium sulphate.
Phosphorus	: 15 kg./ha. as single superphosphate.
Potash	: 30 kg./ha. as muraite of potash.

The entire dose of nitrogen, phosphorus and potash was applied as basal dose at the time of planting.

Intercultivation and weeding: Intercultivation was done twice, 15 days and 30 days after sowing. When the plants were about 15cm in height, thinning was done so as to give a spacing of 25cm between plants.

Irrigation and water management: The crop was irrigated immediately after the thinning operations and thereafter at 15 days interval. The irrigation was stopped just before the fruits began to mature.

Plant protection: As a prophylactic measure, 0.25 per cent B.H.C.(W.P) was sprayed at an interval of two weeks, starting from one month after sowing.

Harvesting: Harvesting was done when the plants turned yellowish and the seeds inside the capsules turned brownish/blackish. First, the border plants in 30cm around the plots were harvested and removed. The remaining experimental plants were harvested by pulling them out along with the pods during the morning hours. The plants were then stacked in bundles for three to four days. Afterwards, they were spread in the sun and beaten with sticks to break open the capsules. The seeds were collected, cleaned, dried in the sun and weight recorded.

(v) Groundnut.

Preparatory tillage: After the harvest of the Mundakan rice, the land was drained fully and the soil allowed to dry. The soil was then brought to a fine tilth by digging properly. The clods were broken and then the plots were levelled, using levelling boards.

Seeds and sowing: Seeds of the variety T.M.V.2 were sown in small furrows at a spacing of 15cm x 15cm and then covered with soil.

Manuring: Farm yard manure was applied at the rate of two tonnes per hectare at the time of land preparation. In addition, the following nutrients were also applied in the form of chemical fertilisers:

Nitrogen : 10 kg./ha. as ammonium sulphate.
Phosphorus : 20 kg./ha. as single superphosphate.
Potash : 40 kg./ha. as muriate of potash.

The entire dose of fertilisers was applied as basal at the time of sowing. Lime at one tonne per hectare was applied at the time of flowering and mixed in the soil by light hoeing.

Interculitvation and weeding: Gap filling was done ten days after sowing. Weeding and hoeing operations were carried out three and six weeks after sowing and also at the time of application of lime.

Irrigation and drainage: A light irrigation was given four days after sowing the crop. Further irrigations were given once in seven days.

Plant protection: Prophylactic measures were taken against the attack of pests and diseases. Parathion (at o.o5 %) was sprayed at an interval of two weeks, starting from one month after sowing. Bordeaux mixture was sprayed before flowering to control Tikka leaf spot disease.

Harvesting: After removing two border rows of plants from all the four sides of the plots, the experimental plants were harvested. The top portions of the plants were cut and removed after which the groundnut pods were dug out. The pods were then dried in the sun, cleaned and the weight recorded.

V Dates of planting and harvest of the crops included in the cropping pattern:

The dates of planting and harvest of the crops included in the cropping patterns are presented in Table 3.

VI Pre-harvest observations:

(i) Rice.

Sampling technique: Random sampling technique was adopted to study the agronomic characters - height and number of tillers. Five sample units of 50 cm x 30 cm were selected from each plot. Biometric observations were recorded first 30 days after planting and subsequently at an interval of 20 days.

(a) Plant height: The height of the plant was measured from the ground level upto the tip of the top most leaf.

(b) Tillering: Total number of tillers of the plants of the five sample units were counted and the number of tillers per square metre computed. The final tiller count represents the number of effective tillers.

(ii) Sweet potato.

Sampling technique: Three rows were selected from

Table-3

Dates of planting and harvest of various crops in the cropping patterns

Treatment (1), RICE_RICE_SWEET POTATO

Year	Virippu rice (Triveni)		Mundakan rice (Jaya)		Punja (summer) season crop sweet potato	
	Planting	Harvest	Planting	Harvest	Planting	Harvest
1974-75	11-7-74	8-10-74	6-11-74	15-2-75	16-3-75	30-6-75
1975-76	3-7-75	8-10-75	4-11-75	9-2-76	27-2-76	5-6-76
1976-77	27-7-76	28-10-76				

Treatment (2), RICE_RICE_COWPEA

	Virippu rice (Triveni)		Mundakan rice (Jaya)		Punja (summer) season crop cowpea	
1974-75	11-7-74	8-10-74	6-11-74	15-2-75	14-3-75	7-6-75
1975-76	3-7-75	8-10-75	4-11-75	9-2-76	10-3-76	5-6-76
1976-77	27-7-76	28-10-76				

Treatment (3), RICE_RICE_SESAMUM

	Virippu rice (Triveni)		Mundakan rice (Jaya)		Punja (summer) season crop sesamum	
1974-75	11-7-74	8-10-74	6-11-74	15-2-75	24-3-75	12-6-75
1975-76	3-7-75	8-10-75	4-11-75	9-2-76	28-2-76	11-5-76
1976-77	27-7-76	28-10-76				

Treatment (4), RICE_RICE_GROUNDNUT

	Virippu rice (Triveni)		Mundakan rice (Jaya)		Punja (summer) season crop Groundnut	
1974-75	11-7-74	8-10-74	6-11-74	15-2-75	14-3-75	13-6-75
1975-76	3-7-75	8-10-75	4-11-75	9-2-76	10-3-76	5-6-76
1976-77	27-7-76	28-10-76				

Treatment (5), RICE_RICE_RICE

	Virippu rice (Triveni)		Mundakan rice (Jaya)		Punja (summer) season crop Rice(Triveni)	
1974-75	11-7-74	8-10-74	6-11-74	15-2-75	15-3-75	11-6-75
1975-76	3-7-75	8-10-75	4-11-75	9-2-76	3-3-76	31-5-76
1976-77	27-7-76	28-10-76				

each plot with the help of Tippet's random numbers and five plants from each row (thus making a total of 15 plants for each plot) were chosen for observations.

(a) Length of the main shoots: Length of the main shoots of the observational plants were measured from the base of the main shoot to the base of the leaf at the tip.

(b) Number of branches: The number of branches were counted for each observational plant, first 30 days after planting and subsequently at 20 days interval.

(iii) Cowpea.

Sampling technique: Random sampling technique was adopted for selecting rows and plants for observation. The plant selected in the row was taken as the central plant of a rectangle. In this way, three rectangles were selected in each plot. There were nine plants in each rectangle and thus 27 plants were taken from each plot for observation of the characters.

(a) Plant height: The height of the selected plants were measured from the ground level upto the tip of the top most leaf, first at 30 days after planting and subsequently at 20 days interval.

(b) The number of branches were counted from each sample plant, first 30 days after planting and subsequently at 20 days interval.

(iv) Sesamum.

Sampling technique: Random sampling technique was adopted to select observational plants for scoring the agronomic characters - plant height and number of branches. Five sample units of 50cm x 20 cm each were selected from each plot and biometric observations were recorded, first 30 days after sowing and subsequently at 20 days interval.

(a) Plant height: All the plants from each selected sample unit were taken for measuring the plant height. Height was measured from the ground level upto the tip of the top most leaf.

(b) Number of branches: The number of branches were counted from each sample plant, first 30 days after sowing and subsequently at 20 days interval.

(v) Groundnut

Sampling technique: The sampling technique adopted for cowpea was adopted for groundnut also.

(a) Plant height: The height of the selected plants were measured from the ground level upto the tip of the top most leaf, first 30 days after sowing and subsequently at 20 days interval.

(b) Number of branches: The number of branches was recorded from each sample plant, first 30 days after planting and subsequently at 20 days interval.

VII Post-harvest observations:

(i) Rice.

(a) Yield of grain and straw: The plot wise yield was recorded after cleaning and drying to 14 per cent moisture level. The straw was dried in the sun and the yield was then recorded. In both the cases, the per hectare yield was then computed.

(b) Straw : grain ratio: The straw : grain ratio was also worked out.

(ii) Sweet potato.

(a) Yield of tubers: The weight of tubers was recorded immediatley after the harvest. The yield per hectare was also computed.

(b) Green weight of vines: The green weight of vines was recorded immediately after the harvest and per hectare yield was calculated from this.

(iii) Cowpea.

(a) Yield of grain: The yield of grains after drying was recorded plot wise and per hectare yield calculated from this.

(b) Yield of haulm: The weight of haulm (sun dried) was recorded plot wise and per hectare yield computed.

(iv) Sesamum.

(a) Yield of grain: The grain yield was recorded plot wise after drying in the sun and the per hectare yield was estimated.

(b) Yield of haulm: The weight of haulm (sun dried) was recorded plot wise to obtain the per hectare yield.

(v) Groundnut.

(a) Yield of pods: The yield from individual plots was recorded after complete drying and the per hectare yield was computed from this.

(b) Yield of haulm: The weight of haulm (sun dried) was recorded plot wise from which the per hectare yield was worked out.

(c) Shelling percentage: The shelling percentage was worked out after shelling all the pods.

B. Studies on the changes in physico-chemical properties of soil due to multiple cropping

The soil from each plot was analysed for the various physico-chemical properties before starting the experiment and after each crop season.

I Collection of soil sample

For the purpose of collection of soil samples, each plot was divided into four equal parts. From each part, one soil sample was collected from the plough layer using a soil auger and the four samples thus obtained were mixed together thoroughly. This composite sample was then air dried.

Undisturbed 'core samples' were collected and dried at room temperature for the study of soil physical properties like, bulk density and water stable aggregates. For the determination of other chemical properties, further processing of the soil was done.

II Processing of soil samples for chemical analysis:

The air-dried samples were powdered and passed through a two mm. sieve. The percentage of moisture was determined prior to the chemical analysis. All the analysis were carried out in duplicate.

III Analytical methods:

The methods followed for the analysis (physical and chemical) of soil samples are given below:

a. Mechanical analysis: Bouyoucos hydrometer method was used for the mechanical analysis of soil.

b. Soil pH: The pH was determined using Beckman pH meter with soil:water ratio of 1:2.5.

c. Water stable aggregates: Wet sieving technique (Yoder, 1936) was used for finding out water stable aggregates in the soil.

d. Bulk density: The bulk density was determined by estimating the weight of the undisturbed core of oven dry soil per unit volume of soil.

e. Organic carbon: Walkley and Black's rapid titration method was used for the determination of organic carbon.

f. Total nitrogen: The conventional Kjeldahl's method was used for the determination of total nitrogen.

g. Extractable phosphorus: Phosphorus was extracted by 0.1 N HCl and 0.03 N NH_4F solution and determined by the method of Dickman and Bray (1940).

h. Exchangeable potassium: Exchangeable potassium was extracted by neutral normal ammonium acetate solution and determined by Elico Flame photometer.

i. Total cation exchange capacity: Cation exchange capacity was determined by the ammonium acetate and potassium chloride method (Piper, 1950).

j. Exchangeable calcium and magnesium: Exchangeable calcium and magnesium were released by leaching the soil with neutral ammonium acetate solution and estimated by titration with versenate (Cheng and Bray, 1951).

k. Exchangeable hydrogen: Exchangeable hydrogen was determined by extracting with 0.5 N barium acetate solution and by titrating against 0.1 N NaOH (Jackson,1958).

C. Studies on the uptake of plant nutrients.

I. Collection and preparation of plant samples:

(i) Rice.

The sample plants selected for recording the observations were harvested separately and used for plant analysis. After drying the plants, the panicles were separated. The plant portions were chopped into small bits and mixed thoroughly. The composite plant samples were then oven dried and ground into fine powder (using an electric grinder) for the chemical analysis.

The grains separated from the panicles were also used for the chemical analysis.

(ii) Sweet potato.

The sample plants selected for recording the observations were used for the plant analysis. The vines, after sun drying, were oven dried, ground into fine powder using an electric grinder and used for chemical analysis.

The tubers were cleaned thoroughly, cut into small slices and dried first in the sun and then in the oven. The dried slices were ground into fine powder in an electric grinder for the chemical analysis.

(iii) Cowpea.

The sample plants after harvest were sun dried for a few days. They were then oven dried and ground into fine powder.

The sun dried pods were shelled and the grains analysed chemically.

(iv) Sesamum.

The sample plants, after the harvest, were dried in the sun for a few days and then oven dried. They were ground into fine powder in an electric grinder and used for the chemical analysis.

(v) Groundnut.

The observational plants were harvested and the pods were separated. The plants were sun dried and then oven dried. They were then ground into fine powder (using an electric grinder) to be used for the chemical analysis.

The groundnut pods were cleaned and sun dried for a few days. Then they were shelled and the shell and the kernels separated. The shell was dried in the oven and powdered in an electric grinder for the chemical analysis.

The kernels were analysed separately.

II Method of analysis:

The plant samples were analysed in duplicate for nitrogen, phosphorus and potash. The methods of analysis followed are given below:

a. Total nitrogen: Nitrogen was determined by the semi-micro Kjeldahl's method, using 0.1 to 0.25 g. of the material.

b. Total phosphorus: One gramme of the plant material was digested with nitric acid, sulphuric acid and perchloric acid (Jackson, 1958) and the digest was filtered and made upto 100 ml. Suitable aliquotes were taken for the determination of phosphorus and potassium.

Phosphorus was determined colorimetrically by the method of Fiske and Subbarow (1925).

c. Total potassium: Suitable aliquotes of the above digest were taken for the determination of potassium, using Flame photometer (Jackson, 1958).

D. Economics of the cropping patterns studied.

The following rates were used for working out the economics of the cropping patterns included in the present investigations. The prevailing rates at Vellayani were taken into account for working out the cost of cultivation and for estimating the value of the produce.

1. Cost of manures and fertilisers:

a. Farm yard manure	- Rs. 50-00/tonne
b. Ammonium sulphate	- Rs. 925-00/tonne
c. Superphosphate (single)	- Rs. 504-00/tonne
d. Muriate of potash	- Rs. 820-00/tonne
e. Lime	- Rs. 200-00/tonne

2. Wages:

a. Male labourer	- Rs. 6-00/day
b. Female labourer	- Rs. 5-00/day

3. Bullocks and Machinery:

a. Bullocks (pair)	- Rs. 15-00/day

4. Seeds and produce:

a. Rice	Seed	- Rs. 2-00/kg.
	grain	- Rs. 1-00/kg.
	straw	- Rs. 0.20/kg.
b. Sweet potato	Vine cuttings	Rs. 5-00/100
	tubers	- Rs. 40-00/quintal

c. Cowpea	seed	- Rs. 4-00/kg.
	grain	- Rs. 2-50/kg.
d. Sesamum	seed	- Rs. 5-00/kg.
	grain	- Rs. 5-00/kg.
e. Groundnut	seed	- Rs. 4-00/kg.
	pod	- Rs. 2-50/kg.

E. Statistical analysis.

I. Analysis of variance:

The data on the various plant characters and soil analysis were statistically analysed by the analysis of variance method (Fisher, 1946). Significance of the various ratios for treatment effects were tested at five per cent and one per cent levels. Significance at five per cent level was denoted by single asterisk and at one per cent level by two asterisks. The standard error for the means (S.Em.) was calculated for each treatment effect separately. The critical difference (C.D.) was calculated at five per cent level and at one per cent level.

II. Correlation studies:

The correlations between the yield of rice and some of the soil fertility factors were worked out and their significance was tested at five per cent and at one per cent levels (Snedecor, 1946).

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

A. Field experiments

(I) Pre-harvest observations

(a) Rice.

Observations on plant height and number of tillers were recorded at 30 days after planting and subsequently at an interval of 20 days to study the effect of the treatments (preceding crops) on the growth of the succeeding crop.

(i) Virippu rice

Plant height.

The data on plant height at different stages of crop growth during the years 1974, 1975 and 1976 are presented in Table 4.

The data show that there was no significant difference in the height of plants during the *virippu* seasons of the three years under study. When the results of the first, second and third year are examined in detail, it may be seen that rice-rice-cowpea produced tallest plants followed by rice-rice-groundnut during all the stages of observation except at harvest during the second year. At harvest stage during the second year, rice-rice-groundnut

Table-4

Plant height in cm at successive stages of growth

(Virippu rice, 1974, 1975 and 1976)

Sl. No.	Treatment	Virippu rice 1974 Variety: Triveni Days after planting				Virippu rice 1975 Variety: Triveni Days after planting				Virippu rice 1976 Variety: Triveni Days after planting			
		30	50	70	Harvest	30	50	70	Harvest	30	50	70	Harvest
1.	Rice-rice-sweetpotato	52.454	73.960	82.960	82.400	48.267	64.987	79.680	78.373	55.947	70.240	77.973	75.573
2.	Rice-rice-cowpea	52.667	74.494	84.827	83.947	48.800	66.053	80.707	78.427	56.667	69.667	77.787	76.560
3.	Rice- rice-sesamum	50.520	72.107	81.387	81.253	45.586	64.347	78.613	78.427	54.373	68.893	76.946	75.653
4.	Rice-rice-groundnut	52.547	74.067	84.707	83.920	48.747	65.933	79.613	79.387	55.680	68.973	76.497	76.480
5.	Rice-rice-rice	49.613	71.573	82.067	81.480	48.707	65.987	79.100	77.280	53.853	67.667	75.976	75.479
	'F' test				N.S.				N.S.				N.S.
	S.Em.				± 1.367				± 0.954				± 0.763

recorded maximum height of plants. It can also be observed from the data that rice-rice-rice treatment produced the shortest plants exhibiting poor performance and growth.

The same variety of rice crop, viz, Triveni was used and the same package of practices were followed for all the virippu crops of all the three years under study and therefore one cannot expect much variation in the height of plants, as the height of plants is mostly a genetic character. The slight variation observed may be due to the effect of preceding crop on soil fertility. The high fertility status especially of nitrogen maintained continuously by the additional nitrogen fixation by the preceding cowpea and groundnut crops would have been responsible for the slight increase in the height of plants in these treatments during the second and third year (Table 51a). According to Tanaka *et al*. (1958) and Srinivasalu and Pawar (1965) the nitrogen influences the height of rice plants.

Tillering behaviour

The data on the average number of tillers per square metre area at different stages of growth of the crop and effective tillers at harvest are presented in Table 5.

Table-5

Number of tillers per square metre at successive stages of growth (Virippu rice, 1974, 1975 and 1976)

Sl. No.	Treatment	*Virippu* rice 1974 Variety: Triveni Days after planting				*Virippu* rice 1975 Variety: Triveni Days after planting				*Virippu* rice 1976 Variety: Triveni Days after planting			
		30	50	70	at harvest effective tillers	30	50	70	at harvest effective tillers	30	50	70	at harvest effective tillers
1.	Rice-rice-sweet potato	511	478	393	356	527	472	485	407	524	501	376	304
2.	Rice-rice-cowpea	543	518	446	408	556	505	489	418	540	515	462	408
3.	Rice-rice-sesamum	525	506	440	408	519	483	473	408	527	496	425	389
4.	Rice-rice-groundnut	523	508	428	379	554	497	485	417	528	520	454	396
5.	Rice-rice-rice	523	499	429	378	549	502	475	403	532	508	427	327
	'F' test				N.S.				N.S.				**
	S.Em.				± 19.801				± 22.1878				± 9.7311
	C.D.(0.05)				..				..				29.175
	C.D.(0.01)				..				..				40.199

** Significant 1%

N.S. Not significant

Number of tillers

The data reveal that in all the treatments there was reduction in the number of tillers per square metre at 50th day after transplanting and this reduction continued till harvest, eventhough the magnitude of reduction varied from treatment to treatment. This reduction in the number of tillers was apparent in all the three years. Mahapatra and Sharma (1970) have shown that irrespective of duration of variety, maximum tillering stage is attained by 40th day after transplanting. Thereafter, a reduction in tiller count occurs due to mortality.

In the first year the treatment rice-rice-cowpea recorded the highest number of tillers per square metre at 30th day, 50th day and 70th day after planting. During the second year also the same treatment recorded the maximum number of tillers starting from 30th day up to 70th day. But during the third year, eventhough the treatment rice-rice-cowpea was able to record the maximum number of tillers at 30th day, when it reached 50th day, the treatment rice-rice-groundnut recorded the maximum number of tillers. But this was again reversed in favour of rice-rice-cowpea treatment at 70th day after transplanting.

It is seen that the effect of cowpea and groundnut as preceding crops was apparent in increasing the number of tillers during the second and third year, as these crops have continuously maintained the nitrogen status of soil by additional nitrogen fixation.

Effective tillers.

It is seen that the treatments rice-rice-cowpea and rice-rice-sesamum recorded the maximum number of effective tillers during the first year. The treatment rice-rice-sweet potato recorded the lowest number of productive tillers although the differences were not significant. During the second year also the treatment rice-rice-cowpea produced the maximum number of effective tillers, although the effect was not significant. The lowest number of effective tillers was produced by the treatment rice-rice-rice. Unlike first year and second year, the treatment rice-rice-cowpea recorded significantly higher number of productive tillers during the third year.

Since all the treatments were planted with the same variety of rice during virippu season, not much variation can be expected during the first year. During the second year also the effect was not significant although the treatment rice-rice-cowpea could produce the maximum number of effective tillers. The high fertility status especially of nitrogen maintained continuously (Table 51a) by the additional nitrogen fixation by two crops of cowpea during the punja seasons of two years would have been responsible for the higher number of effective tillers in virippu rice of third year grown after cowpea crop. Increase in ear bearing tillers due to increase in nitrogen levels was reported by workers like Tanaka et al. (1958) and Alexander et al. (1974).

The lowest number of effective tillers was recorded in rice-rice-rice treatment during the second year and by rice-rice-sweet potato treatment during the third year. The poor growth in the continuous cropping of rice has been reflected on the number of effective tillers thus producing the lowest number of effective tillers in the rice-rice-rice treatment during the second year. The fact that the sweet potato crop removed the highest amount of phosphorus and potash and comparatively higher amount of nitrogen from the soil (Tables 61, 62 and 63) thus exhausting the fertility status of soil would have been responsible for the lowest number of effective tillers in the rice-rice-sweet potato treatment during the third year.

(ii) Mundakan rice

Plant height.

The data on plant height at different stages growth of mundakan rice during the years 1974-75 and 1975-76 are presented in Table 6.

The data reveal that the treatment difference in respect of height of plants was not significant. During the mundakan season the rice variety Jaya was used in all the treatments and therefore the treatment differences could not be expected to be apparent. The treatment rice-rice-rice produced the shortest plants revealing the fact that continuous cropping of rice will lead to poor performance and growth of crop. While the treatment rice-rice-groundnut produced the maximum height of plants at harvest during the first year, the treatment rice-rice-cowpea showed superiority during the second year. The continuous maintanance of fertility by the cowpea as well as by groundnut crop which has been reflected in the height of plants of virippu crop would have been responsible for increasing the height of plants in the mundakan crop also which was immediately following the virippu crop.

Tillering behaviour.

The data on the average number of tillers per square metre at different stages of growth of the mundakan rice and the number of effective tillers at harvest are presented in Table 7.

Table-6

Plant height in cm at successive stages of growth

(Mundakan rice 1974-75 and 1975-76)

Sl. No.	Treatment	Mundakan rice 1974-75 (Variety : Jaya)					Mundakan rice 1975-76 (Variety : Jaya)				
		Days after planting					Days after planting				
		30	50	70	90	harvest	30	50	70	90	harvest
1.	Rice-rice-sweet potato	54.280	67.520	72.273	74.167	71.187	55.680	64.600	72.880	75.826	73.913
2.	Rice-rice-cowpea	54.840	69.000	73.600	74.933	72.520	56.320	68.947	76.226	77.120	74.880
3.	Rice-rice-sesamum	52.760	67.160	72.533	73.080	71.533	55.907	64.853	73.773	74.820	73.773
4.	Rice-rice-groundnut	53.820	68.147	72.747	74.280	72.773	56.853	67.493	75.240	77.240	74.253
5.	Rice-rice-rice	52.307	67.347	71.520	72.833	70.960	53.467	64.773	73.680	74.180	71.307
	'F' test					N.S.					N.S.
	S.Em.					± 0.8394					± 1.0887

N.S. Not significant

Table-7

Number of tillers per square meter at successive stages of growth

(Mundakan rice 1974-75 and 1975-76)

Sl. No.	Treatment	Mundakan rice 1974-75 (Variety: Jaya) Days after planting					Mundakan rice 1975-76 (Variety: Jaya) Days after planting				
		30	50	70	90	harvest (effective tillers)	30	50	70	90	harvest (effective tillers)
1.	Rice-rice-sweet potato	639	674	656	573	348	501	547	528	516	285
2.	Rice-rice-cowpea	654	683	674	587	358	516	565	551	520	297
3.	Rice-rice-sesamum	623	655	643	563	351	511	552	539	521	295
4.	Rice-rice-groundnut	647	678	659	574	356	517	569	556	546	309
5.	Rice-rice-rice	619	654	640	555	341	424	529	509	497	254
	'F' test					N.S.					N.S.
	S.Em.					± 8.897					± 17.001

N.S. Not significant

Total number of tillers

The data reveal that in all the treatments the maximum tillering was attained at 50th day; thereafter a reduction was observed. This may be due to the premature death of tillers. During the first year the number of tillers was comparatively higher in all the treatments than during the second year. The treatment rice-rice-cowpea produced the maximum number of tillers at all stages of growth during the first year, although the differences were not significant at the time of harvest. However, during the second year rice-rice-groundnut treatment recorded the maximum number of tillers starting from 30th day onwards up to the harvest time. Here again the treatment effects were not significant. One interesting observation is that the treatment rice-rice-rice produced the minimum number of tillers at all stages of plant growth during both the years indicating the undesirable effect of continuous cropping with rice.

Number of effective tillers.

During the first year the maximum number of effective tillers was observed in the treatment rice-rice-cowpea, but the effect was not significant. As the change of crops in the crop sequence comes only in the third crop season its effect will be directly reflected only in the next _virippu_ crop immediately following. As the _mundakan_ crop is raised as the second crop and as the change of crop comes only after the _mundakan_ crop, the effect can not be expected in the _mundakan_ crop of first year.

In the second year, the treatment rice-rice-groundnut produced the maximum number of effective tillers. However, the treatment effect was not significant. This is quite natural as the _mundakan_ crop comes in between _virippu_ and _punja_ crops and as such the effect of various treatments will not be fully reflected on the growth and performance of _mundakan_ rice. Next to the treatment rice-rice-groundnut, rice-rice-cowpea produced maximum number of effective tillers in the second year. During both the years, the third position went to the treatment rice-rice-sesamum and the last position to rice-rice-rice. Obviously, continuous cropping of rice has shown a tendency for comparatively poor performance and growth.

(b) _Sweet potato_.

The increase in height and the number of branches put forth by a plant are considered as the satisfactory indices of its growth. Therefore these characters have been studied in detail and observations recorded.

Length of main shoot.

First observation on the length of main shoot was recorded 30 days after planting. Subsequent observations were taken at intervals of 20 days. The data are presented in Table 8.

The data reveal that there was linear increase in the length of main shoot from planting up to harvest in both the years. The length which was 56.307 cm at 30th day was increased to 160.587 cm at the time of harvest during the first year. However, during the second year the length was 54.080 cm at 30th day and was increased to 158.173 cm at the time of harvest. The decrease in length of main shoot during the second year may be due to the lesser duration (100 days) of the crop during second year as compared to that of the first year (107 days).

Number of branches.

The data on the number of branches per plant at different stages of growth are presented in Table 9.

It is seen from the data that the number of branches increased up to 70th day after planting during both the years. During the first year the average number of branches was 6.720 at 30th day while it was 10.933 at

Table-8

Length of main shoot of sweet potato plant in cm at different stages of growth

(Variety-H.42)

Sl. No.	Treatment	1975 (March-June) Days after planting					1976 (February-June) Days after planting				
		30	50	70	harvest	Total duration	30	50	70	harvest	Total duration
1.	Rice-rice-sweet potato	56.307	128.360	153.067	160.587	107	54.080	126.973	152.015	158.173	100
	Rate of increase in height per day in cm	3.603	1.235	0.203			3.645	1.252	0.205		

Table-9

Number of branches of sweet potato at different stages of growth

	Treatment	1975 (March-June) Days after planting				1976(February-June) Days after planting			
		30	50	70	harvest	30	50	70	harvest
1.	Rice-rice-sweetpotato	6.720	8.773	10.613	10.933	6.307	8.373	10.313	10.589

the time of harvest. During the second year it was 6.307 at 30th day and 10.589 at the time of harvest. It may be stated that the lesser duration taken by the crop during the second year may be responsible for the lesser number of branches during the second year.

(c) Cowpea.

The height of plant and number of branches per plant were recorded first 30 days after planting and subsequently at 20 days interval.

Height of plant.

The data on the average height of plant are presented in Table 10.

It is seen that the height of plant increased till harvest during both the years. The maximum height recorded was 66.007 cm during the first year while it was only 63.733 cm during the second year. As there was not much variation in the duration of crop the difference in height may be due to the influence of climatic factors.

Number of branches.

The data on the number of branches per plant at successive stages of plant growth are presented in Table 11.

Table-10

Height of cowpea plant in cm at successive stages of growth

(Variety - Kozhinjil payar)

Treatment	1975(March-June) Days after planting				1976 (March-June) Days after planting			
	30	50	harvest	Total duration (days)	30	50	harvest	Total duration (days)
2. Rice-rice-cowpea	26.893	52.893	66.007	86	35.413	56.867	63.733	88
Rate of increase in height of plant per day in cm	1.300	0.364			1.073	0.361		

Table-11

Number of branches of cowpea at different stages of growth

Treatment	1975 (March - June) Days after planting			1976 (March - June) Days after planting		
	30	50	harvest	30	50	harvest
2. Rice-rice-cowpea	4.700	4.753	4.827	3.947	4.270	4.360

The data reveal that there was not much difference in the number of branches per plant between the different stages of growth. However, the progressive increasing trend in the number of branches per plant was maintained continuously through out the growth period during both the years.

(d) Sesamum.

The height of plants and the number of branches per plant were recorded first 30 days after planting and there after at 20 days interval.

Height of plant.

The data on the height of plant at various stages of growth are presented in Table 12.

The data reveal that the height of plants showed increasing trend from 30th day till harvest during both the years. However, the rate of growth was less after 50th day during both the years. The maximum height was 77.933 cm during the first year and was 75.875 cm during the second year. The shorter duration of crop (74 days) during the second year as compared to that of the first year (81 days) may be responsible for lesser height of plant during the second year.

Table-12

Height of sesamum plant in cm at successive stages of growth.

(Variety - Kayamkulam -1)

Treatment	1975(March-June) Days after planting				1976 (February - May) Days after planting			
	30	50	harvest	Total duration	30	50	harvest	Total duration
3. Rice-rice-sesamum	28.906	75.000	77.933	81	28.653	73.573	75.875	74
Rate of increase in height of plant per day in cm		2.305	0.095			2.246	0.096	

Table-13

Number of branches of sesamum at different stages of growth

Treatment	1975 (March - June) Days after planting			1976 (February - May) Days after planting		
	30	50	harvest	30	50	harvest
3. Rice-rice-sesamum	3.173	3.387	2.880	2.960	3.207	2.793

Number of branches per plant.

The data on the number of branches per plant are presented in Table 13.

It is seen from the data that the number of branches increased up to 50th day and then decreased during both the years. As in the case of height of plants the number of branches, also was comparatively less during the second year. The probable reason for the lesser number of branches per plant recorded during the second year may be due to the shorter duration which the crop has taken during the second year.

(e) Groundnut.

The height of plant and the number of branches per plant were recorded from 30th day after planting till harvest at an interval of 20 days.

Height of plant.

The data on the height of plant are presented in Table 14.

It is seen that the height of plants increased up to the harvest of the crop during both the years. It is further seen that the average height of the plant at all stages of growth during the second year was

<u>Table-14</u>

<u>Height of groundnut plant in cm at successive stages of growth</u>

(Variety - TMV.2)

Treatment	1975 (March-June) Days after planting					1976 (March-June) Days after planting				
	30	50	70	harvest	Total duration	30	50	70	harvest	Total duration
4. Rice-rice-groundnut	27.440	57.200	73.333	78.560	92	22.813	44.813	56.800	62.013	88
Rate of increase in height of plant per day in cm	1.488	0.807	0.238			1.100	0.599	0.290		

<u>Table-15</u>

<u>Number of branches of groundnut at different stages of growth</u>

Treatment	1975(March-June) Days after planting				(1976(March-June) Days after planting			
	30	50	70	harvest	30	50	70	harvest
4. Rice-rice-groundnut	5.227	5.533	6.200	5.146	5.053	5.440	5.480	5.026

comparatively less as compared to that of first year. The maximum height during the first year was 78.560 cm while it was only 62.013 cm during the second year. The shorter duration of crop (88 days) noticed during the second year as compared to that of first year (92 days) might be responsible for the lesser height of plant during the second year.

Number of branches.

The data on the number of branches per plant at the successive stages of growth are presented in Table 15.

The data reveal that the number of branches slowly increased up to 70th day and then decreased during both the years. It is also seen that the number of branches at all stages of growth was comparatively less during the second year as compared to that of the first year. As explained earlier in the case of height of plant, the probable reason for the lesser number of branches during the second year may be due to the lesser duration of crop.

(f) Punja rice.

The average height of plants and the number of tillers per plant were recorded at successive stages of growth of plant. The first observation was taken on 30th day and the subsequent observations at 20 days interval.

Height of plant.

The data on the height of plant are presented in Table 16.

It is seen that the height of plant at harvest was 79.893 cm during the first year and was only 73.467 cm during the second year. Thus the mean height was comparatively lesser in the second year as compared to that of the first year. It may be seen that this is a treatment in which only rice crop was cultivated in all the three seasons and therefore reduction in the height of plants is quite agreeable to the observation that continuous cropping of rice will lead to poor performance and growth of the crop (Sadanandan, 1970).

Number of tillers.

The data on the number of tillers per square metre at successive stages of growth are presented in Table 17.

It is seen that the maximum number of tillers was produced at 30th day after planting during both the years. During the first year the number of tillers per square metre was 737 at 30th day, 520 at 50th day, 474 at 70th day and 387 at the time of harvest. The corresponding figures during the second year were 636, 543, 389 and

Table-16

Height of plant in cm at successive stages of growth

(Punja (summer) rice, 1975 and 1976)

Treatment	1975(March-June) Variety : Triveni					1976(March-May) Variety : Triveni				
	Days after planting					Days after planting				
	30	50	70	harvest	Total duration (days)	30	50	70	harvest	Total duration (days)
5. Rice-rice-rice	52.267	68.973	84.187	79.893	89	50.493	62.853	76.933	73.467	90

Table-17

Number of tillers per square meter at successive stages of growth
punja (summer)rice, 1975 and 1976

	1975 (March-June) Variety : Triveni				1976 (March-May) Variety : Triveni			
	Days after planting				Days after planting			
	30	50	70	harvest (effective tillers)	30	50	70	harvest (effective tillers)
5. Rice-rice-rice	737	520	474	387	636	543	389	319

319 respectively. Thus it is seen that the number of tillers at different stages of plant growth as well as the percentage of productive tillers was lesser in the second year as compared to that of first year. This result once again confirms the findings that continuous cropping of rice will result in comparatively poor performance and growth.

2. Post-harvest observations on various crops.

(a) Rice

(i) Virippu rice

Yield of grain.

The yield of grains of virippu rice during 1974, 1975 and 1976 are presented in Table 18 abd Fig. 3(a).

It is seen that the effect of the treatment was significant only during theyear 1976. In the first year the virippu rice was the first series of crops raised since the begining of experiment, and as the same variety of rice as raised in all the treatments, significant yield differences could not be expected. The slight differences in yield may be due to the difference in the inherent fertility status of soil. In the first year the highest yield was obtained in the treatment rice-rice-sesamum. The data on the initial status of nitrogen in the soil

Table-18

Yield of grain in kg per hectare

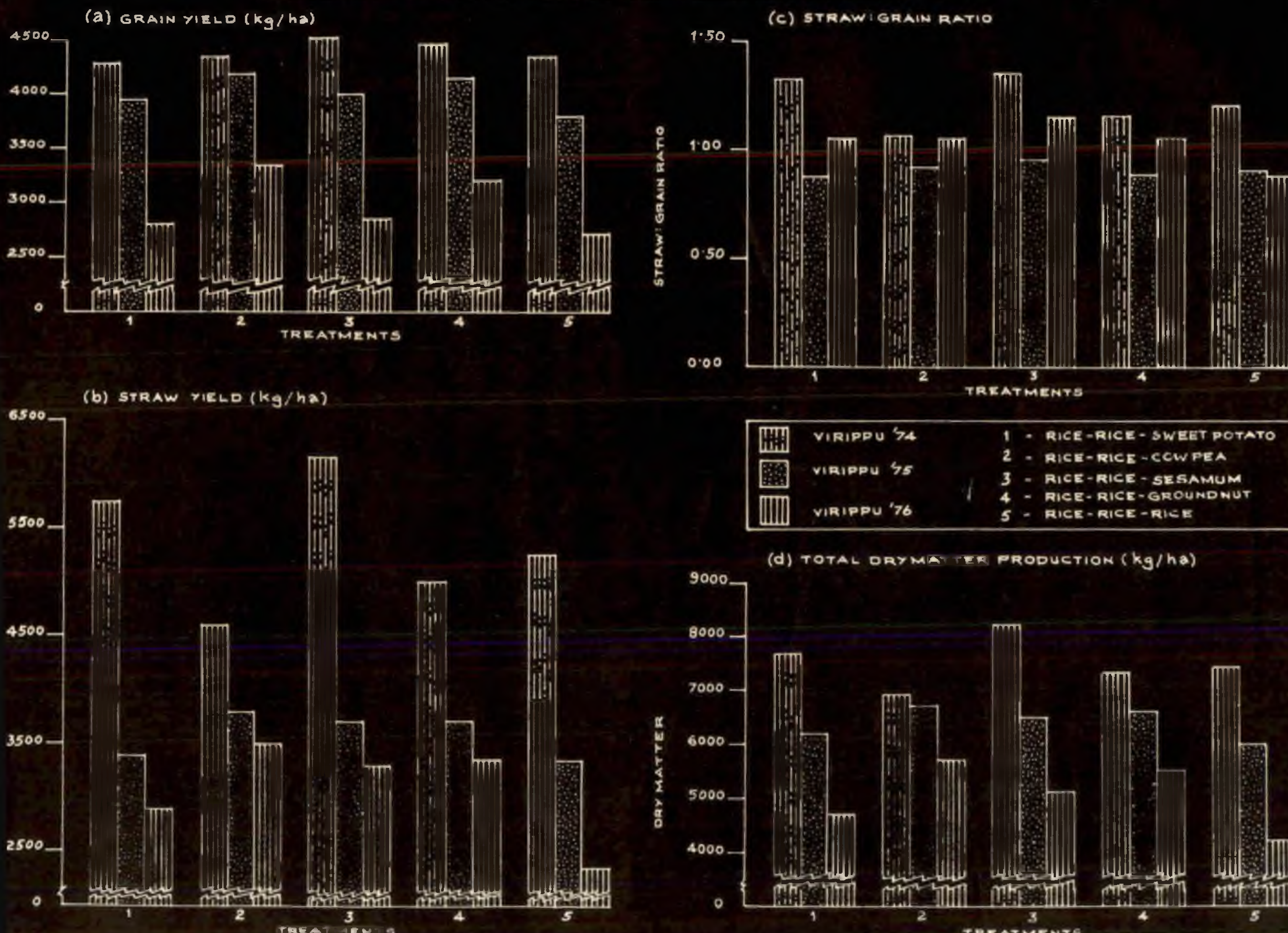
(Virippu rice 1974, 1975 and 1976)

Treatment	Virippu rice 1974 Variety:Triveni		Virippu rice 1975 Variety:Triveni		Virippu rice 1976 Variety:Triveni	
	Yield in kg/ha.	Yield in kg/ha./day	Yield in kg/ha.	yeild in kg/ha./day	yield in kg/ha.	yield in kg/ha./day
1. Rice-rice-sweetpotato	4280	47.556	3950	40.306	2808	29.872
2. Rice-rice-cowpea	4320	48.000	4174	42.592	3332	35.447
3. Rice-rice-sesamum	4560	50.667	4000	40.816	2864	30.468
4. Rice-rice-groundnut	4440	49.333	4140	42.245	3184	33.872
5. Rice-rice-rice	4360	48.444	3792	38.694	2718	28.915
'F' test	N.S.		N.S.		*	
S.Em.	± 162.8		± 169.4		± 144.6	
C.D.(0.05)	..		..		433.562	

N.S. Not significant

* Significant at 5%

FIG. 3. PERFORMANCE OF VIRIPPU RICE (1974-'75-'76)



also revealed the highest soil nitrogen status (Table 51 a) in the treatment rice-rice-sesamum.

During the second year in <u>virippu</u> season there appeared a thorough change in the yield trend of various treatments. Although not significant, the treatment rice-rice-cowpea produced the maximum yield followed by the treatment rice-rice-groundnut. The lowest yield was obtained from the treatment rice-rice-rice. The treatment rice-rice-sesamum stood third in this respect and the fourth position went to rice-rice-sweet potato. The data on the nitrogen status of soil after the first year <u>punja</u> crop (which was just preceding the second year <u>virippu</u> rice crop) show that there was positive increase in the nitrogen status of soil in plots where cowpea and groundnut were cultivated during <u>punja</u> season. This may be the reason for getting increased grain yield from <u>virippu</u> rice crop in the treatments rice-rice-cowpea and rice-rice-groundnut.

In the third year it is seen that the effect of different treatments was significant. The highest yield was obtained from the treatment rice-rice-cowpea which was significantly superior to all the other treatments except rice-rice-groundnut which in turn was superior to the treatment rice-rice-rice. However, the yield differences between the treatments rice-rice-sesamum, rice-rice-sweet potato and rice-rice-rice were not significant and therefore were on par. It is seen that even during the second year the treatment involving cowpea and groundnut tended to increase the yield of succeeding virippu rice crops. In the third year the effect of preceding cowpea crop was significant enough to produce significantly higher yield of succeeding virippu rice crop. The nitrogen status of soil at the begining of third year was 0.1329 per cent in the treatment rice-rice-cowpea which was higher as compared to the rest of the treatments. This clearly illustrates the reason for higher virippu rice grain yield in that treatment. In the rice-rice-groundnut treatment also, the nitrogen content at the begining of the third cycle was high and as such this treatment also could produce increased yield of grain in the succeeding virippu rice crop. According to Mirchandani (1952) the preceding crops of legumes whether lifted as fodder or as grain showed favourable residual effect on the succeeding crop of paddy. According to Doolette (1974) legumes will improve soil nitrogen, the physical condition of soil, and help with the control of weeds, insects and diseases.

Sandor (1975) reported that the preceding leguminous crop increased yield of rice by 12.8 per cent to 137.7 per cent.

When the data are examined in detail, it may be seen that in all the treatments the grain yield of rice decreased progressively year after year. The highest yield was obtained in the first year which progressively declined year after year even in treatments in which the rice crop was preceded with leguminous crops. This observation is a further proof that by continuous cultivation of rice the yield will be reduced. Among the various treatments tried, the treatment rice-rice-rice produced the lowest yield of grain during the <u>virippu</u> season. Experiments conducted through out the world have brought out the fact that every soil is exhausted by continuous cropping (monoculture) and as such yields decline appreciably (Williams, 1926). In U.S.A., the yield of continuous rice plots declined from 4445 lb to 450 lb per acre in a six year period (Adair, 1956). In a silt loam soil in Arkansas, the yield of rice declined from 2232 lb to 1606 lb per acre during ten years of continuous rice culture (Nelson, 1944).

Comparing the yield with the number of effective tillers, it was observed that the treatment effects were not significant in producing more number of effective tillers in the first two years. The very same trend was seen in the yield of crop in the first two years also. However, during the third year the treatment rice-rice-cowpea produced significantly higher number of productive tillers resulting in significantly higher yield.

The data on the yield of grain per day per hectare reveal that the treatments rice-rice-cowpea and rice-rice-groundnut produced the highest grain yield per day per hectare during the second and third year of experiment. The figures were 42.592 kg. and 35.447 kg. per day per hectare respectively during the second year and third year for the treatment rice-rice-cowpea and 42.245 kg. and 33.872 kg. per day per hectare respectively during the second and third year for the treatment rice-rice-groundnut. The highest yield per day per hectare (50.667 kg.) produced by the treatment rice-rice-sesamum during the first year may be due to the high initial soil fertility status in that treatment.

The results in the present study have conclusively proved the beneficial effect of legume crops on the succeeding cereal crop. It appears that under a multiple cropping system in which cereals are fertilized with large quantities of nitrogen, it takes about more than two years for the legume effects to register. This may be because under sub tropical conditions, high temparatures accelerate the decomposition of organic matter contributed by the legumes and cereals. It is not surprising, therefore that short term legumes like cowpea and groundnut probably left only small amounts of residual nitrogen and other beneficial effects on soil properties and took more than two years to make a desirable effect on the yield of cereal following it. Improved fertility status of soil after the cowpea and groundnut crops lends support to this view.

Yield of straw.

The data on the straw yield of viripppu rice of 1974, 1975 and 1976 are presented in Table 19 and Fig. 3(b).

It is seen from the data that the effects of treatments were not significant during the first two years. However, during the third year there was significant difference in straw yield due to different treatments. As the same variety of rice was cultivated

Table-19

Yield of straw in kg per hectare

(Virippu rice 1974, 1975 and 1976)

Treatment	Straw yield in kg/ ha. Virippu rice 1974	Straw yield in kg/ ha. Virippu rice 1975	Straw yield in kg/ ha. Virippu rice 1976
1. Rice-rice.sweetpotato	5720	3409	2892
2. Rice-rice-cowpea	4600	3803	3503
3. Rice-rice-sesamum	6160	3683	3302
4. Rice-rice-groundnut	5000	3698	3366
5. Rice-rice-rice	5240	3348	2340
'F' test	N.S.	N.S.	*
S.Em.	± 639.2	± 333.4	± 217.4
C.D.(0.05)	..	..	651.638

N.S. Not significant

* Significant at 5%

in all the treatments during the _virippu_ season of first year and as this was the first series of crops taken since the begining of experiment, not much variation can be expected due to the treatment effect.

In the second year, although not significant, the highest straw yield was obtained from the treatment in which rice was preceded by cowpea as well as groundnut crops. As the plant height and number of tillers in the continuous cropping of rice (rice-rice-rice treatment) were comparatively lower, the lowest straw yield was produced in that treatment. This is because of the fact that the height of rice plant mostly regulates the straw yield.

In the third year, the treatment rice-rice-cowpea was significantly superior in increasing the straw yield; the reason being the favourable influence of cowpea crop on soil fertility especially of nitrogen. The next highest straw yield was recorded by the treatment rice-rice-groundnut which again may be due to the favourable influence of groundnut crop on the nitrogen status of soil. Here again, the continuous cropping of rice (rice-rice-rice treatment) recorded the lowest straw yield. It is seen that the treatment rice-rice-cowpea which has shown superiority in increasing the grain yield of <u>virippu</u> crop during the third year, was able to show superiority in the case of straw yield also. As stated earlier, the high nitrogen content of soil due to the preceding cowpea crop coupled with other favourable effect of legume crop was responsible for the increase in yield of straw in this treatment. In the case of straw yield also, there appeared a progressive deterioration year after year irrespective of the treatment variations.

<u>Straw : grain ratio</u>.

The study of straw : grain ratio is important for it reveals the relative efficiency of different treatments on straw and grain yields. A narrow ratio means more of grain while a wide ratio results in comparatively less grain yield. The straw : grain ratio for various treatments has been statistically analysed and presented in Table 20 and Fig. 3(c).

It is seen from the data that the treatment effects were not significant during all the three years. This means that the various treatments could not make any significant change in the straw ; grain ratio.

Table-20

Straw : Grain ratio (Virippu rice, 1974, 1975 and 1976)

Treatment	Straw : grain ratio					
	Variety	1974	Variety	1975	Variety	1976
1. Rice-rice-sweet potato	Triveni	1.32	Triveni	0.87	Triveni	1.04
2. Rice-rice-cowpea	"	1.06	"	0.93	"	1.05
3. Rice-rice-sesamum	"	1.35	"	0.94	"	1.15
4. Rice-rice-groundnut	"	1.15	"	0.90	"	1.05
5. Rice-rice-rice	"	1.20	"	0.88	"	0.87
'F' test		N.S.		N.S.		N.S.
S.Em.		± 0.14		± 0.103		± 0.063

N.S. Not significant

Table 21

Total dry matter production of Virippu rice 1974, 1975 and 1976

Treatment	Virippu rice 1974		Virippu rice 1975		Virippu rice 1976	
	Total dry matter production in kg./ha. (Var.Triveni)	Dry matter production in kg./ha. per day	Total dry matter production in kg./ha. (Var.Triveni)	Dry matter production in kg./ha. per day	Total dry matter production in kg./ha. (Var.Triveni)	Dry matter production in kg./ha. per day
1. Rice-rice-sweet potato	7641.60	84.91	6181.99	63.08	4728.48	50.30
2. Rice-rice-cowpea	6926.80	76.96	6695.11	68.32	5667.92	60.30
3. Rice-rice-sesamum	8185.60	90.95	6447.23	65.79	5104.64	54.30
4. Rice-rice-groundnut	7301.60	81.13	6580.62	67.15	5431.04	57.78
5. Rice-rice-rice	7391.20	82.12	5995.75	61.18	4209.48	44.78

When the data are further examined it is seen that the highest straw : grain ratios were obtained during the first year and there was a further reduction during the second year in all the treatments. During the third year the ratios slightly increased as compared to that of second year. The highest ratio was recorded by rice-rice-sesamum during all the three years. The initial nitrogen status was high in this treatment and this high inherent fertility status would have promoted high vegetative growth resulting in comparatively high straw : grain ratio in all the years. While rice-rice-cowpea recorded the lowest straw : grain ratio during the first year, the treatment rice-rice-rice recorded the lowest ratio during the third year. During the second year the treatments rice-rice-sweet potato and rice-rice-rice produced comparatively lower straw : grain ratios. From the data on the yield of grain and straw it is clear that the lowest grain and straw yield were obtained from the treatment rice-rice-rice.

Total dry matter production per hectare per day.

Total dry matter production of virippu rice per hectare per day during the years 1974, 1975 and 1976 are presented in Tables 21 and Fig. 3(d).

It is seen from the data that maximum dry matter production per year as well as per day was in the treatment rice-rice-cowpea during the second and third year. However, during the first year, rice-rice-sesamum treatment produced the highest dry matter which may be due to the high inherent fertility status of the soil in that treatment which is evident from the data on the initial nitrogen status of soil (Table 51 a). As the virippu rice crop was the first series of crops since the beginning of experiment and as the same variety of rice was used in all the treatments, the treatment effects could not play any role in the first year virippu rice crop.

The data show that the rice crop following cowpea produced the highest yield of 68.32 kg. per day in the second year and 60.30 kg. per day during the third year. The next highest yield of 67.15 kg. per day in the second year and 57.78 kg. per day in the third year was produced by the treatment rice-rice-groundnut. As the variation of crops comes in the third crop season (punja) of every year its effect can be expected only in the virippu rice crop of second year as well as third year. Thus it is seen that the favourable effect of leguminous crops like cowpea and groundnut on the succeeding virippu rice cfop was responsible for increased dry matter production in the virippu rice crop of second and third year. The data on the grain and straw yields of virippu rice crop of second and third year also reveal the superiority of these treatments clearly. The total favourable effect of legume crop on the fertility status as well as physical properties of soil would have been responsible for the increased dry matter production.

It is also seen that the lowest dry matter production per hectare as well as per day was by the treatment rice-rice-rice. The data on the height of plants, number of total tillers and effective tillers, grain yield and straw yield also reveal the fact that there was only poor growth and yield in the treatment where continuous cropping of rice was followed. Therefore it is quite natural to have lower dry matter production in that treatment. As in the case of grain and straw yields, the dry matter production also progressively declined year after year in all the treatments.

(ii) Mundakan rice

Yield of grain.

The data on the yield of grain of mundakan rice crop for the years 1974-75 and 1975-76 were statistically analysed and presented in Table 22 and Fig. 4(a).

It is seen that the treatment effects were not significant in increasing the yield of rice during both the years. As the mundakan rice is cultivated as the second series of crops immediately after virippu rice and as the change of crops comes only in the third crop season, not much variation in yield can be expected during the mundakan season. However, the fact that the highest yield of 2790 kg./ha. produced by the rice-rice-groundnut treatment during the second year clearly illustrates the favourable effect of legume crop on the succeeding rice crops. The data reveal that the per day production was also highest (28.469 kg./ha.) in that treatment. The second highest yield of 2725 kg./ha. was also produced by rice crop following another legume crop (cowpea) with a per day production of 27.806 kg. During both the years, the lowest yield per hectare as well as per day was produced by the treatment rice-rice-rice indicating the poor performance of rice when grown continuously in the same field.

Table-22

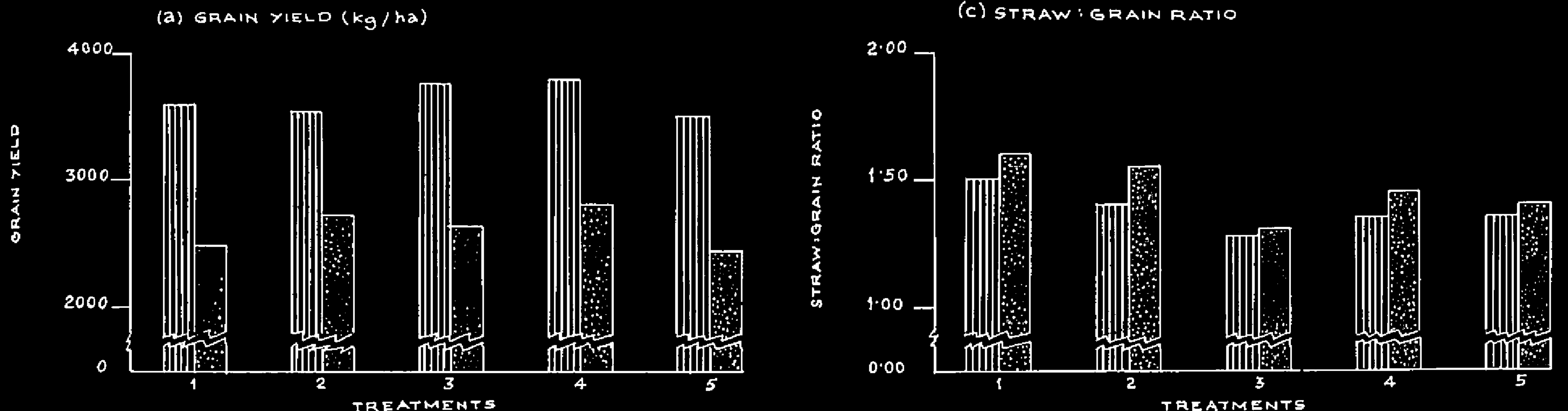
Yield of grain in kg per hectare

(Mundakan rice, 1974-75 and 1975-76)

Treatment	Mundakan rice 1974-75		Mundakan rice 1975-76	
	Variety:Jaya		Variety:Jaya	
	Yield in kg. per hectare	Yield in kg/ ha. per day	Yield in kg. per hectare	Yield in kg/ ha. per day
1. Rice-rice-sweet potato	3577	35.069	2472	25.224
2. Rice-rice-cowpea	3518	34.490	2725	27.806
3. Rice-rice-sesamum	3749	36.755	2624	26.776
4. Rice-rice-groundnut	3767	36.931	2790	28.469
5. Rice-rice-rice	3485	34.167	2416	24.653
'F' test	N.S.		N.S.	
S.Em.	± 129.46		± 99.04	

N.S. Not significant

FIG. 4. PERFORMANCE OF MUNDAKAN RICE (1974-'75 AND '75-'76)



PERFORMANCE OF MUNDAKAN RICE (1974-'75 AND '75-'76)

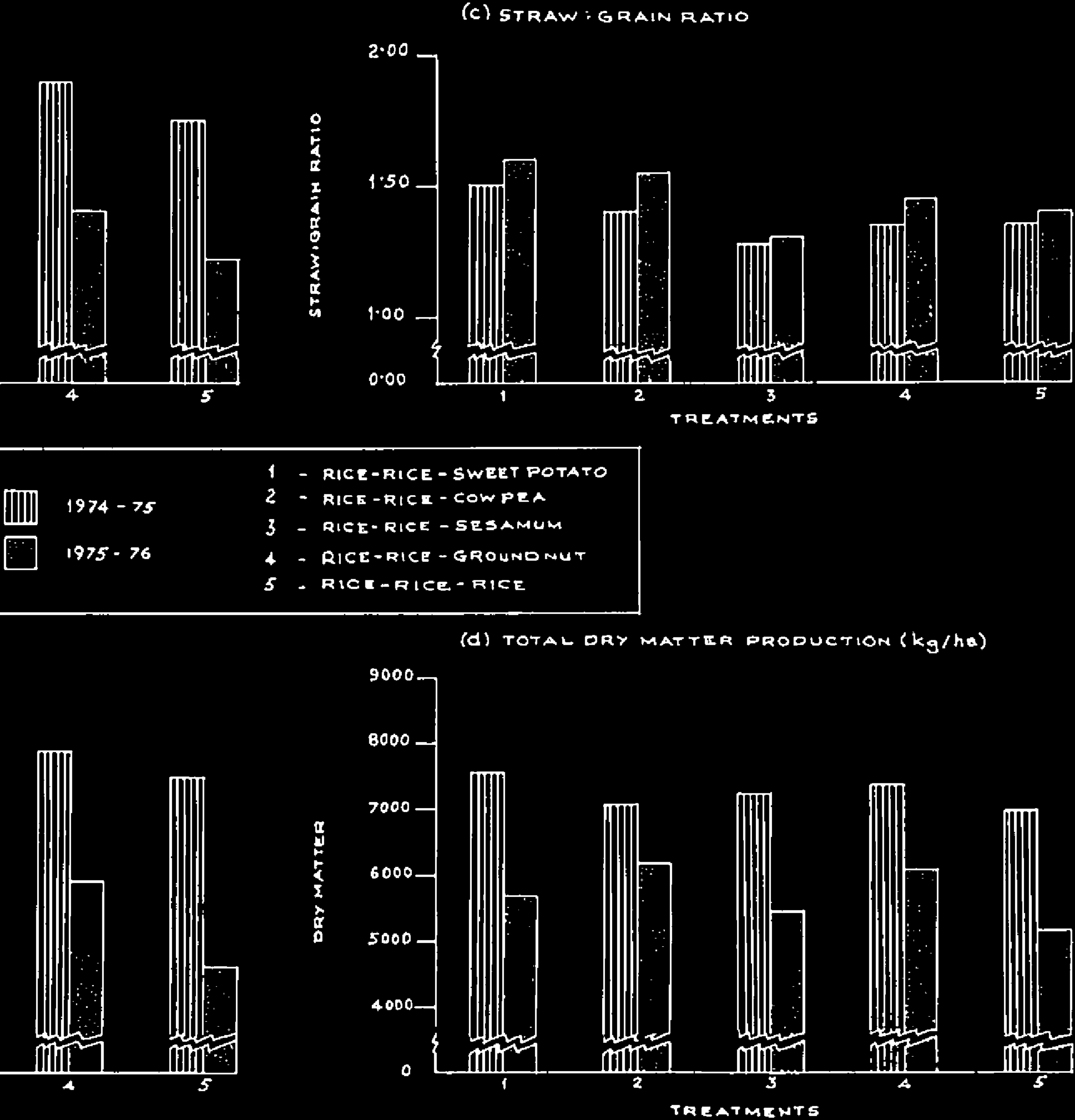


FIG. 4. PERFORMANCE OF MUNDAKAN RICE (1974-'75 AND '75-'76)

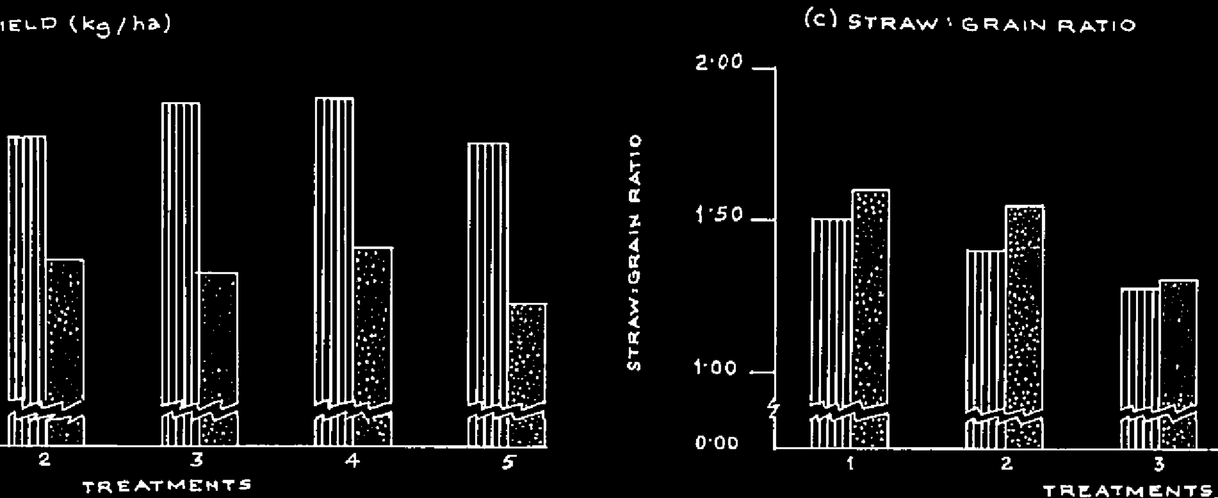
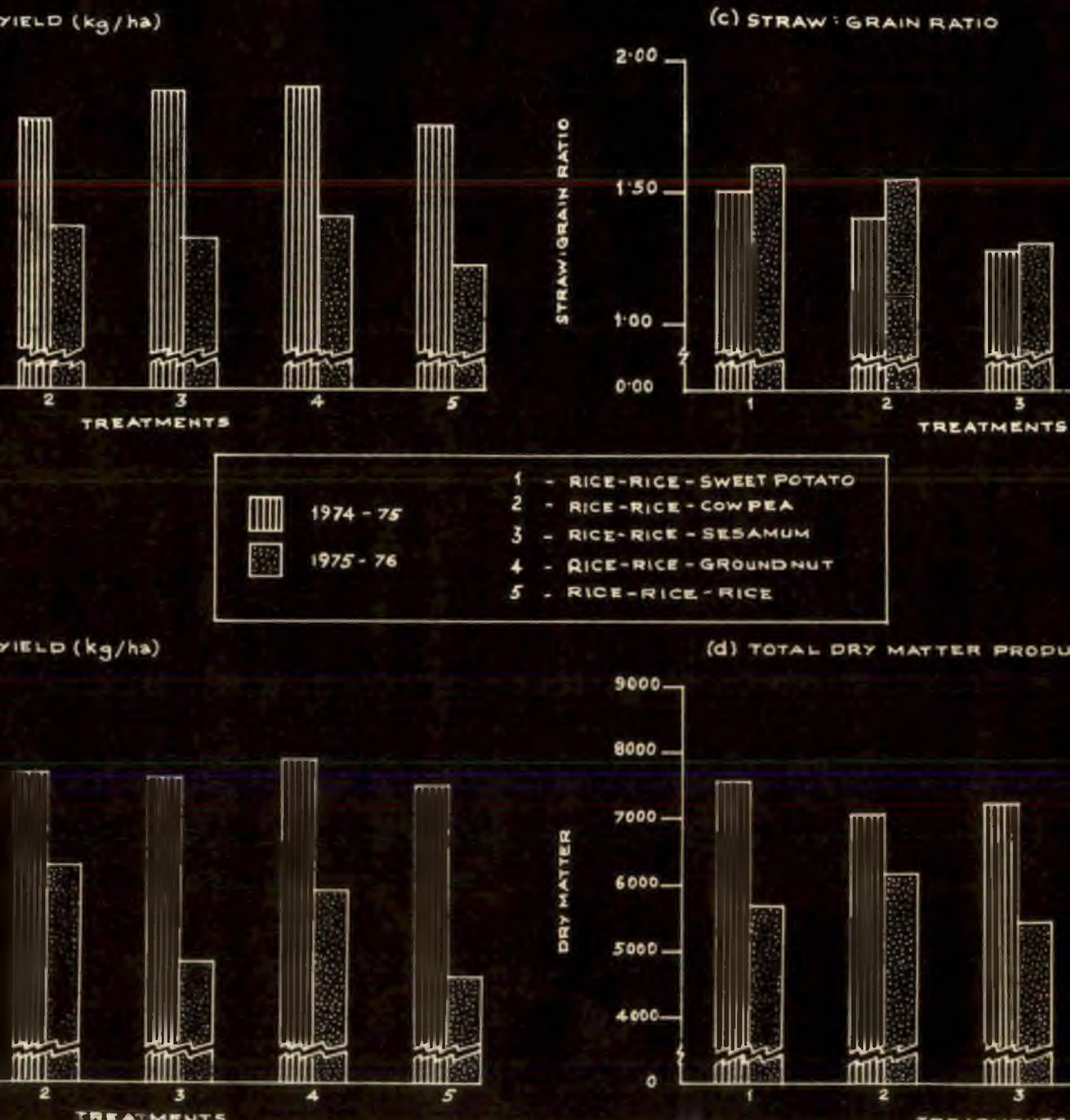


FIG. 4. PERFORMANCE OF MUNDAKAN RICE (1974-'75 AND '75-'76)



As in the case of viripp̲u̲ rice crop the yield of grain was considerably reduced from first year to the second year in all the treatments. The very same trend is seen in the per dry production by the different treatments also. This once again supports the previous observation that continuous cropping of rice will reduce the yield of rice considerably.

Yield of straw.

The data on the yield of straw of mundakan rice of 1974-75 and 1975-76 were statistically analysed and presented in Table 23 and Fig. 4(b).

The data reveal that the different treatments were not significant in increasing the yield of straw. As stated earlier the experiment was started with virippu rice of the same variety followed by mundakan rice of the same variety in all the treatments. Therefore much variation cannot be expected in the first year as the change of crops comes only in the punja season.

During the second year also, the effect of the treatments was not significant. It may be seen that even in the virippu rice crop of second year which was immediately following the punja season of first year where change of crops occured, the various treatments could not

Table-23

Yield of straw in kg. per hectare

(Mundakan rice, 1974-75 and 1975-76)

Treatment	Straw yield in kg/ha. Mundakan rice 1974-75	Straw yield in kg/ha. Mundakan rice 1975-76
1. Rice-rice-sweet potato	5353	3877
2. Rice-rice-cowpea	4836	4158
3. Rice-rice-sesamum	4797	3436
4. Rice-rice-groundnut	4951	3974
5. Rice-rice-rice	4741	3317
'F' test	N.S.	N.S.
S.Em.	± 207.8	± 305.4

N.S. Not significant

make any significant influence on the grain or straw, except a favourable trend by the leguminous crops on the yield of succeeding rice crop by producing the higher grain as well as straw yield in the treatment rice-rice-cowpea and rice-rice-groundnut. It is seen from the data that this favourable influence of leguminous crops was extended to the straw yield of mundakan rice of second year also. Thus the highest straw yield was obtained in the treatment rice-rice-cowpea followed by rice-rice-groundnut.

As in the case of grain yield the straw yield also declined by successive croppings in all the treatments which again reveals the fact that continuous cropping with rice will lead to deterioration in growth and yield of rice crop. This is further substantiated by the data showing that the lowest yield of straw was obtained from the treatment rice-rice-rice during both the years.

Straw : grain ratio.

The straw : grain ratio of mundakan rice during 1974-75 and 1975-76 was statistically analysed and presented in Table 24 and Fig. 4 (c).

It is seen that the straw : grain ratios were high during the second year as compared to that of the

Table-23

Yield of straw in kg per hectare

(Mundakan rice, 1974-75 and 1975-76)

Treatment	Straw yield in kg/ha. Mundakan rice 1974-75	Straw yield in kg/ha. Mundakan rice 1975-76
1. Rice-rice-sweet potato	5353	3877
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'F' test	N.S.	N.S.
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N.S. Not significant

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As in the case of grain yield the straw yield also declined by successive croppings in all the treatments which again reveals the fact that continuous cropping with rice will lead to deterioration in growth and yield of rice crop. This is further substantiated by the data showing that the lowest yield of straw was obtained from the treatment rice-rice-rice during both the years.

Straw : grain ratio.

The straw : grain ratio of mundakan rice during 1974-75 and 1975-76 was statistically analysed and presented in Table 24 and Fig. 4 (c).

It is seen that the straw : grain ratios were high during the second year as compared to that of the first year, indicating that the productive efficiency of the crop has gone down by continuous cropping with rice. The data on the yield of grain and straw during the mundakan rice crop of both the years will reveal that the yields were low during the second year as compared to those of the first year. Thus it is seen that the grain and straw yields were reduced, while the straw : grain ratios were widened by continuous cropping with rice even in treatments in which there was change of crops during punja season. This is a clear indication that cultivation of rice repeatedly in the same area will reduce the production efficiency of the rice crop.

The data on the straw : grain ratios of virippu and mundakan rice crop reveal that the straw : grain ratios were comparatively higher during mundakan season of both the years. It may be observed that Jaya rice was cultivated during the mundakan season, while Triveni was cultivated during the virippu season of both the years. Therefore, the comparatively wider ratio recorded by the mundakan rice crop may be considered as a varietal character.

Total dry matter production per hectare per day.

The data on total dry matter production and dry matter production per hectare per day of mundakan rice during the years 1974-75 and 1975-76 are presented in Table 25 and Fig. 4(d).

It is seen from the data that the maximum dry matter production was obtained in the treatment rice-rice-sweet potato during the first year and in rice-rice cowpea during the second year. As stated earlier there was no change of crops in the various treatments during virippu season and mundakan season as the change of crops occurred only during the punja season. Therefore any difference in the dry matter production during the mundakan season of the first year may be due to the difference in inherent fertility status of soil.

During the second year the highest dry matter was produced by the treatment rice-rice-cowpea. This may be due to the residual favourable effect of cowpea which improved the nitrogen status of soil as well as physical condition of soil. The residual favourable effect of groundnut was also observed by producing the second highest dry matter in the treatment rice-rice-groundnut during the mundakan season of second year. It is seen

Table-24: Straw : Grain ratio
(Mundakan rice, 1974-75 and 1975-76)

Treatment	Straw : grain ratio			
	Variety	1974-75	Variety	1975-76
1. Rice-rice-sweet potato	Jaya	1.50	Jaya	1.59
2. Rice-rice-cowpea	"	1.39	"	1.54
3. Rice-rice-sesamum	"	1.28	"	1.31
4. Rice-rice-groundnut	"	1.33	"	1.43
5. Rice-rice-rice	"	1.36	"	1.38
'F' test		N.S.		N.S.
S.Em.		± 0.077		± 0.126

N.S. Not significant

Table-25: Total dry matter production of Mundakan rice (1974-75 and 1975-76)

Treatment	Mundakan rice 1974-75		Mundakan rice 1975-76	
	Total D.M.* production in kg./ha. (Var.Jaya)	D.M.* production in kg./ha. per day	Total D.M.* production in kg./ha. (Var.Jaya)	D.M.* production in kg./ha. per day
1. Rice-rice-sweet potato	7519.46	73.72	5693.65	58.10
2. Rice-rice-cowpea	7048.18	69.10	6172.62	62.99
3. Rice-rice-sesamum	7222.18	70.81	5435.01	55.46
4. Rice-rice-groundnut	7362.94	72.19	6066.12	61.90
5. Rice-rice-rice	6941.86	68.06	5141.60	52.47

* Dry matter

that there were only two leguminous crops in the rotation and both of them were effective in increasing the dry matter production not only in the _virippu_ rice crop which was immediately following them, but the _mundakan_ rice also which was cultivated after _virippu_ rice. This clearly shows that the favourable effect of leguminous crops will be seen not only in the immediate succeeding crop but will be extended to further succeeding crops also. The fact that the lowest dry matter production was obtained from the treatment rice-rice-rice substantiates the previous observation that the continuous cultivation of rice will reduce the productive efficiency of rice crop.

The data on the dry matter production revealed an important information that the dry matter production efficiency was also going down from season to season. In all the treatments, the dry matter production was less in the second year as compared to that of the first year. This again supports the observation about the unfavourable effect of continuous cropping with rice.

The data on the dry matter production per day revealed that in the treatment rice-rice-cowpea the highest dry matter production of 62.99 kg. per day was obtained during the second year followed by the treatment rice-rice-groundnut in which the dry matter production per day

Table-26

Yield of grain in kg. per hectare of
Virippu and Mundakan rice 1974, 1975 and 1976

Treatment	1974-75					1975-76					1976	
	Virippu rice		Mundakan rice		Percentage of Virippu yield	Virippu rice		Mundakan rice		Percentage of Virippu yield	Virippu rice	
	Yield /ha.	Yield/ ha./ day	Yield /ha.	Yield/ ha./ day		Yield /ha.	Yield/ ha./ day	Yield /ha.	Yield/ ha./ day		Yield /ha.	Yield/ ha./ day
1. Rice-rice-sweet potato	4280	47.556	3577	35.069	83.575	3950	40.306	2472	25.224	62.582	2808	29.872
2. Rice-rice-cowpea	4320	48.000	3518	34.490	81.435	4174	42.592	2725	27.806	65.285	3332	35.447
3. Rice-rice-sesamum	4560	50.667	3749	36.755	82.215	4000	40.816	2624	26.776	65.600	2864	30.468
4. Rice-rice-groundnut	4440	49.333	3767	36.931	84.842	4140	42.245	2790	28.469	67.391	3184	33.872
5. Rice-rice-rice	4360	48.444	3485	34.167	79.931	3792	38.694	2416	24.653	63.713	2718	28.915
'F' test	N.S.		N.S.			N.S.		N.S.			*	
S.Em.	± 162.8		± 129.46			± 169.4		± 99.04			± 144.6	
C.D.(0.05)	..		..			..		..			433.562	

N.S. Not significant

* Significant at 5%

was 61.90 kg. Here again, the lowest dry matter production per day was obtained from the treatment rice-rice-rice.

(iii) Comparative yield performance of Virippu and Mundakan rice.

The yield of *virippu* rice for the years 1974, 1975 and 1976 and the yield of *mundakan* rice for the years 1974-75 and 1975-76 are presented in Table 26.

It is seen from the data that comparatively higher yields were obtained from the *virippu* rice as compared to that of *mundakan* rice during both the years. The data on the height as well as the tiller production also reveal the superiority of *virippu* rice crop of both the years over *mundakan* rice crop. The fact that higher number of effective tillers was produced by the *virippu* rice crops clearly illustrates the reason for higher grain yield. The highest yields obtained from *virippu* crops were 4560 kg. per hectare during 1974-75, 4174 kg. per hectare during 1975-76 and 3332 kg. per hectare during 1976. In all these cases the treatment rice-rice-cowpea produced the highest yield except during the first year during which time the treatment rice-rice-sesamum produced the highest yield and this may be due to the difference in inherent soil fertility and not due to the treatment effects, as the variation of crops comes only in the punja season. A critical analysis of the virippu rice yields reveal that the yields of second year and third year are much lower than that of first year.

As stated earlier, the yields obtained during mundakan season were much lower and among the two mundakan crops, the yield of second year mundakan season was much lower as compared to that of the first year. A comparison of the rice yields obtained from the various virippu and mundakan crops also reveal that the mundakan crop of second year produced the lowest yield. One of the reasons for the lower yield of mundakan crops may be due to the heavy attack of pests and diseases. The number of sunny days was less with more number of cloudy days during mundakan season resulting in poor growth and yield. This coupled with deleterious effect of continuous cropping of rice would have resulted in lower yield during mundakan season.

The data on the yield per hectare per day revealed that the highest per day production was obtained in the virippu crop rather than mundakan crop. Among the various virippu rice crops, the per day production was decreasing from the first year to third year. The unfavourable weather conditions prevailed during the *mundakan* season would have reduced the per day production as well as the per hectare production.

Thus a comparative study of *virippu* and *mundakan* rice crops revealed the superiority of *virippu* crop over *mundakan* crop in respect of growth and yield.

(b) Sweet potato.

Yield of tubers.

The yield of tubers of sweet potato crop in the treatment rice-rice-sweet potato recorded during 1975 and 1976 are presented in Table 27.

No comparison could be made as there was only one treatment with sweet potato crop. Between the two years, the higher yield was obtained during the first year. This is because of the comparatively high initial status of nitrogen in the soil. The nitrogen content of soil which was 0.1175 per cent just prior to the sweet potato crop of the first year was reduced to 0.1115 per cent before the sweet potato crop of the second year resulting in decreased yield during the second year. Moreover as the crop had to be harvested about a week earlier due to rise of water table during the second year there was reduction in the yield of tubers.

Yield of vines.

The data on the yield of vines (fresh weight) recorded during the year 1975 and 1976 are presented in Table 28.

The data reveal that there was reduction in the yield of vines during the second year as compared to that of first year. The reasons mentioned for the reduction in the yield of tubers during the second year are applicable for the reduction in the yield of vines also.

Total dry matter production.

The data on the total dry matter production recorded during the year 1975 and 1976 are presented in Table 29.

The data reveal that the dry matter production during the first year was much higher than that of the second year. From the data on the yield of tubers and vines it is seen that higher yields of both tubers and vines were obtained during the first year and thus it is but natural to get higher dry matter also during the first year as compared to that of second year.

(c) Cowpea

Yield of grain.

The data on the yield of cowpea grains recorded during the years 1975 and 1976 are presented in Table 30.

Table:27: Yield of sweet potato tubers in Rice-rice-sweetpotato treatment during the year 1975 and 1976.

	1975	1976
1. Yield in kg. per hectare	12828.0	10604.8
2. Yield in kg. per hectare/day	119.888	106.048

Table 28: Yield of Vines (fresh weight) of sweet potato crop during the years 1975 and 1976

	1975	1976
1. Yield of vines in kg/hectare	35232.0	32257.2
2. Yield of vines in kg/hectare/day	329.271	322.572

Table 29: Dry matter production from sweet potato in kg/ha/day during the years 1975 and 1976

	1975	1976
1. Yield of tubers in kg/hectare	12828.0	10604.8
2. Yield of vines in kg/hectare	35232.0	32257.2
3. Yield of dry matter/hectare from tubers	3647.2	2990.6
4. Yield of dry matter/hectare from vines	3970.0	3972.8
5. Total yield of dry matter/hectare	7617.2	6963.4
6. Dry matter/hectare/day	71.19	69.63

The data on the grain yield reveal that higher yield was obtained during the second year as compared to that of first year. This higher yield during the second year may be due to the higher fertility status especially of nitrogen during the second year. Cowpea being a legume crop increased the nitrogen status of soil from 0.1242 per cent to 0.1308 per cent during the first year (Table 51 a). It is also seen from the Table 51 a that the residual effect of this increased nitrogen lasted up to the punja season of the second year during which time the second year cowpea was cultivated. This higher nitrogen level would have helped the cowpea crop to have an initial boosting up of growth resulting in good yield. According to Tisdale and Nelson (1966) the initial nitrogen available will improve the growth and yield of leguminous crops.

Yield of haulm.

The data on the yield of haulm obtained during 1975 and 1976 are presented in Table 31.

The data reveal that the trend in the yield of haulm was the same as that of grain yield. The comparatively less yield of haulm during the first year was due to the poor growth of the crop during the first year mainly because of comparatively poor nitrogen content of soil.

Total dry matter production.

The data on the dry matter production per hectare per day during the year 1975 and 1976 are presented in Table 32.

It is seen from the data that the total dry matter production during the second year was high as compared to that of the first year. This was due to the better vegetative growth and higher yield during the second year. The data reveal that the dry matter production per hectare per day was also higher during the second year as compared to that of the first year.

(d) Sesamum

Yield of grain.

The yield of grain of sesamum recorded during the year 1975 and 1976 are presented in Table 33.

It is seen that the yield of sesamum grain was slightly higher during the first year as compared to that of second year. The higher yield of grain obtained during the first year may be ddue to the high status of soil nitrogen present prior to the cultivation of sesamum and as such the lower yield during the second year may be due to the low content of soil nitrogen during the second year. As the cultivation of sesamum crop was started

Table-30: Yield of cowpea grains in Rice-rice-cowpea treatment during the years 1975 and 1976

	1975	1976
1. Yield of cowpea grains in kg/hectare	1080.8	1176.4
2. Yield of cowpea grains in kg/hectare/day	12.567	13.368

Table-31: Yield of haulm (sundried) of cowpea crop

	1975	1976
1. Yield of haulm in kg/hectare	2088.4	2224.8
2. Yield of haulm in kg/hectare/day	24.284	25.282

Table-32: Dry matter production from cowpea in kg/hectare/day

	1975	1976
1. Yield of grain in kg/hectare	1080.8	1176.4
2. Yield of haulm in kg/hectare	2088.4	2224.8
3. Yield of dry matter/hectare from grains	959.7	1050.6
4. Yield of dry matter/hectare from haulm	1802.3	1944.6
5. Total yield of dry matter/hectare	2762.0	2995.2
6. Dry matter production/hectare/day	32.116	34.036

twenty six days earlier during the second year, the crop had to be harvested a month earlier. Because of this slight change in season, the duration of crop was also shortened by about one week resulting in lesser yield of grain. However, this shortage in the duration resulted in higher grain yield per hectare per day during the second year.

Yield of haulm.

The data on the yield of haulm recorded during the years 1975 and 1976 are presented in Table 34.

The data reveal that the yield of haulm was high during the year 1975 as compared to that of the year 1976; the reason being high fertility status of soil prior to sesamum crop during the first year coupled with the shorter duration of crop during the second year due to slight change in the crop season. As in the case of grain, the per day production of haulm was also higher during the second year which may be due to the shortage in duration of crop.

Total dry matter production per hectare per day.

The data on the dry matter production from sesamum crop per hectare per day are presented in Table 35.

Table-33: Yield of sesamum grains in Rice-rice-sesamum treatment during the years 1975 and 1976

	1975	1976
1. Yield of sesamum grains in kg/hectare	565.0	539.6
2. Yield of sesamum grains in kg/hectare/day	6.975	7.292

Table-34: Yield of haulm (sun dried) of sesamum crop

	1975	1976
1. Yield of haulm in kg/hectare	1226.0	1192-0
2. Yield of haulm in kg/hectare/day	15.136	16.108

Table-35: Dry matter production from sesamum in kg/hectare/day

	1975	1976
1. Yield of grain in kg/hectare	565.0	539.6
2. Yield of haulm in kg/hectare	1226.0	1192.0
3. Yield of dry matter/hectare from grains	523.2	494.2
4. Yield of dry matter/hectare from haulm	999.2	960.8
5. Total yield of dry matter/hectare	1522.4	1455.0
6. Dry matter production/hectare/day	18.795	19.662

It is seen from the data that the dry matter production of sesamum grains and haulm per hectare was higher during the first year as compared to that of the second year. Contrary to the above, the per day production of dry matter was slightly higher during the second year, which may be due to shorter duration of crop during the second year.

(e) Groundnut

Yield of groundnut pods.

The yield of groundnut pods recorded during the year 1975 and 1976 are presented in Table 36.

The yield of groundnut pods was higher during the year 1976 as compared to that of 1975. The data on the nitrogen status of soil after every crop in the cropping pattern reveal that the nitrogen status was higher prior to the groundnut crop during the second year resulting in better growth of the crop coupled with higher yield. This high nitrogen status may be due to the high nitrogen fixation by the groundnut crop during the first year which would have lasted up to the groundnut crop of second year producing higher yield of pods of groundnut. As the groundnut crop during the first year was attacked by 'Tikka' disease at the last stage there would have been reduction in yield of pods; as the last weeks of groundnut crop's life are of very great importance and any attack of disease or pest at that stage lowers the yield. (Bunting and Anderson, 1960).

Yield of haulm.

The data on the yield of haulm recorded during the year 1975 and 1976 are presented in Table 37.

It is seen that as in the case of pod yield the yield of haulm during the second year was high as compared to that of the first year.

As explained earlier, the reasons for the higher yield of haulm during the second year may be due to the high nitrogen content in the soil prior to groundnut cultivation during the second year. As the groundnut crop of the first year was severely attacked by 'Tikka' disease, there would have been a reduction in the yield of groundnut haulm during the first year.

Total dry matter production per hectare per day.

The data on dry matter production from groundnut per hectare per day are presented in Table 38.

The data reveal that the dry matter production from groundnut kernels, shells and haulm per hectare per

Table-36: Yield of groundnut pods in Rice-rice-groundnut treatment during the years 1975 and 1976

	1975	1976
1. Yield of groundnut pods in kg/hectare	1882.4	2568.0
2. Yield of pods in kg/hectare/day	20.457	29.182
3. Yield of kernals in kg/hectare	1381.200	1883.6
4. Yield of kernals in kg/hectare/day	15.013	21.405

Table-37: Yield of haulm (sun dried) in kg/hectare

	1975	1976
1. Yield of haulm in kg/hectare	3602.8	4760
2. Yield of haulm in kg/hectare/day	39.161	54.091

Table-38: Dry matter production from groundnut in kg/hectare/day

1. Yield of kernals in kg/hectare	1381.200	1883.6
2. Yield of shell in kg/hectare	501.200	684.400
3. Yield of haulm(sun dried) in kg/hectare	3602.800	4760.0
4. Dry weight of kernals in kg/hectare/day	13.376	19.093
5. Dry weight of shell in kg/hectare/day	4.763	6.782
6. Dry weight of haulm in kg/hectare/day	32.411	46.248
7. Total dry matter in kg/hectare/day	50.550	72.123

day was higher during the year 1976 as compared to that of 1975. As all the characters contributing to the total dry matter were higher during the second year the dry matter production was also higher.

(f) Punja rice

Yield of grain.

The data on the yield of grain from the punja rice during the year 1975 and 1976 are presented in Table 39.

The grain yield was higher during the first year as compared to that of the second year. Similar variation is seen in the case of per day production of grain also. While the per day production of grain was 43.366 kg. during the first year it was only 35.453 kg. during the second year.

In the punja season, rice is cultivated only in the treatment rice-rice-rice, which means a continuous cultivation of rice. Thus it was the third crop of rice cultivated during the punja season of first year, while it was the sixth crop of rice during the punja season of the second year. Continuous cultivation of rice will lead to reduced growth and yield of crop and as such the present observation that the yield of grain during the second year (sixth rice crop) was much lower than that of first year (third rice crop) is in conformity with the previous findings. It may be seen that the rice yield during the punja season was higher than that of the mundakan rice of respective years. This may be due to the extremely favourable climatic conditions like abundant sun shine, good temperature etc. coupled with irrigation facilities during the punja season.

Yield of straw.

The data on the yield of straw recorded by the punja rice crop during the year 1975 and 1976 are presented in Table 40.

It is seen that the yield pattern of straw was also similar to that of grain. While the yield of straw during the first year was 4185.2 kg. per hectare it was only 3496.4 kg. per hectare during the second year. The per day production of straw was also higher during the first year as compared to that of the second year. As in the case of grain the comparatively lower yield of straw during the second year may be due to the adverse effect of continuous cropping of rice. The data in Tables 16 and 17 reveal that the mean height of plants and the number of tillers per square metre at all stages of plant growth were comparatively less during the second year which would have resulted in poor yield of straw during the second year.

Straw : grain ratio.

The data on the straw : grain ratio of punja rice crop during the year 1975 and 1976 are presented in Table 41.

There was not much difference in the straw : grain ratio between the two years. As the straw yield also decreased along with grain yield there was not mcuh variation in the straw : grain ratio during the second year.

Total dry matter production per hectare per day.

The data on the dry matter production by the punja crop of rice during 1975 and 1976 are presented in Table 42.

The dry matter production on account of straw and grain as well as the total dry matter production per hectare were high during the first year as compared to that of the second year. The pattern of dry matter production per day was also similar to that of the total dry matter production.

Comparative yield and dry matter production from different crops in various cropping patterns

(i) Comparative yield of different crops.

The data on the yield of various crops in the

Table-39: Yield of Punja (summer) rice in Rice-rice-rice treatment during the years 1975 and 1976

	1975	1976
1. Yield of grain in kg/hectare	3859.6	3190.8
2. Yield of straw in kg/hectare/day	43.366	35.455

Table-40: Yield of straw in kg/hectare

	1975	1976
1. Yield of straw in kg/hectare	4185.2	3496.4
2. Yield of straw in kg/hectare/day	47.025	38.849

Table-41: Straw:grain ratio Punja (summer) rice 1975 and 1976

	1975	1976
Straw:grain ratio	1.08	1.09

Table-42: Dry matter production from Punja (summer) rice in kg/hectare/day

	1975	1976
1. Yield of dry matter from grain in kg/hectare	3315.4	2846.2
2. Yield of dry matter from straw in kg/hectare	3519.7	3188.8
3. Yield of dry matter from grain in kg/hectare/day	37.252	31.624
4. Yield of dry matter from straw in kg/hectare/day	39.547	35.431
5. Total yield of dry matter in kg/hectare/day	76.799	67.055

cropping patterns per hectare as well as per day during the years 1974-75 and 1975-76 are presented in Tables 43 a and 43 b.

The maximum yield per hectare as well as per day was obtained from sweet potato crop during both the years. However, the yield was less during the second year as compared to that of the first year. A yield of 128 quintals recorded during the first year was reduced to little more than 106 quintals during the second year. The next higher yield per hectare as well as per day was produced by virippu rice in the treatment rice-rice-sesamum during the first year and rice-rice-cowpea during the second year. The corresponding yield figures were 45.60 quintals during the first year and 41.74 quintals during the second year. The lowest yield was obtained from the sesamum crop in the treatment rice-rice-sesamum during both the years, the yield being 565 kg. per hectare during first year and 539.6 kg. per hectare during the second year. The yield per hectare per day was also lowest from sesamum crop during both the years.

As far as the total yield per hectare in a year was concerned, the maximum yield was obtained from the cropping pattern rice-rice-sweet potato during both the

Table-43(a)

Comparative yield per hectare of different crops in various cropping patterns during the year 1974-75

Treatment	*Virippu* rice		*Mundakan* rice		*Punja* (summer) season crop		Total yield in kg/ha.	Total yield in kg/ha./day
	Yield/ha. in kg.	Yield/ha. /day in kg.	Yield/ ha. in kg.	Yield/ha. /day in kg.	Yield/ha. in kg.	Yield/ha. / day in kg.		
1. Rice-rice-sweet potato	4280	47.556	3577	35.069	12828.0	119.888	20685.000	69.181
2. Rice-rice-cowpea	4320	48.000	3518	34.490	1080.8	12.567	8918.800	32.082
3. Rice-rice-sesamum	4560	50.667	3749	36.755	565.0	6.975	8874.000	32.505
4. Rice-rice-groundnut	4440	49.333	3767	36.931	1882.4	20.457	10089.400	35.526
5. Rice-rice-rice	4360	48.444	3485	34.167	3859.6	43.366	11704.600	41.653

Table-43(b)

Comparative yield per hectare of different crops in various cropping patterns during 1975-76

Treatment	Virippu rice		Mundakan rice		Punja(summer) season crops		Total yield in kg/ha.	Total yield in kg/ha./day
	Yield/ha. in kg.	Yield/ha. /day in kg.	Yield/ha. in kg.	Yield/ha. /day in kg.	Yield/ha. in kg.	Yield/ha. /day in kg.		
1. Rice-rice-sweetpotato	3950	40.306	2472	25.224	10604.8	106.048	17026.8	57.523
2. Rice-rice-cowpea	4174	42.592	2725	27.806	1176.4	13.368	8075.4	28.434
3. Rice-rice-sesamum	4000	40.816	2624	26.776	539.6	7.292	7163.6	26.532
4. Rice-rice-groundnut	4140	42-245	2790	28.469	2568.0	29.182	9498.0	33.444
5. Rice-rice-rice	3792	38.694	2416	24.653	3190.8	35.453	9398.8	32.863

years, the yield being nearly 206 quintals during the first year and 170 quintals during the second year. The highest yield per day was also obtained from this treatment. As the grain yield from unit area was less from sesamum and cowpea crops, the total yields from the cropping patterns containing these crops were also comparatively less during both the years.

(ii) Comparative dry matter production of different crops.

The data on the comparative dry matter production of various crops during the years 1974-75 and 1975-76 are presented in Tables 44 a and 44 b. The data on the average of the two years are presented in Table 45.

There was no difference in duration between the virippu crops as well as between the mundakan crops as there was no change of crops during the virippu and mundakan seasons. Among the punja season crops, sweet potato took the maximum duration being 107 days during the first year while it was only 100 days during the second year. The next highest duration was taken by groundnut crop during the first year and by rice crop during the second year. The minimum duration was taken by sesamum crop during both the years.

Table-44(a)

Comparative dry matter production per hectare from different crops in various cropping patterns during the year 1974-75

Treatment	Virippu rice			Mundakan rice			Punja (summer) season crops			Total		
	duration (days)	D.M.*/ ha.in kg.	D.M.*/ ha./ day in kg.	duration (days)	D.M.*/ ha.in kg.	D.M.*/ ha./ day in kg.	duration (days)	D.M.*/ ha.in kg.	D.M.*/ ha./ day in kg.	duration (days)	D.M.*/ ha.in kg,	D.M.*/ ha./ day in kg.
1. Rice-rice-sweet potato	90	7641.60	84.91	102	7519.46	73.72	107	7617.2	71.190	299	22778.26	76.180
2. Rice-rice-cowpea	90	6926.80	76.96	102	7048.18	69.10	86	2762.0	32.116	278	16737.00	60.205
3. Rice-rice-sesamum	90	8185.60	90.95	102	7222.18	70.81	81	1522.4	18.795	273	16930.20	62.015
4. Rice-rice-groundnut	90	7301.60	81.13	102	7362.94	72.19	92	4650.6	50.550	284	19315.10	68.011
5. Rice-rice-rice	90	7391.20	82.12	102	6941.86	68.06	89	6835.1	76.799	281	21168.20	75.332

* Dry-matter

Table 44 (b)

Comparative dry matter production per hectare from different crops in various cropping patterns during the year 1975-76

Treatment	Virippu rice			Mundakan rice			Punja (summer) season crops			Total		
	duration (days)	D.M.*/ ha.in kg.	D.M.*/ ha./ day in kg.	duration (days)	D.M.*/ ha.in kg.	D.M.*/ ha./ day in kg.	duration (days)	D.M.*/ ha.in kg.	D.M.*/ ha./ day in kg.	duration (days)	D.M.*/ ha.in kg.	D.M.*/ ha./ day in kg.
1. Rice-rice-sweet potato	98	6181.99	63.08	98	5693.65	58.10	100	6963.40	69.630	296	18839.04	63.650
2. Rice-rice-cowpea	98	6695.11	68.32	98	6172.62	62.99	88	2995.20	34.036	284	15862.93	55.855
3. Rice-rice-sesamum	98	6447.23	65.79	98	5435.01	55.46	74	1455.00	19.662	270	13337.24	49.397
4. Rice-rice-groundnut	98	6580.62	67.15	98	6066.12	61.90	88	6346.82	72.123	284	18993.56	66.879
5. Rice-rice-rice	98	5995.75	61.18	98	5141.60	52.47	90	6035.00	67.055	286	17172.35	60.043

* Dry matter

Table-45

Comparative dry matter production potential per hectare from different crops in various cropping patterns-average of two years

Treatment	*Virippu* rice			*Mundakan* rice			*Punja* (summer) season crops			Total		
	duration (days)	D.M.*/ ha.in kg.	D.M.*/ ha./ day in kg.	duration (days)	D.M.*/ ha.in kg.	D.M.*/ ha./ day in kg.	duration (days)	D.M.*/ ha.in kg.	D.M.*/ ha./ day in kg.	duration (days)	D.M.*/ ha.in kg.	D.M.*/ ha./ day in kg.
1. Rice-rice-sweet potato	94	6911.795	73.995	100	6606.555	65.910	103.5	7290.300	70.410	297.5	20808.650	69.945
2. Rice-rice-cowpea	94	6810.955	72.640	100	6610.400	66.045	87.0	2878.600	33.076	281.0	16299.965	58.030
3. Rice-rice-sesamum	94	7316.415	78.370	100	6328.595	63.135	77.5	1488.700	19.228	271.5	15133.720	55.706
4. Rice-rice-groundnut	94	6941.110	74.140	100	6714.530	67.045	90.0	5498.710	61.336	284.0	19154.330	67.445
5. Rice-rice-rice	94	6693.475	71.650	100	6041.730	60.265	89.5	6435.050	71.927	283.5	19170.273	67.687

* Dry matter

Regarding dry matter production it is seen that among the individual crops maximum dry matter production per hectare per day was obtained from the virippu rice in the rice-rice-sesamum treatment during the first year and by groundnut in the rice-rice-groundnut treatment during the second year. The lowest dry matter production was obtained from the sesamum crop during both the years.

Regarding the dry matter production per hectare per day in different cropping patterns it is seen that the pattern rice-rice-sweet potato gave the highest dry matter yield per day (76.180 kg.) during the first year and the pattern rice-rice-groundnut produced the highest dry matter (66.879 kg.) during the second year. The second position went to the treatment rice-rice-rice during the first year (75.332 kg.) and to the treatment rice-rice-sweet potato during the second year (63.650 kg.). The lowest dry matter production per day was from the pattern rice-rice-cowpea (60.205 kg.) during the first year and from the pattern rice-rice-sesamum (49.397 kg.) during the second year.

An analysis of the data on the total dry matter production per hectare from different cropping patterns reveals that rice-rice-sweet potato pattern produced the highest dry matter of 22778.26 kg. per hectare during the first year followed by the pattern rice-rice-rice which produced 21168.20 kg. dry matter per hectare. However, during the second year the pattern rice-rice-groundnut produced the highest dry matter of 18993.56 kg. per hectare followed by rice-rice-sweet potato (18839.04 kg. per hectare). When the average of dry matter production for two years has been worked out it is seen that the pattern rice-rice-sweet potato produced the maximum dry matter (20808.650 kg. per hectare) closely followed by the pattern rice-rice-rice (19170.275 kg. per hectare).

It is already seen that the virippu rice crop in the treatment rice-rice-sesamum gave the maximum dry matter production per hectare per day during the first year and groundnut crop in the treatment rice-rice-groundnut during the second year. With regard to the total dry matter production in one season the virippu rice in the treatment rice-rice-sesamum gave the highest dry matter during the first year. While, during the second year the maximum dry matter was produced by the sweet potato crop in the treatment rice-rice-sweet potato. It is also seen that the lowest dry matter production per hectare as well as per day was by sesamum crop during both the years. As the sesamum crop had the shortest duration during both the years, the time span available for dry matter accumulation was also less resulting in lesser dry matter production. This low dry matter efficiency of sesamum crop is also reflected in the total dry matter production by the cropping pattern consisting sesamum as one of the crops in the pattern.

A critical analysis of the dry matter production per day from the various cropping patterns reveal that rice-rice-sweet potato produced the maximum dry matter during both the years. The superiority of sweet potato crop in dry matter production is reflected in the data on average dry matter production of both years in which the pattern rice-rice-sweet potato produced the maximum dry matter per hectare as well as per hectare per day followed by the pattern rice-rice-rice. This clearly indicates that the cropping pattern rice-rice-sweet potato had the maximum dry matter production potential among the various cropping patterns investigated.

B. Soil fertility changes as influenced by cropping patterns

(a) Bulk density.

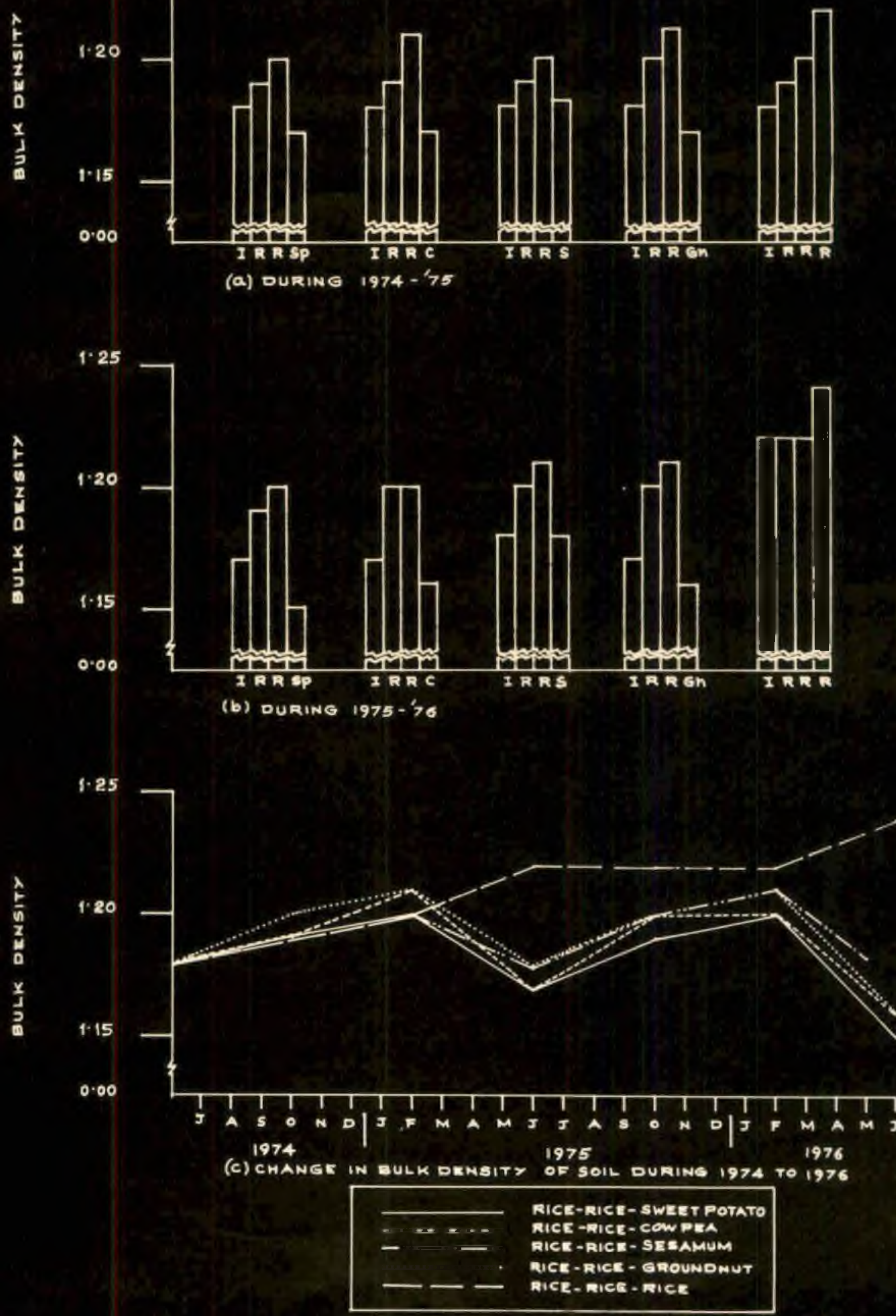
The various crops and cropping patterns will have direct and indirect effect on the various physical properties of soil. The soil physical properties in turn influence the plant growth in many ways. Therefore the effect of the various crops and cropping patterns on bulk density of surface layer of soil was conducted and the data are presented in Table 46 and Fig. 5 (a), (b) and (c).

There was only small change in bulk density after the harvest of certain crops. The bulk density which was 1.18 gm per cc at the begining increased after every rice crop in all the treatments during both the years. However, the bulk density decreased after sweet-potato, cowpea, and groundnut during the punja season of both the years except after sesamum during which time the bulk density did not change, but remained constant. The rate of decrease after sweet potato crop was 0.01 gm per cc during the first year and 0.02 gm per cc during the second year. However, the rate of decrease in bulk density was 0.01 gm per cc after cowpea and groundnut crop during both the years.

In the treatment rice-rice-rice there was increase in bulk density to the tune of 0.004 gm per cc during the first year and 0.002 gm per cc during the second year. The increase in bulk density was slightly higher

Table-46: Bulk density of soil after each crop in gm per cc

Treatment	Initial Status	1974-75			1975-76		
		after Virippu rice	after Mundakan rice	after sweet-potato	after Virippu rice	after Mundakan rice	after sweet-potato
Rice-rice-sweet potato	1.18	1.19	1.20	1.17 after cowpea	1.19	1.20	1.15 after cowpea
Rice-rice-cowpea	1.18	1.19	1.21	1.17 after sesamum	1.20	1.21	1.16 after sesamum
Rice-rice-sesamum	1.18	1.19	1.20	1.18 after groundnut	1.20	1.21	1.18 after groundnut
Rice-rice-groundnut	1.18	1.20	1.21	1.17 after Punja (summer) rice	1.20	1.22	1.16 after Punja (summer) rice
Rice-rice-rice	1.18	1.19	1.20	1.22	1.22	1.22	1.24


BULK DENSITY
1·20
1·15
0·00
I R R Sp
I R R C
I R R S
I R R Gn
I R R R
(a) DURING 1974-'75
BULK DENSITY
1·25
1·20
1·15
0·00
I R R Sp
I R R C
I R R S
I R R Gn
I R R R
(b) DURING 1975-'76
BULK DENSITY
1·25
1·20
1·15
0·00
J A S O N D J F M A M J J A S O N D J F M A M J
1974
1975
1976
(c) CHANGE IN BULK DENSITY OF SOIL DURING 1974 TO 1976
RICE-RICE-SWEET POTATO
RICE-RICE-COW PEA
RICE-RICE-SESAMUM
RICE-RICE-GROUNDNUT
RICE-RICE-RICE

after the *punja* rice in the treatment rice-rice-rice. This may be due to the rapid oxidation of organic fraction of soil during summer and the consequent loss of water stable aggregates. During puddling operations the soil particles get reoriented thereby decreasing porosity and increasing bulk density. Increase in bulk density in the continuous cropping of rice is in agreement with the findings of Sadanandan and Mahapatra (1970).

The decrease in bulk density noticed after sweet-potato crop is due to the large quantity of farm yard manures (10,000 kg. per hectare) applied to this crop. The organic manure would have improved the structure and increased pore space there by decreasing the bulk density of soil. Similar reduction in bulk density by the addition of farm yard manure was reported by Russel *et al.* (1952), Biswas *et al.* (1964) and Das *et al.* (1966). The decrease in bulk density observed after the harvest of the cowpea and groundnut was due to the improvement of soil structure as the bulk density is closely related to soil structure. Better the structure, lower is the bulk density and hence a negative correlation. Bavaskar and Zende (1973) found that inclusion of groundnut as a rotational crop improves the physical condition of soil.

(b) Water stable aggregates

The binding of soil particles in to stable aggregates is essential for the production of optimum soil tilth. Well aggregated soils provide adequate physical conditions for the penetration, growth and anchorage of plant roots and free drainage with moderate retention of rainfall. Therefore the percentage water stable aggregates of different sizes in the soil was determined after each crop to study the effect of various crops and cropping patterns on soil structure. The data are presented in Table 47 and Fig. 6.

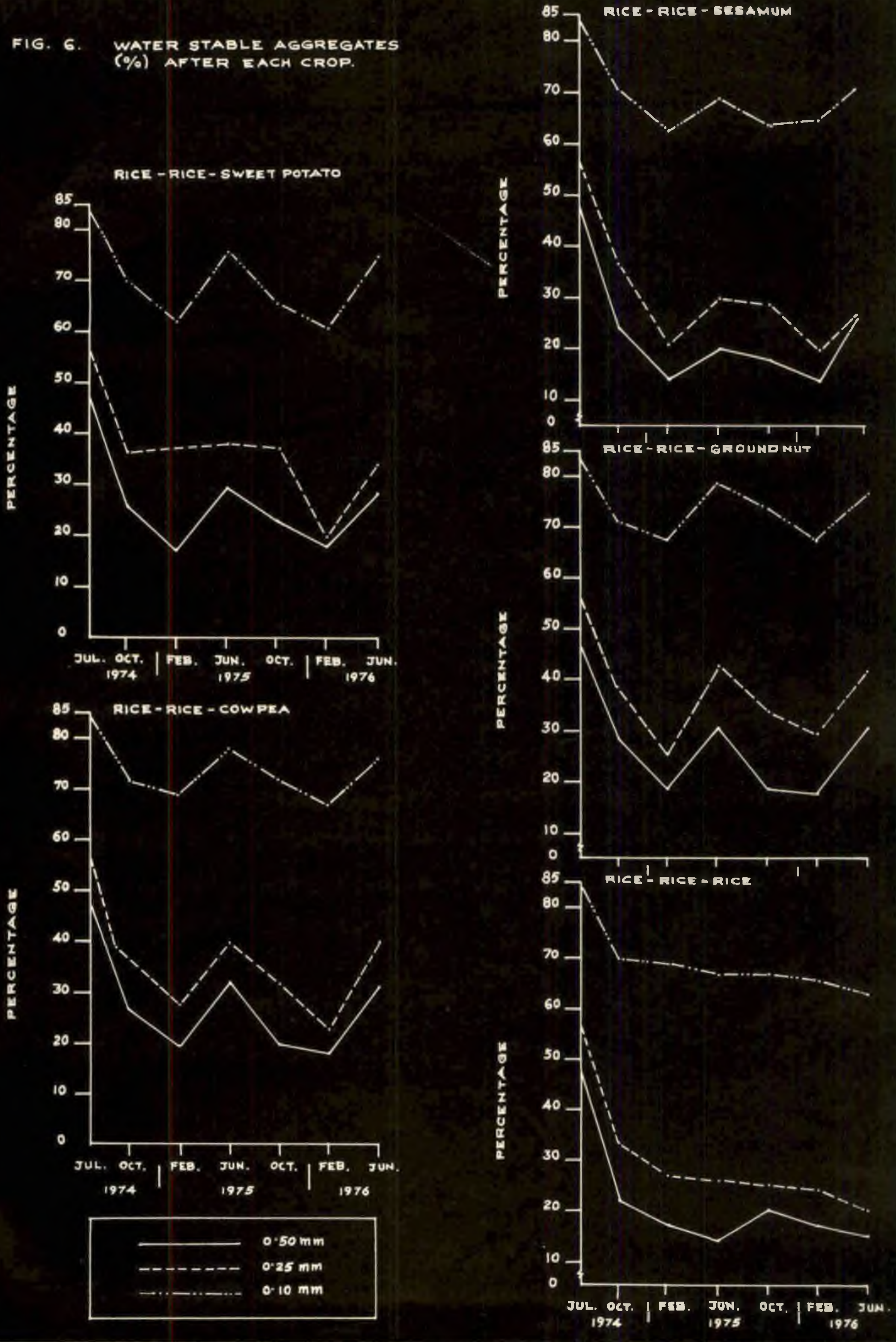
The data reveal that there was very high percentage of water stable aggregates larger than 0.5 mm, 0.25 mm and 0.1 mm before starting of the experiment. As the area under experiment was kept fallow infested with grassy weeds during the summer season prior to starting the experiment there was high percentage of aggregates at the begining. It is seen from the data that the percentage of water stable aggregates of all sizes decreased after rice crop during both the years and the decrease was higher in the treatment rice-rice-rice.

In the treatment rice-rice-sweet potato, there was an increase in the aggregates of all sizes after sweet potato

Table-47: Water stable aggregates (percentage) after each crop

Treatment	size of aggregates in mm	Initial Status	1974-75 after Virippu rice	1974-75 after Mundakan rice	1974-75 after sweetpotato	1975-76 after Virippu rice	1975-76 after Mundakan rice	1975-76 after sweetpotato
Rice-rice-sweet potato	>0.50	46.580	25.816	17.283	29.186	23.646	18.271	27.969
	>0.25	56.085	36.254	19.127	38.277	36.755	19.572	33.684
	>0.10	83.865	69.826	62.345	76.215	66.173	61.229	74.813
					after cowpea			after cowpea
Rice-rice-cowpea	>0.50	46.580	26.643	20.285	32.165	20.279	18.227	31.276
	>0.25	56.085	38.542	28.274	40.216	32.182	22.817	39.818
	>0.10	83.865	72.291	69.166	77.987	72.183	66.554	75.910
					after sesamum			after sesamum
Rice-rice-sesamum	>0.50	46.580	23.629	14.278	20.176	18.119	14.176	26.118
	>0.25	56.085	37.287	21.148	30.173	28.714	20.332	26.898
	>0.10	83.865	71.372	63.413	69.181	64.238	65.137	70.832
					after groundnut			after groundnut
Rice-rice-groundnut	>0.50	46.580	28.821	19.274	30.886	18.722	18.289	30.678
	>0.25	56.085	39.274	26.118	43.223	34.172	30.219	41.837
	>0.10	83.865	71.892	68.213	79.118	73.814	67.611	76.717
					after Punja (summer) rice			after Punja (summer) rice
Rice-rice-rice	>0.50	46.580	22.160	17.355	14.146	20.474	16.725	14.946
	>0.25	56.085	33.472	27.174	25.899	25.126	24.358	20.960
	>0.10	83.865	70.143	68.813	67.017	66.710	65.722	63.217

FIG. 6. WATER STABLE AGGREGATES (%) AFTER EACH CROP.



over the preceding rice crop during both the years. The percentage of water stable aggregates of size larger than 0.1 mm which was 83.865 at the begining was reduced to 62.345 per cent after the mundakan rice during the first year. However, this was again increased to 76.215 per cent after the sweet potato crop. The very same trend is seen during the second year also.

In the treatment rice-rice-cowpea, rice-rice-sesamum and rice-rice-groundnut also there was a reduction in the water stable aggregates of size larger than 0.1 mm after the virippu and mundakan rice crops and a further increase after the punja season crops like cowpea, sesamum and groundnut. This trend is seen during both the years. In the treatment rice-rice-rice, the percentage of aggregates of size larger than 0.1 mm which was 83.865 per cent at the begining was decreased season after season and was 63.217 per cent after two crop cycles.

With regard to aggregates of other sizes also the same trend is seen followed in all the treatments. It is seen that maximum improvement in aggregation was observed after the groundnut crop during both the years. However, maximum break down of aggregates of all sizes was observed in the treatment rice-rice-rice during both the years.

Among the different grades of aggregates, maximum break down occured in aggregates of size larger than 0.5 mm.

The influence of cropping pattern on soil structure is a reflection of continued effect of physical, chemical and biological agencies (Harris et al., 1966). The relative contribution of these agencies in the formation and degradation of soil structure varies with different cropping systems. Crops and cropping systems affect the soil structure directly and indirectly. Direct effect may be the protection afforded by the leaves and stems against the impact of rain drops. This helps in the development of granulation and porosity through root activity which aids in the regeneration of structure. The indirect effects may be the changes in granulation that are caused by the organic matter produced by plant growth (Baver, 1963). Root system of plant plays an important role in the development of soil structure. Root penetration into larger aggregates may cause separation of aggregate soil particles, while non-aggregated soil particles may be trapped and compressed into aggregates by the net work of roots. Further, growing roots may excrete substances which act as soil binding agents. The microbial conversion of plant root secretions and residues in to soil binding agents has been proposed as a major mechanism by which aggregation is affected (Stallings, 1953).

Deterioration of soil structure takes place as a result of cultivation (Tamhane and Tamboli, 1955 and Sankaranarayana and Mehta, 1967). It is seen from the Table 47 that after one complete cycle, maximum break down in soil structure took place in the treatment with continuous cultivation of rice. The water stable aggregates of size 0.5 mm decreased from 46.580 per cent to 14.946 per cent after six crops of rice. This shows that pure cereal rotation do not have a favourable effect on the formation of aggregates. The unfavourable effect of cereals on soil structure may be due to the shallow root system present in the cereals. Moreover, continuous puddling operations in the case of rice cultivation will lead to break down of soil aggregates. Mehant and Singh (1969) found that continuous cultivation of maize and paddy will have a detrimental effect on water stable aggregates in acidic soils. Padmaraju and Deb (1969) and Sadanandan and Mahapatra (1974 a) also reported that continuous cultivation of rice has a deteriorating effect on soil structure.

Another factor that affects aggregation is the application of manures and fertilizers. It has been recognised for a long time that organic manures serve as granulating agents in soils (Baver, 1963). It is seen from the Table 47 that there was an increase in water stable aggregates after sweet potato, cowpea, sesamum and groundnut, maximum increase being noticed after groundnut and cowpea crops during both the years. Legumes will have a structure improving effect when introduced in a rotation. The favourable effect may be due to the rooting habit of the legumes or due to the addition of nitrogen helping in the conservation of organic matter or due to the secretion of structure improving materials by legumes. In the case of sweet potato and sesamum crops, the increase in water stable aggregates may be due to the addition of organic manures to these crops. The fact that sweet potato and cowpea crops received 10,000 kg. and 5000 kg. of farm yard manure per hectare respectively supports this observation. Addition of organic manures increases the activity of bacteria and other soil micro-organisms. Some of these bacteria produce mucus which binds soil particles (Peele, 1940). The cementing action may be due to the gelatinous organic materials such as gums, resins, waxes etc which surround the particles and held them together (Robinsen and Page, 1951 and Martin _et al_., 1955). These cementing substances are the products of microbial activity.

As stated earlier the percentage of water stable aggregates larger than 0.25 mm size was maximum after groundnut crop during both the years. It may be that due to the formation of nuts in the soil which exerted a pressure around them as they grow, and the macro water stable aggregates of larger than 0.5 mm in size are broken up in to smaller portions to increase micro (larger than 0.25 mm) and total water stable aggregates. This is in agreement with the findings of Bavaskar and Zende (1973) that inclusion of groundnut as a rotational crop improves the physical condition of soil. Sadanandan and Mahapatra (1974 a) also reported improvement in soil structure when groundnut was included in the cropping pattern.

(c) Soil pH.

Considering the importance of soil pH for plant growth the pH of soil was determined before and after each crop and the data are presented in Tables 48 a and 48 b and Fig. 7. The summary of data along with statistical analysis are presented in Table 48 c.

The data reveal that the cultivation of crop tends to reduce soil pH. It is seen that in all the

Table-48(a): Effect of various cropping patterns on soil pH after the harvest of each crop

Treatment	Initial Status	1974-75 after Virippu rice	1974-75 after Mundakan rice	1974-75 after sweetpotato	1975-76 after Virippu rice	1975-76 after Mundakan rice	1975-76 after sweetpotato
Rice-rice-sweet potato	4.98	4.85	4.80	4.86 after cowpea	4.76	4.71	4.80 after cowpea
Rice-rice-cowpea	4.96	4.84	4.76	4.78 after sesamum	4.70	4.64	4.74 after sesamum
Rice-rice-sesamum	4.91	4.79	4.73	4.85 after groundnut	4.76	4.72	4.83 after groundnut
Rice-rice-groundnut	5.06	4.94	4.86	4.95 after (Punja) (summer) rice	4.86	4.80	4.90 after Punja (summer) rice
Rice-rice-rice	5.08	4.95	4.89	4.78	4.71	4.63	4.63

Table-48(b): <u>Change in soil pH over initial status due to different cropping patterns</u>

Treatment	1974-75			1975-76		
	after *Virippu* rice	After *Mundakan* rice	after sweet potato	after *Virippu* rice	after *Mundakan* rice	after sweet potato
Rice-rice-sweetpotato	-0.13	-0.18	-0.12	-0.10	-0.15	-0.06
			after cowpea			after cowpea
Rice-rice-cowpea	-0.12	-0.20	-0.18	-0.08	-0.14	-0.04
			after sesamum			after sesamum
Rice-rice-sesamum	-0.12	-0.18	-0.06	-0.09	-0.13	-0.02
			after groundnut			after groundnut
Rice-rice-groundnut	-0.12	-0.18	-0.11	-0.09	-0.15	-0.05
			after *Punja* (summer) rice			after *Punja* (summer) rice
Rice-rice-rice	-0.13	-0.19	-0.30	-0.07	-0.15	-0.15

Table-48(c): Summary Table: Change in pH of the soil over initial status

1. After *Virippu* rice crop

Treatment	Increase or decrease over initial status	
	1974-75	1975-76
1. Rice-rice-sweet potato	-0.13	-0.10
2. Rice-rice-cowpea	-0.12	-0.08
3. Rice-rice-sesamum	-0.12	-0.09
4. Rice-rice-groundnut	-0.12	-0.09
5. Rice-rice-rice	-0.13	-0.07
'F' test	N.S.	N.S.
S.Em.	± 0.00447	± 0.01049

N.S. Not significant

2. After *Mundakan* rice crop

Treatment	Increase or decrease over initial status	
	1974-75	1975-76
1. Rice-rice-sweet potato	-0.18	-0.15
2. Rice-rice-cowpea	-0.20	-0.14
3. Rice-rice-sesamum	-0.18	-0.13
4. Rice-rice-groundnut	-0.18	-0.15
5. Rice-rice-rice	-0.19	-0.15
'F' test	N.S.	N.S.
S.Em.	± 0.01612	± 0.01225

N.S. Not significant

3. After sweet potato, cowpea, sesamum, groundnut and rice

Treatment	Increase or decrease over initial status	
	1974-75	1975-76
1. Rice-rice-sweet potato	-0.12	-0.06
2. Rice-rice-cowpea	-0.18	-0.04
3. Rice-rice-sesamum	-0.06	-0.02
4. Rice-rice-groundnut	-0.11	-0.05
5. Rice-rice-rice	-0.30	-0.15
'F' test	**	**
S.Em.	± 0.00707	± 0.00707
C.D(0.05)	0.02120	0.02224
C.D.(0.01)	0.02921	0.03064

** Significant at 1%

PH
5·0
4·9
4·8
4·7

FIG. 8. CHANGE IN CATION EXCHANGE CAPACITY OF SOIL DUE TO VARIOUS CROPPING PATTERNS

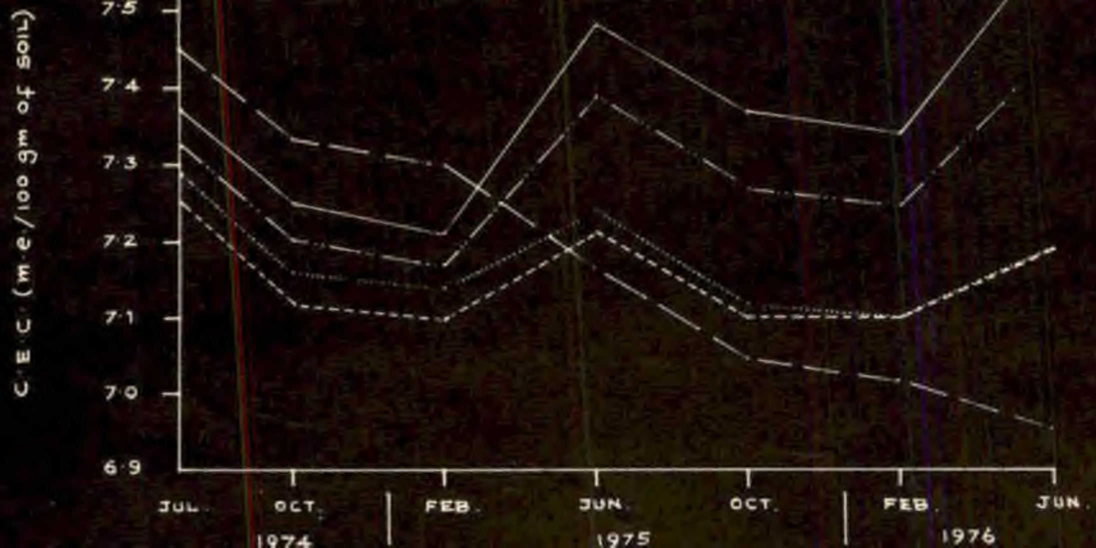
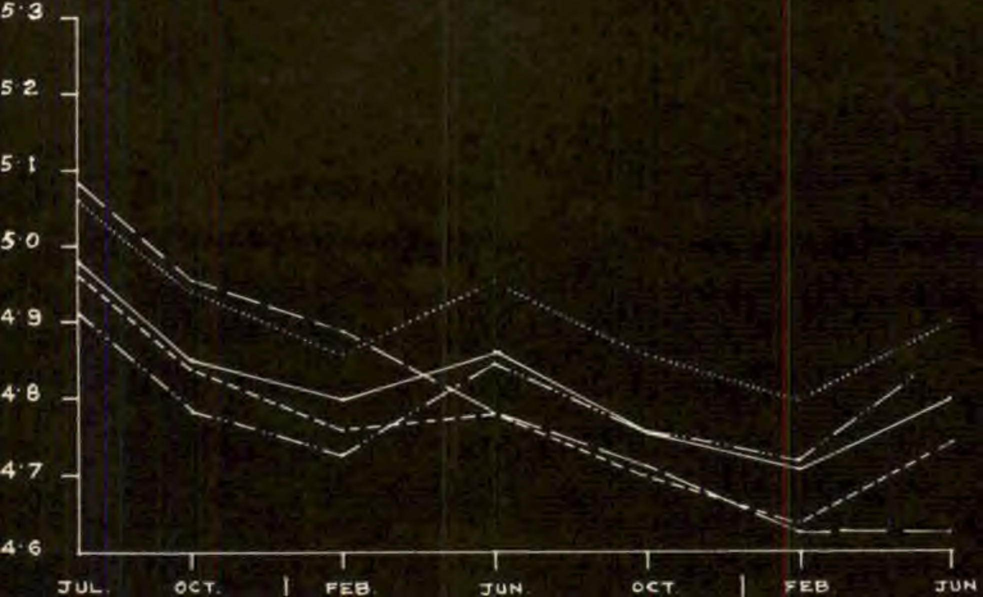

C·E·C· (m·e/100 gm of SOIL)
7·5
7·4
7·3
7·2
7·1
7·0
6·9
JUL.
OCT.
FEB.
JUN.
OCT.
FEB.
JUN.
1974
1975
1976

FIG. 7. CHANGE IN SOIL pH DUE TO VARIOUS CROPPING PATTERNS.



treatments rice crop reduced the soil pH considerably. Thus in all the treatments there was reduction in soil pH after the _viripp_u and _mundakan_ rice crops during both the years.

In the treatment rice-rice-sweet potato, all the crops reduced the soil pH considerably. While the first two rice crops reduced the soil pH by 0.18 units, the reduction by sweet potato crop was only by 0.12 units. The very same trend was observed during the second year also. In the second treatment involving rice-rice-cowpea, all the crops reduced the soil pH from the initial status. However, the reduction of soil pH was considerably less during the second year. In the treatment rice-rice-groundnut, the groundnut crop behaved similar to cowpea crop in its effect on soil pH. In the treatment involving rice-rice-sesamum, during the first year as well as second year the rate of reduction of soil pH after sesamum crop was considerably less being 0.06 units during first year and 0.02 units during the second year. Maximum decrease in soil pH was observed in the continuous cropping of rice, the drop being 0.30 and 0.15 units respectively during the first and second year.

It is an established fact that cropping intensity and cropping patterns have defenite influence on pH of the soil. According to Lal (1973) the soil pH decreased with increase in cropping intensity from 100 per cent to 400 per cent. Raghavulu and Sreeramamoorthy (1975) reported slight reduction in soil pH at the end of three years in all crop rotations involving rice, wheat, green gram, maize, bengal gram, bajra, barly and black gram. Juo and Lal (1975) reported that continuous cropping resulted in decrease in soil pH when tried for a period of three years.

Rice is grown always under water logged conditions. The pH of water logged soils is always near neutral (Ponnamperuma, 1975) and have some sulphides present (Russel, 1961). When the water is completely drained from the field before the harvest of the rice crop, the sulphides get oxidised to sulphates and the pH falls. According to Buckman and Brady (1964) the pH of cultivated soils tend to decline during summer months due to the acids produced by micro organisms. In the present investigation also maximum decrease in soil pH was observed during punja season. Sadanandan and Mahapatra (1972 f) also observed maximum decrease in soil pH in the cropping patterns, rice-jute-rice and rice-rice.

It is a proven fact that addition of ammonium sulphate to rice increases the acidity of soil. Reduction in exchangeable calcium and magnesium and soil pH following addition of ammonium sulphate in continuous cultivation of rice was observed by Lin and Lian (1960). Lowering of soil pH by continuous cultivation of crops using ammonium sulphate was observed by Kanwar and Prihar (1962). In the present experiment all the crops received ammonium sulphate as fertilizer. During each annual cycle of cropping pattern, a quantity of ammonium sulphate ranging from 850 kg. to 1175 kg. has been applied to the crops resulting in the reduction of soil pH considerably. Black (1968) reported a fall of pH by 0.5 units in one year by the addition of 840 kg. of ammonium sulphate per hectare in a sandy soil. The application of single super phosphate will also decrease the soil pH and make the soil acidic. In all the treatments super phosphate was applied to the crops at rates ranging from 593.75 kg. to 812.5 kg. per hectare per year.

Increase in soil acidity may also occur due to decomposition of organic matter, the functional groups of humus materials attract and dissociate hydrogen ions. The humus may also react with iron and aluminium ions to form complexes which may subsequently undergo hydrolysis to yield hydrogen ions. Organic acids may also be produced during this process. The increased concentration of Co_2, the hydrolysis of acid salts and the organic acids produced add to the total acidity of soil. In the first four treatments of the present experiment organic manure (farm yard manure) was applied at rates ranging from 2000 kg. to 10000 kg. per year. The process of decomposition of organic matter as described above may also be one of the reasons for the fall in pH in these treatments.

The roots of plants excrete Co_2 or carbonic acid in the soil solution and this will affect the acidity of soil, or the base reserves if the carbonic acid formed is neutralized by calcium and washed out as calcium carbonate through leaching. In submerged soils large amounts of Fe^{++} and Mn^{++} brought in-to solution displace cations from the clay complex, increasing the concentration of NH_4^+, K^+, Ca^{++} and Mg^{++} in soil solution. The slight increase in concentration of water soluble potassium brought about by cation exchange may not be significant in rice nutrition, but loss from the soil of the calcium and magnesium displaced from the soil colloids in-to the solution may lead to soil acidification by ferrolysis (Brinkman, 1970).

All the above mentioned factors would have been responsible for the fall in the soil pH in the various treatments tried.

(d) <u>Cation exchange capacity</u>.

Next to photosynthesis, cation exchange is considered as the most important as far as plant growth is concerned. The cation exchange capacity of soils is of great significance to the growth of plants because ions existing in soils as exchangeable bases serve as nutrients to plants. Therefore, the cation exchange capacity of soil was found out after every crop and presented in Tables 49 a, 49 b and 49 c and Fig.8.

It is seen from the data that the initial cation exchange capacity is very low in all the plots which ranges from 7.246 to 7.453 m.e. per 100 gm of soil. It is also evident from the data that all the crops excepting sweet potato and sesamum reduced the cation exchange capacity of soil, the maximum reduction was noticed in the continuous cropping of rice during both the years, the reduction being 0.288 m.e. per 100 gm of soil in the first year and 0.203 m.e. per 100 gm of soil during the second year. In all the treatments rice crop reduced the cation exchange capacity of soil irrespective of seasons. However, maximum

Table-49(a): Cation exchange capacity of soil in m.e. per 100 gm of soil after each crop

Treatment	Initial Status	1974-75 after *Virippu* rice	1974-75 after *Mundakan* rice	1974-75 after sweetpotato	1975-76 after *Virippu* rice	1975-76 after *Mundakan* rice	1975-76 after sweetpotato
Rice-rice-sweet potato	7.367	7.245	7.211	7.483 after cowpea	7.368	7.342	7.585 after cowpea
Rice-rice-cowpea	7.246	7.120	7.095	7.214 after sesamum	7.097	7.074	7.190 after sesamum
Rice-rice-sesamum	7.321	7.199	7.167	7.387 after groundnut	7.272	7.248	7.399 after groundnut
Rice-rice-groundnut	7.289	7.163	7.137	7.239 after *Punja* (summer) rice	7.121	7.099	7.188 after *Punja* (summer) rice
Rice-rice-rice	7.453	7.328	7.297	7.165	7.047	7.022	6.962

Table-49(b): Change in cation exchange capacity of the soil over initial status due to different cropping patterns in m.e. per 100 gm of soil

Treatment	1974-75 after Virippu rice	after Mundakan rice	after sweetpotato	1975-76 after Virippu rice	after Mundakan rice	after sweetpotato
Rice-rice-sweet potato	-0.122	-0.156	0.116 after cowpea	-0.115	-0.141	0.102 after cowpea
Rice-rice-cowpea	-0.120	-0.151	-0.032 after sesamum	-0.117	-0.140	-0.024 after sesamum
Rice-rice-sesamum	-0.122	-0.154	0.066 after groundnut	-0.115	-0.139	0.012 after groundnut
Rice-rice-groundnut	-0.126	-0.152	-0.050 after Punja (Summer) rice	-0.118	-0.140	-0.051 after Punja (summer) rice
Rice-rice-rice	-0.125	-0.156	-0.288	-0.118	-0.143	-0.203

Table-49(c): Summary Table: Change in cation exchange capacity of soil in m.e./100 gm of soil

1. After *Virippu* rice crop

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	-0.122	-0.115
2. Rice-rice-cowpea	-0.120	-0.117
3. Rice-rice-sesamum	-0.122	-0.115
4. Rice-rice-groundnut	-0.126	-0.118
5. Rice-rice-rice	-0.125	-0.118
'F' test	N.S.	N.S.
S.Em.	± 0.002000	± 0.0011803

N.S. Not significant

2. After *Mundakan* rice crop

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	-0.156	-0.141
2. Rice-rice-cowpea	-0.151	-0.140
3. Rice-rice-sesamum	-0.154	-0.139
4. Rice-rice-groundnut	-0.152	-0.140
5. Rice-rice-rice	-0.156	-0.143
'F' test	N.S.	N.S.
S.Em.	± 0.00316	± 0.002

N.S. Not significant

3. After sweet potato, cowpea, sesamum, groundnut and rice

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	0.116	0.102
2. Rice-rice-cowpea	-0.032	-0.024
3. Rice-rice-sesamum	0.066	0.012
4. Rice-rice-groundnut	-0.050	-0.051
5. Rice-rice-rice	-0.288	-0.203
'F' test	**	**
S.Em.	± 0.02098	± 0.001414
C.D.(0.05)	0.06324	0.00424
C.D.(0.01)	0.08713	0.00584

** Significant at 1%

reduction was observed after the _punja_ rice crop during both the years. As there was no change of crops during _virippu_ and _mundakan_ seasons, during both the years the treatment effects were not significant.

In the treatments rice-rice-sweet potato and rice-rice-sesamum, the sweet potato and sesamum crops tended to increase the cation exchange capacity of soil against the reduction caused by the preceding _virippu_ and _mundakan_ rice crops. Sweet potato increased the cation exchange capacity of soil from 7.211 to 7.483 m.e. per 100 gm of soil during the first year, and from 7.342 to 7.585 m.e. per 100 gm soil during the second year. Although sesamum crop also increased the cation exchange capacity of soil during both the years, the increase was only marginal during the second year.

In the treatments rice-rice-cowpea and rice-rice-groundnut, all the crops reduced the cation exchange capacity of soil during both the years. However, the reduction caused by the cowpea and groundnut crops was much less as compared to that of the preceding rice crops. The very same trend is seen during the second year also.

As stated earlier the maximum decrease in cation exchange capacity was observed in the continuous cropping of rice, and among the various rice crops maximum reduction was observed after punja during both the years. According to Juo and Lal (1975) continuous cropping for three years decreased the cation exchange capacity and exchangeable bases in soil.

Organic matter plays an important role in the cation exchange capacity of soil. One of the chemical properties of organic matter (humus) is its capacity to absorb nutrient cations and release them for plant use. Generally humus have a cation exchange capacity ranging from 4 to 7 times that of mineral colloidal matter. As the sweet potato and sesamum crops in the present experiment received liberal application of farm yard manure, this high content of organic matter would have been the reason for the increase in the cation exchange capacity of soil. The rapid decomposition of organic matter content during summer season would probably be the reason for heavy reduction in the cation exchange capacity of soil after punja rice. In the case of sweet potato, the increase in cation exchange capacity of soil may be due to the increase in organic matter content on account of dead leaves of sweet potato crop in addition to the farm yard manure applied to the crop.

(e) Organic carbon.

Organic matter is one of the important factors that influences both the physical and chemical properties of soil. As the organic carbon content of soil gives information about the total content of organic matter, the same has been worked out before and after every crop and the data are presented in Tables 50 a, 50 b and 50 c and Fig. 9.

It is seen from the data that the organic carbon content of soil decreased after every crop of rice in all the treatments during both the years. It is also seen that all the *punja* season crops excepting sweet potato and sesamum reduced the organic carbon content of soil during the first year. However, during the second year only the *punja* rice crop reduced the organic carbon content of soil.

In the rice-rice-sweet potato pattern, the initial organic carbon status was 1.680 per cent which was reduced to 1.611 per cent after two successive crops of rice and increased to 1.739 per cent after the sweet potato crop during the *punja* season. In the second year also the organic carbon content of soil underwent the same pattern of changes.

Table-50(a): Organic carbon content (%) in soil after each crop

Treatment	Initial Status	1974-75			1975-76		
		after *Virippu* rice	after *Mundakan* rice	after sweetpotato	after *Virippu* rice	after *Mundakan* rice	after sweet-potato
Rice-rice-sweet potato	1.680	1.622	1.611	1.739	1.705	1.701	1.794
				after cowpea			after cowpea
Rice-rice-cowpea	1.660	1.607	1.609	1.655	1.614	1.610	1.678
				after sesamum			after sesamum
Rice-rice-sesamum	1.756	1.704	1.669	1.786	1.750	1.745	1.839
				after groundnut			after groundnut
Rice-rice-groundnut	1.684	1.625	1.621	1.677	1.638	1.629	1.696
				after *Punja* (summer) rice			after *Punja* (summer) rice
Rice-rice-rice	1.616	1.560	1.559	1.518	1.483	1.475	1.429

Table-50(b): Change in organic carbon content (%) in soil over initial status due to different cropping patterns

Treatment	1974-75			1975-76		
	after <u>Virippu</u> rice	after <u>Mundakan</u> rice	after sweetpotato	after <u>Virippu</u> rice	after <u>Mundakan</u> rice	after sweet potato
Rice-rice-sweet potato	-0.058	-0.069	0.059	-0.034	-0.038	0.055
Rice-rice-cowpea	-0.053	-0.051	after cowpea -0.005	-0.041	-0.045	after cowpea 0.023
Rice-rice-sesamum	-0.052	-0.087	after sesamum 0.030	-0.036	-0.041	after sesamum 0.053
Rice-rice-groundnut	-0.059	-0.063	after groundnut -0.007	-0.039	-0.048	after groundnut 0.019
Rice-rice-rice	-0.056	-0.057	after <u>Punja</u> (summer) rice -0.098	-0.035	-0.043	after <u>Punja</u> (summer) rice -0.089

Table-50(c): Summary Table: Change in organic carbon content of soil (%)

1. After *Virippu* rice crop

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	-0.058	-0.034
2. Rice-rice-cowpea	-0.053	-0.041
3. Rice-rice-sesamum	-0.052	-0.036
4. Rice-rice-groundnut	-0.059	-0.039
5. Rice-rice-rice	-0.056	-0.035
'F' test	N.S.	N.S
S.Em.	± 0.01304	± 0.00849

N.S. Not significant

2. After *Mundakan* rice crop

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	-0.069	-0.038
2. Rice-rice-cowpea	-0.051	-0.045
3. Rice-rice-sesamum	-0.087	-0.041
4. Rice-rice-groundnut	-0.063	-0.048
5. Rice-rice-rice	-0.057	-0.043
'F' test	N.S.	N.S.
S.Em.	± 0.01517	± 0.00775

N.S. Not significant

3. After sweet potato, cowpea, sesamum, groundnut and rice

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	0.059	0.055
2. Rice-rice-cowpea	-0.005	0.023
3. Rice-rice-sesamum	0.030	0.053
4. Rice-rice-groundnut	-0.007	0.019
5. Rice-rice-rice	-0.098	-0.089
'F' test	**	**
S.Em.	± 0.002805	± 0.0009539
C.D.(0.05)	0.008408	0.0028600
C.D.(0.01)	0.011581	0.0039406

** significant at 1%

0·1200
0·1150
0·1100
0·1050

In the case of rice-rice-cowpea and rice-rice-groundnut treatments, all the crops reduced the organic carbon during the first year. However, a slight increase has been noted after cowpea and after groundnut crops during the second year. All the crops in the treatment rice-rice-sesamum behaved just similar to that of the treatment rice-rice-sweet potato during both the years.

As stated earlier, there was a continuous reduction in the organic carbon content of soil after every crop of rice in the rice-rice-rice treatment. The organic carbon content which was 1.616 per cent in the begining was reduced to 1.429 per cent after six successive crops of rice and maximum reduction was noticed after punja rice crop during both the years.

There was an increase in the organic carbon content of soil after sweet potato crop during both the years and the rate of increase was maximum as compared to the other crops in the various treatments. As the sweet potato crop received 10,000 kg. of farm yard manure per hectare. This large quantity of farm yard manure would have resulted in higher content of organic carbon after sweet potato. Moreover, as the sweet potato crop completely covers the surface of the soil thereby reducing the maximum temperature due to shading effect, there would have been reduction in the rate of oxidation of organic matter resulting in high organic carbon content of soil. Such increase in organic carbon content of soil by the sppli-cation of farm yard manure has been reported by several workes like Acharya and Rajagopalan (1956) Biswas et al. (1964), Das et al. (1966) and Bandyopadhya et al. (1969).

There was an increase of organic carbon content after sesamum crop also. The rate of increase was high during the second year as compared to that of the first year. Sesamum crop also received high amount of farm yard manure (5000 kg. per hectare) which could register a small increase in the organic carbon content during the first year. A repeated addition of 5000 kg. of farm yard manure during the second year would have naturally enhanced the rate of increase in the organic carbon content during the second year. The quantity of farm yard manure applied to cowpea and groundnut was so low (2000 kg. per hectare each) that it could not register any increase in the organic carbon content during the first year. But the repeated addition of farm yard manure during the second year could make a slight increase in the organic carbon content during the second year. The superiority of cowpea over groundnut in increasing the organic carbon content of soil may be due to the fact that most of the underground parts of groundnut are removed from the soil during the course of harvest where as only aerial parts are harvested in the case of cowpea. Acharya et al. (1952) observed that cowpea alone could serve the purpose of maintaing the organic matter levels in the soil.

As evidenced from the data the continuous cropping of rice reduced the organic carbon content of soil and the reduction was maximum during the summer season. As the rice crop was not supplied with any organic manures through out the period of study there would not have been any increase in the organic carbon content of soil. Moreover, the rice crop requires frequent puddling and other mechanical manipulations which may also lead to destroy the organic carbon content of soil. The high rate of decomposition of organic matter present in the soil due to high temperature during the summer season would have resulted in high rate of reduction of organic carbon during the summer season. Prasad and Jha (1973) and Sadanandan and Mahapatra (1975) reported that organic carbon content of soil was significantly reduced by the continuous cultivation of rice.

(f) Total Nitrogen.

The total nitrogen content of soil is a measure of soil productivity especially under tropical conditions. The relative contribution of various cropping patterns in increasing the soil productivity can be assessed by finding out the percentage of nitrogen in the soil before and after every crop and at the end of each cycle. The data are presented in Tables 51 a, 51 b and 51 c and Fig. 10.

It is seen from the data that rice crop in all the treatments reduced the nitrogen content of soil during both the years. Among the punja season crops, all the crops except cowpea and groundnut reduced the nitrogen content of soil. In the treatment rice-rice-sweet potato, there was continuous reduction in the total nitrogen content of soil by the virippu and mundakan rice crops as well as by sweet potato during the both the years. However, the magnitude of reduction was less during the second year. In the treatments rice-rice-cowpea and rice-rice-groundnut, there was an increase in the nitrogen content of soil after cowpea and groundnut although the preceding virippu and mundakan rice crops reduced the nitrogen content in both cases. The rate of increase was 0.0038 per cent after cowpea and 0.0021 per cent after groundnut during the first

Table-51(a): Total nitrogen content in soil(%) after each crop

Treatment	Initial Status	1974-75			1975-76		
		after Virippu rice	after Mundakan rice	after sweet-potato	after Virippu rice	after Mundakan rice	after sweet-potato
Rice-rice-sweet potato	0.1207	0.1191	0.1175	0.1153 after cowpea	0.1127	0.1115	0.1121 after cowpea
Rice-rice-cowpea	0.1270	0.1257	0.1242	0.1308 after sesamum	0.1273	0.1266	0.1329 after sesamum
Rice-rice-sesamum	0.1302	0.1293	0.1275	0.1256 after groundnut	0.1232	0.1221	0.1196 after groundnut
Rice-rice-groundnut	0.1267	0.1252	0.1245	0.1288 after Punja (summer) rice	0.1277	0.1260	0.1297 after Punja (summer) rice
Rice-rice-rice	0.1215	0.1196	0.1175	0.1129	0.1097	0.1089	0.1057

Table-51(b): Change in total nitrogen content in soil (%) over initial status due to different cropping patterns

Treatment	1974-75			1975-76		
	after *Virippu* rice	after *Mundakan* rice	after sweetpotato	after *Virippu* rice	after *Mundakan* rice	after sweet-potato
Rice-rice-sweet potato	-0.0016	-0.0032	-0.0054	-0.0026	-0.0038	-0.0032
Rice-rice-cowpea	-0.0013	-0.0028	after cowpea 0.0038	-0.0035	-0.0042	after cowpea 0.0021
Rice-rice-sesamum	-0.0009	-0.0027	after sesamum -0.0046	-0.0024	-0.0035	after sesamum -0.0060
Rice-rice-groundnut	-0.0015	-0.0022	after groundnut 0.0021	-0.0011	-0.0028	after groundnut 0.0009
Rice-rice-rice	-0.0019	-0.0040	after *Punja* (summer) rice -0.0086	-0.0032	-0.0040	after *Punja* (summer) rice -0.0072

Table-51(c): Summary Table: Change in total nitrogen content of soil (%)

1. After *Virippu* rice crop

Treatment	Increase or decrease over initial status 1974-75	Increase or decrease over initial status 1975-76
1. Rice-rice-sweet potato	-0.0016	-0.0026
2. Rice-rice-cowpea	-0.0013	-0.0035
3. Rice-rice-sesamum	-0.0009	-0.0024
4. Rice-rice-groundnut	-0.0015	-0.0011
5. Rice-rice-rice	-0.0019	-0.0032
'F' test	N.S.	N.S.
S.Em.	± 0.0005099	± 0.00067823

N.S. Not significant

2. After *Mundakan* ride crop

Treatment	Increase or decrease over initial status 1974-75	Increase or decrease over initial status 1975-76
1. Rice-rice-sweet potato	-0.0032	-0.0038
2. Rice-rice-cowpea	-0.0028	-0.0042
3. Rice-rice-sesamum	-0.0027	-0.0035
4. Rice-rice-groundnut	-0.0022	-0.0028
5. Rice-rice-rice	-0.0040	-0.0040
'F' test	N.S.	N.S.
S.Em.	± 0.00067082	±0.00072801

N.S. Not significant

3. After Sweet potato, cowpea, sesamum, groundnut and rice

Treatment	Increase or decrease over initial status 1974-75	Increase or decrease over initial status 1975-76
1. Rice-rice-sweet potato	-0.0054	-0.0032
2. Rice-rice-cowpea	0.0038	0.0021
3. Rice-rice-sesamum	-0.0046	-0.0060
4. Rice-rice-groundnut	0.0021	0.0009
5. Rice-rice-rice	-0.0086	-0.0072
'F' test	**	**
S.Em.	± 0.00014142	±0.00034641
C.D.(0.05)	0.000424	0.00103859
C.D.(0.01)	0.000584	0.001431

** Significant at 1%

year. However, there was a reduction in the rate of increase during the second year in both cases, the figures being 0.0021 per cent after cowpea and 0.0009 per cent after groundnut.

As in the case of rice-rice-sweet potato treatment all the crops in the rice-rice-sesamum treatment reduced the total nitrogen content of soil and the same trend with greater magnitude was seen during the second year. In the continuous cultivation of rice (rice-rice-rice treatment) there was continuous reduction in the total nitrogen content of soil from 0.1215 per cent to 0.1057 per cent by six crops of rice. It is also seen from the data that the reduction was appreciable during the summer season of both the years.

A comparison of the effect of various cropping patterns reveal that there was an increase in total nitrogen status of soil after cowpea and groundnut, whereas, there was considerable decrease after rice, sweet potato and sesamum. It is seen that the increase in total nitrogen content of soil after cowpea was significantly higher than that after groundnut during both the years. The maximum decrease in nitrogen content was observed in the treatment rice-rice-rice during both the years followed by rice-rice-sweet potato during the first year and rice-rice-sesamum during the second year.

Increase or gain in total nitrogen status of soil can take place due to the addition of fertilizers, plant residues and organic matter, by rain water, by non symbiotic nitrogen fixation, by bacteria and blue green algae and by symbiotic fixation by leguminous plants. A decrease or less in nitrogen status of soil can occur due to the following: (a) by crop removal, the nitrogen is taken up by growing plants (b) by leaching, most of the nitrogen is lost from the soil by leaching (c) by erosion, nitrogen is also lost from the soil by erosion and conversion in to volatile compounds and lost in to the atmosphere.

As already stated there was increase in the nitrogen content of soil after cowpea and groundnut. This increase in total nitrogen after cowpea and groundnut may be due to the residual effect of organic manures applied to these crops coupled with the additional fixation of nitrogen in the root nodules of these crops. Judicious inclusion of legumes in rotation is found desirable by Mirchandani and Khan (1953) for the maintenance of soil fertility. Legumes have been found to increase the organic matter status of soil by several workers (Jones, 1942; Moore, 1962; Watson, 1963 and Rixon, 1966). This has been attributed to the profuse rooting pattern and their resistance to easy decomposition. Developed root system of legumes favours accumulation of humus in soil even during the growth of the plants due to death of portion of the root systems. The increase in nitrogen content after cowpea as compared to that by groundnut crop in the present study may be due to the comparatively higher fixation of nitrogen by the cowpea crop. Fixation of nitrogen by cowpea was estimated by Nutman (1971) at 73.240 kg. per annum. The fixation of nitrogen in the root nodules of groundnut and thereby increase in the soil nitrogen was also reported by Nijhawan (1963).

The observation that there was reduction in the total nitrogen percentage of soil is in agreement with the findings of several workers. In cropping systems where rice is cultivated year after year, Sturgis (1936) reported that nitrogen content of soil was reduced from 0.20 per cent to 0.08 per cent. Racho and De Dutta (1968) observed that application of fertilizer nitrogen to rice irrespective of the rates of application had no residual value for the succeeding crop. Ghosh and Kanzaria (1964) found that a purely cereal rotation is inferior in all respects regarding residual nitrogen in soil.

The comparatively higher decrease of total nitrogen after punja rice crop may be due to the higher rate of oxudation of nitrogen in to nitrate during the summer season and subsequent losses due to leaching and other ways. Black (1968) reported that after leaching losses, more than 99 per cent of the nitrogen lost was as nitrate. The various factors mentioned above fully explain the changes in total nitrogen content of soil brought about by different cropping patterns.

(g) Carbon : Nitrogen ratio.

The data on carbon : nitrogen ratio are presented in Tables 52 a, 52 b and 52 c.

The data reveal that there was decrease in the carbon : nitrogen ratio after *virippu* and *mundakan* rice in all the treatments during the first year. However, during the *punja* season when change of crops occurs in all the patterns, cowpea and groundnut reduced the carbon : nitrogen ratio, whereas, sweet potato, sesamum and *punja* rice crop increased the carbon : nitrogen ratio, the rate of increase was appreciably higher after sweet potato (1.163) as compared to other crops. During the second year, there was a thorough change in the pattern of carbon : nitrogen ratio. In the treatment rice-rice-sweet potato, all the crops in the cropping pattern increased the carbon : nitrogen ratio and the rate of increase was higher after sweet potato as in the case of first year. In the rice-rice-cowpea treatment, the first

Table-52(a): Carbon:Nitrogen ratio in the soil after each crop

Treatment	Initial Status	1974-75			1975-76		
		after Virippu rice	after Mundakan rice	after sweet-potato	after Virippu rice	after Mundakan rice	after sweet-potato
Rice-rice-sweet potato	13.919	13.619	13.711	15.082 after cowpea	15.129	15.256	16.004 after cowpea
Rice-rice-cowpea	13.071	12.784	12.955	12.653 after sesamum	12.679	12.717	12.626 after sesamum
Rice-rice-sesamum	13.487	13.179	13.090	14.220 after groundnut	14.205	14.292	15.376 after groundnut
Rice-rice-groundnut	13.291	12.977	13.020	13.020 after Punja (summer) rice	12.827	12.929	13.076 after Punja (summer) rice
Rice-rice-rice	13.300	13.043	13.268	13.446	13.519	13.545	13.519

Table-52(b): Change in carbon nitrogen ratio of the soil over initial status due to different cropping patterns

Treatment	1974-75			1975-76		
	after *Virippu* rice	after *Mundakan* rice	after sweet-potato	after *Virippu* rice	after *Mundakan* rice	after sweet-potato
Rice-rice-sweet potato	-0.300	-0.208	1.163	0.047	0.174	0.922
			after cowpea			after cowpea
Rice-rice-cowpea	-0.287	-0.116	-0.418	0.026	0.064	-0.027
			after sesamum			after sesamum
Rice-rice-sesamum	-0.308	-0.397	0.733	-0.015	0.072	1.156
			after groundnut			after groundnut
Rice-rice-groundnut	-0.312	-0.271	-0.271	-0.193	-0.091	0.056
			after *Punja* (summer) rice			after *Punja* (summer) rice
Rice-rice-rice	-0.257	-0.032	0.146	0.073	0.099	0.073

Table-52(c): Summary Table: Carbon Nitrogen ratio in soil

1. After *Virippu* rice crop

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	-0.300	0.047
2. Rice-rice-cowpea	-0.287	0.026
3. Rice-rice-sesamum	-0.308	-0.015
4. Rice-rice-groundnut	-0.312	-0.193
5. Rice-rice-rice	-0.257	0.073
'F' test	N.S.	**
S.Em.	± 0.03808	± 0.00837
C.D.(0.05)	-	0.02508
C.D.(0.01)	-	0.03456

N.S. Not significant
** Significant at 1%

2. After *Mundakan* rice crop

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	-0.208	0.174
2. Rice-rice-cowpea	-0.116	0.064
3. Rice-rice-sesamum	-0.397	0.072
4. Rice-rice-groundnut	-0.271	-0.091
5. Rice-rice-rice	-0.032	0.099
'F' test	**	**
S.Em.	± 0.03114	± 0.00548
C.D.(0.05)	0.09313	0.01499
C.D.(0.01)	0.12832	0.02065

** Significant at 1%

3. After Sweet potato, Cowpea, Sesamum, groundnut and rice

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	1.163	0.922
2. Rice-rice-cowpea	-0.418	-0.027
3. Rice-rice-sesamum	0.733	1.156
4. Rice-rice-groundnut	-0.271	0.056
5. Rice-rice-rice	0.146	0.073
'F' test	**	**
S.Em	± 0.01095	± 0.00707
C.D.(0.05)	0.03216	0.02120
C.D.(0.01)	0.04431	0.02921

** Significant at 1%

two rice crops increased the carbon : nitrogen ratio while the cowpea crop reduced it. In the rice-rice-sesamum treatment, the behaviour of two rice crops was entirely opposite. While the <u>virippu</u> rice reduced the carbon : nitrogen ratio, <u>mundakan</u> rice increased it. The sesamum crop in the cropping pattern made a further increase in carbon : nitrogen ratio over the <u>mundakan</u> rice crop. In the rice-rice-groundnut treatment, the <u>virippu</u> and <u>mundakan</u> rice crops reduced the carbon : nitrogen ratio, while groundnut slightly increased the carbon : nitrogen ratio. In the continuous cropping of rice (rice-rice-rice treatment), all the rice crops increased the carbon : nitrogen ratio irrespective of the seasons.

The area under the experiment was kept fallow from February to June. The field was completely infested with all kinds of weeds and other vegetation. Therefore the initial carbon : nitrogen ratio was naturally high in all the treatments. As the regular cultivation was initiated in this area since July, there occurred higher rate of decomposition of organic matter in the soil. Any condition that encourages decomposition of organic matter naturally lowers the carbon : nitrogen ratio in the soil. Therefore,there was a reduction in the carbon : nitrogen ratio after the _viripppu_ and _mundakan_ rice crops. This observation is quite agreeable to the situation as the rice crop was not supplied with any organic manures.

During the _punja_ season of the first year the reduction in carbon : nitrogen ratio observed after cowpea and groundnut may be due to the increased nitrogen content of soil after these crops. The rate of reduction in carbon : nitrogen ratio was higher after cowpea than groundnut as the nitrogen content of soil after cowpea was higher (0.1308 per cent) than groundnut (0.1288 per cent). The increase in carbon : nitrogen ratio after sweet potato and sesamum may be due to the heavy application of farm yard manure to these crops. The heavy depletion of nitrogen during the _punja_ season rice would be the probable reason for the sudden increase in the carbon : nitrogen ratio after the _punja_ rice.

During the second year, the rate of increase in carbon : nitrogen ratio was high after sweet potato and sesamum revealing that the heavy application of farm yard manure had influence on the carbon : nitrogen ratio of the soil. The decrease in carbon : nitrogen ratio observed after cowpea may be due to the high amount of nitrogen fixation in that treatment. As the organic carbon content was also high after the groundnut crop of second year there was an increase in the carbon : nitrogen ratio after groundnut crop during that period. The difference in the behaviour of virippu and mundakan rice crops in different treatments may be due to the changes in the organic carbon and nitrogen status of soil after each treatment. In the treatment where rice was being continuously cultivated there was a positive increase in carbon : nitrogen ratio, which may be due to the continuous depletion of soil nitrogen under that treatment. Pearsall (1950) observed that the reducing conditions prevailing in waterlogged soils accelerate ammonification as a result of which nitrogen escapes from the soil and thus the carbon : nitrogen ratio of the soil widens.

(h) Extractable Phosphorus.

The extractable phosphorus of the soil was determined before and after every crop and the data are presented in Tables 53 a, 53 b and 53 c and Fig. 11.

It is seen that there was not much difference in the initial status of extractable phosphorus content of soil. There was reduction in the extractable phosphorus content of soil after virippu and mundakan rice crops during both the years. In the treatment rice-rice-sweet potato, the sweet potato crop increased the extractable phosphorus

Table-53(a): Extractable phosphorus in soil (in ppm) after each crop

Treatment	Initial Status	1974-75			1975-76		
		after Virippu rice	after Mundakan rice	after sweet-potato	after Virippu rice	after Mundakan rice	after sweet-potato
Rice-rice-sweet potato	22	20	19	25 after cowpea	23	21	28 after cowpea
Rice-rice-cowpea	18	15	14	25 after sesamum	22	20	31 after sesamum
Rice-rice-sesamum	19	16	17	21 after groundnut	19	21	25 after groundnut
Rice-rice-groundnut	17	13	12	22 after Punja (summer) rice	18	22	26 after Punja (summer) rice
Rice-rice-rice	20	18	18	16	13	12	18

Table-53(b): Change in extractable phosphorus of soil (in ppm) over initial status due to different cropping patterns

Treatment	1974-75			1975-76		
	after *Virippu* rice	after *Mundakan* rice	after sweet-potato	after *Virippu* rice	after *Mundakan* rice	after sweet-potato
Rice-rice-sweet potato	-2	-3	3 after cowpea	-2	-4	3 after cowpea
Rice-rice-cowpea	-3	-4	7 after sesamum	-3	-5	6 after sesamum
Rice-rice-sesamum	-3	-2	2 after groundnut	-2	-2	4 after groundnut
Rice-rice-groundnut	-4	-5	5 after *Punja* (summer) rice	-4	-4	4 after *Punja* (summer) rice
Rice-rice-rice	-2	-2	-4	-3	-4	2

Table-53(c): Summary Table: Extractable phosphorus in soil in ppm

1. After <u>Virippu</u> rice crop

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	-2	-2
2. Rice-rice-cowpea	-3	-3
3. Rice-rice-sesamum	-3	-2
4. Rice-rice-groundnut	-4	-4
5. Rice-rice-rice	-2	-3
'F' test	N.S.	N.S.
S.Em.	± 0.98869	± 1.56205

N.S. Not significant

2. After <u>Mundakan</u> rice crop

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	-3	-4
2. Rice-rice-cowpea	-4	-5
3. Rice-rice-sesamum	-2	-2
4. Rice-rice-groundnut	-5	-4
5. Rice-rice-rice	-2	-4
'F' test	N.S.	N.S.
S.Em.	± 1.12250	± 1.40712

N.S. Not significant

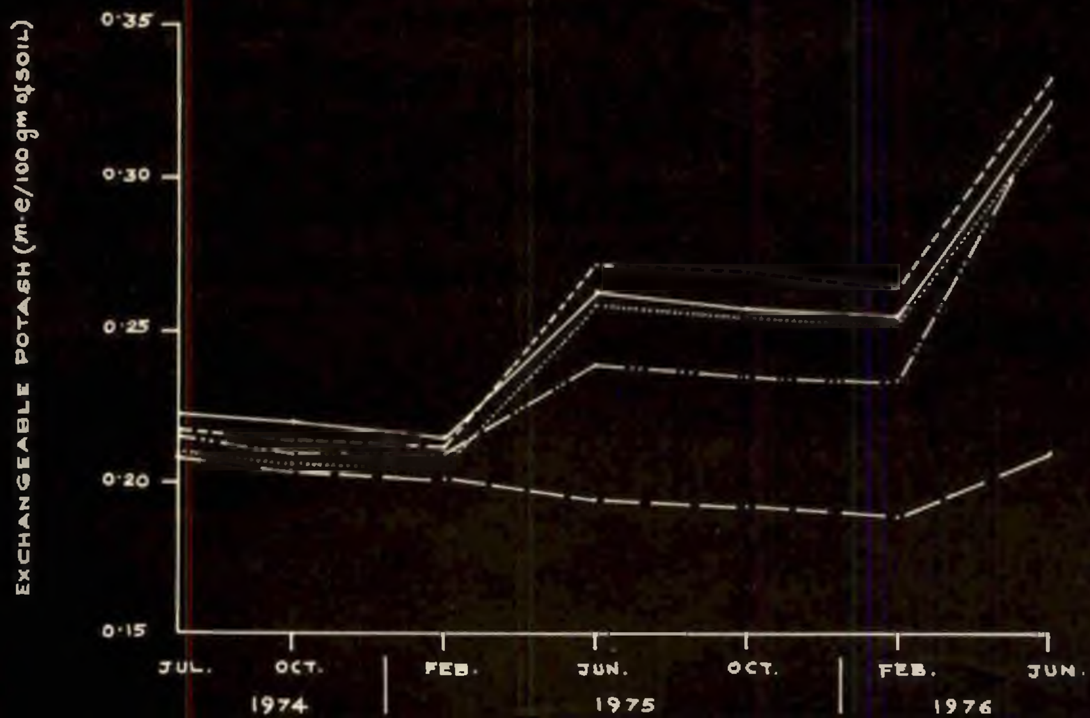
3. After Sweet potato, Cowpea, Sesamum, groundnut and rice

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	3	3
2. Rice-rice-cowpea	7	6
3. Rice-rice-sesamum	2	4
4. Rice-rice-groundnut	5	4
5. Rice-rice-rice	-4	2
'F' test	**	N.S.
S.Em.	± 0.75166	± 2.00125
C.D.(0.05)	2.25358	..
C.D.(0.01)	3.10505	..

** Significant at 1%

N.S. Not significant

FIG. 12. CHANGE IN EXCHANGEABLE POTASH IN SOIL (m.e/100 gm of SOIL) DUE TO VARIOUS CROPPING PATTERNS.



content of soil against the reduction caused by the *virippu* and *mundakan* rice crops during both the years. In the treatments rice-rice-cowpea, rice-rice-sesamum and rice-rice-groundnut also there was decrease in the extractable phosphorus content of soil after the *virippu* and *mundakan* rice crops while cowpea, sesamum and groundnut crops increased the extractable phosphorus depending upon the treatment. However, the rate of increase was maximum after cowpea crop during both the years (7 ppm and 6 ppm respectively during the first year and second year). The second position in this respect went to groundnut crop during the first year, while it was shared by groundnut and sesamum crop during the second year. In the continuous cropping of rice treatment, the extractable phosphorus continued to decrease after every crop of rice up to the fifth crop, while there was a slight increase after the sixth crop of rice.

Thus it is seen that there was an increase in the extractable phosphorus content of soil after sweet potato, cowpea, sesamum and groundnut crops, while the rice crops in all the seasons tried to reduce the extractable phosphorus content of soil. Among the various crops, the increase after cowpea was maximum and was significantly superior to all the other crops except groundnut during the first year. This may be attributed to the 'legume effect' which may be due to the humus or humic substances produced by the legume residues and the mineralizing and solibilizing effect of soil microflora supported by the specific plants and to the Co_2 produced by both the roots and associated micro-organisms which may favour the solubilization of phosphate. Thus cowpea being a legume crop is capable of converting the unavailable sub soil phosphorus in to available form. According to Raheja (1966) sub soil contains adequate quantities of phosphorus which the deep rooted crops are able to tap and make use of in growth of crops. This unique behaviour of legume crops would have been responsible for the high amount of extractable phosphorus after cowpea and groundnut crops. This is in agreement with the findings of Nair et al. (1973 b) that the available phosphorus improved after leguminous crops were grown in a multiple cropping experiment. The addition of comparatively higher quantities of phosphorus (50 kg. P_2O_5 per hectare) in the form of fertilizers to cowpea as compared to groundnut (20 kg. P_2O_5 per hectare) coupled with lesser uptake of phosphorus (Table 62 a) would have been responsible for higher content of extractable phosphorus after cowpea as compared to groundnut.

The addition of farm yard manure increases the readily available phosphorus content of soil. The organic acids evolved by decomposition increases the availability of phosphorus. Thus the increase in the extractable phosphorus after sweet potato and sesamum may be due to the addition of farm yard manure at the rate of 10,000 kg. and 5,000 kg. per hectare respectively. The increase in the available phosphorus by the addition of organic manures has been reported by Datta and Goswami (1962), Hedlin and Ridley (1964), Dhar and Nagpal (1955) and Mahendra Singh and Jaiprakash (1968). In a continuous cropping system, a higher status of available phosphorus in soil was reported in plots receiving super phosphate and organic manure (Ghosh and Kanzaria ,1964). The increase in extractable phosphorus after sweet potato, and sesamum may also be due to the falling of leaves during the life time of the crops which on decomposition contribute their phosphate to the soil.

Rice in all the treatments reduced extractable phosphorus considerably. The rice being grown under flooded conditions increases the available phosphorus content of soil leading to greater uptake by the rice plant. The data presented in Table 62 a and 62 b reveal that the uptake of phosphorus by the rice crop was higher than all the other crops except sweet potato. This higher uptake of phosphorus would have been one of the reasons for the reduction in the extractable phosphorus after rice crops. Another reason may be due to the oxidised condition prevailed in the field as the entire field was drained and dried ten days prior to harvest which would have also reduced the availability of phosphorus. Patrick and Mahapatra (1968) reported that the drying of the soil decreases the available phosphorus content of soil. Ponnamperuma (1972) studied the kinetics of water soluble phosphorus in submerged soils and found that the concentration of water soluble phosphorus increased with soil submergence with time, and decreased somewhat after six to eight weeks. The reduction in the available phosphorus content of soil by continuous cultivation of rice was reported by several workers. Sturgis (1936) reported that by continuous cultivation of rice, the available phosphorus in the soil was reduced from 12.5 ppm to 4.5 ppm. Sadanandan and Mahapatra (1973 b) reported that the balance sheet of available phosphorus of soil showed a loss in all treatments, the maximum loss was obtained in rice-rice cropping pattern.

(i) Exchangeable Potash.

The data on the exchangeable potash content of soil before and after every crop are presented in Table 54 a, 54 b and 54 c and Fig. 12.

It is seen from the data that there was a decrease in the exchangeable potash content after the virippu rice and a further decrease after mundakan rice irrespective of the treatments. The same trend is seen during the second year also. Among the various punja season crops, all the crops except the punja rice of first year increased the exchangeable potash content of soil. The maximum increase was brought about after cowpea crop during both the years, the rate of increase being 0.0536 and 0.0709 m.e. per 100 gm of soil respectively during the first and second year. The second position went to the groundnut crop during both the years.

Comparing the various treatments it is seen that there was an increase in the exchangeable potash after sweet potato, cowpea, sesamum and groundnut during the first year; however, the difference between them were not significant. During the second year, significant increase in exchangeable potash was, however, observed after cowpea crop.

Table-54(a): Exchangeable potash in the soil (in m.e./100 gm of soil) after each crop

Treatment	Initial Status	1974-75 after *Virippu* rice	1974-75 after *Mundakan* rice	1974-75 after sweet-potato	1975-76 after *Virippu* rice	1975-76 after *Mundakan* rice	1975-76 after sweet-potato
Rice-rice-sweet potato	0.2214	0.2202	0.2152	0.2612 after cowpea	0.2575	0.2568	0.3266 after cowpea
Rice-rice-cowpea	0.2182	0.2162	0.2124	0.2718 after sesamum	0.2694	0.2662	0.3321 after sesamum
Rice-rice-sesamum	0.2162	0.2116	0.2093	0.2389 after groundnut	0.2341	0.2337	0.2987 after groundnut
Rice-rice-groundnut	0.2098	0.2066	0.2050	0.2583 after *Punja* (summer) rice	0.2544	0.2534	0.3258 after *Punja* (summer) rice
Rice-rice-rice	0.2086	0.2065	0.2015	0.1951	0.1925	0.1910	0.2094

Table-54(b): Change in exchangeable potash in soil (in m.e./100 gm of soil) due to various cropping patterns

Treatment	1974-75			1975-76		
	after *Virippu* rice	after *Mundakan* rice	after sweet-potato	after *Virippu* rice	after *Mundakan* rice	after sweet-potato
Rice-rice-sweet potato	-0.0012	-0.0062	0.0398 after cowpea	-0.0037	-0.0044	0.0654 after cowpea
Rice-rice-cowpea	-0.0020	-0.0058	0.0536 after sesamum	-0.0024	-0.0056	0.0709 after sesamum
Rice-rice-sesamum	-0.0046	-0.0069	0.0227 after groundnut	-0.0048	-0.0052	0.0598 after groundnut
Rice-rice-groundnut	-0.0032	-0.0048	0.0485 after *Punja* (summer) rice	-0.0039	-0.0049	0.0675 after *Punja* (summer) rice
Rice-rice-rice	-0.0021	-0.0071	-0.0135	-0.0026	-0.0041	0.0143

Table-54(c): Summary Table: Exchangeable potash (m.e./100 gm of soil)

1. After *Virippu* rice crop

Treatment	Increase or decrease over initial status	
	1974-75	1975-76
1. Rice-rice-sweet potato	-0.0012	-0.0037
2. Rice-rice-cowpea	-0.0020	-0.0024
3. Rice-rice-sesamum	-0.0046	-0.0048
4. Rice-rice-groundnut	-0.0032	-0.0039
5. Rice-rice-rice	-0.0021	-0.0026
'F' test	N.S.	N.S.
S.Em.	± 0.00091652	± 0.00123288

N.S. Not significant

2. After *Mundakan* rice crop

Treatment	Increase or decrease over initial status	
	1974-75	1975-76
1. Rice-rice-sweet potato	-0.0062	-0.0044
2. Rice-rice-cowpea	-0.0058	-0.0056
3. Rice-rice-sesamum	-0.0069	-0.0052
4. Rice-rice-groundnut	-0.0048	-0.0049
5. Rice-rice-rice	-0.0071	-0.0041
'F' test	N.S.	N.S.
S.Em.	± 0.00168523	±0.00146629

3. After sweet potato, cowpea, sesamum, groundnut and rice

Treatment	Increase or decrease over initial status	
	1974-75	1975-76
1. Rice-rice-sweet potato	0.0398	0.0654
2. Rice-rice-cowpea	0.0536	0.0709
3. Rice-rice-sesamum	0.0227	0.0598
4. Rice-rice-groundnut	0.0485	0.0675
5. Rice-rice-rice	-0.0135	0.0143
'F' test	N.S.	**
S.Em.	±0.01880745	±0.00245357
C.D.(0.05)	..	0.00735612
C.D.(0.01)	..	0.01013549

** Significant at 1%

N.S. Not significant

The increase in the exchangeable potash after sweet potato and sesamum may be due to the large quantities of farm yard manure applied to these crops. Verma and Verma (1968) and Mithantha et al. (1974) reported that organic matter of the soil bears a positive correlation with the availability of potash. One of the reasons for this is that the organic matter increases the cation exchange capacity and exchangeable cations (Hanway, 1962). Kanwar and Prihar (1962) reported increase in exchangeable potash by the application of farm yard manure to crops. It is seen that maximum increase in exchangeable potash was observed after cowpea followed by groundnut during both the years. One of the reasons may be due to the application of farm yard manure to these crops. As potassium is one of the exchangeable cations, its level and availability are governed by the complementary ions on the exchange complex and by soil properties. Chamber (1953) reported that application of nitrogen in the form of ammonium sulphate decreased the availability of soil potassium. Kumar (1974) also found decrease in potasium uptake due to the application of ammoniacal source of nitrogen in the case of hybrid jowar, C.S.H.I. As the cowpea and groundnut crops in the present study were supplied with only very small quantities of nitrogen (10 kg. nitrogen per hectare each) in the form of ammonium sulphate as compared to other crops in the different cropping patterns, the depressing effect of complementary ion was comparatively less in cowpea and groundnut crops. This also would have helped in increasing the exchangeable potash status of soil after cowpea and groundnut. Nair et al. (1973 b) observed that the available potash improved after leguminous crops were grown in a field experiment consisting of five rice based multiple cropping patterns.

As already stated the exchangeable potash decreased after every crop of rice irrespective of the treatments during both the years. The available potash status in rice soils has been found to increase with submergence or flooding. Ponnamperuma (1965) reported that this increase in the solubility of potash under paddy conditions should result in its greater availability as well as in greater leaching losses. As the virippu and mundakan rice crops were raised during rainy seasons there would have been serious leaching of exchangeable potash in the rice fields resulting in lesser quantity of exchangeable potash after these crops. Sturgis (1936) reported reduction in the exchangeable potash content of soil by continuous cultivation of rice. Lal (1973) observed that the available potash decreased with increase in cropping intensity from 100 to 300 per cent.

The availability of potash is affected by soil pH also. Raychaudhuri and Landey (1960) reported decrease in availability of potash with decreasing pH of some representative soils in India. The fact that there was considerable decrease in soil pH after punja rice crop during the first year (Table 48 b) would have been responsible for the decrease in soil exchangeable potash status of soil after punja rice crop. As the rate of decrease of soil pH after punja rice crop was less during the second year, the exchangeable potash status of soil showed a slight increase after this crop.

(j) Exchangeable Calcium.

The data on the exchangeable calcium of the soil before and after each crop are presented in Tables 55 a, 55 b and 55 c and Fig. 13.

It is seen from the data that there was decrease in the exchangeable calcium status of soil after every crop of rice irrespective of the treatments. In the treatment rice-rice-sweet potato, the exchangeable calcium content of soil increased after sweet potato crop from the initial status of 3.32 m.e. per 100 gm of soil to 3.54 m.e. per 100 gm of soil during the first year and to 3.72 m.e. per 100 gm of soil during the second year. However, there was a

Table-55(a): Exchangeable calcium status of soil (in m.e./100 gm of soil) after each crop

Treatment	Initial Status	1974-75			1975-76		
		after *Virippu* rice	after *Mundakan* rice	after sweet-potato	after *Virippu* rice	after *Mundakan* rice	after sweet-potato
Rice-rice-sweet potato	3.32	3.26	3.24	3.54 after cowpea	3.52	3.47	3.72 after cowpea
Rice-rice-cowpea	3.27	3.20	3.17	3.18 after sesamum	3.08	3.06	3.04 after sesamum
Rice-rice-sesamum	3.19	3.15	3.10	3.34 after groundnut	3.30	3.25	3.52 after groundnut
Rice-rice-groundnut	3.40	3.31	3.29	3.48 after *Punja* (summer) rice	3.42	3.42	3.59 after *Punja* (summer) rice
Rice-rice-rice	3.16	3.13	3.09	2.98	2.89	2.88	2.86

Table-55(b): Change in exchangeable calcium in the soil(in m.e./100 gm of soil) due to various cropping patterns.

Treatment	1974-75			1975-76		
	after Virippu rice	after Mundakan rice	after sweet-potato	after Virippu rice	after Mundakan rice	after sweet-potato
Rice-rice-sweet potato	-0.06	-0.08	0.22 after cowpea	-0.02	-0.07	0.18 after cowpea
Rice-rice-cowpea	-0.07	-0.10	-0.09 after sesamum	-0.10	-0.12	-0.14 after sesamum
Rice-rice-sesamum	-0.04	-0.09	0.15 after groundnut	-0.04	-0.09	0.18 after groundut
Rice-rice-groundnut	-0.09	-0.11	0.08 after Punja (summer) rice	-0.06	-0.06	0.11 after Punja (summer) rice
Rice-rice-rice	-0.03	-0.07	-0.18	-0.09	-0.10	-0.12

Table-55(c): Summary Table: Exchangeable calcium (m.e./100 gm of soil)

1. After *Virippu* rice

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	-0.06	-0.02
2. Rice-rice-cowpea	-0.07	-0.10
3. Rice-rice-sesamum	-0.04	-0.04
4. Rice-rice-groundnut	-0.09	-0.06
5. Rice-rice-rice	-0.03	-0.09
'F' test	N.S.	N.S.
S.Em.	± 0.02145	± 0.02191

N.S. Not significant

2. After *Mundakan* rice

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	-0.08	-0.07
2. Rice-rice-cowpea	-0.10	-0.12
3. Rice-rice-sesamum	-0.09	-0.09
4. Rice-rice-groundnut	-0.11	-0.06
5. Rice-rice-rice	-0.07	-0.10
'F' test	N.S.	N.S.
S.Em.	± 0.03728	± 0.02608

N.S. Not significant

3. After sweet potato, cowpea, sesamum, groundnut and rice.

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	0.22	0.18
2. Rice-rice-cowpea	-0.09	-0.14
3. Rice-rice-sesamum	0.15	0.18
4. Rice-rice-groundnut	0.08	0.11
5. Rice-rice-rice	-0.18	-0.12
'F' test	**	**
S.Em.	± 0.02366	± 0.01924
C.D.(0.05)	0.07086	0.05766
C.D.(0.01)	0.09777	0.07945

** Significant at 1%

reduction in the exchangeable calcium status of soil after _virippu_ and _mundakan_ rice crops during both the years. In the rice-rice-cowpea treatment, all the crops reduced the exchangeable calcium status of soil from the initial status of 3.27 m.e. per 100 gm of soil to 3.18 m.e. per 100 gm of soil after the first cycle and to 3.04 m.e. per 100 gm of soil after the second cycle. In the treatments rice-rice-sesamum and rice-rice-groundnut, there was increase in the exchangeable calcium status of soil after sesamum and groundnut crops although there was reduction after the _virippu_ and _mundakan_ rice crops in both the treatments as well as during both the years.

In the continuous cultivation of rice, however, there was continuous reduction after every crop of rice and it is seen that the maximum reduction was observed after the _punja_ rice crop during both the years.

The increase in exchangeable calcium of soil can occur by the addition of crop residues, by the addition of manures which contain appreciable quantities of calcium and by the application of super phosphate which also supplies good quantities of calcium. Calcium is lost from the soil in three ways, viz, by crop removal, by erosion and by leaching.

From the data it is evident that there was an increase in exchangeable calcium after sweet potato, sesamum and groundnut crops during both the years. The large quantities of farm yard manure applied to sweet potato and sesamum crops would have been responsible for the increase in the exchangeable calcium after these crops. Dhar and Nagpal (1955) reported an increase in exchangeable calcium by the addition of organic manures. Since groundnut crop was supplied with lime at the rate of one tonne per hectare it was quite reasonable to have higher amount of exchangeable calcium after groundnut crop.

The reduction in exchangeable calcium after cowpea crop during both the years may be due to the higher uptake of calcium from the soil by the cowpea crop for nodule formation as the cowpea crop was not supplied with lime. Lyon et al. (1952) reported that the availability of calcium stimulates symbiotic fixation of nitrogen in the nodules of legumes.

As the rice crop was not supplied with any organic manures or lime the only source of applied calcium was through super phosphate. As the soil is acidic in nature a good amount of calcium will be used for neutralizing the acidity in the soil. As flooding or submergence increased the availability of calcium in the rice soil (Chatterjee, 1964, Mahapatra, 1968) the crop requirement is met from this calcium and the balance would have been lost by leaching during the heavy rains that occurred during the <u>virippu</u> and <u>mundakan</u> seasons. According to Kabeerathumma (1975) flooding resulted in an increase in exchangeable calcium in most cases which reached a peak in about 30-50 days after which there was a decrease. Sadanandan and Mahapatra (1972 d) reported that in continuous cultivation of rice (rice-rice-treatment) there was decrease in calcium after every crop of rice.

(k) <u>Exchangeable Magnesium</u>.

The data on the exchangeable magnesium status of the soil before and after every crop are presented in Tables 56 a, 56 b and 56 c and Fig. 14.

The data reveal that there was reduction in the exchangeable magnesium after the first two rice crops in all the treatments during both the years and the pattern of reduction was very similar to that of calcium. In the treatments rice-rice-sweet potato and rice-rice-sesamum, sweet potato and sesamum increased the exchangeable magnesium content of soil although the preceding rice crops reduced it. The same pattern of change was observed during the second year also. However, in the cropping patterns rice-rice-cowpea and

Table-56(a): Exchangeable magnesium status of soil (in m.e./100 gm of soil) after each crop

Treatment	Initial Status	1974-75			1975-76		
		after *Virippu* rice	after *Mundakan* rice	after sweet-potato	after *Virippu* rice	after *Mundakan* rice	after sweet-potato
Rice-rice-sweet potato	0.884	0.872	0.866	0.896 after cowpea	0.864	0.843	0.913 after cowpea
Rice-rice-cowpea	0.867	0.852	0.847	0.859 after sesamum	0.843	0.815	0.854 after sesamum
Rice-rice-sesamum	0.859	0.838	0.836	0.868 after groundnut	0.824	0.811	0.878 after groundnut
Rice-rice-groundnut	0.873	0.851	0.844	0.861 after *Punja* (summer) rice	0.837	0.793	0.831 after *Punja* (summer) rice
Rice-rice-rice	0.846	0.832	0.831	0.828	0.807	0.773	0.760

Table-56(b): Change in exchangeable magnesium in soil (in m.e./100 gm of soil) due to various cropping patterns

Treatment	1974-75			1975-76		
	after *Virippu* rice	after *Mundakan* rice	after sweet-potato	after *Virippu* rice	after *Mundakan* rice	after sweet-potato
Rice-rice-sweet potato	-0.012	-0.018	0.012 after cowpea	-0.032	-0.053	0.017 after cowpea
Rice-rice-cowpea	-0.015	-0.020	-0.008 after sesamum	-0.016	-0.044	-0.005 after sesamum
Rice-rice-sesamum	-0.021	-0.025	0.009 after groundnut	-0.044	-0.057	0.010 after groundnut
Rice-rice-groundnut	-0.022	-0.029	-0.012 after *Punja* (summer) rice	-0.024	-0.068	-0.030 after *Punja* (summer) rice
Rice-rice-rice	-0.014	-0.015	-0.018	-0.021	-0.055	-0.068

Table-56(c): Summary Table: Exchangeable magnesium (m.e./100 gm of soil)

1. After *Virippu* rice

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	-0.012	-0.032
2. Rice-rice-cowpea	-0.015	-0.016
3. Rice-rice-sesamum	-0.021	-0.044
4. Rice-rice-groundnut	-0.022	-0.024
5. Rice-rice-rice	-0.014	-0.021
'F' test	N.S.	N.S.
S.Em.	±0.00447	± 0.01000

N.S. Not significant

2. After *Mundakan* rice

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	-0.018	-0.053
2. Rice-rice-cowpea	-0.020	-0.044
3. Rice-rice-sesamum	-0.023	-0.057
4. Rice-rice-groundnut	-0.029	-0.068
5. Rice-rice-rice	-0.015	-0.055
'F' test	N.S.	N.S.
S.Em.	± 0.00548	± 0.01183

N.S. Not significant

3. After sweet potato, cowpea, sesamum, groundnut and rice

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	0.012	0.017
2. Rice-rice-cowpea	-0.008	-0.005
3. Rice-rice-sesamum	0.009	0.010
4. Rice-rice-groundnut	-0.012	-0.030
5. Rice-rice-rice	-0.018	-0.068
'F' test	**	**
S.Em.	± 0.00316	± 0.00548
C.D.(0.05)	0.00948	0.01643
C.D.(0.01)	0.01306	0.02264

** Significant at 1%

rice-rice-groundnut, all the crops reduced the exchangeable magnesium status of soil during both the years. It is seen from the data that there was continuous decrease in exchangeable magnesium content of soil after every crop of rice in the rice-rice-rice treatment.

The sources of exchangeable magnesium in the soil are crop residues, manures and fertilizers applied to the soil. Exchangeable magnesium is lost from the soil by erosion, crop removal and by leaching. Thus the increase in exchangeable magnesium observed after sweet potato and sesamum was due to the large quantities of farm yard manure applied to these crops. The decrease after cowpea and groundnut might be due to the higher uptake of this nutrient by these crops.

Submergence increased the availability of magnesium due to their displacement from the soil complex and due to exchange with Fe^{++} (Mahapatra, 1968 and Islam and Islam, 1973). This available magnesium would have been lost by leaching due to heavy rains that occured during <u>virippu</u> and <u>mundakan</u> rice seasons. This would probably be the reason for the decrease in exchangeable magnesium after the rice crops in the continuous cropping of rice. Sadanandan (1970) reported that the cropping pattern rice-rice showed a decrease after both rice crops in a multiple cropping experiment.

(1) Exchangeable hydrogen.

The data on the exchangeable hydrogen status of soil before and after every crop are presented in Tables 57 a, 57 b and 57 c and Fig.15.

The data reveal that all the crops irrespective of categories and cropping patterns increased the exchangeable hydrogen status of soil. It is also seen that the rice crops in all the treatments increased the exchangeable hydrogen status of soil more than the other crops. Thus in the treatments rice-rice-sweet potato, rice-rice-cowpea, rice-rice-sesamum and rice-rice-groundnut the increase in exchangeable hydrogen content of soil was comparatively less after sweet potato, cowpea, sesamum and groundnut crops as compared to that caused by the preceding virippu and mundakan rice crops in each treatment. The very same pattern was observed during the second crop cycle also. As stated earlier there was progressive increase in the exchangeable hydrogen status of soil after every crop of rice in the treatment rice-rice-rice and the maximum increase was observed after punja rice crop during both the years.

It is seen from the data that among the different crops other than rice, maximum increase was observed after cowpea followed by groundnut and sweet potato during the

Table-57(a): Exchangeable hydrogen status of soil (in m.e./100 gm of soil) after each crop

Treatment	Initial Status	1974-75			1975-76		
		after Virippu rice	after Mundakan rice	after sweet-potato	after Virippu rice	after Mundakan rice	after sweet-potato
Rice-rice-sweet potato	1.1972	1.2085	1.2184	1.2023 after cowpea	1.2207	1.2320	1.2059 after cowpea
Rice-rice-cowpea	1.1823	1.1922	1.2052	1.1916 after sesamum	1.2110	1.2185	1.2018 after sesamum
Rice-rice-sesamum	1.1851	1.1966	1.2078	1.1872 after groundnut	1.2066	1.2156	1.1890 after groundnut
Rice-rice-groundnut	1.2167	1.2288	1.2384	1.2223 after Punja (summer) rice	1.2396	1.2494	1.2234 after Punja (summer) rice
Rice-rice-rice	1.2045	1.2169	1.2243	1.2485	1.2748	1.2775	1.2868

Table-57(b): Change in exchangeable hydrogen in soil (in m.e./100 gm of soil) due to various cropping patterns

Treatment	1974-75			1975-76		
	after *Virippu* rice	after *Mundakan* rice	after sweet-potato	after *Virippu* rice	after *Mundakan* rice	after sweet-potato
Rice-rice-sweet potato	0.0113	0.0212	0.0051	0.0184	0.0297	0.0036
			after cowpea			after cowpea
Rice-rice-cowpea	0.0099	0.0229	0.0093	0.0194	0.0269	0.0102
			after sesamum			after sesamum
Rice-rice-sesamum	0.0115	0.0227	0.0021	0.0173	0.0284	0.0018
			after ground-nut			after ground-nut
Rice-rice-groundnut	0.0121	0.0217	0.0056	0.0186	0.0271	0.0011
			after *Punja* (summer) rice			after *Punja* (summer) rice
Rice-rice-rice	0.0124	0.0198	0.0440	0.0263	0.0290	0.0383

Table-57(c): Summary Table: Exchangeable hydrogen (m.e./100 gm of soil)

1. After *Virippu* rice

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	0.0113	0.0184
2. Rice-rice-cowpea	0.0099	0.0194
3. Rice-rice-sesamum	0.0115	0.0173
4. Rice-rice-groundnut	0.0121	0.0186
5. Rice-rice-rice	0.0124	0.0263
'F' test	N.S.	N.S.
S.Em.	± 0.00402368	±0.00447

N.S. Not significant

2. After *Mundakan* rice

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	0.0212	0.0297
2. Rice-rice-cowpea	0.0229	0.0269
3. Rice-rice-sesamum	0.0227	0.0284
4. Rice-rice-groundnut	0.0217	0.0271
5. Rice-rice-rice	0.0198	0.0290
'F' test	N.S.	N.S.
S.Em.	± 0.00745	± 0.00657

N.S. Not significant

3. After sweet potato, cowpea, sesamum, groundnut and rice

Treatment	Increase or decrease over initial status 1974-75	1975-76
1. Rice-rice-sweet potato	0.0051	0.0036
2. Rice-rice-cowpea	0.0093	0.0102
3. Rice-rice-sesamum	0.0021	0.0018
4. Rice-rice-groundnut	0.0056	0.0011
5. Rice-rice-rice	0.0440	0.0383
'F' test	**	**
S.Em.	± 0.00447	± 0.00278
C.D.(0.05)	0.01340	0.00833
C.D.(0.01)	0.01846	0.01147

** Significant at 1%

first year. During the second year also maximum increase was seen after cowpea followed by sweet potato and sesamum. While the lowest increase was observed after sesamum during the first year and after groundnut crop during the second year.

Generally increase in exchangeable hydrogen status of soil occurs in humid region soils of heavy rainfall due to the removal of calcium ions from soil colloidal complex accompanied by a substitution of hydrogen ions. The major sources of exchangeable hydrogen in soils is the exchange that occurs with soluble acids. Large quantities of carbonic acid are produced by the soil micro-organisms and higher plants in the soil. Hydrogen ions which are more strongly adsorbed than calcium enter the cationic swarm by cation exchange replacing the calcium. In humid regions this displaced calcium is lost in drainage, there by the soil developing acidity with the dominance of hydrogen ions.

It is seen from the data that maximum increase in exchangeable hydrogen was observed in the cropping pattern rice-rice-rice during both the years. The data on the exchangeable calcium status of soil (Tables 55 a and 55 b) reveal that there was a decrease in exchangeable calcium after every crop of rice. It is also seen that in all the above cases there was a corresponding increase in exchangeable hydrogen also. This indicates that the exchangeable calcium that had been leached during the heavy rainfall occurred during the _virippu_ and _mundakan_ seasons might have been replaced by exchangeable hydrogen which in turn brought about a corresponding decrease in soil pH (Tables 48 a and 48 b). Thus it is seen that an increase in exchangeable hydrogen is accompanied by a decrease in soil pH.

There was maximum increase in exchangeable hydrogen after cowpea among the different crops other than rice. The data on the exchangeable calcium status of soil also indicate that there was heavy reduction in the exchangeable calcium content of soil after cowpea crops presumably because of high calcium absorption for the nodule formation (Lyon, _et al_. 1952) which in turn caused a corresponding increase in exchangeable hydrogen status of soil.

c. Correlation studies.

As the total nitrogen and organic carbon contents of soil are two important soil fertility factors, the relationship between these fertility factors and yield has been studied by working out the correlation coefficients.

I. Relationship between soil nitrogen percentage and organic carbon percentage and grain yield of Virippu rice

The correlation coefficients between nitrogen percentage and organic carbon percentage of soil and yield of *virippu* rice during 1974 and 1975 are presented in Table 58.

Table 58 : Correlation coefficient between soil nitrogen percentage and organic carbon percentage in soil and *Virippu* rice yield

	Correlation coefficient (r)			
	1974		1975	
1. Yield and total nitrogen percentage	0.7845	N.S.	0.8353	N.S.
2. Yield and organic carbon percentage	0.74	N.S.	0.36	N.S.

It is evident from the data that the yield of *virippu* rice was not correlated with total nitrogen and organic carbon contents as the correlation coefficients were not significant during both the years. This finding is in agreement with that of Sadanandan and Mahapatra (1971) who found no significant correlation between the grain yield of rice and the percentage of nitrogen and organic carbon in the soil in a study on the effect of various cropping patterns on soil fertility and crop yields.

2. Relationship between soil nitrogen percentage and organic carbon percentage and the grain yield of Mundakan rice

The correlation coefficients between nitrogen percentage and organic carbon percentage in the soil and the yield of *mundakan* rice during 1974-75 and 1975-76 are presented in Table 59.

Table 59 : Correlation coefficient between soil nitrogen percentage and organic carbon percentage in the soil and *Mundakan* rice yield.

Correlation between	Correlation coefficient (r)			
	1974-75		1975-76	
1. Yield and total nitrogen percentage	0.72	N.S.	0.12	N.S.
2. Yield and organic carbon percentage	0.99	**	0.64	N.S.

It is seen from the data that the yield of *mundakan* rice was not significantly correlated with soil nitrogen percentage during both the years. While the organic carbon percentage was significantly correlated with *mundakan* rice yield during the first year, it failed to give a significant correlation during the second year. However, during the second year also the correlation coefficient between the organic carbon content of soil and mundakan rice yield was high and positive as compared to that between the nitrogen percentage and yield of rice. It appears that organic carbon may have some positive influence on growth and yield of rice.

D. Uptake of nitrogen, phosphorus and potash by various crops.

The uptake of nutrients by the crops gives us an idea about the quantity of nutrients removed from the soil. Therefore all the crops in the various cropping patterns were analysed for nitrogen, phosphorus and potash after the harvest of each crop in a cycle. Each part of the plant was analysed separately and the nutrient removal calculated on the basis of dry matter production at harvest.

1. Nitrogen, phosphorus and potash content of different parts of various crops included in the cropping pattern are presented in Tables 60 a, 60 b and 60 c respectively.

a) Nitrogen.

From the data presented in Table 60 a it is seen that the cowpea grain contained the maximum nitrogen (3.920 per cent) followed by groundnut kernels (3.686 per cent). The sesamum grains and groundnut haulms came next in

Table-60(a): Average nitrogen content (%) at harvest of different plant parts of various crops included in the cropping patterns

Name of crop	Virippu rice		Mundakan rice		Punja(summer) season crop						
	Grain	Straw	Grain	Straw	Grain	Kernel	Tuber	Straw	Haulms	Vine	Shell
1	2	3	4	5	6	7	8	9	10	11	12
1. Rice	1.228	0.823	1.162	0.980	1.246	-	-	0.961	-	-	-
2. Sweet potato	-	-	-	-	-	-	0.479	-	-	1.570	-
3. Cowpea	-	-	-	-	3.920	-	-	-	1.316	-	-
4. Sesamum	-	-	-	-	2.315	-	-	-	0.630	-	-
5. Groundnut	-	-	-	-	-	3.686	-	-	1.674	-	0.823

Table-60(b): Average phosphorus content (%) at harvest of different plant parts of various crops included in cropping pattern

1	2	3	4	5	6	7	8	9	10	11	12
1. Rice	0.276	0.163	0.243	0.169	0.292	-	-	0.149	-	-	-
2. Sweet potato	-	-	-	-	-	-	0.255	-	-	0.260	-
3. Cowpea	-	-	-	-	0.583	-	-	-	0.158	-	-
4. Sesamum	-	-	-	-	0.761	-	-	-	0.362	-	-
5. Groundnut	-	-	-	-	-	0.369	-	-	0.157	-	0.064

Table-60(c): Average potash content (%) at harvest of different plant parts of various crops included in cropping pattern

1	2	3	4	5	6	7	8	9	10	11	12
1. Rice	0.576	1.680	0.566	1.692	0.585	-	-	1.687	-	-	-
2. Sweet potato	-	-	-	-	-	-	1.620	-	-	3.960	-
3. Cowpea	-	-	-	-	1.260	-	-	-	1.360	-	-
4. Sesamum	-	-	-	-	1.080	-	-	-	1.780	-	-
5. Groundnut	-	-	-	-	-	0.725	-	-	0.728	-	0.795

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sequence with 2.315 per cent and 1.674 per cent of nitrogen respectively. The next maximum percentage of nitrogen was observed in sweet potato vines with 1.570 per cent followed by cowpea haulms with 1.316 per cent. Among the various rice crops, _punja_ rice contained maximum nitrogen content in grains (1.246 per cent) followed by _virippu_ (1.228 per cent) and _mundakan_ (1.162 per cent). With regard to rice straw, _mundakan_ rice contained the maximum nitrogen content (0.980 per cent) followed by _punja_ (0.961 per cent) and _virippu_ (0.823 per cent). Groundnut shell contained 0.823 per cent of nitrogen while sesamum straw contained only 0.630 per cent. The lowest nitrogen content was observed in sweet potato tubers with 0.479 per cent of nitrogen.

b) _Phosphorus_.

From the data presented in Table 60 b it is seen that the highest percentage of phosphorus was observed in sesamum grain (0.761 per cent) followed by cowpea grain (0.583 per cent) and groundnut kernels (0.369 per cent). The sesamum haulms contained the next highest percentage of phosphorus (0.362 per cent).

Among the different rice grains, _punja_ rice grains contained maximum phosphorus content (0.292 per cent) followed by _virippu_ (0.276 per cent) and _mundakan_

(0.243 per cent). Among the different rice straws, mundakan rice straw contained the maximum phosphorus content (0.169 per cent) followed by virippu (0.163 per cent) and punja (0.149 per cent). Sweet potato vines contained 0.260 per cent of phosphorus while the sweet potato tubers contained only 0.255 per cent phosphorus. Cowpea and groundnut haulms contained almost equal percentage of phosphorus. The lowest phosphorus percentage was observed in groundnut shell being 0.064 per cent When compared with nitrogen the phosphorus content of all the parts was very low.

(c) Potash.

It is seen from the Table 60 c that sweet potato vines contained the highest potash (3.960 per cent) followed by sesamum haulms (1.78 per cent). Among the different rice grains, punja rice contained the maximum potash content (0.585 per cent) followed by virippu (0.576 per cent) and mundakan (0.566 per cent). However, mundakan straw contained maximum potash content (1.692 per cent) as compared to punja rice (1.687 per cent) or virippu rice (1.680 per cent). Sweet potato tubers contained 1.620 per cent of potash which is low as compared to that of sweet potato vines. Cowpea haulms contained 1.360 per cent of potash while cowpea grains contained only 1.260 per cent. Sesamum grains contained 1.08 per cent of potash. Among the different parts of groundnut crop, groundnut shell contained maximum potash content (0.795 per cent) followed by haulm (0.728 per cent) and kernels (0.725 per cent).

It is seen from the data that the potash content of all plant parts of all the crops was much higher than phosphorus.

2. (a) Uptake of Nitrogen.

The data on the removal of nitrogen by each crop in a cropping pattern for the years 1974-75 and 1975-76 are presented in Tables 61 a and 61 b respectively.

The data reveal that during the first year, the *virippu* and *mundakan* rice crops in all the cropping patterns removed nitrogen almost alike with out much variation, the range being from 72.57 to 83.81 kg. per hectare during the *virippu* and from 73.67 to 79.48 kg. per hectare during the *mundakan*. The very same trend in nitrogen uptake was observed during the second year also. However, the uptake was comparatively less by both *virippu* and *mundakan* rice crops during the second year.

Among the different crops other than rice, groundnut removed the maximum nitrogen content during the first year (98.89 kg. per hectare) as well as during the second year

Table-61(a): Uptake of nitrogen (in kg./ha.) by various crops in cropping patterns during 1974-75

Treatment	Virippu rice			Mundakan rice			Punja(summer) season crops				Total N removed in kg./ha. after one cycle of cropping
	Rice			Rice			Sweet potato				
	Grain	Straw	Total	Grain	Straw	Total	Tuber	Vine		Total	
1 Rice-rice-sweet potato	46.78	31.54	78.32	36.99	42.49	79.48	17.47	62.33		79.80	237.60
	Rice			Rice			Cowpea				
	Grain	Straw	Total	Grain	Straw	Total	Grain	Haulm		Total	
2 Rice-rice-cowpea	47.21	25.36	72.57	36.38	38.39	74.77	37.62	23.72		61.34	208.68
	Rice			Rice			Sesamum				
	Grain	Straw	Total	Grain	Straw	Total	Grain	Haulm		Total	
3 Rice-rice-sesamum	49.84	33.97	83.81	38.77	38.08	76.85	12.11	6.29		18.40	179.06
	Rice			Rice			Groundnut				
	Grain	Straw	Total	Grain	Straw	Total	Kernel	Shell	Haulm	Total	
4 Rice-rice-groundnut	48.53	27.57	76.10	38.96	39.30	78.26	45.36	3.61	49.92	98.89	253.25
	Rice			Rice			Rice				
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw		Total	
5 Rice-rice-rice	47.65	28.89	76.54	36.04	37.63	73.67	41.31	33.82		75.13	225.34

Table-61(b): Uptake of nitrogen (in kg./ha.) by various crops in cropping patterns during 1975-76

Treatment	*Virippu* rice			*Mundakan* rice			*Punja* (summer) season crops				Total N removed in kg./ha. after one cycle of cropping
	Rice			Rice			Sweet potato				
	Grain	Straw	Total	Grain	Straw	Total	Tuber	Vine	Total		
1 Rice-rice-sweet potato	42.01	22.73	64.74	25.79	34.04	59.83	14.32	62.37	76.49		201.06
	Rice			Rice			Cowpea				
	Grain	Straw	Total	Grain	Straw	Total	Grain	Haulm	Total		
2 Rice-rice-cowpea	44.39	25.35	69.74	28.43	36.51	64.94	41.18	25.59	66.77		201.45
	Rice			Rice			Sesamum				
	Grain	Straw	Total	Grain	Straw	Total	Grain	Haulm	Total		
3 Rice-rice-sesamum	42.54	24.55	67.09	27.38	30.17	57.55	11.44	6.05	17.49		142.13
	Rice			Rice			Groundnut				
	Grain	Straw	Total	Grain	Straw	Total	Kernel	Shell	Haulm	Total	
4 Rice-rice-groundnut	44.03	24.65	68.68	29.11	34.89	64.00	61.93	4.91	68.13	134.97	267.65
	Rice			Rice			Rice				
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total		
5 Rice-rice-rice	40.33	22.32	62.65	25.21	29.13	54.34	35.46	30.64	66.10		183.09

(134.97 kg. per hectare) followed by sweet potato (79.80 kg. per hectare during the first year and 76.49 kg. per hectare during the second year). The cowpea removed 61.34 kg. per hectare during the first year and went up to 66.77 kg. per hectare during the second year. The sesamum crop removed the lowest nitrogen content from the soil being 18.40 kg. per hectare during the first year and 17.49 per hectare during the second year.

During the _virippu_ and _mundakan_ seasons of first year, all the treatments contained only rice crops and therefore the slight variations that occurred in the uptake of nitrogen by these crops was due to the variation in the inherent fertility status of soil. During the second year it is seen that the _virippu_ and _mundakan_ rice crops preceded by cowpea during the _punja_ season of the first year removed the maximum quantity of nitrogen. The _virippu_ and _mundakan_ rice crops following groundnut crop removed the next highest quantity of nitrogen. From the data on the total nitrogen content of soil after each crop (Table 51 a) it is clear that there was considerable increase in the total nitrogen content of soil after cowpea and groundnut crops. Because of this higher amount of nitrogen in the soil after cowpea and groundnut crops the succeeding _virippu_ and _mundakan_ rice crops of second year could absorb larger quantities of nitrogen from the soil. It is seen from the data that groundnut crop removed maximum quantity of nitrogen from the soil during both the years. Due to the comparatively high dry matter production as compared to cowpea crop there was higher uptake of nitrogen by the groundnut crop during both the years.

Comparing the total quantity of nitrogen removed by various cropping patterns it is seen that rice-rice-groundnut removed the maximum quantity of nitrogen during both the years closely followed by rice-rice-sweet potato. The lowest recovery during both the years was by the rice-rice-sesamum treatment. The lowest dry matter production obtained in the pattern rice-rice-sesamum clearly illustrates the reason for the lowest removal of nitrogen by this cropping pattern. Generally the nitrogen uptake by crops is controlled by the availability of nutrients in the soil, nutrient absorbing power of roots and the dry matter production of plant. The trend in nitrogen removal by various cropping patterns was directly related to the dry matter production at harvest.

(b) Uptake of phosphorus.

The data on the removal of phosphorus by each crop in a cropping pattern for the years 1974-75 and 1975-76 are presented in Tables 62 a and 62 b respectively.

The phosphorus uptake pattern of rice crop in *virippu* and *mundakan* seasons was similar to that of nitrogen. During the first year there was only slight variation in the uptake of phosphorus ranging from 15.63 to 17.93 kg. per hectare in *virippu* crop and from 14.82 to 15.86 kg. per hectare during the *mundakan* crop. During the second year also there was not much variation between the phosphorus uptake by the *virippu* and the *mundakan* rice crops in different treatments.

Sweet potato took the maximum quantity of phosphorus from the soil (19.62 kg. per hectare during the first year and 17.96 kg. per hectare during the second year). Groundnut removed 9.50 kg. per hectare of phosphorus during the first year and 12.97 kg. per hectare during the second year. Cowpea removed 8.45 kg. per hectare during the first year while it was 9.19 kg. per hectare during the second year. The lowest phosphorus uptake was by the sesamum crop during both the years.

Table-62(a): Uptake of phosphorus (in kg./ha.) by various crops in cropping patterns during 1974-75

Treatment	Virippu rice			Mundakan rice			Punja (summer) season crops				Total P removed in Kg./ha. after one cycle of cropping
	Rice			Rice			Sweet potato				
	Grain	Straw	Total	Grain	Straw	Total	Tuber	Vine	Total		
1 Rice-rice-sweet potato	10.51	6.25	16.76	8.79	7.07	15.86	9.30	10.32	19.62		52.24
	Rice			Rice			Cowpea				
	Grain	Straw	Total	Grain	Straw	Total	Grain	Haulm	Total		
2 Rice-rice-cowpea	10.61	5.02	15.63	8.64	6.38	15.02	5.60	2.85	8.45		39.10
	Rice			Rice			Sesamum				
	Grain	Straw	Total	Grain	Straw	Total	Grain	Haulm	Total		
3 Rice-rice-sesamum	11.20	6.73	17.93	9.21	6.33	15.54	3.98	3.62	7.60		41.07
	Rice			Rice			Groundnut				
	Grain	Straw	Total	Grain	Straw	Total	Kernel	Shell	Haulm	Total	
4 Rice-rice-groundnut	10.91	5.46	11.37	9.25	6.54	15.79	4.54	0.28	4.68	9.50	41.66
	Rice			Rice			Rice				
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total		
5 Rice-rice-rice	10.71	5.72	16.43	8.56	6.26	14.82	9.68	5.24	14.92		46.17

Table-62(b): Uptake of phosphorus (in Kg./ha.) by various crops in cropping patterns during 1975-76

Treatment	Virippu rice			Mundakan rice			Punja (summer) season crops				Total P. removed in kg./ha. after one cycle of cropping
	Rice			Rice			Sweet potato				
	Grain	Straw	Total	Grain	Straw	Total	Tuber	Vine	Total		
1. Rice-rice-sweet potato	9.44	4.50	13.94	5.39	5.87	11.26	7.63	10.33	17.96		43.16
	Rice			Rice			Cowpea				
	Grain	Straw	Total	Grain	Straw	Total	Grain	Haulm	Total		
2. Rice-rice-cowpea	9.98	5.02	15.00	5.95	6.30	12.25	6.12	3.07	9.19		36.44
	Rice			Rice			Sesamum				
	Grain	Straw	Total	Grain	Straw	Total	Grain	Haulm	Total		
3. Rice-rice-sesamum	9.56	4.86	14.42	5.73	5.20	10.93	3.76	3.48	7.24		32.59
	Rice			Rice			Groundnut				
	Grain	Straw	Total	Grain	Straw	Total	Kernel	Shell	Haulm	Total	
4. Rice-rice-groundnut	9.90	4.88	14.78	6.09	6.02	12.11	6.20	0.38	6.39	12.97	39.86
	Rice			Rice			Rice				
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total		
5. Rice-rice-rice	9.06	4.42	13.48	5.27	5.02	10.29	8.31	4.75	13.06		36.83

Regarding the total removal of phosphorus from various cropping patterns it was observed that the highest quantity of phosphorus was removed from the cropping pattern rice-rice-sweet potato during both the years. As the dry matter production was higher in that treatment it is quite natural that a higher quantity of phosphorus was also removed from the soil. The lowest quantity of phosphorus was removed from the treatment rice-rice-cowpea during the first year and rice-rice-sesamum during the second year.

(c) Uptake of Potash.

The data on the uptake of potash by each crop in a cropping pattern for the years 1974-75 and 1975-76 are presented in Tables 63 a and 63 b respectively.

It is seen from the data that the removal of potash by the crops was very high as compared to nitrogen and phosphorus. The cropping pattern rice-rice-sweet potato removed the maximum quantity of potash from the soil followed by rice-rice-rice during both the years.

As in the case of nitrogen there was not much difference in the uptake of potash by the virippu and mundakan rice crops during the first year. As explained earlier there were no treatment differences during the

Table-63(a): Uptake of potash (in kg./ha.) by various crops in cropping patterns during 1974-75

Treatment	*Virippu* rice			*Mundakan* rice			*Punja* (summer) season crops				Total K removed in kg./ha. after one cycle of cropping
	Rice			Rice			Sweet potato				
	Grain	Straw	Total	Grain	Straw	Total	Tuber	Vine	Total		
1 Rice-rice-sweet potato	21.94	64.38	86.32	18.02	73.36	91.38	59.08	157.21	216.29		393.99
	Rice			Rice			Cowpea				
	Grain	Straw	Total	Grain	Straw	Total	Grain	Haulm	Total		
2 Rice-rice-cowpea	22.15	51.78	73.93	17.72	66.28	84.00	12.09	24.50	36.59		194.52
	Rice			Rice			Sesamum				
	Grain	Straw	Total	Grain	Straw	Total	Grain	Haulm	Total		
3 Rice-rice-sesamum	23.38	69.34	92.72	18.89	65.74	84.63	5.65	17.79	23.44		200.79
	Rice			Rice			Groundnut				
	Grain	Straw	Total	Grain	Straw	Total	Kernel	Shell	Haulm	Total	
4 Rice-rice-groundnut	22.76	56.28	79.04	18.98	67.85	86.83	8.92	3.48	21.71	34.11	199.98
	Rice			Rice			Rice				
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total		
5 Rice-rice-rice	22.35	58.98	81.33	17.56	64.98	82.54	19.40	59.38	78.78		242.65

Table-63(b): Uptake of potash (in kg./ha.) by various crops in cropping patterns during 1975-76

Treatment	*Virippu* rice			*Mundakan* rice			*Punja* (summer) season crops				Total K removed in kg./ha. after one cycle of cropping
	Rice			Rice			Sweet potato				
	Grain	Straw	Total	Grain	Straw	Total	Tuber	Vine	Total		
1 Rice-rice-sweet potato	19.70	46.39	66.09	12.56	58.78	71.34	48.45	157.32	205.77		343.20
	Rice			Rice			Cowpea				
	Grain	Straw	Total	Grain	Straw	Total	Grain	Haulm	Total		
2 Rice-rice-cowpea	20.85	51.75	72.60	13.85	63.04	76.89	13.24	25.45	39.69		189.18
	Rice			Rice			Sesamum				
	Grain	Straw	Total	Grain	Straw	Total	Grain	Haulm	Total		
3 Rice-rice-sesamum	19.95	50.12	70.07	13.34	52.09	65.43	5.34	17.10	22.44		157.94
	Rice			Rice			Groundnut				
	Grain	Straw	Total	Grain	Straw	Total	Kernel	Shell	Haulm	Total	
4 Rice-rice-groundnut	20.65	50.32	70.97	14.18	60.25	74.43	12.18	4.74	29.63	46.55	191.95
	Rice			Rice			Rice				
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total		
5 Rice-rice-rice	18.92	45.56	64.48	12.28	50.29	62.57	16.65	53.80	70.45		197.50

virippu and *mundakan* rice crops during the first year and any difference observed may be attributed to the variation in the inherent fertility status of soil. During the second year the *virippu* and *mundakan* rice crops which followed the cowpea crop removed the maximum quantity of potash indicating that the cowpea crop could make availalable large quantities of exchangeable potash in the soil (Table 54 a) which the succeeding rice crops could absorb in large quantities. The *punja* rice crop removed 78.78 kg. per hectare of potash during the first year while it was only 70.45 kg. per hectare during the second year.

Among the different crops other than rice, the maximum quantity of potash was removed by sweet potato during both the years (216.29, 205.77 kg. per hectare during the first and second year respectively). The second position went to cowpea during the first year (36.59 kg. per hectare) and to groundnut (46.5 kg. per hectare) during the second year. During both the years the lowest removal was by sesamum crop. The higher potash content of sweet potato especially of vines resulted in the highest removal of potash by the cropping pattern involving sweet potato as one of the crops. It is seen from the data that in all the crops the quantity of potash removed by way of vegetative parts like straw, haulm or vine was higher than by grain or tuber. Another observation is that the crops which had taken large quantities of phosphorus had absorbed large quantities of potash also.

3. Removal of Nitrogen, Phosphorus and Potash in kg. per tonne of dry matter by individual crops.

The data on the removal of nitrogen, phosphorus and potash in kg. for the production of one tonne of dry matter during the years 1974-75 and 1975-76 are presented in Table 64.

Cowpea removed the maximum quantity of nitrogen for the production of one tonne of dry matter during both the years, the quantity being 22.21 kg. during the first year and 22.29 kg. during the second year. The next highest quantity of nitrogen was removed by groundnut crop, the quantity being 21.26 kg. during the first year and 21.27 kg. during the second year. The third position went to sesamum with 12.09 kg. during first year and 12.02 kg. during the second year. Sweet potato used 10.48 kg. of nitrogen during the first year and 10.99 kg. during the second year. Among the different rice crops, *punja* rice crop used the maximum quantity of nitrogen during both the years. The minimum quantity of nitrogen was used by the *virippu* rice crop.

Table-64: Removal of nitrogen, phosphorus and potash in kg. per ton of dry-matter by individual crops during the years 1974-75 and 1975-76

	Nitrogen	Phosphorus	Potash
1974-75			
1. *Virippu* rice	10.34	2.22	11.04
2. *Mundakan* rice	10.61	2.13	11.90
3. Sweet potato	10.48	2.58	28.40
4. Cowpea	22.21	3.06	13.25
5. Sesamum	12.09	4.99	15.40
6. Groundnut	21.26	2.04	7.33
7. *Punja* (summer)rice	10.99	2.18	11.53
1975-76			
1. *Virippu* rice	10.44	2.25	10.79
2. *Mundakan* rice	10.55	1.99	12.30
3. Sweet potato	10.99	2.58	29.55
4. Cowpea	22.29	3.07	13.25
5. Sesamum	12.02	5.00	15.42
6. Groundnut	21.27	2.04	7.33
7. Punja (summer) rice	10.95	2.16	11.67

From the data on the removal of nitrogen it is clear that the most efficient crop regarding the utilization of nitrogen for dry matter production was rice, especially _virippu_ rice, followed by sweet potato. This means that in the case of _virippu_ rice and sweet potato, all the nitrogen absorbed was fully utilized for vegetative growth resulting in the production of large quantities of dry matter as compared to other crops. Cowpea and groundnut were least efficient in this respect. However, in the case of cowpea and groundnut, the loss of nitrogen from the soil was very low as most of the nitrogen would have been absorbed from the atmosphere by way of biological fixation.

Sesamum crop utilized the maximum quantity of phosphorus for the production of every tonne of dry matter; the quantities being 4.99 kg. during the first year and 5.00 kg. during the second year. While cowpea also used comparatively higher quantities of phosphorus (3.06 and 3.07 kg. during first and second year respectively), groundnut removed only lower quantities of phosphorus for dry matter production. Thus it is seen that groundnut crop removed the lowest quantity of phosphorus (2.04 kg. per hectare) during the first year, and _mundakan_ rice crop removed the lowest quantity of phosphorus (1.99 kg.) during the second year. This indicates that groundnut crop during the first year and _mundakan_ rice crop during the second year were the most efficient crops in utilizing phosphorus for dry matter production.

During both the years sweet potato crop removed the maximum quantity of potash in dry matter production and the sesamum crop was second in this respect. Among the different rice crops, _mundakan_ rice crop removed the maximum quantity of potash, while _virippu_ rice crop removed the lowest quantity of potash during both the years. Among all the crops in various cropping patterns, groundnut removed the minimum quantity of potash during both the years (7.33 kg. during both the years).

Thus it is clear that _virippu_ rice crop was the most efficient crop in the utilization of nitrogen for dry matter production. In the case of phosphorus, both groundnut and _mundakan_ rice were equally efficient and with regard to potash again groundnut was the most efficient crop for dry matter production.

4. <u>Total Protein yield per hectare per day from various cropping patterns</u>

The data on the total protein yield per hectare and protein yield per hectare per day from various cropping patterns are presented in Table 65.

The cropping pattern rice-rice-groundnut produced the maximum quantity of protein during both the years, the quantity being 830.41 kg. per hectare during the first year and 844.35 kg. per hectare during the second year. The next highest protein yield was obtained from the pattern rice-rice-rice, closely followed by rice-rice-cowpea during the first year. However, during the second year the second position went to rice-rice-cowpea pattern. The lowest protein yield was obtained from the cropping pattern rice-rice-sesamum during both the years.

As in the case of total protein yield per hectare, the highest quantity of protein yield per hectare per day was also obtained from the cropping pattern rice-rice-groundnut during both the years, the quantity being 2.924 kg. during the first year and 2.973 kg. during the second year. The next highest protein yield per day was obtained from rice-rice-rice cropping pattern during the first year and

Table-65: Total protein yield per hectare and per day from various cropping patterns during 1974-75 and 1975-76

Treatment	Total protein yield in kg./ha.	Duration (days)	Protein yield in kg./ha. per day
<u>1974-75</u>			
1. Rice-rice-sweet potato	632.72	299	2.116
2. Rice-rice-cowpea	757.72	278	2.726
3. Rice-rice-sesamum	629.64	273	2.306
4. Rice-rice-groundnut	830.41	284	2.924
5. Rice-rice-rice	781.46	281	2.781
<u>1975-76</u>			
1. Rice-rice-sweet potato	513.29	296	1.734
2. Rice-rice-cowpea	712.67	284	2.509
3. Rice-rice-sesamum	508.62	270	1.884
4. Rice-rice-groundnut	844.35	284	2.973
5. Rice-rice-rice	631.43	286	2.208

rice-rice-cowpea during the second year. The lowest protein yield per day was obtained from the cropping pattern rice-rice-sweet potato during both the years.

Thus it is seen that maximum protein production per hectare as well as per day was obtained from the cropping pattern rice-rice-groundnut.

E. Balance sheet of plant nutrients in various cropping patterns.

1. Nitrogen.

The balance sheet of the total soil nitrogen in each cropping pattern for the years 1974-75 and 1975-76 are presented in Table 66.

There was heavy loss of nitrogen in the cropping patterns rice-rice-rice, rice-rice-sesamum and rice-rice-sweet potato. The maximum loss was incurred in the cropping pattern rice-rice-rice during both the years. However, there was gain in nitrogen from the cropping patterns rice-rice-groundnut and rice-rice-cowpea during both the years and the maximum gain obtained was from rice-rice-groundnut.

The loss of nitrogen in the pattern rice-rice-sweet potato was to the tune of 139 kg. per hectare during the first year and 124 kg. per hectare during the second year.

Table-66: Balance sheet of total soil nitrogen in various cropping patterns (kg./ha.)

Treatment	Initial status of total N kg./ha.	Additions of nitrogen as fertilizers and manures in kg. per hectare				Removal of nitrogen by crops in kg. per hectare				Expected balance in kg. per hectare	Actual balance in kg. per hectare	Net loss or gain in kg. per hectare
1974-75												
1 Rice-rice-sweet potato	2716	Rice 70	Rice 90	Sweet-potato 125	Total 285	Rice 78	Rice 79	Sweet-potato 111	Total 268	2733	2594	-139
2 Rice-rice-cowpea	2857	Rice 70	Rice 90	cowpea 20	180	Rice 73	Rice 75	Cowpea 61	209	2828	2943	115
3 Rice-rice-sesamum	2929	Rice 70	Rice 90	Sesamum 55	215	Rice 84	Rice 77	Sesamum 18	179	2965	2826	-139
4 Rice-rice-groundnut	2851	Rice 70	Rice 90	Groundnut 20	180	Rice 76	Rice 78	Groundnut 99	253	2778	2898	120
5 Rice-rice-rice	2734	Rice 70	Rice 90	Rice 70	230	Rice 77	Rice 74	Rice 75	226	2738	2540	-198
1975-76												
1 Rice-rice-sweet potato	2594	Rice 70	Rice 90	Sweet-potato 125	285	Rice 65	Rice 60	Sweet-potato 108	233	2646	2522	-124
2 Rice-rice-cowpea	2943	Rice 70	Rice 90	Cowpea 20	180	Rice 70	Rice 65	Cowpea 67	202	2921	2990	69
3 Rice-rice-sesamum	2826	Rice 70	Rice 90	Sesamum 55	215	Rice 67	Rice 58	Sesamum 17	142	2899	2691	-208
4 Rice-rice-groundnut	2898	Rice 70	Rice 90	Groundnut 20	180	Rice 69	Rice 64	Groundnut 135	268	2810	2918	108
5 Rice-rice-rice	2540	Rice 70	Rice 90	Rice 70	230	Rice 63	Rice 54	Rice 66	183	2587	2378	-209

The loss of nitrogen corresponding to the pattern rice-rice-sesamum was 139 kg. per hectare during the first year and 208 kg. per hectare during the second year. The maximum loss of 198 kg. nitrogen per hectare during the first year and 209 kg. nitrogen per hectare during the second year was from the cropping pattern rice-rice-rice.

Thus it is seen that there was gain in nitrogen in patterns in which legume crops were included like rice-rice-groudnut and rice-rice-cowpea and maximum gain was obtained from the pattern rice-rice-groundnut during both the years (120 kg. per hectare during the first year and 108 kg. per hectare during the second year). It is also seen that the crop removal of nitrogen in the above two treatments exceeded the nitrogen applied to the crops during both the years. Therefore the loss in these treatments was also low resulting in gain in nitrogen. The fact that groundnut and cowpea crops removed more nitrogen than that was added through manures and fertilizers clearly indicates that these crops utilized atmospheric nitrogen in addition to that taken up from the soil. Nijhawan (1963) reported a removal of 166 lb of nitrogen per acre by groundnut crop to which only 25 lb of nitrogen was applied as fertilizers.

The balance sheet prepared brought out the following points:

1. The crops usually removed only a part of the nitrogen applied to the soil. Lowest uptake was by sesamum crop which utilized only 31 per cent to 33 per cent of nitrogen applied.

2. The maximum loss of nitrogen occurred in the continuous cropping of rice.

3. Inclusion of legumes like groundnut and cowpea in a cropping pattern increases the gain of nitrogen in such cropping patterns.

2. Extractable Phosphorus.

The balance sheets of extractable phosphorus in each cropping pattern for the years 1974-75 and 1975-76 are presented in Table 67. For the purpose of calculating the balance sheet, all the phosphorus added through fertilizers and manures have been considered as extractable phosphorus.

It is seen that the extractable phosphorus in all the cropping patterns decreases after each crop cycle, the magnitude of decrease varying from 52 to 96 kg. per hectare during the first year of crop cycle and from 57 to 105 kg.

Table-67: Balance sheet of extractable phosphorus in the soil in various cropping patterns(kg. per hectare)

Treatment	Initial status in kg./ha.	Additions of phosphorus as fertilizers and manures in kg. per hectare				Removal of phosphorus by crops in kg. per hectare				Expected balance in kg. per hectare	Actual balance in kg. per hectare	Net loss or gain in kg. per hectare
1974-75												
1. Rice-rice-sweet potato	50	Rice 35	Rice 45	Sweet-potato 80	Total 160	Rice 17	Rice 16	Sweet-potato 25	Total 58	152	56	-96
2 Rice-rice-cowpea	41	Rice 35	Rice 45	Cowpea 56	136	Rice 16	Rice 15	Cowpea 8	39	138	56	-82
3 Rice-rice-sesamum	43	Rice 35	Rice 45	Sesamum 30	110	Rice 18	Rice 16	Sesamum 8	42	111	47	-64
4 Rice-rice-groundnut	38	Rice 35	Rice 45	Groundnut 26	106	Rice 16	Rice 16	Groundnut 10	42	102	50	-52
5 Rice-rice-rice	45	Rice 35	Rice 45	Rice 35	115	Rice 16	Rice 15	Rice 15	46	114	36	-78
1975-76												
1. Rice-rice-sweet potato	56	Rice 35	Rice 45	Sweet-potato 80	160	Rice 14	Rice 11	Sweet-potato 23	48	168	63	-105
2. Rice-rice-cowpea	56	Rice 35	Rice 45	Cowpea 56	136	Rice 15	Rice 12	Cowpea 9	36	156	70	-86
3. Rice-rice-sesamum	47	Rice 35	Rice 45	Sesamum 30	110	Rice 14	Rice 11	Sesamum 7	32	125	56	-69
4. Rice-rice-groundnut	50	Rice 35	Rice 45	Groundnut 26	106	Rice 15	Rice 12	Groundnut 13	40	116	59	-57
5. Rice-rice-rice	36	Rice 35	Rice 45	Rice 35	115	Rice 13	Rice 10	Rice 13	36	115	41	-74

per hectare during the second year of crop cycle. The main reason for the decrease in extractable phosphorus may be due to the fixation of a major portion of phosphorus added as manures and fertilizers.

The quantity of phosphorus removed by the various crops was relatively very low although large quantities of phosphorus were added through manures and fertilizers. Among the various crops, sweet potato removed the maximum quantity of phosphorus and as such the uptake of phosphorus was maximum in the cropping pattern rice-rice-sweet potato during both the years.

The extractable phosphorus content of soil at a time is determined by factors like soil pH, presence of soluble iron and alluminium and the amount and decomposition of organic matter etc. As the soil pH was decreased after each crop cycle and as the organic matter content has come to a very low level it was but natural that the extractable phosphorus of the soil also decreased in all the treatments.

3. <u>Exchangeable Potash.</u>

The balance sheets of exchangeable potash in the soil after each crop cycle during the years 1974-75 and 1975-76 are presented in Table 68.

Table-68: Balance sheet of exchangeable potash in various cropping patterns (kg./ha.).

Treatment	Initial status of exchangeable K in kg./ha.	Additions of potash as fertilizers and manures in kg. per hectare				Removal of potash by crops in kg. per hectare				Expected balance in kg. per hectare	Actual balance in kg. per hectare	Net loss or gain in kg. per hectare
1974-75												
1 Rice rice-sweet potato	194	Rice 35	Rice 45	Sweet-potato 125	Total 205	Rice 86	Rice 91	Sweet-potato 216	Total 393	6	229	223
2 Rice-rice-cowpea	191	Rice 35	Rice 45	Cowpea 60	140	Rice 74	Rice 84	Cowpea 37	195	136	239	103
3 Rice-rice-sesamum	190	Rice 35	Rice 45	Sesamum 55	135	Rice 93	Rice 85	Sesamum 23	201	124	210	86
4 Rice-rice-groundnut	184	Rice 35	Rice 45	Groundnut 50	130	Rice 79	Rice 87	Groundnut 34	200	114	227	113
5 Rice-rice-rice	183	Rice 35	Rice 45	Rice 35	115	Rice 81	Rice 83	Rice 79	243	55	171	116
1975-76												
1 Rice-rice-sweet potato	229	Rice 35	Rice 45	Sweet-potato 125	205	Rice 66	Rice 71	Sweet-potato 206	343	91	287	196
2 Rice-rice-cowpea	239	Rice 35	Rice 45	Cowpea 60	140	Rice 73	Rice 77	Cowpea 40	190	189	291	102
3 Rice-rice-sesamum	210	Rice 35	Rice 45	Sesamum 55	135	Rice 70	Rice 65	Sesamum 22	157	188	262	74
4 Rice-rice-groundnut	227	Rice 35	Rice 45	Groundnut 50	130	Rice 71	Rice 74	Groundnut 47	192	165	286	121
5 Rice-rice-rice	171	Rice 35	Rice 45	Rice 35	115	Rice 64	Rice 63	Rice 70	197	89	184	95

In contrast to the balance sheet of extractable phosphorus the balance sheet of exchangeable potash showed good gains in all the treatments during both the years. While all the rice crops removed almost double the quantity of potash added through fertilizers and manures, other crops excepting sweet potato removed only lesser quantities of potash than that added through fertilizers and manures. However, the total uptake of potash in a crop cycle was more than what was applied through fertilizers and manures.

Maximum gain in exchangeable potash was observed in the pattern rice-rice-sweet potato during both the years. Similarly the lowest gain was observed in the cropping pattern rice-rice-sesamum during both the years. The increase in exchangeable potash in excess of what has been applied through fertilizers and manures presumably came mostly from non-exchangeable form. This is because weathering of potash minerals in soils is a continuous process and proceeds slowly throughout the year. This may be the reason for the gain seen in treatments mentioned above.

F. Economics of various cropping patterns.

The economics of various cropping patterns have been studied in detail to find out the most profitable cropping pattern, as no cultivator will follow a cropping pattern if it is not remunerative in spite of the fact that it may give high yield per hectare per year and maintain or build up soil fertility. The cost of cultivation, gross income and net profit per hectare per year were worked out on the basis of yield and prevailing market rates for the years 1974-75 and 1975-76. The data are presented in Tables 69, 70 a and 70 b.

From the data on the cost of cultivation of individual crops it is seen that the cost of cultivation was highest for sweet potato crop being Rs. 3555/- per hectare. Out of this the cost of manures and fertilizers alone came to more than one third of the total expenditure. The next highest cost of cultivation was for rice crops. Among the different rice crops, the cost of cultivation for mundakan rice was the highest (Rs. 3185/- per hectare) followed by virippu and punja crops (Rs. 3000/- per hectare each). Here again the single item which consumed a good share of expenditure was manures and fertilizers for mundakan rice while it was seeds and sowing for virippu and punja rice. The cost of cultivation for other crops like groundnut, cowpea and sesamum were Rs. 2800/-, Rs. 2065/- and Rs. 1984/- per hectare respectively. In the case of groundnut crop the major item of expenditure was harvesting charges which was

Table-69: Cost of cultivation per hectare of crops included in cropping patterns

Crops	Preparatory cultivation	Seeds and sowing	Manures and manuring	After cultivation (weeding, plant-protection, irrigation etc.	Harvesting and threshing etc.	Total
1. Rice (Virippu)	625.00	700.00	670.00	555.00	450.00	3,000.00
2. Rice (Mundakan)	625.00	700.00	855.00	555.00	450.00	3,185.00
3. Rice (Punja)(summer)	625.00	700.00	670.00	555.00	450.00	3,000.00
4. Sweet potato	575.00	600.00	1460.00	455.00	465.00	3,555.00
5. Cowpea	550.00	350.00	600.00	235.00	330.00	2,065.00
6. Sesamum	600.00	250.00	639.00	210.00	285.00	1,984.00
7. Groundnut	560.00	640.00	610.00	355.00	655.00	2,820.00

Note: Rates used in calculation.

1. Wages	: Males		- Rs. 6-00 per day
	Females		- Rs. 5-00 per day
2. Manures and fertilizers	: Farm yard manure		- Rs. 50-00 per ton
	Ammonium sulphate		- Rs. 925-00 per ton
	Single superphosphate		Rs. 504-00 per ton
	Muriate of potash		- Rs. 820-00 per ton
	Lime		- Rs. 200-00 per ton
3. Ploughing	: Bullock pair		- Rs. 15-00 per pair
4. Cost of seed and produce	: Rice	: Seed	- Rs. 200-00 per quintal
		Grain	- Rs. 100-00 per quintal
		Straw	- Rs. 20-00 per quintal
	Sweet-potato	: Tubers	- Rs. 40-00 per quintal
	Cowpea	: Seed	- Rs. 400-00 per quintal
		Grain	- Rs. 250-00 per quintal
	Sesamum	: Seed	- Rs. 500-00 per quintal
		Grain	- Rs. 500-00 per quintal
	Groundnut	: Seed	-Rs. 400-00 per quintal
		Pods	- Rs. 250-00 per quintal

Table-70(a): Cost of cultivation and net profit per hectare of cropping patterns-1974-75

Cropping pattern	Crops	Cost of cultivation	Produce: Grain kg./ha.	Produce: Tuber kg./ha.	Produce: Straw/haulm/ kg./ha.	Value	Net profit	Total profit per ha./year of cropping pattern
		Rs. Ps.				Rs. Ps.	Rs. Ps.	Rs. Ps.
1.	Virippu rice	3000-00	4280	-	5720	5424-00	2424-00	
	Mundakan rice	3185-00	3577	-	5353	4648-00	1463-00	
	Sweet potato	3555-00	-	12828	-	5131-00	1576-00	5463-00
2.	Virippu rice	3000-00	4320	-	4600	5240-00	2240-00	
	Mundakan rice	3185-00	3518	-	4836	4485-00	1300-00	
	Cowpea	2065-00	1081	-	-	2703-00	638-00	4178-00
3.	Virippu rice	3000-00	4560	-	6160	5792-00	2792-00	
	Mundakan rice	3185-00	3749	-	4797	4708-00	1523-00	
	Sesamum	1984-00	565	-	-	2825-00	841-00	5156-00
4.	Virippu rice	3000-00	4440	-	5000	5440-00	2440-00	
	Mundakan rice	3185-00	3767	-	4951	4757-00	1572-00	
	Groundnut	2820-00	1882	-	-	4705-00	1885-00	5897-00
5.	Virippu rice	3000-00	4360	-	5240	5408-00	2408-00	
	Mundakan rice	3185-00	3485	-	4741	4433-00	1248-00	
	Punja(summer) rice	3000-00	3860	-	4185	4697-00	1697-00	5353-00

Table-70(b): Cost of cultivation and net profit per hectare of cropping patterns-1975-76

Cropping pattern	Crops	Cost of cultivation Rs. Ps.	Produce: Grain kg./ha.	Produce: Tuber kg./ha.	Produce: Straw/haulm/kg./ha.	Value Rs. Ps.	Net profit Rs. Ps.	Total profit per ha./year of cropping pattern Rs. Ps.
1.	Virippu rice	3000-00	3950	-	3409	4632-00	1632-00	
	Mundakan rice	3185-00	2472	-	3877	3247-00	62-00	
	Sweet potato	3555-00	-	10605	-	4242-00	687-00	2381-00
2.	Virippu rice	3000-00	4174	-	3803	4935-00	1935-00	
	Mundakan rice	3185-00	2725	-	4158	3557-00	372-00	
	Cowpea	2065-00	1176	-	-	2940-00	875-00	3182-00
3.	Virippu rice	3000-00	4000	-	3683	4737-00	1737-00	
	Mundakan rice	3185-00	2624	-	3436	3311-00	126-00	
	Sesamum	1984-00	540	-	-	2700-00	716-00	2579-00
4.	Virippu rice	3000-00	4140	-	3698	4880-00	1880-00	
	Mundakan rice	3185-00	2790	-	3974	3585-00	400-00	
	Groundnut	2820-00	2568	-	-	6420-00	3600-00	5880-00
5.	Virippu rice	3000-00	3792	-	3348	4462-00	1462-00	
	Mundakan rice	3185-00	2416	-	3317	3079-00	-106-00	
	Punja(summer) rice	3000-00	3191	-	3496	3890-00	890-00	2246-00

higher than any other crop. From the data it is clear that the highest investment was for groundnut cultivation while the sesamum cultivation required only the lowest investment.

Among the cropping patterns, the maximum expenditure was for rice-rice-sweet potato, the next being for rice-rice-rice. The lowest was for rice-rice-sesamum.

It is seen from the data that among the different cropping patterns tried, rice-rice-sweet potato showed the maximum production potentiality by yielding more than 300 quintals of produce during the first year and more than 240 quintals during the second year. However, the net income was highest from the cropping pattern rice-rice-groundnut during both the years being Rs. 5897/- during the first year and Rs. 5880/- during the second year. Although total production was highest in the cropping pattern rice-rice-sweet potato, this higher production was more than compensated by the higher price of groundnut pods as the price of groundnut was Rs. 2500/- per tonne while it was only Rs. 400/- for sweet potato. The next most profitable cropping pattern was rice-rice-sweet potato during the first year (Rs. 5463/- per hectare per year) and rice-rice-cowpea (Rs. 3182/- per hectare per year) during the second year. While the pattern rice-rice-rice stood third by yielding a net profit of

Rs. 5353/- during the first year it was rice-rice-sesamum during the second year by producing a net profit of Rs. 2579/-. The lowest net profit was obtained from rice-rice-cowpea during the first year and rice-rice-rice during the second year.

It may be mentioned in this connection that the net profit obtained during the first year cannot be taken in to consideration as the change of crops comes only in the last season ie. punja of first year and their effect will be seen only in the succeeding crops during the second year. Therefore the yield differences during the first year which in turn decide the net profit may be due to the differences in the inherent fertility status of soil rather than due to the treatment effects. From the yield data it can be seen that when there was heavy reduction in the yield of virippu and mundakan rice crops during the second year, the reduction was comparatively less in treatments in which the preceding crops were cowpea and groundnut. In the cropping pattern rice-rice-rice, there occurred even loss to the tune of Rs. 106/- per hectare during the mundakan rice season of the second year making the cropping pattern rice-rice-rice less remunerative.

Thus it is seen that the inclusion of groundnut crop in the rotation makes the cropping pattern most profitable while the continuous cropping of rice results in lowest net returns.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSIONS

The project entitled 'studies on the effect of multiple cropping on soil fertility and crop yields in wet land' was undertaken at the College of Agriculture, Vellayani, Trivandrum during the years 1974-76. Detailed investigations were undertaken both in the field and in the laboratory to determine the effect of five cropping patterns, viz, rice-rice-sweet potato, rice-rice-cowpea, rice-rice-sesamum, rice-rice-groundnut and rice-rice-rice, on the various physical and chemical properties of soil and yield of crops and finally to find out the most suitable and efficient cropping pattern.

A. FIELD EXPERIMENT

The object of the field experiment was to compare the growth and yield performance of the crops in the different cropping patterns.

1. Virippu rice.

In respect of the height of plants, the *virippu* rice in the treatment rice-rice-cowpea produced the tallest plants followed by rice-rice-groundnut during all stages of observation except at harvest during the second year. At harvest stage, rice-rice-groudnut recorded the maximum height during the second year. The *virippu* rice in the treatment rice-rice-rice produced the shortest plants.

The *virippu* rice in the treatment rice-rice-cowpea produced the maximum number of effective tillers during all the three years. The lowest number of effective tillers was produced by the treatment rice-rice-sweet potato during the first and third year and by the treatment rice-rice-rice during the second year.

2. *Mundakan rice*.

During the *mundakan* season maximum height was attained by the rice crop in the treatment rice-rice-groundnut during the first year. During the second year the treatment rice-rice-cowpea showed superiority in this respect. The treatment rice-rice-rice produced the shortest plants during both the years.

The rice plants in the treatment rice-rice-cowpea produced the maximum number of effective tillers during the *mundakan* season of first year. But during the second year the maximum number of effective tillers was observed in the treatment rice-rice-groundnut.

3. <u>Sweet potato</u>.

The length of main shoot as well as the number of branches of sweet potato crop in the treatment rice-rice-sweet potato was slightly higher during the first year than during the second year. The lesser duration of the crop during the second year might be the reason for the decrease in length of main shoot and number of branches during the second year.

4. <u>Cowpea</u>.

The cowpea plants in the treatment rice-rice-cowpea were slightly taller during the first year than in the second year. This difference may be due to the influence of climatic factors.

5. <u>Sesamum</u>.

The height of plants as well as the number of branches of sesamum crop in the treatment rice-rice-sesamum was higher during the first year as compared to that of the second year. The probable reason may be the shorter duration of crop during the second year.

6. <u>Groundnut</u>.

The groundnut plants in the treatment rice-rice-groundnut produced taller plants as well as higher number of branches during the first year than during the second year. This may be due to the shorter duration of crop during the second year.

7. Punja rice.

The height of punja (summer) rice plants in the treatment rice-rice-rice was higher during the first year than in the second year. As in the case of height of plants the percentage of productive tillers was also higher during the first year than in the second year.

8. Virippu rice yield.

Regarding the yield of virippu rice, the highest grain yield was obtained in the treatment rice-rice-sesamum during the first year. But during the second and third year the treatment rice-rice-cowpea produced the highest yield of virippu rice followed by rice-rice-groundnut treatment. This may be due to the effect of preceding cowpea and groundnut crops in increasing the fertility status of soil. The lowest yield was produced by the pattern rice-rice-rice during the second and third year. In all the treatments the grain yield of virippu rice declined progressively year after year.

As far as the yield per hectare per day was concerned, the treatments rice-rice-cowpea and rice-rice-groundnut produced the highest grain yield per hectare per day during the second and third year. The highest grain yield per hectare per day produced by the treatment rice-rice-sesamum during the first year may be due to the high initial fertility status of soil.

The highest straw yield was obtained from the virippu rice crop in the treatment rice-rice-cowpea and rice-rice-groundnut during the second and third year and the lowest straw yield was recorded by the treatment rice-rice-rice. The dry matter production was also highest from the virippu rice crop in the treatments rice-rice-cowpea and rice-rice-groundnut during the second and third year. The virippu rice crop in the treatment rice-rice-rice produced the lowest dry matter during the second and third year.

9. Mundakan rice yield.

During both the years the highest grain yield per hectare as well as per hectare per day of mundakan rice crop was obtained from the treatment rice-rice-groundnut.

The lowest yield per hectare as well as per day was produced by the treatment rice-rice-rice indicating the poor performance of rice when grown continuously in the same field. In mundakan season also the grain yield of rice declined progressively year after year in all the treatments.

As in the case of grain yield the treatment rice-rice-groundnut and rice-rice-cowpea produced the highest straw yield of mundakan rice during both the years. The straw yield also declined by continuous cultivation in all the treatments. The maximum dry matter production was obtained in the treatment rice-rice-sweet potato during the first year and in rice-rice-cowpea during the second year.

A comparison of the yield performance of virippu and mundakan rice showed that comparatively higher yields were obtained from virippu rice than from mundakan rice. The higher number of effective tillers produced by the virippu crop clearly illustrates the reason for higher grain yield. Among the three virippu seasons the yields of second and third year are much lower than the first year. The yields obtained during mundakan season were much lower and among mundakan crops, the yield of second year mundakan rice was much lower as compared to that of the first year.

10. Sweet potato yield.

Between the two years, the higher yield of sweet potato tubers in treatment rice-rice-sweet potato was obtained during the first year. This is because of the comparatively higher initial status of nitrogen in the soil.

11. Cowpea yield.

The grain yield of cowpea in treatment rice-rice-cowpea was higher during the second year than that of first year and this may be due to the higher fertility status especially of nitrogen during the second year.

12. Sesamum yield.

The grain yield of sesamum crop in the treatment rice-rice-sesamum was higher during the first year as compared to that of second year. This may be due to the higher status of soil nitrogen present prior to the cultivation of sesamum during the first year.

13. Groundnut yield.

The yield of groundnut pods in treatment rice-rice-groundnut was higher during the second year. The higher nitrogen status of soil prior to the groundnut crop during the second year resulted in better growth of the crop coupled with higher yield. During the first year, the crop was affected by 'Tikka' disease and hence the low yield.

14. Punja rice yield.

The grain as well as straw yield of punja rice in the cropping pattern rice-rice-rice was higher during the first year than the second year. Similar variation is seen in the case of per day production of grain also. This may be due to the fact that continuous cultivation of rice will lead to reduced growth and yield of crop. The dry matter production per hectare as well as per day was also higher during the first year as compared to that of second year.

B. SOIL FERTILITY CHANGES

The soil fertility changes in respect of bulk density, water stable aggregates, soil pH, cation exchange capacity, organic carbon, total soil nitrogen, carbon : nitrogen ratio, extractable phosphorus, exchangeable potassium, exchangeable calcium, exchangeable magnesium and exchangeable hydrogen were studied before and after every crop in a given cropping pattern. The results obtained are summarised in this section.

There was only small change in bulk density due to various cropping patterns. A slight decrease in bulk density was observed after sweet potato, cowpea and groundnut. In the treatment rice-rice-rice, there was increase in bulk density to the tune of 0.004 gm per cc during the first year and 0.002 gm per cc during the second year.

Continuous cultivation of rice (rice-rice-rice treatment) had deteriorating effect on soil structure. However, inclusion of sweet potato, cowpea, sesamum and groundnut in rotation improved the soil structure. Maximum improvement in aggregation was found after groundnut crop during both the years. It was found that soils where farm yard manure had been applied developed good soil structure as indicated by the higher percentage of water stable aggregates after sweet potato and sesamum.

There was decrease in soil pH in all cropping patterns after each cycle. It is seen that in all the treatments rice crop reduced the soil pH considerably. Maximum decrease in soil pH was observed in the continuous cropping of rice, the drop being 0.30 and 0.15 units respectively during the first and second year.

All the crops excepting sweet potato and sesamum reduced the cation exchange capacity of soil, the maximum reduction was observed in the continuous cropping of rice during both the years, the reduction being 0.288 m.e. per 100 gm of soil in the first year and 0.203 m.e. per 100 gm of soil during the second year. Among the different rice crops, maximum reduction was observed after the punja rice crop during both the years.

There was decrease in organic carbon content of soil after every crop of rice in all the treatments. Among the various punja season crops, sweet potato and sesamum crops increased the organic carbon status of soil during both the years. Cowpea and groundnut reduced the organic carbon content of soil during the first year while a slight increase was observed during the second year. The organic carbon content which was 1.616 per cent in the begining was reduced to 1.429 per cent after six successive crops of rice and maximum reduction was observed after punja rice during both the years.

The rice crops in all the treatments reduced the nitrogen content of soil during both the years. However, the total nitrogen content of soil increased after cowpea and groundnut crops. In the treatments rice-rice-sweet potato, rice-rice-sesamum and rice-rice-rice there was continuous reduction in the total nitrogen content of soil. The maximum decrease in total nitrogen content was observed in the treatment rice-rice-rice during both the years.

There was decrease in carbon : nitrogen ratio after virippu and mundakan rice in all the treatments during the first year. While cowpea and groundnut reduced the carbon : nitrogen ratio, sweet potato, sesamum and _punja_ rice crop increased it. During the second year there was a thorough change in the pattern of carbon : nitrogen ratio. The rate of increase in carbon : nitrogen ratio was high after sweet potato. While cowpea crop reduced the carbon : nitrogen ratio, groundnut slightly increased it. In the continuous cropping of rice, all the rice crops increased the carbon : nitrogen ratio irrespective of the seasons.

The extractable phosphorus content of soil increased after sweet potato, cowpea, sesamum and groundnut. However, the rate of increase was maximum after cowpea during both the years. There was reduction in the extractable phosphorus content of soil after _virippu_ and _mundakan_ rice crops during both the years. In the continuous cropping of rice treatment, the extractable phosphorus continued to decrease after every crop of rice up to the fifth crop, while there was a slight increase after the sixth crop of rice.

Exchangeable potassium status of soil increased after sweet potato, cowpea, sesamum and groundnut, whereas after the _virippu_ and _mundakan_ rice crops this was decreased. The maximum increase was brought about after cowpea crop during both the years. In the continuous cultivation of rice there was decrease in the exchangeable potash content of soil after every crop of rice during both the years except after the punja rice crop in the second year during which time there was slight increase in the exchangeable potash status.

The exchangeable calcium in the soil showed an increase after sweet potato, sesamum, and groundnut crops. In the continuous cultivation of rice there was continuous reduction of exchangeable calcium after every crop of rice. The pattern of reduction of exchangeable magnesium was very similar to that of exchangeable calcium.

All the crops irrespective of cropping patterns increased the exchangeable hydrogen status of soil. The rice crops in all the treatments increased the exchangeable hydrogen status of soil more than the other crops. In the treatment rice-rice-rice, there was progressive increase in the exchangeable hydrogen status of soil after every crop of rice and the maximum increase was observed after punja rice crop during both the years.

C. UPTAKE OF NITROGEN, PHOSPHORUS AND POTASH BY VARIOUS CROPS

Cowpea grains contained the highest percentage of nitrogen. Groundnut kernels, sesamum grains and groundnut haulms came next in sequence. The lowest nitrogen content was found in sweet potato tubers.

The highest percentage of phosphorus was found in sesamum grain followed by cowpea grains and groundnut kernels. The lowest phosphorus percentage was observed in groundnut shell.

The sweet potato vines contained the highest potash followed of sesamum haulms. The lowest potash content was recorded in mundakan rice grain.

So far as total removal or uptake of nitrogen was concerned, groundnut removed the maximum nitrogen, while the sesamum crop removed the minimum quantity of nitrogen.

Among the various cropping patterns rice-rice-groudnut removed the maximum quantity of nitrogen during both the years closely followed by rice-rice-sweet potato. The lowest recovery was from rice-rice-sesamum during both the years.

The sweet potato crop removed the maximum quantity of phosphorus from the soil. While the sesamum crop removed the lowest quantity. Among the cropping patterns, rice-rice-sweet potato removed the highest quantity of phosphorus. The lowest uptake was found in the treatment rice-rice-cowpea during the first year and in rice-rice-sesamum during the second year.

The sweet potato removed the maximum quantity of potash during both the years. The lowest removal was recorded from sesamum. Among the various cropping patterns, the highest quantity of potash was removed by the pattern rice-rice-sweet potato during both the years followed by rice-rice-rice pattern.

For the production of one tonne of dry matter maximum quantity of nitrogen was removed by cowpea crop during both the years. The next highest quantity was removed by grouhdnut. The most efficient crop regarding the utilization of nitrogen for dry matter production was rice especially _virippu_ rice followed by sweet potato.

Sesamum crop utilized the maximum quantity of phosphorus for the production of one tonne of dry matter. While groundnut crop removed the lowest during the first year and _mundakan_ rice removed the lowest quantity during the second year.

During both the years, sweet potato crop removed the maximum quantity of potash for dry matter production. However, groundnut crop removed the minimum quantity of potash during both the years.

The cropping pattern rice-rice-groundnut produced the maximum quantity of protein during both the years. The next highest protein yield was obtained from the pattern rice-rice-rice closely followed by rice-rice-cowpea during the first year. The lowest protein yield was obtained from the pattern rice-rice-sesamum during both the years. The pattern rice-rice-groundnut produced the highest quantity of protein yield per hectare per day also.

D. BALANCE SHEET OF PLANT NUTRIENTS

There was heavy loss of nitrogen in the cropping patterns rice-rice-rice, rice-rice-sesamum and rice-rice-sweet potato and the maximum loss was incurred in the cropping pattern rice-rice-rice during both the years. However, there was gain in nitrogen in patterns in which legume crops were included and maximum gain was obtained from the pattern rice-rice-groundnut during both the years.

The balance sheet of extractable phosphorus of soil showed a loss in all treatments. In general loss was low and the maximum loss was from the crop sequence rice-rice-sweet potato during both the years.

The balance sheet of exchangeable potash showed good gains in all the treatments during both the years. Maximum gain in exchangeable potash was observed in the pattern rice-rice-sweet potato while lowest gain was observed in rice-rice-sesamum, during both the years.

E. ECONOMICS

Among the individual crops the maximum cost of cultivation was for sweet potato, the next highest being *mundakan* rice. The lowest cost of cultivation was for sesamum.

As far as cropping patterns were concerned, the maximum expenditure was incurred for rice-rice-sweet potato. The lowest was for rice-rice-sesamum.

Comparing the different cropping patterns, the maximum net profit per hectare was obtained from rice-rice-groundnut during both the years. The next most profitable cropping pattern was rice-rice-sweet potato during the first year and rice-rice-cowpea during the second year.

The lowest net profit was obtained from rice-rice-cowpea during the first year and rice-rice-rice during the second year.

The present investigation has shown that among the different cropping patterns tried rice-rice-groundnut can be successfully followed for maximum profit with out deteriorating the soil fertility.

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* Original not seen.

APPENDICES

APPENDIX I a

Analysis of variance

Height of plant at harvest - Virippu rice 1974

Source	S.S.	df	M.S.	F
Total	239.839	24		
Block	51.010	4	12.7525	1.365
Treatment	39.310	4	9.8275	1.052 N.S.
Error	149.519	16	9.3449	

APPENDIX I b

Analysis of variance

Height of plant at harvest - Virippu rice 1975

Source	S.S.	df	M.S.	F
Total	111.57	24		
Block	27.58	4	6.8950	1.514
Treatment	11.13	4	2.7825	0.611 N.S.
Error	72.86	16	4.5537	

APPENDIX I c

Analysis of variance

Height of plant at harvest - Virippu rice 1976

Source	S.S.	df	M.S.	F
Total	61.784	24		
Block	9.727	4	2.4318	0.836
Treatment	5.521	4	1.3803	0.474 N.S.
Error	46.536	16	2.9098	

APPENDIX II a

Analysis of variance

Effective tillers - *Virippu* rice 1974

Source	S.S.	df	M.S.	F
Total	12.6530	24		
Block	1.2568	4	0.3142	2.950
Treatment	9.6918	4	2.4229	22.750 **
Error	1.7044	16	0.1065	

APPENDIX II b

Analysis of variance

Effective tillers - *Virippu* rice 1975

Source	S.S.	df	M.S.	F
Total	9.806	24		
Block	0.739	4	0.1848	0.334
Treatment	0.202	4	0.0505	0.091 N.S.
Error	8.865	16	0.5541	

APPENDIX II c

Analysis of variance

Effective tillers - *Virippu* rice 1976

Source	S.S.	df	M.S.	F
Total	13.142	24		
Block	3.898	4	0.9745	2.209
Treatment	2.179	4	0.5447	1.235 N.S.
Error	7.065	16	0.4412	

APPENDIX III a

Analysis of variance

Height of plant - Mundakan rice 1974-75

Source	S.S.	df	M.S.	F
Total	86.191	24		
Block	16.728	4	4.1820	1.187
Treatment	13.090	4	3.2725	0.929 N.S.
Error	56.373	16	3.5233	

APPENDIX III b

Analysis of variance

Height of plant - Mundakan rice 1975-76

Source	S.S.	df	M.S.	F
Total	149.869	24		
Block	17.803	4	4.4508	0.751
Treatment	37.248	4	9.3120	1.571 N.S.
Error	94.818	16	5.9261	

APPENDIX IV a

Analysis of variance

Effective tillers - Mundakan rice 1974-75

Source	S.S.	df	M.S.	E
Total	1.703	24		
Block	0.079	4	0.0198	0.222
Treatment	0.199	4	0.0497	0.558 N.S.
Error	1.425	16	0.0891	

APPENDIX IV b

Analysis of variance

Effective tillers - Mundakan rice 1975-76

Source	S.S.	df	M.S.	F
Total	8.762	24		
Block	1.611	4	0.4028	1.236
Treatment	1.938	4	0.4845	1.487 N.S.
Error	5.213	16	0.3258	

APPENDIX V a

Analysis of variance

Yield of grain - Virippu rice 1974

Source	S.S.	df	M.S.	F
Total	70.960	24		
Block	11.760	4	2.940	0.887
Treatment	6.160	4	1.540	0.465 N.S.
Error	53.040	16	3.315	

APPENDIX V b

Analysis of variance

Yield of grain - Virippu rice 1975

Source	S.S.	df	M.S.	F
Total	76.438	24		
Block	7.187	4	1.797	0.501
Treatment	11.877	4	2.969	0.828 N.S.
Error	57.374	16	3.586	

APPENDIX V c

Analysis of variance

Yield of grain - Virippu rice 1976

Source	S.S.	df	M.S.	F
Total	79.422	24		
Block	2.948	4	0.737	0.282
Treatment	34.650	4	8.663	3.314 *
Error	41.824	16	2.614	

APPENDIX VI a

Analysis of variance

Yield of straw - Virippu rice 1974

Source	S.S.	df	M.S.	F
Total	1341.040	24		
Block	337.440	4	84.360	1.651
Treatment	186.240	4	46.560	0.911 N.S.
Error	817.360	16	51.085	

APPENDIX VI b

Analysis of variance

Yield of straw - Virippu rice 1975

Source	S.S.	df	M.S.	F
Total	258.452	24		
Block	16.593	4	4.148	0.299
Treatment	19.656	4	4.914	0.354 N.S.
Error	222.203	16	13.888	

APPENDIX VI c

Analysis of variance

Yield of straw - *Virippu* rice 1976

Source	S.S.	df	M.S.	F
Total	242.100	24		
Block	36.020	4	9.005	1.525
Treatments	111.594	4	27.899	4.725 *
Error	94.486	16	5.905	

APPENDIX VII a

Analysis of variance

Straw : grain ratio - Virippu rice 1974

Source	S.S.	df	M.S.	F
Total	2.48	24		
Block	0.77	4	0.19	2.11
Treatment	0.28	4	0.07	0.78 N.S.
Error	1.43	16	0.09	

APPENDIX VII b

Analysis of variance

Straw : grain ratio - Virippu rice 1975

Source	S.S.	df	M.S.	F
Total	0.89836	24		
Block	0.03708	4	0.0093	0.177
Treatment	0.01976	4	0.0049	0.093 N.S.
Error	0.84152	16	0.0526	

APPENDIX VII c

Analysis of variance

Straw : grain ratio - Virippu rice 1976

Source	S.S.	df	M.S.	F
Total	0.651	24		
Block	0.125	4	0.031	1.550
Treatment	0.204	4	0.051	2.550 N.S.
Error	0.322	16	0.020	

APPENDIX VIII a

Analysis of variance

Yield of grain - Mundakan rice 1974-75

Source	S.S.	df	M.S.	F
Total	47.417	24		
Block	5.329	4	1.332	0.636
Treatment	8.562	4	2.141	1.022 N.S.
Error	33.526	16	2.095	

APPENDIX VIII b

Analysis of variance

Yield of grain - Mundakan rice 1975-76

Source	S.S.	df	M.S.	F
Total	42.157	24		
Block	9.752	4	2.438	1.989
Treatment	12.793	4	3.198	2.608 N.S.
Error	19.612	16	1.226	

APPENDIX IX a

Analysis of variance

Yield of straw - Mundakan rice 1974-75

Source	S.S.	df	M.S.	F
Total	122.334	24		
Block	5.844	4	1.461	0.271
Treatment	30.186	4	7.547	1.399 N.S.
Error	86.304	16	5.394	

APPENDIX IX b

Analysis of variance

Yield of straw - Mundakan rice 1975-76

Source	S.S.	df	M.S.	F
Total	271.201	24		
Block	19.764	4	4.941	0.424
Treatment	64.778	4	16.195	1.388 N.S.
Error	186.659	16	11.666	

APPENDIX X a

Analysis of variance

Straw : grain ratio - Mundakan rice 1974-75

Source	S.S.	df	M.S.	F
Total	0.592	24		
Block	0.011	4	0.003	0.107
Treatment	0.133	4	0.033	1.179 N.S.
Error	0.448	16	0.028	

APPENDIX X b

Analysis of variance

Straw : grain ratio - Mundakan rice 1975-76

Source	S.S.	df	M.S.	F
Total	1.848	24		
Block	0.334	4	0.084	1.063
Treatment	0.252	4	0.063	0.797 N.S.
Error	1.262	16	0.079	

APPENDIX XI a

Analysis of variance

Soil pH - after Virippu rice 1974

Source	S.S.	df	M.S.	E
Total	0.0026	24		
Block	0.0006	4	0.00015	1.667
Treatment	0.0006	4	0.00015	1.667 N.S.
Error	0.0014	16	0.00009	

APPENDIX XI b

Analysis of variance

Soil pH - after Virippu rice 1975

Source	S.S.	df	M.S.	F
Total	0.0170	24		
Block	0.0058	4	0.00145	2.685
Treatment	0.0026	4	0.00065	1.204 N.S.
Error	0.0086	16	0.00054	

APPENDIX XI c

Analysis of variance

Soil pH - after Mundakan rice 1974-75

Source	S.S.	df	M.S.	F
Total	0.02300	24		
Block	0.00036	4	0.00009	0.068
Treatment	0.00160	4	0.00040	0.303 N.S.
Error	0.02104	16	0.00132	

APPENDIX XI d

Analysis of variance

Soil pH - after Mundakan rice 1975-76

Source	S.S.	df	M.S.	F
Total	0.01420	24		
Block	0.00044	4	0.00011	0.145
Treatment	0.00160	4	0.00040	0.526 N.S.
Error	0.01216	16	0.00076	

APPENDIX XI e

Analysis of variance

Soil pH - after sweet potato, cowpea, sesamum, groundnut and Punja rice 1975

Source	S.S.	df	M.S.	F
Total	0.17420	24		
Block	0.00060	4	0.00015	0.600
Treatment	0.16960	4	0.04240	169.600 **
Error	0.00400	16	0.00025	

APPENDIX XI f

Analysis of variance

Soil pH - after sweet potato, cowpea, sesamum groundnut and Punja rice 1976

Source	S.S.	df	M.S.	F
Total	0.05560	24		
Block	0.00064	4	0.00016	0.593
Treatment	0.05060	4	0.01250	46.296 **
Error	0.00436	16	0.00027	

APPENDIX XII a

Analysis of variance

Cation exchange capacity - after Virippu rice 1974

Source	S.S.	df	M.S.	F
Total	0.00062	24		
Block	0.00017	4	0.00004	2.000
Treatment	0.00012	4	0.00003	1.500 N.S.
Error	0.00033	16	0.00002	

APPENDIX XII b

Analysis of variance

Cation exchange capacity - after Virippu rice 1975

Source	S.S.	df	M.S.	F
Total	0.00023	24		
Block	0.00008	4	0.0000200	3.20
Treatment	0.00005	4	0.0000125	2.02 N.S.
Error	0.00010	16	0.0000062	

APPENDIX XII c

Analysis of variance

Cation exchange capacity - after Mundakan rice 1974-75

Source	S.S.	df	M.S.	F
Total	0.00062	24		
Block	0.00006	4	0.00001	0.333
Treatment	0.00011	4	0.00003	1.000 N.S.
Error	0.00045	16	0.00003	

APPENDIX XII d

Analysis of variance

Cation exchange capacity - after Mundakan rice 1975-76

Source	S.S.	df	M.S.	F
Total	0.00039	24		
Block	0.00002	4	0.000005	0.250
Treatment	0.00005	4	0.000012	0.600 N.S.
Error	0.00032	16	0.000020	

APPENDIX XII e

Analysis of variance

Cation exchange capacity - after sweet potato, cowpea, sesamum, groundnut and Punja rice 1975

Source	S.S.	df	M.S.	F
Total	0.52163	24		
Block	0.00008	4	0.00002	0.009
Treatment	0.48606	4	0.12152	54.739 **
Error	0.03549	16	0.00222	

APPENDIX XII f

Analysis of variance

Cation exchange capacity - after sweet potato, cowpea, sesamum, groundnut and Punja rice 1976

Source	S.S.	df	M.S.	F
Total	0.24792	24		
Block	0.00004	4	0.00001	1.000
Treatment	0.24777	4	0.06194	6194.000 **
Error	0.00011	16	0.00001	

APPENDIX XIII a

Analysis of variance

Organic carbon - after Virippu rice 1974

Source	S.S.	df	M.S.	F
Total	0.01422	24		
Block	0.00007	4	0.00002	0.023
Treatment	0.00019	4	0.00005	0.057 N.S.
Error	0.01396	16	0.00087	

APPENDIX XIII b

Analysis of variance

Organic carbon - after Virippu rice 1975

Source	S.S.	df	M.S.	F
Total	0.006704	24		
Block	0.000762	4	0.00019	0.527
Treatment	0.000170	4	0.00004	0.111 N.S.
Error	0.005772	16	0.00036	

APPENDIX XIII c

Analysis of variance

Organic carbon - after Mundakan rice 1974-75

Source	S.S.	df	M.S.	F
Total	0.02288	24		
Block	0.00060	4	0.00015	0.130
Treatment	0.00382	4	0.00095	0.826 N.S.
Error	0.01846	16	0.00115	

APPENDIX XIII d

Analysis of variance

Organic carbon - after Mundakan rice 1975-76

Source	S.S.	df	M.S.	F
Total	0.00580	24		
Block	0.00111	4	0.00028	1.000
Treatment	0.00029	4	0.00007	0.250 N.S.
Error	0.00440	16	0.00028	

APPENDIX XIII e

Analysis of variance

Organic carbon - after sweet potato, cowpea, Sesamum, groundnut and Punja rice 1975

Source	S.S.	df	M.S.	F
Total	0.0705660	24		
Block	0.0000828	4	0.00002	0.500
Treatment	0.0698540	4	0.01746	436.500 **
Error	0.0006292	16	0.00004	

APPENDIX XIII f

Analysis of variance

Organic carbon - after sweet potato, cowpea, sesamum, groundnut and Punja rice 1976

Source	S.S.	df	M.S.	F
Total	0.069643	24		
Block	0.000060	4	0.000015	3.000
Treatment	0.069510	4	0.017377	3475.400 **
Error	0.000073	16	0.000005	

APPENDIX XIV a

Analysis of variance

Total soil nitrogen - after Virippu rice 1974

Source	S.S.	df	M.S.	F
Total	0.00002330	24		
Block	0.00000007	4	0.00000002	0.016
Treatment	0.00000276	4	0.00000069	0.539 N.S.
Error	0.00002047	16	0.00000128	

APPENDIX XIV b

Analysis of variance

Total soil nitrogen - after Virippu rice 1975

Source	S.S.	df	M.S.	F
Total	0.00006134	24		
Block	0.00000730	4	0.00000183	0.796
Treatment	0.00001726	4	0.00000432	1.878 N.S.
Error	0.00003678	16	0.00000230	

APPENDIX XIVcc

Analysis of variance

Total soil nitrogen - after *Mundakan* rice 1974-75

Source	S.S.	df	M.S.	F
Total	0.00004620	24		
Block	0.00000133	4	0.00000033	0.147
Treatment	0.00000904	4	0.00000226	1.009 N.S.
Error	0.00003583	16	0.00000224	

APPENDIX XIVdd

Analysis of variance

Total soil nitrogen - after *Mundakan* rice 1975-76

Source	S.S.	df	M.S.	F
Total	0.00005212	24		
Block	0.00000369	4	0.00000092	0.347
Treatment	0.00000596	4	0.00000149	0.562 N.S.
Error	0.00004247	16	0.00000265	

APPENDIX XIVee

Analysis of variance

Total soil nitrogen - after sweet potato, cowpea, sesamum, groundnut and *Punja* rice 1975

Source	S.S.	df	M.S.	F
Total	0.00055640	24		
Block	0.00000044	4	0.00000011	1.100
Treatment	0.00055436	4	0.00013859	1385.9 **
Error	0.00000160	16	0.00000010	

APPENDIX XIV f

Analysis of variance

Total soil nitrogen - after sweet potato, cowpea, sesamum, groundnut and Punja rice 1976

Source	S.S.	df	M.S.	F
Total	0.00034848	24		
Block	0.00000203	4	0.00000051	0.864
Treatment	0.00033694	4	0.00008424	142.780 **
Error	0.00000951	16	0.00000059	

APPENDIX XV a

Analysis of variance

Carbon : nitrogen ratio - after Virippu rice 1974

Source	S.S.	df	M.S.	F
Total	0.13513	24		
Block	00.00923	4	0.00231	0.318
Treatment	0.00983	4	0.00246	0.339 N.S.
Error	0.11607	16	0.00725	

APPENDIX XV b

Analysis of variance

Carbon : nitrogen ratio - after Virippu rice 1975

Source	S.S.	df	M.S.	F
Total	0.23011	24		
Block	0.00009	4	0.00002	0.066
Treatment	0.22460	4	0.05615	165.147 **
Error	00000542	16	0.00034	

APPENDIX XV c

Analysis of variance

Carbon : nitrogen ratio - after Mundakan rice 1974-75

Source	S.S.	df	M.S.	F
Total	0.48843	24		
Block	0.01578	4	0.00394	0.816
Treatment	0.39539	4	0.09885	20.466 **
Error	0.07726	16	0.00483	

APPENDIX XV d

Analysis of variance

Carbon : nitrogen ratio - after Mundakan rice 1975-76

Source	S.S.	df	M.S.	F
Total	0.18938	24		
Block	0.00021	4	0.00005	0.404
Treatment	0.18707	4	0.04677	359.769 **
Error	0.00210	16	0.00013	

APPENDIX XV e

Analysis of variance

Carbon : nitrogen ratio - after sweet potato, cowpea, sesamum, groundnut and Punja rice 1975

Source	S.S.	df	M.S.	F
Total	8.97652	24		
Block	0.00114	4	0.00028	0.483
Treatment	8.96609	4	2.24152	3864.690 **
Error	0.00929	16	0.00058	

APPENDIX XV f

Analysis of variance

Carbon : nitrogen ratio - after sweet potato, cowpea, sesamum, groundnut and *Punja* rice 1976

Source	S.S.	df	M.S.	F
Total	6.23027	24		
Block	0.00079	4	0.00019	0.792
Treatment	6.22567	4	1.55642	6485.083 **
Error	0.00381	16	0.00024	

APPENDIX XVI a

Analysis of variance

Extractable phosphorus - after *Virippu* rice 1974

Source	S.S.	df	M.S.	F
Total	101.0	24		
Block	8.8	4	2.2	0.449
Treatment	14.0	4	3.5	0.714 N.S.
Error	78.2	16	4.9	

APPENDIX XVI b

Analysis of variance

Extractable phosphorus - after *Virippu* rice 1975

Source	S.S.	df	M.S.	F
Total	212.0	24		
Block	2.8	4	0.70	0.060
Treatment	14.0	4	3.5	0.290 N.S.
Error	195.2	16	12.2	

APPENDIX XVI c
Analysis of variance

Extractable phosphorus - after Mundakan rice 1974-75

Source	S.S.	df	M.S.	F
Total	138.0	24		
Block	3.2	4	0.8	0.130
Treatment	34.0	4	8.5	1.349 N.S.
Error	100.8	16	6.3	

APPENDIX XVI d
Analysis of variance

Extractable phosphorus - after Mundakan rice 1975-76

Source	S.S.	df	M.S.	F
Total	186.0	24		
Block	3.6	4	0.9	0.091
Treatment	24.0	4	6.0	0.606 N.S.
Error	158.4	16	9.9	

APPENDIX XVI e
Analysis of variance

Extractable phosphorus - after sweet potato, cowpea, sesamum, groundnut and Punja rice 1975

Source	S.S.	df	M.S.	F
Total	398.0	24		
Block	6.8	4	1.7	0.607
Treatment	346.0	4	86.5	30.893 **
Error	45.2	16	2.8	

APPENDIX XVI f

Analysis of variance

Extractable phosphorus - after sweet potato, cowpea sesamum, groundnut and Punja rice 1976

Source	S.S.	df	M.S.	F
Total	368.0	24		
Block	3.6	4	0.900	0.045
Treatment	44.0	4	11.000	0.549 N.S.
Error	320.4	16	20.025	

APPENDIX XVII a

Analysis of variance

Exchangeable potash - after Virippu rice 1974

Source	S.S.	df	M.S.	F
Total	0.00010194	24		
Block	0.00000021	4	0.00000005	0.012
Treatment	0.00003464	4	0.00000866	2.067 N.S.
Error	0.00006709	16	0.00000419	

APPENDIX XVII b

Analysis of variance

Exchangeable potash - after Virippu rice 1975

Source	S.S.	df	M.S.	F
Total	0.00014298	24		
Block	0.00000145	4	0.00000036	0.047
Treatment	0.00001954	4	0.00000489	0.642 N.S.
Error	0.00012199	16	0.00000762	

APPENDIX XVII c

Analysis of variance

Exchangeable potash - after Mundakan rice 1974-75

Source	S.S.	df	M.S.	F
Total	0.00024978	24		
Block	0.00000544	4	0.00000136	0.096
Treatment	0.00001706	4	0.00000427	0.300 N.S.
Error	0.00022728	16	0.00001421	

APPENDIX XVII d

Analysis of variance

Exchangeable potash - after Mundakan rice 1975-76

Source	S.S.	df	M.S.	F
Total	0.00017956	24		
Block	0.00000027	4	0.00000007	0.006
Treatment	0.00000726	4	0.00000182	0.169 N.S.
Error	0.00017203	16	0.00001075	

APPENDIX XVII e

Analysis of variance

Exchangeable potash - after sweet potato, cowpea, sesamum, groundnut and Punja rice 1975

Source	S.S.	df	M.S.	F
Total	0.04355	24		
Block	0.00055	4	0.00014	0.791
Treatment	0.01470	4	0.00367	2.073 N.S.
Error	0.02830	16	0.00177	

APPENDIX XVII f

Analysis of variance

Exchangeable potash - after sweet potato, cowpea, sesamum, groundnut and Punja rice 1976

Source	S.S.	df	M.S.	F
Total	0.01149	24		
Block	0.00003	4	0.00001	0.333
Treatment	0.01097	4	0.00274	91.333 **
Error	0.00048	16	0.00003	

APPENDIX XVIII a

Analysis of variance

Exchangeable calcium - after Virippu rice 1974

Source	S.S.	df	M.S.	F
Total	0.04910	24		
Block	0.00060	4	0.00015	0.065
Treatment	0.01140	4	0.00285	1.228 N.S.
Error	0.03710	16	0.00232	

APPENDIX XVIII b

Analysis of variance

Exchangeable calcium - after Virippu rice 1975

Source	S.S.	df	M.S.	F
Total	0.06150	24		
Block	0.00052	4	0.00013	0.054
Treatment	0.02240	4	0.00560	2.324 N.S.
Error	0.03858	16	0.00241	

APPENDIX XVIII c

Analysis of variance

Exchangeable calcium - after *Mundakan* rice 1974-75

Source	S.S.	df	M.S.	F
Total	0.11620	24		
Block	0.00020	4	0.00005	0.007
Treatment	0.00500	4	0.00125	0.180 N.S.
Error	0.11100	16	0.00694	

APPENDIX XVIII d

Analysis of variance

Exchangeable calcium - after *Mundakan* rice 1975-76

Source	S.S.	df	M.S.	F
Total	0.06700	24		
Block	0.00148	4	0.00037	0.109
Treatment	0.01140	4	0.00285	0.843 N.S.
Error	0.05412	16	0.00338	

APPENDIX XVIII e

Analysis of variance

Exchangeable calcium - after sweet potato, cowpea, sesamum, groundnut and *Punja* rice 1975

Source	S.S.	df	M.S.	F
Total	0.60840	24		
Block	0.00716	4	0.00179	0.642
Treatment	0.55660	4	0.13915	49.874 **
Error	0.04464	16	0.00279	

APPENDIX XVIII f

Analysis of variance

Exchangeable calcium - after sweet potato, cowpea, sesamum, groundnut and Punja rice 1976

Source	S.S.	df	M.S.	F
Total	0.55160	24		
Block	0.01156	4	0.00289	1.562
Treatment	0.51040	4	0.12760	68.973 **
Error	0.02964	16	0.00185	

APPENDIX XIX a

Analysis of variance

Exchangeable magnesium - after Virippu rice 1974

Source	S.S.	df	M.S.	F
Total	0.00224	24		
Block	0.00001	4	0.0000025	0.022
Treatment	0.00039	4	0.0000975	0.848 N.S.
Error	0.00184	16	0.0001150	

APPENDIX XIX b

Analysis of variance

Exchangeable magnesium - after Virippu rice 1975

Source	S.S.	df	M.S.	F
Total	0.01028	24		
Block	0.00002	4	0.0000050	0.010
Treatment	0.00240	4	0.000600	1.222 N.S.
Error	0.00786	16	0.000491	

APPENDIX XIX c

Analysis of variance

Exchangeable magnesium - after Mundakan rice 1974-75

Source	S.S.	df	M.S.	F
Total	0.00296	24		
Block	0.00002	4	0.0000050	0.034
Treatment	0.00057	4	0.0001425	0.962 N.S.
Error	0.00237	16	0.0001481	

APPENDIX XIX d

Analysis of variance

Exchangeable magnesium - after Mundakan rice 1975-76

Source	S.S.	df	M.S.	F
Total	0.01248	24		
Block	0.00005	4	0.00001	0.015
Treatment	0.00149	4	0.00037	0.544 N.S.
Error	0.01094	16	0.00068	

APPENDIX XIX e

Analysis of variance

Exchangeable magnesium - after sweet potato, cowpea, sesamum, groundnut and Punja rice 1975

Source	S.S.	df	M.S.	F
Total	0.00460	24		
Block	0.00014	4	0.00003	0.500
Treatment	0.00350	4	0.00088	14.667 **
Error	0.00096	16	0.00006	

APPENDIX XIX f

Analysis of variance

Exchangeable magnesium - after sweet potato, cowpea, sesamum, groundnut and <u>Punja</u> rice 1976

Source	S.S.	df	M.S.	F
Total	0.02744	24		
Block	0.00113	4	0.00028	1.867
Treatment	0.02391	4	0.00598	39.867 **
Error	0.00240	16	0.00015	

APPENDIX XX a

Analysis of variance

Exchangeable hydrogen - after <u>Virippu</u> rice 1974

Source	S.S.	df	M.S.	F
Total	0.00131573	24		
Block	0.00000192	4	0.00000048	0.006
Treatment	0.00001876	4	0.00000469	0.058 N.S.
Error	0.00129505	16	0.00008094	

APPENDIX XX b

Analysis of variance

Exchangeable hydrogen - after <u>Virippu</u> rice 1975

Source	S.S.	df	M.S.	F
Total	0.002080	24		
Block	0.000001	4	0.00000025	0.002
Treatment	0.000259	4	0.00006475	0.569 N.S.
Error	0.001820	16	0.00011375	

APPENDIX XX c

Analysis of variance

Exchangeable hydrogen - after *Mundakan* rice 1974-75

Source	S.S.	df	M.S.	F
Total	0.00447450	24		
Block	0.00000129	4	0.00000032	0.001
Treatment	0.00003146	4	0.00000787	0.028 N.S.
Error	0.00444175	16	0.00027761	

APPENDIX XX d

Analysis of variance

Exchangeable hydrogen - after *Mundakan* rice 1975-76

Source	S.S.	df	M.S.	F
Total	0.00348076	24		
Block	0.00000235	4	0.00000059	0.003
Treatment	0.00002914	4	0.00000729	0.034 N.S.
Error	0.00344927	16	0.00021558	

APPENDIX XX e

Analysis of variance

Exchangeable hydrogen - after sweet potato, cowpea, sesamum, groundnut and *Punja* rice 1975

Source	S.S.	df	M.S.	F
Total	0.00820	24		
Block	0.00036	4	0.00009	0.818
Treatment	0.00605	4	0.00151	13.727 **
Error	0.00179	16	0.00011	

APPENDIX XX f

Analysis of variance

Exchangeable hydrogen - after sweet potato, cowpea, sesamum, groundnut and Punja rice 1976

Source	S.S.	df	M.S.	F
Total	0.00570506	24		
Block	0.00017149	4	0.00004287	1.112
Treatment	0.00491670	4	0.00122918	31.885 **
Error	0.00061687	16	0.00003855	

N.S. - Not significant

** - Significant at 1% level

* - Significant at 5% level

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STUDIES ON THE EFFECT OF MULTIPLE CROPPING ON SOIL FERTILITY AND CROP YIELDS IN WET LAND

By

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ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

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ABSTRACT

The problem entitled "Studies on the effect of multiple cropping on soil fertility and crop yields in wet land" was conducted at the College of Agriculture, Vellayani, Trivandrum during the years 1974-76 to assess the effect of five cropping patterns, viz, rice-rice-sweet potato, rice-rice-cowpea, rice-rice-sesamum, rice-rice-groundnut and rice-rice-rice on the various physical and chemical properties of soil and yield of crops and finally to find out the most suitable and efficient cropping pattern.

The study revealed that rice-rice-groundnut was the most efficient and suitable cropping pattern for the wet land. The maximum yield per hectare as well as per day was recorded by sweet potato and the minimum by sesamum. While the maximum annual yield was recorded by the cropping pattern rice-rice-sweet potato, the minimum was from the cropping pattern rice-rice-sesamum during both the years.

The dry matter production per hectare per year from individual cropping patterns was maximum in rice-rice-sweet potato and minimum in rice-rice-cowpea during the first year and the corresponding rotations were rice-rice-groundnut and rice-rice-sesamum during the second year.

The maximum economic returns were obtained from the cropping pattern rice-rice-groundnut during both the years. While the minimum economic returns were obtained from the cropping pattern rice-rice-cowpea during the first year it was from rice-rice-rice during the second year.

Soil fertility studies showed that cropping pattern rice-rice-sweet potato resulted in decrease in bulk density, pH and total nitrogen and increase in water stable aggregates, cation exchange capacity, organic carbon, C : N ratio, extractable phosphorus, exchangeable potash, exchangeable calcium, exchangeable magnesium, and exchangeable hydrogen. The cropping pattern rice-rice-cowpea resulted in decrease in bulk density, pH, cation exchange capacity, organic carbon, C : N ratio, exchangeable calcium and exchangeable magnesium and increase in water stable aggregates, total nitrogen, extractable phosphorus, exchangeable potash and exchangeable hydrogen. While there was decrease in bulk density, pH and total nitrogen there was increase in cation exchange capacity, organic carbon, C : N ratio, extractable phosphorus, exchangeable potash, exchangeable calcium, exchangeable magnesium and exchangeable hydrogen in the cropping pattern rice-rice-sesamum. The rice-rice-groundnut cropping pattern resulted in decrease in bulk density, pH, cation exchange capacity, organic carbon, C : N ratio and increase in water stable aggregates, total nitrogen, extractable phosphorus, exchangeable potash, exchangeable calcium, exchangeable magnesium and exchangeable hydrogen. However, cropping pattern rice-rice-rice resulted in increase in bulk density, C : N ratio, exchangeable hydrogen and decrease in water stable aggregates, pH, cation exchange capacity, organic carbon, total nitrogen, extractable phosphorus, exchangeable potash, exchangeable calcium and exchangeable magnesium.

While _virippu_ rice was most efficient in utilizing nitrogen for dry matter production, cowpea was least efficient in this regard. The groundnut crop showed maximum efficiency in the utilization of phosphorus and potash for dry matter production. While sesamum was least efficient in the case of phosphorus it was sweet potato in the case of potash.

The highest and the lowest protein yields were obtained during first and second years from the cropping pattern rice-rice-groundnut and rice-rice-sesamum respectively.

The balance sheet of plant nutrients showed heavy loss of nitrogen in the cropping patterns rice-rice-rice, rice-rice-sesamum and rice-rice-sweet potato. However, there was gain in nitrogen in the cropping patterns rice-rice-cowpea and rice-rice-groundnut. While extractable phosphorus of soil showed a loss in all the treatments, there was good gains in exchangeable potash in all the treatments during both the years.