PRODUCTIVITY OF SEMI - DRY RICE UNDER SIMULTANEOUS *IN SITU* GREEN MANURING

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled "**Productivity of semi-dry rice under simultaneous *in situ* green manuring**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that the thesis entitled "**Productivity of semi-dry rice under simultaneous *in situ* green manuring**" is a record of research work done independently by **Mr.Musthafa Kunnathadi** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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(Qur'ān, 60:4)

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MUSTHAFA KUNNATHADI

Dedicated to My Loving Parents

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Introduction

INTRODUCTION

Semi-dry system of rice cultivation is a unique and extensively adopted practice, during the first crop season, in the unirrigated double crop lands of Kerala. In this system, the early growth of rice, upto 30-40 days, is in a dry soil environment depending on summer showers and only with the onset of monsoon, in June, it becomes a wet crop. The specific advantage of the system is that it helps to start the cropping so early that the first two crops will be completed at an earlier date.

However, this unique system has its own peculiar associated problems that ultimately limit the realisation of a high yield. Any organic residue built up till the previous cropping will be lost (Anilakumar and Sivakumar, 1994) due to exposure of barren land to rainless summer. Effective incorporation of green manures or other organic resources before cropping is difficult due to scarcity of moisture. Under such a dry spell, during the early growth phase, the possibility for the use of fertilizer nitrogen is beyond the scope. Experimental evidences have shown that fertilizer responsiveness of rice beyond 35-40 kg N ha^{-1} shall be obtained only under integrated nutrient management. Thus, finding out a practicable way for generating organic manure and its effective incorporation at the right time is of paramount importance in the semi-dry system.

Further, the dry soil environment with occasional summer showers leads to profuse weed growth in the early phase of the crop which limits the yield expression to as low as 25-30 per cent (Bridgit *et al.*, 1992). Although effective, mechanical weed control is a costly operation in semi-dry rice. Therefore, any programme aiming at productivity imporvement of semi-dry rice should give due consideration to the added benefit of weed control.

Yet another basic problem faced in the laterites is the excess iron in the soil and plant system. Excess iron absorbed by rice limits productivity expression, particularly of high yielding varieties (Bridgit *et al.*, 1992). Thus the system improvement measures should also take in to account the possibility of reducing the influence of excess iron.

Preliminary investigations by Mathew *et al.* (1991) indicated the possibility of *in situ* intercropping of green manure crops with semi-dry rice. Bridgit *et al.* (1993) found that the system is effective to check the weed growth, improve nutrient availability and hence increased yield. However, no information is available regarding the optimum fertilizer requirement of the system, seed rate of green manure crop as well as the interaction effects of green manure crop on rice and weeds. To fill these lacunae the present experiment was undertaken with the following broad objectives:

1) To study the viability and efficacy of simultaneous *in situ* green manuring in providing organic manure and increasing the productivity of rice,
2) to study the pattern and extent of weed control in the system and
3) to study the role, if any, of the system in limiting the influence of excess iron in the soil and plant system.

Plate 1. Simultaneous *in situ* green manuring - a general view

Review of Literature

REVIEW OF LITERATURE

Extensive use of chemical fertilizers has immediate benefits. But this initial advantage has been lost gradually and the productivity has become stagnant. Inclusion of organics in the management programme is the only alternative, of which green manures either raised early or concurrently will be the cheapest. Research results available on the effects of green manuring, feasibility of concurrent raising of green manures as well as their effects with fertilizers on the productivity of rice have been briefly reviewed.

1 Green manuring and rice productivity

Productivity improvement in rice due to green manuring has been established beyond doubt by several workers. Overall yield improvement due to green manuring has been variously estimated as 2.2 t ha^{-1} (Singh *et al.*, 1987; Kolar and Grewal, 1988), 2 t ha^{-1} (Morris *et al.*, 1986; Sharma and Mittra, 1988), 1.5 t ha^{-1} (Becker and Ottow, 1991) and from 5.6-6.4 to 7.2-7.9 t ha^{-1} (Singh *et al.*, 1991).

Alazard and Becker (1987) found that extent of yield increase due to green manuring depends on the season and this will be low in rainy season. They found that green manuring increased the yield by 2.2 to 3.7 t ha^{-1} in dry season whereas the increase was only 1.3 to 1.9 t ha^{-1} in rainy season. According to Relwani and Ganguly (1959) yield improvement is due to an invigorated growth of rice expressed through increased height and tillers whereas Rathore *et al.* (1993) attributed the yield increase specifically to improvement in panicle characteristics viz., panicle length, grains/panicle and seed weight. Mathew *et al.* (1991) and

Bridgit *et al.* (1994) investigated the possibility of raising simultaneous green manure crop with rice in the semi-dry rice culture and found that the system will increase the yield by 5 q ha^{-1}.

2 Effects of green manuring

Increased biomass and nitrogen addition, reducing the loss of nutrients, improving the soil properties, increasing the availability of nutrients, a more balanced nutrition, higher nutrient use efficiency and weed control are the direct beneficial effects attributed to green manuring.

2.1 Green manuring and biomass addition

Biomass addition and its nitrogen equivalent by way of fixation depend upon crop, duration, season, etc.

Singh *et al.* (1982) comparing the different sources of green manure found that cowpea [*Vigna unguiculata* (L.) Walp.] was better as it accumulated more dry matter and nitrogen than sesbania (*S. aculeata*) and cluster bean (*Cyamopsis tetragonoloba*). Investigating on the adaptability of different green manure crops for rice culture Singh *et al.* (1988a) found that cowpea and sunnhemp (*Crotolaria juncea*) were the most efficient sources followed by sesbania and mung bean (*Vigna radiata*). Mathew *et al.* (1991) compared the different sources for dual culture in rice at Regional Agricultural Research Station (RARS), Pattambi and found that *S. aculeata* will not suit the system. Bridgit *et al.* (1994) compared the performance of cowpea and sunnhemp and found that cowpea has a distinct edge over sunnhemp as it produces 80 per cent more green matter in unit time.

Rathore *et al.* (1993) tested the suitability of different green manures and found that *Ipomoea carnea, Cassia tora* and *Parthenium hysterophorus* are good sources of green manures.

Morris *et al.* (1986) attributed the variability among different green manures to the rapidity in growth and nitrogen accumulation. Investigations by them have showed that mung bean and cowpea accumulate 44 to 83 kg N ha^{-1} in 30 to 45 days growth and are equally good in rice culture. Maskina *et al.* (1989) compared the above ground dry matter and N accumulation of cowpea, sesbania and sunnhemp and found that in 50 days they accumulated 3.8, 4.9 and 5.3 tonnes of dry matter and 76, 97 and 101 kg N ha^{-1}, respectively. They also found that efficacy of green manures does not exclusively depend upon dry matter and N accumulation. Inspite of a lower dry matter production and N content cowpea was as good as others in influencing the productivity.

Cowpea root has been reported to release its nitrogen content approximately 1.09 fold more than the above ground portion inspite of comparable C/N ratios of 14.1 and 15.9 and the effectiveness of cowpea as green manure has been attributed to this unique quality (Frankenberger and Abdelmagid, 1985). Das and Rao (1986) stated that N fixed in the soil and that contained in the root mass are of importance in influencing the crop performance. Rebancos *et al.* (1988), however, were of the view that incorporation of shoot and root together is conducive for higher yields.

Season has a profound influence on the efficacy of green manure sources. Harron *et al.* (1992) found *Crotolaria juncea* as the best green manure crop for rice grown during June-September while *Sesbania aculeata* was better for rice grown during October-February. Alazard and Becker (1987) found that this difference in the efficacy of green manure crops depending on season will be reflected in rice productivity also. John *et al.* (1989) found that N equivalent of cowpea green manure is subject to seasonal influence and varied between 34 to 54 kg N ha^{-1} in their two years of study.

Bhardwaj and Dev (1985) correlated the green matter production potential and N accumulation with crop growth duration and found that *Sesbania cannabina* produces 18, 28 and 37 tonnes of green matter per hectare and accumulates 98, 147 and 165 kg N ha^{-1} respectively at 45, 55 and 65 days of growth. Kulkarni and Pandey (1988) found that short duration legumes such as mung bean, cowpea and black gram will contribute 25 to 60 kg N ha^{-1}.

Nitrogen fixation and accumulation by green manure crops have been subject to detailed investigation. Nitrogen fixation has been reported to range from 10-40 kg ha^{-1} in pigeon pea [*Cajanus cajan* (L.) Millsp.] (Narain *et al.*, 1980) to 165 kg ha^{-1} in *Sesbania cannabina* (Bhardwaj and Dev, 1985). Rebancos *et al.* (1988) estimated the nitrogen incorporation by pigeon pea as 55 kg ha^{-1}. *Sesbania aculeata* has been reported to produce yield equivalent to 120 kg N ha^{-1} (Singh *et al.*, 1988b). However, Sharma and Mittra (1988) were of the view that plants like *Crotolaria juncea* and *S. aculeata* add 45-60 kg N ha^{-1}.

Ventura *et al.* (1987) reported that *Sesbania rostrata*, a stem nodulating hydrophyllic legume will add 42 kg N ha^{-1}, almost 12 kg N more than *Azolla microphylla*.

2.2 Green manuring and nutrient content of plant

Contradictory views on plant nutrient content under green manuring and its effect on yield are available. Alazard and Becker (1987) and Rekhi and Bajwa (1993) estimated the yield increase due to a higher N content in the plant as shown by the analysis of grain and straw. Swarup (1987) found that not only the N content of the plant is improved but the uptake of N, P, Ca, Mg, Fe, S, Mn and Zn also is improved through green manuring. Swarup (1987) and George and Prasad (1989) reported that rice plant may remove only a smaller quantity of potassium. Balasubramaniyan *et al.* (1991) however could not record any yield improvement inspite of an increase in N, P and K content of the plant.

Though it is established that there is an increase in N content of plant, the comparative efficacy of green manure nitrogen and urea nitrogen in their entry in to the plant is disputed. While Diekmann *et al.* (1991) were of the view that more than 90 per cent of green manure N found entry in to the plant, Patil and Sarkar (1991) found more of urea N entered the plant.

2.3 Green manuring on soil properties and soil fertility

Green manuring, apart from fixing nitrogen and making it available to the successor crop, is known to influence crop growth in other ways also. One of the early reported effects is Lohins' (1926) priming action which stated that addition of easily decomposable organic matter will lead to decomposition of native organic matter also thus liberating more nutrients for crop growth. Broadbent and Norman (1946), Chapman and Liebig (1947) and Furoc and Morris (1982) have confirmed this. The increased P, K and trace elements due to green manuring have been attributed to the solubilising effect of decomposing organic matter (Lockett, 1938; Copeland and Merkle, 1941; Shrikhande, 1948). Effects of green manuring on increased K availability (Kute and Mann, 1969; Debnath and Hajra, 1972) and higher P content in soil solution (Nagarajah *et al.*, 1986) have been attributed to the combined effect of green manure (Nagarajah *et al.*, 1986) as well as the release of CO_2 and weak acids which can act on insoluble minerals (Rogers and Giddens, 1957; Agboola, 1974). Tiwari *et al.* (1980) found increased NPK content of soil through green manuring.

Ladha *et al.* (1989) reported that green manuring minimised the loss of nitrogen in flooded situation and made available 80 per cent of the N to the two succeeding crops. The loss minimisation effect has been attributed to a reduction in pH of the flood water (Diekmann *et al.*, 1993).

The other beneficial effects of green manuring had been the changes in pH and E^h of the soil. Khind *et al.* (1987) reported that green manuring helped to achieve a near neutral pH in acidic non calcareous soils. This effect, similar to that of soil submergence, though temporary, was responsible for the beneficial effect of liming. Katyal (1977) noted a significant reduction in E^h of water logged soil due to green manuring. Similar results have also been reported by Thind and Chahal (1983), Sadana and Bajwa (1985) and Khind *et al.* (1987).

Green manuring also helps to improve soil productivity through modifying the natural trends in soil degradation in wet land rice culture. Boparai *et al.* (1992) found that wet land rice culture caused a break down of soil structure and decreased the infiltration rate through formation of a compact layer at a depth of 5-

20 cm. Green manuring was found to effectively correct this soil degradation. They further found that green manuring increased the water stable aggregates of 0.1 to 0.5 mm dimension by 62 per cent and reduced the bulk density. Green manuring also increased the infiltration rate by breaking the compact layer between 5-20 cm below the surface. These favourable changes could be noticed through a higher root density and grain yield in the subsequent wheat crop. Improving the water stable aggregates as well as their stability has also been reported by Morey (1976). A better aggregation and better aggregate stability led to an increased porosity and hydraulic conductivity, reduced bulk density and improved water holding capacity (Darra *et al.*, 1968; Biswas *et al.*, 1970; Havanagi and Mann, 1970; Jiao *et al.*, 1986; Liu, 1988; Singh *et al.*, 1980).

Agboola (1974) has reported that green manure crops because of their deep penetrating root system will absorb nutrients from lower layers of the soil and enrich the top soil on decomposition to benefit the crops. He attributed the beneficial effects of green manures to this recycling effect.

Yet another way of influencing by green manuring is through the release of CO_2 during decomposition. Katyal (1977) and subsequently Sadana and Bajwa (1985) have reported enhanced release of CO_2 from soils amended with green manures. Shivashankar and Vlassak (1978) observed a direct relationship of this availability of CO_2 to photosynthetic process and yield of rice.

Green manuring is not without ill effects also. Ishikawa (1988) observed accumulation of organic acids in significant amounts at the time of decomposition of green manures which can restrict root elongation as well as nutrient uptake and reduce shoot weight (Watanabe, 1984). Diekmann *et al.* (1992) found that the release of phenolic substances during decomposition is also likely to retard the growth of main crop.

3 Effects of concurrent raising of green manures

John *et al.* (1992) cited loss of a season without food or cash value as the main reason for the reluctance of farmers to grow and incorporate green manures. But experimental evidences indicated that beneficial effects of green manures shall be obtained by concurrent cropping and incorporation of azolla. Venkataraman (1980); Ventura and Watanabe (1993), Mathewkutty (1982) and Alexander *et al.* (1988) have produced evidence to show that nitrogen fixed by azolla in concurrent cropping benefits rice crop. Mathew *et al.* (1991) compared the efficacy of different green manure crops for concurrent cropping and found that cowpea is the best from the point of view of rice yield. Bridgit *et al.* (1994) had recorded a yield increase of the tune of 500 kg ha^{-1} by concurrent cropping of cowpea.

Experiments at RARS, Pattambi (Anon, 1991) on the nitrogen release pattern from glyricidia (*Glyricidia maculata*) leaves has indicated that it is as fast as that from ammonium sulphate and is immediate.

Swarup (1988) found that substantial N content in green manure is released within a decomposition period of one week. Kundu *et al.* (1991) compared the agronomic efficiencies of urea and green manures and found that they did not differ. Diekmann *et al.* (1991) found that peak period of mineralisation from green manures is within 10 days of incorporation. Though several authors have cast doubt on the efficacy of nitrogen fixation by legumes in such a system (Smith *et al.*, 1987; Terman, 1979; Lathwell *et al.*, 1989), Wade and Sanches (1983) were categorical that positive effects on weed suppression will positively balance against N losses by volatilisation. Lal (1975) found maximum benefit of such a practice on improved physical properties of the soil.

Rice (1984) has reported that a canopy that covers the soil throughout will minimise the necessity of weed control. Thakur (1993) found a reduction in weed growth to the extent of 35-40 per cent due to intercropping. Shethy and Rao (1981) attributed the reduction in weed population to the smothering effect of inter-crop.

Weerakoon *et al.* (1992) found that weed control effect of sesbania is a function of density of intercrop - higher density will diminish weed biomass - and in inverse proportion with increase in biomass of intercrop. Troublesome weeds like *Isachne globosa* (Thunb) and *Cyperus rotundus* L. will be affected. Singh *et al.* (1993) however have cautioned against increase in the population of intercrop. Inter-cropping rice with pigeonpea, they found that grain yield of rice was maximum when 4:1 row ratio between rice and pigeonpea was used and this fell to the minimum when the ratio was increased to 2:1. Bridgit *et al.* (1994) have also observed a significant reduction in weed biomass through concurrent cropping of cowpea for green manure in semi-dry rice.

Chandra *et al.* (1992) failed to subscribe to this view. They found that weeds tended to increase with intercropping pigeonpea and the larger cumulative population led to a higher incidence of sheath blight through increased relative humidity. Thakur (1993) found that intercropping is conducive to a reduction of shoot borers and he attributed this to a physical and/or biological interference in line with the observations of Lawani (1982) and Natarajan *et al.* (1991).

4 Integrated Nutrient Management

Intensive rice cultivation with the use of high yielding varieties and an over dependence on chemical fertilizers which characterised the early phase of green revolution showed that exclusive use of fertilizers cannot sustain the productivity of rice lands. Prasad and Datta (1979) attributed this to the fact that the efficiency of applied chemical nitrogen never exceeds 50 per cent even with the best agronomic management. The low efficiency of chemical N has been due to the inevitable losses through one or more means like volatilization, denitrification, leaching, immobilization etc. Datta (1981) further suggested integrated nutrient management as the means for high current and sustained yields. Mahapatra *et al.* (1987) opined that either an integrated approach or a complete substitution of chemical N with biological sources is the only alternative for sustained productivity. Singh *et al.* (1991) were of the opinion that judicious combination of organic and inorganic sources of N can bring about the desired objective. Becker *et al.* (1991) demonstrated that manuring of rice with pre-grown green manures fertilized with NPK is effective in ensuring fertility and current crop yield.

Singh and Singh (1989) compared the efficacy of different bioorganic sources like blue green algae, azolla, green manures, etc. and found that they increase the yield of grain and straw through an enhanced recovery of nitrogen which contributes to higher number of tillers and better growth. Panda *et al.* (1994) found that integrated manuring increased the yield through an improvement of productive tillers, while Azam and Yousaf (1991) reported it due to a qualitative improvement of seedlings because of higher N and Zn contents.

Integrated nutrient management has been found to result in response of rice to higher levels of applied nitrogen as well as higher nitrogen use efficiency.

Singh *et al.* (1987), Anil *et al.* (1988), Goswamy *et al.* (1988) and Das and Datta (1992) reported that incorporation of green manures raised the upper limit of rice response to 120 kg chemical nitrogen per hectare. Hati (1987), Rakotonaivo and Schramm (1988), Rabindra *et al.* (1989) and Rathore *et al.* (1993) have also obtained response to higher levels of nitrogen in the presence of green manures. This enhanced expression of response has been attributed to a higher effective availability and better utilization of chemical nitrogen (Chatterjee *et al.*, 1979) due to the limiting influence of green manures on loss of nitrogen by leaching (Russel, 1975) and volatilization (Santra *et al.*, 1988). The rate limiting influence of green manures on volatilization loss of N according to Chakravorti *et al.* (1989) was dependent on the level of application of chemical nitrogen. They found that the efficacy of green manures decreases with increase in chemical nitrogen beyond 40 kg ha^{-1} level and beyond this level volatilization loss will increase.

Increase in the extent of nitrogen use efficiency (NUE) due to integrated management has been variously expressed by various authors. Ahmed and Miah (1988) from Philippines found that a 50 per cent increase in NUE could be obtained by incorporation of green manures. Rathore *et al.* (1993) showed an increase of 33 per cent while Maskina *et al.* (1985) and Panda *et al.* (1994) reported it as high as 200 per cent. Panda *et al.* (1994) have further stated that integrated manuring also increases both uptake and apparent recovery by 36 per cent.

Sharma and Mittra (1989) observed that NUE in integrated management varies with the sources of organic manures. Use of azolla and sesbania resulted in a NUE of 50 per cent while farm yard manure, compost and *Cicer arietinum* registered only 20-25 per cent.

Nitrogen use efficiency is also dependent on the level of nitrogen applied. Anil *et al.* (1988) found that integrated nitrogen management is useful to increase NUE only at higher levels of N when the efficiency shall be even doubled. Chakravorti and Chalam (1992) fixed the optimum ratio of organic and inorganic nitrogen at 1:1 for maximum NUE.

Benefits of integrated manuring is not confined to that of N alone.

Arunachalam (1959), Ramankutty and Padmaja (1972) and Thakur (1991) have reported that integrated manuring facilitates phosphorus nutrition. Application of P through green manure leads to rice response to P upto 90 kg ha^{-1} in the experiments of Arunachalam (1959). Ramankutty and Padmaja (1972) and Thakur (1991) could get rice response to P only when it was applied through green manures.

Waksman as early as 1938 reported that decomposition products of organic matter will solubilise the P of rockphosphate and make it available. But Gerresten (1948) attributed this to direct microbial action. Detailed investigations of Stevenson (1982) showed that combined use of manures and fertilizers influences the form and extent of available P through the combined action of organic acids and products of microbial decomposition by interacting the P binding cations and clay minerals. Ramamoorthy *et al.* (1971) observed that when biogas slurry was incorporated it formed a coating around single super phosphate granules which in turn retarded the dissolution and consequent fixation.

Anilakumar *et al.* (1992) found that integrated management is necessary for getting rice response in laterite soils beyond 40-45 kg N ha^{-1}. They found that the yield improvement is brought about by the twin effects of increased dry matter production as well as shift in partitioning coefficient.

Materials and Methods

MATERIALS AND METHODS

An investigation aimed to study the influence of simultaneous *in situ* green manuring on the growth, development and productivity of semi-dry rice was carried out during the virippu season (May-September) of 1993.

1 Site, soil and climate

The field experiment was conducted at Agricultural Research Station, Mannuthy under the Kerala Agricultural University. The Research Station is located geographically at 12° 32' N latitude and 74° E longitude and at an elevation of 22 m above mean sea level. The experimental area was a double crop wet land where a semi-dry crop during April-May to August-September and a wet crop during September-October to December-January were conventionally practised. This is the typical pattern of rice culture in most part of the state.

The soil of the experimental area belongs to the order 'Oxisols' to which 58 per cent of rice area of the state belongs. These soils are low to medium in fertility. The soil was sandy clay loam in texture and acidic in reaction with a pH of 5.6. The physico-chemical properties of the soil before the commencement of experiment are given in Table 1. The soil was low in organic carbon, medium in available potassium and high in available phosphorus and iron.

The area enjoys a tropical monsoon climate with more than 80 per cent of the rainfall getting distributed through South-West and North-East monsoon showers. The normal weather of the area and the weather which prevailed during the

Table 1. Physico-chemical properties of the soil

Particulars	Value	Method employed
A. Mechanical composition		
Coarse sand	27.2%	Robinson's International Pipette method (Piper, 1966)
Fine sand	23.8%	
Silt	22.6%	
Clay	26.4%	
Bulk density	1.52 g cc^{-1}	Core sampler method (Piper, 1966)
B. Chemical composition		
Organic C	0.579%	Walkley and Black method (Soil Survey Staff, 1992)
Total N	0.084%	Semi-microkjeldahl method (Soil Survey Staff, 1992)
Available N	279.30 kg ha^{-1}	Alkaline permanganate distillation (Subbiah and Asija, 1956)
Available P	79.79 kg ha^{-1}	Bray-I extractant - Ascorbic acid reductant method (Soil Survey Staff, 1992)
Available K	112.00 kg ha^{-1}	Neutral normal ammonium acetate extractant flame photometry (Jackson, 1973)
Available Fe	58.52 kg ha^{-1}	Orthophenanthroline method using Spectrophotometer (Olson, 1948)
pH	5.6	1:2.5 soil:water suspension using pH meter (Jackson, 1973)
Electrical conductivity	1.25 dS m^{-1}	Supernatent of 1:2.5 soil:water suspension using EC bridge (Jackson, 1973)

experimental period are presented in Appendix I and Appendix II and illustrated in Fig.1 and Fig.2, respectively. The mean annual rainfall of the area is 2669 mm with 75 per cent received during South-West monsoon, 16.6 per cent during North-East monsoon and rest being distributed in the summer months. The mean monthly maximum and minimum temperatures of the area during virippu season are 34.2°C (May) and 23°C (July) while the mean weekly maximum and minimum temperatures recorded during the cropping period were 34.5°C (May) and 22.6°C (July), respectively. The relative humidity of the area during virippu season normally ranges from 73 (May) to 86 (July) per cent and the bright sunshine hours from 3.4 (June-July) to 7.1 (May). The relative humidity recorded during the cropping period ranged from 75 (May) to 88 (June-July) per cent and the bright sunshine hours from 1.8 (July) to 8.3 (September). The weather which prevailed during the experimental period was largely normal and typical of semi-dry crop season.

2 Planting material

a) Rice

Jyothi (PTB-39), a medium duration and the most popular HYV of the state was used.

b) Cowpea

Kanakamony (PTB-1), a pure line selection of cowpea was used for *in situ* green manuring. It is autodecomposable under water stagnation and characterised by an early fast growth. Its utility for green manuring has been established in trials (Mathew *et al.*, 1991).

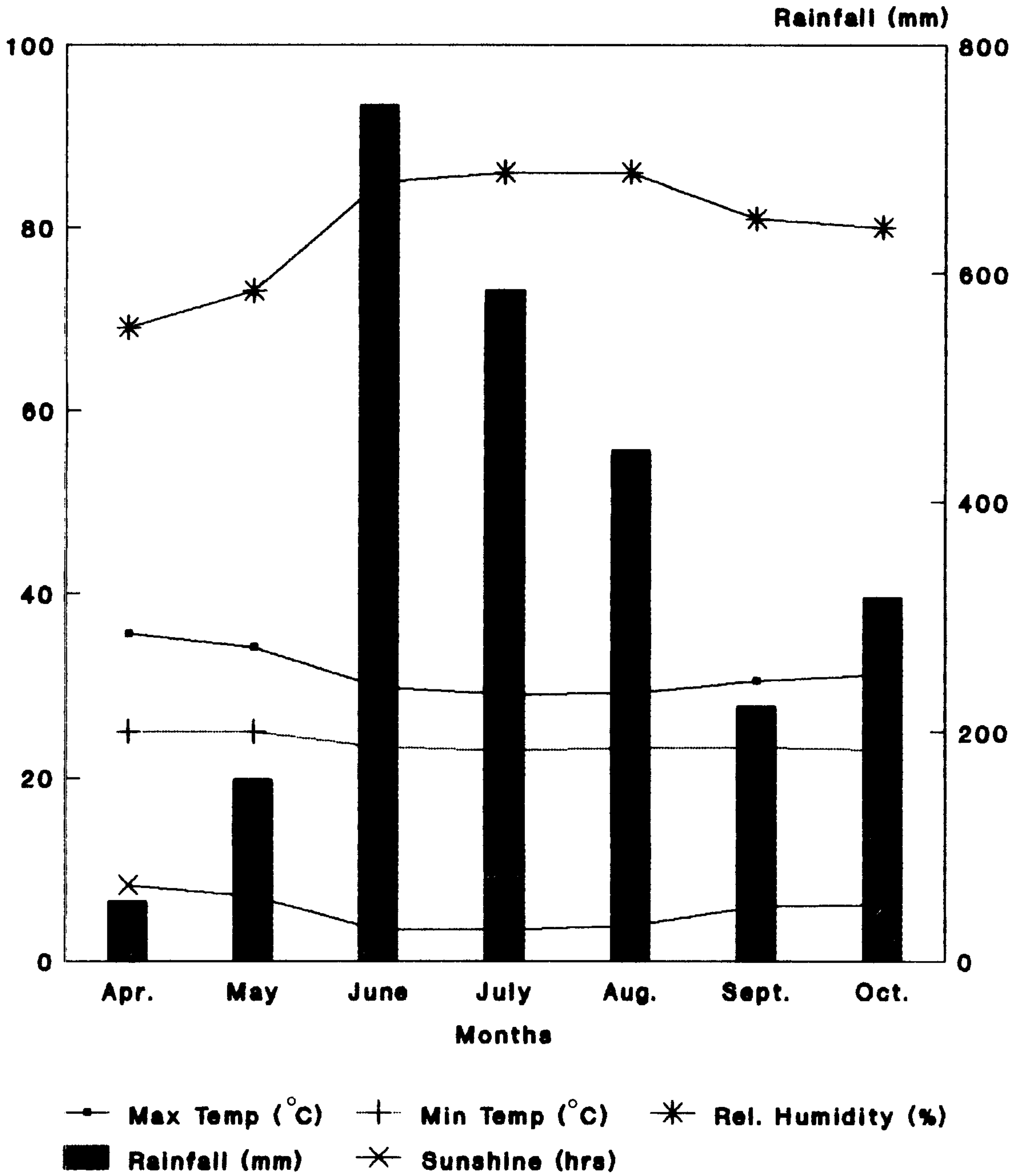


Fig. 1 Weather parameters for the virippu season averaged over 12 years.

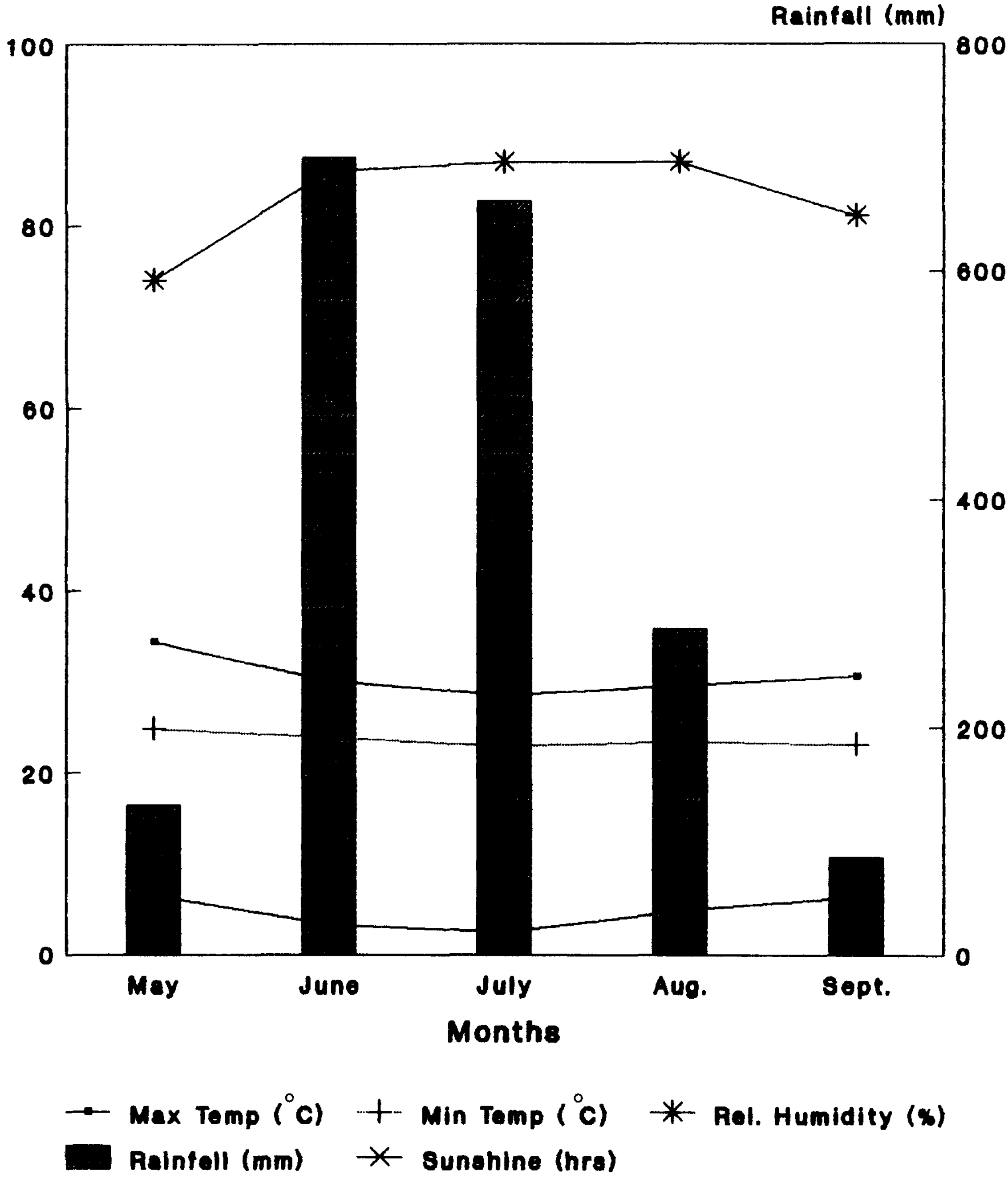


Fig. 2 Weather parameters for the experimental period (May '93 to Sept. '93)

3 **Fertilizer material**

Plant nutrients such as nitrogen, phosphorus and potassium were supplied through urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively.

4 **Treatments**

The treatments consisted of the factorial combinations of 2 levels of cowpea seed rate, 4 levels of nitrogen and 2 levels of phosphorus as described below:

A. Levels of Cowpea seed rate

S_1 - 25% (15 kg ha^{-1}) } of the recommended rate of 50-
S_2 - 50% (30 kg ha^{-1}) } 60 kg ha^{-1} (KAU, 1993)

B. Levels of Nitrogen

N_1 - 0 kg N ha^{-1}
N_2 - 35 kg N ha^{-1}
N_3 - 70 kg N ha^{-1}
N_4 - 105 kg N ha^{-1}

C. Levels of Phosphorus

P_1 - 0 kg P_2O_5 ha^{-1}
P_2 - 35 kg P_2O_5 ha^{-1}

A treatment following the Package of Practices Recommendations (KAU, 1993) without *in situ* growing of cowpea was included as the control.

5 Design and lay out

Design	:	Randomised Block Design with factorial combinations of the treatment levels
Replications	:	3
Gross plot size	:	20 m^2 (5 m x 4 m)
Sampling area	:	1.0 m strip along the 5 m side
Net plot size	:	11.05 m^2 (4.25 m x 2.6 m)

The layout of the experiment is given in Fig.3.

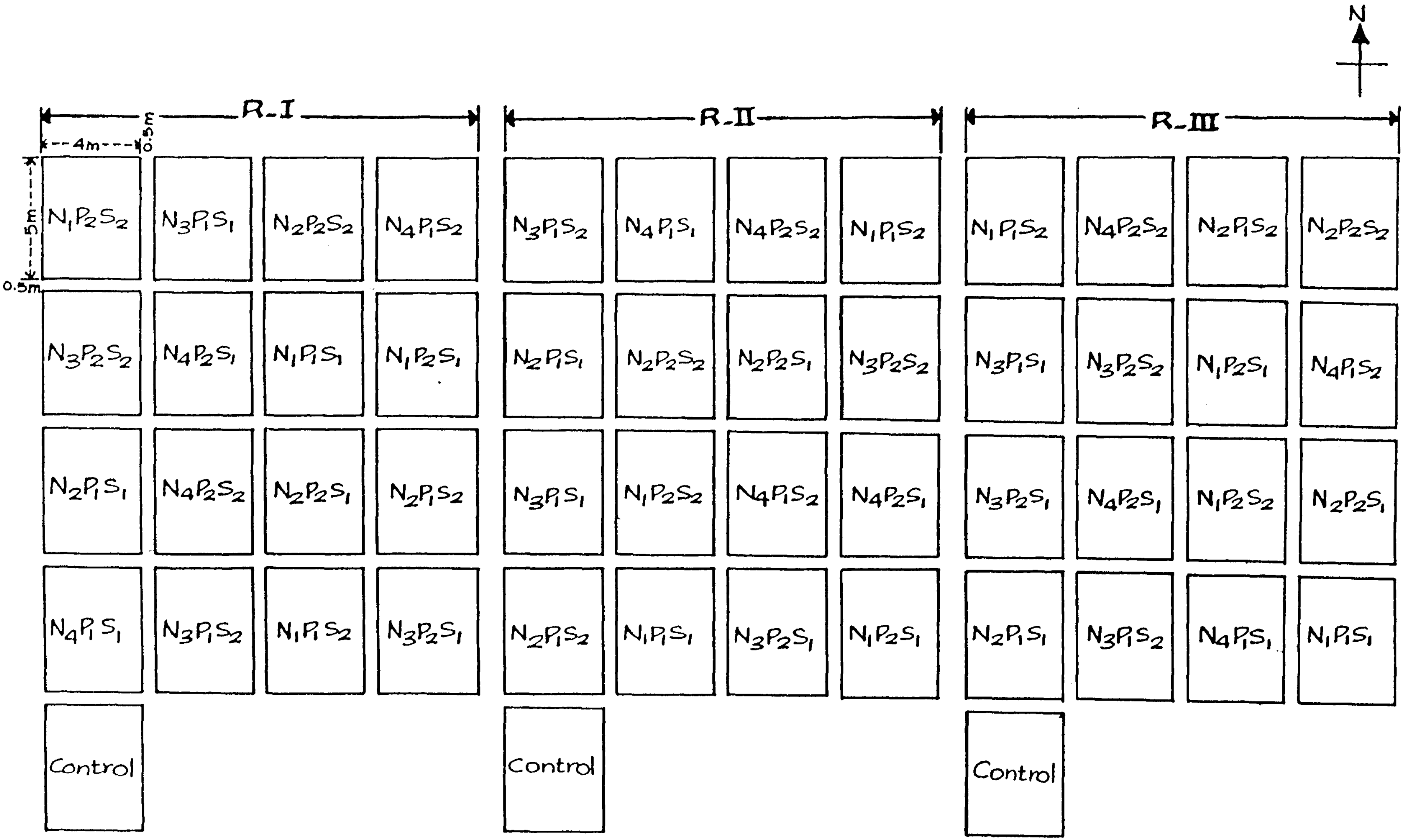
6 Field culture

The rice-cowpea dual culture experiment was started on 14th May 1993.

The field was ploughed twice under dry conditions and brought to a fine tilth. All the weeds and stubbles were removed from the field. Bunds and channels were made and divided the field into three blocks of seventeen plots each.

After the basal application of fertilizers dry rice seeds were dibbled @ 80-90 kg ha^{-1} at a spacing of 15 cm x 15 cm. Alternating with each row of rice, cowpea seeds were dibbled as per the treatment levels, i.e., 4 seeds per metre row length in S_1 level and 8 seeds per metre row length in S_2 level.

Application of nitrogen and phosphorus was done as per the technical programme and a uniform dose of 35 kg K_2O ha^{-1} was given to all the plots. Entire quantities of phosphorus and potassium were applied basally and nitrogen in three



N1 - 0 kg N ha^{-1}
N2 - 35 kg N ha^{-1}
N3 - 70 kg N ha^{-1}

Fig-3 Plan of lay out

P1 - 0 kg P_2O_5 ha^{-1}
P2 - 35 kg ,, ha^{-1}
S1 - 25% cowpea seed rate

equal split doses - first as basal, second at active tillering and the third at panicle initiation stage.

All the cultural operations were carried out uniformly in all plots irrespective of the treatments. One hand weeding was done at 20 days after sowing (DAS). In order to control the leaf roller and rice bug attacks Phosphamidon (Dimecron 86% EC) was sprayed at 70 DAS.

The crop was harvested on 9th September 1993 when about 80 per cent of the grains were matured. The net plot harvest was carried out by leaving two border rows on each side and the sampling area.

7 Observations

In order to take the biometric observations on crop, cowpea and weeds sampling areas were marked in each plot by using quadrats of 50 cm x 50 cm size.

7.1 Rice

7.1.1 Biometric observations

Biometric observations were taken as per the standard procedure (IRRI, 1980) at different periods mentioned below:

Plant height (cm)	- 20, 40, 60, 80 DAS, at harvest
Tiller count (No./hill)	- ,,
Dry matter production (q ha^{-1})	- 20, 30, 50, 60, 75, 90 DAS, at harvest
Root characteristics [Length (cm), number of roots/plant, dry weight (q ha^{-1})]	- 30 and 60 DAS

7.1.2 Yield attributes and yield

Observations were taken as per the standard procedure (IRRI, 1980) on yield attributes such as productive tillers/hill, length of panicle (cm), filled grains per panicle, total grains per panicle and 1000 grain weight (g) and yield of grain and straw (q ha^{-1}). Harvest index was worked out by using the formula

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

7.1.3 Incidence of pest and disease

a) Percentage incidence of leaf roller

Twenty hills were selected at random from each plot and the incidence was assessed by counting the number of healthy as well as the damaged leaves. The incidence was expressed as percentage of total leaves.

b) Disease index for sheath blight

By adopting the Standard Evaluation System for Rice Diseases (IRRI, 1980) the scoring was done and the Disease Index (DI) worked out as

$$DI = \frac{\text{Sum of scores obtained x 100}}{\text{No. of total hills observed x 9}}$$

7.2 Cowpea

Biometric observations were taken at the different periods mentioned on

Plant height (cm)	- 20 and 40 DAS
Dry matter production (q ha^{-1})	- 20, 40 DAS and decomposition stage
Root characteristics [Length (cm), number of roots/plant, dry weight (q ha^{-1})]	- 30 DAS

7.3 Weeds

Observations on weed count (No. m^{-2}) and dry matter production (q ha^{-1}) were taken at 20 and 40 DAS.

8 Chemical analyses

8.1 Estimation of chlorophyll

The chlorophyll content of rice leaves at 25, 50 and 75 DAS and of the boot leaf was estimated spectrophotometrically and expressed as mg g^{-1} fresh weight of leaf (Yoshida *et al.*, 1972).

8.2 Plant analysis

The samples of crop and weed were dried separately in a hot air oven, powdered well in Wiley mill and analysed for N, P, K, Ca, Mg, S and Fe content. The methods used for plant analysis are given in Table 2.

Table 2. Methods used for plant analysis

Sl.No.	Nutrients	Method	References
1	Nitrogen	Microkjeldahl Method	Jackson, 1973
2	Phosphorus	Colorimetric diacid extract Vanadomolybdophosphoric Yellow colour method in nitric acid medium	Jackson, 1973
3	Potassium	Diacid extract method using Flame photometer	Jackson, 1973
4	Calcium	Alternate versonate method	Piper, 1966
5	Magnesium	Alternate versonate method	Piper, 1966
6	Sulphur	Turbidimetric method	Hart, 1961
7	Iron	Orthophenanthroline method	Olson, 1948

The nutrient contents of the crop were analysed at 25, 50 and 75 DAS and at harvest and that of weeds at 20 and 40 DAS. At harvest stage, the grain and straw were analysed separately.

The dry matter produced by the crop as well as the weed was multiplied with the respective nutrient contents to arrive at the N, P, K, Ca, Mg, S and Fe removal by the crop and weed and it was expressed in kg ha^{-1}.

8.3 Soil analysis

The soil samples collected at 20, 40, 60 and 80 DAS were dried in shade, ground, sieved and analysed for pH, organic carbon and available N, P, K and Fe contents. The methods used for soil chemical analysis are as in Table 3.

Table 3. Methods used for soil analysis

Sl.No.	Chemical properties	Method	References
1	pH	1:2.5 soil:water suspension using pH meter	Jackson, 1973
2	Organic carbon	Walkley and Black method	Piper, 1966
3	Available Nitrogen	Alkaline permanganate distillation	Subbiah & Asija, 1956
4	Available Phosphorus	Bray-I extractant - Ascorbic acid reductant method	Soil Survey Staff, 1992
5	Available Potassium	Neutral normal ammonium acetate extractant flame photometry	Jackson, 1973
6	Available Iron	Orthophenanthroline method	Olson, 1948

The content of organic carbon was expressed in percentage and that of available N, P, K and Fe in kg ha^{-1}.

9 Statistical analysis

The data were compiled, tabulated and analysed by applying the analysis of variance technique (Panse and Sukhatme, 1978). Wherever the F-tests were significant appropriate critical differences (CD) were calculated to test the significance of difference between treatment means. Correlation coefficients between important characters, mainly the predictors of yield, were also attempted.

10 Economics

The benefit-cost ratio was calculated by using the formula

$$\text{Benefit-cost ratio} = \frac{\text{Gross return (Rs. ha}^{-1}\text{)}}{\text{Total cost of cultivation (Rs. ha}^{-1}\text{)}}$$

Results

RESULTS

The results of the present study are described below:

1 Rice

1.1 Plant height

1.1.1 Main effects

Data on the main effect of treatments on height of plants are presented in Table 4.

Progressive increase in the levels of N increased the height of plants at all the stages of observation. At 20 days after sowing (DAS) the highest level of N could not bring about a significant increase in height, though the effect was manifested at all the subsequent observations. The effect of N on increasing the height of plants tended to decline with increasing levels. Thus 35 kg N ha^{-1} increased the height significantly over no nitrogen at all stages of observation while 70 kg increased, it at 20 DAS only. However, this treatment had resulted in a significant increase in height of plants at the time of harvest.

Significant effect of P application @ 35 kg ha^{-1} on increasing the height was observed at 20 and 40 DAS and the increases were 5 and 3.7 per cent, respectively.

The marginal influence of cowpea seed rates on plant height was found to be significant only at 20 DAS and 25 per cent seed rate increased the height by 3.1 per cent over 50 per cent seed rate.

Table 4. Effect of treatment levels on plant height (cm) and tiller count (number/hill) of rice

Treatments	Plant height (cm)					Tiller count (number/hill)				
	20 DAS	40 DAS	60 DAS	80 DAS	Harvest	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
N (kg ha^{-1})										
0	34.60	59.44	67.05	80.91	80.55	5.17	7.16	4.78	9.68	7.45
35	36.59	67.36	74.03	91.03	87.28	4.82	7.08	4.61	7.97	7.95
70	38.55	68.36	76.23	93.58	90.92	5.81	8.34	5.23	9.79	8.27
105	38.78	72.98	79.15	97.02	93.39	5.46	7.84	4.78	12.30	11.49
p	0.01	0.01	0.01	0.01	0.01	NS	NS	NS	0.01	0.05
SEm±	0.708	1.232	1.154	2.018	1.57	0.398	0.571	0.348	1.026	0.525
CD (0.05)	1.442	2.51	2.351	4.11	3.201	-	-	-	2.091	1.069
P_2O_5 (kg ha^{-1})										
0	36.20	65.83	73.42	90.63	89.04	5.09	7.79	4.78	9.92	8.01
35	38.05	68.24	74.81	90.64	87.02	5.54	7.42	4.91	9.96	8.43
p	0.01	0.01	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	0.50	0.871	0.816	1.427	1.11	0.282	0.403	0.246	0.726	0.371
CD (0.05)	1.00	1.774				-	-	-	-	-
Cowpea seed rate										
25%	37.70	66.32	73.76	91.84	88.40	5.58	8.16	4.99	9.55	8.46
50%	36.56	67.76	74.48	89.43	87.66	5.09	7.05	4.70	10.32	7.98
p	0.05	NS	NS	NS	NS	NS	0.01	NS	NS	NS
SEm±	0.50	0.871	0.816	1.427	1.11	0.282	0.403	0.246	0.726	0.371
CD(0.05)	1.00					-	0.822	-	-	-
Mean for seed rates	37.13	67.04	74.12	90.64	88.03	5.32	7.61	4.85	9.94	8.22
Control	36.60	65.00	64.27	84.57	80.53	6.79	8.60	6.43	11.00	10.80
p	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	1.415	2.463	2.308	4.036	3.142	0.796	1.141	0.677	2.053	1.049
CD (0.05)	-	-	-	-	-	-	-	-	-	-

1.1.2 Interaction effects

Data on the interaction effects of treatments on plant height are presented in Table 5.

Application of P @ 35 kg ha^{-1} tended to increase the height of plants with increasing levels of N till 60 DAS but there was a non-significant reduction in plant height when N_2 and N_3 levels were compared.

Interaction effect between N and green manure cowpea on plant height was significant at 20 DAS and at harvest. At 20 DAS maximum height was recorded by N_3S_1 combination and at harvest by N_4S_2 which was on par with N_3S_1.

1.2 Tiller count

1.2.1 Main effects

Evidence on the influence of N levels on tiller count was manifested at 80 DAS and at harvest (Table 4). At these two stages N @ 105 kg ha^{-1} increased the tiller count by 25.64 and 38.94 per cent, respectively over 70 kg. There was no significant difference among the other levels. Effect of phosphorus application on tiller count was not significant. A lower seed rate of cowpea significantly increased the tiller count per hill on 40th day which was 15.74 per cent more than the higher seed rate. The tiller count at harvest in the control plot significantly differed from that in the cowpea raised plots and the percentage decline in tiller count was less in control.

Table 5. Interaction effect on plant height (cm) of rice

a. N x P

Levels of P / Levels of N	20 DAS P_1	20 DAS P_2	40 DAS P_1	40 DAS P_2	60 DAS P_1	60 DAS P_2	80 DAS P_1	80 DAS P_2	Harvest P_1	Harvest P_2
N1	33.30	35.90	57.11	61.77	65.51	68.59	79.84	81.97	80.42	80.68
N2	37.03	36.15	65.74	68.98	72.65	75.42	90.67	91.38	88.12	86.43
N3	37.50	39.60	69.51	67.22	77.83	74.63	96.68	90.48	94.33	87.50
N4	36.98	40.57	70.97	74.99	77.70	80.60	95.32	98.73	93.30	93.47
P	0.05		0.05		0.05		NS		NS	
SEm±	1.00		1.74		1.63		2.85		2.22	
CD (0.05)	2.04		3.55		3.33		-		-	

b. N x Cowpea

Cowpea seed rate / Levels of N	20 DAS S_1	20 DAS S_2	40 DAS S_1	40 DAS S_2	60 DAS S_1	60 DAS S_2	80 DAS S_1	80 DAS S_2	Harvest S_1	Harvest S_2
N1	34.35	34.85	57.99	60.89	66.78	67.32	81.47	80.35	80.12	80.98
N2	38.33	34.85	66.49	68.23	74.11	73.96	93.85	88.20	88.68	85.87
N3	39.72	37.38	68.79	67.93	76.47	75.99	96.47	90.70	93.43	88.40
N4	38.38	39.17	71.99	73.97	77.67	80.63	95.58	98.47	91.38	95.38
P	0.05		NS		NS		NS		0.05	
SEm±	1.00		1.74		1.63		2.85		2.22	
CD (0.05)	2.04		-		-		-		4.50	

N1 - 0 kg N ha^{-1} P1 - 0 kg P_2O_5
N2 - 35 kg N ha^{-1} P2 - 35 kg ,,
N3 - 70 kg N ha^{-1} S1 - 25% Cowpea seed rate
N4 - 105 kg N ha^{-1} S2 - 50% ,,

The data also show two phases of tiller decline viz., between 40 and 60 DAS and between 80 DAS and harvest and a secondary tillering phase after 60 DAS.

1.2.2 Interaction effects

Data on the interaction effects of treatments on tiller count are presented in Table 6. It can be seen that in the absence of applied N (N_1 level) higher cowpea seed rate tended to increase the tiller count on 20th day where as with increasing N levels the trend was reversed. Thus at 70 kg N ha^{-1} a higher seed rate of cowpea produced only 4.84 tillers per hill as against 6.78 at lower seed rate. At 105 kg N ha^{-1} higher seed rate of cowpea (N_4S_2) produced only 4.95 tillers compared with 4.84 at N_2S_1 level. Such an enhancing effect of lower seed rate on tiller production at higher levels of N was observed at 40 DAS also. Interaction effects of N and cowpea seed rate at other stages were not significant.

The data further show that at 40 DAS highest tiller count of 9.90 per hill was recorded at $N_3P_2S_1$ combination. This was statistically on par with $N_4P_1S_1$ but significantly superior to 0 and 35 kg N ha^{-1}. The results also showed that the trend of increasing tiller count manifested by increasing levels of N was negatively influenced by higher seed rate of cowpea as well as application of phosphorus.

1.3 Dry matter production

1.3.1 Main effects

Data showing the main effects of treatments on dry matter production (DMP) by rice are presented in Table 7.

Table 6. Interaction effect on tiller count (number/hill)

a. N x Cowpea

Cowpea seed rates / Levels of N	20 DAS S_1	20 DAS S_2	40 DAS S_1	40 DAS S_2	60 DAS S_1	60 DAS S_2	80 DAS S_1	80 DAS S_2	Harvest S_1	Harvest S_2
N1	4.72	5.61	6.67	7.65	4.72	4.83	8.98	10.38	7.27	7.63
N2	4.84	4.79	7.50	6.67	4.73	4.48	8.28	7.65	8.40	7.50
N3	6.78	4.84	9.13	7.55	5.45	5.00	8.85	10.73	8.77	7.77
N4	5.95	4.95	9.33	6.33	5.07	4.48	12.10	12.50	9.40	9.03
p	0.01		0.05		NS		NS		NS	
SEm±	0.56		0.81		0.49		1.45		0.74	
CD (0.05)	1.15		1.64		-		-		-	

b. N x P x Cowpea

Levels of N	Cowpea seed rate	20 DAS P_1	20 DAS P_2	40 DAS P_1	40 DAS P_2	60 DAS P_1	60 DAS P_2	80 DAS P_1	80 DAS P_2	Harvest P_1	Harvest P_2
N1	S1	4.11	5.33	6.00	7.33	4.33	5.10	8.43	9.53	6.47	8.07
	S2	5.79	5.44	8.77	6.53	4.87	4.80	10.77	10.00	6.40	8.87
N2	S1	5.01	4.68	8.77	6.23	5.13	4.33	8.80	7.77	8.27	8.53
	S2	5.01	4.57	6.23	7.10	4.93	4.03	8.63	6.67	7.67	7.33
N3	S1	5.45	8.11	8.37	9.90	5.33	5.57	8.80	8.90	9.27	8.27
	S2	4.57	5.12	8.10	7.00	4.67	5.33	9.70	11.77	7.40	8.13
N4	S1	6.11	5.80	9.90	8.77	4.57	5.57	12.20	12.00	9.73	9.07
	S2	4.68	5.23	6.17	6.50	4.43	4.53	12.00	13.00	8.87	9.20
p		NS		0.05		NS		NS		NS	
SEm±		0.79		1.14		0.69		2.05		1.05	
CD (0.05)				2.23							

N1 - 0 kg N ha^{-1}
N2 - 35 kg N ha^{-1}
N3 - 70 kg N ha^{-1}
N4 - 105 kg N ha^{-1}

P1 - 0 kg P_2O_5 ha^{-1}
P2 - 35 kg ,, ha^{-1}
S1 - 25% cowpea seed rate
S2 - 50% ,,

Table 7. Effect of treatment levels on dry matter production (q ha^{-1}) of rice at various stages

Treatments	20 DAS	30 DAS	50 DAS	60 DAS	75 DAS	90 DAS	Harvest
N (kg ha^{-1})							
0	5.92	11.04	24.98	16.32	41.17	83.97	69.09
35	7.70	13.66	25.15	20.15	47.44	88.78	66.22
70	5.74	11.81	27.70	18.15	52.26	92.59	81.07
105	6.44	14.70	25.44	20.85	57.70	82.70	79.74
p	NS	NS	NS	NS	0.01	NS	NS
SEm±	1.014	1.649	2.491	2.232	4.589	8.556	7.057
CD (0.05)	-	-	-	-	9.349	-	-
P_2O_5							
0	6.02	13.07	26.10	20.08	48.19	89.37	74.98
35	6.89	12.54	25.54	17.66	51.10	84.65	73.08
p	NS	NS	NS	NS	NS	NS	NS
SEm±	0.717	1.166	1.761	1.578	3.245	6.05	4.99
CD (0.05)	-	-	-	-	-	-	-
Cowpea seed rate							
25%	6.59	12.94	26.98	19.23	49.77	85.00	77.79
50%	6.31	12.67	24.66	18.50	49.52	89.02	70.28
p	NS	NS	NS	NS	NS	NS	NS
SEm±	0.717	1.166	1.761	1.578	3.245	6.05	4.99
CD (0.05)	-	-	-	-	-	-	-
Mean for seed rates	6.45	12.81	25.82	18.87	49.65	87.01	74.04
Control	6.22	16.74	24.00	22.67	48.30	64.45	74.07
p	NS	NS	NS	NS	NS	NS	NS
SEm±	2.03	3.29	4.98	4.46	9.18	17.11	14.11
CD (0.05)	-	-	-	-	-	-	-

The data show that nitrogen levels differed significantly in DMP only at 75 DAS. Highest dry matter yield of 57.7 q ha^{-1} was observed at 105 kg N ha^{-1}, the highest level tried in the experiment which was significantly superior to both N_1 and N_2 levels and the percentage increases were 40 and 21.6, respectively. The data also show that though 70 and 105 kg N levels were statistically on par, the latter had recorded an excess dry matter yield of 5.5 q ha^{-1}.

Phosphorus and cowpea seed rate did not exert any significant effect on the pattern or quantity of DMP at any stage of growth. Concurrent cropping of cowpea with rice showed a tendency to increase the DMP by rice, especially from the middle stages of crop growth onwards.

Observation on the pattern of DMP showed two distinct phases of decline in DMP, i.e., between 50 and 60 DAS and between 90 DAS and harvest and the magnitude of decline was highest at N_1 and N_3 levels in the first phase and at N_2 in the second phase. Further increase in DMP appeared to be independent of the N level and at 75 DAS, 105 kg N ha^{-1} gave the highest dry matter yield.

1.4 Root characteristics

1.4.1 Main effects

Data on the main effects of treatments on root characteristics are given in Table 8.

It can be seen from the table that levels of N, P or cowpea seed rate did not significantly influence any of the root characteristics at any time. Pure cropping

Table 8. Effect of treatment levels on root characteristics of rice

Treatments	Root number per plant		Root length (cm)		Fresh weight (q ha^{-1})		Dry weight (q ha^{-1})	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
N (kg ha^{-1})								
0	30.25	56.92	11.13	10.59	15.07	5.33	3.92	2.52
35	35.92	58.00	11.35	11.12	10.96	6.41	4.22	2.74
70	34.17	57.59	11.25	10.57	15.11	6.70	3.74	2.74
105	34.92	56.33	11.06	10.38	12.15	7.30	4.54	2.52
P	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	2.79	4.95	0.78	0.65	2.49	0.96	0.99	0.51
CD (0.05)	-	-	-	-	-	-	-	-
P_2O_5 (kg ha^{-1})								
0	34.38	58.96	11.34	10.56	12.31	6.52	4.48	2.83
35	33.25	55.46	11.05	10.76	14.33	6.35	3.73	2.43
P	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	1.98	0.46	0.55	0.46	3.51	0.68	0.70	0.36
CD (0.05)	-	-	-	-	-	-	-	-
Cowpea seed rate								
25%	33.08	57.29	10.88	10.92	13.48	6.54	3.84	2.30
50%	34.54	57.12	11.52	10.41	13.17	6.33	4.37	2.96
P	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	1.98	0.46	0.55	0.46	3.51	0.68	0.70	0.36
CD (0.05)		-	-	-	-	-	-	-
Mean for seed rates	33.81	57.21	11.20	10.67	13.33	6.44	4.11	2.63
Control	40.67	51.00	11.67	11.58	11.26	5.19	4.89	3.56
P	NS	NS	NS	NS	0.01	NS	NS	NS
SEm±	5.59	9.91	1.56	1.30	9.92	1.91	1.99	1.01
CD(0.05)	-	-	-	-	20.21	-	-	-

of rice showed a nonsignificant increase in root number, root length and dry weight of roots over concurrent cropping.

1.5 Chlorophyll content

1.5.1 Main effects

Data on chlorophyll a, chlorophyll b and total chlorophyll content of leaves are presented in Table 9.

Highest chlorophyll 'a' content of 1.713 mg g^{-1} fresh weight of leaf on 50th day was recorded by N_3 and this was significantly superior to that at N_1 level. Another important observation is the absence of chlorophyll 'a' at 75 DAS. Significant difference among nitrogen levels was noticed in the chlorophyll 'a' content of boot leaf. Chlorophyll 'a' content increased with increasing levels of N and the highest content was observed at 105 kg N ha^{-1} which was significantly superior to that at 35 kg N but those at 70 and 105 kg N levels did not differ significantly between themselves. Chlorophyll 'b' content of the leaves on 75th day as well as of the boot leaf was significantly increased by progressive increase in N levels. Highest chlorophyll 'b' contents of 2.523 mg g^{-1} fresh weight of leaves at 75 DAS and 1.520 mg g^{-1} of boot leaf were recorded at 105 kg N ha^{-1}.

Chlorophyll 'b' content of the boot leaf was affected significantly by both phosphorus and seed rate of cowpea. Phosphorus application at 35 kg level significantly reduced the chlorophyll 'b' content by 12 per cent, while a higher seed rate of cowpea increased it by 15 per cent. Concurrent raising of cowpea, though not significant, increased the chlorophyll components over control.

Table 9. Effect of treatment levels on chlorophyll components of leaf at various stages of rice, mg g^{-1} fresh weight

Treatments	25 DAS			50 DAS			75 DAS			Of Boot leaf		
	Chl. a	Chl. b	Total Chl.	Chl. a	Chl. b	Total Chl.	Chl. a	Chl. b	Total Chl.	Chl. a	Chl. b	Total Chl.
N (kg ha^{-1})												
0	1.283	1.300	3.033	1.428	1.673	3.510	-0.033	1.670	1.425	0.865	1.020	1.855
35	1.208	1.220	2.898	1.563	1.928	3.678	-0.050	2.063	1.883	0.858	1.030	1.893
70	1.060	1.000	2.400	1.713	2.010	4.160	-0.038	2.313	2.028	1.123	1.403	2.505
105	1.268	1.183	2.853	1.620	1.823	3.923	-0.013	2.523	2.080	1.228	1.520	2.665
P	NS	NS	NS	0.05	NS	NS	NS	0.05	0.05	0.01	0.01	0.01
SEm±	0.170	0.209	0.438	0.090	0.183	0.248	0.018	0.274	0.213	0.086	0.111	0.164
CD (0.05)	-	-	-	0.184	-	-	-	0.557	0.434	0.174	0.226	0.334
P_2O_5 (kg ha^{-1})												
0	1.138	1.101	2.666	1.550	1.876	3.881	-0.029	2.191	1.889	1.054	1.324	2.314
35	1.271	1.250	2.925	1.581	1.840	3.754	-0.031	2.093	1.819	0.983	1.163	2.145
P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.05	NS
SEm±	0.120	0.148	0.309	0.064	0.129	0.176	0.013	0.193	0.151	0.001	0.079	0.116
CD (0.05)	-	-	-	-	-	-	-	-	-	-	0.160	-
Cowpea seed rate												
25%	1.136	1.095	2.639	1.521	1.814	3.719	-0.025	2.100	1.754	1.013	1.155	2.130
50%	1.273	1.256	2.953	1.630	1.903	3.916	-0.035	2.184	1.954	1.024	1.331	2.329
P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.05	NS
SEm±	0.120	0.148	0.309	0.064	0.129	0.176	0.013	0.193	0.151	0.061	0.079	0.116
CD (0.05)	-	-	-	-	-	-	-	-	-	-	0.160	-
Mean for seed rates	1.205	1.176	2.796	1.580	1.800	3.818	-0.030	2.142	1.854	1.020	1.243	2.229
Control	1.420	1.600	3.310	1.550	1.800	4.220	-0.040	2.510	2.070	0.920	1.060	1.980
P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	0.340	0.418	0.876	0.181	0.365	0.497	0.036	0.547	0.427	0.171	0.222	0.328
CD (0.05)	-	-	-	-	-	-	-	-	-	-	-	-

1.5.2 Interaction effects

Data on the interaction effect of treatments on chlorophyll content are presented in Table 10. The data show that highest content of chlorophyll 'a' as well as total chlorophyll at 50 DAS was recorded at N_3 level with lower seed rate of cowpea which was significantly superior to all other combinations except N_4S_2.

A two-way interaction among the treatments showed significant variation in the chlorophyll 'a' and total chlorophyll content of the leaves at 25 DAS, and the highest values were recorded by $N_3P_2S_2$ combination.

1.6 Nutrient content of plant

1.6.1 Main effects

Data on the main effects of treatments on the nutrient content of the plant are given in Table 11.

a) Nitrogen content

Application of fertilizer N significantly improved the N content of plant in the progressive growth stages. However, on 25th day significant improvement was observed upto 70 kg N ha^{-1} where as on 50th and 75th day the response was observed upto 35 kg ha^{-1} only.

Effect of P application on the N content of plant was significant only at 25 DAS. Application of P @ 35 kg ha^{-1} increased the N content at 25 DAS by 20.9 per cent over no phosphorus.

Table 10. Interaction effect on chlorophyll components (mg g^{-1} fresh weight) of rice

a. N x Cowpea

Levels of N	25 DAS						50 DAS					
	Chl.a		Chl.b		Total Chl.		Chl.a		Chl.b		Total Chl.	
Cowpea seed rate	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
N1	1.20	1.37	1.37	1.23	2.87	3.19	1.25	1.60	1.51	1.84	3.05	3.96
N2	1.06	1.35	1.03	1.41	2.55	3.25	1.56	1.57	1.94	1.92	3.67	3.69
N3	1.00	1.12	0.81	1.19	2.19	2.61	1.87	1.56	2.16	1.86	4.58	3.74
N4	1.29	1.24	1.17	1.20	2.94	2.77	1.45	1.79	1.65	2.00	3.57	4.27
P	NS		NS		NS		0.01		NS		0.01	
SEm±	0.24		0.30		0.62		0.13		0.26		0.35	
CD (0.05)	-		-		-		0.26		-		0.72	

b. N x P x Cowpea

Levels of N	Cowpea seed rate	25 DAS						50 DAS					
		Chl.a		Chl.b		Total Chl.		Chl.a		Chl.b		Total Chl.	
	Levels of P	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
N1	S1	1.24	1.15	1.40	1.34	2.94	2.81	1.11	1.40	1.52	1.49	2.89	3.22
	S2	1.47	1.27	1.27	1.19	3.49	2.89	1.64	1.56	1.90	1.78	4.11	3.82
N2	S1	0.90	1.22	0.87	1.19	2.25	2.84	1.49	1.62	1.86	2.02	3.29	4.05
	S2	1.30	1.41	1.37	1.45	3.22	3.28	1.69	1.45	2.21	1.62	4.08	3.30
N3	S1	1.05	0.95	0.84	0.78	2.40	1.99	1.85	1.89	1.98	2.35	4.58	4.58
	S2	0.60	1.64	0.62	1.76	1.35	3.86	1.62	1.49	1.94	1.77	4.04	3.44
N4	S1	1.04	1.54	1.00	1.34	2.41	3.47	1.57	1.32	1.49	1.80	3.89	3.26
	S2	1.50	0.99	1.44	0.95	3.27	2.26	1.67	1.92	2.11	1.89	4.18	4.36
P		0.05		NS		0.05		NS		NS		NS	
SEm±		0.34		0.42		0.88		0.18		0.37		0.49	
CD (0.05)		0.69				1.36							

N1 - 0 kg N ha^{-1}
N2 - 35 kg N ha^{-1}
N3 - 70 kg N ha^{-1}
N4 - 105 kg N ha^{-1}

P1 - 0 kg P_2O_5 ha^{-1}
P2 - 35 kg ,, ha^{-1}
S1 - 25% cowpea seed rate
S2 - 50% ,,

Table 11. Effect of treatment levels on nutrient content of rice, %

Treatments	Nitrogen			Phosphorus			Potassium			Calcium			Magnesium			Sulphur			Iron		
	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS
N (kg ha^{-1})																					
0	1.71	1.49	1.41	0.29	0.20	0.21	3.25	2.28	2.02	0.37	0.32	0.32	0.21	0.14	0.15	0.40	0.14	0.14	0.12	0.06	0.04
35	2.38	2.13	1.70	0.29	0.21	0.20	3.01	2.27	2.15	0.38	0.32	0.38	0.18	0.18	0.12	0.37	0.14	0.13	0.15	0.04	0.04
70	2.95	2.08	1.88	0.31	0.21	0.21	3.19	2.46	2.25	0.39	0.34	0.36	0.21	0.17	0.18	0.40	0.15	0.13	0.12	0.06	0.04
105	3.14	2.00	1.91	0.28	0.20	0.21	3.31	2.48	2.34	0.36	0.33	0.38	0.22	0.18	0.15	0.37	0.15	0.16	0.12	0.05	0.04
℘	0.01	0.01	<0.01	NS	NS	NS	NS	0.05	0.01	NS	NS	0.05	0.05	0.01	0.01	NS	NS	NS	NS	NS	NS
SEm±	0.19	0.18	0.13	0.02	0.01	0.01	0.12	0.08	0.06	0.02	0.04	0.02	0.01	0.01	0.01	0.03	0.01	0.01	0.02	0.01	0.01
CD (0.05)	0.38	0.36	0.26	-	-	-	-	0.17	0.11	-	-	0.04	0.03	0.03	0.02	-	-	-	-	-	-
P_2O_5 (kg ha^{-1})																					
0	2.53	1.89	1.69	0.27	0.20	0.20	3.11	2.33	2.16	0.37	0.33	0.36	0.19	0.14	0.15	0.36	0.14	0.14	0.11	0.05	0.04
35	3.06	1.96	1.77	0.31	0.21	0.21	3.26	2.46	2.23	0.38	0.33	0.36	0.22	0.15	0.15	0.40	0.15	0.15	0.14	0.05	0.04
℘	0.01	NS	NS	<0.01	NS	NS	NS	NS	NS	NS	NS	NS	0.01	NS	NS	0.05	NS	NS	NS	NS	NS
SEm±	0.13	0.12	0.09	0.01	0.01	0.01	0.08	0.08	0.04	0.01	0.04	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
CD (0.05)	0.27	-	-	0.03	-	-	-	-	-	-	-	-	0.02	-	-	0.04	-	-	-	-	-
Cowpea seed rate																					
25%	2.82	1.76	1.69	0.27	0.20	0.20	3.07	2.32	2.15	0.38	0.33	0.34	0.21	0.16	0.14	0.38	0.14	0.13	0.11	0.05	0.04
50%	2.76	2.09	1.76	0.31	0.21	0.21	3.31	2.43	2.23	0.37	0.33	0.38	0.20	0.18	0.15	0.39	0.15	0.15	0.14	0.05	0.04
℘	NS	<0.05	NS	0.05	NS	NS	0.01	NS	NS	NS	NS	0.05	NS	NS	NS	NS	NS	0.05	0.05	NS	NS
SEm±	0.13	0.12	0.09	0.01	0.01	0.01	0.08	0.08	0.04	0.01	0.04	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
CD (0.05)	-	0.25	-	0.03	-	-	0.17	-	-	-	-	0.03	-	-	-	-	-	0.02	0.03	-	-
Mean for seed rates	2.79	1.93	1.73	0.29	0.21	0.21	3.19	2.38	2.19	0.38	0.33	0.36	0.21	0.17	0.15	0.39	0.15	0.14	0.13	0.05	0.04
Control	3.41	1.83	1.59	0.26	0.21	0.18	3.27	2.33	2.17	0.36	0.28	0.29	0.18	0.19	0.14	0.37	0.16	0.14	0.11	0.05	0.04
℘	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	0.372	0.352	0.253	0.036	0.026	0.018	0.234	0.165	0.110	0.036	0.036	0.036	0.026	0.026	0.016	0.052	0.026	0.026	0.036	0.026	0.009
CD (0.05)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Compared with control, concurrent raising of cowpea had a positive influence on the N content of crop towards the later stages. The influence of a higher seed rate of cowpea on increasing the plant N content was significant only at 50 DAS.

b) Phosphorus content

The data on P content of plant show that N levels did not affect P content of the plant at any stage of observation. Even the effects of P and seed rate of cowpea were significant only at 25 DAS when application of P @ 35 kg ha^{-1} or use of a higher seed rate of cowpea increased the P content of plant by 14.8 per cent over no phosphorus or a lower seed rate of cowpea. Compared with control there was a marginal increase in the P content of plant when cowpea was raised concurrently.

c) Potassium content

Higher levels of N brought about a significantly higher content of K over the lower levels at 50 and 75 DAS. Phosphorus application had a tendency to increase the K content of plant throughout the crop period but the effect was not significant.

A higher seed rate of cowpea also tended to increase the K content of the plant at all stages, though the effect was significant only at 25 DAS. At this stage a higher seed rate of cowpea improved the K content by 7.8 per cent over the lower seed rate. When compared with control it can be seen that the K content of plant was less tilted by *in situ* green manuring.

d) Calcium content

It can be seen from the table that significant effect of N on Ca content was observed at 75 DAS while P did not have any influence at any stage of growth.

The higher seed rate of green manure cowpea improved the Ca content of rice significantly at 75 DAS and the percentage increase worked out to 11.8. A comparison between the control and green manuring would suggest that concurrent raising of cowpea had a tendency to increase the Ca content of rice at all stages.

e) Magnesium content

Application of higher levels of N tended to increase the Mg content of plant. But this trend was not observed towards the later stages. Significant influence of P on increasing the Mg content of plant was also confined to the earlier stages and the increase worked out to 15.8 per cent.

Concurrent cropping of cowpea for green manuring had a marginal effect on Mg content of plant while the seed rate effects did not differ significantly.

f) Sulphur content

It can be seen from the table that application of N did not have any effect on the S content of rice at any stage of growth, while P application at 35 kg ha^{-1} increased the S content at 25 DAS significantly and the increase worked out to 11 per cent. Green manure cowpea sown at 50 per cent recommended dose increased the S content significantly at 75 DAS and the increase was 15 per cent over 25 per cent seed rate.

g) Iron content

The data on iron content of plant show that neither N nor P did affect the content while seed rates of cowpea varied significantly in the Fe content of rice. Thus a higher seed rate of cowpea increased the Fe content of plant by 27 per cent.

1.6.2 Interaction effects

Data on the interaction effects of treatments on nutrient content of plant are given in Table 12.

a) Nitrogen content

Interaction effect between N and P on N content of crop was found to be significant at the initial stages. At 25 DAS highest N content of 3.64 per cent recorded by N_4P_2 was 38 per cent higher than that in the treatment receiving N alone.

Interaction effect between P and seed rate of cowpea was found to be significant at 50 DAS when a higher seed rate of cowpea coupled with P application recorded the highest N content of plant and the percentage increase worked out to 38.4 over the lower seed rate. The same trend was observed at the earlier and later stages also but was not significant.

b) Calcium content

At 105 kg N ha^{-1}, application of P @ 35 kg ha^{-1} increased the Ca content significantly by 28 per cent at 25 DAS where as at lower levels of N phosphorus application had not much effect.

Table 12. Interation effect on nutrient content of rice, %

a. N x P and P x Cowpea

Levels of P	25 DAS		50 DAS		75 DAS		Grain		Straw	
Levels of N & Cowpea	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
					Nitrogen					
N1	2.64	2.78	1.55	1.43	1.47	1.35	1.54	1.66	0.59	0.64
N2	1.77	2.99	2.01	2.25	1.66	1.75	1.59	1.61	0.57	0.64
N3	3.08	2.82	1.87	2.27	1.80	1.96	1.54	1.73	0.83	0.69
N4	2.63	3.64	2.12	1.88	1.82	2.01	1.63	1.66	0.78	0.74
p	0.01		NS		NS		NS		0.05	
SEm±	0.26		0.25		0.18		0.12		0.09	
CD (0.05)	0.54		-		-		-		0.19	
S1	2.61	3.03	1.88	1.64	1.70	1.68	1.59	1.65	0.69	0.67
S2	2.45	3.08	1.89	2.27	1.67	1.86	1.56	1.68	0.69	0.67
p	NS		0.05		NS		NS		NS	
SEm±	0.19		0.18		0.13		0.08		0.07	
CD (0.05)	-		0.36		-		-		-	
					Calcium					
N1	0.40	0.35	0.31	0.33	0.32	0.32	0.08	0.07	0.41	0.38
N2	0.38	0.38	0.34	0.31	0.38	0.37	0.06	0.11	0.46	0.41
N3	0.39	0.38	0.34	0.35	0.36	0.36	0.10	0.08	0.51	0.43
N4	0.32	0.41	0.33	0.32	0.37	0.38	0.08	0.10	0.41	0.47
p	0.01		NS		NS		0.05		NS	
SEm±	0.03		0.03		0.03		0.02		0.05	
CD(0.05)	0.05		-		-		0.04		-	
S1	0.37	0.39	0.33	0.32	0.35	0.34	0.09	0.09	0.49	0.42
S2	0.37	0.36	0.32	0.33	0.36	0.38	0.07	0.10	0.41	0.43
p	NS		NS		NS		NS		NS	
SEm±	0.02		0.02		0.02		0.01		0.03	
CD (0.05)	-		-		-		-		-	
					Magnesium					
N1	0.20	0.22	0.18	0.10	0.16	0.14	0.08	0.07	0.12	0.13
N2	0.19	0.17	0.18	0.18	0.12	0.12	0.07	0.07	0.14	0.14
N3	0.20	0.22	0.20	0.14	0.20	0.15	0.07	0.08	0.20	0.14
N4	0.18	0.26	0.16	0.20	0.12	0.17	0.07	0.09	0.10	0.18
p	0.01		0.01		0.01		NS		0.05	
SEm±	0.02		0.02		0.01		0.01		0.03	
CD(0.05)	0.04		0.04		0.02		-		0.05	
S1	0.19	0.23	0.18	0.14	0.15	0.14	0.07	0.08	0.11	0.14
S2	0.20	0.21	0.18	0.17	0.15	0.15	0.08	0.07	0.16	0.16
p	NS		NS		NS		0.05		NS	
SEm±	0.01		0.01		0.01		0.008		0.021	
CD(0.05)	-		-		-		0.01		-	

contd.

b. N x Cowpea

Cowpea seed rate / Levels of N	25 DAS S1	25 DAS S2	50 DAS S1	50 DAS S2	75 DAS S1	75 DAS S2	Grain S1	Grain S2	Straw S1	Straw S2
Calcium										
N1	0.37	0.37	0.35	0.29	0.29	0.35	0.07	0.08	0.41	0.39
N2	0.39	0.37	0.30	0.35	0.39	0.37	0.09	0.09	0.43	0.44
N3	0.39	0.37	0.35	0.34	0.35	0.37	0.09	0.09	0.49	0.46
N4	0.37	0.35	0.31	0.34	0.35	0.40	0.09	0.09	0.49	0.39
P	NS		0.05		NS		NS		NS	
SEm±	0.03		0.03		0.03		0.02		0.05	
CD (0.05)	-		0.05		-		-		-	
Magnesium										
N1	0.22	0.20	0.11	0.16	0.16	0.14	0.07	0.08	0.10	0.15
N2	0.20	0.16	0.17	0.18	0.10	0.14	0.07	0.07	0.11	0.17
N3	0.21	0.22	0.15	0.19	0.16	0.18	0.07	0.08	0.14	0.20
N4	0.20	0.24	0.20	0.16	0.14	0.14	0.08	0.08	0.15	0.13
P	0.05		0.01		0.01		NS		NS	
SEm±	0.02		0.02		0.01		0.01		0.03	
CD (0.05)	0.04		0.04		0.02					

c. N x P x Cowpea

Levels of N	Cowpea seed rate	25 DAS P1	25 DAS P2	50 DAS P1	50 DAS P2	75 DAS P1	75 DAS P2	Grain P1	Grain P2	Straw P1	Straw P2
Calcium											
N1	S1	0.41	0.33	0.35	0.35	0.29	0.28	0.09	0.05	0.44	0.37
	S2	0.39	0.36	0.27	0.31	0.35	0.36	0.07	0.09	0.39	0.39
N2	S1	0.35	0.43	0.31	0.29	0.36	0.41	0.07	0.11	0.47	0.40
	S2	0.41	0.33	0.37	0.32	0.40	0.33	0.05	0.12	0.45	0.43
N3	S1	0.39	0.40	0.37	0.32	0.36	0.35	0.11	0.08	0.53	0.44
	S2	0.39	0.36	0.31	0.37	0.36	0.37	0.09	0.08	0.49	0.43
N4	S1	0.33	0.41	0.31	0.31	0.39	0.31	0.08	0.11	0.52	0.45
	S2	0.31	0.40	0.35	0.33	0.35	0.45	0.08	0.09	0.29	0.48
P		0.05		NS		0.01		NS		NS	
SEm±		0.04		0.04		0.04		0.03		0.07	
CD (0.05)		0.08		-		0.08					
Magnesium											
N1	S1	0.20	0.23	0.14	0.08	0.19	0.13	0.07	0.06	0.10	0.10
	S2	0.20	0.21	0.21	0.12	0.13	0.14	0.10	0.07	0.14	0.16
N2	S1	0.21	0.20	0.22	0.13	0.11	0.09	0.06	0.09	0.10	0.12
	S2	0.18	0.14	0.14	0.22	0.13	0.15	0.08	0.06	0.17	0.17
N3	S1	0.20	0.22	0.15	0.14	0.19	0.14	0.06	0.08	0.15	0.13
	S2	0.20	0.23	0.25	0.14	0.20	0.17	0.08	0.08	0.25	0.16
N4	S1	0.14	0.27	0.19	0.21	0.09	0.20	0.07	0.10	0.10	0.19
	S2	0.22	0.25	0.14	0.19	0.15	0.14	0.07	0.09	0.10	0.16
P		NS		0.01		0.01		NS		NS	
SEm±		0.03		0.03		0.02		0.02		0.04	
CD (0.05)		-		0.05		0.03		-		-	

N1 - 0 kg N ha^{-1} P1 - 0 kg P_2O_5 ha^{-1}
N2 - 35 kg N ha^{-1} P2 - 35 kg ,, ha^{-1}
N3 - 70 kg N ha^{-1} S1 - 25% cowpea seed rate
N4 - 105 kg N ha^{-1} S2 - 50% ,,

The data on N x cowpea interaction show that N_2S_2 and N_3S_1 are on par in influencing the Ca content at 50 DAS, i.e., at lower levels of N a higher seed rate of cowpea is conducive to improve the Ca content of plant.

It can be seen from the table that at higher levels of N lower cowpea seed rate coupled with P application could increase the Ca content significantly at 25 DAS, while at 75 DAS higher seed rate was found to be better.

c) Magnesium content

Significant superiority of 105 kg N ha^{-1} along with P on increasing the Mg content of plant was observed at 25 DAS. But towards the later stages application of 70 kg N ha^{-1} without P showed higher content of Mg in the plant.

Interaction effect between N and cowpea shows that at 25 DAS higher levels of N along with higher cowpea seed rate tended to increase the Mg content while at lower levels of N the response pattern was the reverse. At 50 DAS, though N_4S_1 recorded highest content this was on par N_3S_2. Similarly at 75 DAS also N_3S_2 recorded the highest Mg content.

Significant N x P x cowpea interation effect on Mg content of rice plant can be noticed at 50 and 75 DAS when the highest Mg content was noticed in $N_3P_1S_2$ combination. At these levels of N and cowpea seed rate, application of P showed a depressing effect on the Mg content.

1.7 Nutrient content of grain and straw

1.7.1 Main effects

Data on the main effects of treatments on nutrient content of grain and straw are given in Table 13.

The data show that higher levels of N application significantly increased the N content of straw over the lower levels. Nitrogen application at 70 kg ha^{-1} increased the N content of straw by 27 per cent over that at 35 kg ha^{-1}. Phosphorus and cowpea seed rate did not have any effect on N content of grain or straw.

The data show that N, P or cowpea green manure did not affect the P, K and Ca contents of grain or straw significantly.

Effects of N and P on Mg content of grain and straw were not significant while a higher seed rate of cowpea increased the Mg content of straw significantly and the increase worked out to 33 per cent. Similarly S and Fe contents of grain and straw were not significantly influenced by the treatment levels.

1.7.2 Interaction effects

Data on the interaction effects of treatments on nutrient content of grain and straw are given in Table 12.

a) Nitrogen content

Interaction effect between N and P on increasing the N content of straw was significant at higher levels. Application of P at higher levels of N decreased the

Table 13. Effect of treatment levels on nutrient content of grain and straw, %

Treat-ments	Nitrogen		Phosphorus		Potassium		Calcium		Magnesium		Sulphur		Iron	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
N (kg ha^{-1})														
0	1.60	0.62	0.13	0.14	0.21	1.99	0.08	0.40	0.08	0.13	0.05	0.16	0.01	0.04
35	1.60	0.60	0.12	0.15	0.18	1.97	0.09	0.44	0.07	0.14	0.05	0.15	0.01	0.03
70	1.63	0.76	0.12	0.15	0.18	2.11	0.09	0.47	0.08	0.17	0.05	0.15	0.01	0.04
105	1.65	0.76	0.14	0.13	0.17	2.33	2.09	0.44	0.08	0.14	0.05	0.14	0.01	0.04
F	NS	0.01	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	0.08	0.07	0.01	0.01	0.02	0.16	0.01	0.03	0.01	0.02	0.01	0.01	0.02	0.01
CD (0.05)	-	0.13	-	-	-	-	-	-	-	-	-	-	-	-
P_2O_5 (kg ha^{-1})														
0	1.58	0.69	0.12	0.15	0.18	2.03	0.08	0.45	0.07	0.14	0.04	0.14	0.01	0.03
35	1.66	0.68	0.13	0.14	0.19	2.17	0.09	0.42	0.08	0.15	0.05	0.15	0.01	0.04
F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	0.06	0.05	0.01	0.01	0.01	0.11	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.01
CD (0.05)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cowpea seed rates														
25%	1.62	0.69	0.13	0.15	0.18	2.10	0.09	0.45	0.07	0.12	0.05	0.15	0.01	0.04
50%	1.62	0.69	0.12	0.14	0.19	2.10	0.08	0.42	0.08	0.16	0.05	0.15	0.01	0.03
F	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.01	NS	NS	NS	NS
SEm±	0.06	0.05	0.01	0.01	0.01	0.11	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.01
CD (0.05)	-	-	-	-	-	-	-	-	-	0.03	-	-	-	-
Mean for seed rate	1.62	0.69	0.13	0.15	0.19	2.10	0.09	0.44	0.08	0.14	0.05	0.15	0.01	0.04
Control	1.68	0.75	0.15	0.10	0.22	2.53	0.08	0.39	0.10	0.16	0.06	0.14	0.01	0.05
F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.05	NS
SEm±	0.162	0.132	0.026	0.026	0.036	0.312	0.026	0.068	0.015	0.036	0.013	0.018	0.005	0.026
CD (0.05)	-	-	-	-	-	-	-	-	-	-	-	-	0.009	-

N content while at lower levels the reverse was true. Highest N content of straw was recorded at 70 kg N ha^{-1} when the same was not accompanied by P.

b) Calcium content

Supplementing N with P application increased the Ca content of grain at 35 and 105 kg levels of N significantly and the magnitude of influence was more at lower levels of nitrogen.

c) Magnesium content

Phosphorus application with N could not improve the Mg content of straw. Thus highest Mg content of 0.2 per cent in rice straw was observed when 70 kg N ha^{-1} was given without P.

Data on interaction between P and cowpea seed rate show that lower seed rate of cowpea with P and higher seed rate without P increased the Mg content of grain and this combinations were found to be on par.

1.8 Nutrient ratios in the plant

1.8.1 Main effects

Application of increasing levels of N was found to have little influence on its ratios with elements other than K, S and Fe at 50 and 75 DAS (Table 14). Progressive increase in N levels tended to widen the N/Fe ratio at 50 DAS which was further widened at 75 DAS. N/K and N/S ratios remained more or less constant.

Table 14. Nutrient ratios in the plant as influenced by the treatment levels at different stages of rice

Levels of treatments	50 DAS						75 DAS					
	N/P	N/K	N/Ca	N/Mg	N/S	N/Fe	N/P	N/K	N/Ca	N/Mg	N/S	N/Fe
N (kg ha^{-1})												
0	7.45	0.65	4.66	10.64	10.64	24.83	6.71	0.69	4.41	9.40	10.07	35.25
35	10.14	0.94	6.66	11.83	15.21	53.25	8.50	0.79	4.47	14.17	13.08	42.50
70	9.90	0.85	6.12	12.24	13.87	34.67	8.95	0.84	5.22	10.44	14.46	47.00
105	10.00	0.81	6.06	11.11	13.33	40.00	9.09	0.82	5.03	12.73	11.94	47.75
P_2O_5 (kg ha^{-1})												
0	9.45	0.81	5.73	13.50	13.50	37.80	8.45	0.78	4.69	11.27	12.07	42.25
35	9.33	0.81	5.94	13.07	13.07	39.20	8.43	0.79	4.92	11.80	11.80	44.00
Cowpea seed rate												
25%	8.80	0.76	5.33	11.00	12.57	35.20	8.45	0.79	4.97	12.07	13.00	42.25
50%	9.95	0.86	6.33	11.61	13.93	41.80	8.38	0.79	4.63	11.73	11.73	44.00
Control	8.71	0.79	6.54	9.63	11.44	36.60	8.83	0.73	5.48	11.36	11.36	39.75

Phosphorus application did not have any worthwhile influence on ratios of N with other elements.

Compared with control intercropping cowpea widened the N/Mg, N/S and N/Fe ratios. Lower seed rate of cowpea tended to widen N/Fe ratio from 50th to 75th day.

1.8.2 Interaction effects

Among the interactions $N_2P_2S_2$ recorded the widest N/Fe ratio at 50 DAS and $N_3P_2S_1$ at 75 DAS. When N levels were low, N/Fe ratio tended to narrow down from 50th to 75th day and when N levels were high the N/Fe ratio tended to widen (Table 15).

1.9 Nutrient uptake by the crop

1.9.1 Main effects

Data on the main effects of treatments on the progressive removal of nutrients are presented in Table 16.

a) Nitrogen uptake

The data show that increasing levels of N increased the N removal by rice significantly throughout the crop growth. Though 105 kg level had a significant superiority over 70 kg level at 25 and 50 DAS, there was only a numerical superiority at 75 DAS which by the time of harvest declined to a deficit by 2 kg ha^{-1}. A general decrease in N uptake can also be noticed at the time of harvest.

Table 15. Interaction effect on nutrient ratios of rice

Levels of N	Cowpea seed rate	N/P P1	N/P P2	N/K P1	N/K P2	N/Ca P1	N/Ca P2	N/Mg P1	N/Mg P2	N/S P1	N/S P2	N/Fe P1	N/Fe P2
							50 DAS						
N1	S1	7.75	6.85	0.70	0.61	4.43	3.91	11.07	17.13	10.33	9.79	31.00	22.83
	S2	7.38	7.89	0.66	0.64	5.74	4.84	7.38	12.50	11.92	10.00	38.75	25.00
N2	S1	11.79	9.35	1.00	0.81	7.23	6.45	10.18	14.38	18.67	16.00	56.00	46.75
	S2	8.05	12.52	0.83	1.09	4.78	8.22	12.64	11.95	12.64	11.06	44.25	65.75
N3	S1	7.30	9.89	0.60	0.80	3.95	5.56	9.73	12.71	8.59	10.43	29.20	35.60
	S2	11.45	11.54	0.94	1.00	7.39	7.49	9.16	19.79	17.62	17.31	45.80	30.78
N4	S1	12.05	7.75	0.95	0.61	7.39	5.00	12.05	7.38	17.62	9.69	76.33	31.00
	S2	10.32	9.61	0.78	0.89	5.60	6.69	14.00	11.63	15.08	13.00	32.67	55.25
							75 DAS						
N1	S1	7.70	6.63	0.82	0.61	5.31	4.50	8.11	9.69	12.83	11.45	38.50	25.20
	S2	6.67	6.30	0.69	0.68	4.00	4.03	10.77	10.36	10.00	7.63	46.67	36.25
N2	S1	7.33	8.58	0.74	0.75	4.28	3.98	14.00	18.11	11.85	12.54	38.50	32.60
	S2	8.85	8.90	0.85	0.82	4.43	5.67	13.62	12.47	13.62	13.36	59.00	46.75
N3	S1	9.35	9.55	0.82	0.89	5.19	5.46	9.84	13.64	14.38	14.69	46.75	63.67
	S2	8.65	8.74	0.74	0.86	4.81	5.43	8.65	11.82	14.42	13.40	43.25	50.25
N4	S1	8.90	9.55	0.80	0.82	4.79	6.16	20.78	9.55	13.36	12.73	46.75	47.75
	S2	8.85	9.55	0.78	0.87	5.06	4.67	11.80	15.00	10.41	11.05	59.00	52.50

Levels of P: P1, P2

N1 - 0 kg N ha^{-1} P1 - 0 kg P_2O_5 ha^{-1}
N2 - 35 kg N ha^{-1} P2 - 35 kg ,, ha^{-1}
N3 - 70 kg N ha^{-1} S1 - 25% cowpea seed rate
N4 - 105 kg N ha^{-1} S2 - 50% ,,

Table 16. Effect of treatment levels on nutrient uptake by rice, kg ha^{-1}

Treatments	Nitrogen				Phosphorus				Potassium				Calcium			
	25 DAS	50 DAS	75 DAS	Harvest	25 DAS	50 DAS	75 DAS	Harvest	25 DAS	50 DAS	75 DAS	Harvest	25 DAS	50 DAS	75 DAS	Harvest
N (kg ha^{-1})																
0	14.87	41.26	67.12	61.65	1.86	4.40	10.25	9.48	18.19	64.33	95.10	103.44	1.96	8.59	14.68	21.51
35	18.48	62.36	90.60	61.47	2.01	5.06	11.66	9.16	22.80	62.10	120.56	84.38	2.83	8.53	18.84	20.13
70	18.72	59.41	119.32	86.47	1.94	6.05	12.63	11.13	18.17	75.39	139.47	115.89	2.19	10.22	21.98	27.24
105	22.99	68.91	121.24	84.66	1.58	5.75	14.28	10.64	18.31	74.69	153.32	127.41	2.07	9.10	23.11	25.63
p	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SEm±	0.67	1.02	1.45	1.05	0.06	0.10	0.80	0.55	0.64	1.10	1.24	2.98	0.08	0.30	0.71	0.83
CD (0.05)	1.37	2.08	2.96	2.13	0.13	0.21	1.64	1.11	1.33	2.25	2.52	6.07	0.17	0.61	1.46	1.69
P_2O_5 (kg ha^{-1})																
0	18.23	55.80	90.23	74.61	1.56	5.13	11.34	10.48	18.43	69.42	120.18	104.66	2.06	8.95	18.14	24.23
35	19.30	60.17	108.91	73.75	2.14	5.50	13.06	9.99	20.31	68.83	133.99	109.99	2.47	9.27	21.17	22.59
p	0.05	0.01	0.01	NS	0.01	0.01	0.01	NS	0.01	NS	0.01	0.01	0.01	NS	0.01	0.01
SEm±	0.48	0.78	1.03	0.74	0.04	0.07	0.57	0.39	0.45	0.78	0.88	2.11	0.06	0.21	0.51	0.59
CD (0.05)	0.97	1.47	2.09	-	0.09	0.15	1.16	-	0.92	-	1.78	4.29	0.121	-	1.03	1.19
Cowpea seed rate																
25%	20.49	54.12	102.36	71.51	1.87	5.32	11.69	10.05	20.72	66.04	128.30	100.07	2.51	9.23	19.34	22.72
50%	17.04	61.86	96.80	77.38	1.83	5.31	12.71	10.38	18.02	72.22	131.91	114.67	2.02	8.98	19.97	24.01
p	0.01	0.01	0.01	NS	NS	NS	NS	NS	0.01	0.01	0.01	NS	0.01	NS	NS	0.01
SEm±	0.48	0.72	1.03	0.74	0.04	0.07	0.57	0.39	0.45	0.78	0.88	2.11	0.06	0.21	0.51	0.59
CD (0.05)	0.97	1.47	2.09	-	-	-	-	-	0.92	1.59	1.78	-	0.121	-	-	0.197
Mean for seed rates	18.77	57.99	99.58	74.45	1.85	5.31	12.20	10.21	19.37	69.13	130.10	107.37	2.26	9.11	19.66	23.37
Control	18.32	36.79	112.66	80.92	1.53	3.71	10.79	8.77	20.37	40.63	79.73	124.38	2.04	4.96	9.17	20.43
p	NS	0.01	0.01	0.01	0.01	0.01	NS	NS	NS	0.01	0.01	0.01	NS	0.01	0.01	NS
SEm±	1.347	2.039	2.901	2.792	0.124	0.208	1.605	1.089	1.283	2.206	2.476	5.961	0.167	0.59	1.55	1.66
CD (0.05)	-	4.155	5.911	5.690	0.252	0.424	-	-	-	4.495	5.044	12.15	-	1.21	3.16	-

Contd.

Table **16**. Continued

Treatments	Magnesium				Sulphur				Iron			
	25 DAS	50 DAS	75 DAS	Harvest	25 DAS	50 DAS	75 DAS	Harvest	25 DAS	50 DAS	75 DAS	Harvest
N (kg ha^{-1})												
0	1.28	4.03	5.84	8.03	2.32	3.61	5.88	9.91	0.70	1.28	1.37	2.19
35	1.30	4.75	6.34	7.47	2.51	3.41	6.61	7.36	1.04	0.93	1.75	1.47
70	1.18	4.98	9.56	11.21	2.46	3.87	7.45	9.30	0.67	1.37	2.05	2.39
105	1.21	4.87	9.16	9.54	2.18	3.36	9.32	8.73	0.67	1.12	2.10	2.38
p	NS	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SEm±	0.05	0.09	0.16	0.91	0.09	0.11	0.26	0.49	0.04	0.09	0.08	0.08
CD (0.05)		0.19	0.33	1.86	0.19	0.23	0.54	1.00	0.07	0.19	0.16	0.16
P_2O_5 (kg ha^{-1})												
0	1.10	4.85	7.04	8.69	2.09	3.42	6.68	7.93	0.70	1.17	1.65	1.74
35	1.38	4.47	8.42	9.24	2.65	3.70	7.95	8.51	0.84	1.19	1.99	2.19
p	0.01	0.01	0.01	NS	0.01	0.01	0.01	NS	0.01	NS	0.01	0.01
SEm±	0.04	0.07	0.11	0.65	0.07	0.08	0.03	0.35	0.03	0.07	0.06	0.06
CD (0.05)	0.07	0.13	0.23	-	0.14	0.16	0.07	-	0.05	-	0.12	0.11
Cowpea seed rate												
25%	1.39	4.30	7.87	7.19	2.60	3.45	6.93	8.07	0.70	1.11	1.82	2.07
50%	1.10	5.01	7.59	10.41	2.13	3.67	7.69	9.12	0.84	1.25	1.81	1.82
p	0.01	0.01	0.05	0.01	0.01	0.05	0.01	NS	0.01	0.05	NS	0.01
SEm±	0.04	0.07	0.11	0.65	0.07	0.08	0.03	0.35	0.03	0.07	0.06	0.06
CD (0.05)	0.07	0.13	0.23	1.32	0.14	0.16	0.07	-	0.05	0.13	-	0.11
Mean for seed rates	1.25	4.66	7.73	8.80	2.37	3.56	7.31	8.59	0.77	1.18	1.81	1.94
Control	1.21	3.58	6.64	10.21	2.03	3.06	5.07	8.17	0.70	1.09	1.46	2.61
p	NS	0.01	0.01	0.05	0.05	0.01	0.01	NS	NS	NS	0.01	0.01
SEm±	0.103	0.18	0.32	1.83	0.19	0.23	0.53	0.793	0.073	0.184	0.161	0.16
CD (0.05)	-	0.38	0.65	3.73	0.39	0.46	1.07		-	-	0.33	0.31

Application of P significantly increased the N uptake at all stages except at harvest. Thus application of P @ 35 kg ha^{-1} increased the N uptake by 6, 8 and 20 per cent over no P at 25, 50 and 75 DAS, respectively.

Seed rate of cowpea also significantly influenced the N uptake by rice during the progressive stages of rice growth. Lower seed rate of cowpea registered a higher recovery at 25 and 75 DAS and the increases were 20 and 6 per cent over the higher seed rate. A comparison of the mean effects of intercropping with control showed that though nitrogen uptake in the normal practice was significantly low at 50 DAS it was higher at 75 DAS and harvest. Thus *in situ* green manuring registered an increase of 57 per cent in N uptake over control at 50 DAS, while it reduced the uptake by 11 and 8 per cent at 75 DAS and harvest, respectively.

b) Phosphorus uptake

Effect of increasing N levels on increasing the P uptake was manifested progressively with advancing growth. Thus 35 kg N ha^{-1} significantly recorded the highest P uptake on 25th day, 70 kg N on 50th day and 105 kg N on 75th day. A general decrease of P recovery was noticed at the time of harvest when maximum uptake was recorded at 70 kg N level.

Application of P caused a significantly higher uptake of P at 25, 50 and 75 DAS and the increases were 37, 7 and 15 per cent, while at harvest it showed a nonsignificant reduction.

Seed rates used in concurrent cropping of cowpea did not have any significant influence in affecting the P uptake at any stage of growth. Intercropping with cowpea recorded a significantly higher removal of P at 25 and 50 DAS over control and the increases worked out to 19.6 and 43 per cent at the respective stages.

c) Potassium uptake

It can be seen from the table that effect of N levels on K removal by rice changed with advancing growth. Thus 35 kg N ha^{-1} significantly recorded the highest K uptake at 25 DAS, 70 kg N at 50 DAS and 105 kg N at 75 DAS and harvest.

Application of P @ 35 kg ha^{-1} significantly increased the K uptake at 25 and 75 DAS and at harvest and the increases were 10.2, 11.5 and 5 per cent, respectively over no phosphorus.

At 25 DAS a lower seed rate of cowpea recorded a significantly higher removal of K while at 50 and 75 DAS significant increase was noticed with higher seed rate. A comparison of the normal practice and concurrent raising of green manure cowpea showed that concurrent raising of cowpea increased the K removal by rice significantly at all stages except at 25 DAS and harvest. Cowpea raising increased the K removal by 71 per cent at 50 DAS and 59 per cent at 75 DAS over control.

d) Calcium uptake

Just like P and K uptake significant effect of N levels on increasing the Ca uptake also increased with progressive advancement of time. Thus at 25 DAS maximum Ca removal was observed at 35 kg N ha^{-1} while at 50 and 75 DAS it was observed at 70 and 105 kg N levels, respectively.

Application of P increased the Ca uptake at all stages of rice growth except at harvest and the increases over no phosphorus at 25 and 75 DAS were 20, and 16.7 per cent respectively while at 50 DAS the effect was not significant.

Significant influence of variation in the seed rate of cowpea on Ca uptake by rice was manifested only at 25 DAS when a higher seed rate led to a lower removal and the percentage decline was 19.5 more than the lower seed rate. However, at harvest higher seed rate of cowpea contributed to a significantly higher Ca uptake. Simultaneous *in situ* growing of cowpea helped in a significant increase in the Ca uptake by rice at 50 and 75 DAS and the increases were 83 and 114 per cent more over control, respectively.

e) Magnesium uptake

Significant influence of N levels on Mg uptake by the crop became progressively apparent only with advancing growth. Thus in the semi-dry environment at early stages 35 kg N ha^{-1} recorded the highest uptake of 1.3 kg ha^{-1} and further increase in N levels tended to decline the Mg uptake by the crop. But at 50 and 75 DAS and at harvest 70 kg N ha^{-1} gave the highest Mg uptake of 4.98, 9.56 and 11.21 kg ha^{-1}.

Phosphorus application significantly increased the Mg uptake both at 25 and 75 DAS and the percentage increases were 25.5 and 19.6 respectively over no phosphorus application. However, at harvest the effect was not significant.

Comparative effects of seed rates of cowpea on Mg uptake revealed that lower seed rate of cowpea significantly improved the Mg uptake at 25 and 75 DAS, while at 50 DAS and at harvest higher seed rate showed highest uptake values. A comparison of concurrent cropping of cowpea with normal practice of rice cultivation on Mg uptake showed that concurrent cropping helped in raising the magnesium uptake significantly at 50 and 75 DAS and the increases were 30 and 16.4 per cent. But it failed to improve the Mg uptake significantly at harvest.

f) Sulphur uptake

Data presented in Table 16 show that while 35 kg N level gave the highest S uptake of 2.51 kg ha^{-1} on 25th day the effect of 70 kg N became more apparent and significantly superior at 50 DAS and at harvest with uptake of 3.87 and 9.3 kg ha^{-1} respectively. Application of 105 kg N ha^{-1} gave the highest S uptake of 9.32 kg ha^{-1} on 75th day but at the time of harvest this treatment was inferior to 70 kg N ha^{-1}.

Application of P increased the S uptake at all stages of growth and the effect was significant at harvest and the increases at 25, 50 and 75 DAS and at harvest were 26.8, 8.2, 19 and 7.3 per cent, respectively over no phosphorus application.

Higher seed rate of cowpea increased the S uptake by the crop significantly at 50 and 75 DAS over the lower seed rate and the corresponding increases were 6.4 and 10.9 per cent. The data also show that concurrent cropping recorded a higher uptake of S over control at all progressive stages and the increases were 16.3, 16.3, 44.2 and 5.2 per cent, respectively.

g) Iron uptake

Application of N increased the Fe uptake and the significant effect of progressive increase in N levels became apparent with advancing growth. Thus N_2, N_3 and N_4 recorded Fe uptake values of 1.04, 1.37 and 2.1 kg ha^{-1} at 25, 50 and 75 DAS respectively.

Application of P at 35 kg ha^{-1} increased the Fe uptake significantly at all stages of observation except at 50 DAS and the increases over no phosphorus application at 25 and 75 DAS and at harvest were 20, 20.6 and 22 per cent, respectively.

A higher seed rate of cowpea significantly increased the Fe uptake both at 25 and 50 DAS, while this trend was reversed towards the later stages, and at harvest lower seed rate increased the Fe uptake significantly. A comparison between concurrent cropping of cowpea and control showed that they did not differ significantly in Fe uptake in the early growth phase. At 75 DAS concurrent cropping showed a significantly higher uptake where as at the time of harvest control recorded higher uptake.

1.9.2 Interaction effects

Data on the interaction effects on nutrient uptake by rice are presented in Table 17.

a) Nitrogen uptake

Significant interaction effect between N and P on N uptake was observed at all stages of observation. Thus application of P with increasing levels of N

Table 17. Interaction effect on nutrient uptake by rice, kg ha^{-1}

a. N x P

Levels of P / Levels of N	25 DAS P1	25 DAS P2	50 DAS P1	50 DAS P2	75 DAS P1	75 DAS P2	Harvest P1	Harvest P2
Nitrogen								
N1	13.48	16.25	46.00	36.51	71.08	63.16	56.40	66.48
N2	17.28	19.69	55.32	69.39	87.63	93.58	63.26	68.42
N3	18.44	18.99	55.96	62.87	98.08	140.56	98.59	75.42
N4	23.71	22.28	65.91	71.91	104.13	138.34	84.02	85.00
P	0.05		0.01		0.01		0.01	
SEm±	0.952		1.442		2.051		1.478	
CD (0.05)	1.940		2.937		4.178		3.011	
Phosphorus								
N1	1.47	2.26	4.79	4.01	10.69	9.81	7.69	5.0
N2	1.96	2.07	4.48	5.64	12.11	11.21	6.38	9.13
N3	1.51	2.38	5.29	6.81	9.75	15.50	11.07	7.40
N4	1.29	1.87	5.95	5.55	12.82	15.73	7.81	9.67
P	0.01		0.01		0.01		0.01	
SEm±	0.088		0.147		1.135		0.770	
CD (0.05)	0.178		0.299		2.363		1.569	
Potassium								
N1	17.22	19.17	66.30	62.37	97.39	92.62	95.69	111.17
N2	20.81	24.80	55.47	68.73	120.07	121.04	72.33	96.59
N3	15.73	20.61	73.36	77.43	119.29	159.65	138.38	94.32
N4	19.96	16.66	82.57	66.80	143.96	162.68	116.15	139.62
P	0.01		0.01		0.01		0.01	
SEm±	0.907		1.559		1.751		4.215	
CD (0.05)	1.848		3.177		3.566		8.587	

contd.

				Calcium				
N1	1.80	2.12	8.40	8.77	14.44	14.93	21.49	20.97
N2	2.49	3.16	7.73	9.33	20.64	17.04	17.87	21.39
N3	1.80	2.58	9.95	10.64	17.72	26.25	34.45	20.80
N4	2.14	2.00	9.71	8.49	19.78	26.44	26.51	27.91
p	0.01		0.01		0.01		0.01	
SEm±	0.118		0.421		1.010		1.175	
CD(0.05)	0.241		0.858		2.058		2.394	
				Magnesium				
N1	1.06	1.49	5.11	2.95	5.72	5.97	7.26	8.10
N2	1.28	1.32	4.32	5.18	6.57	6.11	6.84	8.09
N3	0.90	1.45	5.99	3.97	9.48	9.64	14.46	8.19
N4	1.15	1.27	3.97	5.76	6.37	11.95	7.09	11.83
p	0.01		0.01		0.01		0.01	
SEm±	0.073		0.130		0.227		1.293	
CD (0.05)	0.149		0.266		0.462		2.634	
				Sulphur				
N1	2.04	2.58	3.78	3.43	5.59	6.16	7.69	9.50
N2	2.49	2.53	3.20	3.61	6.45	6.75	6.38	9.13
N3	1.90	3.02	3.68	4.06	6.08	8.81	11.07	7.40
N4	1.91	2.45	3.01	3.70	8.56	10.06	7.81	9.67
p	0.01		0.01		0.01		0.01	
SEm±	0.137		0.160		0.372		0.695	
CD (0.05)	0.278		0.326		0.758		1.415	
				Iron				
N1	0.64	0.76	1.15	1.41	1.19	1.54	2.43	2.78
N2	0.92	1.15	0.85	1.01	1.65	1.86	1.93	2.39
N3	0.53	0.80	1.45	1.34	1.99	2.10	3.53	2.91
N4	0.69	0.64	1.24	0.99	1.76	2.44	1.92	3.90
p	0.01		0.05		0.01		0.01	
SEm±	0.052		0.130		0.114		0.109	
CD (0.05)	1.105		0.260		0.232		0.223	

contd.

b. N x Cowpea and P x Cowpea

Levels of N and P	25 DAS		50 DAS		75 DAS		Harvest	
	S1	S2	S1	S2	S1	S2	S1	S2
Nitrogen								
N1	14.84	14.89	40.02	42.49	71.95	62.28	60.87	61.55
N2	21.48	15.48	68.02	56.69	82.53	98.67	61.18	69.96
N3	19.88	17.55	41.98	76.85	129.61	109.02	79.98	93.67
N4	25.75	20.24	66.44	71.39	125.35	117.12	82.94	82.93
p	0.01		0.01		0.01		0.01	
SEm±	0.05		1.44		1.05		1.48	
CD(0.05)	1.94		2.94		4.18		3.01	
P1	18.43	18.02	53.00	58.59	94.79	85.66	72.06	76.84
P2	22.25	16.06	55.22	65.12	109.94	107.88	70.29	76.52
p	0.01		0.01		0.01		0.01	
SEm±	0.67		1.02		1.45		1.05	
CD(0.05)	1.37		2.08		2.96		2.13	
Phosphorus								
N1	2.07	1.66	4.49	4.31	8.71	11.80	8.39	8.80
N2	1.84	2.18	5.67	4.45	9.84	13.48	7.56	7.16
N3	2.10	1.78	5.67	6.43	13.05	12.20	6.83	11.45
N4	1.46	1.70	5.45	6.06	15.18	13.37	8.70	9.01
p	0.01		0.01		0.01		0.01	
SEm±	0.09		0.15		1.13		0.77	
CD (0.05)	0.18		0.30		2.31		1.57	
P1	1.46	1.65	4.88	5.38	10.78	11.90	20.26	22.82
P2	2.28	2.01	5.77	5.24	12.60	13.52	19.91	25.90
p	0.01		0.01		NS		0.01	
SEm±	0.06		0.10		0.80		0.55	
CD (0.05)	0.13		0.21		-		1.11	
Potassium								
N1	19.74	16.65	62.00	66.66	96.79	93.22	100.39	106.29
N2	22.33	23.27	64.34	59.56	100.41	140.70	91.89	76.86
N3	20.70	15.63	67.29	83.49	138.71	140.23	78.34	156.94
N4	20.09	16.53	70.51	78.87	153.17	153.47	130.70	124.02
p	0.01		0.01		0.01		0.01	
SEm±	0.91		1.56		1.75		4.22	
CD (0.05)	1.85		3.18		3.57		8.59	
P1	18.19	18.67	63.24	75.61	115.74	124.62	107.54	101.89
P2	23.25	17.37	68.84	68.83	128.00	139.19	91.68	129.05
p	0.01		0.01		NS		0.01	
SEm±	0.64		1.10		1.24		2.98	
CD (0.05)	1.31		2.25		-		6.07	

Contd

Calcium

N1	2.20	1.73	9.09	8.08	13.42	15.94	22.21	20.64
N2	2.92	2.73	9.39	7.67	18.22	19.46	20.51	19.31
N3	2.57	1.81	10.17	10.43	24.03	19.94	20.97	33.57
N4	2.34	1.80	8.29	9.91	21.67	24.55	27.41	23.70
p		0.05		0.01		0.01		0.01
SEm±		0.12		0.42		1.01		1.17
CD (0.05)		0.24		0.86		2.06		2.39
P1	2.04	2.07	8.23	9.66	18.11	18.71	26.63	21.35
P2	2.97	1.96	10.23	8.38	20.56	21.77	19.57	26.42
p		0.01		0.01		NS		0.01
SEm±		0.08		0.29		0.71		0.83
CD(0.05)		0.17		0.61		-		1.69

Magnesium

N1	1.56	0.99	3.16	4.90	6.76	4.93	6.42	8.89
N2	1.48	1.21	4.80	4.70	4.89	7.80	6.28	8.50
N3	1.29	1.06	4.15	5.81	10.08	9.05	7.44	15.59
N4	1.21	1.21	5.10	4.64	9.74	8.58	9.72	9.33
p		0.01		0.01		0.01		0.01
SEm±		0.07		0.13		0.23		1.29
CD (0.05)		0.15		0.27		0.46		2.63
P1	1.10	1.10	4.27	5.42	6.93	7.14	7.15	9.91
P2	1.67	1.09	4.33	4.60	8.80	8.04	7.82	10.59
p		0.01		0.01		0.01		NS
SEm		0.05		0.09		0.16		0.91
CD (0.05)		0.11		0.19		0.33		-

Sulphur

N1	2.65	1.98	3.37	3.84	4.85	6.90	8.31	8.88
N2	2.58	2.44	3.25	3.57	6.15	7.05	7.56	7.16
N3	2.76	2.16	3.84	3.81	8.13	6.76	6.83	11.45
N4	2.43	1.93	3.35	3.36	8.57	10.05	8.70	9.01
p		0.05		NS		0.01		0.01
SEm±		0.14		0.16		0.37		0.69
CD (0.05)		0.28		-		0.76		1.41
P1	2.06	2.12	3.27	3.57	6.25	7.10	8.45	7.91
P2	3.15	2.14	3.64	3.77	7.60	8.28	7.45	10.36
p		0.01		NS		NS		0.01
SEm±		0.10		0.11		0.26		0.50
CD (0.05)		0.20		-		-		1.00

Iron

N1	0.67	0.73	1.19	1.36	1.38	1.36	2.23	1.66
N2	0.81	1.26	1.06	0.79	1.56	1.95	1.51	1.43
N3	0.76	0.57	1.26	1.53	2.29	1.80	1.43	2.97
N4	0.54	0.79	0.92	1.31	2.06	2.14	1.79	3.54
p		0.01		0.01		0.01		0.01
SEm±		0.05		0.13		0.11		0.11
CD (0.05)		0.11		0.27		0.23		0.22
P1	0.56	0.83	1.03	1.31	1.72	1.57	1.74	1.73
P2	0.83	0.85	1.19	1.19	1.92	2.06	1.49	3.03
p		0.01		0.05		0.05		0.01
SEm±		0.04		0.09		0.08		0.08
CD (0.05)		0.07		0.19		0.16		0.16

contd.

c. N x P x Cowpea

Levels of N	Cowpea seed rate	25 DAS P1	25 DAS P2	50 DAS P1	50 DAS P2	75 DAS P1	75 DAS P2	Harvest P1	Harvest P2
		Nitrogen							
N1	S1	9.79	19.89	43.42	36.63	63.30	80.61	56.39	64.57
	S2	17.16	12.62	48.59	36.40	78.85	45.70	55.02	68.48
N2	S1	20.82	22.15	74.66	61.38	100.15	64.91	56.63	66.12
	S2	13.74	17.22	35.98	77.41	75.10	122.25	69.00	70.98
N3	S1	14.87	24.89	37.77	46.18	112.99	146.24	62.32	69.43
	S2	22.01	13.09	74.15	79.55	83.16	134.88	103.08	83.45
N4	S1	28.24	23.26	56.17	76.71	102.70	148.00	83.06	83.34
	S2	19.17	21.30	75.65	67.12	105.55	128.69	87.41	85.23
p		0.01		0.01		0.01		0.01	
SEm±		1.347		2.038		2.901		2.096	
CD (0.05)		2.744		4.153		5.909		4.270	
		Phosphorus							
N1	S1	1.28	2.85	4.16	4.82	7.35	10.06	10.29	8.00
	S2	1.66	1.66	5.42	3.19	14.04	9.56	8.61	11.31
N2	S1	1.96	1.73	5.23	6.11	12.77	6.91	7.29	10.36
	S2	1.96	2.40	3.72	5.18	11.46	15.50	9.28	8.21
N3	S1	1.20	3.01	5.27	6.08	10.46	15.46	12.63	7.51
	S2	1.81	1.75	5.31	7.54	8.85	15.55	13.68	12.52
N4	S1	1.39	1.52	4.84	6.05	12.38	17.98	10.02	11.50
	S2	1.18	2.23	7.06	5.06	13.26	13.48	9.67	13.28
p		0.01		0.01		0.01		0.01	
SEm±		0.124		0.208		1.605		1.089	
CD (0.05)		0.252		0.424		3.271		2.219	
		Potassium							
N1	S1	16.36	23.13	65.47	58.53	91.78	101.80	108.55	91.99
	S2	18.09	15.21	67.12	66.21	103.01	83.43	82.42	132.34
N2	S1	19.52	25.14	62.92	65.77	114.49	86.32	67.25	118.39
	S2	22.09	24.46	48.02	71.69	125.65	155.76	76.81	76.88
N3	S1	15.37	26.04	64.63	69.96	124.67	152.75	114.49	44.09
	S2	16.08	15.18	82.08	84.90	113.91	166.56	164.12	150.07
N4	S1	21.49	18.69	59.92	81.09	132.01	174.34	143.37	117.09
	S2	18.42	14.64	105.21	52.52	155.92	151.01	91.72	161.87
p		0.01		0.01		0.01		0.01	
SEm±		1.283		2.206		2.476		5.961	
CD (0.05)		2.614		4.494		5.043		12.144	

Contd

					Calcium				
N1	S1	1.78	2.62	8.80	9.38	12.13	14.72	26.33	17.88
	S2	1.83	1.62	8.01	8.16	16.74	15.14	17.15	24.14
N2	S1	2.04	3.81	8.32	10.46	21.17	15.27	16.70	23.98
	S2	2.94	2.51	7.13	8.20	20.10	18.81	18.88	19.29
N3	S1	1.67	3.47	9.65	10.69	19.08	28.98	32.02	11.38
	S2	1.93	1.69	10.25	10.60	16.35	23.52	36.59	30.43
N4	S1	2.69	1.98	6.17	10.40	20.07	23.26	31.83	23.21
	S2	1.58	2.02	13.24	6.58	19.48	29.62	15.76	32.32
p		0.01		0.01		0.01		0.01	
SEm±		0.167		0.596		1.549		1.662	
CD (0.05)		0.341		1.213		3.157		3.386	
					Magnesium				
N1	S1	1.17	1.96	3.94	2.39	6.85	6.66	6.81	5.82
	S2	0.95	1.03	6.28	3.52	4.59	5.27	7.62	10.54
N2	S1	1.28	1.68	5.63	3.96	5.97	3.80	4.56	8.42
	S2	1.29	0.95	3.00	6.40	7.18	8.42	9.09	7.97
N3	S1	0.85	1.73	4.08	4.22	10.15	10.01	9.98	5.27
	S2	0.95	1.17	7.90	3.72	8.81	9.28	19.69	12.26
N4	S1	1.10	1.32	3.45	6.74	4.76	14.73	7.43	11.24
	S2	1.20	1.22	4.49	4.79	7.98	9.17	6.69	12.24
p		0.05		0.01		0.01		0.05	
SEm±		0.103		0.184		0.320		1.829	
CD (0.05)		0.210		0.376		0.653		3.762	
					Sulphur				
N1	S1	2.21	3.09	3.91	2.84	4.89	4.80	8.17	8.37
	S2	1.88	2.08	3.65	4.03	6.30	7.50	7.05	10.73
N2	S1	2.16	3.00	3.12	3.38	5.87	6.44	6.05	9.81
	S2	2.82	2.07	3.29	3.85	7.04	7.07	7.04	6.85
N3	S1	1.62	3.89	3.53	4.15	6.79	9.48	9.88	9.92
	S2	2.17	2.14	3.84	3.97	5.38	8.14	11.57	11.20
N4	S1	2.23	2.63	2.52	4.18	7.45	9.70	9.83	7.73
	S2	1.60	2.27	3.49	3.23	9.68	10.43	5.80	11.95
p		0.01		0.01		NS		0.01	
SEm±		0.193		0.227		0.526		0.983	
CD (0.05)		0.394		0.462				2.002	
					Iron				
N1	S1	0.61	0.73	1.28	1.11	1.21	1.54	1.86	2.49
	S2	0.67	0.80	1.01	1.72	1.17	1.55	1.51	2.49
N2	S1	0.66	0.96	1.06	1.07	1.47	1.64	1.51	1.84
	S2	1.18	1.34	0.64	0.94	1.82	2.08	1.47	1.39
N3	S1	0.54	0.98	1.09	1.42	2.31	2.27	2.47	0.73
	S2	0.52	0.63	1.81	1.25	1.67	1.93	3.07	3.55
N4	S1	0.44	0.64	0.68	1.15	1.90	2.21	1.97	1.62
	S2	0.95	0.63	1.79	0.84	1.61	2.67	1.22	5.87
p		0.01		0.01		NS		0.01	
SEm±		0.073		0.184		0.161		0.155	
CD (0.05)		0.149		0.376				0.316	

N1 - 0 kg N ha^{-1}
N2 - 35 kg N ha^{-1}
N3 - 70 kg N ha^{-1}
N4 - 105 kg N ha^{-1}

P1 - 0 kg P_2O_5 ha^{-1}
P2 - 35 kg ,, ha^{-1}
S1 - 25% cowpea seed rate
S2 - 50% ,,

increased the N uptake but at harvest highest uptake was observed when 70 kg N ha^{-1} was applied alone.

At 25 and 75 DAS higher levels of N with lower seed rate of cowpea significantly increased the N uptake, while at 50 DAS and at harvest highest uptake was noticed at higher levels of N along with higher seed rate of cowpea.

Application of P @ 35 kg ha^{-1} along with lower seed rate of cowpea increased the N recovery at 25 and 75 DAS, while at 50 DAS and at harvest P application with higher seed rate increased the N uptake by the crop.

Phosphorus application along with higher seed rate of cowpea significantly decreased the N recovery by rice at all levels of N at 25 DAS. However, the trend was changed at 50 and 75 DAS. On 50th day P application with higher seed rate increased the N uptake at 35 and 70 kg levels of N while at 75 DAS the decline was not observed at 35 kg N ha^{-1}.

b) Phosphorus uptake

Data on the combined effect of N and P on P uptake by rice show that the effect was manifested only upto 70 kg N level at all stages of growth. Thus maximum uptake value of 15.73 kg ha^{-1} at 75 DAS, though noticed at 105 kg N level, was on par with the uptake recorded at 70 kg N and 35 kg P ha^{-1}.

It can be seen from the table that combined effect of a higher cowpea seed rate with increasing N levels on P uptake which commenced on 25th day became progressively more apparent with advancing growth. Thus the highest uptake values of 2.18 and 6.43 kg ha^{-1} at 25 and 50 DAS were observed at N_2S_2 and N_3S_2

levels, respectively. At 75 DAS the highest uptake of 15.18 kg ha^{-1} though noticed at N_4S_1 level, was on par with N_2S_2. The data also show that the P recovery at harvest by the crop declined and the highest uptake of 11.45 kg ha^{-1} was recorded at N_3S_2 level.

Data on the combined effect of P and green manure cowpea show that at 25 and 50 DAS P application with lower seed rate of cowpea registered a significantly higher P removal and the values were 13 and 10 per cent higher than those with a higher seed rate. But at harvest highest removal was noticed when P was applied along with a higher seed rate of cowpea.

Maximum P uptake of 3.01 kg ha^{-1} at 25 DAS was recorded at $N_3P_2S_1$ level and at 50 DAS at $N_3P_2S_2$ level and these were significantly superior to all other combinations. However, at 75 DAS highest plant uptake of P was recorded by $N_4P_2S_1$ combination and at harvest by $N_4P_2S_2$ which was on par with that at $N_3P_2S_2$.

c) Potassium uptake

Interaction effect between N and P on K uptake was found to be significant at all stages of rice growth. Highest K uptake at 25 DAS was recorded at N_2P_2 and that at 75 DAS and at harvest at N_4P_2. The uptake of 162.68 kg ha^{-1} at N_4P_2 by 75th day was on par with N_3P_2.

Combined effect of cowpea and N on K uptake was seen to have changed with the variation in the N levels. Thus the highest removal of 23.27, 83.49 and 153.47 kg ha^{-1} at 25, 50 and 75 DAS were recorded by N_2S_2, N_3S_2 and N_4S_2, respectively.

The trend of K removal by the interaction effect between cowpea seed rate and P followed a zig-zag pattern with advancing growth of rice. Highest K removal of 23.25, 75.61 and 139.19 kg ha^{-1} at 25, 50 and 75 DAS were recorded by P_2S_1, P_1S_2 and P_2S_2 combinations respectively. At harvest P_2S_2 recorded the highest uptake.

The data show that $N_3P_2S_1$, $N_4P_1S_2$, $N_4P_2S_1$ and $N_3P_1S_2$ recorded the highest removal of K at 25, 50 and 75 DAS and at harvest. Thus at higher levels of N a higher seed rate of cowpea in the absence of P or a lower seed rate of cowpea in the presence of P increased the K uptake by rice.

d) Calcium uptake

Interacting influence of N and P on Ca uptake was significant at all stages and the effect of higher levels of N with P was manifested with advancement in growth. Thus at 25, 50 and 75 DAS the highest uptake was recorded at N_2P_2, N_3P_2 and N_4P_2 combinations, respectively. At harvest N_3P_1 recorded the highest Ca uptake and this was significantly superior to other treatment combinations.

Interaction effect between seed rate of cowpea and N levels was significant on Ca uptake. Maximum Ca uptake was recorded by N_2S_1, N_3S_2, N_4S_2 and N_3S_2 combinations at 25, 50 and 75 DAS and at harvest, respectively. Thus towards the later stages a higher seed rate of cowpea increased the Ca uptake at higher levels of N.

Application of P at 35 kg ha^{-1} with a lower seed rate of cowpea significantly increased the Ca uptake by rice both at 25 and 50 DAS. But towards the later stages this trend was changed.

Combined effect of N, P and cowpea was significant on Ca uptake at all the stages of observation and the magnitude of effect increased with advancing levels as growth progressed. Thus highest Ca uptake of 3.81, 13.24 and 29.62 kg ha^{-1} at 25, 50 and 75 DAS were recorded respectively at $N_2P_2S_1$, $N_4P_1S_2$ and $N_4P_2S_2$ levels. However, at harvest highest Ca uptake was recorded at $N_3P_1S_2$ level.

e) Magnesium uptake

Significant influence of combined effect of N and P on Mg uptake varied with levels of N as well as crop growth phases. Thus at 50 DAS and at harvest highest Mg uptake was recorded at N_3P_1 level while at 75 DAS it was at N_4P_2 and these were found significantly superior to all other combinations.

Interaction effect between N and cowpea on Mg uptake was significant at all stages of rice growth. At 25 DAS N_2S_1 and at 75 DAS N_3S_1 recorded the highest Mg uptake while at 50 DAS and at harvest N_3S_2 recorded the highest uptake.

Application of P @ 35 kg ha^{-1} along with lower seed rate of cowpea significantly increased the Mg uptake at 25 and 75 DAS and the increases were 53 and 9.5 per cent more over P_2S_2. However, significantly higher Mg uptake of 10.59 kg ha^{-1} at harvest was recorded when P was applied along with a higher seed rate.

Second order interaction effect among N, P and seed rate of cowpea showed that highest Mg uptake values of 7.9 and 14.73 kg ha^{-1} at 50 and 75 DAS were observed at $N_3P_1S_2$ and $N_4P_2S_1$ levels, respectively and that they were significantly superior to the rest of the treatment combinations. The results also showed that with increasing levels of N (70 and 105 kg ha^{-1}), application of P with higher seed rate of concurrent crop significantly reduced the Mg uptake. At the time of harvest also highest Mg uptake was recorded at $N_3P_1S_2$ levels and it was significantly superior to all other combinations.

f) Sulphur uptake

It can be seen that interaction effect between N and P significantly influenced the S uptake at all stages of rice growth. N_3P_2 gave the highest uptake of 3.02 and 4.06 kg ha^{-1} at 25 and 50 DAS where as at 75 DAS N_4P_2 gave the highest uptake value. However, at harvest N_4P_2 and N_3P_1 were on par.

The interaction effect between N levels and seed rate of cowpea significantly influenced the S uptake at all stages of rice growth except at 50 DAS. Highest S uptake was recorded by N_3S_1 in the initial stages, while towards the later stages, higher levels of N recorded higher uptake values with higher seed rate of cowpea.

Seed rate of cowpea and P significantly interacted to influence the S uptake only at 25 DAS and at harvest. At 25 DAS P_2S_1 recorded an uptake of 3.15 kg ha^{-1} which was superior to other three combinations where as at harvest P_2S_2 gave the highest uptake of 10.36 kg ha^{-1}.

Data on the interaction effect among N, P and cowpea seed rate show that $N_3P_2S_1$ and $N_4P_2S_1$ gave the highest S uptake of 3.89 and 4.18 kg ha^{-1} at 25 and 50 DAS while $N_4P_2S_2$ gave the highest uptake of 10.43 and 11.95 kg ha^{-1} at 75 DAS and harvest, respectively.

g) Iron uptake

Application of N at 105 kg level combined with P gave the highest Fe uptake at 75 DAS and at harvest and this was significantly superior to other combinations. The uptake values at these stages were 2.44 and 3.9 kg ha^{-1}. This meant that higher levels of P and N were conducive to a higher uptake of Fe in the later stages of crop growth.

Application of 70 kg N ha^{-1} combined with higher seed rate of cowpea recorded the highest Fe uptake by the crop at 50 DAS while at harvest it was by N_4S_2.

Treatments combining higher seed rate of cowpea and P significantly increased the Fe uptake by rice at 75 DAS and at harvest.

The second order interaction shows that maximum Fe uptake values of 2.67 and 5.87 kg ha^{-1} at 75 DAS and at harvest were recorded by $N_4P_2S_2$ and these were superior to all other combinations. But during the earlier stages this trend was not observed. The data also show that $N_3P_2S_1$ recorded the least Fe uptake by the crop at the time of harvest.

1.10 Disease and pest incidence

Data on the main effects of treatments on the incidence of pests and diseases are given in Table 18.

Table 18. Effect of treatment levels on pest and disease incidence in rice

Treatments	Disease Index (Sheath blight)	% Incidence of leaf roller
N (kg ha^{-1})		
0	24.00	6.69
35	28.56	7.95
70	33.51	10.42
105	38.29	10.25
p	0.05	0.01
SEm±	2.47	0.97
CD (0.05)	5.04	1.97
P_2O_5 (kg ha^{-1})		
0	28.09	8.48
35	24.09	9.18
p	0.01	NS
SEm±	1.75	0.68
CD (0.05)	3.56	-
Cowpea seed rate		
25%	31.92	8.97
50%	30.26	8.68
p	NS	NS
SEm±	1.75	0.68
CD (0.05)	-	-
Mean for seed rate	31.09	8.83
Control	24.30	3.27
p	NS	NS
SEm±	4.946	1.935
Cd (0.05)	-	-

1.10.1 Main effects

Progressive increase in the levels of N application significantly increased the incidence of sheath blight in rice. Maximum incidence was observed at the highest level of N which was significantly superior to the lower levels of N_1 and N_2. Though statistically on par, enhancement of N level from 70 to 105 kg ha^{-1} increased the disease index by 14 per cent. As against the effect of N, application of P @ 35 kg ha^{-1} significantly reduced the disease index and the decline worked out to 14 per cent over no P. Further, though there was no significant difference between the two levels of seed rate on the incidence of sheath blight, concurrent raising of cowpea increased the incidence by 28 per cent over control but the effect was not significant.

The data on leaf roller incidence show that application of increased levels of N increased the incidence of leaf roller significantly, while application of P did not have any effect. Thus application of N @ 70 kg ha^{-1} increased the leaf roller incidence by 31 per cent over 35 kg N ha^{-1}. Leaf roller incidence was unaffected by further increase in N levels. The data also show that *in situ* raising of green manure cowpea increased the incidence of leaf roller in rice over control but variation in the seed rate of cowpea had no significant effect.

1.10.2 Interaction effects

Data on interaction effects on pest and disease are presented in Table 19.

The results showed that P application without N was conducive to the incidence of disease. Similarly at lower levels of N simultaneous raising of cowpea

Table 19. Interaction effect on pest and disease incidence in rice

a. N x P, N x Cowpea and P x Cowpea

Levels of P & Cowpea seed rate / Levels of N & P	Disease incidence				% incidence of leaf roller			
	P1	P2	S1	S2	P1	P2	S1	S2
N1	18.12	29.88	27.43	20.57	4.38	9.01	8.45	4.94
N2	30.27	26.85	29.80	27.32	8.62	7.28	7.08	8.82
N3	23.59	43.43	29.64	37.38	9.91	10.92	12.62	8.20
N4	40.40	36.19	40.81	35.78	11.00	9.50	7.75	12.76
p	0.01		0.05		0.05		0.01	
SEm±	3.50		3.50		1.37		1.37	
CD (0.05)	7.13		7.13		2.79		2.79	
P1			32.35	23.85			7.95	9.0
P2			31.50	36.68			10.00	8.36
p			0.01				NS	
SEm±			2.47				0.97	
CD (0.05)			5.04				-	

b. N x P x Cowpea

Levels of N	Cowpea seed rate	Disease index P1	Disease index P2	% incidence of leaf roller P1	% incidence of leaf roller P2
N1	S1	20.23	34.64	5.31	11.59
	S2	16.00	25.13	3.45	6.42
N2	S1	36.27	23.32	7.91	6.24
	S2	24.27	30.38	9.32	8.32
N3	S1	26.61	32.68	9.98	15.27
	S2	20.57	54.19	9.83	6.58
N4	S1	46.27	35.35	8.60	6.89
	S2	34.53	37.03	13.40	12.11
p		0.05		NS	
SEm±		4.95		1.94	
CD (0.05)		10.08		-	

N1 - 0 kg N ha^{-1}
N2 - 35 kg N ha^{-1}
N3 - 70 kg N ha^{-1}
N4 - 105 kg N ha^{-1}

P1 - 0 kg P_2O_5 ha^{-1}
P2 - 35 kg ,, ha^{-1}
S1 - 25% cowpea seed rate
S2 - 50% ,,

with a higher seed rate tended to reduce the incidence of sheath blight while at higher levels of N the reverse was observed. Whereas application of P accompanied by a higher seed rate of cowpea tended to increase the disease index. Interaction effect among N, P and seed rate of cowpea was found to be significant and the highest disease index was recorded when 70 kg N and 35 kg P ha^{-1} were accompanied by a higher seed rate of cowpea. On the other hand the same levels of N and seed rate of cowpea with no phosphorus application drastically reduced the disease index by 60 per cent.

Data presented in the table further show that least percentage incidence of leaf roller was noticed at N_1P_1 combination and the highest at N_4P_1 and the differences were statistically significant. Nitrogen x cowpea interaction showed the highest incidence of leaf roller at N_3S_1 and N_4S_2 levels and the lowest at N_1S_2 and the differences were statistically significant. At 105 kg N ha^{-1} leaf roller incidence was significantly increased by a higher seed rate of cowpea while at 70 kg N a lower seed rate was conducive.

1.11 Yield attributes

1.11.1 Main effects

Data on the main effects of treatments on the yield attributes are presented in Table 20.

Results showed that application of N significantly increased the length of panicle, filled grains per panicle, total grains per panicle, 1000 grain weight and grain-straw ratio. The maximum panicle length of 22.29 cm was recorded at 105 kg level of N which was significantly superior to N_1 level and the increase worked out

Table 20 Effect of treatment levels on yield attributes and yield of rice

Treat-ments	Productive tillers/ hill	Panicle length cm	Filled grains/ panicle	Total grains/ panicle	% of filled grains/ panicle	1000 grain weight g	Yield ($q\ ha^{-1}$) Grain	Straw	Chaff	Grain straw ratio	Harvest Index
N ($kg\ ha^{-1}$)											
0	6.25	20.76	93.83	113.87	82.57	31.58	19.13	15.76	1.30	1.12	0.545
35	7.07	21.51	107.53	125.67	85.64	32.56	25.74	19.81	1.47	1.32	0.553
70	6.83	22.02	104.95	127.10	82.79	32.46	28.58	26.79	1.84	1.09	0.518
105	7.57	22.29	102.84	126.59	82.23	32.51	27.03	25.14	1.90	1.09	0.515
p	NS	0.01	0.05	0.05	NS	0.05	0.01	0.01	0.01	0.01	NS
SEm±	0.501	0.395	4.073	4.742	2.09	0.109	1.832	1.681	0.175	0.073	0.018
CD (0.05)	-	0.805	8.297	9.66	-	0.221	3.733	3.425	0.356	0.149	-
P_2O_5 ($kg\ ha^{-1}$)											
0	6.74	21.71	102.57	126.94	81.36	32.36	25.70	23.51	1.62	1.11	0.521
35	7.12	21.58	102.01	119.67	85.25	32.19	24.54	20.24	1.64	1.26	0.544
p	NS	NS	NS	0.05	0.05	NS	NS	0.01	NS	0.01	NS
SEm±	0.354	0.279	2.879	3.353	1.478	0.233	1.298	1.189	0.123	0.052	0.013
CD (0.05)	-	-	-	6.832	3.011	-	-	2.422	-	0.105	-
Cowpea seed rate											
25%	6.85	21.57	101.22	122.54	82.78	31.98	25.49	21.89	1.62	1.19	0.530
50%	7.01	21.72	103.36	124.08	83.83	32.58	24.75	21.86	1.63	1.17	0.535
p	NS	NS	NS	NS	NS	0.05	NS	NS	NS	NS	NS
SEm±	0.354	0.279	2.879	3.353	1.478	0.233	1.296	1.189	0.123	0.052	0.013
CD (0.05)	-	-	-	-	-	0.475	-	-	-	-	-
Mean for seed rates	6.93	21.65	102.29	123.31	83.31	32.28	25.12	21.88	1.63	1.18	0.533
Control	8.67	20.74	86.20	106.20	81.20	32.24	27.28	21.52	2.63	1.27	0.560
p	NS	NS	0.05	0.05	NS	NS	NS	NS	0.01	NS	NS
SEm±	1.003	0.791	8.145	9.485	4.181	0.659	3.664	3.362	0.349	0.146	0.037
CD	-	-	16.513	19.323	-	-	-	-	0.711	-	-

to 7.4 per cent. Highest grain number was recorded at 70 kg N level while maximum number of filled grains was recorded at 35 kg N level and this was significantly superior to N_1 level. Thousand grain weight as well as grain-straw ratio was the highest at 35 kg level of N and further increase in N levels did not affect them significantly. Nitrogen levels did not significantly influence the number of productive tillers, percentage of filled grains and harvest index.

Application of P significantly influenced the total grains per panicle, percentage of filled grains and grain-straw ratio. Phosphorus application significantly reduced the mean total grains per panicle to 119.67 from 126.94 but increased the percentage of filled grains from 81.36 to 85.25 and grain-straw ratio from 1.11 to 1.26. Number of produtive tillers, length of panicle, number of filled grains, 1000 grain weight and harvest index remained unaffected by P application.

Variation of cowpea seed rate could bring about a significant influence only on thousand grain weight, while other yield attributes were unaffected. A lower seed rate of cowpea brought about a 2 per cent increase in 1000 grain weight over the higher seed rate. Compared with control concurrent cropping significantly increased the filled grains as well as total grains per panicle.

Table 21 shows the influence of primary and secondary tillers on the yield attributes of rice. A comparison between the influences of primary and secondary tillers on yield attributes shows that secondary tillers are capable of contributing less to the final yield of the crop.

Table 21. Effect of primary and secondary tillers on yield attributes of rice

Treatment combinations	Productive tillers/hill * Primary	Productive tillers/hill ** Secondary	Panicle length (cm) Primary	Panicle length (cm) Secondary	Filled grains/panicle Primary	Filled grains/panicle Secondary	Total grains/panicle Primary	Total grains/panicle Secondary	% of filled grains Primary	% of filled grains Secondary
N1 S1 P1	4.33	1.33	18.64	11.28	61.66	11.96	72.88	19.06	83.15	62.78
N1 S1 P2	4.67	3.33	20.59	16.18	69.75	43.83	88.85	56.00	78.06	78.31
N1 S2 P1	7.67	5.33	19.07	14.53	63.17	32.31	75.71	40.39	83.45	79.77
N1 S2 P2	5.33	3.33	20.67	16.71	78.53	46.16	92.44	55.64	85.51	85.60
N2 S1 P1	3.67	1.67	19.02	14.62	84.72	13.33	102.92	28.75	82.32	46.24
N2 S1 P2	3.00	1.67	21.05	16.97	72.50	42.67	94.98	54.00	76.08	78.92
N2 S2 P1	4.33	2.67	20.45	14.29	63.72	18.67	94.06	25.17	67.84	73.62
N2 S2 P2	4.00	2.00	20.64	14.75	77.67	26.94	94.93	39.41	81.78	68.86
N3 S1 P1	3.67	2.67	21.46	15.12	84.18	26.41	103.03	37.90	81.54	68.71
N3 S1 P2	3.00	1.67	21.54	15.71	77.19	24.31	101.35	37.21	75.98	66.20
N3 S2 P1	4.00	3.33	20.53	14.51	57.23	21.67	84.70	34.95	68.35	63.89
N3 S2 P2	4.67	3.33	18.94	14.99	57.25	34.08	76.74	40.45	74.20	83.80
N4 S1 P1	4.67	3.67	20.79	15.17	69.53	27.88	85.89	39.45	81.17	70.97
N4 S1 P2	5.00	2.33	21.66	13.88	64.83	20.42	97.13	35.12	67.08	64.36
N4 S2 P1	5.33	3.00	20.25	13.99	72.50	23.08	85.04	31.16	85.21	73.27
N4 S2 P2	4.33	2.67	19.88	16.19	68.23	33.05	90.58	44.71	75.08	73.91
Control	4.00	3.00	18.90	14.53	55.33	17.33	[illegible]	[illegible]	86.97	[illegible]
p	NS	0.01	NS	0.01	NS	0.01	NS	0.01	NS	NS
SEm±	0.934	0.744	0.832	0.876	10.13	3.71	11.42	4.37	4.74	6.79
CD (0.05)	-	1.515	-	1.783	-	7.56	-	8.91	-	-

* Mother shoots

** Shoots produced from mother shoots

N1 - 0 kg N ha^{-1}
N2 - 35 kg N ha^{-1}
N3 - 70 kg N ha^{-1}
N4 -105 kg N ha^{-1}

P1 - 0 kg P_2O_5 ha^{-1}
P2 - 35 kg ,, ha^{-1}
S1 - 25% cowpea seed rate
S2 - 50% ,,

1.11.2 Interaction effects

Data on the interaction effects of treatments on yield attributes are presented in Table 22. Interaction effect between N and P significantly influenced the number of filled grains per panicle as well as the grain-straw ratio and the highest value in both the aspects was recorded by N_2P_2 combination. The percentage increase in the number of filled grains per panicle over N_2P_1 and N_3P_2 worked out to 13 and 18 per cent and that in grain-straw ratio to 14.6 and 33 per cent respectively.

1.12 Yield of grain and straw

1.12.1 Main effects

Data presented in Table 20 show that progressive increase in N levels significantly increased the yield of grain upto 35 kg N ha^{-1} level and yield of straw upto 70 kg N ha^{-1} level. 35 kg N ha^{-1} significantly increased the yield of grain over no N and the increase worked out to 34.5 per cent. Highest yield of 28.58 q grain ha^{-1} was recorded at 70 kg N level which was 2.9 q more than the yield at 35 kg N level though they were statistically on par. Highest straw yield of 26.79 q ha^{-1} was obtained at 70 kg N level which was significantly superior to the lower N levels. The increase in the level of N application from 0 to 35 kg and 35 to 70 kg increased the straw yield by 4 and 7 q ha^{-1} respectively.

Application of P did not influence the grain yield significantly. Straw yield was reduced by the application of P @ 35 kg ha^{-1} and the decrease was 3.3 q ha^{-1}.

Table 22. Interaction effect on yield attributes and yield of rice

a. N x P

Levels of P / Levels of N	Productive tiller/ hill		Filled grains per panicle		1000 grain weight g		Grain yield q ha^{-1}		Straw yield q ha^{-1}		Grain/Straw ratio	
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
N1	5.23	7.27	96.20	91.47	31.58	31.58	18.06	20.21	17.65	13.86	1.05	1.40
N2	7.00	7.13	101.03	114.03	32.75	32.38	27.13	24.35	22.37	17.26	1.23	1.41
N3	6.10	6.57	113.27	96.63	32.45	32.47	30.88	26.29	27.50	26.07	1.12	1.06
N4	7.63	7.50	99.77	105.90	32.66	32.35	26.73	27.33	26.51	23.77	1.03	1.15
p	NS		0.01		NS		NS		NS		0.05	
SEm±	0.71		5.76		0.47		2.59		2.38		0.10	
CD (0.05)	-		11.73		-		-				0.21	

b. N x Cowpea and P x Cowpea

Cowpea seed rate / Levels of N & P	Productive tiller/ hill		Filled grains per panicle		1000 grain weight g		Grain yield q ha^{-1}		Straw yield q ha^{-1}		Grain/Straw ratio	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
N1	6.27	6.23	99.60	88.07	31.89	31.28	18.90	19.37	15.18	16.33	1.27	1.21
N2	7.53	6.60	109.13	105.93	32.59	32.53	21.93	29.56	16.75	22.87	1.31	1.29
N3	7.17	6.50	102.97	106.93	33.14	31.78	32.78	24.38	30.79	22.78	1.09	1.09
N4	7.07	8.07	101.73	103.93	32.70	32.31	25.40	28.65	24.72	25.56	1.03	1.15
p	NS		NS		NS		0.01		0.01		NS	
SEm±	0.71		5.76		0.47		2.59		2.38		0.10	
CD (0.05)			-		-		5.28		4.84			
P1	6.83	6.65	105.00	100.13	32.54	32.18	23.62	27.78	21.19	25.82	1.13	1.09
P2	7.18	7.05	101.72	102.30	32.62	31.77	25.88	23.20	22.52	17.96	1.22	1.30
p	NS		NS		NS		0.05		0.01		NS	
SEm±	0.50		4.07		0.11		1.83		1.68		0.07	
CD (0.05)	-		-				3.73		3.43			

c. N x P x Cowpea

Levels of P		Grain yield q ha^{-1}		Straw yield q ha^{-1}		Harvest index		Grain/straw ratio	
		P1	P2	P1	P2	P1	P2	P1	P2
Levels of N	Cowpea seed rate								
N1	S1	16.59	21.20	15.30	15.06	0.52	0.59	1.12	1.42
	S2	19.52	19.22	19.99	12.67	0.49	0.58	0.98	1.44
N2	S1	22.31	21.54	17.14	16.36	0.57	0.57	1.30	1.31
	S2	31.96	27.15	27.59	18.15	0.54	0.53	1.17	1.50
N3	S1	31.62	33.95	26.24	35.34	0.54	0.49	1.20	0.98
	S2	30.13	18.63	28.76	16.80	0.51	0.53	1.05	1.13
N4	S1	23.96	26.85	26.10	23.34	0.47	0.53	0.91	1.15
	S2	29.49	27.82	26.92	24.21	0.53	0.53	1.15	1.15
P		0.05		0.05		NS		NS	
SEm±		3.67		3.36		0.04		0.15	
CD (0.05)		7.47		6.85		-		-	

N1 - 0 kg N ha^{-1} P1 - 0 kg P_2O_5 ha^{-1}
N2 - 35 kg N ha^{-1} P2 - 35 kg ,, ha^{-1}
N3 - 70 kg N ha^{-1} S1 - 25% cowpea seed rate
N4 - 105 kg N ha^{-1} S2 - 50% ,,

Varying the seed rate of cowpea between 25 and 50 per cent did not affect the yield of grain or straw to any significant extent. Compared with control *in situ* green manuring reduced the chaff yield significantly.

1.12.2 Interaction effects

Data on the interaction effects of treatments on the yield of rice are presented in Table 22. The data show that the highest grain and straw yields of 32.78 and 30.79 q ha^{-1} were obtained at N_3S_1 level. Increasing the seed rate of cowpea at this level significantly reduced the yields of grain and straw. On the other hand at 35 kg level of N higher seed rate of cowpea was better which recorded a grain yield of 29.56 q ha^{-1} which was statistically on par with the highest yield obtained at N_3S_1 level.

Phosphorus application along with a higher seed rate of cowpea tended to reduce the yield of grain and straw and thus the highest grain yield of 27.78 q ha^{-1} and straw yield of 25.82 q ha^{-1} were recorded by the higher seed rate of cowpea in the absence of phosphorus. At the lower seed rate, however, application of P tended to increase the yield of grain and straw and the increases were 9.5 and 6.3 per cent over no phosphorus.

A second order interaction among the treatments showed a significant influence on the yield of both grain and straw. The highest grain yield of 33.95 q ha^{-1} and straw yield of 35.34 q ha^{-1} were recorded when 70 kg N and 35 kg P ha^{-1} were applied along with 25 per cent seed rate of cowpea. The data also show that there was a tendency to increase the yield of both grain and straw at all levels of N when a higher seed rate of cowpea was used in the absence of P.

1.13 Correlation analysis

From the correlation coefficients obtained (Table 23) it can be seen that all the yield predicting attributes as well as the chlorophyll components (Chlorophyll 'a' at 50 DAS and total chlorophyll at 75 DAS and of boot leaf) and also the nutrient uptake by rice at 75 DAS significantly correlated with grain yield while the nutrient composition of rice at 50 DAS showed no significant correlation. Nitrogen and S content at 50 DAS showed significant correlation with panicle length while K correlated significantly with both productive tillers and panicle length.

2 **Cowpea**

2.1 Plant height and root characteristics

2.1.1 Main effects

It can be seen from Table 24 that N influenced the height of cowpea throughout its growth. Though the magnitude of variation was low, increasing levels of N upto 70 kg ha^{-1} significantly increased the height at 20 DAS. The variation between the effects of N levels was nullified with advancing growth and by 40 DAS application of 105 kg N ha^{-1} recorded significant improvement in height over lower levels. Nitrogen levels had little influence on varying the root length and number of roots while root biomass production was significantly reduced with application of N.

Application of P at 35 kg ha^{-1} also significantly improved the height of plants at 20th and 40th days. The height improved by 1.5 cm at 20th day and by 7.47 cm at 40th day. Application of P significantly reduced the root biomass production while other characters were unaffected.

Table 23. Simple correlation coefficients between various parameters

Sl. No.	Parameters x	Parameters y	Correlation coefficient (r)
1	Productive tillers	Grain yield	0.492**
2	Panicle length	Grain yield	0.475**
3	Filled grains/panicle	Grain yield	0.278*
4	1,000 grain weight	Grain yield	0.381**
5	Secondary tillers	Grain yield	-0.090^{NS}
6	Chlorophyll 'a' at 50 DAS	Grain yield	0.289*
7	Total chlorophyll at 75 DAS	Grain yield	0.328*
8	Total chlorophyll - boot leaf	Grain yield	0.280*
9	Chlorophyll 'a' at 50 DAS	Straw yield	0.406**
10	Chlorophyll 'a' - boot leaf	Straw yield	0.408**
11	Chlorophyll 'b' - boot leaf	Straw yield	0.372**
12	Total chlorophyll at 50 DAS	Straw yield	0.385**
13	Total chlorophyll at 75 DAS	Straw yield	0.346*
14	Total chlorophyll - boot leaf	Straw yield	0.417**
15	N content at 50 DAS	Panicle length	0.381**
16	K content at 50 DAS	Productive tillers	0.383**
17	K content at 50 DAS	Panicle length	0.630**
18	S content at 50 DAS	Panicle length	0.571**
19	N content at 50 DAS	Grain yield	0.237^{NS}
20	P content at 50 DAS	Grain yield	0.024^{NS}
21	K content at 50 DAS	Grain yield	0.198^{NS}
22	Ca content at 50 DAS	Grain yield	-0.064^{NS}
23	Mg content at 50 DAS	Grain yield	0.250^{NS}
24	S content at 50 DAS	Grain yield	0.241^{NS}
25	Fe content at 50 DAS	Grain yield	0.001^{NS}
26	N uptake at 75 DAS	Grain yield	0.357**
27	K uptake at 75 DAS	Grain yield	0.322*
28	Ca uptake at 75 DAS	Grain yield	0.288*
29	Mg uptake at 75 DAS	Grain yield	0.373**
30	S uptake at 75 DAS	Grain yield	0.345*
31	Fe uptake at 75 DAS	Grain yield	0.467**

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

Table 24. Effect of treatment levels on plant height and root characteristics of cowpea

Treatment	Plant height, cm		Root characteristics at 30 DAS			
	20 DAS	40 DAS	No. of roots/ plant	Length (cm)	Biomass production, q ha^{-1}	
					Fresh weight	Dry weight
N (kg ha^{-1})						
0	28.14	87.38	16.58	11.13	0.98	0.24
35	29.24	85.09	15.67	11.21	0.85	0.19
70	30.79	86.41	17.75	10.63	0.80	0.18
105	29.78	102.88	17.25	10.59	0.95	0.21
p	0.01	0.01	NS	NS	0.01	0.01
SEm±	0.714	2.508	0.870	0.575	0.029	0.006
CD (0.05)	1.459	5.122	-	-	0.059	0.012
P_2O_5 (kg ha^{-1})						
0	28.74	86.83	17.00	10.90	0.94	0.22
35	30.24	94.30	16.62	10.88	0.84	0.18
p	0.01	0.01	NS	NS	0.01	0.01
SEm±	0.505	1.774	0.62	0.406	0.020	0.004
CD (0.05)	1.031	3.622	-	-	0.042	0.008
Copea seed rate						
25%	32.53	88.21	16.04	11.04	0.72	0.16
50%	30.11	92.92	17.58	10.73	1.06	0.25
p	0.01	0.05	0.05	NS	0.01	0.01
SEm±	0.505	1.774	0.62	0.406	0.020	0.004
CD (0.05)	1.031	3.622	1.26	-	0.042	0.008

The significant effect of a lower seed rate of cowpea on recording a better height at 20 DAS was reversed by 40th day. At 40th day plants in the higher seed rate plot recorded an increase in height by 4.71 cm from 88.21 cm. The root number and root weight of cowpea varied significantly with variation in the seed rate of cowpea. When there was a larger population of cowpea the number roots and root biomass were increased over those in a smaller population.

2.1.2 Interaction effects

Data on the interaction effects of treatments on plant height and root characteristics of cowpea are presented in Table 25. Height of plants was significantly influenced by N x P interaction. At 40 DAS maximum height of 108.68 cm was recorded at 105 kg N and 35 kg P ha^{-1} which was 12 per cent more than the N applied alone at 105 kg ha^{-1}. Maximum root length as well as highest root weight were recorded at N_1P_1 level. Phosphorus application with N_3 level of N reduced the root dry weight while it increased the root length significantly.

Nitrogen x cowpea interaction significantly affected the height of cowpea at 40 DAS. A higher seed rate of cowpea coupled with 105 kg N ha^{-1} recorded the maximum height of 108 cm which was 10.4 cm more than that at the same level of N but with a lower seed rate of cowpea. Highest number of roots was recorded by N_2S_2 which was significantly superior to N_2S_1 and N_3S_2 combinations. Maximum root fresh and dry weights of 1.31 and 0.34 q ha^{-1} were recorded at N_1S_2 level and this was significantly superior to all other combinations.

Observation on the interaction effect between P and cowpea showed that height of plants was significantly influenced by varying levels of seed rates at 40

Table 25. Interaction effect on plant height and root characteristics of cowpea

a. N x P

Levels of P	Plant height, cm				Root characteristics at 30 DAS							
	20 DAS		40 DAS		No. of roots/ plant		Length (cm)		Biomass production, q ha^{-1}			
									Fresh weight		Dry weight	
Levels of N	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
N1	27.37	28.90	78.40	97.37	17.83	15.33	12.17	10.08	1.23	0.72	0.34	0.14
N2	29.14	29.33	88.20	81.98	15.83	15.50	10.58	11.83	0.73	0.96	0.15	0.23
N3	29.40	32.18	83.67	89.15	17.17	18.33	9.83	11.42	0.91	0.70	0.22	0.14
N4	29.03	30.53	97.07	108.68	17.17	17.33	11.00	10.17	0.90	1.00	0.19	0.23
p	NS		<0.01		NS		<0.01		<0.01		<0.01	
SEm±	1.003		3.547		1.231		0.813		0.041		0.008	
CD (0.05)			7.243				1.659		0.083		0.017	

b. N x Cowpea

Cowpea seed rate	Plant height, cm				Root characteristics at 30 DAS							
	20 DAS		40 DAS		No. of roots/ plant		Length (cm)		Biomass production, q ha^{-1}			
									Fresh weight		Dry weight	
Levels of N	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
N1	27.15	29.12	92.48	83.28	17.50	15.67	9.67	12.58	0.64	1.31	0.13	0.34
N2	29.47	29.00	80.22	89.97	12.33	19.00	13.67	8.75	0.81	0.88	0.19	0.19
N3	29.68	31.90	82.47	90.35	16.67	18.83	10.08	11.17	0.46	1.14	0.12	0.25
N4	29.14	30.43	97.68	108.07	17.67	16.83	10.75	10.42	0.98	0.92	0.21	0.20
p	NS		<0.01		<0.01		0.01		<0.01		0.01	
SEm±	1.003		3.547		1.231		0.813		0.041		0.008	
CD (0.05)	-		7.243		2.513		1.659		0.083		0.017	

c. P x Cowpea

Cowpea seed rate	Plant height, cm				Root characteristics at 30 DAS							
	20 DAS		40 DAS		No. of roots/ plant		Length (cm)		Biomass production, q ha^{-1}			
									Fresh weight		Dry weight	
Levels of P	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
P1	28.23	29.24	87.11	86.56	16.75	17.25	11.67	10.13	0.82	1.06	0.18	0.27
P2	28.49	30.99	89.32	99.28	15.33	17.92	10.42	11.33	0.62	1.06	0.14	0.23
p	NS		0.01		NS		0.01		0.01		NS	
SEm±	0.714		2.508		0.870		0.575		0.029		0.006	
CD (0.05)	-		5.122		-		1.174		0.059		-	

d. N x P x Cowpea

Levels of N	Cowpea seed rate	Plant height, cm				Root characteristics at 30 DAS							
		20 DAS		40 DAS		No. of roots/ plant		Length (cm)		Biomass production, q ha^{-1}			
										Fresh weight		Dry weight	
		P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
N1	S1	26.40	27.91	88.63	96.33	20.33	14.67	10.33	9.00	0.88	0.40	0.20	0.05
	S2	28.34	29.90	68.17	98.40	15.33	16.00	14.00	11.17	1.57	1.05	0.48	0.21
N2	S1	29.37	29.57	87.10	73.33	12.67	12.00	13.00	14.33	0.88	0.73	0.21	0.18
	S2	28.91	29.09	89.30	90.63	19.00	19.00	8.17	9.33	0.58	1.19	0.10	0.23
N3	S1	28.40	30.97	88.80	76.13	16.00	17.33	11.00	9.17	0.58	0.34	0.14	0.09
	S2	30.40	33.40	78.53	102.17	18.33	19.33	8.67	13.67	1.24	1.05	0.30	0.19
N4	S1	28.77	29.51	83.90	111.47	18.00	17.33	12.33	9.17	0.94	1.02	0.18	0.24
	S2	29.30	31.55	110.23	105.90	16.33	17.33	9.67	11.17	0.86	0.97	0.19	0.21
p		NS		0.01		NS		0.01		0.01		0.01	
SEm±		1.429		5.016		1.740		1.149		0.058		0.012	
CD (0.05)				10.243				2.347		0.118		0.0[illegible]	

N1 - 0 kg N ha^{-1} P1 - 0 kg P_2O_5 ha^{-1}
N2 - 35 kg N ha^{-1} P2 - 35 kg ,, ha^{-1}
N3 - 70 kg N ha^{-1} S1 - 25% cowpea seed rate
N4 - 105 kg N ha^{-1} S2 - 50% ,,

DAS. Maximum height (99.28 cm) was recorded at P_2S_2 combination which was 11 per cent more than that recorded at P_2S_1 level. Maximum root length of cowpea recorded at P_1S_1 level was significantly superior to P_2S_1 and P_1S_2 and was on par with P_2S_2. A higher seed rate of cowpea was found conducive to increase the fresh weight of roots but at lower seed rate the increase in root weight was negated significantly by P application.

As evident from the data on second order interaction maximum height of 111.47 cm which was significantly superior to all other treatment combinations was recorded at $N_4P_2S_1$ level. While root length was maximum at $N_2P_2S_2$ and root weight at $N_1P_1S_2$.

2.2 Biomass production

2.2.1 Main effects

The data on wet and dry weights accumulation of biomass by cowpea in the intercropping system are presented in Table 26.

The results showed that at 20 DAS highest biomass accumulation was recorded at 105 kg N ha^{-1} while at 30 DAS and at decomposition stage it was at 35 kg level. At decomposition stage 9.23 q ha^{-1} of dry matter recorded at 35 kg N level was one per cent higher than that at 105 kg level.

Application of phosphorus had more profound effect than N. Phosphorus applied at 35 kg ha^{-1} brought about a significant increase in the yield of both wet and dry matter. At decomposition stage 51.9 q ha^{-1} of green matter and 9.35 q ha^{-1} of dry matter were produced by P application which were 22.6 and 24 per cent higher than the same with no P application.

Table 26. Effect of treatment levels on biomass production (q ha^{-1}) of cowpea at different stages

Treatments	20 DAS		30 DAS		Decomposition	
	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight
N (kg ha^{-1})						
0	10.41	1.05	28.49	3.98	37.45	6.50
35	10.41	1.06	30.79	4.35	50.63	9.23
70	12.83	1.20	27.06	3.63	49.69	8.89
105	12.86	1.40	28.40	3.83	50.67	9.14
p	0.01	0.01	0.01	0.01	0.01	0.01
SEm±	0.224	0.022	0.392	0.05	0.865	0.190
CD (0.05)	0.457	0.046	0.800	0.102	1.766	0.388
P_2O_5 (kg ha^{-1})						
0	11.03	1.10	25.59	3.65	42.32	7.53
35	12.22	1.25	31.79	4.24	51.90	9.35
p	0.01	0.01	0.01	0.01	0.01	0.01
SEm±	0.158	0.016	0.277	0.035	0.611	0.134
CD (0.05)	0.323	0.023	0.566	0.072	1.249	0.275
Cowpea seed rates						
25%	8.16	0.84	22.65	3.05	38.98	6.75
50%	15.10	1.52	34.72	4.82	55.24	10.13
p	0.01	0.01	0.01	0.01	0.01	0.01
SEm±	0.158	0.016	0.277	0.035	0.611	0.134
CD (0.05)	0.323	0.032	0.566	0.072	1.249	0.275

Variation in the seed rates of cowpea showed significant difference in the biomass accumulation by cowpea throughout its growth period. A higher seed rate of cowpea produced more biomass than a lower seed rate and the increase was of the order of 40-50 per cent.

2.2.2 Interaction effects

Data on interaction effects of treatments are given in Table 27. Interaction effect between N and P on biomass accumulation showed that application of P @ 35 kg ha^{-1} along with 105 kg N ha^{-1} recorded maximum biomass accumulation at 20 DAS and decomposition stage, while at 30 DAS biomass accumulated at N_2P_2 level was significantly superior to all other combinations.

Significant N x cowpea interaction was noticed on biomass production of cowpea at various stages of growth. Highest quantity of biomass at 30 DAS was recorded by N_1S_2 which was 52 (wet) and 50.7 (dry) per cent higher than the biomass accumulated by N_4S_2. However, this effect was short lived and by decomposition stage N_4S_2 recorded 57.09 (fresh) and 11.16 (dry) q ha^{-1} biomass which was significantly superior to all other combinations.

The data also show that cowpea seed rate and phosphorus interacted significantly in increasing the biomass production of cowpea. A higher seed rate coupled with P consistently registered a significantly higher biomass production which at the time of decomposition was 62.64 and 11.47 q ha^{-1} of wet and dry matter, respectively.

Table 27. Interaction effect on biomass production (q ha^{-1}) of cowpea at different stages

a. N x P

Levels of P / Levels of N	20 DAS				30 DAS				Decomposition stage			
	Fresh weight		Dry weight		Fresh weight		Dry weight		Fresh weight		Dry weight	
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
N1	11.00	9.81	1.04	1.07	29.19	27.79	4.07	3.88	39.45	35.40	7.03	5.96
N2	10.08	10.74	0.98	1.15	26.34	35.24	3.97	4.73	44.90	56.36	8.27	10.20
N3	13.25	12.41	1.25	1.14	23.75	30.38	3.43	3.82	44.49	54.89	8.08	9.70
N4	9.79	15.92	1.15	1.65	23.08	33.73	3.13	4.52	40.43	60.90	6.74	11.53
p	0.01		<0.01		0.01		<0.01		0.01		0.01	
SEm±	0.317		0.032		0.554		0.071		1.223		0.269	
CD (0.05)	0.647		0.065		1.132		0.144		0.497		0.549	

b. N x Cowpea

Copwea seed rate / Levels of N	20 DAS				30 DAS				Decomposition stage			
	Fresh weight		Dry weight		Fresh weight		Dry weight		Fresh weight		Dry weight	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
N1	8.36	12.46	0.81	1.30	15.58	41.40	2.20	5.76	25.58	49.32	4.47	8.53
N2	8.46	12.36	0.87	1.26	27.05	34.52	3.73	4.98	43.22	58.04	7.52	10.95
N3	6.42	19.24	0.68	1.72	18.41	35.72	2.45	4.80	42.87	56.50	7.92	9.86
N4	9.38	16.33	1.00	1.80	29.56	27.24	3.84	3.82	44.25	57.09	7.11	11.16
p	0.01		0.01		0.01		<0.01		0.01		0.01	
SEm±	0.317		0.032		0.554		0.071		1.223		0.269	
CD (0.05)	0.647		0.065		1.132		0.144		2.497		0.549	

c. P x Cowpea

Cowpea seed rate / Levels of P	20 DAS Fresh weight S1	20 DAS Fresh weight S2	20 DAS Dry weight S1	20 DAS Dry weight S2	30 DAS Fresh weight S1	30 DAS Fresh weight S2	30 DAS Dry weight S1	30 DAS Dry weight S2	Decomposition stage Fresh weight S1	Decomposition stage Fresh weight S2	Decomposition stage Dry weight S1	Decomposition stage Dry weight S2
P1	8.47	13.59	0.78	1.43	22.75	28.43	3.10	4.21	36.80	47.83	6.28	8.78
P2	7.84	16.60	0.90	1.61	22.55	41.02	3.01	5.47	41.16	62.64	7.23	11.47
p	0.01		NS		0.01		0.01		0.01		0.01	
SEm±	0.224		0.022		0.392		0.05		0.865		0.190	
CD (0.05)	0.457		-		0.800		0.102		1.766		0.388	

d. N x P x Cowpea

Levels of N	Cowpea seed rate	20 DAS Fresh weight P1	20 DAS Fresh weight P2	20 DAS Dry weight P1	20 DAS Dry weight P2	30 DAS Fresh weight P1	30 DAS Fresh weight P2	30 DAS Dry weight P1	30 DAS Dry weight P2	Decomposition stage Fresh weight P1	Decomposition stage Fresh weight P2	Decomposition stage Dry weight P1	Decomposition stage Dry weight P2
N1	S1	9.74	6.97	0.92	0.70	18.64	12.51	2.59	1.80	27.04	24.12	4.88	4.06
	S2	12.26	12.65	1.15	1.45	39.73	43.07	5.55	5.96	51.85	46.78	9.18	7.87
N2	S1	10.10	6.83	0.87	0.87	23.98	30.12	3.36	4.10	38.11	48.31	6.70	8.33
	S2	10.07	14.66	1.08	1.43	28.69	40.35	4.58	5.37	51.67	64.41	9.83	12.07
N3	S1	6.87	5.97	0.65	0.71	20.03	16.78	2.83	2.08	52.31	33.43	9.89	5.95
	S2	19.63	18.86	1.85	1.58	27.46	43.99	4.03	5.57	36.66	76.34	6.28	13.44
N4	S1	7.17	11.59	0.68	1.33	28.33	30.80	3.61	4.06	29.72	58.77	3.64	10.59
	S2	12.41	20.25	1.62	1.98	17.82	36.66	2.66	4.99	51.14	63.03	9.84	12.48
p		0.01		0.01		0.01		0.01		0.01		0.01	
SEm±		0.448		0.045		0.784		0.01		1.729		0.380	
CD (0.05)		0.915		0.091		1.601		0.020		3.532		0.777	

N1 - 0 kg N ha^{-1} P1 - 0 kg P_2O_5 ha^{-1}
N2 - 35 kg N ha^{-1} P2 - 35 kg ,, ha^{-1}
N3 - 70 kg N ha^{-1} S1 - 25% cowpea seed rate
N4 - 105 kg N ha^{-1} S2 - 50% ,,

Results of the second order interaction showed that cowpea accumulated maximum biomass (both on wet and dry weight basis) when N and P were applied at 70 and 35 kg ha^{-1}, respectively along with a higher seed rate of cowpea. At these levels cowpea accumulated 76.34 and 13.44 q ha^{-1} of wet and dry matter, respectively which were superior to all other treatment combinations, while a lower seed rate accompanied with 105 kg N and 35 kg P ha^{-1} produced 58.77 and 10.59 q ha^{-1} of fresh and dry weights.

3 Weeds

3.1 Weed count

3.1.1 Main effects

Data on the main effect of treatments on weed count on 20th and 40th day are presented in Table 28.

The data show that there is an inverse relationship between N levels and weed count on 20th day. The count of grasses and sedges at 20 DAS decreased significantly with increasing levels of N while that of dicot weeds was not affected. Thus at 105 kg N ha^{-1} counts of grasses and sedges were only 70 and 93 per cent of those in the control. It was further seen that the count of weeds further decreased by 40th day. The effect of higher levels of N was more apparent on 40th day in dicots when the reduction was found to be significant.

Phosphorus application did not have any significant effect on weed count at both the stages of observation.

Table 28. Effect of treatment levels on weed count (number m^{-2}) at different stages of rice

Treatments	20 DAS			40 DAS		
	Grasses	Sedges	Dicots	Grasses	Sedges	Dicots
N (kg ha^{-1})						
0	34.00	28.67	31.67	30.33	10	30.67
35	31.67	10.67	26.33	27.67	5	25.33
70	21.33	10.00	31.00	21.83	6	17.67
105	20.67	8.67	24.33	15.33	4	16.34
p	0.05	0.01	NS	0.01	NS	0.05
SEm±	3.787	5.577	5.227	2.092	4.284	4.51
CD (0.05)	7.715	11.362	-	4.262	-	9.189
P_2O_5 (kg ha^{-1})						
0	27.00	13.00	27.50	25.42	6.5	22
35	26.83	16.00	29.17	22.17	6.0	23
p	NS	NS	NS	NS	NS	NS
SEm±	2.678	3.944	3.696	1.479	1.615	3.189
CD (0.05)						
Cowpea seed rate						
25%	28.50	16.83	27.33	23.92	8.0	22.00
50%	25.34	12.17	29.33	23.67	4.5	23.00
p	NS	NS	NS	NS	0.05	NS
SEm±	2.678	3.344	3.696	1.479	1.615	3.189
CD (0.05)	-	-	-	-	3.289	-
Mean for seed rates	26.92	14.50	28.33	23.79	6.25	22.50
Control	29.33	9.33	46.67	20.00	5.00	29.00
p	NS	NS	0.05	NS	NS	NS
SEm±	7.57	11.15	10.454	4.18	4.57	9.02
CD (0.05)	-	-	21.297	-	-	-

In situ raising of green manure cowpea using a higher seed rate significantly reduced the count of sedges at 40 DAS and the reduction was 56 per cent more than the lower seed rate effect. Intercropping with cowpea drastically reduced the count of dicot weeds and the grassy weeds were little affected while it had no effect on decreasing the count of sedges.

3.2 Dry matter production

3.2.1 Main effects

Data on the dry matter production by weeds at 20 and 40 DAS are presented in Table 29.

It can be seen from the results that at 20 DAS maximum dry matter of 5.16 q ha^{-1} was recorded at N_1 level which was significantly superior to all the other levels and the minimum value was at N_4 level. On the other hand on 40th day, however, maximum weed dry matter of 1.28 q ha^{-1} was recorded at N_4 level which was significantly superior to all other levels and the minimum was at N_1 level.

Application of P @ 35 kg ha^{-1} increased the weed dry matter significantly over zero level of P at 20 DAS and the increase worked out to 45 per cent, while at 40 DAS effect of P was not significant.

Intercropping with cowpea significantly affected the weed DMP. Compared with control weed DMP was significantly lower in the plots intercropped with cowpea. Though the weed DMP remained unaffected by the different seed rates of cowpea at 20 DAS, significant effect of seed rate on influencing DMP by weeds was apparent on 40th day. Intercropping cowpea with higher seed rate significantly reduced the weed DMP by 33 per cent over lower seed rate.

Table 29. Effect of treatment levels on dry matter production (q ha^{-1}) of weeds

Treatments	20 DAS	40 DAS
N (kg ha^{-1})		
0	5.16	0.64
35	2.94	1.03
70	3.59	0.94
105	2.63	1.28
p	0.01	0.01
SEm±	0.202	0.037
CD (0.05)	0.411	0.074
P_2O_5 (kg ha^{-1})		
0	2.92	0.98
35	4.23	0.97
p	0.01	NS
SEm±	0.143	0.026
CD (0.05)	0.290	-
Cowpea seed rate		
25%	3.61	1.17
50%	3.55	0.78
p	NS	0.01
SEm±	0.143	0.026
CD (0.05)	-	0.053
Mean for seed rates	3.58	0.975
Control	6.46	0.360
p	0.01	0.01
SEm±	0.403	0.730
CD (0.05)	0.822	0.149

3.2.2 Interaction effects

Table 30 shows the influence of interactions on weed dry matter production. Interaction effect between N and P on DMP was significant at both the stages of observation. At 20 DAS significantly superior DMP was registered by N_1P_1 combination and application of P at this zero level of N reduced the DMP significantly. The lowest DMP values were noticed at the highest level of N in the absence as well as in the presence of P. At 40 DAS the reverse was noticed and lower levels of N combined with P application reduced the DMP by weeds significantly.

Significant interaction effect between levels of N and cowpea on DMP was noticed at 20 and 40 DAS. At 20 DAS lower levels of N with a lower seed rate of cowpea recorded more DM, and the DMP at zero level of N was the highest and significantly superior to all other combinations, while at higher levels of N the reverse was noticed. As against this, at 40 DAS highest DMP was recorded by N_3 level with a lower seed rate of cowpea.

Highest DMP as influenced by P x cowpea interaction at 40 DAS was recorded when a lower seed rate of cowpea was used in the absence of P. A higher seed rate of cowpea with application of P could reduce the weed DMP to a significant level.

At 20 DAS the highest DMP was recorded when a lower seed rate of cowpea was used in the absence of both N and P. But at higher levels of N a higher seed rate of cowpea could not reduce the DMP in the presence of P. Thus at higher levels of N use of a lower seed rate of cowpea in the absence of P could reduce the

Table 30. Interaction effect on dry matter production (q ha^{-1}) of weeds

a. N x P, N x Cowpea and P x Cowpea

Cowpea seed rate and levels of P / Levels of N & P	20 DAS		40 DAS		20 DAS		40 DAS	
	S1	S2	S1	S2	P1	P2	P1	P2
N1	5.98	4.34	0.62	0.67	5.88	4.43	0.77	0.52
N2	3.03	2.85	1.23	0.83	1.58	4.30	1.00	1.05
N3	3.47	3.71	1.44	0.44	2.24	4.94	1.00	0.89
N4	1.95	3.30	1.40	1.17	1.98	3.27	1.14	1.42
P	0.01		0.01		0.01		0.01	
SEm±	0.285		0.052		0.285		0.052	
CD (0.05)	0.581		0.105		0.581		0.105	
P1	2.87	2.97	1.27	0.68				
P2	4.35	4.12	1.07	0.88				
P	NS		0.01					
SEm±	0.202		0.037					
CD (0.05)			0.074					

b. N x P x Cowpea

Levels of N	Cowpea seed rate	20 DAS		40 DAS	
		P1	P2	P1	P2
N1	S1	6.88	5.07	0.81	0.43
	S2	4.88	3.80	0.73	0.61
N2	S1	1.96	4.10	1.05	1.40
	S2	1.20	4.49	0.94	0.71
N3	S1	1.40	5.55	1.82	1.06
	S2	3.09	4.33	0.17	0.72
N4	S1	1.23	2.67	1.41	1.38
	S2	2.74	3.87	0.87	1.46
P		0.01		0.01	
SEm±		0.403		0.930	
CD (0.05)		0.822		0.149	

N1 - 0 kg N ha^{-1}
N2 - 35 kg N ha^{-1}
N3 - 70 kg N ha^{-1}
N4 - 105 kg N ha^{-1}

P1 - 0 kg P_2O_5 ha^{-1}
P2 - 35 kg ,, ha^{-1}
S1 - 25% cowpea seed rate
S2 - 50% ,,

DMP by weeds significantly. At 40 DAS the lowest DMP was recorded at zero level of nitrogen when P application along with a lower seed rate of cowpea was adopted. Increasing the N levels in the presence of P but with a lower seed rate increased the DMP by weeds.

3.3 Nutrient content of weeds

3.3.1 Main effects

Data on the nutrient content of weeds on 20th day as effected by main effects of treatments are presented in Table 31.

It can be seen from the results that increasing levels of N significantly affected the P, Ca, S and Fe content at 20 DAS while at 40 DAS content of all the elements was increased and the increases were significant except for K and Ca. At 20 DAS P and Ca contents significantly increased with increasing levels of N application while Fe content decreased. The S content of weeds at 105 kg N ha^{-1} was on par with that at 35 kg N ha^{-1}.

Phosphorus application did not have any effect on the elemental composition of weeds at 20 DAS while at 40 DAS it significantly increased the K and S contents by 6 and 11 per cent and decreased the Fe content by 12 per cent.

Variation between seed rates of cowpea did not affect the elemental composition of weeds at 20 DAS. However, compared with control, intercropping reduced the N, K and Fe content of weeds by 6, 12 and 10.5 per cent, respectively. While at 40 DAS a higher seed rate of cowpea significantly reduced the P and Fe contents and a lower seed rate reduced the sulphur content significantly.

Table 31. Effect of treatment levels on nutrient content of weeds, %

Treatments	20 DAS							40 DAS						
	N	P	K	Ca	Mg	S	Fe	N	P	K	Ca	Mg	S	Fe
N (kg ha^{-1})														
0	3.26	0.198	4.04	0.335	0.290	0.345	0.225	1.65	0.215	3.47	0.489	0.253	0.253	0.240
35	3.50	0.238	4.02	0.445	0.298	0.400	0.235	1.43	0.208	3.51	0.498	0.290	0.285	0.260
70	3.37	0.213	4.92	0.398	0.300	0.365	0.190	1.81	0.153	3.73	0.490	0.280	0.288	0.208
105	3.50	0.243	3.90	0.423	0.328	0.393	0.170	1.70	0.223	3.63	0.525	0.310	0.240	0.225
p	NS	0.01	NS	0.01	NS	0.01	0.01	0.05	0.01	NS	NS	0.01	0.01	NS
SEm±	0.137	0.013	0.097	0.022	0.013	0.009	0.013	0.128	0.009	0.118	0.018	0.013	0.013	0.013
CD (0.05)	-	0.026	-	0.046	-	0.017	0.026	0.262	0.018	-	-	0.026	0.026	0.026
P_2O_5 (kg ha^{-1})														
0	3.46	0.219	4.00	0.411	0.306	0.376	0.201	1.56	0.186	3.48	0.501	0.286	0.253	0.248
35	3.36	0.226	3.95	0.389	0.301	0.375	0.209	1.73	0.213	3.69	0.499	0.278	0.280	0.219
p	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.05	NS	NS	0.05	0.01
SEm±	0.097	0.009	0.069	0.160	0.009	0.006	0.009	0.091	0.006	0.083	0.013	0.009	0.009	0.009
CD (0.05)	-	-	-	-	-	-	-	-	-	0.169	-	-	0.019	0.019
Cowpea seed rates														
25%	3.41	0.215	3.96	0.384	0.308	0.369	0.208	1.56	0.205	3.61	0.491	0.291	0.250	0.244
50%	3.40	0.230	3.99	0.416	0.300	0.383	0.203	1.73	0.194	3.56	0.509	0.273	0.283	0.223
p	NS	NS	NS	NS	NS	NS	NS	NS	0.01	NS	NS	NS	0.01	0.01
SEm±	0.097	0.009	0.069	0.016	0.009	0.006	0.009	0.091	0.006	0.083	0.013	0.009	0.009	0.009
CD (0.05)								-	0.013	-	-	-	0.019	0.019
Mean for seed rates	3.4	0.223	3.98	0.40	0.304	0.376	0.206	1.645	0.199	3.585	0.500	0.282	0.267	0.234
Control	3.64	0.200	4.50	0.320	0.260	0.350	0.230	1.31	0.150	3.670	0.370	0.210	0.260	0.150
p	NS	NS	NS	NS	NS	NS	NS	NS	0.01	NS	0.01	NS	NS	NS
SEm±	0.27	0.03	0.195	0.045	0.045	0.017	0.026	0.26	0.018	0.235	0.037	0.026	0.026	0.026
CD (0.05)								-	0.036	-	0.074	-	-	-

3.3.2 Interaction effects

Data on interaction effects of treatments on nutrient content of weeds are presented in Table 32.

Significant interaction effect between N and P was observed to influence the K, Mg, S and Fe content of weeds at 20 DAS and N, K, S and Fe at 40 DAS. Highest N content of weeds at 40 DAS was recorded at N_3P_2, i.e., higher levels of N and P. It can be further seen that at higher levels of N, application of P significantly reduced the K content of weeds at 20 DAS while it increased the content at 40 DAS. Thus at N_4 level, application of P decreased the K content of weeds by 10 per cent at 20 DAS while at 40 DAS increased it by 18 per cent. In the absence of N, Mg content of weeds was reduced significantly on P application at both the stages while at 70 kg N level it was increased. In the case of S highest content was observed at N_2P_1 level at 20 DAS and at N_2P_2 level at 40 dAS which were significantly superior to all other N x P treatment combinations. Highest Fe content of 0.31 per cent at 20 DAS was also recorded at N_2P_1 level which was significantly higher than the Fe content in all other N x P treatment combinations. With P application at 70 kg N level Fe content was significantly increased over N_1P_1 and the increase was of the order of 20 per cent. While at 40 DAS the decreasing trend of Fe content of weeds with P application was seen to have assumed significance at higher levels of N. Thus at 105 kg N ha^{-1}, application of P @ 35 kg ha^{-1} reduced the Fe content of weeds by 33 per cent.

Significant interaction effect between levels of nitrogen and cowpea seed rate was noticed in the case of K, Ca, S and Fe contents at 20 DAS and P, K, Ca, Mg and Fe contents at 40 DAS. Increasing N levels with higher seed rate of cowpea

Table 32. Interaction effect on nutrient content of weeds, %

a. N x p

Levels of P / Levels of N	N		P		K		Ca		Mg		S		Fe	
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
20 DAS														
N1	3.20	3.31	0.18	0.21	3.76	4.33	0.33	0.35	0.33	0.25	0.33	0.36	0.20	0.25
N2	3.48	3.52	0.23	0.24	3.98	4.06	0.48	0.41	0.30	0.30	0.43	0.37	0.31	0.16
N3	3.55	3.20	0.21	0.21	4.18	3.72	0.39	0.40	0.26	0.34	0.34	0.38	0.13	0.24
N4	3.62	3.38	0.24	0.24	4.10	3.70	0.45	0.40	0.34	0.32	0.39	0.39	0.16	0.18
F	NS		NS		0.01		NS		0.01		0.01		0.01	
SEm±	0.193		0.018		0.138		0.032		0.018		0.012		0.018	
CD (0.05)	-		-		0.280		-		0.037		0.025		0.037	
40 DAS														
N1	1.38	1.92	0.20	0.23	3.32	3.62	0.49	0.48	0.26	0.23	0.24	0.26	0.21	0.26
N2	1.47	1.38	0.19	0.23	3.45	3.58	0.52	0.48	0.28	0.30	0.24	0.33	0.26	0.25
N3	1.49	2.12	0.13	0.18	3.83	3.63	0.50	0.49	0.27	0.29	0.30	0.27	0.24	0.17
N4	1.90	1.50	0.22	0.23	3.32	3.93	0.50	0.55	0.33	0.30	0.23	0.26	0.27	0.18
F	0.01		NS		0.05		NS		NS		0.01		0.01	
SEm±	0.182		0.013		0.166		0.026		0.018		0.018		0.018	
CD (0.05)	0.370		-		0.339		-		-		0.037		0.037	

b. N x Cowpea

Cowpea seed rate / Levels of N	N		P		K		Ca		Mg		S		Fe	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
20 DAS														
N1	3.36	3.15	0.17	0.22	4.20	3.88	0.25	0.42	0.29	0.29	0.32	0.38	0.22	0.23
N2	3.45	3.55	0.24	0.23	3.83	4.21	0.41	0.48	0.30	0.30	0.40	0.40	0.17	0.31
N3	3.20	3.55	0.20	0.22	3.87	4.03	0.37	0.42	0.29	0.31	0.35	0.37	0.20	0.18
N4	3.64	3.36	0.24	0.24	3.97	3.83	0.50	0.35	0.36	0.30	0.41	0.38	0.24	0.10
F	NS		NS		0.01		0.01		NS		0.01		0.01	
SEm±	0.193		0.018		0.138		0.032		0.018		0.182		0.018	
CD (0.05)	-		-		0.280		0.064		-		0.025		0.037	
40 DAS														
N1	1.69	1.61	0.21	0.23	3.58	3.35	0.50	0.47	0.24	0.26	0.23	0.28	0.25	0.23
N2	1.40	1.45	0.24	0.17	3.50	3.52	0.52	0.48	0.35	0.23	0.27	0.30	0.29	0.22
N3	1.61	2.01	0.16	0.14	3.89	3.57	0.45	0.53	0.29	0.27	0.27	0.30	0.20	0.21
N4	1.55	1.85	0.20	0.24	3.46	3.80	0.50	0.55	0.28	0.34	0.23	0.25	0.23	0.22
F	NS		0.01		0.05		0.01		0.01		NS		0.01	
SEm±	0.182		0.013		0.166		0.026		0.018		0.018		0.018	
CD (0.05)	-		0.025		0.339		0.053		0.037		-		0.037	

c. N x P x Cowpea

Levels of N	Levels of P / Cowpea seed rate	N P1	N P2	P P1	P P2	K P1	K P2	Ca P1	Ca P2	Mg P1	Mg P2	S P1	S P2	Fe P1	Fe P2
20 DAS															
N1	S1	3.22	3.50	0.17	0.18	4.10	4.30	0.21	0.29	0.34	0.24	0.30	0.33	0.20	0.25
	S2	3.17	3.13	0.20	0.24	3.42	4.35	0.44	0.40	0.32	0.26	0.37	0.38	0.20	0.25
N2	S1	3.31	3.59	0.21	0.27	3.77	3.88	0.41	0.41	0.24	0.35	0.41	0.39	0.23	0.10
	S2	3.64	3.45	0.26	0.21	4.18	4.23	0.55	0.41	0.36	0.24	0.45	0.35	0.39	0.22
N3	S1	3.41	2.99	0.22	0.18	4.48	3.25	0.40	0.35	0.26	0.32	0.35	0.36	0.18	0.22
	S2	3.69	3.41	0.21	0.24	3.88	4.18	0.39	0.45	0.26	0.36	0.34	0.41	0.09	0.27
N4	S1	0.59	3.69	0.25	0.24	4.20	3.73	0.60	0.40	0.36	0.35	0.42	0.39	0.23	0.25
	S2	3.64	3.08	0.23	0.25	4.00	3.67	0.29	0.40	0.31	0.29	0.37	0.39	0.09	0.11
p		NS		0.01		0.01		0.01		0.01		0.01		0.01	
SEm±		0.273		0.026		0.195		0.045		0.026		0.017		0.026	
CD (0.05)		-		0.053		0.397		0.091		0.053		0.035		0.53	
40 DAS															
N1	S1	1.41	1.97	0.17	0.24	3.33	3.83	0.48	0.53	0.25	0.23	0.22	0.24	0.20	0.30
	S2	1.35	1.87	0.24	0.21	3.30	3.40	0.51	0.43	0.28	0.23	0.26	0.29	0.23	0.23
N2	S1	1.21	1.59	0.22	0.27	3.40	3.60	0.54	0.49	0.34	0.37	0.21	0.33	0.31	0.28
	S2	1.73	1.17	0.16	0.18	3.50	3.55	0.49	0.47	0.23	0.22	0.28	0.32	0.22	0.23
N3	S1	1.49	1.73	0.13	0.20	3.87	3.92	0.46	0.44	0.30	0.29	0.29	0.25	0.23	0.17
	S2	1.49	2.52	0.13	0.15	3.80	3.33	0.53	0.53	0.24	0.29	0.31	0.30	0.26	0.17
N4	S1	1.69	1.41	0.19	0.22	3.25	3.67	0.44	0.55	0.27	0.28	0.19	0.27	0.32	0.14
	S2	2.11	1.59	0.25	0.23	3.40	4.20	0.56	0.55	0.38	0.31	0.26	0.24	0.22	0.23
p		0.05		NS		NS		NS		NS		NS		0.01	
SEm±		0.256		0.018		0.235		0.037		0.026		0.026		0.026	
CD (0.05)		0.523		-		-		-		-		-		0.053	

N1 - 0 kg N ha^{-1}
N2 - 35 kg N ha^{-1}
N3 - 70 kg N ha^{-1}
N4 - 105 kg N ha^{-1}

P1 - 0 kg P_2O_5 ha^{-1}
P2 - 35 kg ,, ha^{-1}
S1 - 25% cowpea seed rate
S2 - 50% ,,

showed a gradual decrease at 20 DAS and a gradual increase at 40 DAS in K content of weeds. Highest Ca, S and Fe contents at 20 DAS were recorded at N_4S_1 level while at 40 DAS they were at N_4S_2 level. Zero level of N with a lower seed rate of cowpea registered lower percentages of Ca, S and Fe in weeds at 20 DAS. Magnesium content at 40 DAS was significantly influenced by higher levels of N and cowpea.

It can be seen from the table that N x P x cowpea interaction significantly affected the composition of all elements studied except N at 20 DAS and of N and Fe at 40 DAS. A higher seed rate of cowpea at N_3 level resulted in the highest content of N at 40 DAS in the presence of P. At 35 kg ha^{-1} of N, P application along with a lower seed rate of intercropped cowpea significantly increased the P content of weeds at 20 DAS while at higher levels of N there was no significant effect for P content. Potassium content was significantly declined by the interaction at higher levels of the treatments. However, at higher levels of N, P and seed rate of cowpea the Ca content was increased and the Mg content was reduced. Positive effect on S content of weeds due to the interaction was more apparent at lower level of N at which a higher cowpea seed rate increased S in the absence of P while at higher levels higher S content was noticed in the absence of P and lower seed rate of cowpea. Iron content of weeds at both stages registered lower values with lower levels of treatments but at higher levels of N the trend was reversed.

3.4 Nutrient uptake by weeds

3.4.1 Main effects

Data on the main effects of treatments on nutrient uptake by weeds are presented in Table 33. The data reveal that removal of all nutrients by weeds pro-

Table 33. Effect of treatment levels on nutrient uptake by weeds, kg ha^{-1}

Treatments	20 DAS							40 DAS						
	N	P	K	Ca	Mg	S	Fe	N	P	K	Ca	Mg	S	Fe
N (kg ha^{-1})														
0	16.03	0.915	20.17	1.64	1.50	1.74	1.13	1.03	0.133	2.21	0.31	0.16	0.16	0.15
35	9.91	0.668	11.74	1.24	0.86	0.95	0.58	1.51	0.205	3.60	0.52	0.31	0.29	0.27
70	11.15	0.730	13.43	1.38	1.11	1.31	0.73	1.74	0.143	3.55	0.44	0.27	0.26	0.19
105	9.20	0.663	10.78	1.04	0.83	1.02	0.41	2.02	0.275	4.66	0.67	0.39	0.31	0.29
p	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.01
SEm±	0.724	0.039	0.564	0.069	0.045	0.079	0.026	0.118	0.013	0.084	0.013	0.013	0.046	0.007
CD (0.05)	1.474	0.079	1.149	0.142	0.091	0.162	0.053	0.239	0.026	0.170	0.026	0.026	0.095	0.014
P_2O_5 (kg ha^{-1})														
0	9.68	0.565	11.16	1.04	0.89	1.49	0.53	1.50	0.174	3.39	0.48	0.28	0.24	0.24
35	13.46	0.923	16.90	1.61	1.25	1.49	0.89	1.66	0.204	3.62	0.58	0.33	0.27	0.21
p	0.01	0.01	0.01	0.01	0.01	0.01	0.01	NS	0.01	0.01	NS	NS	NS	0.01
SEm±	0.512	0.027	0.399	0.049	0.032	0.056	0.018	0.083	0.009	0.059	0.009	0.009	0.033	0.005
CD (0.05)	1.042	0.056	0.813	0.100	0.064	0.115	0.037	-	0.019	0.121	-	-	-	0.010
Cowpea seed rates														
25%	11.43	0.710	14.14	1.22	1.11	1.27	0.73	1.80	0.221	2.11	0.57	0.34	0.30	0.28
50%	11.71	0.778	13.92	1.43	1.04	1.25	0.69	1.36	0.156	2.80	0.40	0.22	0.21	0.17
p	NS	0.05	NS	0.01	0.05	NS	0.05	0.01	0.01	-	0.01	0.01	0.05	0.01
SEm±	0.512	0.027	0.399	0.049	0.032	0.056	0.018	0.083	0.009	0.059	0.009	0.009	0.033	0.005
CD (0.05)	-	0.056	-	0.100	0.064	-	0.037	0.169	0.019	0.121	0.019	0.019	0.067	0.010
Mean for seed rates	11.57	0.744	14.03	1.325	1.075	1.26	0.71	1.58	1.88	2.46	0.48	0.28	0.26	0.23
Control	24.57	1.350	29.01	2.05	1.70	2.26	1.47	0.41	0.05	1.30	0.130	0.07	0.36	0.05
p	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	NS	0.01
SEm±	1.447	0.079	1.129	0.139	0.089	0.159	0.052	0.235	0.026	0.167	0.026	0.026	0.093	0.014
CD (0.05)	2.949	0.159	2.229	0.283	0.182	0.324	0.105	0.479	0.053	0.341	0.053	0.053	-	0.028

gressively decreased with increasing levels of N at 20 DAS. Thus in the absence of applied N weeds removed 16 kg N, 0.91 kg P, 20 kg K, 1.64 kg Ca, 1.50 kg Mg, 1.74 kg S and 1.13 kg Fe per hectare. They were respectively 74, 38, 87, 58, 80.7, 70.5 and 75.6 per cent higher than those at 105 kg N ha^{-1}. Unlike at 20 DAS, increasing levels of N increased the nutrient removal by weeds at 40 DAS significantly. Application of 105 kg N ha^{-1} led to a removal of 2.02, 0.275, 4.66, 0.67, 0.39, 0.31 and 0.29 kg ha^{-1} by weeds as against 1.74, 0.143, 3.55, 0.44, 0.27, 0.26 and 0.19 kg ha^{-1} at 70 kg N ha^{-1}.

The data show that application of P @ 35 kg ha^{-1} increased the removal of elements significantly at both stages. Compared to P_1, the excess removal of N, P, K, Ca, Mg and Fe at P_2 level at 20 DAS worked out to 39, 63, 46, 55, 40 and 68 per cent respectively. At 40 DAS the percentage increases in P and K uptake were 17 and 7 and the reduction in Fe uptake was 12.5 per cent.

Seed rate of cowpea intercropped also significantly influenced the removal of P, Ca, Mg and Fe by weeds at 20 DAS. At 50 per cent seed rate weeds significantly removed more of P and Ca and less of Mg and Fe. The excess removal of P and Ca at 50 per cent seed rate of cowpea worked out to 9.6 and 17 per cent while removal of Mg and Fe were 6.7 and 5.5 per cent less compared to that at 25 per cent seed rate. At 40 DAS lower seed rate of cowpea led to a significantly higher removal of nutrients except K.

Compared with control concurrent cropping of cowpea resulted in a drastic reduction in the nutrient removal by weeds at 20 DAS and the percentage decline was 53, 45, 52, 35, 37, 44 and 52 per cent respectively of N, P, K, Ca, Mg, S and Fe. While at 40 DAS the reverse was observed.

3.4.2 Interaction effects

Data on the interaction effects of treatments on nutrient uptake by weeds are given in Table 34. N x P interaction significantly influenced the removal of all elements at 20 DAS. Highest removal of N was recorded at N_1P_1 which was significantly superior to all other combinations. The data also show a decrease in N removal when phosphorus was not applied. Maximum quantities of P, Ca and Fe were removed at N_3P_2 level and K, Mg and S at N_1P_1 level. Further increase in N level both in the presence and absence of P significantly reduced the weed removal of all the nutrients. Thus the P, Ca and Fe removal at N_4P_2 level respectively were 16, 29 and 55 per cent less than that of N_3P_2 level. At 40 DAS N x P interaction significantly influenced P, K, Ca, Mg and Fe absorption by weeds. Application of N @ 105 kg ha $^{-1}$ along with P @ 35 kg ha^{-1} caused greater removal of P, K, Ca and Mg while Fe was removed more at N_4P_1.

Data on N x cowpea interaction effect show that at 20 DAS all the elements except Ca was affected and the effect was identical on all the elements. N_1S_1 registered the highest removal of 17.97 kg N, 0.99 kg P, 24.58 kg K, 1.73 kg Mg, 1.86 kg S and 1.31 kg Fe per hectare and was significantly superior to the rest of the combinations. At 40 DAS the interaction effect on the absorption of elements varied with elements. Highest level of N, K and S removal were at N_3S_1 level while highest levels of Mg and Fe were removed at N_2S_1 level. Highest level of P was removed at N_4S_2 level.

The effect of P x cowpea interaction was less conspicuous at 20 DAS and P and K removal were not affected at all. Higher level of P combined with lower

Table 34. Interaction effect on nutrient uptake by weeds, kg ha^{-1}

a. N x P

Levels of P / Levels of N	N P1	N P2	P P1	P P2	K P1	K P2	Ca P1	Ca P2	Mg P1	Mg P2	S P1	S P2	Fe P1	Fe P2
20 DAS														
N1	18.52	13.52	0.95	0.88	21.71	18.62	1.81	1.47	1.90	1.09	1.91	1.58	1.16	1.10
N2	5.27	14.55	0.37	0.97	6.09	17.39	0.75	1.73	0.45	1.27	0.67	0.24	0.46	0.70
N3	8.01	14.29	0.46	1.00	9.04	17.82	0.87	1.89	0.58	1.64	0.77	1.86	0.25	1.20
N4	6.91	11.47	0.49	0.84	7.82	13.75	0.75	1.34	0.64	1.01	0.76	1.28	0.26	0.54
P	0.01		0.01		0.01		0.05		0.01		0.01		0.01	
SEm±	1.023		0.055		0.798		0.098		0.063		0.113		0.036	
CD (0.05)	2.085		0.112		1.626		0.200		0.129		0.229		0.074	
40 DAS														
N1	1.02	1.03	0.15	0.11	2.56	1.86	0.38	0.24	0.20	0.12	0.19	0.14	0.16	0.13
N2	1.57	1.45	0.18	0.23	3.42	3.77	0.51	0.52	0.29	0.33	0.24	0.34	0.26	0.27
N3	1.48	2.00	0.13	0.16	3.83	3.28	0.46	0.42	0.28	0.26	0.29	0.24	0.23	0.15
N4	1.92	2.13	0.24	0.31	3.76	5.55	0.55	0.78	0.35	0.42	0.25	0.36	0.32	0.26
P	NS		0.01		0.01		0.01		0.01		NS		0.01	
SEm±	0.166		0.018		0.118		0.018		0.018		0.066		0.010	
CD(0.05)	-		0.037		0.241		0.037		0.037		-		0.019	

b. N x Cowpea

Cowpea seed rate / Levels of N	N S1	N S2	P S1	P S2	K S1	K S2	Ca S1	Ca S2	Mg S1	Mg S2	S S1	S S2	Fe S1	Fe S2
20 DAS														
N1	17.97	14.08	0.99	0.85	24.58	15.75	1.46	1.82	1.73	1.26	1.86	1.62	1.31	0.95
N2	9.87	9.95	0.72	0.62	11.42	12.06	1.24	1.24	0.97	0.75	1.20	0.71	0.43	0.73
N3	10.40	11.89	0.64	0.82	12.12	14.74	1.23	1.54	1.05	1.16	1.24	1.38	0.73	0.72
N4	7.46	10.93	0.50	0.83	8.42	13.15	0.95	1.14	0.69	0.96	0.78	1.27	0.47	0.34
P	0.01		0.01		0.01		NS		0.01		0.01		0.01	
SEm±	1.023		0.055		0.798		0.098		0.063		0.113		0.036	
CD (0.05)	2.085		0.112		1.626		-		0.129		0.229		0.074	
40 DAS														
N1	0.98	1.06	0.12	0.14	2.17	2.25	0.31	0.32	0.15	0.17	0.14	0.19	0.14	0.15
N2	1.95	1.07	0.27	0.14	4.29	2.91	0.63	0.40	0.43	0.19	0.34	0.25	0.35	0.18
N3	2.28	1.21	0.22	0.06	5.59	1.51	0.65	0.23	0.41	0.13	0.39	0.13	0.30	0.08
N4	1.96	2.08	0.27	0.28	4.81	4.51	0.69	0.64	0.38	0.39	0.32	0.29	0.32	0.26
P	0.01		0.01		0.01		0.01		0.01		0.05		0.01	
SEm±	0.166		0.018		0.118		0.018		0.018		0.066		0.010	
CD (0.05)	0.339		0.037		0.241		0.037		0.037		0.134		0.019	

c. P x Cowpea

	20 DAS													
	N		P		K		Ca		Mg		S		Fe	
Cowpea seed rate / Levels of P	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
P1	8.68	10.68	0.51	0.62	11.53	10.80	0.88	1.21	0.88	0.91	0.96	1.10	0.58	0.49
P2	14.17	12.75	0.91	0.94	16.74	17.05	1.56	1.66	1.34	1.16	1.58	1.39	0.88	0.89
P	0.01		NS		NS		0.05		0.01		0.01		0.01	
SEm±	0.724		0.039		0.564		0.069		0.045		0.079		0.026	
CD (0.05)	1.474		-		-		0.142		0.091		0.162		0.053	
	40 DAS													
P1	1.89	1.10	0.21	0.14	4.46	2.32	0.60	0.35	0.36	0.20	0.30	0.18	0.34	0.15
P2	1.70	1.61	0.23	0.17	3.96	3.27	0.54	0.44	0.33	0.24	0.30	0.24	0.22	0.19
P	0.01		NS		0.01		0.01		0.01		NS		0.01	
SEm±	0.118		0.013		0.084		0.013		0.013		0.046		0.007	
CD (0.05)	0.239		-		0.170		0.026		0.026		-		0.014	

d. N x P x Cowpea

		20 DAS													
		N		P		K		Ca		Mg		S		Fe	
Levels of N	Levels of P / Cowpea seed rate	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
N1	S1	19.82	16.12	1.02	0.95	28.12	21.04	1.45	1.47	2.25	1.21	2.03	1.69	1.35	1.26
	S2	17.23	10.93	0.88	0.81	15.31	16.20	2.17	1.46	1.55	0.97	1.79	1.46	0.97	0.94
N2	S1	6.12	13.62	0.42	1.02	6.97	15.87	0.81	1.68	0.47	1.47	0.79	1.60	0.46	0.40
	S2	4.42	15.48	0.31	0.92	5.20	18.91	0.70	1.78	0.43	1.08	0.54	0.88	0.46	1.00
N3	S1	4.78	16.02	0.30	0.98	6.23	18.0[illegible]	0.55	1.90	0.35	1.75	0.49	1.99	0.24	1.21
	S2	11.23	12.56	0.62	1.02	11.84	17.64	1.18	1.89	0.80	1.52	1.04	1.72	0.26	1.19
N4	S1	3.99	10.94	0.29	0.70	4.79	12.05	0.70	1.19	0.44	0.94	0.51	1.05	0.28	0.66
	S2	9.84	12.01	0.68	0.98	10.85	15.44	0.79	1.49	0.85	1.08	1.01	1.52	0.25	0.43
P		0.01		NS		0.01		0.01		0.01		0.05		0.01	
SEm±		1.447		0.077		1.129		0.139		0.089		0.159		0.052	
CD (0.05)		2.948		-		2.299		0.283		0.182		0.324		0.105	
		40 DAS													
N1	S1	1.13	0.84	0.14	0.11	2.68	1.65	0.39	0.23	0.20	0.10	0.18	0.10	0.16	0.13
	S2	0.90	1.23	0.16	0.12	2.43	2.07	0.37	0.26	0.20	0.14	0.19	0.18	0.17	0.14
N2	S1	1.71	2.19	0.21	0.33	3.56	5.01	0.57	0.69	0.35	0.51	0.22	0.45	0.32	0.39
	S2	1.43	0.72	0.15	0.13	3.29	2.53	0.46	0.34	0.22	0.16	0.26	0.23	0.20	0.16
N3	S1	2.72	1.84	0.23	0.21	7.03	4.16	0.83	0.46	0.51	0.31	0.52	0.26	0.42	0.18
	S2	0.25	2.16	0.02	0.11	0.63	2.39	0.09	0.38	0.04	0.21	0.05	0.21	0.04	0.12
N4	S1	2.00	1.93	0.26	0.28	4.58	5.03	0.62	0.76	0.38	0.39	0.27	0.37	0.45	0.19
	S2	1.83	2.33	0.22	0.34	2.94	6.08	0.49	0.79	0.33	0.45	0.23	0.35	0.19	0.33
P		0.01		0.01		0.01		0.01		0.01		0.01		0.01	
SEm±		0.235		0.026		0.167		0.026		0.026		0.093		0.014	
CD (0.05)		0.479		0.053		0.341		0.053		0.053		0.189		0.028	

N1 - 0 kg N ha^{-1} P1 - 0 kg P_2O_5 ha^{-1}
N2 - 35 kg N ha^{-1} P2 - 35 kg ,, ha^{-1}
N3 - 70 kg N ha^{-1} S1 - 25% cowpea seed rate
N4 - 105 kg N ha^{-1} S2 - 50% ,,

seed rate removed larger quantities of N, Mg and S than other treatments and the differences were statistically significant. At 40 DAS lower seed rate of cowpea at zero level of P recorded a higher removal of N, K, Ca, Mg, S and Fe, while higher level of P removal was observed when P was applied along with lower seed rate of cowpea.

Observation on the effect of N x P x cowpea interaction on nutrient removal by weeds at 20 DAS showed that while highest quantity of Ca was removed by weeds at $N_1P_1S_2$, maximum quantity of all other elements was removed by $N_1P_1S_1$. The removal of N, K, Ca, Mg, S and Fe was of the order of 19.82, 28.12, 1.45, 2.25, 2.03 and 1.35 kg ha^{-1}, respectively. At 40 DAS largest removal of N, K, Ca, Mg and S of 2.72, 7.03, 0.83, 0.51 and 0.52 kg ha^{-1} respectively were at $N_3P_1S_1$ and they were significantly superior to other levels. Phosphorus removal was highest at $N_4P_2S_2$ while that of Fe was at $N_4P_1S_1$.

4 Soil characteristics

4.1 Soil pH and Organic carbon

4.1.1 Main effects

Data on the main effects of treatments on pH and organic carbon percentage of the soil during crop growth are presented in Table 35.

It can be seen from the table that neither N or P levels nor varying seed rate of cowpea affected the soil pH. However intercropping significantly affected soil pH at 20 DAS by bringing down the pH from 6.03 in the control plot to 5.69. Nitrogen levels were found to influence the organic carbon content at 20, 60 and 80 DAS. Organic carbon content of the soil at N_1 and N_2 levels was significantly

Table 35. Effect of treatment levels on pH and organic carbon content (%) of soil at various stages of rice growth

Treatments	20 DAS		40 DAS		60 DAS		80 DAS	
	pH	Org. C	pH	Org. C	pH	Org. C	pH	Org. C
N (kg ha^{-1})								
0	5.80	0.55	5.98	0.53	5.58	0.56	5.64	0.59
35	5.66	0.59	5.81	0.53	5.45	0.61	5.47	0.65
70	5.64	0.52	5.89	0.54	5.51	0.64	5.55	0.60
105	5.66	0.58	5.75	0.51	5.36	0.64	5.58	0.57
p	NS	0.01	NS	NS	NS	0.01	NS	0.05
SEm±	0.101	0.013	0.088	0.013	0.077	0.022	0.074	0.022
CD (0.05)	-	0.026	-	-	-	0.046	-	0.046
P_2O_5 (kg ha^{-1})								
0	5.71	0.55	5.84	0.53	5.50	0.61	5.62	0.59
35	5.67	0.57	5.86	0.52	5.45	0.62	5.50	0.61
p	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	0.071	0.009	0.063	0.009	0.055	0.016	0.052	0.016
CD (0.05)	-	-	-	-	-	-	-	-
Cowpea seed rates								
25%	5.64	0.56	5.86	0.53	5.49	0.62	5.59	0.61
50%	5.74	0.56	5.85	0.53	5.46	0.61	5.53	0.69
p	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	0.071	0.009	0.063	0.009	0.055	0.016	0.052	0.016
CD (0.05)	-	-	-	-	-	-	-	-
Mean for seed rates	5.69	0.56	5.85	0.53	5.47	0.61	5.56	0.60
Control	6.03	0.59	5.73	0.52	5.38	0.62	5.55	0.65
p	0.05	NS	NS	NS	NS	NS	NS	NS
Sem±	0.202	0.026	0.177	0.026	0.155	0.045	0.148	0.045
CD (0.05)	0.411	-	-	-	-	-	-	-

Table 36. Effect of treatment levels on available N and P content (kg ha^{-1}) of soil at different stages of rice

Treatments	N				P			
	20 DAS	40 DAS	60 DAS	80 DAS	20 DAS	40 DAS	60 DAS	80 DAS
N (kg ha^{-1})								
0	275.35	273.71	277.08	280.95	97.66	93.52	111.26	89.94
35	280.64	273.75	283.19	287.59	101.37	114.24	110.08	102.59
70	272.76	274.01	286.65	281.56	96.35	91.84	104.62	80.43
105	279.80	271.41	286.36	278.45	98.90	97.24	115.29	89.76
p	0.01	NS	0.05	0.01	NS	NS	0.05	0.01
SEm±	1.818	1.366	2.722	2.493	2.982	11.882	3.135	3.364
CD (0.05)	3.704	-	5.545	5.079	-	-	6.387	6.853
P_2O_5 (kg ha^{-1})								
0	276.44	273.57	282.89	281.04	92.87	98.31	104.66	82.80
35	277.83	272.87	283.76	283.24	104.27	100.10	115.97	98.55
p	NS	NS	NS	NS	0.01	NS	0.01	0.01
SEm±	1.286	0.966	1.925	1.763	2.109	8.402	2.217	2.379
CD (0.05)	-	-	-	-	4.296		4.517	4.846
Cowpea seed rate								
25%	276.96	273.39	283.97	283.02	97.42	104.06	113.24	89.71
50%	277.32	273.05	282.67	281.26	99.73	94.36	107.39	91.65
p	NS	NS	NS	NS	NS	NS	0.05	NS
SEm±	1.286	0.966	1.925	1.763	2.109	8.402	2.217	2.379
CD (0.05)	-	-	-	-			4.517	
Mean for seed rates	277.14	273.22	283.32	282.14	98.58	99.21	110.32	90.68
Control	280.95	272.76	283.76	287.59	99.09	91.53	109.02	94.29
p	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	3.64	2.73	5.44	4.98	5.965	23.76	6.27	6.73
CD (0.05)	-	-	-	-	-	-	-	-

Table 37. Interaction effect on available N content (kg ha^{-1}) of soil at different stages of rice

a. N x P x Cowpea

		20 DAS		40 DAS		60 DAS		80 DAS	
Levels of P		P1	P2	P1	P2	P1	P2	P1	P2
Levels of N	Cowpea seed rate								
N1	S1	264.42	281.12	271.47	275.18	276.53	278.11	277.60	284.60
	S2	281.79	274.08	272.33	275.86	282.35	271.34	284.64	276.96
N2	S1	283.45	283.45	275.30	273.09	278.07	288.71	289.35	294.06
	S2	281.12	274.51	276.33	270.28	289.03	276.92	285.23	281.71
N3	S1	272.89	270.47	277.56	272.33	288.76	287.57	279.93	282.90
	S2	272.85	274.83	271.94	274.20	280.96	289.31	281.71	281.71
N4	S1	277.01	282.86	271.42	270.79	284.68	289.31	275.82	279.89
	S2	278.03	281.32	272.17	271.27	282.70	288.76	274.04	284.05
p		0.01		NS		0.05		NS	
SEm±		3.636		2.733		5.444		4.986	
CD(0.05)		7.408		-		11.089			

Table 38. Interaction effect on available P content (kg ha^{-1}) of soil at various stages of rice

a. N x P x Cowpea

Levels of P		20 DAS		40 DAS		60 DAS		80 DAS	
		P1	P2	P1	P2	P1	P2	P1	P2
Levels of N	Cowpea seed rate								
N1	S1	84.28	104.41	85.33	98.59	102.53	137.93	68.42	97.82
	S2	95.52	106.43	88.74	101.42	97.54	107.03	95.65	97.87
N2	S1	105.52	96.88	159.89	98.35	110.80	114.77	96.98	133.72
	S2	87.61	115.46	84.28	114.42	103.37	111.38	81.83	97.81
N3	S1	96.43	97.29	97.73	92.36	112.82	98.35	77.43	69.04
	S2	90.12	101.57	81.39	95.86	97.74	109.58	71.07	104.16
N4	S1	89.98	104.53	96.78	103.45	104.65	124.04	85.13	89.12
	S2	93.49	107.61	92.36	96.38	107.83	124.65	85.91	98.87
p		0.01		NS		0.01		0.01	
SEm±		5.965		23.763		6.271		6.728	
CD(0.05)		12.151		-		12.775		13.707	

N1 - 0 kg N ha^{-1}
N2 - 35 kg N ha^{-1}
N3 - 70 kg N ha^{-1}
N4 - 105 kg N ha^{-1}

P1 - 0 kg P_2O_5 ha^{-1}
P2 - 35 kg ,, ha^{-1}
S1 - 25% cowpea seed rate
S2 - 50 % ,,

Application of P @ 35 kg ha^{-1} led to a significantly higher status of available P in the soil than zero level of P at 20, 60 and 80 DAS.

Between the cowpea seed rates the lower one increased the content of available P in the soil significantly at 60 DAS and the increase worked out to 5.4 per cent over the higher seed rate.

4.3.2 Interactions effects

Data on interaction effects of treatments on available P are presented in Table 38. Observation on second order interaction showed that status of available P varied differently among treatments during various phases of crop growth. At 40 DAS the treatments did not differ significantly. During other phases when treatments differed significantly, $N_2P_2S_2$ at 20 DAS, $N_1P_2S_1$ at 60 DAS and $N_2P_2S_1$ at 80 DAS recorded phosphorus content significantly superior to other treatment combinations.

4.4 Available Potassium

4.4.1 Main effects

Data on the main effects of treatments on available K are given in Table 39. Nitrogen levels affected the available K content significantly only at 80 DAS while seed rate of cowpea intercropped affected it only at 20 DAS. Phosphorus did not have any effect on K content of the soil.

At 80 DAS application of 35 kg N ha^{-1} registered 354 kg of available K ha^{-1} and this was significantly superior to N applied @ 70 kg ha^{-1}. Similarly lower

Table 39. Effect of treatment levels on available K and Fe content (kg ha^{-1}) of soil at different stages of rice

Treatments	K				Fe			
	20 DAS	40 DAS	60 DAS	80 DAS	20 DAS	40 DAS	60 DAS	80 DAS
N (kg ha^{-1})								
0	564.33	423.00	464.17	350.67	84.75	32.85	26.68	23.71
35	569.00	437.42	445.34	354.00	87.60	41.65	27.84	24.45
70	550.99	399.17	431.33	306.00	82.13	39.08	29.87	19.94
105	541.99	389.58	432.34	320.00	82.05	41.73	30.51	27.26
P	NS	NS	NS	0.05	NS	0.01	0.05	0.01
SEm±	17.255	25.529	17.935	18.001	2.399	1.870	1.36	1.005
CD (0.05)				36.672	-	3.810	2.77	2.048
P_2O_5 (kg ha^{-1})								
0	555.83	413.96	448.92	328.83	81.94	40.71	28.74	24.06
35	557.33	410.62	437.67	336.50	86.17	36.95	28.71	23.62
P	NS	NS	NS	NS	0.05	0.01	NS	NS
SEm±	12.201	18.052	12.682	12.729	1.696	1.323	0.960	0.711
CD (0.05)	-	-	-	-	3.455	2.694	-	-
Cowpea seed rate								
25%	575.67	402.00	431.83	333.50	83.07	36.66	28.27	23.30
50%	537.50	422.58	454.75	331.83	85.05	40.99	29.18	24.38
P	0.01	NS	NS	NS	NS	0.01	NS	NS
SEm±	12.201	18.052	12.682	12.729	1.696	1.323	0.966	0.711
CD (0.05)	24.856	-	-	-	-	2.694	-	-
Mean for seed rates	556.59	412.29	443.29	332.60	84.06	38.83	28.73	23.84
Control	518.67	440.00	353.33	290.67	84.49	35.11	30.72	34.78
P	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	34.51	51.06	35.87	36.00	4.79	3.74	2.73	2.01
CD (0.05)	-	-	-	-	-	-	-	-

seed rate of cowpea recorded 575.67 kg ha^{-1} of available K at 20 DAS which was significantly superior to that of higher seed rate. Though there was an increase in the available K content of the soil in the green manured plot over control, at certain stages, the effect was not significant.

4.4.2 Interaction effects

Table 40 shows the interaction effects of treatments on available K content of soil. Interaction effect among N, P and seed rate of cowpea was significantly noticed at 20 and 60 DAS. At 20 DAS $N_2P_2S_1$ recorded the highest content of available K while at 60 DAS it was recorded uniformly by $N_1P_2S_2$, $N_2P_1S_2$ and $N_4P_2S_2$ showing less response to N application in combination with P and higher cowpea seed rate.

4.5 Available Iron

4.5.1 Main effects

Main effects of treatments on available Fe content of the soil are presented in Table 39.

Progressive N application significantly affected the Fe content of soil at 40, 60 and 80 DAS. Application of 105 kg N ha^{-1} recorded the highest available Fe content of 41.73, 30.51 and 27.26 kg ha^{-1} at 40, 60 and 80 DAS respectively and were significantly superior to N_1 at 40 and 60 DAS and to all other levels at 80 DAS.

Application of P at 35 kg ha^{-1} increased the content of available Fe at 20 DAS by 4.23 kg ha^{-1} over that recorded in the absence of P, while at 40 DAS P_1

Table 40. Interaction effect on available K content (kg ha^{-1}) of soil at various stages of rice

c. N x P x Cowpea

Levels of P		20 DAS		40 DAS		60 DAS		80 DAS	
Levels of N	Cowpea seed rate	P1	P2	P1	P2	P1	P2	P1	P2
N1	S1	588.00	560.00	393.33	408.00	464.00	445.33	352.00	328.00
	S2	536.00	573.33	445.33	445.33	464.67	482.67	361.33	361.33
N2	S1	532.00	672.00	378.67	435.33	426.67	464.00	337.33	389.33
	S2	545.33	526.67	445.33	490.33	482.67	408.00	346.67	342.67
N3	S1	581.33	589.33	402.67	426.00	473.33	398.67	290.67	342.67
	S2	541.33	492.00	402.67	365.33	417.33	436.00	300.00	290.67
N4	S1	541.33	541.33	402.67	369.33	398.67	384.00	300.00	328.00
	S2	581.33	504.00	441.00	345.33	464.00	482.67	342.67	309.33
p		0.05		NS		0.05		NS	
SEm±		34.509		51.059		35.869		36.002	
CD (0.05)		70.302		-		73.074		-	

N1 - 0 kg N ha^{-1}
N2 - 35 kg N ha^{-1}
N3 - 70 kg N ha^{-1}
N4 - 105 kg N ha^{-1}

P1 - 0 kg P_2O_5 ha^{-1}
P2 - 35 kg ,, ha^{-1}
S1 - 25% cowpea seed rate
S2 - 50% ,,

gave a significantly higher content of 40.71 kg ha^{-1} which was 3.76 kg more than P_2.

Higher seed rate of cowpea significantly increased the available Fe content of the soil at 40 DAS when it increased the Fe content from 36.6 to 40.99 kg ha^{-1}. Concurrent raising of cowpea tended to reduce the available Fe content of the soil especially towards the later stages of crop growth, but the effect was not significant. There was a gradual decline in the available Fe content of soil from the initial stage to the final stage of crop growth. This decline was higher in the green manured plot (71.64%) than in the control plot (58.84%).

4.5.2 Interaction effects

Interaction effects on available Fe content are presented in Table 41. N_1P_2 and N_1P_1 recorded respectively the highest and lowest available Fe contents at 20 DAS which were significantly superior to other N x P combinations, while at 40 and 80 DAS significantly superior level of available Fe was recorded by N_4P_1 combination and the inferior level by N_1P_1 and N_3P_2 respectively.

Data on N x cowpea interaction show that highest Fe content of the soil at 20 DAS was recorded by N_1S_1 and at 40 and 80 DAS by N_2S_2 and N_4S_1 respectively. At 80 DAS N_4S_1 was on par with N_2S_1. The least available iron content at 80 DAS was recorded by N_3S_1.

The interaction between P and cowpea significantly influenced the Fe content of soil at 40 and 80 DAS. The effect of higher seed rate of cowpea in increasing the Fe content of soil was boosted up by phosphorus application at 20 and 40 DAS when it recorded 88.44 and 43.3 kg ha^{-1} respectively.

Table 41. Interaction effect on available Fe content (kg ha^{-1}) of soil at various stages of rice

a. N x P

Levels of P	20 DAS		40 DAS		60 DAS		80 DAS	
Levels of N	P1	P2	P1	P2	P1	P2	P1	P2
N1	76.18	92.72	3.195	33.74	26.98	26.38	21.31	26.12
N2	89.01	86.19	35.56	47.72	27.25	28.42	26.30	22.60
N3	80.57	83.69	44.33	33.83	29.57	30.16	21.07	18.80
N4	82.01	82.09	50.98	32.48	31.14	29.87	27.55	26.96
p	0.01		0.01		NS		0.01	
SEm±	3.392		2.645		1.933		1.422	
CD (0.05)	6.911		5.389		-		2.896	

b. N x Cowpea and P x Cowpea

Cowpea seed rate	20 DAS		40 DAS		60 DAS		80 DAS	
Levels of N & P	S1	S2	S1	S2	S1	S2	S1	S2
N1	91.80	77.09	29.82	35.88	26.97	26.39	21.61	25.81
N2	86.03	89.16	35.59	47.70	27.83	27.84	27.73	21.17
N3	78.03	86.24	44.00	34.16	29.86	29.87	15.44	24.44
N4	76.40	87.71	37.24	46.22	28.41	32.61	28.42	26.09
p	0.01		0.01		NS		0.01	
SEm±	3.392		2.645		1.933		1.422	
CD (0.05)	6.911		5.389		-		2.896	
P1	82.23	81.66	42.73	38.69	28.70	28.77	22.58	25.53
P2	83.90	88.44	30.60	43.30	27.83	29.59	24.02	23.22
p	NS		0.01		NS		0.05	
SEm±	2.399		1.870		1.367		1.005	
CD (0.05)	-		3.810		-		2.048	

c. N x P x Cowpea

Levels of P		20 DAS		40 DAS		60 DAS		80 DAS	
Levels of N	Cowpea seed rate	P1	P2	P1	P2	P1	P2	P1	P2
N1	S1	88.17	95.44	30.15	29.48	27.85	26.09	14.80	28.42
	S2	64.18	90.00	33.75	38.01	26.10	26.68	27.81	23.81
N2	S1	88.93	83.13	37.40	33.78	28.40	27.26	29.90	25.55
	S2	89.08	89.25	33.73	61.67	26.10	29.58	22.69	19.64
N3	S1	81.35	74.71	59.03	28.98	31.33	28.39	17.76	13.11
	S2	79.79	92.68	29.63	38.69	27.81	31.93	24.39	24.48
N4	S1	70.46	82.34	44.33	30.15	27.23	29.58	27.85	28.99
	S2	93.57	81.84	57.64	34.81	35.05	30.17	27.24	24.94
p		0.01		0.01		NS		0.01	
SEm±		4.797		3.741		2.734		2.010	
CD (0.05)		9.773		7.621		-		4.096	

N1 - 0 kg N ha^{-1}
N2 - 35 kg N ha^{-1}
N3 - 70 kg N ha^{-1}
N4 -105 kg N ha^{-1}

P1 - 0 kg P_2O_5 ha^{-1}
P2 - 35 kg ,, ha^{-1}
S1 - 25% cowpea seed rate
S2 - 50% ,,

Effect of P and higher seed rate of cowpea on increasing the Fe content of soil was positively influenced by increasing levels of N with advancing growth. Thus combinations of N_1, N_2 and N_3 with P_2S_2 at 20, 40 and 60 DAS, respectively recorded comparatively higher levels of available Fe while at 80 DAS this trend was not observed. The lowest Fe content of soil at 80 DAS was recorded by $N_3P_2S_1$.

5 Economics of the system

It can be understood from Table 42 that rice cultivation without fertilizer application is economically unprofitable. Application of 35 kg N ha^{-1} with or without P or green manure could not add much to the net income where as application of 70 kg N ha^{-1} along with simultaneous *in situ* green manuring could contribute to the income of the farmer and which rewarded an amount of seventy nine paise per rupee invested, i.e. a benefit-cost ratio of 1.79.

Table 42. Economics of the system, Rs. ha^{-1}

Treatment combinations	Cost of cultivation	Return			Net return	B/C ratio
		Grain	Straw	Gross return		
N1 S1 P1	7003	5807	1224	7031	28	1.00
N1 S1 P2	7770	7420	1205	8625	855	1.11
N1 S2 P1	7413	6832	1599	8431	1018	1.14
N1 S2 P2	8180	6727	1014	7741	-439	0.95
N2 S1 P1	7231	7809	1371	9180	1949	1.27
N2 S1 P2	7998	7539	1309	8848	850	1.11
N2 S2 P1	7641	11186	2207	13393	5752	1.75
N2 S2 P2	8408	9503	1452	10955	2547	1.30
N3 S1 P1	7459	11067	2099	13166	5707	1.77
N3 S1 P2	8226	11883	2827	14710	6484	1.79
N3 S2 P1	7867	10546	2301	12847	4978	1.63
N3 S2 P2	8636	6521	1344	7865	-771	0.91
N4 S1 P1	7687	8386	2088	10474	2787	1.36
N4 S1 P2	8454	9394	1867	11261	2807	1.33
N4 S2 P1	8097	10322	2154	12476	4379	1.54
N4 S2 P2	8864	9737	1937	11674	2810	1.32
Control	8136	9548	1722	11270	3134	1.38

N1 - 0 kg N ha^{-1}
N2 - 35 kg N ha^{-1}
N3 - 70 kg N ha^{-1}
N4 - 105 kg N ha^{-1}

P1 - 0 kg P_2O_5 ha^{-1}
P2 - 35 kg ,, ha^{-1}
S1 - 25% cowpea seed rate
S2 - 50% ,,

Grain Rs.350 q^{-1}
Straw Rs. 80 q^{-1}
Men - Rs.50/-
Women - Rs.40/-
Tractor - Rs.140 hr^{-1}

Discussion

DISCUSSION

The important results of the present study are discussed in this chapter.

1 Effects of Nitrogen

1.1 Nutrient content and its influence

Application of increasing levels of nitrogen has increased the N content of plant throughout the growth of rice and the increase was statistically significant upto 70 kg N ha^{-1} (Table 11). The increase in N levels has brought about a corresponding increase in the yield of grain and straw (Table 20; Fig.4). Thus the results showed that direct effect of N application has been to increase the yield through an increase in the content of the element in the plant. Wallace (1971) has stated that N is the most important element and any system of crop production requires its application. Zelitch (1971) has stated that yield increase could be expected with increase in N content of the leaves upto 6 mg dm^{-2}.

Yield of rice has been described as the sum of volume of the container and the contents by Murata (1970) and the yield attributes except 1000 grain weight constitute the volume. Increasing levels of N upto 70 kg ha^{-1} has increased the length of panicle and total number of grains formed (Table 20). Panicle length had shown significant positive correlation with grain yield (Table 23; Fig. 5). Thus the results showed that N increased the yield through a steady improvement of the yield attributes.

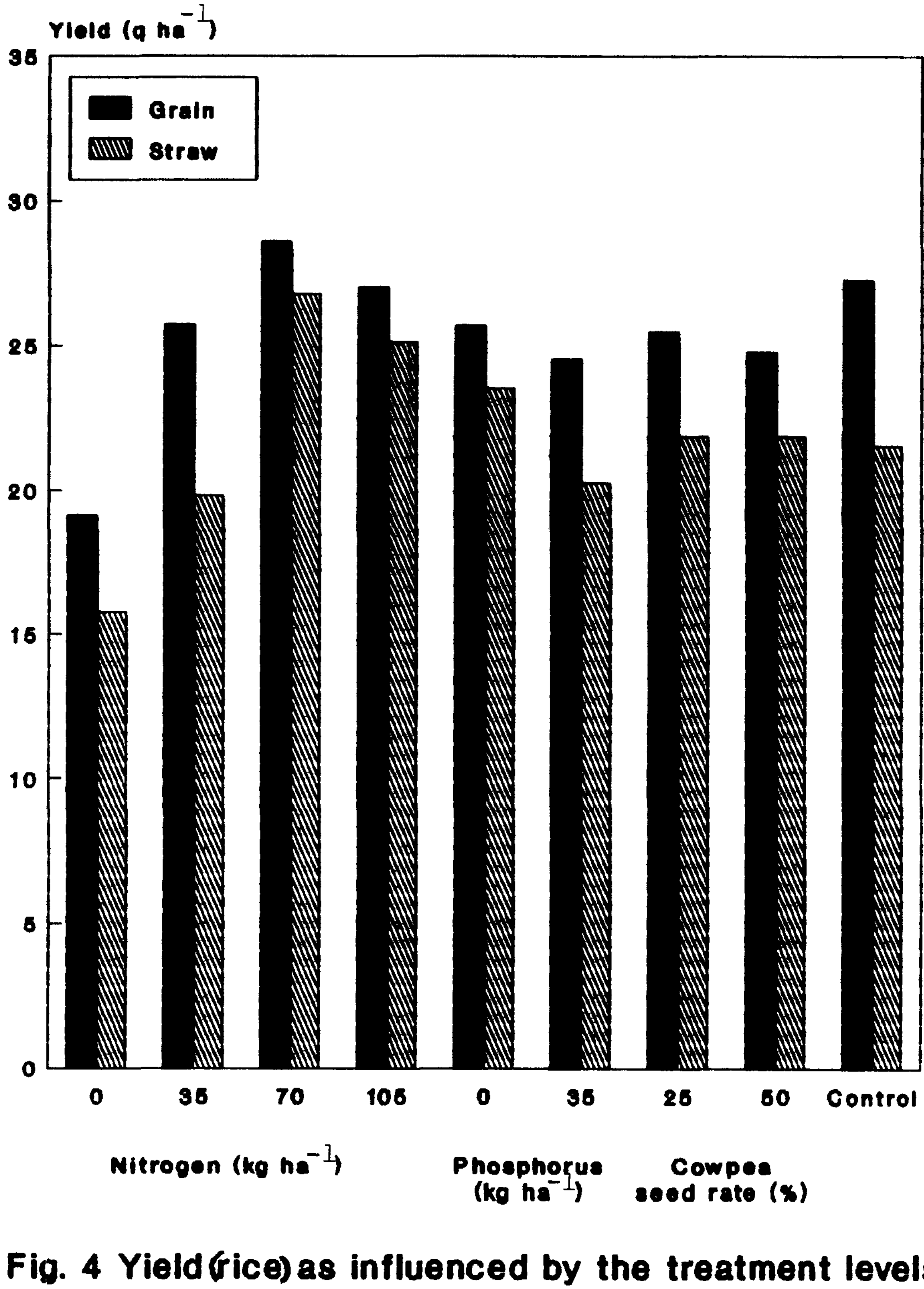


Fig. 4 Yield (rice) as influenced by the treatment levels

Chlorophyll is considered as the metabolic index of N utilization by rice plant as more than 75 per cent of N in the leaf is concentrated in the chloroplast. Total chlorophyll and its constituents increased with increasing N levels (Tabel 9). The increase in chlorophyll content and yield have been in parallel lines and this suggests that the metabolic pathway of N in yield formation is through formation and development of chlorophyll.

A perusal of the data on the role of N in increasing the plant content of other elements showed that K and Mg contents were significantly increased with increase in the levels of N application (Table 11). Potassium content at 50 DAS was found to be significantly correlated with both productive tillers and length of panicle (Table 23; Fig. 5). Thus the results showed that productivity improvement of rice by N was at least in part through an improvement in the content of K in the plant. The main role of K is in charge balance in the plant system for metabolic efficiency and hence the results showed that N contributed to yield through an improvement in the internal nutritional environment.

Observations on growth characteristics of rice showed that increasing levels of N increased the height of plants significantly throughout the growth period (Table 4). Tiller count on the other hand though started showing a positive response, significant response to higher levels of N was obtained only at 80 DAS. Thus the increase in height and tiller count was also in parallel lines with N content of the plant and the increase in these vegetative attributes has been the natural result of the functional association of N with development of plant. Failure of higher levels of N to significantly affect the tiller count at initial stage may be due to the stress due to

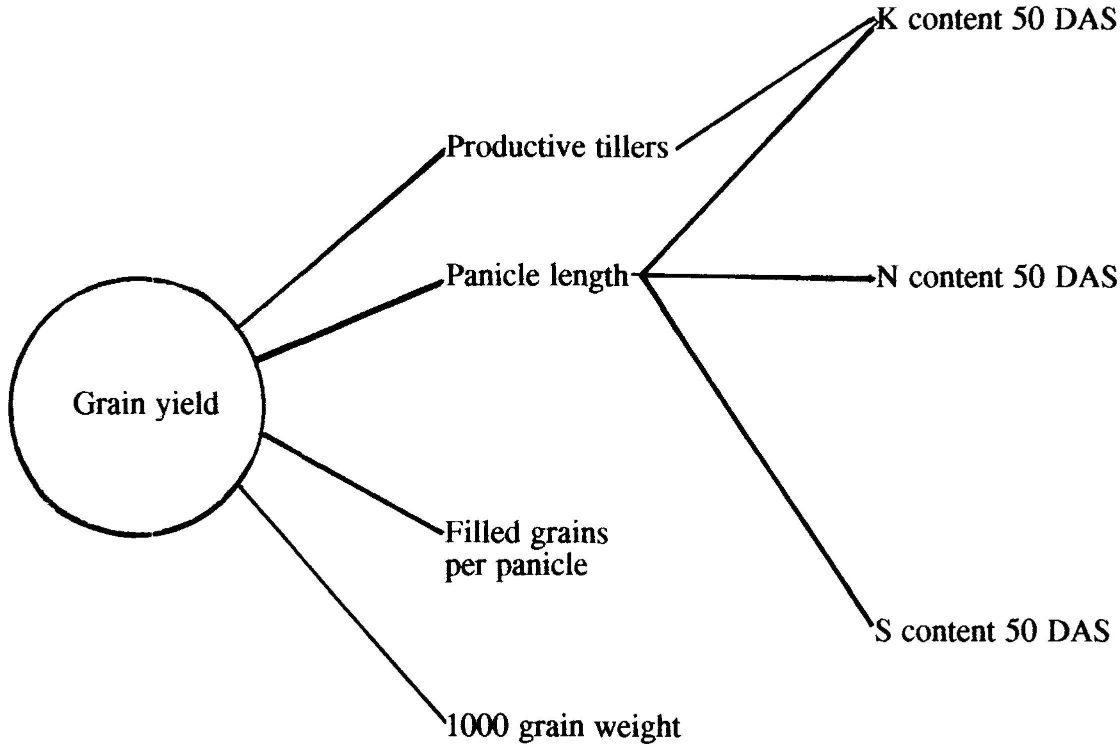


Fig.5. Interrelation of grain yield and other factors

low soil moisture content. Nair (1968) has also reported that increasing N levels will fail to influence growth characters positively.

Results of the present study showed that N did not have any influence on plant content of iron (Table 11). Similar results have also been reported by Pillai (1972). The crop in the present study has shown a very high content of Fe, to the extent of 0.15 per cent (1500 ppm) at 20 DAS. At all stages of observation it had been well over 300 ppm which is considered as the upper critical level of Fe in rice (Yoshida, 1981). Hassan (1977) has reported that iron content of laterite soils range in the order of 4 - 7 per cent. Potty *et al.* (1992) have shown that rice plants grown in laterite soils manifest continuous absorption and high content of iron. Bridgit *et al.* (1992) have found that nitrogen use efficiency and productivity of high yielding rice varieties are limited by excess iron in the plant system. High yielding varieties of rice tend to develop a coating of iron on the roots which may even restrict absorption (Marykutty *et al.*, 1992). Elaborating further on their work Bridgit *et al.* (1993) have stated that under situations of excess iron in the plant relative contents rather than absolute contents of elements may show better relation to productivity.

In the present study, beyond 35 kg ha^{-1} the role of N in increasing the productivity showed signs of shifting more towards straw (Fig. 4). This is illustrated further from the fact that among the factors contributing to yield, though 1000 grain weight comprises the weight it had shown minimum correlation with yield behind productive tillers and length of panicle (Table 23). Moreover chlorophyll content also was showing significant positive correlation with yield. In addition to this crop response to N beyond 35 kg ha^{-1} was little and higher level failed to bring about any significant effect inspite of an increase in N content of plant (Table 11 and 20). It is possible that the dwindling response to higher levels of N and associated phenomenon is probably related to excess iron. This, however, requires detailed investigation.

1.2 Dry matter production

Increasing levels of N application in the present study significantly affected the dry matter production (DMP) only at 75 DAS (Table 7) though plant content of N had significantly increased at all stages of observation. The results also showed that the tendency for a higher DMP with higher plant content of N was maintained till 75 DAS but at 90 DAS and at harvest this superiority was vanished. A comparison of the data on DMP with that of tiller production and decline pattern will show that the distinct phases of dry matter decline has corresponded to the decline in tiller counts (Fig. 6 and 7). Exess production of tillers at the active tillering phase and their decline subsequently has been reported by Datta (1981). However, in the present trial the extent of decline after the normal active tillering phase has been of the order of 30-40 per cent which corresponded to 20-30 per cent reduction in dry matter. The extent of tiller decline may appear to be high. One possible reason for this high tiller decline may be the higher seed rate used in dibbled crop and consequent higher number of seedlings and invigorated competition compared to transplanted crop. Recommended seed rates for dibbling and transplanting are 80-90 and 60-85 kg ha^{-1}, respectively (KAU, 1993).

A perusal of the data will further show that the crop had manifested a rapid increase in DMP after 60 days upto 90 days of sowing which corresponded to the early productive phase. However, the rate of increase in DMP had been lowest at 105 kg N ha^{-1} in this period especially between 75 and 90 DAS. This would

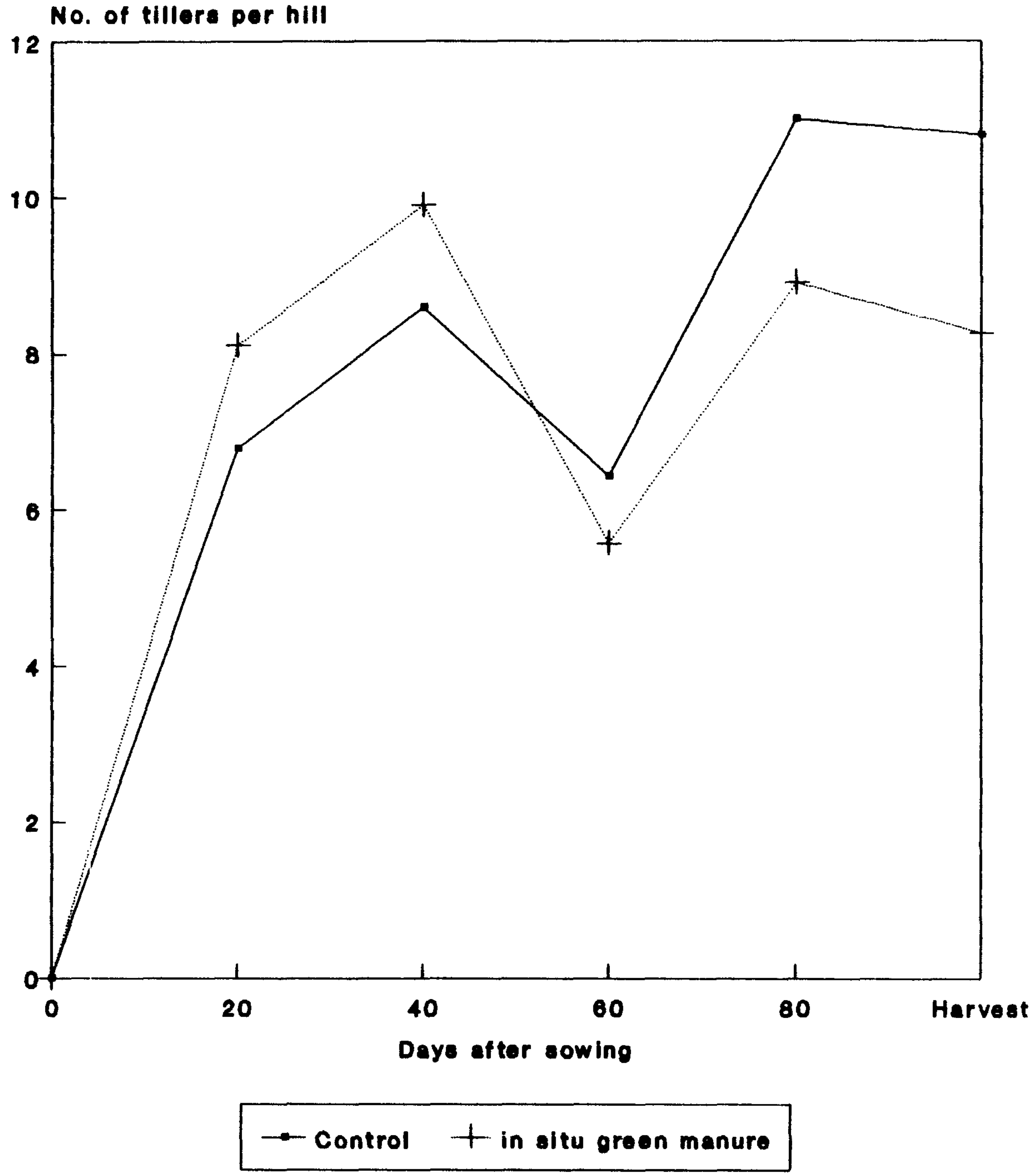


Fig. 6. Influence of *in situ* green manuring on tiller production of rice.

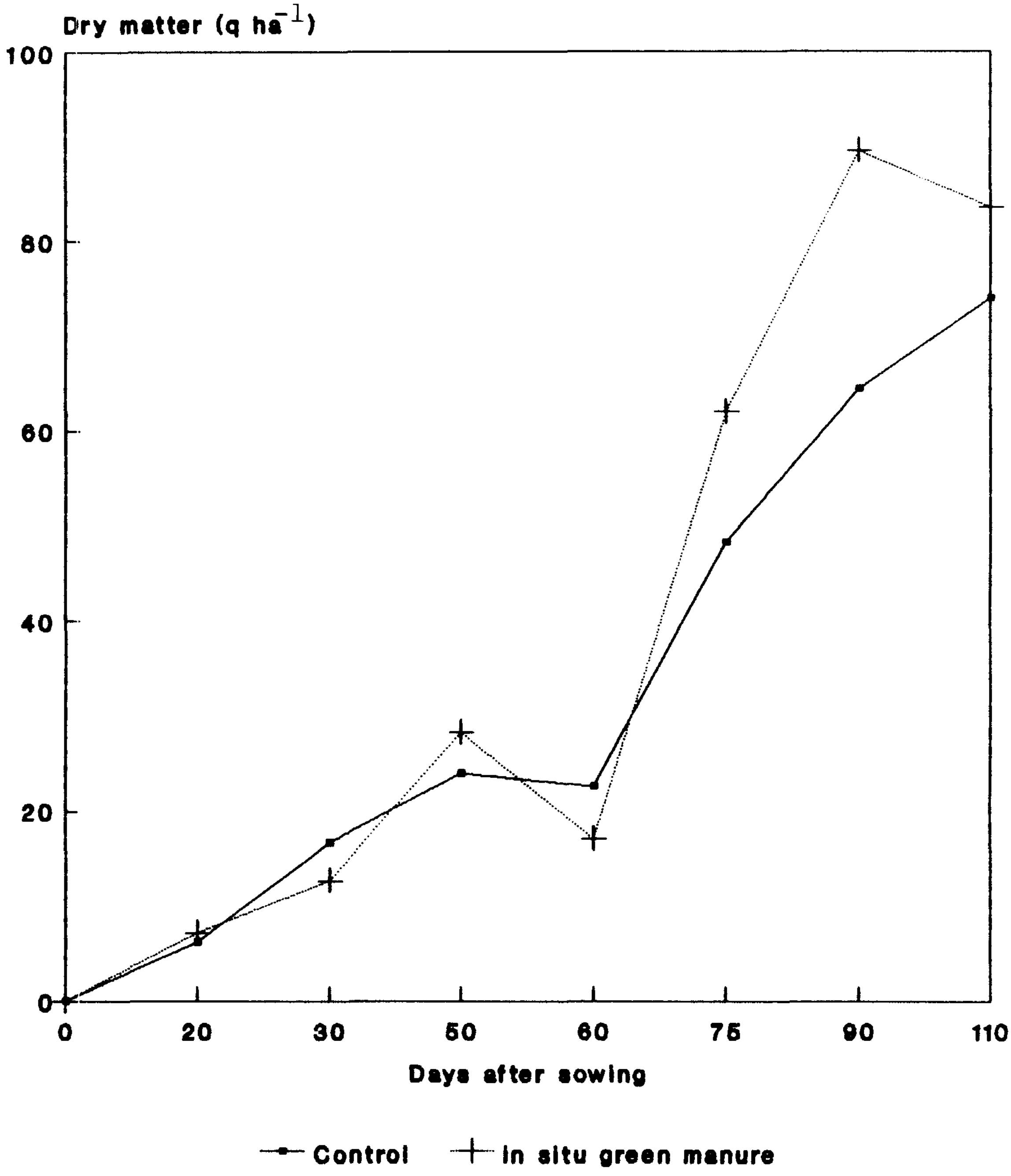


Fig. 7 Dry matter production of rice
as influenced by *in situ* green manuring

suggest that the efficacy of applied N is lost during this period, the cause for which is not known and requires further experimentation.

Dry matter has shown a further decline between 90 DAS and harvest (Table 7; Fig. 7). This decline evidently is that of non productive tillers and suggests that the crop has manifested a continuous tiller production-decline phenomenon leading to a diversion and waste of nutrients and photosynthates.

Another observation worth mentioning is the absence of chlorophyll 'a' in leaves below the boot leaf at 75 DAS irrespective of the treatments (Table 9). Chlorophyll 'a' is the photosynthetic unit and chlorophyll 'b' acts as the light trapping unit (Conn and Stumpf, 1976). Hence an absence of chlorophyll 'a' in the lower leaves points out to their incapability for photosynthesis. These leaves will still be respiring and consuming away the photosynthates which in turn might have been responsible for the second tillering and declining phase and general loss of productivity. Bridgit and Potty (1992) have reported similar defective chlorophyll biosynthesis in iron rich lateritic soils. In the present study the plant content of iron at 75 DAS was well above the critical level of 300 ppm.

1.3 Nutrient uptake

Effect of increasing levels of N application increased the uptake of all elements at all stages of observation and the increases were statistically significant upto 70 kg N ha^{-1} (Table 16). A comparative perusal of the dry matter production and N uptake will show that DMP and nutrient removal have followed more or less the same pattern. Uptake rate of N, P, K, Ca, Mg, S and Fe had been stimulated by nitrogen. It can also be seen that while NPK uptake decreased at harvest due to reduction in DMP, Ca, Mg, S and Fe uptake registered improvement indicating an improportionate accumulation (Table 16; Fig. 8 and 9). The cause and effect relationships need further investigation.

2 Effects of phosphorus

Application of phosphorus had increased the P content of plant only at 25 DAS (Table 11). It had also increased the N and Mg contents at 25 DAS. However, the effect of phosphorus was confined only upto 25 DAS. This is because of the nature of the system of cultivation. In the early phase when the soil was not wet, applied P had effect but subsequently when water stagnation started native P becomes available and probably the entire requirement of the plant is met. Increased availability of P under situations of water stagnation has also been reported by Ponnamperuma (1972). Moreover as the effect of applied P on plant content was confined to 25 DAS response for this cannot be expected.

Application of P showed a pattern of nutrient uptake similar to that of N but the magnitude of variation was sudden.

3 Effects of *in situ* green manuring

Variation in the seed rate of cowpea for *in situ* green manuring though has not affected the growth and yield in general, it affected certain specific attributes. Among them comes the nutrient content. A higher seed rate increased the P, K and Fe content at 25 DAS, N at 50 DAS and Ca and S at 75 DAS significantly over lower seed rate (Table 11). Chlorophyll 'b' content of the boot leaf was also affected (Table 9). These results showed that intercropping shall definitely modify the internal nutritional environment as well as the nutritional balance differently at different

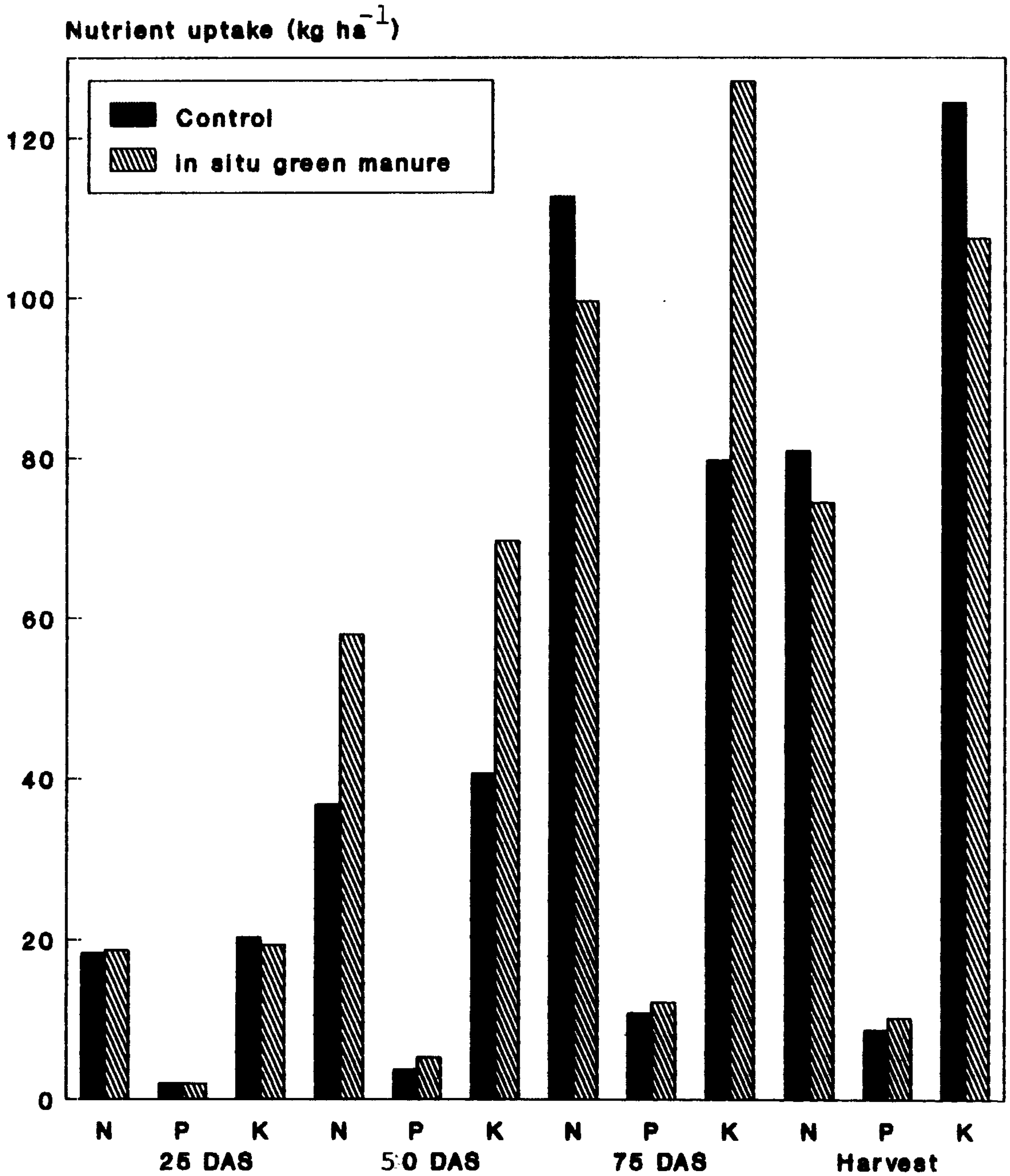


Fig. 8 Influence of *in situ* green manuring on the uptake of NPK by rice.

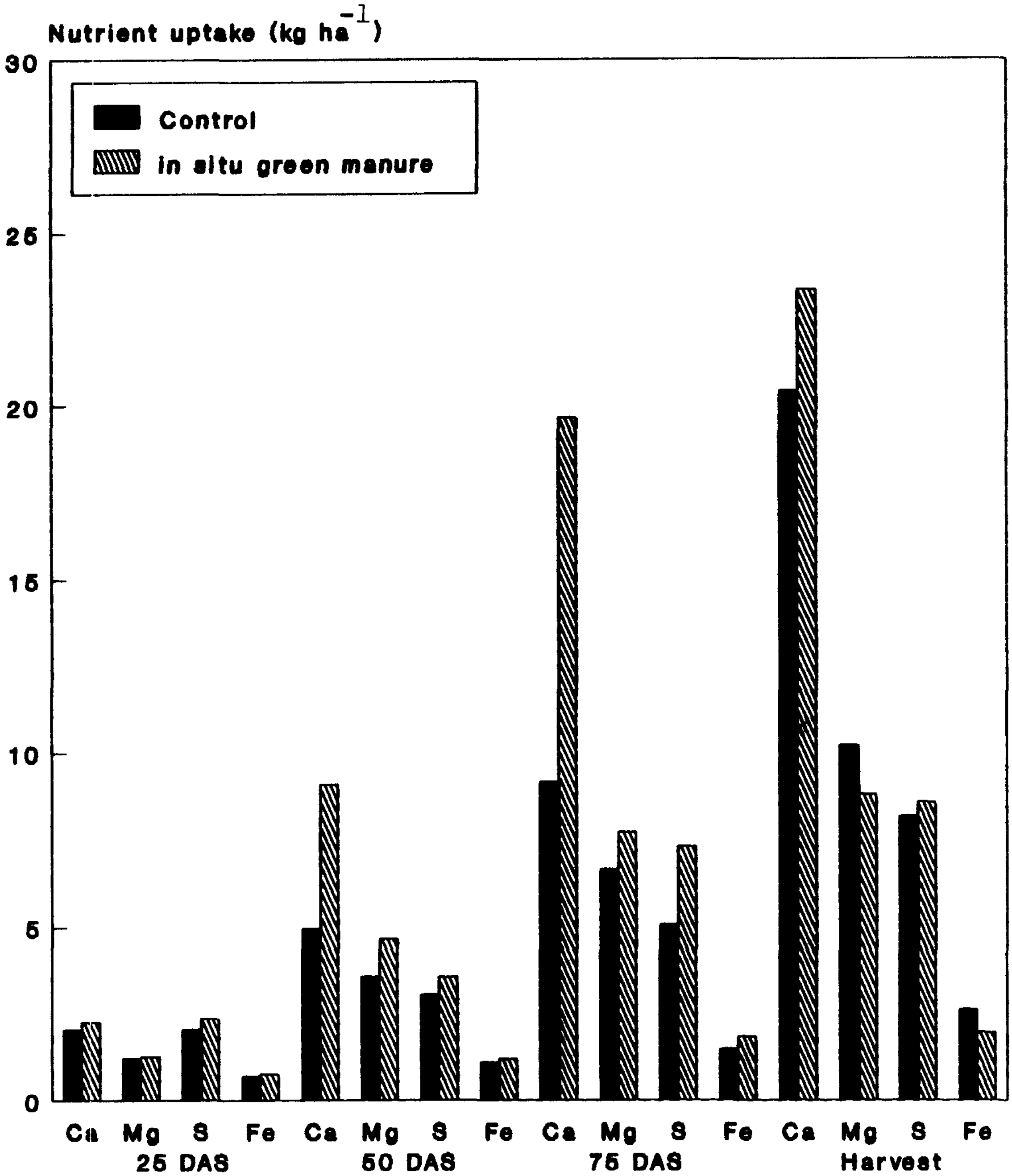


Fig. 9 Influence of *In situ* green manuring on the uptake of Ca, Mg, S and Fe by rice.

stages of plant growth and that specific influences will be affected by population also. In the present study cowpea had been sown over and above the normal population of rice and the overcrowding itself would have affected the attributes. However, variation in S and Ca contents by 75th day suggests metabolic changes in the plant system due to variation in seed rate. Tisdale *et al.* (1985) have reported that non-legumes intercropped with leguminous crop get benefitted by the root excretions as well as microbial decomposition of sloughed-off portions of roots and nodular tissue of the legume. The increase in S and Ca contents at 75 DAS may be due to their higher availability from decomposed cowpea. Cowpea being a legume is richer in Ca and S.

Nutrient content of plant at any time is a function of availability and is a factor for growth where as nutrient uptake is a function of growth, absorption and accumulation. Nutrient uptake study has shown that though nutrient contents were not affected, uptake of all elements was affected significantly. Higher seed rate of cowpea increased the uptake of all elements except iron at harvest (Table 16). Thus it may appear likely that uptake of iron and other elements does not follow identical lines. The fact that nutrient uptake was increased without any corresponding increase in yield would suggest accumulation of the elements arising out of availability which in turn had been the effect of higher seed rate used. Soil analyses have also shown a higher availability of the elements.

The influence of seed rates on nutrient ratios showed that the most pronounced effect of seed rate of cowpea had been on N/Fe ratio (Table 14). The lower seed rate showed a narrower ratio both at 50 and 75 DAS, though with the decomposition of cowpea the gap between the N/Fe ratios at the two seed rates narrowed by 75 DAS. The superiority of higher seed rate of cowpea in significantly influencing the 1000 grain weight which is the net result of translocation to the grain appears to be due to the widening of N/Fe ratio. Increased grain weight due to the widening of N/Fe ratio has also been reported by Pillai (1972).

A comparison of rice performance at the two seed rates of intercropping individually with normal recommended practice will show that they do not differ (Table 20; Fig. 4). This will be misleading as the rice performance under intercropping is the mean of all treatment combinations with 52 kg N and 17.5 kg P per hectare. On par performance itself will suggest that intercropping is advantageous over conventional practice as the former equates with the performance of the latter with a less of 18 kg N and 17.5 kg P per hectare.

4 Interaction effects

4.1 N x P interaction

Interaction effect between N and P significantly increased the number of filled grains and grain-straw ratio at 35 kg N level, and the significance waned with increasing levels of N (Table 22a). Grain filling is the result of the photosynthesis in the boot leaf and translocation from the vegetative portions. Application of P along with N appears to have brought about a more efficient translocation to the grains in this case. The fact that this effect was not corroborated with corresponding nutrient contents would suggest that more than nutrient content some other factor has been responsible for this. N/Fe ratio can be seen to have widened by 75 DAS due to the interaction and it is likely that the widened N/Fe ratio has contributed to better grain-straw ratio and higher number of filled grains. Increase in number of filled grains and grain-straw ratio could not however bring about significant increase in yield.

4.2 N x Cowpea interaction

Interaction between N levels and seed rates of cowpea significantly affected the grain and straw yield of rice and the effect was pronounced at 35 and 70 kg N levels. At the lower level of N higher seed rate increased the grain and straw yield while at 70 kg N level lower seed rate of cowpea was better (Table 22b). Significant influence of intercrop cowpea could be expected only after 50 days when cowpea would have decomposed. The increase in yield in these treatments would appear to be the natural corollary of the enhanced elongation at 80 DAS as well as the near absence of the pehnomenon of second tiller decline (Table 6). In the N_2S_2 and N_3S_1 treatments the number of tillers/hill at 80 DAS were 7.65 and 8.85 respectively. At harvest the corresponding tiller counts were 7.5 and 8.77. Thus the data would indicate that *in situ* green manuring increased the yield of both grain and straw by minimising the post flowering tillering phenomenon. In this respect the effect of intercropping has been contrary to that of exclusive use of fertilizer alone. Thus it appears that inter cropping has helped in improving the use of fertilizer nitrogen by reducing the wasteful use of photosynthates in the productive phase. The fact that yield improvement as well as accumulation of biomass at harvest has followed the very same pattern points out to this regulatory influence as one mechanism of yield improvement under *in situ* green manuring. However corroboratory evidences are not available to confirm this. In this case also more than nutrient content of the plant in the preceding phases the nutrient ratios appeared to be important. The respective N/Fe ratios in N_2S_2 and N_3S_1 at 75 DAS were 59 and 46.75 respectively. In treatments yielding low the ratio can be seen to be narrower. Thus the results in N x cowpea seed rate interaction would suggest that second tiller decline is a post flowering yield limiting phenomenon and that intercropping contributes to increased yield by minimising this tiller decline which appeared to be the result of an unfavourable N/Fe ratio at 75 DAS. Bridgit *et al.* (1992) also have reported that an unfavourable N/Fe ratio is the main yield limiting influence of rice in laterite soils.

4.3 N x P x Cowpea interaction

Interaction effect between N, P and cowpea seed rate has also registered significant influence on grain and straw yield. The highest yield of 33.95 q ha^{-1} was obtained in $N_3P_2S_1$ followed by 31.96 q ha^{-1} in $N_2P_1S_2$ (Table 22c; Fig. 10). Corresponding straw yields were 35.34 and 27.59 q ha^{-1} (Fig. 11). The high yield of grain and straw in $N_3P_2S_1$ treatment has been resulted from an increase in the productive attributes viz., productive tillers and 1000 grain weight brought about by the interacting influences of fertilizer N and cowpea intercropping. The results are in similar lines with those of Mathew *et al.* (1991) and Bridgit *et al.* (1993) who have also reported that *in situ* raising of cowpea in semi-dry rice system will increase the yield of rice. In the present study the treatment $N_3P_2S_1$ has recorded a yield increase of 6.67 q grains and 13.8 q straw ha^{-1} over the normal recommended practice.

In this intercropping system green manure gets incorporated only after 50 days of sowing. The high yield obtained from such a treatment would suggest that in such systems of crop production where application of green manures is not possible at the time of crop commencement, they can be supplied with advantage even subsequently. Experiments at Pattambi (Anon, 1991) have shown that release of nutrients

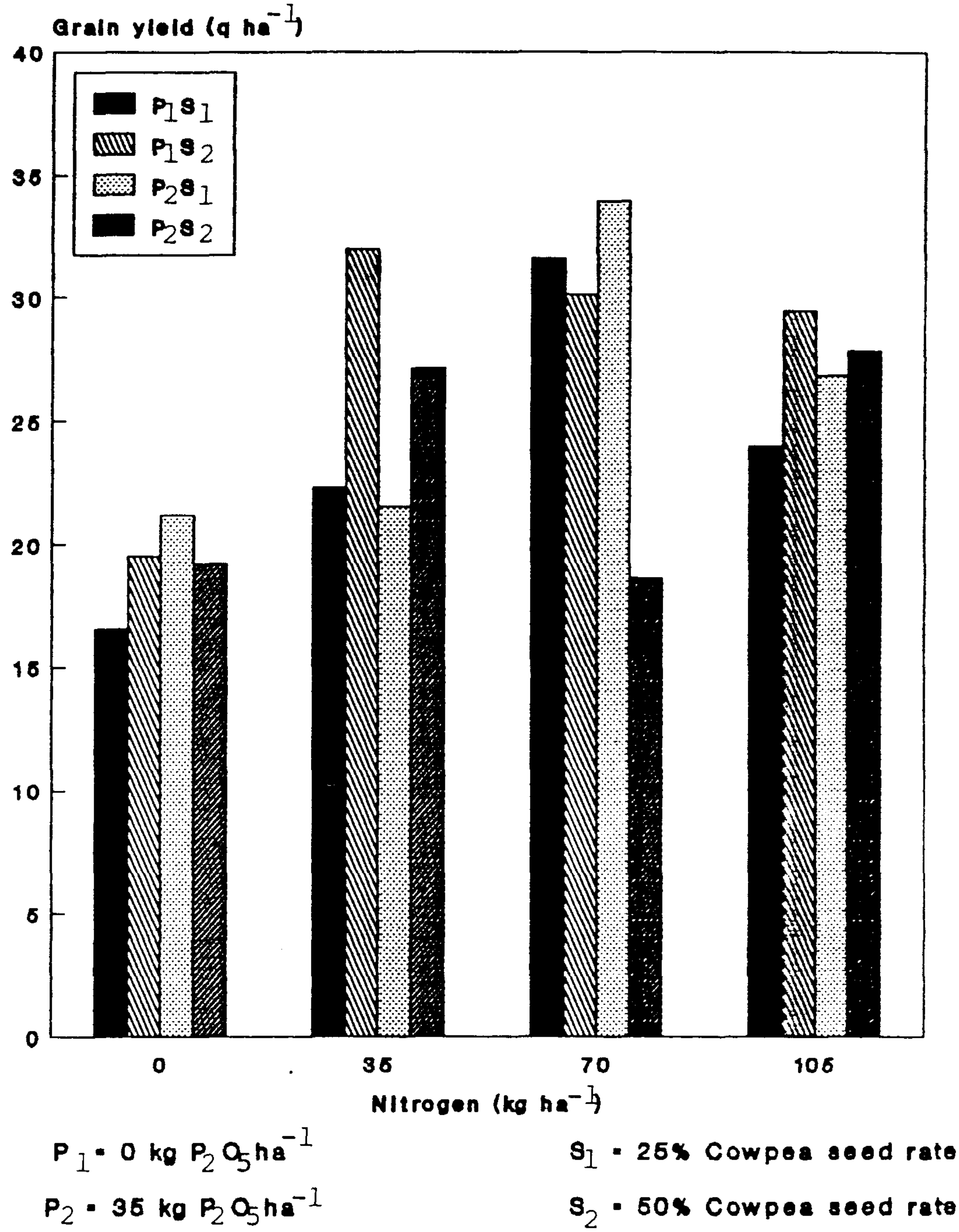


Fig. 10 Grain yield as influenced by the treatment combinations

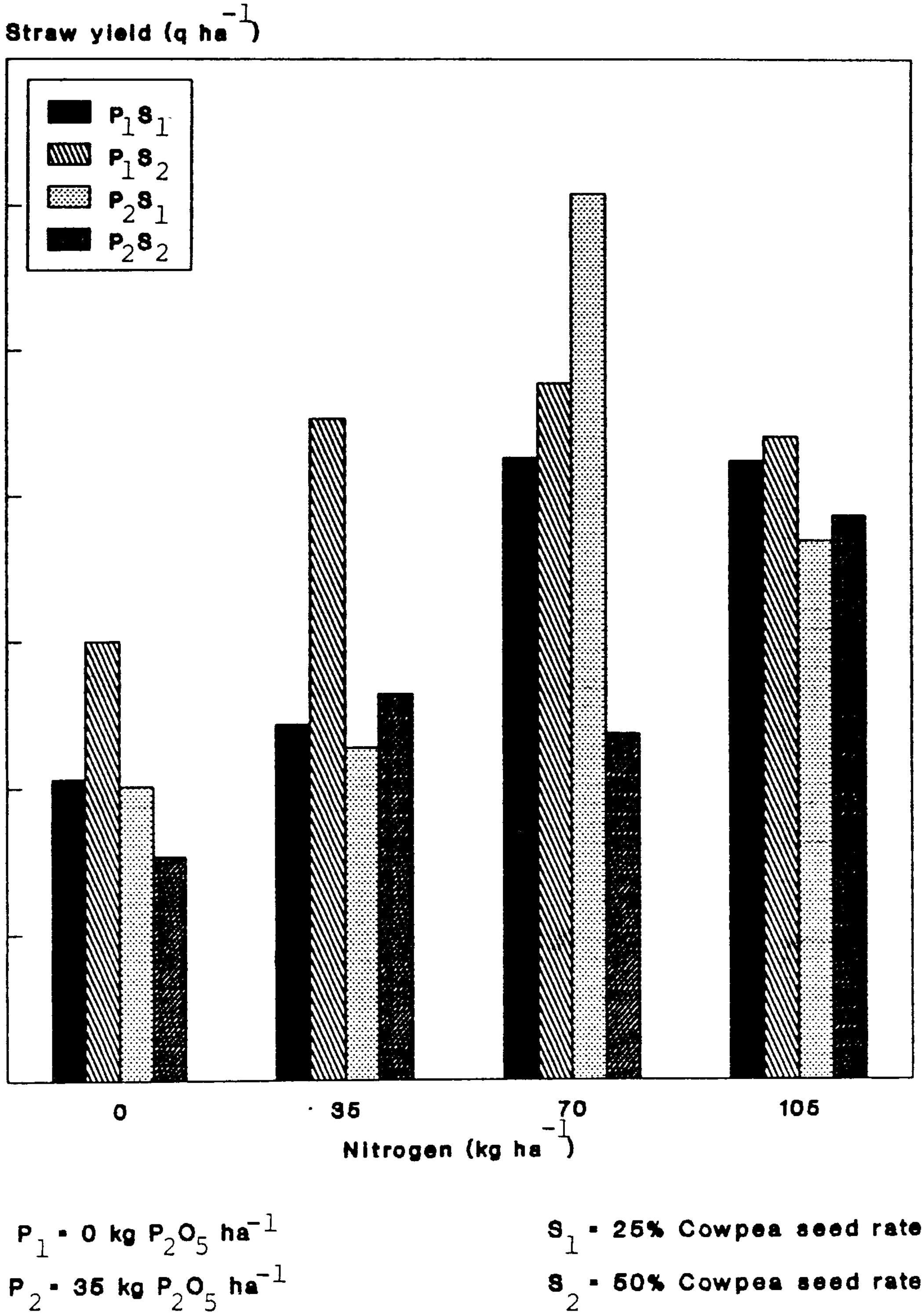


Fig. 11 Straw yield as influenced by the treatment combinations

Plate 2. Simultaneous *in situ* cropping with the recommended practice, using lower seed rate of cowpea

Plate 3. Simultaneous *in situ* cropping with the recommended practice, using higher seed rate of cowpea

from nonlignified carbonaceous materials like glyricidia leaves is fast and high and may commence within 5 days of incorporation.

In the present trial cowpea intercropping @ 15 kg seed ha^{-1} has increased the yield of rice over that of the fertilizer effect both at 35 and 70 kg levels of N. Anilakumar *et al.* (1992) reviewing the fertilizer trials conducted for over 10 years have reported that response to exclusive use of fertilizer N will be limited upto 40-45 kg ha^{-1} in rice and further increment in yield could be expected only if organic manures are used. In the present study also cowpea intercropping increased the efficiency of applied N as the comparison with the recommended practice will indicate.

A perusal of the data on tiller count/hill and dry matter production in the context of the improved yield obtained in the present study will indicate that the increase in productivity has been realised not by increasing the dry matter but by minimising its loss in the productive phase especially between 90 DAS and harvest which was of the order of more than 10 q ha^{-1}. Thus it can be assumed that cowpea intercropping has increased the yield by minimising wasteful production possibly through an improvement in the metabolic system. Conversely it will also imply that response to fertilizer nitrogen is often limited due to wasteful production.

A critical analysis of the data on nutrient contents and nutrient ratios observed in the present study will show that more than the contents the ratios have influenced productivity. The treatment ($N_3P_2S_1$) that gave the highest yield has recorded an N/Fe ratio of 1/63 at 75 DAS, the widest ratio observed in the study followed by 1/59 of $N_2P_1S_2$ which ranked next in yield expression. Thus the results showed that cowpea had increased the yield of rice by contributing to widen the

N/Fe ratio in the plant system. The necessity of ideal ratios for yield expression has been reported by Potty (1980) in sunflower and Marykutty *et al.* (1992) and Bridgit *et al.* (1993) in rice.

A comparative appraisal of the nitrogen effect vis a vis the N/Fe ratio will show that efficacy of N levels beyond 35 kg ha^{-1} in widening the ratio is small. It is possible that failure of fertilizer N beyond 35 to 70 kg ha^{-1} to improve the yield may be due to its failure to widen the N/Fe ratio. Cowpea intercropping has probably improved this inability.

Data on uptake studies will show that intercropping cowpea irrespective of seed rate had registered a significantly higher plant uptake of P, Ca and S and a lesser uptake of N, K, Mg and Fe at the time of harvest (Table 16; Fig. 8 and 9). After 75 DAS intercropping reduced the rate of uptake of Ca, Mg and Fe and shed N and K and changed the balance. Thus it can be assumed that cowpea intercropping increased the productivity through improving the metabolic efficiency by modifying the internal nutritional environment through regulated absorption of some nutrients. Increased productivity through regulation of the nutritional environment has also been reported by Singh (1970) in pea, Pillai (1972) in rice and Potty (1980) in sunflower.

Nutrient use efficiency analysis showed that based on the uptake at harvest, cowpea intercropping has registered a higher efficiency than fertilizer alone. Nutrient use efficiency itself is an index of metabolic utilization. When cowpea was intercropped @ 15 kg seeds ha^{-1} along with N and P the efficiency of N worked out to 49 kg grain kg^{-1} N as against 33.7 kg grain kg^{-1} N of the fertilizer nitrogen effect. Wilcox (1937) has stated that the productivity is a function of the capacity of the plant to dilute the nitrogen content of tissues and as such the results of the experiment are in similar line.

The results of the study have shown that the semi-dry rice showed a protracted production and decline of tillers. Initial decline though did not affect the dry matter production the second one had decreased the dry matter and nutrient recovery compared to the previous observations. An analysis of the relationship of dry matter increase after the first tiller decline with nutrient uptake characteristics showed that the dry matter produced between 50 and 75 DAS accounting for a 65 per cent increase was associated with an increase in the N, P, K, Ca, Mg, S and Fe removal of 63, 133, 48, 71, 45, 63 and 7 per cent respectively (Table 16). The fact that 65 per cent increase in DMP was associated with only 7 per cent increase in iron uptake would suggest that the tiller decline process was metabolically meant to shed excess iron the plant had absorbed. The process of tiller decline was also related with shedding of normal levels of N and S and slightly excess Mg. In the second phase prior to harvest this tiller decline led to a loss of dry matter and nutrients. As there was no further growth the loss could not be made up. The reason for lower recovery of nutrients at harvest compared to 75th day may be this decline. The results may also suggest that excessive tiller production and decline which includes shedding of absorbed elements is due to excess iron in the external and internal environments. This, however, requires further investigation.

5 Weed growth and weed control effects

The data presented in Table 28 showed that simultaneous raising of cowpea for *in situ* green manuring had reduced the weed count and the reduction at 20 DAS worked out to 8.2 and 39.3 per cent of grasses and dicots, respectively.

Reduction in weed growth evidently had been due to the successful smothering effect of cowpea. Cowpea with its broader leaves and early fast growth might have blocked the light reaching the ground. Increase in weed count and biomass was observed when the cowpea seed rate was lower where the blocking of light had been less effective. Shethi and Rao (1981) also had attributed the lower weed growth to the smothering effect. The magnitude of weed control at 20 DAS worked out to 27 per cent by cowpea intercrop. Thakur (1993) has reported the magnitude of weed control due to intercropping as 35-40 per cent.

However, the results showed that intercropping had no significant effect on weed control at 40 DAS. This was mainly due to the fact that all the weeds had been removed by 20th day and that the observation at 40 DAS related to the second flush of weeds which was lower due to the advancement in growth of the crop. At this stage, however, the weeds that further emerged would have benefitted from nutrients added by cowpea. Tisdale *et al.* (1985) have pointed out that concurrent plants benefit from the sloughed-off roots and root excretions of legumes.

Another interesting observation in the present study has been an apparent differential influence of cowpea on different groups of weeds. Though not significant, cowpea tended to increase sedges and reduce dicot weeds while it had virtually little effect on grassy weeds at 20 DAS (Fig. 12). Similar effects were observed on 40th day also. However, these results point out to the role of management practices on spectral changes in the weed flora. Results of the Permanent Manurial Trials (PMT) at Rice Research Station, Kayamkulam have also indicated similar results (Anon., 1993).

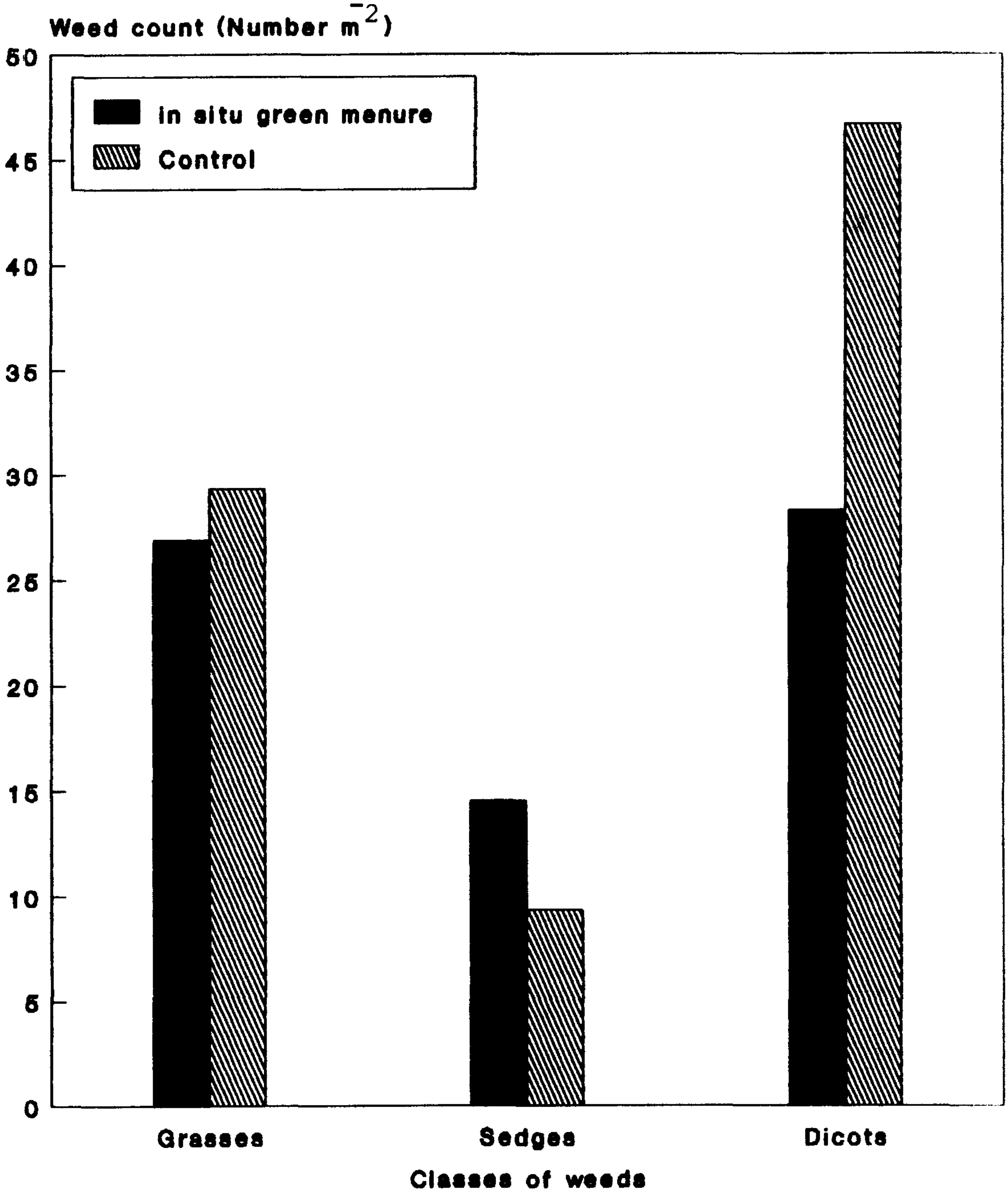


Fig. 12 Influence of *in situ* green manuring on spectral changes of weeds

Increasing levels of N also tended to reduce weed count and weed biomass in the early stages (Fig. 13). This may be because of the effect of fertilizer N. Nair (1968) has reported that basal dressing of increased N levels would affect the plants deliteriously through the effect of salt index.

A perusal of the observation on weed biomass, elemental composition and nutrient removal of the weeds in comparison with rice crop showed that weeds have produced comparable amount of dry matter to the rice crop by 20 DAS, though fields had been completely free of weeds at sowing. This high rate of emergence and growth of weeds evidently is the result of their better adaptability to the Fe rich lateritic alluvium as compared to the high yielding variety of rice. Bridgit *et al.* (1992) have reported that high yielding varieties of rice fail to grow well in lateritic soils.

Weeds also have removed proportionately larger quantities of N, K and Mg (Fig. 14). Magnesium is not a recommended element and far more K is absorbed than what is usually applied. Thus, even assuming that deficiency of N is made up through application of chemical fertilizer, weeds inevitably go on depleting the soil of K and Mg and steadily erode the fertility and productivity of soil. Sreedevi and Iyer (1974) have reported that laterite soils are deficient in K and Marykutty *et al.* (1992) have found an unfavourable ratio of N/K and Ca + Mg/K as one of the limiting factors in rice culture in laterites. Cowpea intercropping in the early stages of semi-dry rice for *in situ* green manuring appears to have contributed at least in part by limiting weed growth and there by conserving more of K and Mg. Nutrient balance analysis in the present study confirms this observation.

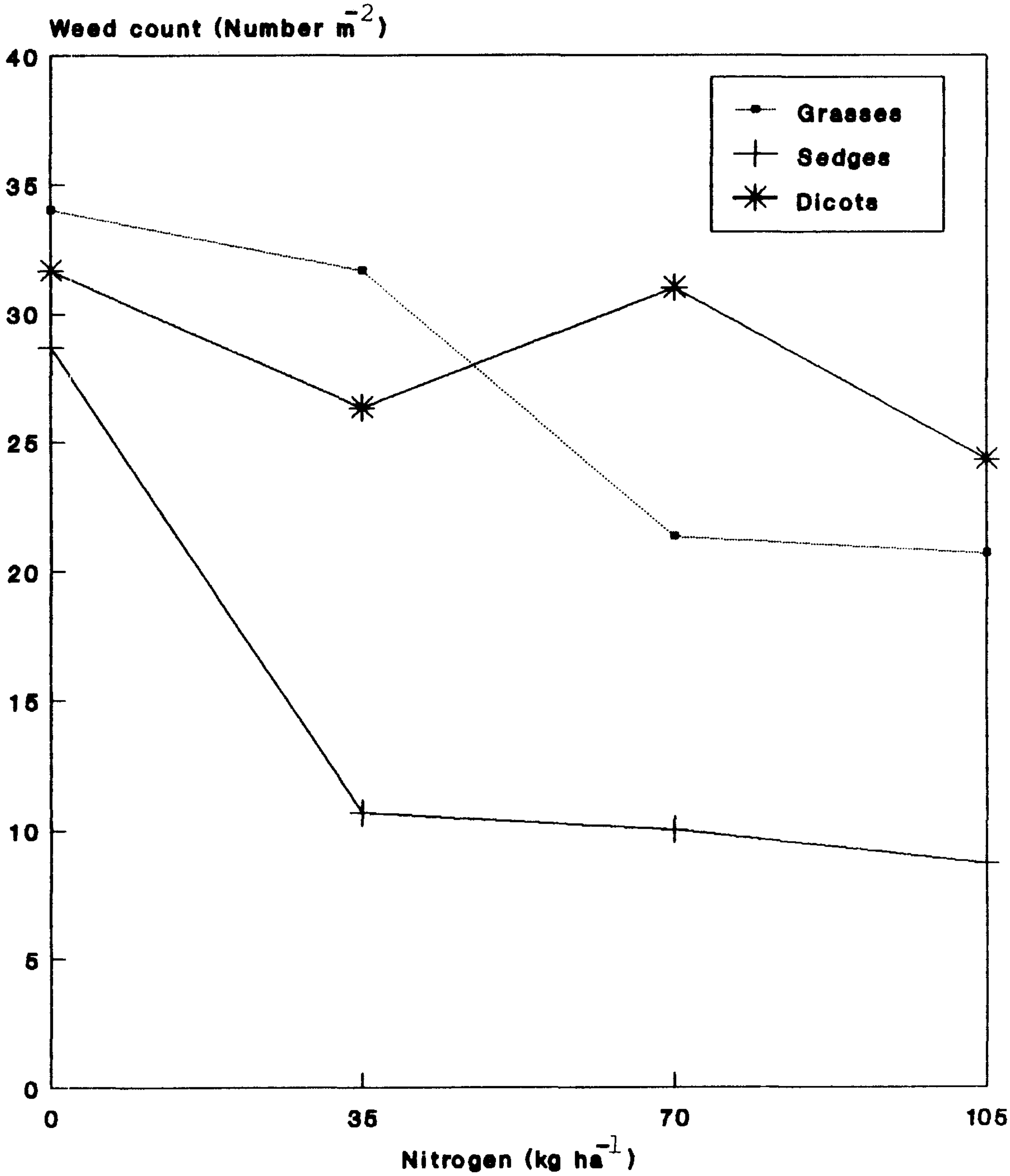


Fig. 13. Influence of Nitrogen on weed count at 20 DAS

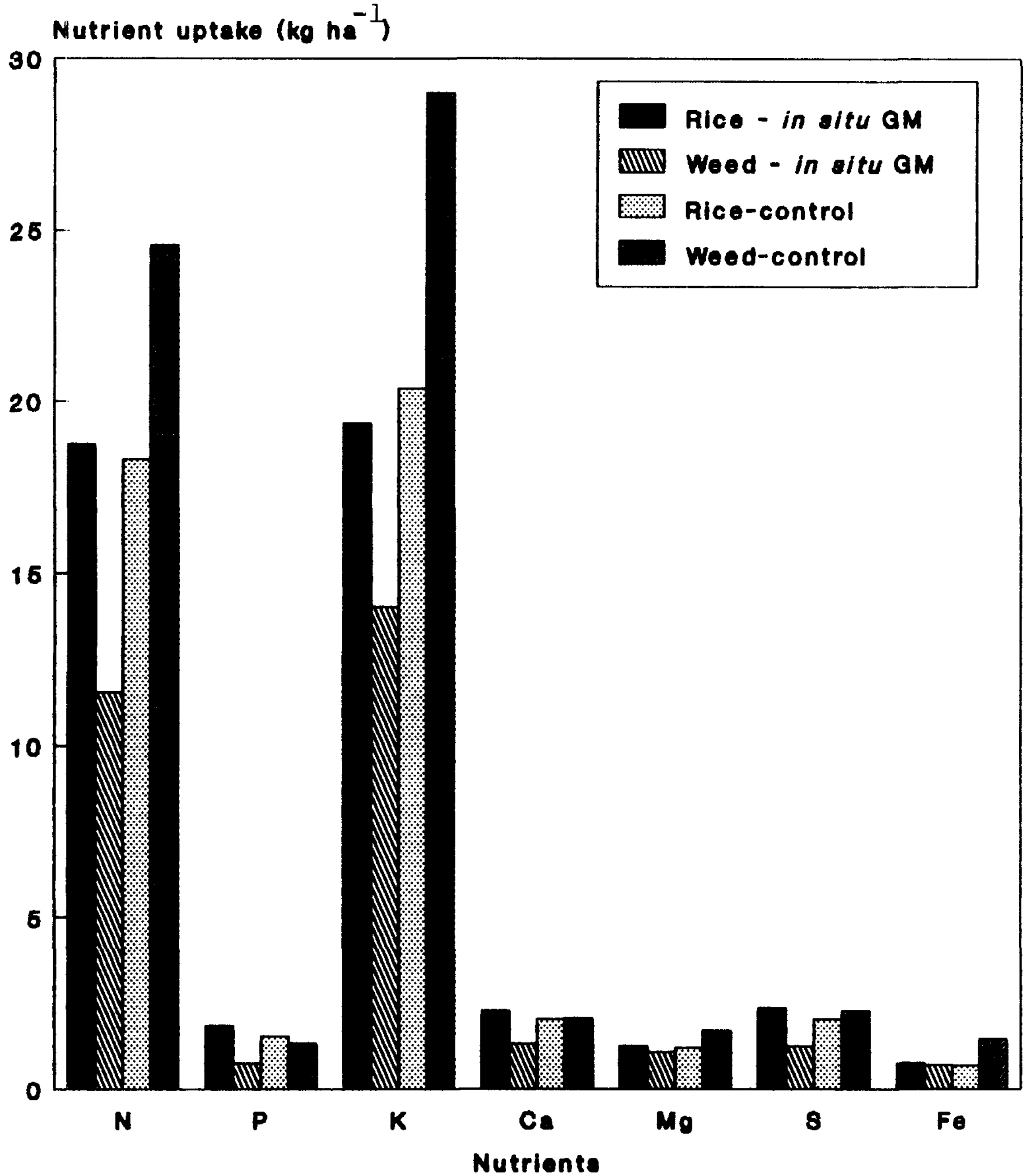


Fig. 14 Influence of *in situ* green manuring on variation in the nutrient uptake by rice and weeds

The effect of increasing levels of N, 1/3 of which applied basally as per POP recommendations (KAU, 1993) on weed growth also appeared to be significant. Basal application of N by inhibiting weed growth in the early stages would restrict the weed removal and depletion of elements and limits the erosion of soil fertility.

Though individual species within each group of weeds have not been analysed for their differential pattern of nutrient removal, the comparison with rice will indicate that all species do not remove every element in equal proportions and amounts. The spectral changes in weed flora may be due to the gradual and differential erosion of fertility which requires further detailed investigation.

6 Crop susceptibility to pest and disease

Interacting influences of N with P and cowpea green manure have been found to increase the vulnerability of rice crop to incidence of leaf roller and sheath blight. Maximum incidence of leaf roller was observed at N_4P_1 and N_4S_2 levels. The leaf roller incidence was noticed in the early stages of crop, especially after 50 days. Increased N supply stimulates early vegetative growth leading to mutual shading. Mutual shading reduces the photosynthetic activity and thus an unfavourable nitrogen/carbohydrate (N/C) balance results which leads to accumulation of soluble N and ammonium toxicity which has been reported (Ito and Sakamoto, 1942; Murata, 1970) to be the basic cause of increased susceptibility of crop to leaf roller incidence under high N regimes (Fig. 15). Increased leaf roller incidence due to green manuring with *Glyricidia maculata* has also been reported from RARS, Pattambi (Anon., 1988).

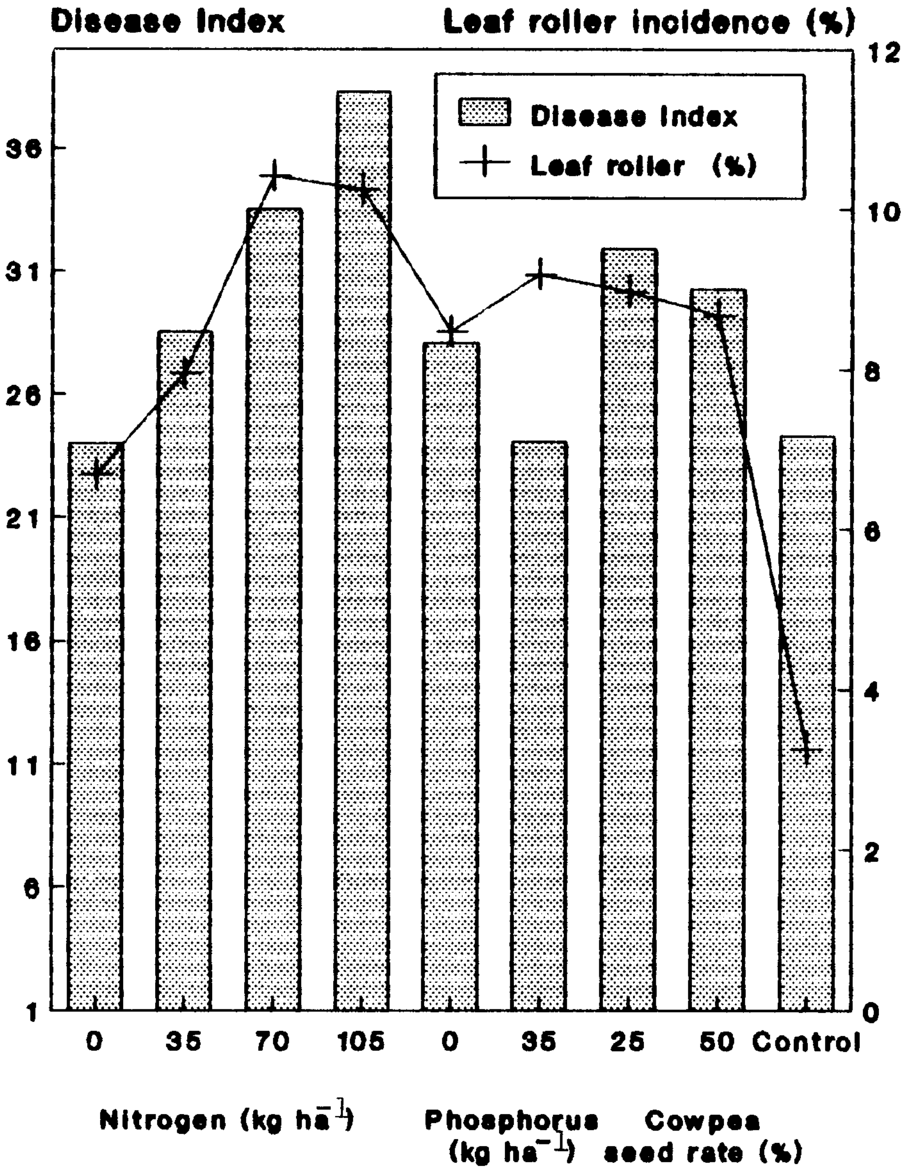


Fig. 15 Incidence of pest and disease as influenced by the treatment levels

Incidence of sheath blight has been reported to be an expression of K deficiency (Sarkar *et al.*, 1991) and application of K is recommended to minimise the incidence (KAU, 1993). Maximum disease index was observed at N_3P_2 and N_4S_1 combinations. Thus an increase in the N content of the plant without proportionate increase in K content appears to be the reason for the higher incidence of leaf roller and sheath blight.

In the present study a higher level of cowpea seed rate, application of higher levels of chemical N as well as P and their first and second order interactions could be seen to have contributed to an increased N content of the plant which in turn had been responsible for increased susceptibility to sheath blight and leaf roller. Thus the higher incidence of pest and disease is found to be a direct effect of N.

7 Viability of the system

Intercropping is a practice in widely spaced crops and the principle of intercropping is utilization of otherwise wasted radiation and soil resources without affecting the main crop. As such in closely sown crops like rice the system may appear to be untenable and hence calls for critical appraisal of the viability of the system which shall be done from different angles.

Viewed in the context of growth, cowpea has performed well with 19 roots per plant with an average length of 13 cm and a shoot height of 100 cm in about 40 days (Table 25) accounting for a better green matter production. The productivity of green matter has been related to the seed rate of cowpea with 58 and 76 q ha^{-1} at 15 and 30 kg seeds ha^{-1}, respectively. This green matter has been more than sufficient to meet the requirement of 50 q ha^{-1} of organic manures recommended for rice in the State (KAU, 1993). Bridgit *et al.* (1994) have recorded a cowpea green matter yield of 110 q ha^{-1} when intercropped in rice with full seed rate.

Success of the system of concurrent raising of cowpea for green manure in April-May is a function of the rainfall received during this period as well as the slow start of monsoon in early June. Comparative perusal of the rainfall data for the year (Appendix-II) with that of the mean for the last twelve years (Appendix-I) shows that the current year was characterised with marginal pre-monsoon rains and early onset of monsoon. Biomass production of 76 q ha^{-1} inspite of such an unfavourable weather situation would indicate that the system is viable and is capable of meeting the recommended organic matter requirement even in adverse weather situation.

Viability of concurrent raising of green manures in closely seeded crops will largely depend on the possibility of competition it may offer to the main crop, both on the nutritional and radiation interception planes. Observation on root characteristics showed that root lengths of rice and cowpea were more or less the same (Tables 8 and 24; Plate 4) which implied that both crops have tapped the same depth which shall reasonably be suspected to induce competition. But based on the number of hills the proportion of cowpea to rice had only been 1:2 and 1:4 when the higher and lower seed rates of cowpea, respectively were used. This inturn will mean that only 1/4th of the soil volume is tapped by cowpea and hence competition effect should be only of a small order. A perusal of the data on the limiting influence of cowpea on nutrient removal by weeds will show that nutritional competiton of cowpea with rice is not even a possibility. Cowpea which accumulated a total dry

Plate 4. Growth of rice and cowpea at 40 days of growth

Plate 5. Plot with simultaneous *in situ* green manuring + 105 kg N ha^{-1}

matter of 1.58 q ha^{-1} by 20th day after seeding, has limited the weed dry matter accumulation by 45 per cent and thus limited the weed removal of N, P, K, Ca, Mg, S and Fe by 13, 0.61, 15, 0.73, 0.63, 1.0 and 0.76 kg ha^{-1}, respectively. This loss of nutrients at this stage would have been unavoidable under the normal systems of management as weeds are removed only after 20 days (KAU, 1993). The dry matter production by cowpea was very less compared to weeds and the decrease in the dry matter production of weeds brought about by simultaneous growing of cowpea itself was more than the dry matter accumulation of cowpea. These results point out that cowpea has grown only at the expense of weeds by using the nutrients which weeds would have otherwise utilized and cannot have competed with rice for nutrients. In addition cowpea is a leguminous plant that fixes atmospheric N for its need and as such may not compete with rice.

The system viability is also enhanced by the fact that cowpea is autodecomposable and does not require manual incorporation. Mathew *et al.* (1991) have shown that crops like daincha (*Sesbania aculeata*) which require manual incorporation on concurrent raising may affect the yield. This may at least in part be because of the destruction of tillers. The higher grain yield of the order of 34 q ha^{-1} obtained due to intercropping with cowpea and automatic incorporation along with recommended rate of fertilizers would imply that unlike hitherto believed, easily decomposable green manures can be applied even up to 50 days after sowing of rice crop. This is especially important in the case of semidry crop of rice as no green manures shall be applied at the time of sowing because the soil is dry.

A perusal of the data on yield and plant N content will show that in cowpea intercropped plots, N content of the plant was lower than the others (Tables

12 and 22). Thus the data suggested that yield improvement by simultaneous *in situ* green manuring had not been because of an increased efficiency of applied N but due to some other effects.

Thus from all the angles of growth, adaptability and competition it appears that the system is viable. Moreover the economics of the system also showed that the system is economically profitable with a reward of 79 paise per rupee incurred.

Summary

SUMMARY

The salient findings of the study are summarised below:

1. The system of simultaneous *in situ* green manuring, where in green manure cowpea grown along with rice in alternate rows gets self decomposed under water stagnation by about 50 DAS, is a viable practice under the available agroclimatic situation in the area. The system had not affected adversely the growth and development characteristics of rice crop at any stage.

2. The system increased the yield of grain and straw. Highest yields of 33.95 q grain and 35.34 q straw ha^{-1} were recorded by the treatment combination $N_3P_2S_1$, ie., 25 per cent seed rate of cowpea with the recommended dose of 70:35:35 kg NPK ha^{-1} and were respectively 6.67 and 13.82 q more than the yield in the recommended practice. The increase in yield was brought about by

i) Minimising the loss of dry matter in the productive phase brought about by way of production and decline of non productive tillers.

ii) Increasing significantly the number of filled grains per panicle.

iii) Increasing the efficiency of nitrogen in the plant. The efficiency of N absorbed at harvest was 49 kg grain kg^{-1} N as against 33.7 kg grain kg^{-1} N in control.

iv) Regulating the nutrient balance inside the plant, especially N/Fe ratio. The N/Fe ratio tended to widen with increasing yield and this widening by 75

DAS was brought about through a regulation in the absorption of Fe. The N/Fe ratio in the highest yielded treatment was 1/63.

v) Significantly influencing the chlorophyll 'a' content of boot leaf.

3. The system could generate 58 and 76 q green matter ha^{-1} at 15 and 30 kg seeds ha^{-1} respectively, and these were well above the recommended dose of 50 q ha^{-1}.

4. Higher cowpea seed rate of 30 kg ha^{-1} was found to be better at lower level of N while at higher level of N lower cowpea seed rate of 15 kg ha^{-1} performed better.

5. The system could not significantly modify the nutrient content in the plant.

6. Simultaneous *in situ* green manuring reduced the emergence, development and nutrient removal of weeds. The overall emergence was reduced by 27 per cent and dry matter accumulation by 45 per cent. This resulted in the saving of 13 kg N, 0.61 kg P, 15 kg K, 0.73 kg Ca, 0.63 kg Mg, 1 kg S and 0.76 kg Fe ha^{-1} by 20 DAS.

7. The effect of simultaneous cropping of cowpea on limiting weed growth was not uniform on all groups of weeds. Under the system dicot weeds declined by 39 per cent, grassy weeds were little affected and sedges tended to increase.

8. Intercropping of cowpea for *in situ* green manuring tended to increase the incidence of leaf roller and sheath blight.

9. The performance of the system suggests that green manures can be applied with advantage even up to 45 to 50 days after sowing of rice in the semi-dry system of cultivation.

10. Application of fertilizer nitrogen brought about a progreessive increase in the N content of plant at all stages of growth.

11. Increase in N levels brought about a progressive increase in the height of the crop. However this effect failed to manifest itself in tiller count while the yield attributes were significantly increased at 35 kg N ha^{-1} and beyond this level influence of fertilizer N tapered down.

12. Effect of fertilizer N on increasing the yield of semi-dry rice was noticed upto 70 kg N ha^{-1}. The effect was significant only upto 35 kg N ha^{-1} beyond which the increase narrowed down.

13. The crop appeared to have failed to metabolize the N absorbed beyond 35 kg ha^{-1} as is evidenced by the chlorophyll content corresponding to 70 kg N ha^{-1} at 25 DAS.

14. Application of P @ 35 kg ha^{-1} increased the P content of plant in the initial stages of crop growth but failed to increase the yield.

15. The crop manifested two distinct phases of tiller decline, one between 40 and 60 DAS and the other between 80 and 100 DAS. This resulted in a corresponding decline in dry matter production also.

16. Nutrient absorption studies showed that rice absorbed very large quantities of Fe. At all stages of observation the plant Fe content was above the toxicity level of 300 ppm. The Fe content of plants at 25, 50 and 75 DAS and at harvest were 1200, 600, 400 and 100 (grain) and 400 (straw) ppm respectively.

17. The lack of response to absorbed N appeared to be due to the effect of excess Fe absorbed. In the process of shedding this Fe through tiller decline other nutrients are also lost.

18. Increasing levels of N application above 70 kg ha^{-1} failed to widen the N/Fe ratio beyond 1/45.

19. Semi-dry system of rice cultivation with simultaneous *in situ* green manuring is found to be economically viable and it could reward an amount of 79 paise per rupee incurred within a crop period of four months.

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Appendices

APPENDIX-I

Weather parameters for the virippu season averaged over twelve years (1983-1994)

Sl. No.	Month	Temperature, °C		Relative humidity	Rainfall mm	Bright sunshine hrs
		Maximum	Minimum			
1	April	35.7	25.0	69	52.4	8.3
2	May	34.2	25.0	73	158.3	7.1
3	June	29.9	23.4	85	747.3	3.4
4	July	29.1	23.0	86	584.8	3.4
5	August	29.2	23.3	86	445.3	3.8
6	September	30.5	23.3	81	222.3	5.9
7	October	31.2	23.1	80	316.6	6.2

APPENDIX-II

Weather parameters for the experimental period (May '93-Sept. '93)

Sl. No.	Standard week No.	Month & week	Temperature °C		Relative humidity	Rainfall mm	No. of bright sunshine hours
			Maximum	Minimum			
1	18	Apr 30-6	35.3	25.7	70	3.0	7.9
2	19	7-13	35.4	25.9	69	1.4	8.6
3	20	14-20	34.1	23.8	76	31.9	6.0
4	21	21-27	34.5	24.4	75	6.0	6.6
5	22	May 28-3	32.8	24.0	80	103.8	4.3
6	23	4-10	29.6	23.3	88	236.6	1.8
7	24	11-17	29.2	23.8	88	237.9	1.9
8	25	18-24	30.4	24.5	84	85.5	4.4
9	26	Jun 25-1	29.2	23.6	88	186.4	2.9
10	27	2-8	28.6	22.7	87	188.9	2.0
11	28	9-15	28.7	22.6	88	167.8	1.8
12	29	16-22	28.9	22.9	85	128.1	2.8
13	30	23-29	28.0	23.1	87	101.0	2.9
14	31	Jul 29-5	29.1	23.7	86	96.4	3.6
15	32	6-12	29.9	23.5	85	54.9	4.6
16	33	13-19	29.2	23.1	86	66.3	3.3
17	34	20-26	29.8	23.2	85	61.9	5.6
18	35	Aug 27-2	29.8	23.5	84	33.6	6.5
19	36	3-9	29.4	23.0	84	23.7	3.9
20	37	10-16	30.7	23.1	81	11.5	7.5
21	38	17-23	31.7	23.4	79	23.2	8.3
22	39	Sep 24-30	31.0	23.2	78	14.9	6.7

APPENDIX-III

Cost of cultivation of rice with simultaneous *in situ* green manuring, Rs. ha^{-1}

Items	$N_1S_1P_1$	$N_1S_1P_2$	$N_1S_2P_1$	$N_1S_2P_2$	$N_2S_1P_1$	$N_2S_1P_2$	$N_2S_1P_1$	$N_2S_2P_2$	$N_3S_1P_1$	$N_3S_1P_2$	$N_3S_2P_1$	$N_3S_2P_2$	$N_4S_1P_1$	$N_4S_1P_2$	$N_4S_2P_1$	$N_4S_2P_2$	Control
Materials																	
Paddy seed (80 kg)	520	520	520	520	520	520	520	520	520	520	520	520	520	520	520	520	520
Cowpea seed	210	210	420	420	210	210	420	420	210	210	420	420	210	210	420	420	-
Fertilizers																	
Urea	-	-	-	-	228	228	228	228	456	456	456	456	684	684	684	684	456
SSP	-	767	-	767	-	767	-	767	-	767	-	767	-	767	-	767	767
MOP	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223
PP chemical																	
Dimecron (250 ml)	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
Land preparation																	
Tractor - 6 hrs	840	840	840	840	840	840	840	840	840	840	840	840	840	840	840	840	840
Men -10	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Women - 4	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
Fertilizer application																	
Men - 6	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
Sowing																	
Women - 35, 40, 30	1400	1400	1600	1600	1400	1400	1600	1600	1400	1400	1600	1600	1400	1400	1600	1600	1200
Weeding																	
Women - 12, 20	480	480	480	480	480	480	480	480	480	480	480	480	480	480	480	480	480
PPC application																	
Men - 1	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Harvesting																	
Women -20	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800
Threshing																	
Men -4	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Women -20	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800
Cleaning and winnowing																	
Women - 10	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
Total	7003	7770	7413	8180	7231	7998	7641	8408	7459	8226	7869	8636	7687	8454	8097	8864	8136

N_1 - 0 kg N ha^{-1}
N_2 - 35 kg N ha^{-1} (76 kg urea)
N_3 - 70 kg N ha^{-1} (152 kg urea)
N_4 - 105 kg N ha^{-1} (228 kg urea)

Paddy seed - Rs. 6.50 kg^{-1}
Cowpea seed - Rs.14.00 kg^{-1}
Urea - Rs. 3.00 kg^{-1}
SSP - Rs. 3.50 kg^{-1}

PRODUCTIVITY OF SEMI - DRY RICE UNDER SIMULTANEOUS *IN SITU* GREEN MANURING

By

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ABSTRACT OF A THESIS

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ABSTRACT

An investigation aimed to study the influence of simultaneous *in situ* green manuring on the growth, yield and nutritional characteristics of rice was conducted during the first crop season of 1993-94 in the sandy clay loam soils of the Agricultural Research Station, Mannuthy. The treatments consisted of factorial combinations of four levels of nitrogen (0, 35, 70 and 105 kg N ha^{-1}), two levels of phosphorus (0 and 35 kg P_2O_5 ha^{-1}) and two seed rates of cowpea (15 and 30 kg ha^{-1}) for *in situ* green manuring and a control without green manure. Cowpea was raised in alternate rows of rice. The experiment was laid out in RBD with three replications.

Results of the study showed that simultaneous *in situ* raising of cowpea for green manure can be successfully practised in semi-dry rice for improving the productivity.

At the recommended level of fertilizers (70:35:35 kg N, P_2O_5, K_2O ha^{-1}) a lower seed rate of cowpea was found to be the best which gave 24 and 64 per cent more yield of grain and straw, respectively than the recommended practice. However, a higher seed rate of cowpea was required if the level of N was limited to 35 kg ha^{-1}.

The system added 58 and 76 q of green matter ha^{-1} at the lower and higher seed rates, respectively.

The system effectively minimised the production and decline of non productive tillers in the post flowering phase and contributed to the increased yield. The increased efficiency of plant N achieved in the system appeared to arise from a

widening of N/Fe ratio as well as a regulatory influence on elements in the plant system.

Intercropping of cowpea for green manure increased the incidence of leaf roller and sheath blight marginally.

The system also suppressed the weed growth in the cropped field and the weed biomass production declined by 45 per cent by 20 DAS.

Weeds remove larger quantities of K and Mg than rice and deplete the soil of these nutrients. Intercropping effectively checked this.

The suppression effect was not uniform on all types of weeds. Sedges showed a tendency to increase when broad leaved weeds declined. Grassy weeds remained unaffected. Thus simultaneous *in situ* green manuring appears to change the weed spectrum in rice fields.

A comparative analysis of the weather pattern during the season with that of the normal showed that the system can be successfully adopted in similar areas.