INTEGRATED NUTRIENT MANAGEMENT FOR RICE (SEMI-DRY) BASED GROPPING SYSTEMS

By

GADDAM PRABHAKARA REDDY, B Sc. (Ag.)

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ANDHRA PRADESH AGRICULTURAL UNIVERSITY
TIRUPATI - 517502

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CERTIFICATE

Mr.G. PRABHAKARA REDDY has satisfactorily prosecuted the course of research and that the thesis entitled INTEGRATED NUTRIENT MANAGEMENT FOR RICE(SEMI-DRY) BASED CROPPING SYSTEMS submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

Date: 10/8/90

Major Advisor

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This is to certify that the thesis entitled "INTEGRATED NUTRIENT MANAGEMENT FOR RICE(SEMI-DRY) BASED CROPPING SYSTEMS" submitted in partial fulfilment of the requirements for the degree of "MASTER OF SCIENCE IN AGRICULTURE" of the Andhra Pradesh Agricultural University, Hyderabad, is a record of the bonafide research work carried out by Mr.G.PRABHAKARA REDDY under my guidance and supervision. The subject of the thesis has been approved by the student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigations has been duly acknowledged by the author of the thesis.

10/8/90

Chairman of the Advisory Committee

Thesis approved by the Student Advisory Committee

Chairman: (Dr.T.YELLAMANDA REDDY) 10/8/90
Agronomist
Agricultural Research Station
ANANTAPUR.

Member : (Dr.M.SESHAGIRI RAO) 8/8/90
Assistant Professor
Department of Soil Science
and Agricultural Chemistry
S.V.Agricultural College
TIRUPATI.

Member : (Sri.M. REDDEPPA REDDY) 10/8/9
Farm Superintendent
S.V.Agricultural College
TIRUPATI.

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(G. PRABHAKARA REDDY)

Author	:	G. PRABHAKARA REDDY
Title	:	INTEGRATED NUTRIENT MANAGEMENT FOR RICE (SEMI-DRY) BASED CROPPING SYSTEMS
Degree	:	M.Sc., (Ag)
Faculty	:	Agriculture
Department	:	Agronomy
Major Advisor	:	Dr. T. YELLAMANDA REDDY
University	:	Andhra Pradesh Agricultural University
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ABSTRACT

Pot culture and field investigations were carried out to suggest remedy for iron chlorosis and to study the integrated nutrient management for rice (semi-dry) based cropping systems during kharif and late kharif 1989 at S.V.Agricultural College, Tirupati. Pot culture study consisted of different treatments viz., application of ferrous sulphate to soil, Fe-EDTA to soil, foliar application of ferrous sulphate, incorporation of green manure and continuous submergence. From the study it was found that plant growth was higher with green manure incorporation and continuous submergence.

The treatments of field experiment consisted of four cropping systems (fallow-rice, greengram-rice, sunnhemp-rice and cowpea-rice) and five fertility levels (FYM 10 t ha^{-1} + 20 kg N ha^{-1}, 80 kg N ha^{-1}, 120 kg N ha^{-1}, 120 kg N ha^{-1} + 40 kg $FeSO_4$ ha^{-1} to soil and 120 kg N ha^{-1} + foliar application of $FeSO_4$ @ 0.5 per cent) to semi-dry rice. In greengram-rice system, greengram haulm was incorporated after removing pods. In case of sunnhemp-rice and cowpea-rice systems, the preceding crops were used as green manure crops. Farm yard manure @

10 t ha^{-1} was applied at the time of sowing and 20 kg N at flooding, while the other two levels of N viz., 80 and 120 kg N ha^{-1} were applied in three splits (one-fourth basal, one-fourth at active tillering and the remaining half at panicle-initiation stage). In case of soil application of iron 40 kg ferrous sulphate ha^{-1} was applied at the time of sowing. Ferrous sulphate was sprayed @ 0.5 per cent starting from one month after sowing and repeated thrice at weekly intervals. A common dose of 60 kg P_2O_5 ha^{-1} and no potassic fertilizers were applied to rice. The experiment was conducted in split-plot design with three replications. Semi-dry rice was grown under rainfed conditions upto 60 days and subsequently it was flooded and grown under submergence up to 15 days before harvesting. The variety tried was IR-64.

Based on growth and net returns greengram and cowpea were found suitable to precede rice. Cowpea was found to tolerate moisture stress due to longer tap roots, high relative water content and foliar movements. Plant height, LAI, tiller number, dry matter chlorophyll content and CGR of rice were higher with cowpea incorporation compared to fallow. Cowpea incorporation resulted in higher organic carbon, soil available iron, nitrogen content and its uptake by rice compared to fallow.

Incorporation of greengram haulm gave better growth, yield attributes, yield and nutrient uptake of rice than that obtained with rice grown after fallow. Soil organic carbon content, available iron in soil, chlorophyll content and nitrogen use efficiency were also higher with greengram haulm incorporation compared to fallow.

Plant height, tiller number, LAI and dry matter production were significantly increased with increase of N levels upto 120 kg ha^{-1}. Yield and yield attributes of rice were high with 120 kg N ha^{-1} campared to lower levels of N. Foliar application of iron resulted in higher chlorophyll content where as the soil available iron was more with soil application.

The grain yield obtained with greengram haulm incorporation and 80 kg N ha^{-1} was more than that obtained with 120 kg N ha^{-1} alone. Incorporation of cowpea along with FYM and 20 kg N ha^{-1} gave higher grain yield compared to 120 kg N ha^{-1} alone.

The evaluation of cropping systems indicated that cowpea-rice and greengram-rice systems were better than other systems, due to higher dry matter production and rice-grain equivalents. The gross and net returns were more with greengram-rice system.

INTRODUCTION

I INTRODUCTION

Rice is the staple food for more than fifty per cent of world's population. The area under rice in India is 40.81 million hectares with a total production of 60.38 million tonnes. In Andhra Pradesh the area under rice is 34.32 lakh hectares with a production of 67.43 lakh tonnes (Agricultural situation in India 1988). In India there are three principal systems of rice cultivation: dry, semi-dry and wet. Under the system of semi-dry cultivation seeds are sown in unpuddled soil; grown as a dry crop for about two months and when water is available, it is treated as wet crop (Chatterjee and Maiti 1985). Rice is grown mainly as semi-dry crop in tankfed areas of Chittoor, Prakasam and Nellore districts in Andhra Pradesh. The area under tanks in Andhra Pradesh is 11.4 lakh hectares (Statistical Abstract of A.P. 1979).

Generally monsoon starts in June and the earlier rains are not utilised in tankfed areas. Runoff inducing rains occur in September or October and tanks are filled during these months. Hence, the crop is sown from August second fortnight to September first fortnight and grown under rainfed conditions until tanks are filled. From then onwards, it is converted to lowland conditions with 3 to 5 cm of standing water. The amount of rainfall that occur during June to September is sufficient to raise rainfed crops of short duration. Several rice based cropping systems have been developed by agronomists for lowland and upland conditions. However, no studies were carried out to develop a suitable cropping system for semi-dry rice. To make use of available resources in tankfed areas most effectively, a study on suitable cropping system for tankfed areas is warranted with semi-dry rice as the main component.

The objective of integrated nutrient supply system is to take care of soil health and plant nutrients by integrating organic and biological sources with mineral fertilizers in one package. This system puts the local resources to the best and maximum use and this approach fits into the philosophy of low-cost technology needed for the small and marginal farmers. Adequate information is generated regarding the integrated nutrient management in cropping systems under lowland conditions. The information available on integrated nutrient management in semi-dry rice based cropping systems is meagre.

Iron chlorosis commonly occurs in uplands particularly where the soils are of coarse texture. Suitable remedy for iron chlorosis is needed because it will occur even under semi-dry conditions due to lack of reducing conditions in the early stage of the crop. After reveiwing the situation, the present experiment was conducted keeping the following objectives in view:

1. To develop a suitable semi-dry rice based cropping system for tankfed areas

2. To study the feasibility of integrated nutrient management for semi-dry rice based cropping system and

3. To suggest remedy for iron chlorosis.

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

The information available on various rice-based cropping systems, integrated use of organic and inorganic source of nitrogen and iron chlorosis has been reviewed in this chapter.

2.1 RICE-BASED CROPPING SYSTEMS

The productivity per unit area per unit time can be increased by increasing the cropping intensity. This could be achieved by a suitable combination of crops in sequence (Singh *et al* 1980). Rice is a component of widely varying cropping systems; beginning with one crop of rice after ten years of bush fallow in shifting cultivation system to 500 per cent cropping intensity under intensive system in permanent agriculture (Mahapatra *et al* 1985).

2.1.1 Lowland rice based cropping systems

Rice-rice is the most dominant cropping system under irrigated conditions in south and eastern India, while rice-wheat, rice-groundnut, rice-legumes, rice-mustard or rice-potato are some of the important rice-based cropping systems with 200 per cent cropping intensity in different north Indian states (AICARP 1978). Rice-rice-pulse (greengram/blackgram) is the predominant cropping system of major rice growing areas of Tamilnadu (Palaniappan 1985). Reddy and Reddy (1988) reported that rice-groundnut-greengram was the best system for the southern agro-climatic zone of Andhra Pradesh.

2.1.2 Rainfed rice based cropping systems

Sequential cropping under rainfed conditions is frequently observed where rainfall exceeds 1000 mm and on soils having a storage capacity of 150 to 200 mm of available moisture (Spratt and Choudhury 1978). However, double cropping is possible even in slightly low rainfall areas with short duration varieties and improved soil and water management practices (Krantz et al 1978; Surajbhan and Khan 1981). Short duration legumes such as greengram, cowpea, blackgram are found better before growing rice compared to fodder crops of maize or clusterbean (De et al 1983). A crop sequence of wheat-greengram-rice was found better for upland sandy loam soils under rainfed conditions

(Boruah et al 1984). Reddy and Reddy (1988) opined that growing of pearl millet or sesamum in Kharif followed by semi-dry rice was advantageous over monocropping of semi-dry rice in tankfed areas of Rayalaseema region. Salu Reddy (1989) reported that sunnhemp-semi-dry rice was more profitable cropping system followed by greengram-semi-dry rice in tankfed areas.

The fore-going review indicates the possibility of growing short duration crops preceding rice.

2.2 NUTRIENT REMOVAL

Growing of two cereal crops a year yielding 10 t ha^{-1} or more removes plant nutrients heavily. Sharma and Rajendra Prasad (1980) reported that rice-wheat system removed 155 to 160 Kg N, 46 to 57 Kg P_2O_5 and 192 to 247 Kg K_2O ha^{-1} yr^{-1}. In a rice-rice cropping system the nutrient removal could be 225 to 275 kg N ha^{-1}, 72 to 80 kg P_2O_5 ha^{-1} and 390 to 450 kg K_2O ha^{-1} (Mahapatra et al 1981). Sadanandan and Mahapatra (1973) observed a decrease in available P in soil as a result of raising rice-based cropping systems on upland alluvial soils and the magnitude of decrease being 7 to 35 kg ha^{-1}. High N, P and K removal in various rice-based multiple cropping systems was observed after two years of intensive cultivation (Nair et al 1973; Purushothaman 1979).

From the brief review it can be seen that N, P_2O_5 and K_2O removal could be very high in rice-based cropping systems and could exceed the recommended doses of fertilizers added to crops.

2.3 NUTRIENT REQUIREMENT

The nutrient requirement for a fixed rice-rice cropping system has been estimated to be 120 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1} for one crop of rice (AICARP 1980). Similar results were reported by Singh et al 1987. In rice based cropping systems each crop of rice requires N application at the recommended rate (Purushothaman, 1979; Mahapatra et al 1985). Even if a considerable proportion of N applied to a crop is present in the soil after harvest, its availability to the following crop is less than three per cent (Subbiah and Sachdev 1983). Mahapatra et al (1985) reviewed that N dose could be reduced by 20 to 25 kg ha^{-1} and no phosphorus application would be made to rice crop in rice-groundnut cropping system when groundnut crop has been supplied with phosphorus. Reddy (1988) observed increased grain production with increased levels of fertilizer N applied to rice in rice-rice-greengram cropping system.

2.4 NUTRIENT MANAGEMENT IN CROPPING SYSTEMS

Until recently, crop production research has been focussing attention on individual crops disregarding the fact that each crop is only a component of a cropping system. Nutrient dosage for the individual crops is usually prescribed based on the responses of crops without considering the cropping system as a whole. As a result, rather high and uneconomic recommendations of fertilizers are made. Hence fertilization must be considered not for individual crop but for cropping system as a whole. Swaminathan (1981) emphasized the need for systems approach of nutrient supply for increasing the fertilizer use efficiency and economising the use of costly mineral fertilizers. While developing a suitable fertilizer schedule it is necessary to take into account the residual effect of fertilizers applied to the previous crop and the influence of the preceding crop on succeeding one (Biswas *et al* 1987).

Food and Agricultural organization (FAO) had conceptualised the idea of systems approach to plant nutrition (SPAN). The concept of SPAN integrates three systems:

(i) Integrated plant nutrient system (IPNS);

(ii) Plant nutrition based on cropping system as a whole rather than on single crop in the system; and

(iii) Soil fertility conservation and enhancing soil management system (Roy and Braun 1984).

2.5 INTEGRATED USE OF DIFFERENT SOURCES OF NITROGEN FOR RICE

In view of relatively high cost of fertilizers better management practices should be advocated to get highest yield of rice with the smallest possible amount of fertilizer. With the adoption of modern technology of intensive cropping with high yielding varieties, there is a considerable demand on the soil for nutrients. However, the native fertility of our soils is poor and cannot sustain high crop yields (Ghosh and Hasan 1980).

Food and Agricultural Organisation advocated an integrated nutrient supply system approach to crops. The objective of such an approach was to take care of soil health and supply plant nutrients by integrating organic and biological sources with mineral fertilizers in one package. The integrated nutrient system puts the local resources to the best and maximum use and this approach fits into the philosophy of low-cost technology needed for the small and marginal farmers. Integrated nutrient supply system does not and cannot dispense with the use of fertilizers.

Fortunately, some of the farmers have FYM and alternatively grow a greenmanure crop as a source of organic manure which not only supplies balanced plant nutrients but substantially reduces the cash investment on inorganic fertilizers. Meelu and Morris (1984) studied the integrated use of organic, biological and chemical fertilizers in rice and rice-based cropping systems and found that integrated nutrient management was beneficial in maintaining organic matter, improving soil fertility and increasing rice yields.

The use of organic sources of nitrogen like farmyard manure, green manure, residues of legumes and crops can be made along with inorganic fertilizers to improve the soil fertility status and thereby improving the crop yields in a cropping system. The available literature on farmyard manure, greenmanure, inclusion of legumes in a cropping system and fertilizers is reviewed individually.

2.6 FARM YARD MANURE

This is the traditional organic manure and is not readily available to the farmers. On account of rapid increase in the use of chemical fertilizers, the importance of farm yard manure is ignored in the last two decades. But once again the scarcity and high costs of fertilizers have led to a fresh appraisal of their role and scope in crop production. Meelu *et al* (1981) found that the yields of rice with 120 kg N ha^{-1} or FYM 12t ha^{-1} + 80 kg N ha^{-1} through urea were similar. Application of 12t FYM with 90 kg N ha^{-1} to Kharif crop followed by 60 kg N ha^{-1} to Rabi crop could produce a satisfactory yield comparable to 120 kg N, 60 kg P_2O_5, 60 kg K_2O to Kharif and 60 kg N ha^{-1} to Rabi crop in a rice-rice cropping system (Kulakarni *et al* 1983). Maskina and Meelu (1984) reported that application of 12t FYM ha^{-1} to rice crop gave a residual effect equivalent to that of 30 kg N and 13 kg P ha^{-1} for succeeding wheat. Application of 12t FYM ha^{-1} added about 40 kg N and 13 kg P ha^{-1} in rice-wheat cropping system (Mahapatra *et al* 1985). Application of 30 kg N ha^{-1} in the form of FYM at puddling and 30 kg N ha^{-1} as urea at planting gave grain yield comparable to that of 60 kg N ha^{-1} as urea applied in 3 splits (Khan *et al* 1986).

Farm yard manure could substitute fertilizer N to an extent of 30 kg N and improve the grain yields in a system.

2.7 GREEN MANURE

Green manuring is cheap and a feasible alternative for substituting inorganic N sources. Sunnhemp (*Crotalaria juncea*) and dhaincha (*Sesbania aculeata*) are the most common green-manuring crops in India. These are also widly grown in other rice growing tropical countries (Sano 1977; FAO 1978; Pandey and Morris 1983; Meelu and Morris 1986). For upland conditions besides sunnhemp, greengram and cowpea are suitable (Panda 1980). The benefits of green manuring include increase in available plant nutrients and organic matter content of soil, improvement in physical and biological properties of soil-the overall impact of which results in increased crop production.

The available literature on decomposition of green manure, and its effect on soil properties, nutrient availability and on growth and yield of crops is reviewed hereunder.

2.7.1 Decomposition of green manure

Dhaincha was able to supply the nutrients immediately after incorporation to the next crop (Debnath and Hajra 1972). The same or better rice yield was obtained if the interval between green manure application and transplanting was as short as possible (Beri and Meelu 1981; Tiwari et al 1980). Khind et al (1985) reported that incorporation of Sesbania one day before transplanting released 60 to 120 kg N ha^{-1} depending on the amount incorporated. Azam et al (1985) studied the transformations in soil and availability of N applied as fertilizer and sesbania incorporation. The results revealed that there was a 5 per cent increase in N uptake from Sesbania and losses of nitrogen from fertilizer were reduced in the presence of sesbania.

According to Bouldin (1987), green manure contains two fractions; one which decomposes immediately upon incorporation and a second fraction which decomposes slowly over several years. With most of green manures, the first fraction approximates to 50 to 80 per cent of total.

2.7.2 Effect on soil properties

There was a 6.5 per cent increase in organic carbon in green manure-wheat system (Singh and Awasthi 1978). Aggregation was increased by green manuring (Burns and Davis 1986). Hulugalle et al (1986) reported the ameleoration of compacted soils with green manuring. Anandswarup (1988) reported that with the addition of green manures to soil not only the peaks of CO_2 production and maximum concentration of extractable Fe and Mn and other cations earlier, but their concentration was also significantly higher as compared to control (no organic matter) even at later stage. There was an increase in water holding capacity in green manure-wheat sequence over initial value (singh and Awasthi 1978). Wade and Sanchez (1983) observed beneficial effects of incorporating green manure in conserving soil moisture and reducing soil moisture stress.

From the above review it is clear that green manuring improves the physical and chemical properties of soil.

2.7.3 Nitrogen

Green manures will substitute for nutrients derived from fertilizers to obtain similar crop yield (Singh 1984). Response of rice to green manuring equivalent to 80 kg fertilizer N ha^{-1} was obtained on upland soil (Tiwari *et al* 1980). There was a saving of 74.5 kg N ha^{-1} with the incorporation of sunnhemp in rice (Bharadwaj *et al* 1981). Contribution of green manuring ranged from 45-80 kg N ha^{-1} in rice (Moris and Meelu. 1984 and Rajbhandari, 1984). Nitrogen equivalent to 50 to 100 kg ha^{-1} was contributed by green manuring (Meelu *et al* 1985 and Ladha *et al* 1987). Hati (1987) reported that the grain yield obtained with sesbania alone equalled with 40 kg N ha^{-1}. Yield obtained with 60 kg N application along with *dhaincha* green manure crop was statistically on par with the application of 120 kg N alone showing an economy of 60 kg N to the succeeding rice crop (Rana *et al* 1988). Similar results were reported by Kolar and Grewal (1988).

It is evident from above that there is possibility of considerable fertilizer N economy in rice farming with the use of green manure.

2.7.4 Availability of other nutrients

Generally it is thought that green manuring is useful for only N substitution ignoring its contribution to the availability of other nutrients. Kute and Mann (1969) reported increase of P content in wheat and a further increase was observed when P was applied to green manure crop. There was a increased availability of fertilizer phosphate to crops by green manuring (Lemare *et al* 1987). Kute and Mann (1969) observed solubulizing effect on potassium with green manuring which was confirmed by increased K content in plant and uptake by wheat crop. Wade and Sanchez (1983) reported that calcium and magnesium were released from the decomposition of green manure.

There was an increased availability of micronutrients particularly iron due to green manuring (Abrol and Palaniappan 1987). Green manuring caused a greater increase in water soluble plus exchangeable iron (Chahal and Khehra 1988).

2.7.5 Yield

Hernandez et al (1958) have shown that 79 to 82 per cent higher yields could be harvested when green manure @ 10t ha^{-1} was incorporated before rice planting. Increased yields with green manuring both under flooded and non-flooded conditions were reported by Lao-Lao et al (1978). Khind et al (1982) reported higher grain yields with green manuring.

It is evident from the several experimental results that there was positive effect of green manuring in increasing the rice yields to varying magnitudes (Sudhakar 1984; Rajbhandari 1984; Meelu et al 1985; Meelu and Morris 1986; Hati 1987 and Kolar and Grewal 1988).

The encouraging results of extensive studies indicate the potentiality of green manuring in increasing rice production.

2.8 LEGUMES

For maintenance of productivity of soil, a leguminous crop which supplies nitrogen and organic matter to the soil should be grown in between two rice crops. The inclusion of legumes in rotation increases the yield of succeeding rice crop or cereal crops in the sequence. The haulms of legumes can be used as green manure for rice Mahapatra *et al* 1985). Palaniappan *et al* (1976) reported that inclusion of pulses in the cropping systems, improves the soil N status and thus reduces the necessity for N application to the succeeding crop. Misra and Misra (1975) obtained 2 to 4 Q ha^{-1} of more rice yield after greengram than that obtained after fallow. Fodder legume grown in monsoon season benefited the following wheat and maize crops to the extent of about 40 kg fertilizer N ha^{-1} (Lal *et al* 1978). Yields of pearl millet were significantly increased when grown after grain legumes such as groundnut, cowpea or pigeonpea instead of after pearl millet (Giri and De 1979). Previous grain crops of greengram, cowpea and blackgram increased the grain and straw yields of a subsequent crop of rice (De *et al* 1983). Dahama and Sinha (1985) reported that wheat following cowpea grown in Kharif season gave significantly higher grain yields than after Kharif fallow. N uptake by dry season rice following wet season crops of soybean and greengram was more than after fallow. Grain yield and N uptake in rice were higher after greengram crop (Antil *et al* 1988)

Greengram frequently found a place in different rice-based cropping systems in India. Some of the cropping systems involving greengram as a component are: rice-wheat-greengram (Buck 1972; Rekhi and Meelu 1983); rice-rice-greengram (AICARP 1978); Purushothaman 1978; Pandey et al 1985). In addition to above, rice-fallow pulses are most common in single cropped rice areas of deltaic regions of Andhra Pradesh and Tamilnadu, the chief pulse being greengram (Abrol and Palaniappan 1987). Rekhi and Meelu (1981) found that incorporation of greengram haulms after harvesting of pods supplied 60 kg N ha^{-1} to the succeeding rice crop. The incorporation of greengram haulm improved plant hight, dry matter accumulation, panicle number and yield of succeeding rice crop (Rekhi and Meelu 1983). Similar beneficial effects were also reported by Rajat De (1981) and Rajendra Prasad (1985). Reddy (1988) reported that greengram haulm in place of green manure were equally effective in improving the growth and yield attributes, nutrient uptake and yield. Incorporation of cowpea biomass increased the soil organic carbon, exchangeable N and grain yield of the following rice crop (Timsina and Carangal 1984).

John et al (1989) reported that incorporation of residues of cowpea significantly increased the rice grain yield and total N uptake both under upland and lowland conditions.

With the overall view of maintaining soil fertility and economising the fertilizer application, it is beneficial to include legumes as components of intensive cropping systems.

2.9 FERTILIZERS

The use of faramyard manure, green manures, crop residues etc., cannot replace the use of chemical fertilizers. They must be added to maintain sufficient level of nutrients in the soil. The available information on the response of rice (upland) to rates of nitrogen and split application is reviewed hereunder.

2.9.1 Effect of nitrogen

Singh et al (1972) studied the effect of fertilizers on rice yields and concluded that nitrogenous fertilizers increases grain yield significantly. Cordero and Miner (1974) found that 100 to 120 kg N ha^{-1} was sufficient for upland rice. Tewari and Harcharan Singh (1976) reported that 60 kg N ha^{-1} has given higher grain yield compared to no nitrogen under rainfed conditions. Singh and Singh (1976) found that there was increase in the grain yield with the increase in N levels from 0 to 90 kg N ha^{-1} under dry land conditions. Singh and Modgal (1978) obtained significant yield increase with increasing N levels up to 90 kg N ha^{-1} under rainfed conditions. Giri and Bhatade (1980) reported increased paddy yields with increased N levels up to 120 kg N ha^{-1} under upland conditions.

Application of nitrogen promotes the growth of rice by increasing plant height, tiller production, leaf area index and dry matter accumulation (Singh *et al* 1981; Ramasamy 1982 and Reddy 1985). Dubey *et al* (1983) reported that 120 kg N ha^{-1} was sufficient for rice under rainfed conditions. Yield attributes and yield were increased with the increase of N levels (Reddy, 1985). Increasing the N rates from 0 to 120 kg N ha^{-1} increased the yields of upland rice (Wankade and Pandrangi. 1988). Salu Reddy (1989) reported that grain yield was increased with the increase of N level from 40 to 120 kg ha^{-1} in semi-dry rice.

2.9.2 Split application of nitrogen

Transanasongchan et al (1976) found that split application of urea was superior to single application at sowing in light soil. Application of 25 per cent N at sowing and the remainder in 2 equal top dressings at tillering and panicle initiation stages gave highest paddy yields compared to single application of full N at sowing under rainfed conditions (Tewari and Haracharan Singh. 1976). Sarkar and Sinha (1976) reported that application of N in 2 splits at 15 DAS and at the panicle initiation stage gave higher paddy yields than full N applied at 15 DAS. Split application of Nitrogen was found better than the single basal application in upland rice (Harbir Singh and Modgal 1978). N applied in 2 equal split dressings at sowing and at 40-45 days later gave higher yields than when applied in a single dressing at sowing (Giri and Bhatade 1980). Split application of small doses of 10 - 40 kg N ha^{-1} produced almost the same yield as 50 kg N ha^{-1} applied as basal (Singh et al 1981). Sudhakar Raju and Yellamanda Reddy (1989) reported that split application of nitrogen ($\frac{1}{4}$ basal + $\frac{1}{4}$ at 20 DAS + $\frac{1}{2}$ at 60 DAS) was better than single basal application in semi-dry rice.

2.10 EFFECT OF IRON ON RICE

Iron is an important micronutrient necessary for synthesis of chlorophyll, though it actually does not enter its composition. The available information on iron chlorosis in rice and its management is reviewed hereunder.

2.10.1 Symptoms of iron chlorosis

Most of the high yielding rice varieties when grown under upland conditions exhibit iron chlorosis in highly calcarious soil. Chlorosis occurs generally in coarse texture soils with high p^H and percolation rate. Iron chlorosis in paddy seedlings is a chronic problem in sandy loam soils (Patel et al 1977). Symptoms of iron deficiency in rice appear in the form of chlorosis (yellowing) of new leaves (Raju 1977; Takkar and Nayyar 1979). Under moderate iron deficiency, chlorosis is only mild and restricted to interveinal areas of young leaves while older leaves remain green, where as under sefere cases of deficiency, new leaves become white or bleached and few brown scars may also appear resulting in final death of the plant (Takkar and Nayyar 1979). Ferrous iron (Fe^{+2}) content in plants has been reported as a good index for differentiating the iron deficient plants from sufficient ones (Katyal and Sharma 1980). The critical limit of iron in the leaf blade of rice at tillering was 70 ppm (De Datta 1981). A concentration of 4.5 ppm of DTPA extractable iron was found to be critical limit in the soil for chlorosis (Lindsay and Norvell 1978). Groundnut plants begin to be chlorotic when DTPA extractable iron in the soil was below 2.5 ppm (Papastylianou 1989).

2.10.2 Correction of iron chlorosis

Westfall *et al* (1971) recommended the soil application of 100 kg Fe ha^{-1} to control iron chlorosis. Patel *et al* (1977) found that application of ferrous sulphate to soil @ 40 kg ha^{-1} increased the survival period of seedlings. Iron concentration was increased due to ferrous sulphate application along with the organic amendment (cotton leaves @ 20t ha^{-1}) in sorghum (Francis *et al* 1979). Meelu and Sagar (1980) reported that spraying of iron sulphate at 0.5 per cent concentration was enough to check iron chlorosis of rice nursery. Foliar application of ferrous sulphate increased the dry matter production and yield (Alam 1986). Incorporation of 10t ha^{-1} of sesabania green manure counteracted the iron chlorosis in rice (Sharma and Katyal 1982). Seedling chlorosis was alleviated by drilling water soluble iron compounds with the seed at rates of 20 to 30 kg Fe ha^{-1} (Snyder and Jones 1988). The ferrous sulphate obtained as a byproduct of steel plants is more effective in correcting the chlorosis than $FeSO_4$ available in the market due to low p^H of it (Singh et al 1988).

From the above review it is clear that there are beneficial effects of FYM, green manure and legumes in improving the soil fertility status and in substituting fertilizer N for low land rice. Cropping intensity can be increased by including short duration pulse crops in upland rice. It is also evident that chlorosis may occur under semi-dry conditions. Integrated nutrient management is better for rice utilising organic resources and reducing costly fertilizers. However, information on suitable cropping systems for semi-dry rice under tankfed areas is limited. Feasibility of growing and incorporating green manure crops in semi-dry rice is not known. Information on integrated nutrient supply for semi-dry rice is meagre. Hence the present investigation is planned accordingly.

MATERIALS AND METHODS

III MATERIALS AND METHODS

In this chapter, the materials used and methods followed during the course of present investigation are briefly described. Experiments were conducted both under glasshouse and field conditions.

3.1 POT-CULTURE EXPERIMENT

The bulk soil sample was air dried under shade, ground with a wooden hammer and passed through 2 mm sieve. The sample was thoroughly mixed to make homogeneous mixture and 5 kg portion of soil sample was transfered to plastic buckets of 7 kgs capacity. A common basal dose of nitrogen @ 20 kg N ha^{-1} was applied in the form of urea to all the buckets. The details of the treatments are given below.

T_1 = Green manure @ 10t ha^{-1}

T_2 = $FeSO_4$ @ 40 kg ha^{-1} at the time of sowing

T_3 = $FeSO_4$ @ 40 kg ha^{-1} at 20 DAS

T_4 = Fe-EDTA @ 5 kg ha^{-1} at the time of sowing

T_5 = Fe-EDTA @ 5 kg ha^{-1} at 20 DAS

T_6 = $FeSO_4$ 0.4% spray

T_7 = Submergence (5 cm)

Each treatment was replicated thrice and the design followed was R.B.D. Good quality seeds of paddy variety BPT-2740 were selected and seeds were sown at the rate of 5 seeds per bucket. All the buckets are irrigated at regular intervals with measured quantity of water except in submergence treatment so as to maintain upland condition. In case of submergence treatment, the drainage hole of the bucket was closed and standing water of 5 $\pm$ 2 cm was maintained. After germination the plants were thinned at the rate of two per bucket. The plants were cut at 60 days after sowing. Plant height, number of leaves and dry matter were measured at 60 DAS.

3.2 FIELD LOCATION

The field experiment was carried out in the wetland farm of S.V.Agricultural College, Tirupati. The location is geographically situated at 13.5^{o}N latitude and 79.5^{o}E longitude at an altitude of 189.2m above mean sea level.

3.3 WEATHER CONDITIONS

The weather conditions prevailed during *kharif* and late *kharif* were presented separately.

3.3.1 *Kharif* 1989

The weather conditions prevailed during the crop period (11.7.1989 to 23.9.1989) of *kharif* crops viz., greengram, sunnhemp and cowpea are furnished in table 1 and depicted in Fig. 1. During the crop season a total amount of 193.3 mm rainfall was received in 10 rainy days. The rainfall received was more during the vegetative phase of the crop. A dry spell for a period of 28 days (19-8-89 to 16-9-89) prevailed during the reproductive phase of the crops (Appendix A). However a good amount of rainfall was received just before the incorporation of the crops (95.6 mm). During the entire crop growth period bright sunshine hours on an average were 5.7 per day. The mean maximum temperature ranged from 31.7°C to 36.4°C with an average of 34.5°C and the mean minimum temperature ranged from 22.9°C to 25.6°C with an average of 24.4°C. The mean relative humidity ranged from 48.7 to 73.2 per cent with an average of 57.3 per cent. The evaporation from the USWB class A pan evaporimeter ranged from 5 to 10 mm with an average of 7.6 mm per day. The weather condition during the crop season was characterised by high temperature, moderate sunshine hours, relative humidity and evaporation.

Table 1. Weather data during Kharif crop period (11-7-1989 to 23-9-1989)

Standard weak	Date	Temperature (°C) Max.	Min.	R H (%)	Sunshine (h.day^{-1})	Rainfall mm	Rainy days	Evaporation (mm. day^{-1})
28	11.7 - 15.7	34.7	23.6	63.8	5.3	42.4	2.0	6.4
29	16.7 - 22.7	31.7	23.7	65.2	4.1	45.6	3.0	5.8
30	23.7 - 29.7	32.5	23.2	60.0	3.7	2.0	0.0	5.0
31	30.7 - 5.8	34.7	24.5	53.3	9.3	4.9	1.0	8.2
32	6.8 - 12.8	35.2	25.6	48.7	7.2	0.0	0.0	9.6
33	13.8 - 19.8	33.7	24.0	57.8	2.8	2.8	1.0	7.2
34	20.8 - 26.8	35.3	25.6	51.6	3.4	0.0	0.0	8.9
35	27.8 - 2.9	36.1	25.2	51.3	7.2	0.0	0.0	8.9
36	3.9 - 9.9	36.4	24.4	51.6	8.0	0.0	0.0	8.0
37	10.9 - 16.9	35.6	25.5	54.3	6.1	0.0	0.0	10.0
38	17.9 - 23.9	33.5	22.9	73.2	5.8	95.6	3.0	5.1

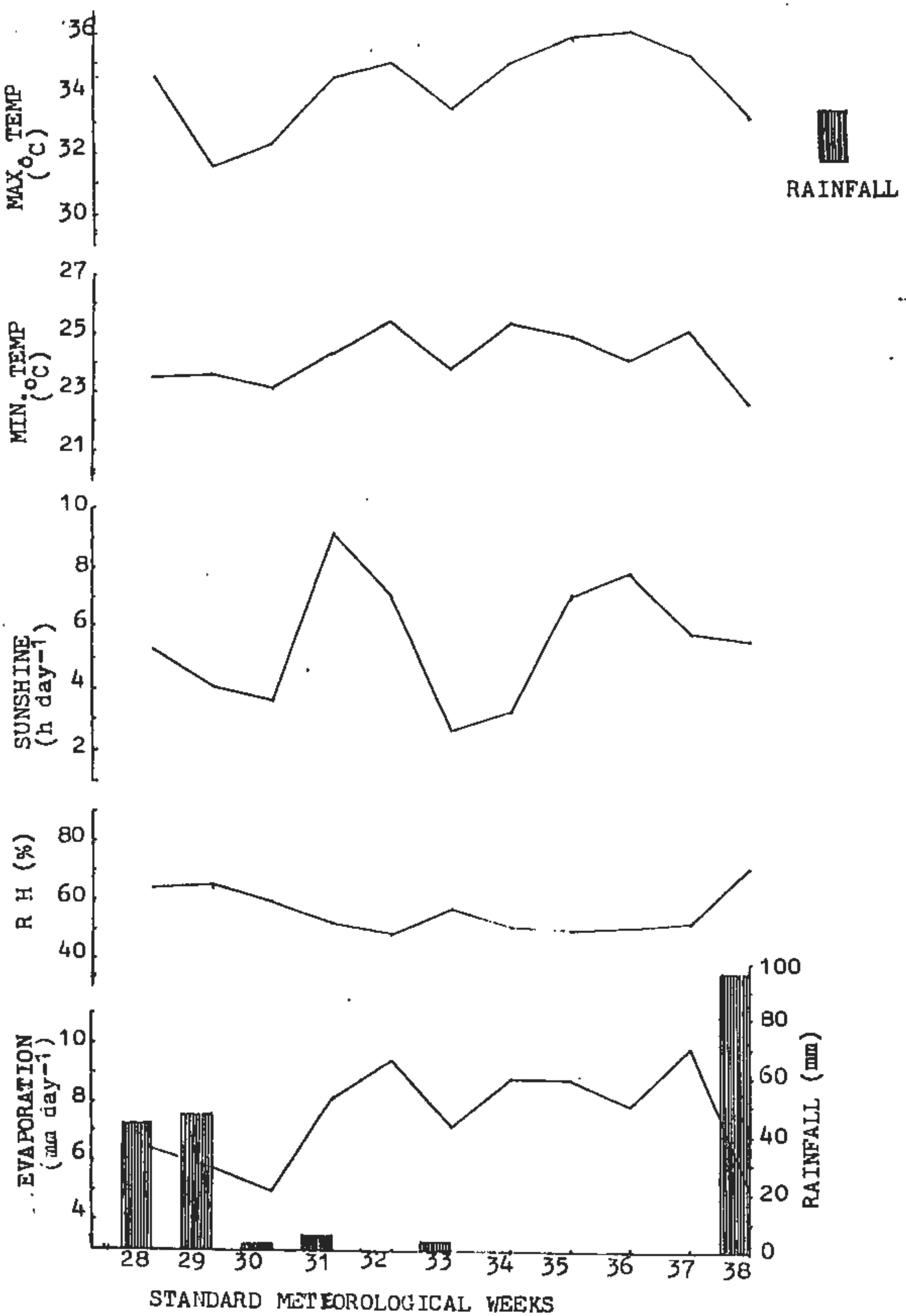


Fig. 1. Weather data for crop period, Kharif 1989

3.3.2 Late kharif, 1989

The weather data pertaining to crop period (15-10-89 to 7-3-90) of semi-dry rice are presented in Table 2 and depicted in Fig. 2. During the crop season a total amount of 379.2 mm rainfall was received in 15 rainy days. A prolonged dry spell (from 4-12-89 to 31-12-89) for a period of 28 days prevailed during the tillering stage (Appendix A) in addition to dry spell (15-10-1989 to 1-11-1989) for a period of 15 days during the seedling stage of the crop. The mean maximum temperature ranged from 27.7°C to 36.8°C with an average of 31.4°C and the minimum temperature ranged from 12.1°C to 23.4°C with an average of 18.1°C. The temperature gradually decreased from sowing to tillering stage and then increased reaching peak just before harvest. The bright sunshine hours during the crop growth period were on an average 8.6 per day. The mean relative humidity ranged from 43.5 to 80.9 per cent with an average of 63.7 per cent. The evaporation from the USWB Class A pan evaporimeter ranged from 3.8 to 7.3 mm with an average of 5.4 mm per day. It was high during reproductive phase compared to vegetative phase but it was minimum at harvest. Rainfall was more

Table 2. Weather data during late Kharif crop period (15-10-1989 to 7-3-1990)

Standard weak	Date	Temperature (°C) Max.	Min.	R H (%)	Sunshine ($h.day^{-1}$)	Rainfall (mm)	Rainy days	Evaporation ($mm.day^{-1}$)
42	15.10 - 21.10	34.9	20.2	56.2	9.3	0.0	0.0	5.3
43	22.10 - 28.10	33.3	20.1	61.1	7.0	0.0	0.0	5.8
44	29.10 - 4.11	32.4	20.0	71.2	8.9	9.8	1.0	4.7
45	5.11 - 11.11	31.9	19.9	65.4	7.4	48.0	1.0	6.1
46	12.11 - 18.11	28.4	19.7	80.9	4.3	89.4	4.0	4.5
47	19.11 - 25.11	29.6	15.7	65.7	9.3	29.2	2.0	6.0
48	26.11 - 2.12	29.5	17.1	76.1	6.7	105.2	2.0	5.7
49	3.12 - 9.12	27.7	16.9	71.4	5.9	51.0	1.0	4.7
50	10.12 - 16.12	28.2	16.7	72.4	8.5	0.0	0.0	5.1
51	17.12 - 23.12	28.2	16.3	73.7	7.9	0.0	0.0	4.0
52	24.12 - 31.12	30.2	17.7	73.8	9.1	0.0	0.0	5.4

Contd...

Table 2(continued.) Weather data during late Kharif crop period (15-10-89 to 7-3-1990)

Standard weak	Date	Temperature (°C) Max.	Min.	R H (%)	Sunshine (h.day^{-1})	Rainfall (mm)	Rainy days	Evaporation (mm. day^{-1})
1	1.1 - 7.1	29.2	18.2	71.3	6.1	7.4	1.0	4.8
2	8.1 - 14.1	29.3	13.8	58.4	10.1	1.6	0.0	4.7
3	15.1 - 21.1	31.5	12.1	43.5	10.5	0.0	0.0	5.3
4	22.1 - 28.1	31.4	13.4	53.4	10.6	0.0	0.0	5.6
5	29.1 - 4.2	30.8	14.1	55.3	10.4	0.0	0.0	6.2
6	5.2 - 11.2	31.6	17.1	63.9	10.3	0.0	0.0	6.0
7	12.2 - 18.2	33.6	21.4	59.6	9.2	0.0	0.0	6.0
8	19.2 - 25.2	35.4	23.3	56.9	9.7	0.0	0.0	5.9
9	26.2 - 4.3	36.8	23.4	55.1	9.0	11.6	1.0	7.3
10	5.3 - 7.3	34.8	23.2	62.3	10.0	25.8	2.0	3.8

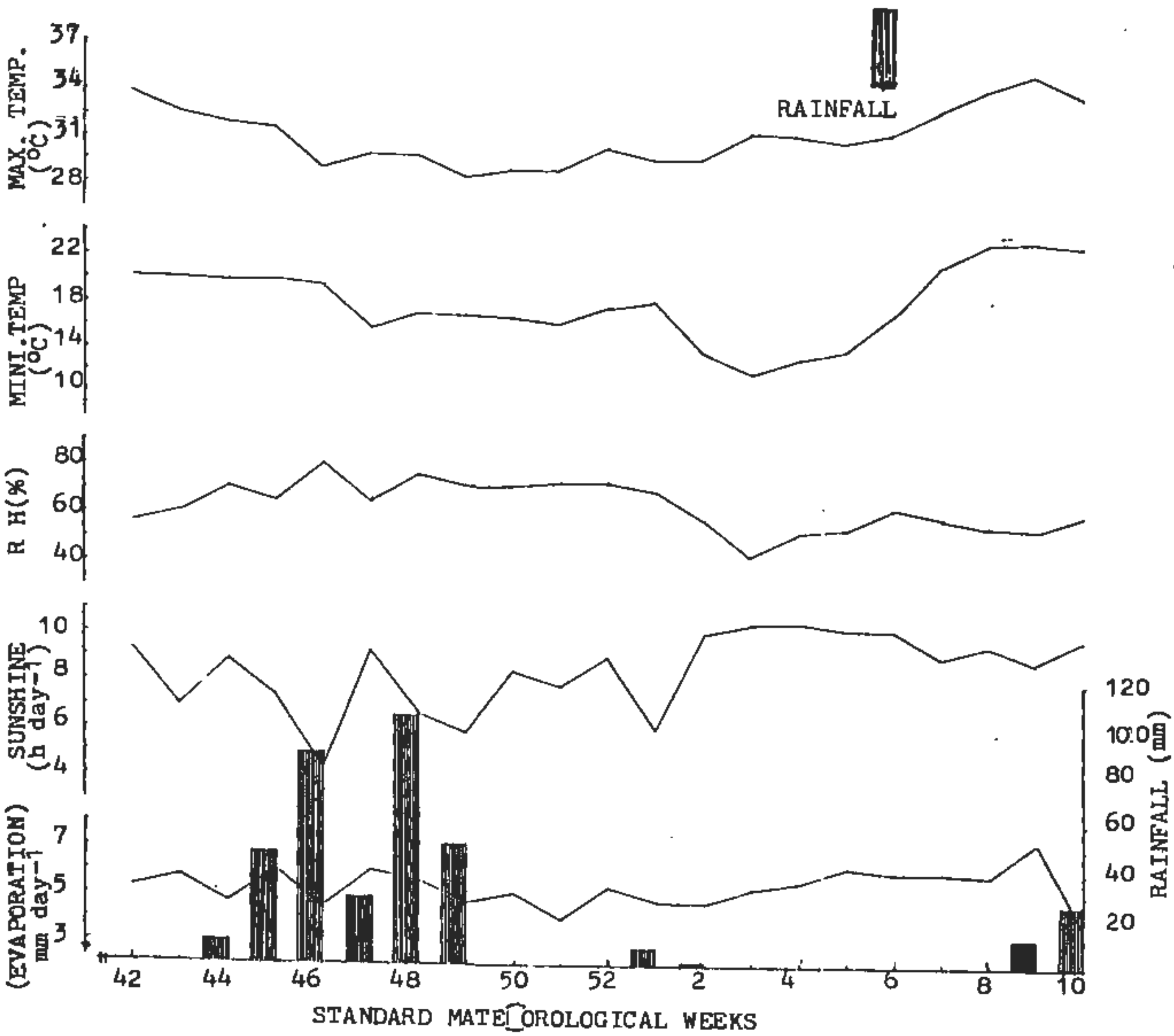


Fig. 2. Weather during crop period, late Kharif 1989

Table 3. Soil analysis data of the experimental plot

Particulars	Values
Mechanical composition (Piper 1950)	
Coase sand (%)	14.61
Fine sand (%)	54.19
Silt (%)	20.11
Clay (%)	11.85
Textural classification	Sandy loam
Chemical characters	
Available nitrogen (Subbiah and Asija 1950)	95 Kg N ha^{-1}
Available phosphorus (Olsen et al 1954)	23.1 Kg P_2O_5 ha^{-1}
Available potassium (Stanford and English 1954)	310 Kg P_2O_5 ha^{-1}
DTPA extractable iron (Lindsay and Norvell 1978)	2.0 ppm
p^H (1:2 soil water suspension)	7.4
EC (1:2 soil water suspension)	0.07 dS m^{-1}

during the vegetative stage compare to reproductive stage of the crop. The weather condition was characterised by more bright sunshine hours, high temperature and moderate relative humidity and evaporation.

3.4 SOIL

The soil of the experimental plot was analysed for physico-chemical properties and the data are furnished in Table 3. The soil is sandy loam in texture, neutral in reaction (pH 7.4) low in available nitrogen, medium in available phosphorus and high in available potassium. The soil available iron is 2.0 ppm.

3.5 CROPPING HISTORY OF THE EXPERIMENTAL PLOT

Details of the cropping history of the preceding years are given below

Year	Kharif	Rabi
1986-87	Fallow	Greengram
1987-88	Paddy	Fallow
1988-89	Greengram	Groundnut
1989-90	Present experiment	

3.6 SEASONS, CROPS AND VARIETIES

A local variety of sunnhemp, PIMS-4 of greengram and C-152 of cowpea were grown during <u>kharif</u>, 1989. Rice Cv. IR 64 was grown during late <u>kharif</u>, 1989 after harvest of kharif crops.

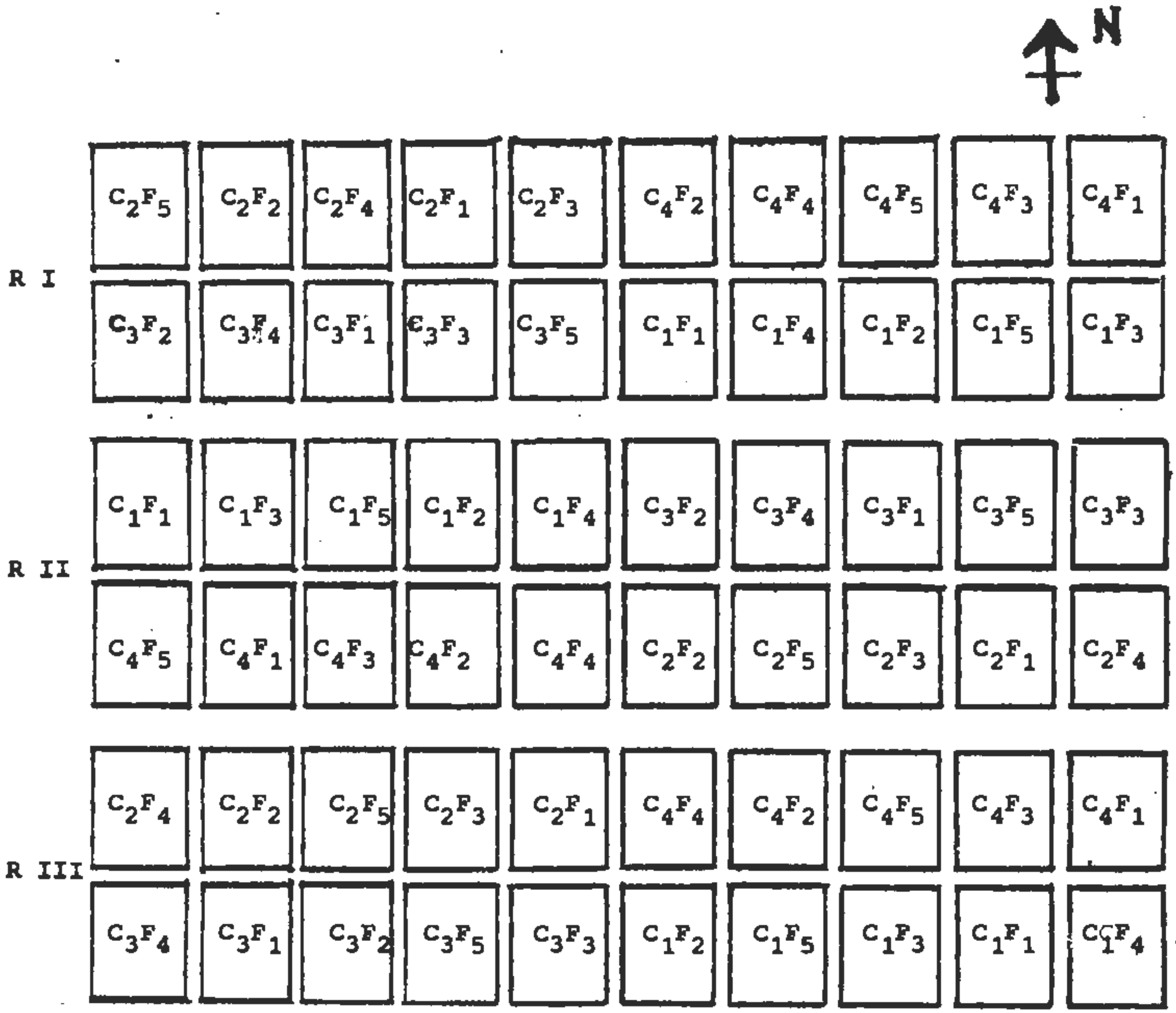
PIMS-4 is photoinsensitive, possess wider adoptability and matures in 60 to 65 days with an average yield of 1.2 to 1.4 t ha^{-1}.

C-152 is a semierect, tall variety maturing in 90 to 100 days with an average fresh fodder yield of 20 t ha^{-1}.

Rice variety IR 64 is a cross between IR 5657-33-2-1- and IR 2061-465-1-5-5 and matures in 120 days. It is a superfine quality variety with long slender grain having an yield potential of 6.5 t ha^{-1} under lowland conditions.

3.7 EXPERIMENTAL DETAILS

The experiment was laid out in a split-plot design replicated thrice. The experimental layout was kep undisturbed throughout the course of investigation. Cropping



DESIGN : SPLIT-PLOT

PLOT SIZE : 5.0 x 3.6 m

TREATMENTS

CROPPING SYSTEMS (MAIN PLOTS)

C_1 : FALLOW-RICE

C_2 : GREENGRAM-RICE

C_3 : SUNNHEMP-RICE

C_4 : COWPEA-RICE

FERTILITY LEVELS (SUB-PLOTS)

F_1 : FYM @ 10t ha^{-1} + 20 kg N ha^{-1}

F_2 : 80 kg N ha^{-1}

F_3 : 120 kg N ha^{-1}

F_4 : 120 kg N ha^{-1} + 40kg $FeSo_4$ ha^{-1} TO SOIL

F_5 : 120 kg N ha^{-1} + $FeSo_4$ @ 0.5% FOLIAR SPRAY.

Fig.3 LAYOUT OF EXPERIMENTAL PLOT

systems were alloted to main plots and fertility levels to subplots.

Main plots (4) - cropping system

C_1 - Fallow - rice

C_2 - Greengram - rice

C_3 - Sunnhemp -rice

C_4 - Cowpea - rice

Subplots (5) - Fertility levels to semi-dry rice

F_1 - 10 t ha^{-1} of farm yard manure + 20 kg N ha^{-1}

F_2 - 80 kg N ha^{-1}

F_3 - 120 kg N ha^{-1}

F_4 - 120 kg N ha^{-1} + soil application of ferrous sulphate @ 40 kg ha^{-1}

F_5 - 120 kg N ha^{-1} + foliar application of 0.5 per cent ferrous sulphate

Sunnhemp and Cowpea were incorporated at 70 days after sowing with spade. Greengram haulm, immediately after final picking of pods were incorporated insitu with spade. Farm yard manure @ 10 t ha^{-1} was applied as per the treatment at the time of field preparation for rice. Nitrogen in the form of urea was applied to rice as per the treatments in three splits (one-fourth of the N as basal, one-fourth at active-tillering stage and the remaining half at panicle-initiation stage (60 DAS)).

Ferrous sulphate was broadcasted on the soil and was incorporated along with the green manure crops before sowing of rice. In case of the foliar application of ferrous sulphate, the first spraying was started one month after sowing and it was repeated thrice at weekly intervals as per the treatments.

The gross and net plot sizes were 18.0 m^2 (3.6m x 5m) and 11.88 m^2 (2.7 m x 4.4 m) respectively. The lay out with treatmental details is shown in Fig. 3.

3.8 FIELD PREPARATION

The field was brought to condition by working with disc harrow and cultivator. Later it was levelled with bullock-drawn levelling plank. The levelled area was laid out into plots. The individual plots were levelled with spades before sowing of <u>kharif</u> crops.

3.9 SEEDS AND SOWING

Greengram, sunnhemp and cowpea were sown by opening furrows with hand-hoes. The spacing adopted was 30 cm x 10 cm for all the crops. After harvest of *kharif* crops, field preparation was done with spades without disturbing the lay out. Rice was sown by opening furrows with hand-hoes. The spacing adopted was 15 cm x 10 cm. The crop was sown by placing 3 to 4 seeds per hill.

3.10 FERTILIZERS

Nitrogen fertilizer in the form of urea was applied to *kharif* crops @ 20 kg N ha^{-1} to greengram and 10 kg N ha^{-1} to cowpea. *kharif* crops (greengram and cowpea) received 40 kg P_2O_5 ha^{-1} in the form of single super phosphate and no potassic fertilizers were applied. No fertilizers were applied to sunnhemp crop. Phosphatic fertilizers @ 60 kg P_2O_5 ha^{-1} were applied to rice in the form of single superphosphate. No potassic fertilizers were applied to rice also. Zinc sulphate @ 25 kg ha^{-1} was applied to rice before sowing of the crop.

3.11 IRRIGATION

The rice was grown as dry crop upto 60 days and it was converted into lowland rice subsequently. From then onwards, the crop was irrigated regularly to maintain a moisture regime of saturation to submergence (5 cm). Prior to first flooding, two life saving irrigations were given during the dry spells.

3.12 WEED MANAGEMENT

One weeding was given to *kharif* crops. First weeding was given to rice at 20 DAS. Two more hand-weedings were given one at 40 DAS and another at 10 days after first flooding.

3.13 PLANT PROTECTION

No plant protection measures were undertaken because the crop was free from pests and diseases.

3.14 HARVESTING AND THRESHING

Sunnhemp and cowpea were incorporated at 70 DAS.

In case of greengram, the pods in the border rows were picked first and then the pods in the net plot area were picked. The pods were threshed and grain yields were recorded. The haulm was incorporated into the soil. In case of rice, border rows all round the plots were harvested first and then the net plots were harvested and threshed. Grain and straw yields were recorded separately.

3.15 OBSERVATIONS

3.15.1 Plant height and tiller number

Five plants from each net plot were tagged for recording plant height and tiller number. Plant height was measured in cm from the base of the plant to the tip of longest leaf stretched at 20, 40 and 60 DAS and up to tip of panicle at flowering and maturity. Total number of tillers per hill were counted at tillering, flowering and panicle initiation stage in rice.

3.15.2 Leaf Area Index

The leaf area of five plants in *kharif* crops and rice was measured by leaf area meter and LAI was worked out by the following formula

$$LAI = \frac{\text{Total leaf area}}{\text{Ground area}}$$

3.15.3 Dry matter production

Five plants from sample rows were removed at different intervals in all crops. These samples were ovendried at 110°C for 24 hours and then at 85°C to constant weight. The weights were recorded and expressed as g m^{-2}.

3.15.4 Relative Water Content

Relative water content (RWC) was estimated as per the procedure suggested by Slavik (1974) in *kharif* crops by taking five leaves (second fully developed leaf from the top) from sampling rows. RWC was calculated by the formula,

$$RWC = \frac{FW - DW}{TW - DW} \times 100$$

where FW, TW and DW are fresh, turgid and ovendry weight of leaves.

3.15.5 Leaflet angle

Leaflet angle was calculated by the formula as suggested by Ramesh Babu *et al* (1983).

$$\text{Leaflet angle} = 2\ (\text{Sin inverse}\ \frac{D}{2L})$$

where

D is the distance between the tips of the leaflets

L is the length of the leaflets along the midrib.

3.15.6 Tap root length

Tap root length of the *kharif* crops (greengram, sunnhemp and cowpea) was measured at 40 DAS and expressed in centimeters.

3.15.7 Chlorophyll content

Chlorophyll content of rice was estimated at flowering stage by method given by Witham *et al* (1971)

$$\text{Total chlorophyll in mg g}^{-1} = \frac{D\ 652 \times 1000}{34.5} \times \frac{V}{1000 \times W}$$

where

D = Optical density at respective nm

V = final volume of the 80% acetone chlorophyll extract

W = Fresh weight in grams of the tissue

3.15.8 Growth Analysis

The crop growth rate (CGR) during the crop growth period was calculated by the following formula

$$CGR = \frac{W_2-W_1}{t_2-t_1} \text{ g m}^{-2} \text{ day}^{-1}$$

Where W_1 and W_2 are dry weights at periods t_1 and t_2 respectively.

The Relative Growth Rate (RGR) was calculated by the following formula

$$RGR = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{t_2-t_1} \text{ mg g}^{-1} \text{ day}^{-1}$$

Where W_1 and W_2 are dry weights at periods t_1 and t_2 respectively.

3.15.9 Yield Components

The yield components were recorded at harvest from 10 randomly selected plants. The yield components recorded in greengram were number of clusters per plant, number of pods per plant, length of pod (cm), number of seeds per pod and 1000 grain weight (g). In the case of rice, number of productive tillers per hill, number of filled grains per panicle, sterility percentage and 1000 grain weight were estimated.

3.15.10 Yield

The grain yield of greengram and rice was recorded from net plot area and expressed in kg ha^{-1}. Straw yield of rice was recorded from the net plot area and expressed in kg ha^{-1}. Weight of haulm of greengram and biomass of sunnhemp and cowpea (incorporated) were estimated.

3.15.11 Harvest Index (H.I)

Harvest index (H I) was calculated by using the formula

$$H.I = \frac{\text{Grain yield}}{\text{Total biological yield}}$$

3.15.12 Soil Analysis

Soil samples were analysed for N, P, K and Fe before the start of the experiment. Nitrogen and Fe were estimated in soil samples after the harvest of each crop. Available nitrogen was estimated by Alkaline potassium permanganate method as suggested by Subbiah and Asija (1956). Phosphorus was estimated by Olsen's method as suggested by Olsen _et al_ (1954). Potassium was estimated by flame photometer (Jackson 1973). Available iron was estimated by using DTPA extractant as given by Lindsay and Norvell (1978).

3.15.13 Plant Analysis

The plant samples taken for drymatter estimation at tillering, flowering and harvest were ground into fine powder and used for chemical analysis. For calculating nutrient uptake at harvest, nutrient content of grain and straw (analysed separately) was multiplied with respective dry weights of grain and straw and summed up. The N content of plant samples was estimated by micro kjeldahl method (Humphries 1956) and uptake was estimated by multiplying the nutrient content with drymatter yield and expressed as Kg ha^{-1}. Phosphorus was estimated by vanado molybdo phospharic acid (yellow colour) method. The K content at harvest was determined using flame photometer (Jackson 1973) and uptake was calculated in Kg ha^{-1}. Total iron was estimated by feeding tri acid extract to atomic absorption spectrophotometer (170-30 model, Hittachi make, Japan) (Lindsay and Norvell 1978).

3.15.14 Nitrogen Use Efficiency (NUE)

The NUE was computed by the formula suggested by Novoa and Loomis (1981) and expressed as Kg of grain produced per Kg of N applied.

$$\text{NUE} = \frac{\text{Grain yield (Kg ha}^{-1}\text{)}}{\text{N applied (Kg ha}^{-1}\text{)}}$$

3.15.15 Economic Analysis

Gross and net returns per hectare were computed for the cropping system as a whole, considering the present market price of inputs and produce. Benefit-cost ratio was worked out for different treatments by dividing the gross returns by cost of cultivation. Rice-grain equivalents were estimated by dividing cost of the produce of other crops with cost of Kg rice grain.

3.15.16 Statistical Analysis

The data on various characters during the course of investigation were statistically analysed as suggested by Panse and Sukhatme (1975). Wherever the treatmental differences were found significant with F test, critical differences (CD) were worked out at five per cent probability level and the values were furnished.

RESULTS

IV RESULTS

The results of the experiment entitled "Integrated nutrient management for rice (semi-dry) based cropping systems" are presented in this Chapter.

4.1 POT-CULTURE EXPERIMENT

Pot-culture studies were conducted to find the ways for correcting severe iron deficiency symptoms in semi-dry rice. The results on growth of rice at 60 days after sowing (DAS) revealed that (Table 4) the plant height and number of leaves were not significantly differed with different treatments. Highest dry matter (95.7 mg $Plant^{-1}$) was recorded with the application of 10 t of gliricidia green manure ha^{-1} and the next best treatment was the maintenance of sumbergence. The Plants were non-chlorotic in those pots. Soil application of ferrous sulphate at the time of sowing was not helpful.

4.2 PRECEDING CROPS

Greengram, sunnhemp, and cowpea were grown prior to rice. The results on growth, yield attributes, yield and

Table 4. Plant height, number of leaves and dry matter of rice as influenced by different treatments

Treatment	Plant height (cm)	No. of leaves (no. $plant^{-1}$)	Dry matter (mg $plant^{-1}$)
Green manure @ 10 t ha^{-1}	37.2	11.3	95.7
$FeSO_4$ @ 40 Kg ha^{-1} at the time of sowing	20.1	6.3	25.3
$FeSO_4$ @ 40 Kg ha^{-1} 20 DAS	33.8	9.5	49.3
Fe EDTA @ 5 Kg ha^{-1} at the time of sowing	21.3	5.5	12.2
Fe EDTA @ 5 Kg ha^{-1} at 20 DAS	9.7	3.0	2.8
$FeSO_4$ 0.4% spray	19.6	5.7	23.8
Submergence (5 cm)	33.8	8.2	54.0
SEm ±	8.5	2.7	20.8
CD 5%	NS	NS	55.3

fertility status of the soil of these crops are presented individually.

4.2.1 Greengram

The results on growth of greengram (Table 5) showed that the average plant height at harvest was 28 cm and LAI at flowering was 1.53. Dry matter recorded at harvest was 1 623 kg ha^{-1}. There were 3 clusters and 9 pods per plant with an average pod length of 6.0 cm. The number of seeds per pod was 7.0 and the 1000 grain weight was 36.9 g. The data on yield show that greengram gave 420 kg ha^{-1} of grain yield and the N present in grain was 10.1 kg ha^{-1}. Fresh biomass addition through incorporation of greengram haulm was 1 925 kg ha^{-1} which added 19.8 kg N ha^{-1} into the soil. The P and K addition to the soil were 1.26 kg P_2O_5 and 20.69 kg K_2O ha^{-1} respectively.

4.2.2 Sunnhemp

The data on growth and green matter yield of sunnhemp was presented in table 6. Sunnhemp attained a plant height of 65 cm at the time of incorporation. The LAI at

Table 5. Growth, yield attributes and yield of greengram

Particulars	Values
Plant height (cm) at harvest	28
Leaf area index at flowering	1.53
Dry matter (Kg ha^{-1}) at harvest	1 623
No. of clusters per plant	3.0
No. of pods per plant	9.0
Pod length (cm)	6.0
No. of seeds per pod	7.0
Thousand seed weight (g)	36.9
Grain yield (Kg ha^{-1})	420
Fresh weight of hanlm (Kg ha^{-1})	1 925
N content (%) in grain	2.41
N removal by grain (Kg ha^{-1})	10.1
N content (%) in hanlm	1.03
N added through hanlm (Kg ha^{-1})	19.8
P uptake (Kg ha^{-1})	1.26
K uptake (Kg ha^{-1})	20.69
Net returns (Rs. ha^{-1})	875

Table 6. Growth, green matter yield of sunnhemp and N addition to soil

Particulars	Values
Plant height (cm) at the time of incorporation	65
LAI	1.87
Total dry matter (Kg ha^{-1})	1 821
Green matter yield (Kg ha^{-1})	5 254
N content (%) (wet-weight basis)	0.44
N added in soil through in corporation (Kg ha^{-1})	23.1
Net returns (Rs. ha^{-1})	276

flowering was 1.87 and accumulated 1 821 kg ha^{-1} of dry matter at the time of incorporation. The growth was very poor due to severe moisture stress. The amount of N added into the soil through incorporation of 5 254 kg ha^{-1} (fresh weight) was 23.1 kg ha^{-1}.

4.2.3 Cowpea

The data pertaining to growth and green matter yield of cowpea was presented in Table 7. Cowpea attained a plant height of 48 cm with LAI of 2.08 and accumulated 2 259 kg ha^{-1} of dry matter at the time of incorporation. The green matter yield was 7 526 kg ha^{-1}. The amount of N added into the soil through incorporation of 7 526 kg ha^{-1} (fresh weight) was 76.8 kg ha^{-1}.

4.2.4 Moisture stress on preceding crops

A prolonged dry spell set in one month after sowing of preceding crops and lost for 28 days. The soil moisture contents in 0-15 cm and 15-30 cm soil layers were 3.26 per cent and 1.75 per cent, respectively which were below the permanant wilting point (3.5%). The data on the number of

Table 7. Growth, green matter yield of cowpea and N addition to soil

Particulars	Values
Plant height (cm) at the time of incorporation	48
LAI	2.08
Total dry matter (Kg ha^{-1}) yield	2 259
Green matter yield (Kg ha^{-1})	7 526
N content (%)	1.02
N added in soil through incorporation (Kg ha^{-1})	76.8
Net returns (Rs. ha^{-1})	355

Table 8. Stress-related parameters of preceding crops

Preceding crop	Tap root length (cm)	Relative Water content (%)	Leaflet angle	Number of dead plants (Number m^{-2})
Greengram	14.90	80.06	106.83	1.11
Sunnhemp	13.84	49.35	43.72	1.31
Cowpea	16.93	78.98	106.80	0.75
SEm ±	0.45	3.73	5.17	0.11
CD 5%	1.37	12.17	15.52	0.32

dead plant m^{-2}, tap root length (cm), relative water content (%) and leaf-let angle of the preceding crops are presented in table 8. The number of dead plants m^{-2} were lowest in cowpea compared to greengram and sunnhemp. Among the different preceding crops cowpea recorded higher tap root length. Cowpea and greengram recorded similar relative water content and leaflet angles but significantly higher than sunnhemp.

4.3 SEMI-DRY RICE

Normally farmers under tankfed areas apply 10 t of FYM as basal and 20 kg N ha^{-1} at flooding. This practice was adopted as check. N_{80} and N_{120} levels were applied in three splits viz., one-fourth as basal, one-fourth at active tillering stage and the remaining half at panicle-initiation stage.

4.3.1 Plant height

Plant height at different stages of semi-dry rice was influenced by preceding crops and fertility levels (Tables 9 and 10). At seedling stage the plants were

Table 9. Plant height (cm) of rice as influenced by preceding crops and fertility levels during vegetative stage.

Preceding crops	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
			Seedling stage			
Fallow	6.5	8.2	8.9	9.3	8.8	8.3
Greengram	8.7	10.4	11.0	11.8	11.1	10.6
Sunnhemp	9.4	11.2	12.0	12.4	12.0	11.4
Cowpea	11.1	13.5	14.1	14.4	14.0	13.4
Mean	8.9	10.8	11.5	12.0	11.5	
	Crops	Fertility	F at C	C x F		
SEm ±	0.13	0.21	0.41	0.32		
CD 5%	0.5	0.6	NS	NS		
			Active tillering stage			
Fallow	16.4	20.3	23.4	24.9	25.3	22.1
Greengram	18.3	22.2	25.2	26.9	27.5	24.0
Sunnhemp	20.3	26.5	27.8	28.6	28.9	26.4
Cowpea	20.8	27.2	28.9	30.1	30.7	27.8
Mean	19.2	24.1	26.3	27.6	28.1	
	Crops	Fertility	F at C	C x F		
SEm ±	1.0	0.5	1.0	2.0		
CD 5%	3.4	1.4	NS	NS		

Table 10. Plant height (cm) of rice as influenced by preceding crops and fertility levels during reproductive stage

Preceding crops	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
			Panicle initiation stage			
Fallow	27.4	33.8	36.3	38.4	39.5	35.1
Greengram	29.6	39.4	39.0	41.8	42.5	38.5
Sunnhemp	31.3	39.7	41.4	43.1	44.2	40.0
Cowpea	33.6	39.3	42.9	44.8	46.0	41.3
Mean	30.5	38.1	39.9	42.0	43.1	
	Crops	Fertility	F at C	C x F		
SEm±	0.9	0.7	1.4	1.9		
CD 5%	3.1	2.1	NS	NS		
			Flowring stage			
Fallow	39.1	45.3	46.9	48.8	50.3	46.1
Greengram	43.1	49.2	50.8	52.0	53.2	49.7
Sunnhemp	44.8	49.3	51.2	52.4	53.5	50.2
Cowpea	46.7	51.9	52.8	54.3	53.8	52.3
Mean	43.4	48.9	50.4	51.9	53.2	
	Crops	Fertility	F at C	C x F		
Sem +	2.1	0.8	1.6	4.2		
CD 5%	NS	2.3	NS	NS		
			Maturity stage			
Fallow	43.5	48.2	50.3	52.9	53.3	49.6
Greengram	46.8	52.3	54.1	55.7	56.9	53.2
Sunnhemp	48.6	53.2	55.4	57.1	58.6	54.6
Cowpea	50.3	56.4	58.0	59.3	61.1	57.0
Mean	47.3	52.5	54.5	56.3	57.5	
	Crops	Fertility	F at C	C x F		
SEm ±	1.6	0.8	1.5	3.2		
CD 5%	NS	2.2	NS	NS		

taller when rice was grown either after, cowpea, sunnhemp or greengram than that when grown after fallow. Plant height was significantly higher with the application of 120 kg N ha^{-1} compared to all other N levels. Soil application of iron did not influence plant height. The interaction of preceding crops and fertility levels was not significant.

The data on plant height at active-tillering stage also showed the same trend, except with few variation, where foliar application of iron increased plant height significantly at 120 kg N ha^{-1}. At panicle-initiation stage, the plant height was significantly higher with the application of 80 kg N ha^{-1} compared to farmers level of N management. The interaction of preceding crops and fertility levels was not significant.

The influence of preceding crops on the plant height of semi-dry rice was only up to panicle-initiation stage; at subsequent stages fertility levels only had influence on plant height. The interaction of preceding crops and fertility levels was not significant. At both the flowering and maturity stages application of 80 kg N ha^{-1} recorded significantly higher plant height compared to farmers level of N Management (Table 10). There was no difference in plant height between 80 and 120 kg N ha^{-1}. Foliar application of iron resulted in taller plants at 120 kg N ha^{-1}.

4.3.2 Tillers

Tiller number in semi-dry rice was influenced by preceding crops and fertility levels (Table 11). At active-tillering stage, higher number of tillers m^{-2} was recorded with incorporation of cowpea, sunnhemp or greengram haulm compared to fallow. Tiller production was higher with 120 kg N ha^{-1} than all other N levels. A combination of 120 kg N ha^{-1} + 40 kg $FeSO_4$ ha^{-1} recorded significantly higher tiller number compared to application of 120 kg N ha^{-1} alone. Foliar application of iron recorded more tiller number compared to soil application. Tiller number with 120 kg N ha^{-1} was significantly higher than all other N levels with different preceding crops. At all levels of fertility management the tiller number was significantly higher when rice was grown after cowpea, sunnhemp or greengram compared to fallow.

Table 11. Number of tillers (no. m^{-2}) as influenced by preceding crops and fertility levels at different stages

Preceding crops	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
			Active-tillering stage			
Fallow	290	311	318	332	347	320
Greengram	310	336	347	358	369	344
Sunnhemp	314	345	359	368	379	353
Cowpea	321	363	374	384	396	368
Mean	309	339	350	361	373	
	Crops	Fertility	F at C	C x F		
Sem ±	2.1	1.3	2.6	4.3		
CD 5%	7.0	4.0	8.0	13.0		
			Panicle-initiation stage			
Fallow	457	486	505	522	529	500
Greengram	483	515	533	540	648	524
Sunnhemp	508	540	551	563	572	547
Cowpea	515	552	575	588	596	565
Mean	491	523	541	553	561	
	Crops	Fertility	F at C	C x F		
Sem ±	0.8	0.7	1.5	1.7		
CD 5%	3.0	2.0	4.0	5.0		
			Flowring stage			
Fallow	477	500	529	546	555	521
Greengram	492	527	539	547	555	532
Sunnhemp	515	551	557	562	567	551
Cowpea	521	569	579	586	595	570
Mean	501	537	551	560	568	
	Crops	Fertility	F at C	C x F		
SEm ±	0.9	0.7	1.3	1.9		
CD 5%	3.0	2.0	4.0	6.0		

The data on tiller production at panicle initiation stage also showed the same trend. Tiller production was significantly higher with incorporation of cowpea compared to all other corps. At farmers level of N management cowpea incorporated crop recorded higher tiller number compared to other crops and fallow. Tiller production at flowering stage also recorded same trend as that of panicle initiation stage.

4.3.3 Leaf Area Index (LAI)

LAI at different stages of semi-dry rice was influenced by preceding crops and fertility levels (Table 12 and 13). LAI was maximum (0.57) at seedling stage when rice was grown after cowpea and significantly higher than that recorded when rice was grown after other crops and fallow. LAI was significantly higher with the application of 120 kg N ha^{-1} and 40 kg $FeSO_4$ ha^{-1} compared to application of 120 kg N ha^{-1} alone. With regard to interaction, cowpea incorporated crop recorded highest LAI at all levels of fertility management compared to other crops and fallow.

Table 12. Leaf area index of rice as influenced by preceding crops and fertility levels during vegetative stage

Preceding crops	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (40 Kg)	Mean
			Seedling stage			
Fallow	0.23	0.31	0.35	0.37	0.35	0.32
Greengram	0.26	0.36	0.41	0.43	0.41	0.37
Sunnhemp	0.31	0.55	0.60	0.63	0.60	0.54
Cowpea	0.35	0.58	0.63	0.65	0.63	0.57
Mean	0.29	0.45	0.50	0.52	0.50	
	Crops	Fertility	F at C	C x F		
SEm ±	0.002	0.003	0.007	0.005		
CD 5%	0.01	0.01	0.02	0.02		
			Active-tillering stage			
Fallow	1.13	1.39	1.45	1.48	1.58	1.39
Greengram	1.23	1.59	1.62	1.64	1.63	1.54
Sunnhemp	1.34	1.77	1.87	1.88	1.88	1.75
Cowpea	1.44	1.89	2.00	2.01	2.02	1.87
Mean	1.29	1.66	1.74	1.75	1.76	
	Crops	Fertility	F at C	C x F		
SEm ±	0.007	0.003	0.006	0.015		
CD 5%	0.03	0.01	0.02	0.05		

Table 13. Leaf area index of rice as influenced by preceding crops and fertility levels during reproductive stage

Preceding crops	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
			Panicle-initiation stage			
Fallow	2.69	3.02	3.07	3.08	3.09	2.99
Greengram	2.77	3.13	3.27	3.29	3.29	3.15
Sunnhemp	2.97	3.40	3.58	3.61	3.62	3.44
Cowpea	3.02	3.51	3.67	3.67	3.69	3.51
Mean	2.86	3.27	3.40	3.41	3.42	
	Crops	Fertility	F at C	C x F		
SEm ±	0.002	0.002	0.003	0.003		
CD 5%	0.01	0.01	0.01	0.01		
			Flowering stage			
Fallow	4.18	4.68	4.76	4.79	4.80	4.64
Greengram	4.42	4.85	5.01	5.03	5.05	4.87
Sunnhemp	4.60	4.97	5.14	5.18	5.19	5.02
Cowpea	4.74	5.06	5.22	5.25	5.27	5.11
Mean	4.49	4.89	5.03	5.06	5.08	
	Crops	Fertility	F at C	C x F		
SEm ±	0.02	0.002	0.004	0.004		
CD 5%	0.06	0.06	0.012	0.012		
			Maturity stage			
Fallow	2.04	2.32	2.38	2.40	2.41	
Greengram	2.28	2.53	2.64	2.65	2.64	
Sunnhemp	2.39	2.64	2.83	2.86	2.87	
Cowpea	2.46	2.68	2.85	2.87	2.88	
Mean	2.29	2.54	2.68	2.70	2.70	
	Crops	Fertility	F at C	C x F		
SEm ±	0.006	0.006	0.006	0.12		
CD 5%	0.02	0.02	0.12	0.24		

The data on LAI at active-tillering stage and panicle initiation stage showed same trend except for a few changes. The foliar application of iron recorded more LAI at 120 kg N ha^{-1}. At flowering stage, the LAI was maximum (5.11) with cowpea incorporation. LAI increased with each increment of N upto 120 kg N ha^{-1}. At 120 kg N ha^{-1} level, iron application either to the soil or to the foliage had influence on LAI. LAI at maturity stage was reduced compared to flowering stage.

4.3.4 Dry-matter production

Dry-matter production as influenced by preceding crops and fertility levels was presented in Table 14 and 15 and fig. 4. During seedling stage, significantly higher dry matter (74.4 g m^{-2}) was produced when rice was grown after incorporation of cowpea while it was 73.0 g m^{-2} after sunnhemp and 51.3 g m^{-2} after fallow. The dry matter at farmers level of N management was significantly less than 120 kg N ha^{-1}. Higher dry matter production of rice with cowpea as a preceding crop was also recorded at active tillering, panicle-initiation, flowering and maturity stages. Dry matter production was significantly higher at 120 kg N ha^{-1}

Table 14. Dry matter (g m^{-2}) as influenced by preceding crops and fertility levels during vegetative stage

Preceding crops	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
			Seedling stage			
Fallow	41.3	48.5	54.1	58.3	53.9	51.3
Greengram	55.7	62.3	73.5	75.2	74.0	68.1
Sunnhemp	62.7	72.4	76.5	77.1	76.2	73.0
Cowpea	64.9	74.0	77.5	78.0	77.6	74.4
Mean	56.2	64.3	70.4	72.1	70.4	
	Crops	Fertility	F at C	C x F		
SEm ±	0.2	0.2	0.4	0.4		
CD 5%	0.6	0.6	1.2	1.3		
			Active-tillering stage			
Fallow	86.4	111.1	120.6	122.5	123.3	112.8
Greengram	114.7	139.0	148.4	151.2	152.2	141.1
Sunnhemp	127.8	150.4	159.2	161.6	162.4	152.3
Cowpea	133.3	157.4	168.2	170.6	171.5	160.2
Mean	115.6	139.5	149.1	151.5	152.4	
	Crops	Fertility	F at C	C x F		
SEm ±	0.5	0.6	1.0	1.1		
CD 5%	1.4	1.5	2.9	3.1		

Table 15. Dry matter ($g\ m^{-2}$) as influenced by preceding crops and fertility levels during reproductive stage

Preceding crops	Fertility levels: FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
			Panicle-initiation stage			
Fallow	201.7	240.4	256.3	260.6	262.7	244.3
Greengram	250.6	291.4	310.7	314.7	317.1	296.9
Sunnhemp	265.5	311.2	325.3	329.4	331.3	312.5
Cowpea	271.4	320.8	338.6	343.3	345.2	323.9
Mean	247.3	300.0	307.7	312.0	314.1	
	Crops	Fertility	F at C	C x F		
SEm ±	1.3	1.1	2.2	1.7		
CD 5%	3.5	2.9	5.7	4.6		
			Flowering stage			
Fallow	401.1	450.4	480.7	487.2	493.1	462.5
Greengram	448.7	557.2	586.9	592.8	595.7	556.3
Sunnhemp	481.8	582.3	604.7	611.8	616.8	579.5
Cowpea	502.5	594.9	619.2	629.4	634.2	595.1
Mean	458.5	546.2	572.9	580.3	584.2	
	Crops	Fertility	F at C	C x F		
SEm ±	1.2	1.2	2.0	2.2		
CD 5%	3.3	3.2	5.3	6.1		
			Maturity stage			
Fallow	431.1	490.5	535.5	544.1	549.7	510.2
Greengram	486.5	597.6	643.5	650.7	656.9	607.1
Sunnhemp	520.7	631.7	656.5	664.2	669.5	628.5
Cowpea	543.4	648.5	674.7	683.1	688.2	647.6
Mean	495.4	592.1	625.5	635.5	641.1	
	Crops	Fertility	F at C	C x F		
SEm ±	2.3	2.4	3.4	3.7		
CD 5%	6.2	6.4	9.2	10.0		

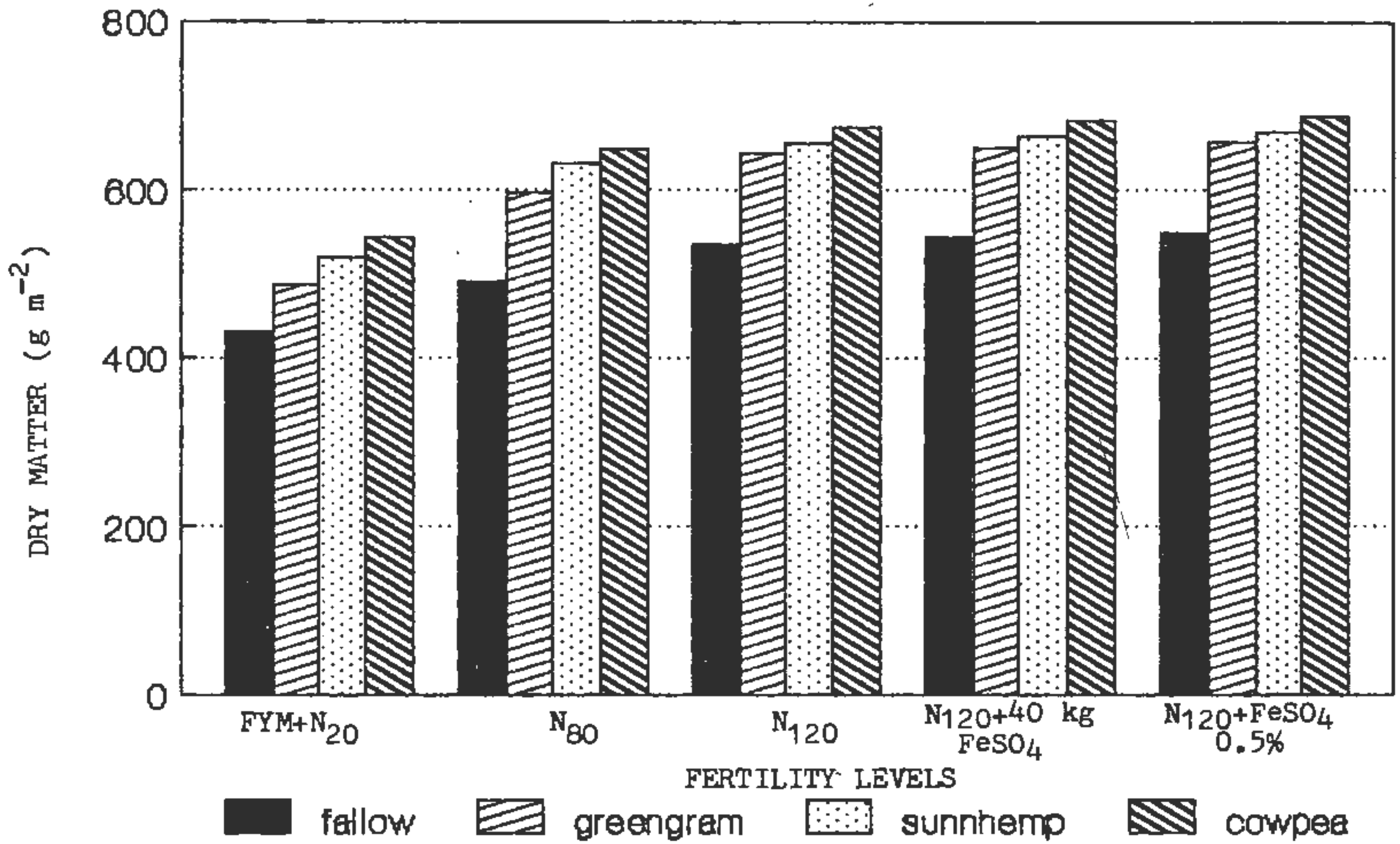


Fig. 4. Dry matter as influenced by preceding crops and fertility levels at maturity.

than that of lower N levels at all stages of crop growth.

At seedling stage and active tillering-stage soil application of iron recorded significantly more dry matter production compared to no iron application. Foliar application of iron recorded significantly higher dry matter production compared to soil application at flowering stage. At maturity stage iron application either to soil or to foliage produced more dry matter at the same level of 120 kg N ha^{-1}.

With regard to interaction highest dry matter production was obtained with combination of cowpea incorporation and application of 120 kg N ha^{-1} + 40 kg $FeSO_4$ ha^{-1} to soil at seedling and active tillering stages. The dry matter obtained with cowpea incorporation combined with farmers level of N management was more than the dry matter obtained with 120 kg N ha^{-1} in fallowed plots. At panicle-initiation, flowering and maturity stages foliar application of iron along with 120 kg N ha^{-1} after cowpea incorporation resulted in highest dry-matter production.

4.3.5 Crop Growth Rate (CGR)

Significant differences in CGR due to different preceding crops and fertility levels were observed at all stages of crop growth (Table 16 and 17). The CGR recorded at seedling stage (sowing to seedling stage) revealed that maximum CGR was recorded with cowpea incorporation. Application of 120 kg N ha^{-1} + 40 kg $FeSO_4$ ha^{-1} recorded higher CGR than application of 120 kg N ha^{-1} alone. With regard to interaction at farmers level of N management incorporation of cowpea recorded significantly higher, CGR compared to all other crops and fallow. Maximum CGR (3.90 g m^{-2} day^{-1}) was recorded with cowpea incorporation in combination with 120 kg N ha^{-1} + 40 kg $FeSO_4$ ha^{-1}.

During seedling to active-tillering stage CGR was more (3.92 g m^{-2} day^{-1}) with cowpea incorporation which was superior to all other crops and fallow. CGR recorded with sunnhemp incorporation was 3.78 g m^{-2} day^{-1} while, it was 2.80 g m^{-2} day^{-1} after fallow. Among the fertility levels, CGR was more (3.84 g $m^{-2}$$day^{-1}$) with 120 kg N ha^{-1} + foliar application of $FeSO_4$ @ 0.5 per cent. Highest CGR (4.24 g m^{-2} day^{-1}) was observed with combination of cowpea incorpo-

Table 16. Crop growth rate (g m^{-2} day^{-1}) as influenced by preceding crops and fertility levels during vegetative stage.

Preceding crops	Fertility levels $FYM+N_{20}$	N_{80}	N_{120}	N_{120} + ($FeSO_4$) (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
			Sowing to seedling stage			
Fallow	2.08	2.43	2.71	2.92	2.70	2.57
Greengram	2.79	3.11	3.68	3.76	3.70	3.41
Sunnhemp	3.14	3.62	3.82	3.85	3.81	3.65
Cowpea	3.25	3.70	3.87	3.90	3.88	3.72
Mean	2.81	3.22	3.52	3.61	3.52	
	Crops	Fertility	F at C	C x F		
SEm ±	0.001	0.011	0.021	0.021		
CD 5%	0.03	0.03	0.06	0.06		
			Seedling to active-tillering stage			
Fallow	2.26	2.75	2.95	2.97	3.09	2.80
Greengram	2.96	3.42	3.74	3.82	3.92	3.57
Sunnhemp	3.26	3.69	3.90	3.95	4.10	3.78
Cowpea	3.36	3.80	4.09	4.13	4.24	3.92
Mean	2.96	3.42	3.67	3.72	3.84	
	Crops	Fertility	F at C	C x F		
SEm ±	.03	.02	.04	.05		
CD 5%	.09	.06	NS	NS		

ration and 120 kg N ha^{-1} + foliar application of $FeSO_4$ @ 0.5 per cent. The CGR was 3.09 g m^{-2} day^{-1} with 120 kg N ha^{-1} + foliar application of $FeSO_4$ @ 0.5 per cent, when rice was grown after fallow. The CGR recorded with cowpea incorporation along with farmers level of N management was more than the CGR recorded with 120 kg N ha^{-1} in fallowed plots.

during active-tillering to panicle-initiation stage, higher CGR (8.19 g m^{-2} day^{-1}) was recorded with cowpea incorporation. Application of 120 kg N ha^{-1} resulted in higher CGR than all other N levels. A combination of 120 kg N ha^{-1} and foliar application of iron recorded higher CGR compared to application of 120 kg N ha^{-1} alone. With regard to interaction, cowpea incorporation along with 120 kg N ha^{-1} gave higher CGR compared to all other combinations. The CGR recorded with 120 kg N ha^{-1} when rice was grown after fallow was similar to that obtained with cowpea incorporation even at farmers level of N management.

The CGR of rice during panicle-initiation to flowering stage, was significantly influenced by preceding crops and fertility levels. The CGR recorded with cowpea incorpo-

Table 17. Crop growth rate (g m^{-2} day^{-1}) as influenced by preceding crops and fertility levels during reproductive stage

Preceding crops	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
	Active tillering to panicle-initiation stage					
Fallow	5.77	6.47	6.78	6.91	6.97	6.58
Greengram	6.80	7.62	8.12	8.18	8.58	7.86
Sunnhemp	6.88	8.04	8.31	8.38	8.44	8.01
Cowpea	6.91	8.17	8.52	8.63	8.69	8.19
Mean	6.59	7.58	7.93	8.03	8.17	
	Crops	Fertility	F at C	C x F		
SEm ±	0.04	0.04	0.08	0.09		
CD 5%	0.13	0.12	0.24	0.26		
	Panicle initiation to flowering stage					
Fallow	6.65	7.00	7.48	7.56	7.68	7.27
Greengram	6.60	8.86	9.21	9.27	9.29	8.65
Sunnhemp	7.21	9.04	9.31	9.41	9.52	8.90
Cowpea	7.70	9.14	9.35	9.54	9.63	9.07
Mean	7.04	8.51	8.84	8.94	9.03	
	Crops	Fertility	F at C	C x F		
SEm ±	0.01	0.01	0.03	0.02		
CD 5%	0.02	0.04	0.08	0.05		
	Flowering to maturity stage					
Fallow	1.00	1.34	1.83	1.90	1.91	1.59
Greengram	1.26	1.35	1.89	1.93	2.04	1.69
Sunnhemp	1.30	1.64	2.07	2.11	2.14	1.85
Cowpea	1.36	1.89	2.18	2.19	2.23	1.97
Mean	1.23	1.56	1.99	2.03	2.08	
	Crops	Fertility	F at C	C x F		
SEm ±	0.02	0.01	0.03	0.04		
CD 5%	0.07	0.04	0.07	0.13		

ration was 9.07 g m^{-2} day^{-1} while it was 8.90 g m^{-2} day^{-1} with sunnhemp incorporation and 7.27 g m^{-2} day^{-1} after fallow. Higher CGR was obtained with 120 kg N ha^{-1} and foliar application of iron compared to all other fertility levels. With regard to interaction, cowpea incorporation followed by application of 120 kg N ha^{-1} and foliar application of iron gave highest CGR (9.63 g m^{-2} day^{-1}). The CGR recorded with cowpea incorporation followed by farmers level of N management was more than the CGR recorded with 120 kg N ha^{-1} after fallow.

CGR during (flowering to maturity stage was significantly high with cowpea incorporation than other crops and fallow. Combined application of 120 kg N ha^{-1} + foliar application of iron was resulted in higher CGR than other fertility levels. With regard to interaction cowpea incorporation incombination with 120 kg N ha^{-1} gave higher CGR than all other combinations. The CGR obtained with 120 kg N ha^{-1} + 40 kg $FeSO_4$ ha^{-1} after fallow was equal to that of cowpea incorporation followed by 80 kg N ha^{-1}.

4.3.6 Relative Growth Rate (RGR)

RGR was influenced by preceding crops and fertility levels during all the stages of crop growth (Table 18 and 19).

During active-tillering stage, the RGR of rice was more when grown after fallow compared to previous crops. Among the different fertility levels, 80 kg N ha^{-1} recorded highest RGR. With regard to interaction highest RGR (41.66 mg g^{-1} day^{-1}) was recorded with 120 kg N ha^{-1} + foliar application of iron after fallow compared to all other combinations.

The RGR of rice during active-tillering to panicle initiation stage was influenced by preceding crops and fertility levels (Table 18). Rice crop grown on fallow plots recorded higher RGR compared to different previous crop. Greengram haulm incorporation recorded higher RGR among the different crops. RGR obtained with farmers level of N management was significantly higher compared to all other N levels. With regard to interaction farmers level of N management after fallow recorded highest RGR (42.39 mg g^{-1} day^{-1})

Table 18. Relative growth rate (mg g^{-1} day^{-1}) as influenced by preceding crops and fertility levels during vegetative stage

Preceding crops	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (40 Kg)	Mean
	Seedling to Active-tillering stage					
Fallow	36.94	41.39	39.94	37.08	41.66	39.40
Greengram	36.01	40.16	35.11	34.96	36.09	36.47
Sunnhemp	35.62	36.52	36.74	36.80	37.84	36.70
Cowpea	35.95	37.72	39.63	39.14	39.65	38.42
Mean	36.13	38.95	37.86	36.99	38.81	
	Crops	Fertility	F at C	C x F		
SEm ±	0.26	0.25	0.49	0.56		
CD 5%	0.89	0.71	1.42	1.69		
	Active tillering to panicle initiation stage					
Fallow	42.39	38.62	37.67	37.75	37.83	38.85
Greengram	39.08	37.00	36.95	36.64	36.69	37.27
Sunnhemp	36.54	36.34	35.74	35.61	35.64	35.98
Cowpea	35.57	35.72	34.98	34.96	35.01	35.25
Mean	38.40	36.92	36.33	36.24	36.29	
	Crops	Fertility	F at C	C x F		
SEm ±	0.10	0.11	0.23	0.22		
CD 5%	0.34	0.33	0.65	0.65		

Table 19. Relative growth rate (mg g^{-1} day^{-1}) as influenced by preceding crops and fertility levels during reproductive stage

Preceding crops	Fertility levels					Mean
	FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 kg)	N_{120} + $FeSO_4$ (0.5%)	
	Panicle initiation to flowering stage					
Fallow	22.91	20.92	20.97	20.86	20.99	21.33
Greengram	19.42	21.61	21.20	21.11	21.01	20.87
Sunnhemp	19.87	20.89	20.67	20.65	20.72	20.56
Cowpea	20.53	20.59	20.12	20.21	20.27	20.34
Mean	20.68	21.00	20.74	20.71	20.75	
	Crops	Fertility	F at C	C x F		
SEm ±	0.01	0.04	0.09	0.05		
CD 5%	0.04	0.13	0.25	0.13		
	Flowring to Maturity stage					
Fallow	2.41	2.84	3.60	3.69	3.62	3.23
Greengram	2.70	2.34	3.07	3.11	3.27	2.90
Sunnhemp	2.59	2.71	2.74	2.74	2.73	2.70
Cowpea	2.68	2.88	2.86	2.73	2.69	2.77
Mean	2.59	2.69	3.07	3.07	3.08	
	Crops	Fertility	F at C	C x F		
SEm ±	0.04	0.03	0.05	0.08		
CD 5%	0.14	0.08	0.15	0.26		

among the different combinations. RGR of rice obtained with greengram haulm incorporation with 80 kg N ha^{-1} was equal to that obtained with greengram haulm incorporation along with 120 kg N ha^{-1}.

RGR during panicle-initiation to flowering stage was significantly influenced by preceding crops and fertility levels. RGR of rice grown after fallow was higher compared to different crops. Among the different fertility levels, 80 kg N ha^{-1} recorded higher RGR. With regard to interaction highest RGR (22.91 mg g^{-1} day^{-1}) was obtained with farmers level of N management after fallow.

During flowering to maturity stage higher RGR was recorded after fallow compared to different preceding crops. Among the different fertility levels, 120 kg N ha^{-1} recorded higher RGR than all other fertility levels. Highest RGR (3.69 mg g^{-1} day^{-1}) was obtained with 120 kg N ha^{-1} + 40 kg $FeSO_4$ ha^{-1} after fallow.

4.3.7 Chlorophyll content

Total chlorophyll content (mg g^{-1}) of rice estimated at flowering stage was influenced by preceding crops and

Table 20. Total chlorophyll content (mg g^{-1}) of rice at flowering stage as influenced by preceding crops and fertility levels*

Preceding crops	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
Fallow	0.6	0.8	1.1	1.1	1.5	1.0
Greengram	0.7	1.0	1.3	1.4	1.6	1.2
Sunnhemp	1.0	1.1	1.4	1.5	1.7	1.3
Cowpea	1.1	1.2	1.3	1.6	1.7	1.4
Mean	0.9	1.0	1.3	1.4	1.6	

*The data was not analysed statistically

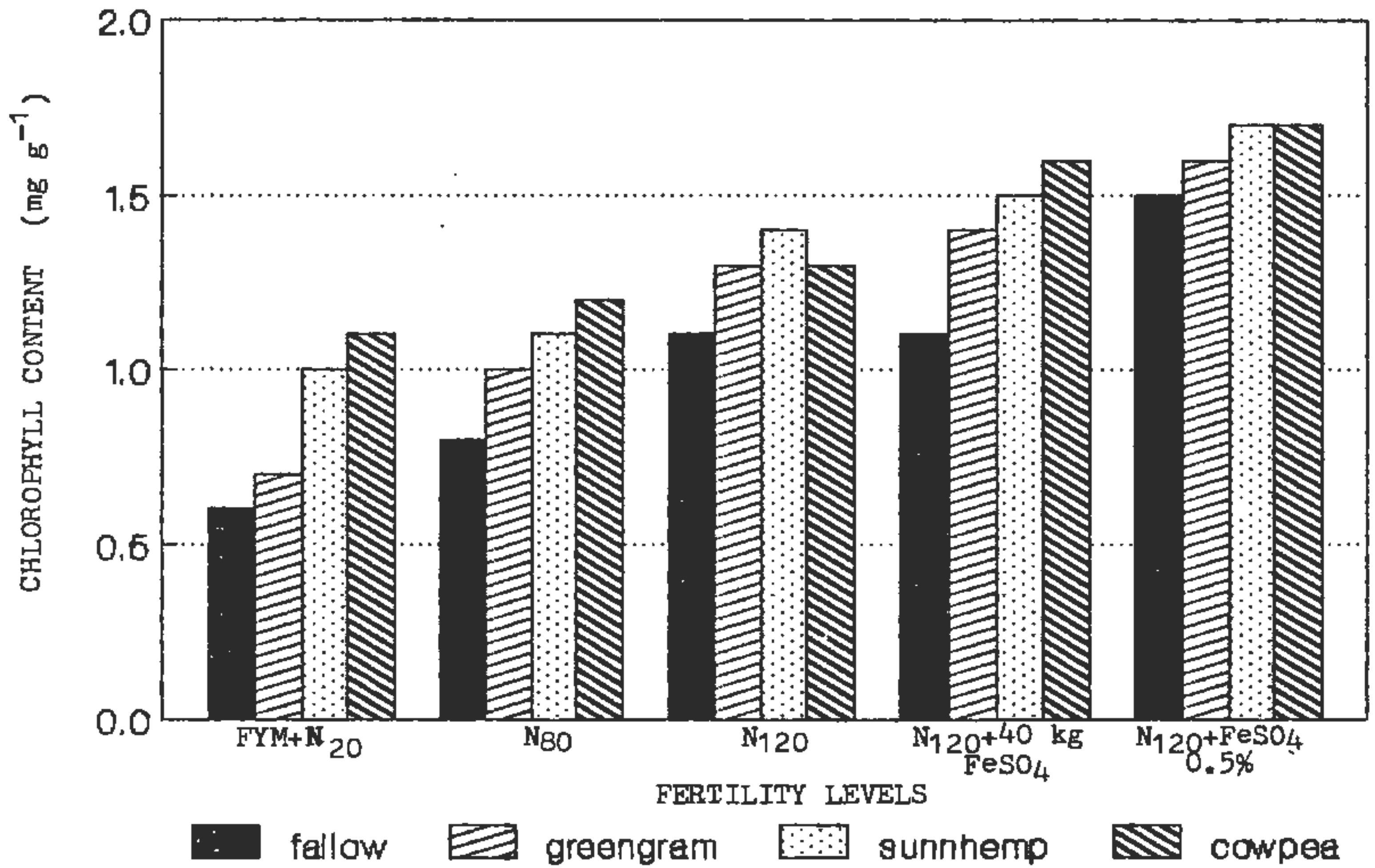


Fig.5. Chlorophyll content as influenced by preceding crops and fertility levels.

fertility levels (Table 20 and fig. 5). The chlorophyll content of rice with cowpea incorporation was 1.4 mg g^{-1} while with that of fallow was 1.0 mg g^{-1}. Farmers level of N management and 120 kg N ha^{-1} resulted in the chlorophyll contents of 0.9 mg g^{-1} and 1.3 mg g^{-1} respectively. The application of iron recorded more chlorophyll content than no iron application. The chlorophyll content of rice with foliar application of iron was 1.6 mg g^{-1} and with that of soil application was 1.4 mg g^{-1} at the same level of 120 kg N ha^{-1}.

4.3.8 Soil organic carbon

The data pertaining to soil organic carbon content (%) at 60 DAS as influenced by preceding crops and fertility levels were presented in Table 21. Incorporation of cowpea resulted in highest organic carbon content of soil among the different preceding crops and fallow. Soil organic carbon content with cowpea incorporation was 0.36 per cent while it was 0.30 per cent with fallow. Organic carbon content increased with increase in N level and it was maximum with 120 kg N ha^{-1}. The interaction between preceding crops and fertility levels was not significant.

Table 21. Soil organic carbon (%) as influenced by preceding crops and fertility levels at 60 DAS

Preceding crops	Fertility levels					
	FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
Fallow	0.29	0.30	0.31	0.30	0.31	0.30
Greengram	0.31	0.32	0.33	0.33	0.32	0.32
Sunnhemp	0.32	0.34	0.35	0.35	0.35	0.34
Cowpea	0.34	0.36	0.37	0.36	0.37	0.36
Mean	0.32	0.33	0.34	0.34	0.34	
	Crops	Fertility	F at C	C x F		
SEm ±	0.004	0.003	0.006	0.009		
CD 5%	0.01	0.01	NS	NS		

4.3.9 Nitrogen content and uptake at tillering stage

Cowpea incorporation resulted in higher N content than that obtained with rice when grown after other preceding crops and fallow (Table 22). Application of 120 kg N ha^{-1} resulted in higher N content compared to all other N levels. The interaction of preceding crops and fertility levels on N content of plants was non significant.

Different preceding crops and fertility levels significantly influenced the nitrogen uptake (Table 22). Incorporation of cowpea resulted in maximum N uptake (30.3 kg ha^{-1}) which was significantly higher than that obtained with other preceding crops and fallow. The N uptake with greengram haulm incorporation was 25.2 kg ha^{-1} and it was 17.3 kg ha^{-1} after fallow. Application of 120 kg N ha^{-1} gave higher uptake compared to all other N levels. Combined application of 120 kg N ha^{-1} and foliar application of iron recorded significantly higher nitrogen uptake than application of 120 kg N ha^{-1} alone. The interaction of preceding crops and fertility levels was not significant.

Table 22. Nitrogen content and uptake as influenced by preceding crops and fertility levels at tillering stage

Preceding crops	Fertility levels					Mean
	FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	
	N Content (%)					
Fallow	1.08	1.41	1.66	1.68	1.69	1.50
Greengram	1.38	1.66	1.92	1.93	1.94	1.77
Sunnhemp	1.42	1.74	1.94	1.94	1.95	1.80
Cowpea	1.46	1.81	1.99	2.00	2.09	1.87
Mean	1.34	1.66	1.88	1.89	1.92	
	Crops	Fertility	F at C	C x F		
SEm ±	0.022	0.025	0.050	0.048		
CD 5%	0.07	0.07	NS	NS		
	N uptake (Kg ha^{-1})					
Fallow	9.3	15.7	20.0	20.6	20.8	17.3
Greengram	15.8	23.1	28.5	29.2	29.5	25.2
Sunnhemp	18.2	26.2	30.9	31.3	31.7	27.6
Cowpea	19.5	28.5	33.5	34.1	35.9	30.3
Mean	15.7	23.4	28.2	28.8	29.5	
	Crops	Fertility	F at C	C x F		
SEm ±	0.4	0.4	0.8	0.8		
CD 5%	1.3	1.2	NS	NS		

Table 23. Nitrogen content and uptake as influenced by preceding crops and fertility levels at flowering stage

Preceding crops	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
	N Content (%)					
Fallow	0.53	0.73	0.75	0.75	0.76	0.70
Greengram	0.55	0.77	0.80	0.81	0.81	0.75
Sunnhemp	0.58	0.78	0.82	0.82	0.83	0.77
Cowpea	0.59	0.79	0.83	0.84	0.85	0.78
Mean	0.56	0.77	0.80	0.81	0.81	
	Crops	Fertility	F at C	C x F		
SEm ±	0.012	0.008	0.016	0.025		
CD 5%	NS	0.02	NS	NS		
	N uptake (Kg ha^{-1})					
Fallow	21.3	32.9	36.1	36.5	37.5	32.8
Greengram	24.7	42.9	47.0	48.1	48.2	42.2
Sunnhemp	27.9	45.4	49.6	50.2	51.2	44.9
Cowpea	29.7	47.0	51.4	52.9	53.9	47.0
Mean	25.9	42.1	46.0	46.9	47.7	
	Crops	Fertility	F at C	C x F		
SEm ±	0.7	0.4	0.9	1.4		
CD 5%	2.4	1.3	2.6	4.5		

4.3.10 Nitrogen content and uptake at flowering stage

The N content in the plants was significantly influenced by fertility levels but the interaction between preceding crops and fertility levels was found non-significant (Table 23). Higher N content in the plants (0.80 per cent) was observed with 120 kg N ha^{-1} which was superior to all other N levels.

Nitrogen uptake was more with cowpea incorporation (47.0 kg ha^{-1}) than that obtained by rice when grown after other crops and fallow (Table 23). Among the fertility levels, application of 120 kg N ha^{-1} along with foliar application of iron recorded maximum N uptake (47.7 kg ha^{-1}). Application of 120 kg N ha^{-1} along with foliar application of iron after incorporation of cowpea recorded highest N uptake (53.9 kg ha^{-1}) which was 43.7 per cent more over its application after fallow. At 120 kg N ha^{-1} level, N uptake after fallow was 36.1 kg ha^{-1} while it was 51.4 kg ha^{-1} after cowpea incorporation.

4.3.11 Amount of nitrogen in grain and straw

Cowpea incorporation recorded maximum amount of N in grain (54.3 kg ha^{-1}) which was significantly superior

Table 24. Amount of nitrogen (Kg ha^{-1}) in grain and straw as influenced by preceding crops and fertility levels.

Preceding crops	Fertility levels: FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
			Grain			
Fallow	35.6	42.8	46.5	47.0	47.1	43.8
Greengram	40.7	49.8	52.0	52.6	52.8	49.6
Sunnhemp	42.8	52.1	54.6	55.0	55.2	51.9
Cowpea	44.3	54.8	57.1	57.5	57.7	54.3
Mean	40.9	49.9	52.6	53.0	53.2	
	Crops	Fertility	F at C	C x F		
SEm ±	0.33	0.26	0.53	0.71		
CD 5%	1.2	0.7	NS	NS		
			Straw			
Fallow	14.3	18.4	18.9	19.0	19.1	17.9
Greengram	17.5	27.4	28.9	29.0	29.2	26.4
Sunnhemp	18.4	28.9	29.9	30.1	30.2	27.5
Cowpea	18.9	29.5	30.6	30.7	30.8	28.1
Mean	17.3	26.1	27.1	27.2	27.3	
	Crops	Fertility	F at C	C x F		
SEm ±	0.3	0.2	0.4	0.6		
CD 5%	1.0	0.5	1.0	1.9		

to that obtained with other preceding crops (Table 24). The amount of nitrogen recorded with sunnhemp incorporation was 51.9 kg ha^{-1} while it was 43.8 kg ha^{-1} after fallow. Application of 120 kg N ha^{-1} resulted in higher nitrogen in grain than all other N levels. Interaction of precedings crops and fertility levels was not significant.

The N content in straw was significantly influenced by preceding crops and fertility levels and their interaction (Table 24). Straw of rice grown after incorporation of cowpea had higher amount of N than grown after fallow. The amount of nitrogen in straw with cowpea incorporation was 28.1 kg ha^{-1} while it was 17.9 kg ha^{-1} after fallow. Among fertility levels, application of 120 kg N ha^{-1} resulted in higher nitrogen in straw compared to all other N levels.

4.3.12 Nitrogen uptake at harvest

The total N uptake at harvest was significantly influenced by preceding crops and fertility levels and their interaction (Table 25 and fig.6). Cowpea incorporation recorded maximum N uptake (82.4 kg ha^{-1}) which was superior to that obtained with other preceding crops.

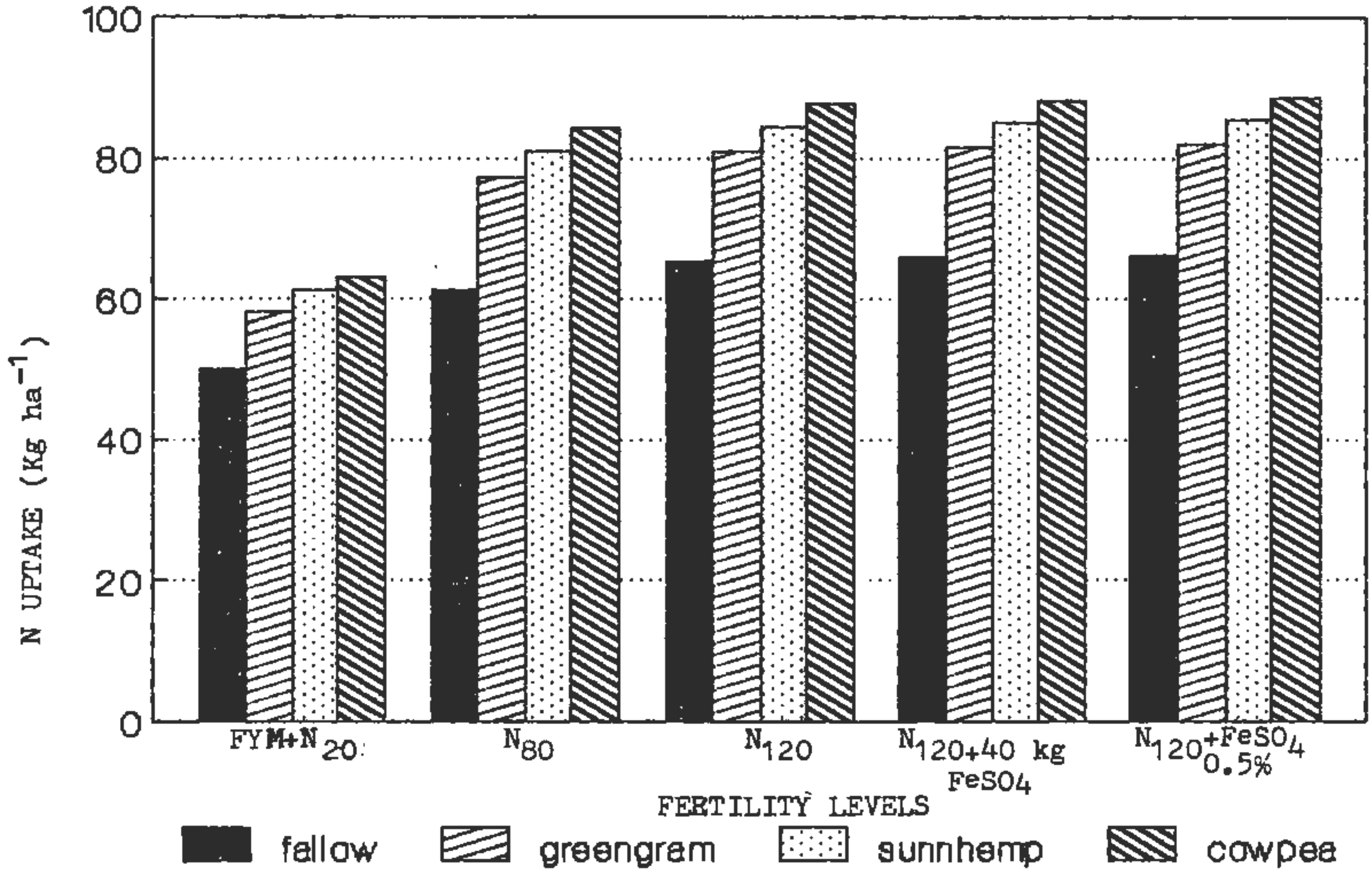


Fig.6. N uptake at harvest as influenced by preceding crops and fertility levels.

Application of 120 kg N ha^{-1} resulted in higher N uptake compared to other N levels. With regard to interaction, highest N uptake (88.5 kg N ha^{-1}) was obtained with the combination of cowpea incorporation and 120 kg N ha^{-1} along with foliar application of iron. The N uptake with combination of cowpea incorporation and 80 kg N ha^{-1} was equivalent with that obtained with the combination of sunnhemp incorporation and 120 kg N ha^{-1}.

4.3.13 Available soil nitrogen

The available soil nitrogen was significantly influenced by preceding crops and fertility levels (Table 25 and fig.7). Incorporation of cowpea and sunnhemp resulted in similar available soil nitrogen but significantly higher than greengram and fallow. The available soil nitrogen after greengram haulm incorporation was 119 kg ha^{-1} while it was 101 kg ha^{-1} after fallow. Among different N levels application of 120 kg N ha^{-1} recorded higher available soil nitrogen compared to other N levels. The interaction of preceding crops and fertility levels was found non-significant.

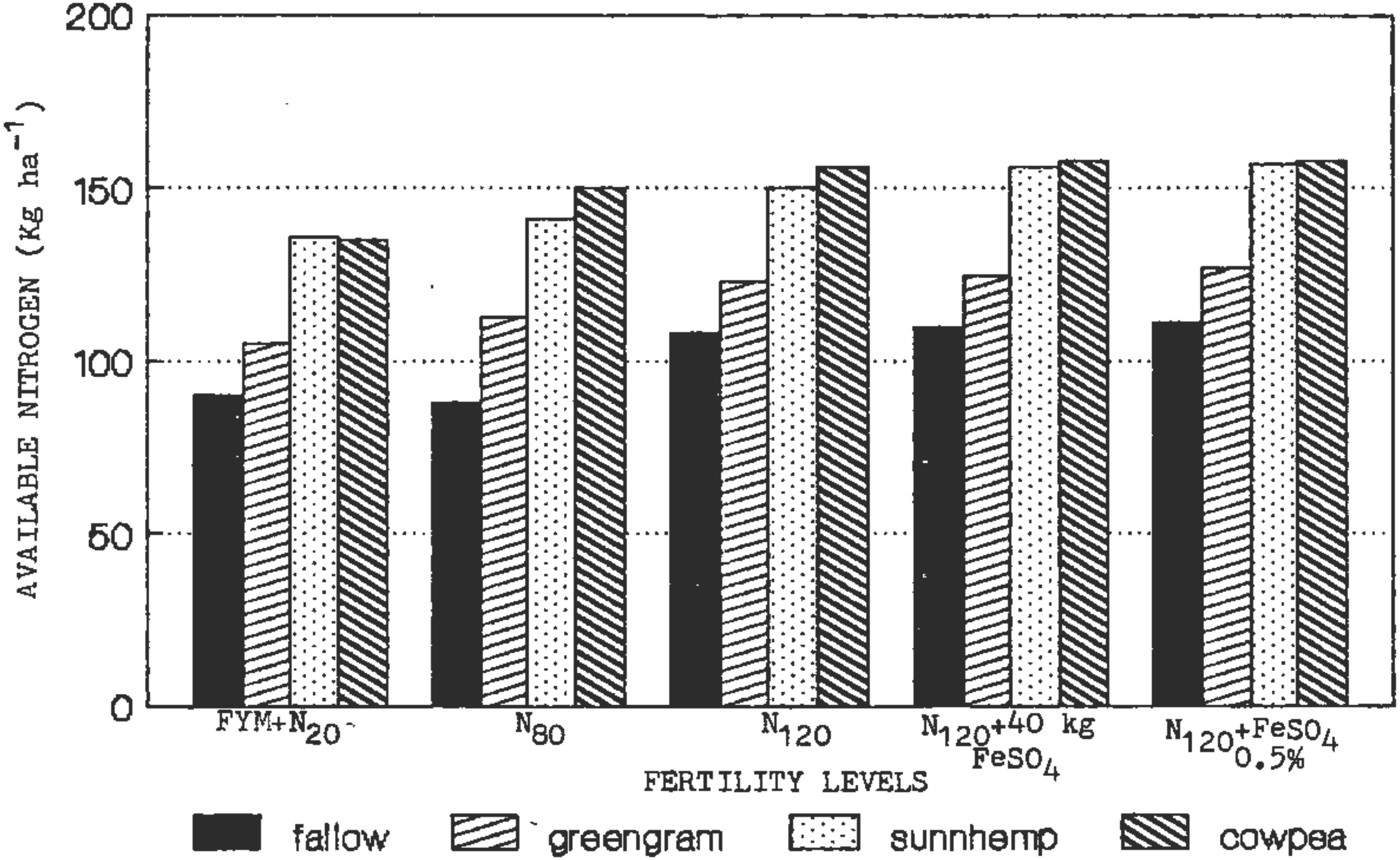


Fig.7. Available nitrogen in soil as influenced by preceding crops and fertility levels

Table 26. Nitrogen use efficiency (Kg grain Kg N^{-1}) as influenced by preceding crops and fertility levels

Preceding crops	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
Fallow	23.07	26.00	18.37	18.63	18.77	20.97
Greengram	30.70	34.00	23.23	23.43	23.87	27.05
Sunnhemp	34.23	36.87	25.07	25.27	25.43	29.37
Cowpea	36.97	39.00	26.20	26.40	26.53	31.02
Mean	31.24	33.97	23.22	23.43	23.65	
	Crops	Fertility	F at C	C x C		
SEm ±	0.16	0.12	0.25	0.33		
CD 5%	0.54	0.35	0.71	1.01		

4.3.14 Nitrogen-use effeciency

Nitrogen-use efficiency was significantly influenced by preceding crops, fertility levels and their interaction (Table 26). Incorporation of cowpea recorded higher nitrogen-use efficiency (31.02 kg grain kg N^{-1}) in rice which was superior to rice grown after all other preceding crops. The nitrogen-use efficieny with greengram haulm incorporation was 27.05 kg grain kg N^{-1} while it was 20.97 kg grain kg N^{-1} after fallow. Nitrogen use efficiency of rice was high (33.97 kg grain kg N^{-1}) with 80 kg N ha^{-1} and low with other fertility levels. Highest nitrogen-use efficiency was observed with the combination of cowpea incorporation and 80 kg N ha^{-1}. The nitrogen use efficiency recorded at 120 kg N ha^{-1} after fallow was lowest (18.37 kg grain kg N^{-1}), compared to all other treatments.

4.3.15 Amount of phosphorus in grain and straw

The amount of phosphorus in grain was influenced by fertility levels only (Table 27). Application of 120 kg N ha^{-1} gave higher phosphorus amount (12.8 kg P_2O_5

Table 27. Amount of phosphorus (P_2O_5 Kg ha^{-1}) in grain and straw as influenced by preceding crops and fertility levels

Preceding crops	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
			Grain			
Fallow	9.5	10.8	11.6	11.3	11.1	10.9
Greengram	10.0	11.7	12.4	12.2	12.1	11.7
Sunnhemp	10.7	12.6	13.4	13.1	12.9	12.5
Cowpea	11.2	12.7	13.6	13.1	13.2	12.8
Mean	10.4	12.0	12.8	12.4	12.3	
	Crops	Fertility	F at C	C x F		
SEm ±	0.3	0.2	0.5	0.6		
CD 5%	NS	0.7	NS	NS		
			Straw			
Fallow	4.2	4.8	5.0	4.9	4.9	4.8
Greengram	4.7	5.1	5.3	5.2	5.1	5.1
Sunnhemp	5.1	5.5	5.8	5.7	5.5	5.5
Cowpea	5.4	5.7	5.9	5.7	5.6	5.7
Mean	4.9	5.3	5.5	5.4	5.3	
	Crops	Fertility	F at C	C x F		
SEm ±	0.2	0.2	0.3	0.5		
	NS	NS	NS	NS		

Table 28. Phosphorus uptake (P_2O_5 Kg ha^{-1}) as influenced by preceding crops and fertility levels

Preceding crops	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
Fallow	13.7	14.9	16.6	16.2	16.0	15.5
Greengram	14.7	16.8	17.8	17.4	17.2	16.8
Sunnhemp	15.8	18.1	19.2	18.8	18.4	18.1
Cowpea	16.7	18.4	19.5	18.8	18.8	18.4
Mean	15.2	17.1	18.3	17.8	17.6	

	Crops	Fertility	F at C	C x F
SEm ±	0.5	0.3	0.6	1.0
CD 5%	NS	0.9	NS	NS

ha^{-1}) in grain which was significantly higher than all other N levels. The amount of phosphorus present in straw was not influenced by preceding crops, fertility levels and their interaction (Table 28).

4.3.16 Phosphorus uptake at harvest

Phosphorus uptake at harvest was influenced only by fertility levels (Table 28). Application of 120 kg N ha^{-1} recorded higher phosphorus uptake compared to other N levels. Application of iron reduced the phosphorus uptake compared to no iron application.

4.3.17 Amount of potassium in grain and straw

Incorporation of cowpea and sunnhemp recorded higher amount of potassium in grain which was significantly higher than that obtained when rice was grown after greengram and fallow (Table 29). Application of 120 kg N ha^{-1} recorded higher amount of potassium compared to other N levels. The interaction was found non-significant.

The amount of potassium in straw was significantly influenced by preceding crops, fertility levels and their

Table 29. Amount of Potassium (K_2O Kg ha^{-1}) in grain and straw as influenced by preceding crops and fertility levels

Preceding crops	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
			Grain			
Fallow	8.9	12.3	13.4	13.9	14.1	12.5
Greengram	12.6	15.3	17.1	17.3	17.4	15.9
Sunnhemp	13.5	16.7	18.2	18.5	18.7	17.1
Cowpea	14.4	17.2	18.4	18.7	18.9	17.5
Mean	12.4	15.4	16.8	17.1	17.3	
	Crops	Fertility	F at C	C x F		
SEm ±	0.3	0.2	0.3	0.5		
CD 5%	0.9	0.5	NS	NS		
			Straw			
Fallow	52.8	60.5	65.3	66.1	66.4	62.2
Greengram	55.9	69.4	73.1	75.1	75.6	69.8
Sunnhemp	56.8	71.9	75.5	76.1	76.4	71.3
Cowpea	58.8	75.4	82.2	84.5	85.1	77.2
Mean	56.1	69.3	74.0	75.5	75.9	
	Crops	Fertility	F at C	C x F		
SEm ±	0.3	0.2	0.4	0.6		
CD 5%	1.0	0.6	1.2	1.8		

interaction (Table 29). Cowpea incorporation recorded higher potassium amount in straw (77.2 kg ha^{-1}) than that obtained when rice was grown after other crops. Among the fertility levels application of 120 kg N ha^{-1} along with foliar application of iron gave higher potassium content in straw compared to 120 kg N ha^{-1} alone. Cowpea incorporation in combination with 120 kg N ha^{-1} and soil application of iron resulted in higher potassium amount (84.5 kg ha^{-1}) which was significantly superior to all other treatment combinations.

4.3.18 Potassium uptake at harvest

Potassium uptake at harvest was significantly influenced by preceding crops and fertility levels (Table 30). Growing of rice after cowpea recorded maximum potassium uptake (94.7 kg K_2O ha^{-1}) which was significantly higher compared to its growing after other preceding crops. Application of 120 kg N ha^{-1} resulted in higher potassium uptake (90.8 kg K_2O ha^{-1}) which was superior to all other N levels. The interaction between preceding crops and fertility levels was not significant.

Table 30. Potassium uptake (Kg ha^{-1}) as influenced by preceding crops and fertility levels at harvest

Preceding crops	Fertility levels					Mean
	$FYM+N_{20}$	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	
Fallow	61.7	72.8	78.7	80.0	80.5	74.7
Greengram	68.5	84.7	90.2	92.4	93.0	85.8
Sunnhemp	70.3	88.6	93.7	94.6	95.1	88.5
Cowpea	73.2	92.6	100.6	103.2	104.0	94.7
Mean	68.4	84.7	90.8	92.6	93.2	

	Crops	Fertility	F at C	C x F
SEm ±	0.8	1.1	2.3	1.8
CD 5%	2.6	3.2	NS	NS

4.3.19 Iron concentration at tillering stage

Total iron concentration (ppm) of whole plant was significantly influenced by preceding crops, fertility levels and their interaction (Table 31). Plants grown after fallow recorded higher (678 ppm) iron content than those grown after different preceding crops. Among the fertility levels, farmers level of N management resulted in higher iron concentration in plants than all other fertility levels. Chlorotic plants had higher iron content that non-chlorotic plants. With regard to interaction combination of greengram haulm incorporation and farmers level of N management recorded highest iron concentration than all other combinations. Farmers levels of N management recorded higher iron concentration irrespective of the previous crops.

4.3.20 Iron concentration at flowering stage

Rice crop grown after fallow recorded higher total iron concentration (ppm) than that rice grown after different preceding crops (Table 32). Iron content was higher at tillering stage than that recorded at flowering stage.

Table 31. Total iron concentration (ppm) of whole plant as influenced by preceding crops and fertility levels at tillering stage

Preceding crops	Fertility levels: $FYM+N_{20}$	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
Fallow	731	718	740	591	609	678
Greengram	743	721	735	492	485	635
Sunnhemp	650	631	618	482	461	568
Cowpea	731	702	640	503	482	612
Mean	714	693	683	517	509	

	Crops	Fertility	F at C	CxF
SEm ±	3	3	7	6
CD 5%	10	10	19	19

Table 32. Total iron concentration (ppm) of whole plant as influenced by preceding crops and fertility levels at flowering stage

Preceding crops	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
Fallow	531	342	331	332	231	351
Greengram	561	223	232	201	183	280
Sunnhemp	332	281	262	231	211	263
Cowpea	570	323	252	233	205	317
Mean	499	292	269	247	208	
	Crops	Fertility	F at C	C x F		
SEm ±	1	2	4	2		
CD 5%	3	5	11	7		

Farmer level of N management resulted in higher iron concentration than all other fertility levels. Application of iron recorded less iron concentration than that with no iron application. With regard to interaction, cowpea incorporation with farmers level of N management resulted in highest (570 ppm) iron concentration in rice plant than all other combinations.

4.3.21 Soil available iron

The soil available iron (DTPA extractable) content estimated after harvest of rice was significantly influenced by preceding crops, fertility levels and their interaction (Table 33 and fig.8). The soil available iron content with cowpea incorporation was 22.4 ppm where as, with that of fallow was 8.9 ppm. Different levels of nitrogen did not differ the soil available iron content. At the same level of 120 kg N ha^{-1} soil and foliar application of iron resulted in iron contents of 24.3 ppm and 16.6 ppm respectively. With regard to interaction cowpea incorporation along with soil application of iron at 120 kg N ha^{-1} gave highest (31.5 ppm) soil available iron content.

Table 33. Soil available iron (ppm) as influenced by preceding crops and fertility levels at harvest

Preceding crops	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
Fallow	8.0	8.5	8.7	10.2	9.1	8.9
Greengram	16.2	16.8	17.3	26.3	17.4	18.8
Sunnhemp	18.4	18.5	19.0	29.2	19.4	20.9
Cowpea	19.5	20.1	20.3	31.5	20.5	22.4
Mean	15.5	16.0	16.3	24.3	16.6	
	Crops	Fertility	F at C	c x F		
SEm ±	0.9	0.4	0.7	1.9		
CD 5%	3.2	1.0	2.1	6.1		

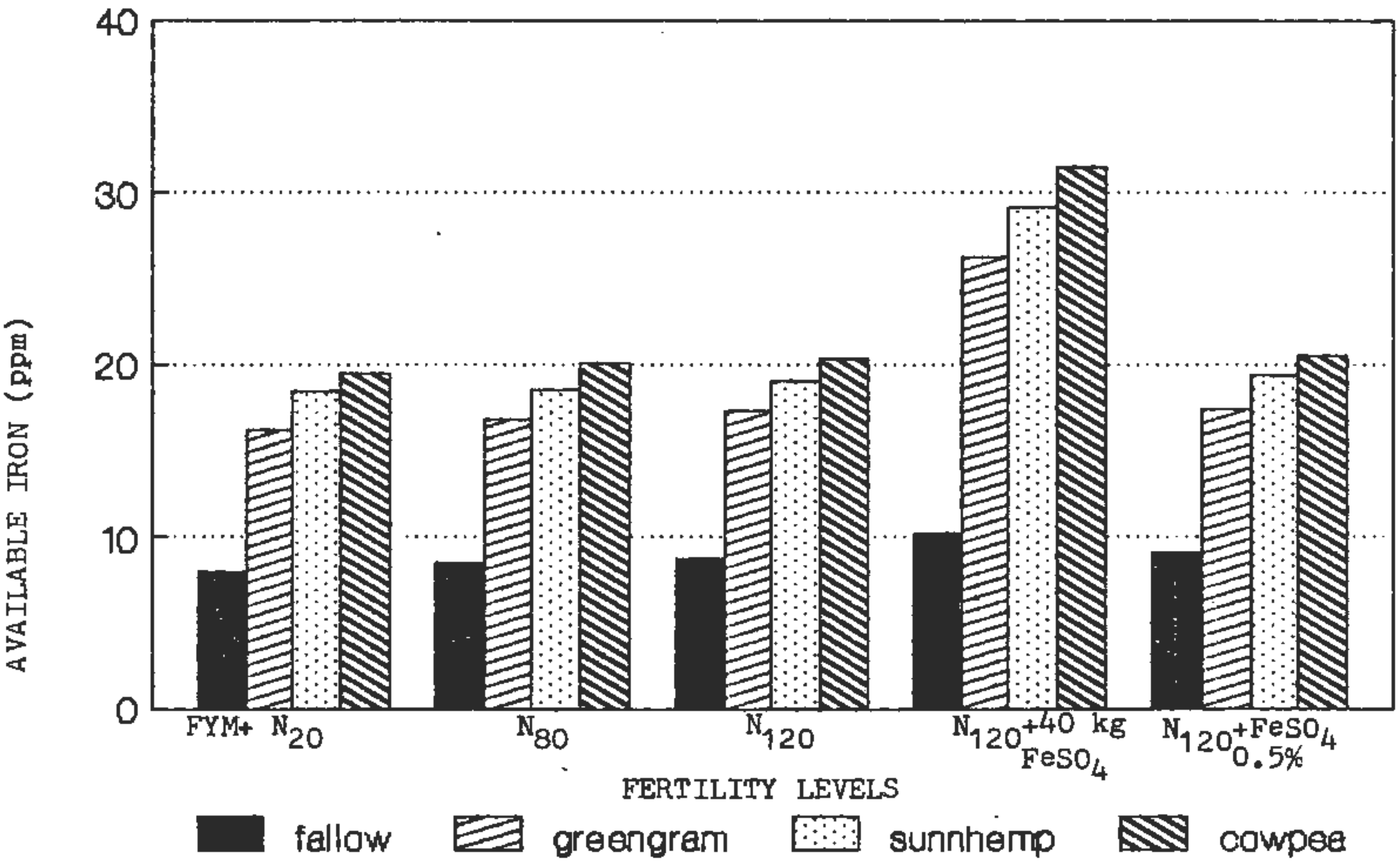


Fig.8. Available iron in soil as influenced by preceding crops and fertility levels

4.3.22 Yield attributes

The panicle number m^{-2} was maximum (309) with cowpea incorporation which was superior to succeeding effect of all other crops and fallow in producing number of panicles. The panicles produced with sunnhemp incorporation was 300 while it was 275 after fallow (Table 34 and fig.9). Application of 120 kg N ha^{-1} with foliar application of iron produced more number of panicles (308) than all other fertility levels. Application of 80 kg N ha^{-1} produced significantly higher number of panicles compared to farmers level of N management. With regard to interaction, combination of cowpea incorporation and 120 kg N ha^{-1} with foliar application of iron produced maximum number of panicles (323).

Number of filled grains $panicle^{-1}$ were significantly influenced by preceding crops and fertility levels (Table 34 and fig. 10). Higher number of filled grains were recorded when rioe was grown after cowpea incoporation than that obtained when it was grown after greengram or fallow. The number of filled grains $panicle^{-1}$ was 58.9 after sunnhemp incorporation and 48.7 after fallow. Application of 120 kg

Table 34. Yield attributes as influenced by preceding crops and fertility levels

Preceding crops	Fertility levels: FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
			Panicles (number m^{-2})			
Fallow	249	267	282	286	291	275
Greengram	265	285	290	296	302	288
Sunnhemp	273	297	305	308	315	300
Cowpea	286	305	311	318	323	309
Mean	268	289	297	302	308	
	Crops	Fertility	F at C	C x F		
SEm ±	0.5	0.6	1.2	1.1		
CD 5%	1.7	1.7	3.5	3.4		
			Filled grains (number $panicle^{-1}$)			
Fallow	41.5	48.3	50.6	51.3	51.7	48.7
Greengram	46.5	53.3	55.4	55.9	56.5	53.5
Sunnhemp	49.4	58.4	61.6	62.2	62.8	58.9
Cowpea	52.2	62.3	64.4	64.9	65.5	61.9
Mean	47.4	55.6	58.0	58.6	59.1	
	Crops	Fertility	F at C	C x F		
SEm ±	0.9	0.2	0.4	1.7		
CD 5%	3.0	0.5	1.0	5.8		

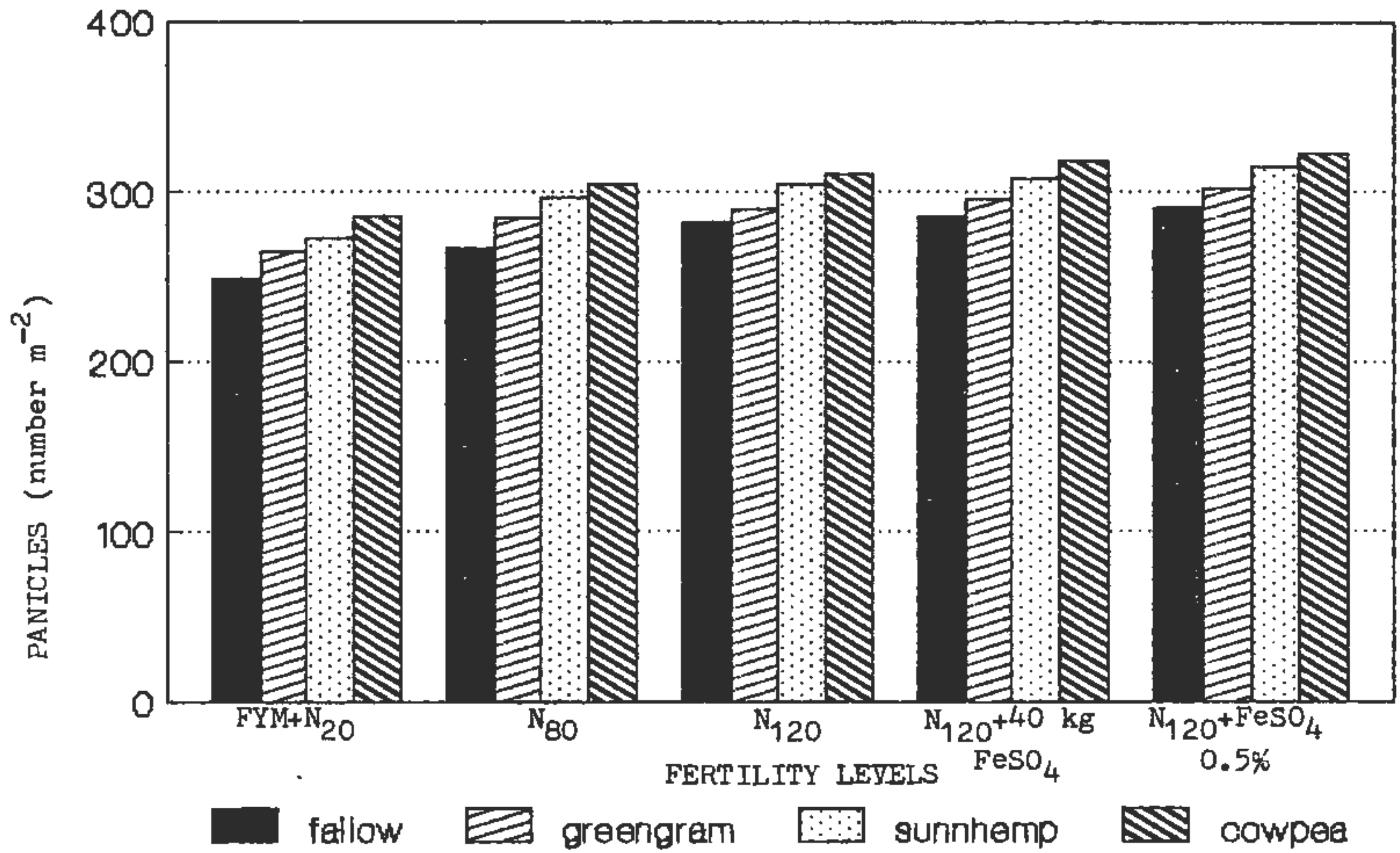


Fig.9. Number of panicles as influenced by preceding crops and fertility levels

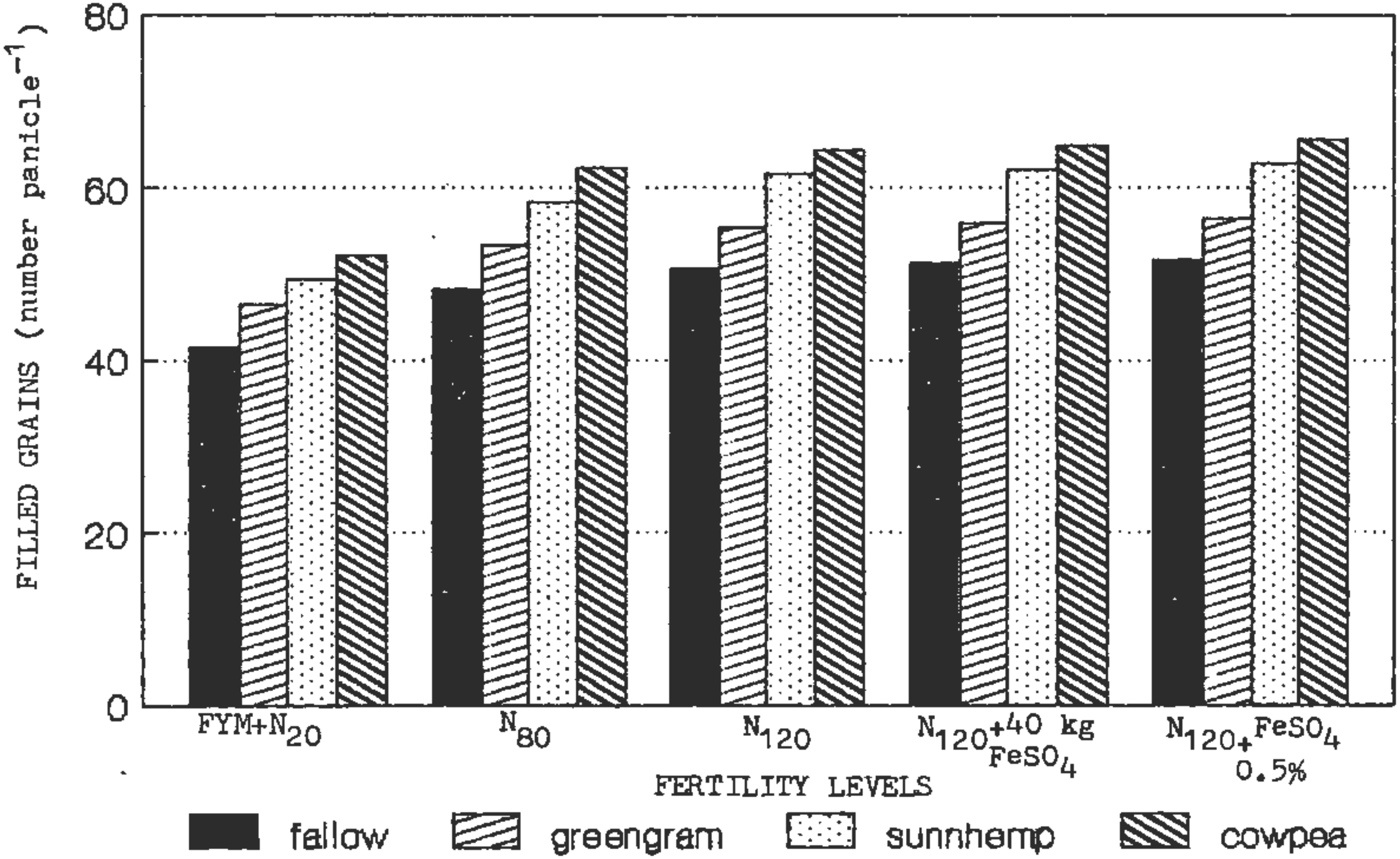


Fig.10. Number of filled grains as influenced by preceding crops and fertility levels

N ha^{-1} along with application of iron either to soil or to foliage resulted in more number of filled grains compared to all other fertility levels. With regard to interaction highest number of filled grains $panicle^{-1}$ were recorded with a combination of cowpea incorporation with 120 kg N ha^{-1} and foliar application of iron compared to all other combinations. The number of filled grains obtained with 120 kg ha^{-1} after fallow was on par with the cowpea incorporation followed by farmers levels of N management.

The data on sterility percentage as influenced by preceding crops and fertility levels was presented in table 35. Among the different preceding crops cowpea incorporation resulted in higher sterility percentage compared to all other crops. Application of 120 kg N ha^{-1} resulted in significantly higher sterility percentage than 80 kg N ha^{-1} and farmers level of N management.

The 1000 grain weight was not influenced by preceding crops (Table 35). Among the different fertility levels application of 120 kg N ha^{-1} along with soil application of iron resulted in higher 1000 grain weight. The 1000 grain weight obtained with 120 kg N ha^{-1} was on par with

Table 35. Yield attributes as influenced by preceding crops and fertility levels

Preceding crops	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
	Sterility percentage					
Fallow	14.20	16.30	17.90	18.00	18.10	16.90
Greengram	15.30	16.80	18.40	18.30	18.40	17.44
Sunnhemp	15.90	17.10	19.00	19.10	19.00	18.02
Cowpea	16.30	18.10	19.40	19.30	19.40	18.50
Mean	15.43	17.08	18.68	18.68	18.73	
	Crops	Fertility	F at C	C x F		
SEm ±	0.13	0.11	0.22	0.28		
CD 5%	0.45	0.32	NS	NS		
	Thousand grain weight (g)					
Fallow	19.13	20.42	20.51	20.93	21.43	20.48
Greengram	19.18	19.55	20.14	20.91	21.28	20.21
Sunnhemp	19.49	20.45	20.74	21.46	21.47	20.72
Cowpea	19.50	20.00	20.71	21.27	21.16	20.53
Mean	19.32	20.11	20.53	21.14	21.16	
	Crops	Fertility	F at C	C x F		
SEm ±	0.23	0.17	0.33	0.48		
CD 5%	NS	0.48	NS	NS		

that obtained with 80 kg N ha^{-1}. The interaction of preceding crops and fertility levels on thousand grain weight was non-significant.

4.3.23 Yield

Grain and straw yield was significantly influenced by preceding crops and fertility levels (Table 36 and fig.11). The rice crop grown after cowpea incorporation gave higher grain yield (3 035 kg ha^{-1}) compared to its yields after other crops and fallow. Rice crop grown after cowpea gave 46.1 per cent more grain yield than that obtained after fallow. Among the fertility levels, application of 120 kg N ha^{-1} produced a grain yield of 2710 kg ha^{-1} which was significantly higher than that obtained with lower levels of N. The grain yield of rice was not influenced by iron either to soil or to foliage at 120 kg N ha^{-1}.

With regard to interaction, combination of cowpea incorporation and application of 120 kg N ha^{-1} along with foliar application of iron produced highest grain yield (3 183 kg ha^{-1}). At farmers level of N management cowpea incorporation gave maximum grain yield (2 587 kg ha^{-1})

Table 36. Grain and straw yield as influenced by preceding crops and fertility levels

Preceding crops	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
	Grain Yield (Kg ha^{-1})					
Fallow	1 614	2 080	2 203	2 235	2 252	2 077
Greengram	2 149	2 718	2 790	2 814	2 861	2 666
Sunnhemp	2 398	2 949	3 008	3 033	3 051	2 888
Cowpea	2 587	3 093	3 143	3 168	3 183	3 035
Mean	2 187	2 710	2 786	2 813	2 837	
	Crops	Fertility	F at C	C x F		
SEm ±	15	11	22	31		
CD 5%	50	32	63	94		
	Straw yield (Kg ha^{-1})					
Fallow	2 073	2 667	2 821	2 854	3 062	2 695
Greengram	2 632	3 368	3 566	3 677	3 763	3 401
Sunnhemp	2 770	3 609	3 732	3 840	3 972	3 651
Cowpea	3 053	3 862	4 065	4 195	4 217	3 878
Mean	2 716	3 377	3 546	3 642	3 754	
	Crops	Fertility	F at C	C x F		
SEm ±	30	39	77	70		
CD 5%	105	111	221	207		

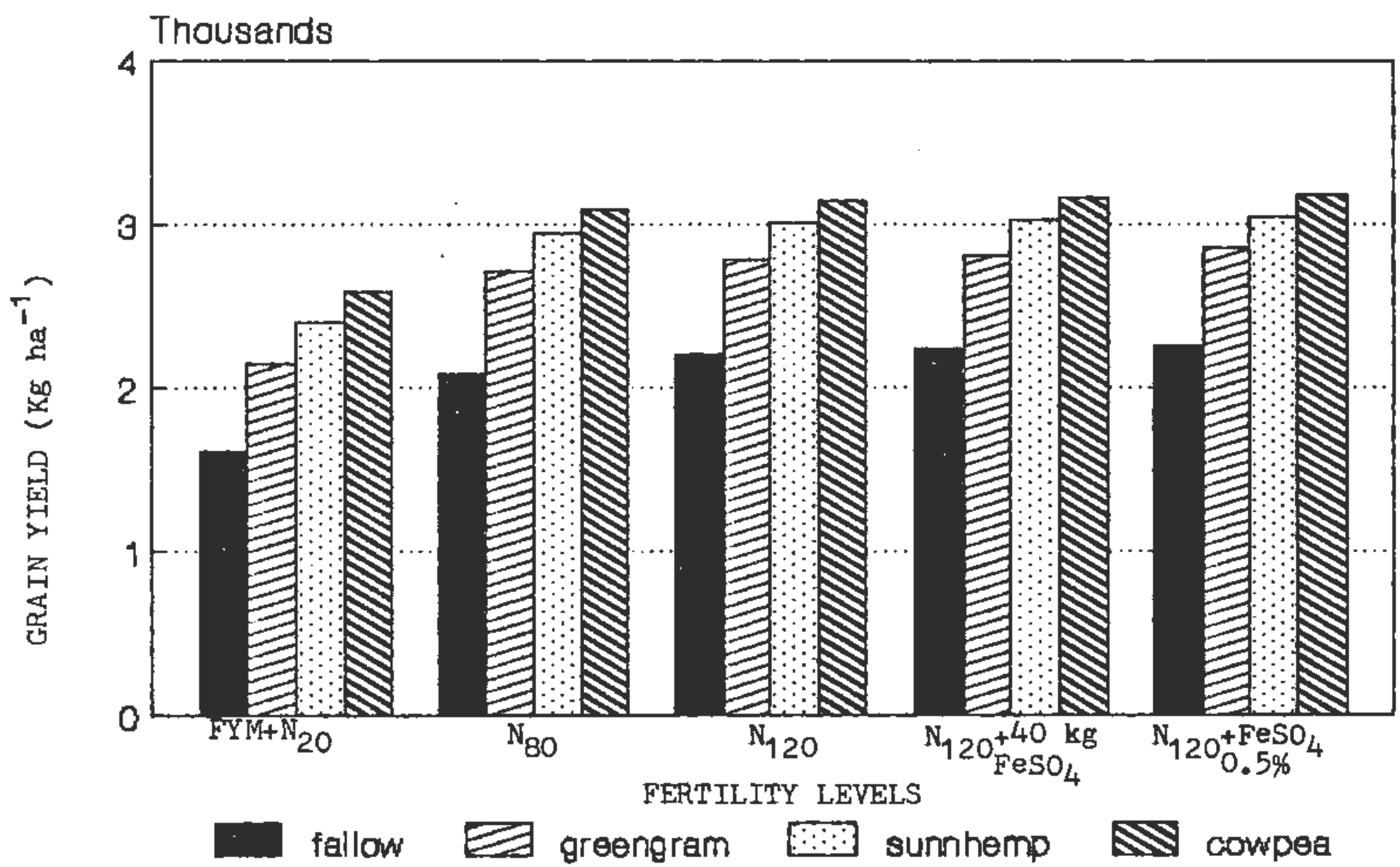


Fig.11. Grain yield as influenced by preceding crops and fertility levels

than all other preceding crops and fallow. Cowpea incorporation gave higher grain yield than all other crops and fallow at all levels of fertility.

The straw yield of rice was significantly higher (3 878 kg ha^{-1}) with cowpea incorporation compared to its growing after other crops and fallow (Table 36). Straw yield recorded after greengram haulm incorporation was 3 401 kg ha^{-1} which was significantly higher than that obtained after fallow (2 695 kg ha^{-1}). Application of 120 kg N ha^{-1} produced higher straw yield compared to other levels of N management. Combined application of 120 kg N ha^{-1} and foliar application of iron gave significantly higher straw yield than that obtained with application of 120 kg N ha^{-1} alone. Cowpea incorporation in combination with 120 kg N ha^{-1} along with foliar application of iron gave highest straw yield than all other treatmental combinations. Incorporation of cowpea produced significantly higher straw yield than all other previous crops and fallow at any level of fertility management.

4.3.24 <u>Harvest index</u>

Harvest index of rice was not influenced by preceding crops (Table 37). Among the fertility levels farmers

Table 37. Harvest index as influenced by preceding crops and fertility levels

Preceding crops	Fertility					Mean
	FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	
Fallow	0.45	0.44	0.44	0.44	0.42	0.44
Greengram	0.45	0.45	0.44	0.43	0.43	0.44
Sunnhemp	0.46	0.45	0.44	0.44	0.44	0.45
Cowpea	0.45	0.44	0.44	0.43	0.43	0.44
Mean	0.45	0.44	0.44	0.44	0.43	
	Crops	Fertility	F at C	C x F		
SEm ±	0.003	0.002	0.004	0.006		
CD 5%	NS	0.01	NS	NS		

level of N management recorded higher (0.45) harvest index. The harvest index obtained with 80 kg N ha^{-1} was equal to that obtained with 120 kg N ha^{-1}. The interaction of preceding crops and fertility levels on harvest index was not significant.

4.4 EVALUATION OF CROPPING SYSTEMS

4.4.1 Dry matter

Total dry matter produced by the component crops in a system was considered to see the efficiency of each system. The dry matter produced with fallow-rice system was low (5 102 kg ha^{-1}) while it was highest (8 735 kg ha^{-1}) with cowpea-rice system (Table 38).

4.4.2 Rice-grain equivalents

The yields of preceding crops were converted into rice-grain equivalents and were presented in Table 39. Greengram-rice system gave more rice-grain equivalents 3 506 kg ha^{-1}) which was superior to other cropping systems. Cowpea-rice gave rice-grain equivalents of 3 035 kg ha^{-1}, while fallow-rice system gave 2 077 kg ha^{-1}.

Table 38. Total dry matter production with different cropping systems

Cropping system	Dry matter (Kg ha^{-1})
Fallow-rice	5 102
Greengram-rice	7 694
Sunnhemp-rice	8 106
Cowpea - rice	8 735

Table 39. Rice-grain equivalents and cost of cultivation (Rs. ha^{-1}) of cropping systems

Cropping system	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
	Rice-grain equivalents (Kg ha^{-1})					
Fallow-rice	1 614	2 080	2 203	2 235	2 252	2 077
Greengram-rice	2 989	3 558	3 630	3 654	3 701	3 506
Sunnhemp-rice	2 398	2 949	3 008	3 033	3 051	2 888
Cowpea-rice	2 587	3 093	3 143	3 168	3 183	3 035
Mean	2 397	2 920	2 996	3 022	3 047	
	Crops	Fertility	F at c	C x F		
SEm ±	15	11	22	31		
CD 5%	50	32	NS	NS		
	Cost of cultivation (Rs. ha^{-1})*					
Fallow-rice	3 176	3 020	3 220	3 630	3 370	3 283
Greengram-rice	4 322	4 167	4 367	4 777	4 517	4 430
Sunnhemp-rice	3 900	3 745	3 945	4 355	4 095	4 008
Cowpea-rice	4 327	4 112	4 312	4 722	4 460	4 387
Mean	3 931	3 761	3 961	4 371	4 111	

* The data was not analysed statistically

4.4.3 Cost of cultivation

The cost of cultivation computed for cropping systems revealed that sunnhemp-rice system recorded low cost of cultivation (Rs.4 008 ha^{-1}) when compared to cowpea-rice and sunnhemp-rice systems (Table 39). The cost of cultivation was highest with greengram-rice followed by cowpea-rice.

4.4.4 Gross returns

The gross returns were highest with greengram-rice system (9 783 Rs. ha^{-1}) which was higher than that obtained with all other systems (Table 40). The next best system was cowpea-rice with a gross returns of Rs. 8 763 ha^{-1}. The interaction was found nonsignificant.

4.4.5 Net returns

Greengram-rice system gave higher returns compared to other systems (Table 40). The net returns with sunnhemp-rice (Rs.4 288 ha^{-1}) and cowpea-rice (Rs.4 349 ha^{-1}) were similar. Greengram-rice system gave 23 per cent more net returns than cowpea-rice system. The interaction was found nonsignificant.

Table 40. Gross returns, net returns (Rs. ha^{-1}) and benefit-cost ratio of cropping systems

Cropping systems	Fertility levels FYM+N_{20}	N_{80}	N_{120}	N_{120} + $FeSO_4$ (40 Kg)	N_{120} + $FeSO_4$ (0.5%)	Mean
			Gross returns			
Fallow - rice	4657	6000	6354	6443	6549	6000
Greengram-rice	8262	9906	10129	10237	10381	9783
Sunnhemp-rice	6926	8454	8639	8734	8820	8315
Cowpea-rice	7383	8953	9077	9179	9223	8763
Mean	6807	8329	8550	8648	8743	
	Crops	Fertility	F at C	C x F		
SEm ±	33	31	62	71		
CD 5%	113	90	NS	NS		
			Net returns			
Fallow-rice	1481	2987	3134	2813	3179	2719
Greengram-rice	3940	5739	5751	5460	5864	5351
Sunnhemp-rice	3046	4709	4630	4379	4673	4288
Cowpea-rice	3056	4841	4628	4457	4763	4349
Mean	2881	4569	4536	4227	4620	
	Crops	Fertility	F at C	C x F		
SEm ±	30	36	72	68		
CD 5%	103	104	NS	NS		
			Benefit-cost ratio			
Fallow-rice	1.52	1.99	1.97	1.78	1.94	1.84
Greengram-rice	1.91	2.38	2.32	2.14	2.29	2.21
Sunnhemp-rice	1.78	2.25	2.19	2.00	2.15	2.07
Cowpea-rice	1.70	2.18	2.10	1.95	2.07	2.00
Mean	1.73	2.20	2.15	1.97	2.11	
	Crops	Fertility	F at C	C x F		
SEm ±	0.011	0.011	0.021	0.025		
CD 5%	0.04	0.03	NS	NS		

Rice grain cost - Rs. 2.50 kg^{-1}; Greengram - Rs. 5.00 kg^{-1}
Rice straw - Rs. 0.30 kg^{-1}; Cowpea green matter - Rs. 0.20 kg^{-1}
Sunnhemp green matter - Rs. 0.20 kg^{-1}; Nitrogen - Rs. 5.20 kg^{-1}
P_2O_5 - Rs. 6.50 kg^{-1}; K_2O - Rs. 2.00 kg^{-1}.

4.4.6 Benefit-cost ratio

Greengram-rice system gave highest benefit-cost ratio (2.21) while sunnhemp-rice gave a ratio of 2.07 (Table 40). The benefit-cost ratio of fallow-rice system was lowest (1.84), followed by cowpea-rice (2.00).

DISCUSSION

V DISCUSSION

5.1 POT-CULTURE EXPERIMENT

A preliminary trial was conducted in a glass house to find the ways to overcome the iron chlorosis in semi-dry rice. Among the different treatments tried to find the remedy of iron chlorosis the application of green manure (gliricidia) at 10 t ha^{-1} resulted in higher dry matter-production by rice. This treatment reduced the chlorosis in the rice plants. Submergence also resulted in similar effects. This reduction in iron chlorosis and better growth of rice with green manure was due to higher availability of iron owing to the chelating effect of organic matter. Similar results were reported by several workers (Jaggi and Russel 1973; Katyal 1977; Abrol and Palaniappan 1987; Anand Swarup 1988; Chahal and Khehra 1988). Better growth of rice under submergence was due to conversion of insoluble ferric iron to soluble ferrous iron under anaerobic condition (De Datta 1981).

5.2 PRECEDING CROPS

Field experiments were conducted to develop suitable cropping system for tankfed areas where the land is generally kept vacant in *kharif* season; another object being to substitute part of N requirement of rice through preceding legume crops and to rectify iron deficiency by incorporating green matter of the preceding crops.

The suitability of a particular crop in the sequence cropping system depends on its growth, duration, yield and economics in addition to its influence on soil fertility.

The growth of a crop can be quantified as plant height, LAI and dry matter. The growth not only depends on its genetic characters but also on the influence of climate. The total amount of rainfall received during the entire crop season was 193.3 mm. Two dry spells were occurred during the crop season, one lost for 19 days (at 20 DAS) and the other for 28 days (at 38 DAS). But the evaporation (mm day^{-1}) during that dry spells was relatively high (8.3 and 9.0 mm day^{-1}, respectively). Due to these dry spells severe moisture stress was experienced by the preceding crops. The growth of preceding crops was poor, but cowpea resulted in relatively better growth than other crops. This better growth of cowpea might be due to its deep root system which exploited more soil volume for extracting the soil moisture. Hence the dry matter-production of cowpea was higher than all other crops.

To understand the better growth of cowpea under severe moisture stress condition, stress related parameters like tap-root length, RWC, foliar movements and survival of seedlings were measured (Table 8). Under stress conditions cowpea recorded higher (16.93 cm) tap root length compared to all other crops. Cowpea and greengram maintained higher relative water content (%) and leaf let angles compared to sunnhemp. The percentage of dead plants observed m^{-2} were 3.3, 3.9, and 2.3 in greengram, sunnhemp and cowpea respectively. Due to deeper tap roots and maintenance of higher relative water and leaf let angles led to tolerance of cowpea to severe moisture conditions. All the three crops were harvested at the same time i.e., 70 days after sowing. Lack of sufficient rain delayed the sowing of rice upto October 15.

The average grain yield of greengram was 420 kg ha^{-1}. The net returns were high with greengram among the preceding crops due to its high price. The next best crop was cowpea followed by sunnhemp with net returns of 276 Rs. ha^{-1} and Rs. 355 ha^{-1} respectively. The fertility as measured by organic carbon and available nitrogen was higher with cowpea incorporation followed by sunnhemp. Incorporation of 7 526 kg ha^{-1} of cowpea added 76.8 kg N ha^{-1} to the soil while it was 23.1 kg N ha^{-1} with sunnhemp. Considering all aspects of these crops cowpea and greengram are considered as suitable preceding crops for semi-dry rice.

5.3 SEMI-DRY RICE

The influence of farm yard manure, green manure, fertilizers and iron, on rice was presented in brief and the probable reasons for such behaviour was explained with the help of the findings of other scientists.

5.3.1 Farm yard manure

Farm yard manure (FYM) was applied at 10 t ha^{-1} at the time of sowing of rice, in the treatment FYM + 20 kg N ha^{-1} and 20 kg N was applied at 60 DAS whereas in other fertilizer treatments, one-fourth dose at the time of sowing, one-fourth at tillering and the remaining half at 60 DAS was applied. The results revealed that the difference in plant height, LAI, dry matter at seedling stage between FYM and 80 kg N was more compared to later stages. This implies that growth was less with farm yard manure than chemical fertilizers in initial stages. This might be due to slow release of N from FYM.

5.3.2 Sunnhemp

The data on soil organic oarbon content estimated at 60 DAS (Table 21) revealed that there was a 13.3 per cent increase in organic carbon content in sunnhemp incorporated plots over fallowed plots. Similar increase in organic carbon content with green manuring was observed by Singh and Awasthi (1978) and Salu Reddy (1989).

The plant height, LAI, tiller number and dry matter at all stages of crop growth were significantly higher in the treatments where sunnhemp was incorporated irrespective of N levels compared to fallow (Tables 8 to 15). Interaction effect of green manuring and nitrogen was found to be significant. It was observed that the growth of rice recorded in most of the stages with 80 kg ha^{-1} plus green manuring was more than the growth that was observed with a dose of 120 kg N ha^{-1} after fallow.

Better growth after sunnhemp incorporation was due to several reasons viz. improved soil structure, reduction in p^H, increased availability of nitrogen and iron. Burns and Davis (1986) reported that green manuring increased aggregate stability. Anand Swarup (1988) reported that CO_2 production increased with the addition of green manure. It is very well known that green manuring adds considerable quantities of N ranging from 50 to 100 kg ha^{-1} (Meelu et al 1985; Ladha et al 1987). In the present study organic carbon estimated at 60 DAS was higher with sunnhemp incorporation over fallowed plots (Table 21). Iron deficiency was observed at 30 DAS in all the plots but the incidence was less in green manured plots. Similar results were reported by Salu Reddy (1989). The available soil iron (Table 33 and fig. 8) estimated after the harvest of the crop revealed that there was an increase in the soil available iron and it might be the probable reason for the less incidence of iron chlorosis in green manured plots. These results were in agreement with the findings of Abrol and

Palaniappan (1987), Anand Swarup (1988) and Chahal and Khehra (1988).

The crop growth rate (CGR) was more at all stages of rice when sunnhemp was incorporated, irrespective of N level (Table 16 and 17). The combination of sunnhemp incorporation and 120 kg N ha^{-1} recorded higher CGR at all stages of crop growth and lowest CGR was recorded at farmers level of N management after fallow. The CGR observed at farmers level of N management with sunnhemp incorporation was comparable to that observed at 80 kg N ha^{-1} after fallow at all stages of crop growth. The benefits of green manuring can be attributed to N substitution. In addition green manuring might have increased the other macro and micro nutrients availability in the soil.

The nitrogen content recorded at all stages of rice was significantly higher in all the treatments where sunnhemp was incorporated over fallow (Tables 22 to 24). N uptake at tillering, flowering and harvest was considerably higher with sunnhemp incorporation (Fig. 6) than after fallow. Increasing the dose of N further increased the uptake of N at all stages of rice crop when sunnhemp was incorporated.

The N uptake with 120 kg N plus green manuring was 84.5 kg ha^{-1} while with the fallow was 65.4 kg ha^{-1}. Favourably effect of green manuring and nitrogen fertilization on the uptake of nitrogen has been reported by Tiwari et al (1980).

The phosphorus uptake of rice at harvest was not influenced by preceding crops. The data on potassium uptake (Table 30) revealed that the uptake was significantly higher when sunnhemp was incorporated. The decomposing organic matter might have solubulized the native potassium of the soil and there by increased K uptake in plants after green manuring. Debnath and Hajra (1972), Salu Reddy (1989) also reported increased availability of K in soil and its higher uptake by crop after green manuring.

The available nitrogen at the beginning of the season was 95 kg ha^{-1}. The available soil nitrogen after harvest of rice was significantly higher when sunnhemp was incorporated. There was a 46.5 per cent increase in available soil N in sunnhemp incorporated plots over fallowed plots (Table 25 and fig. 7).

The nitrogen use efficiency was significantly higher in all the treatments where sunnhemp was incorporated plots than on fallowed plots. Application of 120 kg N ha^{-1} after fallow recorded lowest NUE (18.37 kg grain kg N^{-1}).

Panicle number and filled grains were significantly higher when sunnhemp was incorporated irrespective of N levels (Table 34). There was a 9.0 per cent and 20.9 per cent increase in number of panicles and filled grains respectively when sunnhemp was incorporated than after fallow. Number of panicles and filled grains per panicle were increased significantly upto 120 kg N ha^{-1} with sunnhemp incorporation. The number of panicles and filled grains per panicle recorded with sunnhemp incorporation plus 80 kg N ha^{-1} were more than that obtained with 120 kg N ha^{-1} after fallow. The 1000 grain weight with sunnhemp incorporation was significantly higher than that obtained after fallow.

The favourable influence of green manuring on yield attributes was due to higher availability of N, more uptake of N, P and K and less iron deficiency. Similar results were obtained by Rekhi and Meelu (1983). Sunnhemp incorporation raised the grain yield of rice significantly and there was 39.0 per cent increase over fallow (Table 36 and Fig. 11). Grain yield increased significantly with increase in N level upto 120 kg ha^{-1} when sunnhemp was incorporated. The increased yield might have been due to additional nutrients supplied by green manure and also as a result of better utilization of applied N through improved micro-environmental conditions in rhizosphere (Thakur and Singh 1987). Similar increased yields were reported by Tiwari et al (1980), Bharadwaj (1982), Gill and Meelu (1982), Rajbhandari (1984), Sudhakar (1984), Meelu et al (1985), Meelu and Morris (1986), Hati (1987), Kolar and Grewal (1988) and Rana et al (1988).

The data further revealed that green manuring with sunnhemp plus 80 kg N ha^{-1} gave more yield than that of 120 kg N ha^{-1} after fallow. Response of rice to green manuring equivalent to 80 kg fertilizer N ha^{-1} was obtained on upland soil by Tiwari et al (1980). Meelu and Morris (1984) and Rajbhandari (1984) also reported that 80 kg N ha^{-1} could be substituted with green manuring. Ladha et al (1987), reported that green manuring contributed nitrogen equivalent to 50 to 100 kg N ha^{-1}. Green manuring substituted nitrogen to the extent of 60 kg ha^{-1} as reported by Rana et al (1988).

5.3.3 Greengram and cowpea

Greengram was grown for grain purpose but haulm was incorporated. Cowpea was grown for fodder purpose. Due to less production of green matter yield by cowpea entire green matter was incorporated.

A close perusal of the data on the influence of incorporation of greengram haulm and green matter of cowpea on rice growth, yield attributes and yield indicated that cowpea was resulted in better growth of rice but the net returns were less owing to lack of grain production. Considering the net returns the green gram was found to be best preceding crop.

The growth parameters of rice viz., plant height, tiller number, LAI and dry matter-production were considerably higher with cowpea incorporation over incorporation of greengram haulm. The dry matter of rice crop at maturity with cowpea incorporation was 3.5 and 23.2 per cent higher than that obtained with greengram haulm and fallow. Similar results were reported by Timsina and Carangal (1984) and John et al (1989). The plant height, LAI, tillers and dry matter production were significantly higher with greengram haulm incorporation compared to fallow. These results are in confirmity with the findings of Rekhi and Meelu (1983) Rajendra Prasad (1985) and Reddy (1988).

The nitrogen uptake at harvest with cowpea incorporation was highest (82.4 kg ha^{-1}) than the incorporation of greengram haulm (79.5 kg ha^{-1}). Soil available nitrogen after harvest of rice was significantly higer with cowpea incorporation. Similar increase in soil available N was also reported by Timsina and Carangal (1984). The NUE of rice was higher with the cowpea incorporation than greengram haulm incorporation. The available soil N status after the harvest of rice crop (Table 25) revealed that it was more with greengram-rice than fallow-rice. The results were in confirmity with the reports of Palaniappan et al (1976), Rajat De (1981), Rekhi and Meelu (1983), Rajendra Prasad (1985) who reported that the N status of soil was improved with greengram haulm incorporation.

Panicle number and filled grains in rice were considerably higher with cowpea incorporation than greengram haulm incorporation. Grain and straw yields of rice were favourably influenced with cowpea incorporation. The grain yield recorded with cowpea incorporation was 3 035 kg ha^{-1} which was 13.8 per cent higher than that obtained with greengram haulm incorporation. Similar increase in yield attributes and yield was reported by Timsina and Carangal (1984) and John et al (1989). The yield attributes and yield (2 666 kg ha^{-1}) were significantly higher with greengram haulm incorporation than the fallow. Similar results were reported by Rajat De (1981), Rekhi and Meelu (1983), Rajendra Prasad (1985) and Reddy (1988). Soil available iron (ppm) estimated after harvest of rice crop (Table 33 and fig. 8) revealed that it was higher with cowpea incorporation or greengram haulm incorporation compared to fallow. The soil available iron recorded with cowpea incorporation (22.4 ppm) was more than double the quantity than obtained after fallow (8.9 ppm). This might be due to solubilization action of decomposed organic matter on inorganic Fe present in the soil (Francis et al 1979). Similar results were also reported by Abrol and Palaniappan (1987), Anand Swarup (1988) and Chahal and Khehra (1988).

5.3.4 Response of rice to nitrogen

The application of nitrogen significantly increased the growth parameters viz., plant height, total tillers, LAI and dry matter-production (Table 9 to 15). Similar results were reported by Singh et al (1981), Ramaswamy (1982) and Reddy (1985). Significant increase in nitrogen content in whole plant at tillering, flowering and in grain and straw at harvest was observed with increase in the level of N application (Tables 22, 23 and 24). The greater N content at higher level of N application viz., 120 kg ha^{-1} may be due to increased availability of nitrogen. Similar results were reported by Reddy (1985). At all stages of crop growth there was a significant increase in N uptake by rice crop due to N levels. At 120 kg N ha^{-1}, the increase in dry matter accumulation and higher nitrogen content combinedly resulted in higher N uptake. The results were in accordance with the reports of Mehta et al (1983) and Salu Reddy (1989).

Application of 120 kg N ha^{-1} resulted in maximum number of panicles and there was a 10.8 per cent increase in panicle number over farmers level of N mangement (Table 34.)

There was an increase in the number of filled grains also due to nitrogen application. Higher availability of nitrogen might be responsible for increased number of filled grains per panicle at 120 kg N ha^{-1}. Similar increase in the number of filled grains per panicle were also reported by Reddy (1985) and Salu Reddy (1989). With increase in the level of nitrogen fertilization grain and straw yields increased upto 120 kg N ha^{-1}. Giri and Bhatade (1980), Sharma and Rajendra Prasad (1980), Reddy (1985), Wankade and Pandrangi (1988), Salu Reddy (1989) also reported the similar results.

5.3.5 Iron chlorosis

Iron chlorosis was observed in the rice crop at one month after sowing. Total chlorophyll content estimated at flowering stage revealed that it was increased (Table 20 and fig.5) with iron application. Foliar application of iron proved better than soil application in increasing the total chlorophyll content. The increased chlorophyll content in the plants may be due to the involvement of iron in chlorophyll formation thus reducing the chlorosis to some extent. Similar increase in the chlorophyll content was also reported by Agboola and Fube (1983) and Bina Agarwal and Srivastava (1984). Meelu and Sagar (1980) and Alam (1986) also reported that foliar application of iron was found to be better for correcting the iron chlorosis.

The total iron content (ppm) estimated at tillering and flowering of rice plants revealed that the total iron content was more in the plants where chlorosis symptoms were observed (Tables 31 and 32). These results were in confirmity with the findings of Katyal and Sharma (1980). The soil available iron content (ppm) estimated after the harvest of rice crop was higher with the incorporation of crops compared to fallow (Table 33). This increase in the soil available iron content may be due to chelating effect of organic matter (Jaggi and Russel 1973; Katyal 1977; Francis et al 1979; Abrol and Palaniappan 1987; Anand Swarup 1988; Chahal and Khehra 1988).

5.3.6 Influence of iron on rice

Plant height measured at active-tillering, panicle-initiation, flowering and maturity stages was higher with foliar application of iron with 120 kg N ha^{-1} compared to application of 120 kg N ha^{-1} alone (Table 9 and 10). Foliar application of iron resulted in significantly higher tiller number at active-tillering, panicle-initiation and flowering stages (Table 11). LAI estimated at active-tillering and panicle-initiation stages was significantly higher with foliar application of iron + 120 kg N ha^{-1} compared to 120 kg N ha^{-1} alone (Table 12 and 13). Both the soil and foliar application of iron (Table 14 and 15) did not differ significantly in dry matter-production at different stages of rice. Similar results were reported by Alam (1986).

Number of panicles m^{-2} and filled grains per panicle were significantly higher with foliar application of iron compared to soil application (Table 34). No significant differences were observed between soil (3 168 kg ha^{-1}) and foliar (3 183 kg ha^{-1}) application of iron regarding grain yield, but with respect to straw yield foliar application of iron recorded higher (3 754 kg ha^{-1}) straw yield compared to soil application (3 642 kg ha^{-1}).

5.4 EVALUATION OF CROPPING SYSTEMS

The viability of a cropping system depends on biological suitability and economic viability of a system. The economic worthiness of a system is decided on economic indices such as gross returns, cost of cultivation and benefit-cost ratio (Palaniappan 1985).

In the present study an attempt was made to evaluate rice based cropping systems depending on biological efficiencies and economic viability. The biological efficiency was estimated by total dry matter, grain-equivalents, while economic viability was based on cost of cultivation, gross returns, net returns and benefit-cost ratio.

5.4.1 Biological efficiency of cropping systems

The data on total dry matter yield of component crops of cropping systems revealed that cowpea-rice was better than greengram-rice and sunnhemp-rice systems (Table 38).

Rice-grain equivalents were more with greengram-rice system (3 506 kg ha^{-1}) which were superior to other cropping systems (Table 39). The rice-grain equivalents were lowest in fallow-rice system. Thus, greengram-rice system was found to be biologically efficient system.

5.4.2 Economic evaluation of cropping systems

The cost of cultivation was high in greengram-rice followed by cowpea-rice system and sunnhemp-rice system (Table 39). Among these three systems greengram-rice system was found to be economical where financial resources are in short supply. Among the preceding crops cost of cultivation of sunnhemp was found to be low and it was Rs. 4 008 ha^{-1} in the sunnhemp-rice system which was low compared to cowpea-rice and greengram-rice. It can be concluded that where financial resources are limited, sunnhemp-rice and cowpea-rice were better than other systems.

Greengram-rice system gave highest gross returns (Table 40). Next in order were cowpea-rice and sunnhemp rice systems. Greengram-rice system gave higher net returns because the price of greengram was high and 420 kg grain ha^{-1} of greengram was included in the returns. Although the net returns were less with cowpea-rice system it can be recommended for low rainfall situations because it has given more green matter yield compared to other system even under moisture stress conditions.

The benefit-cost ratio computed for different systems (Table 40) indicated that greengram-rice system was better than other cropping systems.

The close perusal of the evaluation of cropping systems indicates that cowpea-rice and greengram-rice systems were biologically efficient and economically viable systems. In contrary, Salu Reddy (1989) reported that sunnhemp-rice system was biologically efficient. The discrepancy can be explained by the fact that green matter production of sunnhemp was more than 25 t ha^{-1} due to high rainfall in 1988 compared to 1989. Inclusion of grain legumes in the system to improve soil N and to enhance grain yields was reported by many workers (Ambika Singh 1975; Misra and Misra 1975; Palaniappan et al 1976; Rajat De 1981; Mahapatra et al 1985; Pandey et al 1985).

From the present study, it can be concluded that greengram-rice and cowpea-rice systems were the best for the tankfed areas of Rayalaseema region. The fertilizer nitrogen necessary for semi-dry rice was 120 kg N ha^{-1} when grown after greengram and 80 kg N ha^{-1} when grown after cowpea incorporation. Incorporation of cowpea or sunnhemp was found helpful for semi-dry rice. Inclusion of greengram or cowpea in the monocropped semi-dry rice regions, improves soil nitrogen and iron. Incorporating cowpea green matter or greengram haulm will reduce the yield reduction due to iron deficiency.

SUMMARY

VI SUMMARY

The present study was conducted with three main objectives viz., to develop a suitable cropping system for tankfed areas, to study the feasibility of integrated nutrient management for semi-dry rice based cropping system and to find the remedy for iron chlorosis. To tackle iron chlorosis problem of semi-dry rice a pot-culture study was conducted with different treatments like application of ferrous sulphate to soil, Fe-EDTA to soil, foliar application of ferrous sulphate, green manure incorporation and maintenance of submergence. Application of green manure and continuous submergence were found better to reduce iron chlorosis. Subsequently a field experiment was conducted with four cropping systems (fallow-rice, greengram-rice, sunnhemp-rice and cowpea-rice) and five fertility levels (FYM + 20 Kg N ha^{-1}, 80 kg N ha^{-1}, 120 kg N ha^{-1}, 120 kg N ha^{-1} + 40 kg $FeSO_4$ ha^{-1} to soil and 120 kg N ha^{-1} + foliar application of $FeSO_4$ @ 0.5 per cent) to semi-dry rice. Greengram was grown for grain purpose and haulm was incorporated. Cowpea and sunnhemp were grown for fodder and green manure purpose. However, owing to severe moisture stress, growth of these crops were less and therefore entire green matter was incorporated as green manure. The results of the study were summarised.

The results on growth and yield of preceding crops revealed that cowpea and greengram were suitable to precede rice due to higher growth and higher net returns. Among the three preceding crops, cowpea was able to tolerate severe moisture stress; it had longer tap root, quicker foliar movements and higher relative water content of leaves. The net returns with greengram and cowpea were Rs. 875 and Rs. 355 ha^{-1} respectively. The growth of semi-dry rice measured in terms of plant height, number of tillers, LAI and dry matter was higher when it was grown after incorporation of cowpea than when grown after other preceding crops. Application of 120 kg N ha^{-1} gave higher growth of rice, compared to all other N levels. Addition of green manure resulted in better growth of rice at all levels of N; especially cowpea incorporation gave higher dry matter production of rice compared to non-incorporation of green manure. CGR of rice was higher with cowpea incorporation compared to all other crops and fallow at all stages of crop growth. Application of 120 kg N ha^{-1} resulted in higher CGR compared to all other levels of N. Foliar application of iron recorded higher CGR than soil application at 120 kg N ha^{-1}. Cowpea incorporation with 10 t FYM at 20 kg N ha^{-1}

recorded higher CGR compared to 120 kg N ha^{-1} after fallow. The total chlorophyll content of rice was higher with cowpea incorporation compared to its content when rice was grown after other crops and fallow. Application of 120 kg N ha^{-1} recorded higher chlorophyll content than all other N levels. Foliar application of iron recorded higher chlorophyll content than soil application. Chlorophyll content was higher in all plots that received crop residues or green manure.

The soil organic carbon content was higher with cowpea incorporation than all other crops and fallow. Application of 120 kg N ha^{-1} resulted in high organic carbon content than farmers level of N management (FYM + 20 kg N ha^{-1}). The N content and uptake at tillering was higher in cowpea incorporated crop than that after crops and fallow. Application of 120 kg N ha^{-1} resulted in high N content and uptake at tillering compared to all other N levels. The N uptake at flowering and harvesting stages was higher with cowpea incorporation compared to all other crops. Application of 120 kg N ha^{-1} recorded higher N uptake compared to all other N levels. The application of iron either to soil or to foliage differed in the N uptake only at flowering stage. The soil available nitrogen was significantly higher in sunnhemp or cowpea incorporated plots compared to fallow. Application of 120 kg N ha^{-1} resulted in higher soil available nitrogen than all other N levels. The NUE was higher with cowpea incorporation than all other crops and fallow. The NUE was increased upto 120 kg N ha^{-1}. Foliar application of iron resulted in marginal increase in NUE at 120 kg N ha^{-1}. The NUE was highest with 80 kg N ha^{-1} in combination with cowpea incorporation. Phosphorus uptake was influenced only by fertility levels and it was higher with 120 kg N ha^{-1}. Cowpea incorporated crop recorded higher potassium uptake compared to all other crops and fallow. Application of 120 kg N ha^{-1} resulted in higher K uptake.

Total iron concentration of rice at tillering and flowering stages was less with the incorporation of green-matter or crop residue compared to fallow. Lower levels of nitrogen resulted in higher iron content in rice plants compared to higher N levels. Application of 120 kg N ha^{-1} recorded higher iron content than 120 kg N ha^{-1} + iron application either to soil or foliage. The soil available iron content was higher with cowpea incorporation compared to fallow and all other crops. Application of nitrogen did not influence the soil available iron. A combination of cowpea incorporation with 120 kg N ha^{-1} and soil application of iron resulted in highest soil available iron content.

Number panicles were higher with cowpea and greengram haulm incorporation compared to fallow. Application of 120 kg N ha^{-1} resulted in higher number of panicles than all other N levels. Foliar application of iron recorded higher panicle number than soil application. The number of panicles with FYM + 20 kg N ha^{-1} + cowpea incorporation was more than that obtained with 120 kg N ha^{-1} alone. More number of filled grains were produced in rice when grown after cowpea incorporation compared to other crops and fallow. Application of 120 kg N ha^{-1} resulted in higher number of filled grains than all other N levels. Application of iron either to soil or to foliage resulted in higher number of filled grains. The number of filled grains obtained with farmers level of N management (FYM + 20 kg N ha^{-1}) in combination with cowpea incorporation were more than that obtained with 120 kg N ha^{-1} after fallow. The 1000 grain weight was not influenced by preceding crops.

Higher grain yield (3 035 kg ha^{-1}) of rice was obtained in cowpea incorporated plots than that obtained with other crops and fallow. Application of 120 kg N ha^{-1} resulted in higher grain yield compared to all other N levels. Combined application of 120 kg N ha^{-1} and foliar application of iron produced higher grain yield compared to 120 kg N ha^{-1} alone. Combined application FYM 10 t and 20 kg N ha^{-1} after incorporation of cowpea green matter gave higher grain yield (2 587 kg ha^{-1}) compared to application of 120 kg N alone (2 203 kg ha^{-1}).

The total dry matter produced by the cowpea-rice cropping system was higher compared to all other systems. Greengram-rice gave higher rice-grain equivalents (3 506 kg ha^{-1}) compared to other systems. The rice-grain equivalents were higher with 120 kg N ha^{-1} than all other N levels. Gross and net returns and benefit-cost ratio were higher with greengram-rice system.

From the present study, it can be concluded that greengram - semi-dry rice or cowpea - semi-dry rice systems are suitable for tankfed areas. Incorporation of crop residue or green matter of leguminous crops along with

120 kg N ha^{-1} is recommended for higher yields. Iron chlorosis problem can be alleviated by the application of green manure or greengram haulm.

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LITERATURE CITED

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* Original not seen

APPENDICES

APPENDIX - A

Daily rainfall (mm) during the crop period Kharif, 1989

Date	Rainfall (mm)	Date	Rainfall (mm)
11.7.89	9.4	30.7.89	4.9
13.7.89	33.0	19.8.89	2.8
16.7.89	17.6	17.9.89	15.4
17.7.89	23.0	19.9.89	46.2
22.7.89	5.0	21.9.89	34.0
28.7.89	2.0		

Late Kharif, 1989

Date	Rainfall (mm)	Date	Rainfall(mm)
2.11.89	9.8	1.12.89	4.2
10.11.89	48.0	2.12.89	101.6
12.11.89	43.6	3.12.89	51.0
13.11.89	23.2	1.1 .90	7.4
17.11.89	18.2	8.1. 90	1.6
18.11.89	4.4	4.3. 90	11.6
19.11.89	25.4	5.3. 90	5.5
20.11.89	3.8	6.3. 90	19.8

APPENDIX - B

Calender of Operations

Date	Operation
30-6-1989	Mainfield preparation
7-7-1989	Layout of the plot
11-7-1989	Sowing of Kharif crops
1-8-1989	Hand-weeding to preceding crops
23-8-1989	Harvesting and incorporation of Preceding c
15-10-1989	Sowing of semi-dry rice
4-11-1989	First hand-weeding to rice
15-11-1989	First spray of ferrous sulphate
22-11-1989	Second spray of ferrous sulphate
24-11-1989	Second hand-weeding to rice
29-11-1989	Third spray of ferrous sulphate
25-12-1989	Third hand-weeding to rice
7-3-1990	Harvesting
8-3-1990	Threshing