NUTRITIONAL CONSTRAINTS OF RICE –LEGUME SYSTEM IN LATERITE SOILS OF HUMID TROPICS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Nutritional Constraints of Rice – Legume System In Laterite Soils Of Humid Tropics" is a bonafide record of research work done by me during the course of research and that thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship, associateship or other similar title, of any other University or Society.

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Introduction

INTRODUCTION

Poor productivity and low nutrient efficiency are the two major issues that characterize the rice production scenario of the laterite soils of the west coast. Intense weathering, heavy leaching and natural water stagnation in the crop growth period have transformed laterite rice tracts of the west coast into a special entity different from conventional rice tracts elsewhere in physico- chemical properties and crop production capabilities. These characteristics pose special problems that influence crop growth and yield. The fact that more than 60 per cent of rice areas of the state is lateritic and that internal production is hardly 25 per cent of the requirement calls for problem characterization to evolve effective production technology. As nutrition is the component of health and yield, a comprehensive analysis of nutritional implications on laterite soil has been deemed to serve the objective.

Levels of soil organic matter and its enrichment through extraneous additions and/or recycling alone as well as supplemented by chemical inputs is generally considered as the panacea for soils and crop productivity. Comparative efficacy of such efforts to realize potential capabilities of the variety as well as its nutritional effects remains yet to be assessed.

Anilakumar and Sivakumar (1994) have reported that direct soil exposure to radiation during summer fallow has been the cause of degradation of carbon from rice tracts. Summer crop covers especially with green manures are expected to arrest the loss and develop an *in situ* source of organic matter to improve soil health. John *et al.* (1992) found that input use efficiency shall be greatly increased by including basal organic sources in nutritional programmes. As a matter of fact the organic sources tend to effect conservation of N against losses. Leguminous crop cover in summer has the advantage of more deeply penetrating roots which open up the soil and lead to earlier leaching down of higher contents of Fe and Mn which will benefit successive rice (Musthafa, 1995).

Crop production is actually a system over time where progressively successive crops have to stand to the beneficial and harmful build up of input and input effects. Problems of low nitrogen use efficiency and failure of high yielding varieties have to be verified in this context. The conventional independent individual crop performances may elude them. Any effort to identify the yield limiting influences cannot forgo this analysis.

System analysis has yet another advantage in that it will help to study the super imposing weather influence on yield expression. Viswambaran *et al.*(1989) has reported that variational effect is of the order of 4000-6000 kg ha^{-1} in extreme cases. Moreover inherently poorer yield in *rabi* rice continues to be an uncharacterized and unresolved problem. Results generated in the study is expected to throw light on possible nutritional means to manage the problem of low *rabi* rice yield. Water management assumes greater significance in this context as variations in redox potential drastically modifies the availability of native elements.

Low yields are often the result of deficiency or excess of one or more elements. Potty *et al.* (1992) exhibited the low productivity of rice in laterite soils due to excess availability and absorption of Fe by rice. Bridgit and Potty (2001) suggested "Relative Optimum" approach to circumvent the negative influence of native elements. Conventionally, only three major nutrients are involved in the management though 16 elements are involved in nutrition. As the deficiency or otherwise of non applied elements can not be guessed in conventional studies, a real cause finding mission should envisage as many elements as possible.

One of the hardships that confront crop production has been the inherent soil problem that limit absorption. Mode of application shall not only circumvent this but also reduce the cost involved. Foliar application of especially micronutrients is worthy in this context.

Crop production as an ever continuing enterprise should ensure sustainability through maintenance of soil health. Easiest way of achieving soil health will be by compensating crop removal through addition, as nutritional erosion of soil health results from induced imbalance between addition and removal.

In this background, the present study was taken up with the following specific objectives.

1. To study the impact of nutrient management practices on soil and plant elemental status and productivity of rice-rice-legume cropping system

2. To study the effect of crop residue recycling on soil productivity and crop growth

3. To study the effect of tillage and water management practices on soil and plant elemental composition and productivity of the crops in the system

Review of literature

2. REVIEW OF LITERATURE

Laterite soils account for more than 60 per cent of rice areas in the state. The productivity and fertilizer responsiveness of rice grown in these soils remains to be substantially low in spite of several technological advancements. Efforts to improve and sustain the productivity of this soil should have multi-faceted approach which may include maintenance of soil organic carbon, managing nutritional constraints, modifying soil physico-chemical environment etc. through selective management strategies. A review of the background information on these aspects is given in this chapter.

2.1. Weather effects on rice

Crop production involves a complex interaction between crop genotype, soil and aerial environment and the crop management practices. Rice is cultivated under diverse climatic, hydrological and edaphic conditions. Its wide adaptability is illustrated by rice cultivation at latitudes from 40° S to 53° N, at elevations ranging from below sea level to more than 2000 m; at water regimes ranging from upland with no accumulated surface water to low lands with five meter deep water and under a wide range of temperature and humidity conditions. Though rice is grown under such wide range of agro ecological situations, more than 50 per cent of its yield expression is governed by climatic factors (IRRI, 1986).

2.1.1. Temperature

Optimum aerial temperatures for tillering are $32\text{-}34^{O}$ C (Matsuo, 1959) and that for fertility is $14 - 38^{O}$ C (Best, 1959) and for ripening it is 23^{O} C (Nagai, 1963). According to Sreedharan (1975) a minimum air temperature of $25\text{-}26^{O}$ C was ideal for shoot and root growth in rice. Low temperature (19^{O} C) from booting to heading delayed heading, decreased grain fertility and yield (Kim *et al.*, 1989). Munakata (1979) found that yield process develops properly when the maximum and minimum temperatures are below 34^{O} C and 22^{O} C, respectively and bright sunshine hours is more than 8 hours day^{-1}.

Low temperature (24/18^{O} C) during the growing season decreased the number and area of inner vascular.bundles in indica cultivars while in japonica they were increased. High temperature induced sterility in rice and heading was the most sensitive stage to high temperature (Satake and Yoshida, 1978). Oldeman *et al.* (1986) reported that if cold spell occurs during panicle initiation to flowering, sterility occurs. Grain yield was higher when temperature during ripening stage is low, an effect attributed to more favourable balance between photosynthesis and respiration. Extending the ripening period gave more time for grain filling (Boerma, 1974).

Lower night temperatures during post flowering correlated positively with yield. Oldeman *et al.* (1986) reported that a high diurnal difference in temperature led to more efficient.conversion and use of solar energy during photosynthesis leading to a higher net photosynthesis. He has further reported that higher temperatures accelerate the rate of development at all phenological stages. This implies that the length of a given phenological phase is shorter at higher temperatures. Samui *et al.* (1998) studied the influence of weather on yield of rice at Pattambi. They found that the optimum minimum and maximum temperatures were 23.5^{O} C and 29.1^{O} C respectively.

Chowdhury and Gore (1991) observed that a combination of maximum temperature of 30.5^{O} C, 81 per cent relative humidity and rainfall of 1000 mm during physiological growth phases is ideally suited to give optimum rice yield. Sunil (2000) observed that wind speed, minimum temperature and mean temperature during flowering to maturity had a negative correlation with yield.

Chaudhury and Ghildayal (1970) found that a day/night submerged soil temperature regime of 32^{O} C/20^{O} C was optimum for root growth, tillering, panicle production, grain .development and nutrient absorption. The low temperature delayed maturity and facilitated better translocation to the ear head and resulted in more number of filled grains and grain weight.

Yoshida (1981 b) indicated that environmental factors (such as high or low temperatures during ripening or unfavourable weather during a reduction division and anthesis) and cultural practices (such as high plant density and protection against pests) determine the number of filled grains per panicle.

The minimum accumulated day degrees (32.28 klx) required for rice was found to be much higher than that required for any other crop. Excessive tillering, leafy growth and tallness were not conducive to photosynthesis. All these features would be suppressed more by lower early season temperatures than by the temperatures that prevail in rainy weather (Murata, 1967). A large part of the starch in grain was formed from photosynthesis in the six week period from two week before flowering to four week after flowering. Bright sunny weathers with cool temperatures in later phases of the crop would be conducive to photosynthesis (Tanaka, 1964). Due to these the highest yields were obtained in the high latitudes of both the southern and northern hemispheres and varieties yielded better in the clear, cool seasons than in the hot, clear seasons and yielded lowest in the wet, warm, cloudy seasons.

2.1.2. Sunshine

Venkateswarlu *et al.* (1977) found that dry matter production was highly dependent on solar radiation. The low light intensity up to flowering in wet season decreased tillering and dry matter production. Yoshida (1981 b) noticed that a long vegetative period and high radiation during this period was generally beneficial for tillering. A high total radiation sum from transplanting to flowering lead to more panicles per m^2. Panicles per m^2 was found to be an important yield component and the radiation sum from transplanting to flowering was an important weather variable in relation to yield. Radiation levels were particularly important during the reproductive phase. Low radiation during post flowering reduced the number of filled grains.

The receipt of radiant energy mostly as diffuse radiation and the prevalence of high temperature with little diurnal range accelerated the problems of formation of photosynthates and respiratory loss of carbohydrates respectively (Yoshida, 1973). He further observed that low light intensity during the vegetative phase affected the yield and yield components of rice. Shading delayed tillering and decreased tillering rate.

Sato (1956) reported that sunshine during the last two months of crop growth should total more than 400 h. Moonmaw and Vergara (1964) reported that sunshine hours in the last month should total 220-240 h and that accumulated sunshine during the optimum growth stage should total 1000 h. Vamadevan and Murty (1976) reported that the traditional rice growing areas in India are exposed to less than 450 h of bright sunshine from July to September.

The optimum duration of a rice crop is four and a half months, with a total sunshine requirement of 1000 h. Such a crop would spend about a month in nursery and would have reproductive and ripening durations of a month each (Oldeman *et al.*, 1986)

The optimum level of N in a plant is dependent on the intensity of solar radiation and the temperature at each growing stage. Lack of available N and lower solar radiation at ripening was considered more yield limiting (Akita *et al.*, 1986).

Murty and Sahu (1986) observed that low light at anthesis led to high spikelet sterility and low harvest index. Under low light at flowering, carbohydrate content, protein synthesis and proline and cytokinin accumulation decreased and gibberellins and soluble N in the panicle increased, leading to high spikelet sterility. Leaf chlorophyll increased but photosynthetic rate declined due to impaired RuBP carboxylase activity.

Singh *et al.* (1995) found that the flag leaves of rice variety, Ratna had higher proline level than Swarnaprabha under normal and low light level. Chlorophyll content was found to be increased more under low light than under normal light (Murty *et al.*, 1975). Among the chlorophyll fractions the increase was more prominent in chlorophyll b, leading to a lower chlorophyll a/b ratio. Under low light, the relative proportion of blue light was higher and because of its affinity with chlorophyll 'b', varieties with higher chlorophyll 'b' were considered to be more adapted to low light (Nayak *et al.*, 1978)

Low light during reproductive and ripening stages was more detrimental to yield. Low light during primordial initiation to flowering or from flowering to harvest reduced grain yield considerably. Under low light dry matter produced was reduced by impaired photosynthesis. Further under low light a considerable proportion of grain carbohydrate was contributed by reserve assimilates at flowering (Janardhan *et al.*, 1980). Apart from the direct influence of low solar radiation, the impaired translocation of carbohydrates from source to developing grain during ripening also contributed to sterility (Nayak *et al.*, 1979).

The reduction of photosynthesis under low light could be attributed to high stomatal and mesophyll resistance to CO_2 exchange. Under shade, total sugars (mostly non reducing sugars and starch) are markedly reduced in all plant parts. Total, soluble and amino N were enhanced. High sterility under low light was ascribed to disturbed N metabolism and accumulation of higher concentrations of soluble N in the panicle, which was toxic to normal grain setting (Murty *et al.*, 1983).

2.1.3. Rainfall

Rainfall and soil moisture are other important weather parameters affecting rice growth. A monthly rainfall of 200 mm was considered sufficient for lowland rice and 100 mm for upland crops (Oldeman, 1975). Sreenivasan and Banerjee (1978) found that additional rainfall above the normal exerted negative influence during sowing, tillering and flowering stages of rice. Yield decreases with increase in total amount of rainfall from 900 to 1100 mm. had been reported by Samui *et al.* (1998)

Tillering in a number of varieties continued up to 42-45 days in rainy season, whereas it was up to 50-55 days in dry season (Chatterjee, 1970). Many varieties responded better to N in dry season than in wet season (Chandler, 1963).

Higher panicle number in *Rabi* compared to *Kharif* season and corresponding higher yield in *Rabi* were attributed to rainfall variability (Venkateswarlu *et al.*, 1977). Viswambaran *et al.* (1989) reported a negative correlation between yield and number of rainy days during maturity stage.

2.1.4. Humidity

Rice crop requires a fairly high degree of humidity for proper growth. Relative humidity (RH) of 80-85 per cent was found to be ideal for shoot and root growth (Sreedharan, 1975). Hirai *et al.* (1984) reported that N uptake and content of leaves and roots in plants grown at 90 per cent RH were higher at 24/20 and 28/24^{O} C of day/night temperature, but lower at 32/38 and 36/32^{O} C than those of the plants grown in 60 per cent RH.

High humidity during the wet season and relatively higher temperature are favourable for insect pests and diseases. The morning relative humidity and mean relative humidity during transplanting to panicle initiation stage had a significant positive influence on yield (Sunil, 2000). The higher the RH, the higher the photosynthesis rate irrespective of light intensity, suggesting that stomatal aperture increased with increasing RH. (Hirai et al., 1984).

2.1.5. Wind

Saran *et al.* (1972) reported that strong winds dried up the ovary and blew off the pollen from the stigma. Under strong winds, fertilizer response and grain maturity were bound to be poor. The strong winds caused mechanical injury to the crops. Venkataraman and Krishnan (1992) found that too much waving and fluttering of the crop due to winds interfered with the ascent of plant sap and lead to drying of top leaves and earheads. These conditions were not conducive for optimum photosynthesis, absorption of fertilizer and maximum retention of assimilates in the earheads

Matsubayashi *et al.* (1963) opined that a gentle wind during the growing period of the rice plant improve grain yields as it replenishes the carbon dioxide supply of the plant. However, strong winds, if they occur after heading, cause severe lodging and shattering in some varieties, desiccate the panicles, increase floret sterility and number of abortive endosperm. Vergara (1976) found that dry winds cause desiccation of rice leaves and thus adversely affect photosynthesis and dry matter accumulation.

In Kerala, rice is generally grown in two seasons, April-May to August- September and August- September to December- January. Of these second crop yields lower than the first crop. Lower temperature range during flowering season, withdrawal of monsoon etc. have been suggested as possible causes.

Studies of Alexander *et al.* (1990) at Pattambi, Kerala revealed that weather components in the specific growth phases affected productive tillers per unit area, number of grains per panicle, weight of grains and sterility. Atmospheric environment during the post flowering phase of the crop was found to be an important yield determinant in rice and that improper integration of the genotype with the weather would inhibit proper yield expression. Further studies by Alexander *et al.* (1991) revealed that commencement of the crop so as to coincide its post flowering phase with the weather situations as available during mid December to early February in North Kerala shall boost up the yield by 1000 kg ha^{-1}.

Kabindra *et al.* (1997) attributed weather as the factor responsible for the instability in rice production in Assam. Flooding and rainfall in the pre transplanting and pre harvesting stages were found to be the main causes. They found that the dry season crop was more stable due to less variations in weather.

Samui (1999) studied the influence of meterological parameters on yield of high yielding and traditional photosensitive rice cultivars during *kharif* season and it was found that yield was highest when average rainfall ranged between 100-115 cm with maximum and minimum temperature ranges from 29-32 °C and 23-25° C. He also observed that the photosensitive HYV performed well even at low light intensity of 250-350 h bright sunshine.

2.2. Mineral nutrition and rice growth

Mineral nutrition is one of the most important factors affecting growth and productivity of a crop. In addition to the specific functions of each nutrients, the interacting influences of the different nutrients, the nutrient ratios and their balances in the plant system are also important.

2.2.1. Primary nutrients

Nitrogen, phosphorous and potassium are the primary nutrients for plant growth. Out of this, nitrogen is involved in the formation of protein as well as chlorophyll. Tanaka (1961) reported that photosynthesis increases as the leaf N content increases to 3-4 per cent. Early N absorption favoured tiller production and panicle formation (Tisdale *et al.*, 1995).

Anilakumar *et al.*, (1992 b) have reported that rice crop does not respond to fertilizer levels beyond 45 kg N ha^{-1} in laterite soils. Menon (1987) found that rice crop manifests some inhibitions in the translocation of N to the leaf blade. According to Musthafa and Potty (1996) absorption of N was not fully effective and its metabolism gets inhibited and photosynthesis becomes inefficient.

Mosi *et al.* (1973) stated that lowland rice is not as likely to respond to addition of phosphatic fertilizers as upland rice crop. Release of soil P in a flooded soil might be attributed to reduction of ferric phosphate to the more soluble ferrous phosphate and displacement of phosphate from ferric and aluminium phosphates by organic anions (Islam and Elahi, 1954). However, Davide (1960) reported that the beneficial effects of flooding on P availability depend on the intensity of reduction and on the iron content of the soil . Gupta and Singh (1989) observed that application of P decreased the toxic level of Fe and Al.

Potassium, the third major nutrient, is absorbed by plants in large quantity. K apparently does not form an integral part of any plant component and its function is catalytic in nature. It is essential for the physiological function of carbohydrate metabolism, N metabolism and synthesis of protein, control and regulation of various essential mineral elements, promotion of the growth of meristematic tissues and adjustment of stomatal movement and water relation (Tisdale *et al.*, 1995).

Potassium absorbed at the maximum tillering stage increased the number of panicles, spikelets per panicle and weight of grains (Mandal and Dasmahapatra, 1983). Mikkelsen and Patrick (1968) indicated that 75 per cent of the total amount of K is absorbed prior to the booting stage and no absorption took place from grain forming to grain filling stage. Application of K tended to increase grain N content and total N uptake while P content was little affected. Applied K decreased Ca and Mg contents in plants grown in alluvial soils (Chakravorti, 1989). Mitra *et al.* (1990) noticed that the application of higher levels of K up to 160 kg ha^{-1} in an iron toxic laterite soil decreased the Fe toxicity symptoms. Bridgit (1999) reported that increased application of K in laterite soil increased the silica content in the grain and straw.

2.2.2. Secondary nutrients

Out of the three secondary nutrients viz. Ca, Mg and S, the element Ca helps to maintain the integrity of the plant structure and function of biomembranes. Calcium stimulated the absorption of P and K (Erdei and Zoldos, 1977). Marykutty (1986) found that Ca application though raised the pH could not bring down Fe content below the critical level of 300 ppm in rice in laterite soil. Role of lime in decreasing K content of rice has also been reported by many workers (Mackay and Mac Eachern, 1962; Kalia and Ryti, 1969).

Magnesium has similar function to that of Ca, which in addition, is a constituent of the chlorophyll molecule essential for photosynthesis and of several essential enzymes. Pot culture experiments on rice conducted by Varghese and Money (1965) and Padmaja and Varghese (1966) indicated that Mg either alone or in combination with Ca and Si appreciably improved crop growth and significantly increased grain yield. Increase in grain yield of rice by Mg application has been reported by many workers (Mani *et al.*, 1993; Muralidharan and Jose,1993; Varughese and Jose, 1993). Mahanta and Choudhury (1997) found that the uptake of Ca and Mg had a significant positive correlation with grain yield.

Sulphur is now recognized as the fourth major nutrient in addition to N, P and K. It is a constituent element of amino acids cysteine, cystine and methionine and the plant hormones thiamin and biotin. Sulphur is involved in the formation of chlorophyll, activation of enzymes and in the formation of glucosides or glucosinolates.

Sulphur application reduced plant content of Fe by reducing leaf sap pH and increasing chlorophyll content (Singh, 1970; Pillai, 1972). Clarson and Ramaswamy (1992) found that rice plant removed 37-42 kg S ha^{-1} and that elemental S would not facilitate heavy absorption immediately. Patra *et al.* (1998) found that application of fertilizer or soil drying for two weeks during active tillering or panicle initiation stage and reflooding increased crop yield by enhancing S mineralisation and supply in S deficient wet land rice soil.

2.2.3. Micronutrients

The micronutrients essential for rice are Fe, Mn, Zn, Cu, B, Mo and Cl. Without the availability of micronutrients, it would not be possible to get maximum benefit from NPK fertilizers (Muralidharan and Jose, 1994 a). Fe is related to the formation of chlorophyll, but is not a constituent of it. Hassan

(1977) has reported that iron content of laterite soils range in the order of 4 to 7 per cent.

Tanaka *et al* (1968) reported that excess Fe in the soil solution readily entered the shoot of rice plant causing Fe toxicity. Rice plants grown in solution containing more than 200 ppm Fe showed Fe toxicity symptoms and yield was reduced and the uptake of other essential elements decreased (Saerayossakul, 1968). Due to the high content of the element in the soil, rice plants absorbed very large quantities of Fe (Anon., 1994). High yielding varieties tended to deposit two kg of Fe on their roots which incapacitated the root system (Marykutty *et al.*, 1993). Pathirana *et al.* (1995) found that Fe uptake was positively correlated with Fe concentration and deposition was greater in roots than shoots. Medhi *et al.* (1999) found that plant Fe concentration was highest at 45^{th} day. Das *et al.* (1997) reported that Fe content of plants significantly decreased in heavy textured soils indicating a positive influence of the soil clay content towards reducing Fe content in the plant.

According to Duarte *et al.* (1993) yellowing of leaves of upland rice after excessive irrigation was associated with Fe toxicity and Mg deficiency. The Fe content of rice collected from Fe toxic soil were as high as 1183-2590 ppm (Tanaka and Yoshida, 1970). However, the plants did not show Fe toxicity symptoms but encountered with severe yield reduction.

Ponnamperuma and Lantin (1985) opined that the reduction in the grain yield of rice due to the toxicity was the reflective of the sterility caused due to excess Fe. The higher concentration of Fe in plant tissues at tillering and panicle initiation stages depressed the absorption of other nutrients leading to poor nutrient uptake and yield. The upper tolerance limit of Fe content for rice has been reported to be 300 ppm beyond which it will interfere in the metabolism of rice (Yoshida, 1981 a). Singh (1970) reported that excess Fe in plant will limit N utilization and will primarily effect chlorophyll development. Potty *et al.*(1992) found that higher yield was associated with lower Fe content in index leaves.

Manganese serves as an activator of several enzymes. This element also occurs in excess concentration in soils of many parts of the State and hence important in limiting rice productivity. Hariguchi and Kitagishi (1976) reported that more than 60 per cent of Mn contained in the plant leaves is in chloroplast and Mn along with Fe and Cu take part in indispensable roles in the electron transport system

Rice has a high degree of tolerance for high Mn concentration in its tissue. Cheng and Quellete (1971) reported that critical tissue content for Mn toxicity was 7000 ppm. According to De Datta (1981) the critical limits of deficiency and toxicity of Mn in rice plants are 20 ppm and 2500 ppm, respectively. Tadano and Yoshida (1978) suggested that a high Mn content in rice tissue was frequently associated with high yields; possibly indicating that a high Mn content in the plant was associated with various favourable soil conditions.

Zinc is involved in the activation of many enzymatic reactions and in N metabolism. Zinc application increased its content in root and shoot and decreased the content of P and Fe in root and Fe in shoot (Gangwar *et al.*, 1989). Subbiah *et al.* (1994) reported that grain yield of rice in black clay loam soil deficient in Zn was significantly correlated with leaf Zn. Rath *et al.* (1999) found that fertilizer containing Zn and Fe brought significant changes in total sugar, amino acid, phenol and chlorophyll contents in rice.

The micronutrient Cu functions as a component of a metallo enzyme and as a regulator of enzymatic action. Copper, along with Fe and Mn, have an important role in the electron transport system of photosynthesis (Kanematsu and Asada, 1989). Excessive Cu hampered root elongation and caused damage to crops when Cu in soil is higher than 125 ppm (Mizuno and Kamada, 1982). Zhou *et al.* (1994) observed sterility of rice plants when Cu was deficient.

Mukhopadyay and Haldar (1994) found that increasing Mo levels with lime decreased shoot and root growth causing an imbalance in nutrition and metabolic disturbances in the plants.

Muralidharan and Jose (1994 b) reported that during *Rabi* season, the highest grain yield was obtained with combined application of S, Mg, Zn, Mn, Cu, B and Mo. Anilakumar *et al.* (1992 a) found that application of NPK fertilizer did not cause significant variation in the micronutrient content of the soil. Soil available Fe and Mn initially increased after submergence and then decreased, while Zn and Cu availability decreased with the period of submergence.

2.2.4. Silica

Rice, like other members of the graminae is reported to accumulate silica in its culms, leaf blades and husks which confers rigidity and resistance against pests and diseases. It also plays a role in transport of oxygen to roots (Ponnamperuma, 1965). He found that Si supply facilitated oxygen transport more efficiently from the plant tops to the roots through enlargement or rigidity of gas channels and as a result increased oxidation and subsequent deposition of Fe and Mn on the root surface, thus excluding them from absorption by the plants. Silica showed beneficial effect on the growth of rice (Yoshida, 1965). The advantages of silicon application in rice have been reported by many workers (Jones and Hendreck, 1967; Lee *et al.*, 1989).

Padmaja and Varghese (1966) found that application of sodium silicate as soil amendment in laterite soil increased the tillering, height of plants and depth of penetration of the root system and the proportion of thicker to thinner roots. Takahashi *et al.* (1966) noticed that silicon promotes CO_2 assimilation in the leaf blades and translocation of assimilated products to the panicle.

Application of silica up to 1000 kg ha^{-1} has increased yield of rice in laterite soils (Potty, 1965). The yield increase due to silicate application varied from 5-13 per cent (Lian, 1976). According to Bridgit (1999), application of sodium silicate at 250 kg ha^{-1} in laterite soil significantly increased the yield of grain and the increase was to the tune of 619 kg ha^{-1}. Combined application of silica with high level of K increased grain yield by 1000 kg ha^{-1} over control (Lakshmikanthan, 2000).

Ma *et al.* (1989) reported that the application of Si at various growth stages of rice increased the plant height and root dry weight. But Si applied at ripening stage has no effect on growth attributes. According to Agarie *et al.* (1992), the maintenance of photosynthetic activity due to Si fertilization could be one of the reasons for the increased dry matter production. Subramanian and Gopalaswamy (1990) observed significant increase in Si content of both grain and straw with addition of various silicate materials in rice soil where rice husk ranked first. Takahashi (1997) reported that rice is known to be a Si accumulator and Si had the fastest uptake rate among the nutrients in solution. Si was mainly accumulated in leaf blades and chaffs.

Takijima *et al.* (1959) noticed an increase in the uptake of potassium by the application of Si. Islam and Saha (1969) reported that the application of Si along with other nutrients in the culture solution has decreased the potassium uptake of rice plants which could be due to more absorption of Ca and Mg ions promoted by Si application. Wagava and Kashima (1963) observed that when Si was applied, the percentage of nitrogen in every part of the rice plant was decreased.

Vora *et al.*(1979) opined that silicon nutrition to rice was essential as it acted similar to phosphates and also as a substitute for sulphate, besides its inter relationship with several other nutrients. Application of silica promoted the utilization of P, reduced absorption of Fe and Mn and stimulates photosynthesis. Levels of lignin·carbohydrate complexes in cell walls were decreased by silicon deficiency (Inanaga *et al.*, 1995). Silica content in rice leaf blade was negatively correlated with N content in soil and plant (Sumida, 1992). Mao *et al.* (1999) found that leaf sheaths and blades contained the highest proportion of Si. Silica content was the lowest during stem elongation and hence the crop at this stage was easily susceptible to stem borer.

Application of silica increased the resistance of rice plants to white backed plant hopper (Mishra and Misra, 1992). Wang *et al.* (1999) reported that application of Si increased plant height, grain weight, yield and decreased *Helminthosporium* leaf spot and sheath blight of rice plant.

Saigusa *et al.* (1998) found that porous hydrate calcium silicate (from the industrial wastes of autoclaved light concrete) is an effective silicate material for improving the silica nutrition of rice. Silicon soil amendment like rice hull ash reduced disease severity in rice (Lee *et al.*, 1998). Yein *et al.* (1983) suggested that the application of rice hull at 20 t ha^{-1} about one week before planting increased the grain yield from 7.2 to 8.2 t ha^{-1}.

2.3. Soil submergence and rice nutrition

When an aerobic mineral soil is submerged it undergoes reduction and the redox potential drops to a fairly stable value of + 0.2 to –0.3 V (Ponnamperuma, 1972). The oxygen supply in a soil is curtailed and facultative and anaerobic microorganisms start the reduction of soil components with high oxidation state. Mensovoort *et al.* (1984) reported that the soil reduction takes place in a sequence and during this process, organic matter is oxidized, acid is consumed and consequently pH is rised.

The chemical changes created by soil submergence provided both benefits and disadvantages for the rice plants' nutrition. Ponnamperuma (1972) observed that soil submergence creates a unique environment for the growth and nutrition of rice. While it provides an ample supply of water to rice, which is the greatest advantage, it creates for rice roots an environment that is characterized by lack of oxygen and a subsequent series of reductive chemical changes. To avoid suffocation of root tissues in submerged soils, the rice plant has developed special tissues through which air is transported from shoot to root (Van Raalte, 1944).

Following soil submergence, concentration of P, K, Fe, Mn and Si in the soil solution were increased (Ponnamperuma, 1965) and the concentration of Zn was decreased (Forno *et al.*, 1975). The increase in ferrous iron concentration in the soil solution was often excessive and induced Fe toxicity in rice.

Transformations of N in wet land rice soil included changes in both aerobic and anaerobic microsystems. Ammonia volatilization, nitrification, leaching and run-off were reported to be the pathways through which N is lost from the rice soil (Patrick and Mahapatra, 1968; Savant and De Datta, 1982). Studies have revealed that major portion of N in wet lands occured in organic pool. Mineralisation of organic N to NH_4^+ ions presumably takes place in the reduced layer. Because of the lack of adequate oxygen, mineralisation stopped resulting in the accumulation of NH_4^+ ions (Abichandani and Patnaik, 1958; John and Thomas, 1990).

Patrick (1960) reported that in a submerged soil nitrate is extremely unstable. Within a few days after submergence, the bulk of original or added nitrate is lost as N gas by denitrification. The loss of N by denitrification could be minimized by keeping the soil continuously flooded (Castro and Lantin, 1976). Conversely, alternate wetting and drying of soils led to high N loss (Patrick and Mahapatra, 1968).

Patrick (1981) reported that most of the anaerobic organic matter decomposition taking place in soil were supported by oxidized bioreducible ferric compounds. The high capacity of the oxidized Fe compounds for accepting electrons made Fe the key redox element in flooded soil. The reduction of Fe was more dominant than that of Mn because of the presence of much higher content of active Fe in rice soils (Mitra and Mandal, 1983).

Tanaka and Yoshida (1970) found that iron toxicity symptoms of rice appeared as tiny brown spots on the tips of lower leaves, spreaded to the upper leaves and eventually the lower leaves turned gray and died. The nutritional status of the plant has been found to affect the plants' tolerance for Fe toxicity. K content of rice plants exhibiting bronzing symptom was often low. Deficiency of K, Ca, Mg, P and Mn weakened the iron excluding power of roots. When there was high level of Fe in the growth medium, the Fe excluding power and Fe retaining power of the roots were impaired by the iron itself (Tadano, 1976).

The reported critical concentration of Fe in soil solution for rice varied greatly. At one extreme, 45 ppm (Baba, 1958) or 50 ppm Fe (Ishizuka *et al.*, 1961) produced Fe toxicity in the plant. At the other extreme rice growth was not affected when the Fe concentration was as high as 1680 ppm (De and Mandal, 1957). Thus there seems to be no simple relationship between the Fe concentration in the soil solution and occurrence of Fe toxicity. The concentration of Fe that produce Fe toxicity symptoms appears to vary with pH of the soil solution. Tanaka *et al.* (1966) reported that it was about 100 ppm at pH 3.7 and 300 ppm or higher at pH 5.0.

Tadano and Tanaka (1970) observed Fe and K interaction in rice. Plants suffering from iron toxicity symptoms were low in K and K deficiency accelerated the development of these symptoms. There was a clear evidence that the susceptibility of rice to Fe toxicity was influenced by the physiological status of the plants.

Cheng and Quellette (1971) reported that .Mn concentration in the soil solution increased after flooding. Mn toxicity in wet land rice was uncommon since rice roots have a high degree of Mn excluding power and rice has a high degree of tolerance for high Mn content in tissues. Apart from its role as a plant nutrient, Mn plays an important part in redox equilibria. Ponnamperuma (1965) found that soils high in Mn undergo slow reduction and addition of Manganese oxide retarded soil reduction and improved the growth of rice in problem soils (Nhung and Ponnamperuma, 1966).

Under highly reduced conditions, in submerged soils, sulfate was reduced to sulfide (Takai and Kamura, 1966). Sulfide inhibited the respiration and oxidizing power of rice roots, thus retarded the uptake of various nutrients and hence caused poor growth (Mitsui *et al.*, 1951).

Organic acids such as formic, acetic, propionic and butyric acids occured in submerged soils. Acetic acid was generally the major organic acid produced (Motomura, 1962). The production of organic acids is enhanced by incorporation of readily decomposable organic matter.

2.4. Laterite soils

The high rainfall and temperature conditions of Kerala state are conducive for the laterisation process leading to the development of highly weathered, leached and infertile soils. Laterite soils cover nearly 60 per cent of the total area of the state occupying the mid land and mid upland regions.

Martin and Doyne (1927) put forth the chemical definition of laterite and related soils based on the silica/alumina ratios of clay fractions. According to them, soils in which this ratio was less than 1.33 might be called laterite soils; 1.33-2.00 indicated lateritic soils and ratios above 2.0, non lateritic soils.

According to Alexander and Cady (1962) laterite is a highly weathered material, rich in secondary oxides of iron, aluminium or both. It is nearly void of bases and primary silicates, but it may contain large amounts of quartz and kaolinite.

According to Venkataraman and Krishnan (1992) the development of the soil profile and its physical and chemical composition have a significant bearing on crop performance. These were either the result of or were very greatly affected by weather. In soils of high rainfall region, there would be a large accumulation of iron oxide (indicating ferralisation). Since ferralisation and desilicification were associated with laterisation, the overall effect was the formation of a lateritic type of soil characterized by acidic reaction, low base status and presence of plinthitic gravel.

2.4.1. Rice production in laterite soils

Lateritic soils of the state, often referred to as middle valley laterites, occupy 235000 km^2 of the land area of the state. It accounts for more than 60 per cent of the rice soils in Kerala. The productivity of rice in laterite soils is seriously affected because of several limiting factors associated with these soils. This includes the characteristic physico-chemical properties of these soils, including nutrient toxicities. The soils are inherently acidic and infertile with high phosphate fixation. Due to high rainfall during monsoons the recovery of applied N and K is very less, with a fertilizer use efficiency of 30-35 per cent for N and 50-60 per cent for K. According to Patnaik (1971), low productivity of laterite and allied soils could generally be attributed to low pH, low base saturation, low available P and high P fixing capacity and toxicity of Fe and Al. Due to the lateritic nature of the soils, phosphorus and potassium nutrition of rice was adversely affected leading to the non responsiveness to P and K. Washing off of cations and toxicity of soluble iron and aluiminium in low lying areas added to the soil problems.

Iron and Mn chlorosis in paddy due to excess available forms of iron and Mn was reported by Karim and Mohsin (1964). Santos (1966) was of the opinion that the low yields of rice in acid soils were not due to Ca deficiency; but due to decreased availability of P and toxic levels of Al and Fe. Kanwar and Grewal (1960) noticed that when soluble phosphoric acid was applied to laterite and acid soils, it becomes fixed in the soil largely as basic iron phosphates. The free sesquioxides were responsible for 72 per cent of the P fixed in acid soils.

Bridgit and Potty (1992) reported that individually all the elements in the plant system were higher than what is required to produce a yield above 7000 kg ha^{-1}. The low yield in laterite soils therefore had been not due to deficiency of major elements, but due to excesses of native elements like Fe, Mn and Zn getting absorbed into the plant and inhibiting the expression of yield. These elements were far higher than the critical level proposed by Tandon (1991). They have further found that Fe content in the root was as high as 98000 ppm and has been higher in the plant through the progressive phases. While Fe decreased steadily from culm to boot leaf, Mn level increased from culm to boot leaf. John *et al.* (2001) also has reported that toxicities of Fe, Al and,Mn are limiting the crop production in many areas and that these nutrient imbalances are to be rectified for sustaining crop production.

Ota (1968) found that poor development of lateral roots and root hairs and the development of lion tail roots were often observed in plants grown under iron toxic conditions. He also noticed that bronzing of paddy was due to high Al content and Ca deficiency. IRRI (1972) reported that excess iron led to bronzing in laterite soils of India, Ceylon, Thailand, Malaysia and Combodia. Howeler (1973) found that excess iron induced deficiency of P, K, Ca and Mg .

Anilakumar *et al* (1992 b) noted accumulation of an extraordinary high level of iron in rice in early stages but the content declined as growth advanced. The sluggish growth rate observed in early stages as well as incomplete metabolism of N might be partly due to this excess Fe. Singh (1992) found that Fe toxicity caused fewer panicles and filled grains, delayed crop maturity and yield reduction of 1 to 2.0 t ha^{-1}.

Musthafa and Potty (1996) have reported that high nitrogen absorption and resultant narrow N/Fe ratio leads to low productivity of rice. Response of K in laterite soil is in part by limiting the uptake of cations like Fe, Mn, Cu etc. which in turn implied that a relatively high content of K will be required. Yoshida (1981 a) have also reported that the deficiency of K increased the uptake of Fe by the rice plant.

2.4.2. Management of iron toxic soils

Measures to improve and sustain the productivity of rice-rice cropping system in iron toxic soil should include balanced fertilization, selection of varieties and adoption of suitable management practices.

2.4.2.1. Balanced fertilization

Ismunadji *et al.* (1989) stated that the Fe toxic soils could be made productive with proper fertilization. They have observed that an increase in the yield of rice from 2958 to 5594 kg ha^{-1} and a low percentage of empty grains (<30%) with the application of potasssium in these soils. Similar reports were also made by Yoshida (1981 b) and Mitra *et al.* (1990). Application of 90 kg P_2O_5 ha^{-1} to Fe toxic soils resulted in a drastic reduction in Fe^{2+} from 3.60 to 1.63 mg kg^{-1} at Barapani farm of Meghalaya in India (Singh *et al.*, 1992). The highest grain yield response was observed in the treatment where rice seedling roots were dipped in single super phosphate and farm yard manure slurry before transplanting (Singh *et al.*, 1994).

Benckiser *et al.* (1984) claimed that Ca and Mg played an important role in alleviating Fe toxicity of rice. They indicated that a multiple nutritional stress was the main cause of Fe toxicity in rice and suggested that fertilization with N, P, K, Ca. Mg and Zn improved the Fe excluding mechanism of the plant, since root tissues had lower Fe and higher K, Ca and Mg than unfertilized plants. Sulphur application also is reported to reduce plant content of iron by reducing leaf sap pH and increasing chlorophyll content (Singh, 1970; Pillai, 1972).

Singh *et al.* (1992) recorded the greatest yield response (1.2 t ha^{-1}) with 4 kg Cu ha^{-1} and almost equalled with the treatment receiving 12 kg Zn ha^{-1} in Fe toxic soils of Meghalaya. According to them the significant increase in the uptake of Zn, Cu, Mn, P, K over the control and the simultaneous reduction in Fe might have led to proper nutrient balance and higher efficiency.

According to Aime (1990) the application of Mn and Cu alleviated Fe toxicity by counterbalancing higher Fe concentration and reducing sterility. Application of N, P and K with Zn and Cu caused drastic reduction in the content of Fe^{2+} in different plant parts by mutual antagonism (Suresh, 1996)

Devi *et al.* (1996) found that considerable reduction in Fe^{2+} concentration was found in soil as well as plants during panicle initiation stage when 600 kg ha^{-1} lime was applied entirely as one top dressing. Addition of NPK and /or lime with or without manure reduced Fe concentration in plants while manure alone increased Fe concentration (Brancher *et al.*, 1996).

Mitra *et al.* (1993) found that Fe toxicity was reduced by K application at a level of 120 kg K_2O ha^{-1} or more and it resulted in increased yield. Similar observations were reported by Bandara and Gunatilaka (1994) also. They found that increased application of P also decreased Fe toxicity symptoms.

Quang *et al.* (1996) reported that increasing P concentration in plant increased grain yield by reducing deleterious effects of increasing Al and Fe concentrations. Increasing P uptake resulted in formation of Al-P complex, thus reducing the concentration of Al^{3+}.

Liao *et al.* (1994 b) found that leaf oranging from Fe toxicity was reduced by application of Si and/or Mn. It also decreased Fe concentration in soil solution. They found that fertilizing with Mn raised Mn:Fe ratio and that Mn treatment led to reduce Fe deposit in root epidermis and more Ca and Si in roots and it could correct Fe toxicity. Bhattacharya *et al.* (1996) reported that in iron toxic soils, application of FYM and K could maintain a balanced uptake of N and P in rice leading to better grain and straw yield.

Olomu *et al.* (1973) reported that iron in soil solution was complexed with organic matter. IRRI (1976) reported that addition of organic matter reduces the severity of iron toxicity and that apparently straw can serve as an ameliorant for iron toxic soils. It implies that application of straw to such soils can improve the early growth of paddy.

2.4.2.2. Varieties and iron toxicity

Selection of Fe^{2+} tolerant rice should be based on plant height, root biomass, the ability of roots to oxidize, flag leaf photosynthetic rate and dry matter production. Rice is known to have a peculiar capacity to exclude Fe from its normal metabolic process by either preventing its absorption from the soil or by limiting its accumulation in the roots (Tadano and Yoshida, 1978). It is also known that varieties differ in their potential for Fe exclusion power

High yielding varieties are more susceptible to Fe toxicity than traditional local varieties (Elsy *et al.*, 1994).

Marykutty *et al.* (1993) reported that the contents of iron and phosphorous in the root deposits were high in Red Triveni, BR-51 and Jyothi. This variation among varieties in the quantity of deposits appears to be a function of root oxidizing power of the varieties.

Sahrawat *et al.* (1996) opined that genetic tolerance to Fe toxicity could significantly improve rice production in Fe toxic soils. The application of N, P, K and also Zn decreased the uptake of Fe in rice and this could be a significant factor in the iron toxicity tolerance of the cultivars.

Nipah *et al.* (1999) reported that genes responsible for tolerance to Fe toxicity were dominant. Bode *et al.* (1995) estimated the super oxide dismutase and peroxide activity of root extracts of iron tolerant variety to be about twice higher than iron sensitive cultivar. Hu *et al.* (1999) found that iron stress significantly increased the activities of ascorbate peroxidase, glutathione dehydrogenase and glutathione reductase. Activities in the tolerant lines were higher than those in sensitive lines

2.4.2.3. Tillage and water management

Drainage is effective in reducing iron toxicity. Under oxidized condition ferrous iron (Fe^{2+}) would be converted to ferric iron (Fe^{3+}) which is not available to the rice plant. Irrigation three days after disappearance of ponded water was better than submergence. Submergence led to a reduced environment and facilitates increased availability and uptake of elements like Fe, Mn etc. (Datta, 1981). Hence higher yields with drainage would be due to minimised uptake of elements like Fe and Mn. Zaini *et al.* (1987) reported that intermittent drainage could lessen the severity of Fe toxicity. Pot experiment using Fe toxic soils conducted by Tahir and Misran (1984) indicated that the application of N, P, K, Mg, Cu and Zn along with draining twice during the crop growth increased plant height, tiller number and yield of rice.

The advantages of deep tillage in rice culture have been reported by many workers. The breaking up of hard subsoil was reported to increase paddy yield by 50 per cent in heavy clay soil (Oh *et al.*, 1962). Experiments at Regional Agricultural Research Station, Pattambi also have indicated the beneficial effects of deep tillage in rice (Anon., 1989). Kundu *et al.* (1996) observed that mineral N availability in the 0-45 cm profile and rice N uptake was significantly higher with tillage to a depth of 40 cm than to 15 or 25 cm. Wade *et al.* (1996) found that root mass density was almost tripled by deep tillage. On the contrary, Pearce *et al.* (1999) has reported that deep tillage was not superior to conventional tillage. Bridgit (1999) reported that digging to a depth of 30 cm instead of 15 cm significantly increased the yield by 621 kg ha^{-1} grain and 319 kg ha^{-1} straw. Increasing the depth of digging increased the soil volume for root ramification which in turn facilitate better nutrient absorption, plant growth and yield. Increase in rice yield due to deep digging have also been reported by Mosand *et al.* (1993). But in a situation wherein excess elements limit growth, deep digging will also increase the excess elements.

2.5. Nutrient interactions and rice growth

Nutrients do not work in isolation. Interactions among nutrients can be antagonistic or synergistic. Marykutty *et al.* (1992) found that ratios of elements in tissues and not the levels or levels of application to soil governs the productivity expression of rice.

Sahu (1968) reported that high K content of leaf decreased the bronzing in rice plant due to higher Fe content. In a healthy plant the Fe:K ratio is 1: 9.5 to 1 : 22.9 while in an infected plant it is 1: 1.3 to 1: 6.3. Singh and Singh (1987) studied the effect of applied K on Fe toxicity and found that K content was increased with K application and was more pronounced at flowering stage. P content was increased with K application while Fe concentration reduced drastically indicating K-P synergism and K- Fe antagonism. The total uptake and percentage translocation of N, P and K by rice increased significantly with increasing levels of K. Musthafa and Potty (1996) reported that widening N/Fe ratio has increased the yield of rice. Sreeman narayana and Sairam (1995) found that increasing K rate decreased leaf Fe and Mn contents while it increased leaf Zn content slightly.

The ionic ratios of Fe:P and Ca:Fe at tillering stage could be used for predicting yield of rice grown in Fe toxic soil (Pattanayak *et al.*, 1998). Bulbule and Despande (1989) reported that tolerant varieties maintained a high nutrient ratio of N/Fe, P/Fe, K/Fe. Mg/Fe and Mn/Fe. They also stated that excess Fe absorption was related with multiple nutritional stress and the resulting low K/Fe and P/Fe ratios led to more serious yield reduction than Ca/Fe and Mg/Fe ratios. Also higher uptake of Mn reduced the injurious effect of Fe.

Application of $CaCO_3$ decreased concentration of Fe^{2+} in the soil solution and increased N and P contents of straw. Addition of MnO_2 decreased Fe^{2+} : Mn ratio in plant tissue and increased grain yield (Li, 1993). Fageria *et al.* (1995) also found that increasing levels of lime reduced the uptake of P, Zn, Cu, Mn and Fe and increased the uptake of Ca and Mg. Reports of Mizuno and Kamada (1982) showed that Fe absorption increased with Cu deficiency and plant became sterile when Cu/Fe ratio of above ground parts became less than 0.01. Zhang *et al.* (1999) stated that under anaerobic conditions, ferric hydroxide deposits on the surface of rice roots have shown to affect the uptake of some nutrients.

Iron toxicity in rice was accompanied by deficiency symptoms of N, P and K (Medhi *et al.*, 1999). K deficiency reduced the iron excluding power of the rice roots (Chatterjee and Maiti, 1981). Tanaka and Yoshida (1970) also reported that an interaction existed between Fe and K in the plant; plants exhibiting bronzing symptoms were usually low in K and application of K remedied the disorder. Application of lime and P also minimised the problem. Gangwar and Mann (1972) reported that Zn application decreased both Fe and Mn concentration in plants. Application of N, P, K with Zn + Cu caused drastic reduction in the content of Fe^{2+} in different plant parts by mutual antagonism (Suresh, 1996).

According to Mahanta and Choudhury (1997) there was a significant effect of interaction between N and K on Ca and Mg uptake by grain and straw.

Mensovoort *et al.* (1984) found that excess Fe reduces yield by tilting the balance between Ca and K. Decrease in K uptake due to high lime was probably due to antagonistic effects of Ca and Mg and reduced micronutrient uptake is probably due to increased soil pH resulting in decreased availability of these elements.

Varughese and Jose (1994) reported decrease in available K with increased Mg application which confirms K-Mg antagonism. Muralidharan and Jose (1994 a) reported that both Ca and Mg compete with K for entry into plants. Marykutty *et al.* (1992) found no relationship of plant contents N, P and K to rice productivity, but found the relative balance between Ca + Mg as the nutritional yield determinant.

The weathered soil is low in Si and high in Fe. According to Liao (1994 a) leaf oranging was associated with low Ca uptake because of heavy Fe oxide coating of the roots. Leaf oranging, however was not associated with toxic levels of Fe or Mn in soil.

Tadano (1976) attributed the beneficial effects of silica to reduced absorption of Fe and Mn. Silica uptake in plant was generally influenced by the nutritional status of the rice plant and not by K, Mg and S.

Gangwar *et al.* (1989) reported that Zn application increased its content in root and shoot and decreased the content of P and Fe in root and Fe in shoot. Chitdeshwari and Krishnaswamy (1998) also found that application of Zn decreased the availability of Fe and Mn which indicated the mutual competition of these two ions at the absorption sites.

Haldar *et al.* (1997) reported that application of P increased the content of extractable P and Zn but decreased that of Si and Cu in soil. Application of Si increased Si, P and Zn content, but decreased that of Cu.

Zinc application increased the availability of Zn while B decreased it. Availability of Cu and Mn were not affected by fertilizer treatments. Application of S markedly increased Zn uptake. Zn application increased the uptake of Cu (Muralidharan and Jose, 1995).

Muralidharan and Jose (1994 b) reported that total N uptake was significantly enhanced by the application of B, Cu and Mo in laterite rice soil. Application of B resulted in higher uptake of P whereas application of Zn resulted in low P uptake. This suggests the antagonism between Zn and P.

Mukhopadyay and Haldar (1994) reported that the application of Mo with or without lime decreased the concentration and uptake of Al and Fe by both the shoot and the root.

Continuous nutrient imbalances lead to deterioration in soil health, which is reflected in overall reduction in physical, chemical and biological properties of soil. These results bring forward the idea that the interactions among the macro and micro-nutrients determine productivity.

2.6. Cropping system and productivity of soil

In rice-rice cropping system where intensive cultivation system are followed, in order to attain high and assured levels of productivity , efficient management of manures and fertilizers is needed. It is generally agreed that at least a part of the nutrient left over in the soil is utilized by the succeeding crop raised in the same field. Long term experiments with modern rice varieties showed that after several years of intensified cropping with constant and high fertilizer inputs, grain yields began declining (Cassman and Pingali, 1995).

2.6.1. Use of manures and chemical fertilizers

De Datta *et al.* (1998) reported that N use efficiency decrease over time. The effects of successive application of fertilizers on cation exchange capacity and exchangeable calcium in the soil were not consistent. According to Santhi and Selvakumari (1998) in a rice-rice cropping system, compared with NPK fertilizers alone, use of a green manure and phosphobacteria in combination with NPK increased yield of all crops and residual soil fertility.

Devi *et al.* (1997) found that application of 45:45:45 kg NPK ha^{-1} as mineral fertilizers and 45 kg N ha^{-1} as farm yard manure in the *kharif* season followed by 90:45:45 kg NPK ha^{-1} in the *rabi* season gave the highest yield. Maximum net production was recorded in the sequence where both the rice crops were green manured with legumes along with 75 per cent recommended dose of N, P and K (Pradhan and Mondal, 1997). Kitada *et al.* (1993) noticed that available soil nutrient were increased more by a short term rotation (2-3 years) than by long term rotations. Short term rotation was an effective means of soil management for paddy and it maintain stable soil productivity.

According to Zhou *et al.* (1994) soil fertility was increased with balanced application of N, P and K fertilizers and pig manure in double cropping rice field. Yamoah et al. (1998) observed that crop rotations increased the N removal index and reduced its year to year variability and zero N application rate increased the return of N in residue to the soil N pool compared with continuous cropping of single species.

Basumatary *et al.* (1996) observed that continuous application of graded levels of NPK in rice-rice sequence for seven years significantly increased all forms of K in the low K soils of Assam. Integrated treatment replacing 25 and 50 per cent of chemical N with organic sources was superior.

Hegde (1996) observed positive N and P balance and negative K balance with the recommended levels of nutrients applied. It was also observed that grain yield was not decreased by substituting 25 per cent N with rice straw and that integration of FYM and rice straw with chemical fertilizer had a more favourable effect on nutrient balance than did green manures.

An experiment at Hyderabad showed that constant productivity is possible with 80 kg N + 40 kg P_2O_5 and 40 kg K_2O ha^{-1} in both *kharif* and rainy seasons. After 10 consecutive years of cropping, available soil P and K were depleted compared to their initial status. Available Fe, Zn, pore space, water holding capacity and volume expansion increased over the experimental period (Reddy *et al.*, 1999).

Panda *et al.* (1999) found that continuous fertilizer application in rice-rice sequence resulted in increase in available P whereas soil available K declined over the years. Kulkarni *et al.* (1983) has reported that cattle manures by virtue of their nutrient content and organic carbon content were more effective in their direct as well as residual effect in a rice-rice cropping system than green manure.

Katyal and Gangwar (2000) reported that application of 25 to 50 per cent of fertilizers in organic form gave the best yield stability in rice-rice double cropping system set up in Andhra Pradesh, Orissa and Kerala from 1983-96. Mohanty and Sharma (2000) opined that in the eastern and southern states of India where intensive rice cultivation systems are followed under irrigated conditions, efficient management of fertilizers including organic manures is required to obtain high and assured levels of productivity in rice-rice cropping system.

2.6.2. Use of crop residues

The return of plant nutrients absorbed by crops back to the soil is one of the basic principles in maintaining soil fertility. Eighty per cent of K, Ca and Si, 50 per cent of Mg and 25 per cent N, P and S absorbed by rice plants are accumulated in the straw (Chatterjee and Maiti, 1981). Hence application of straw returns substantial amounts of these nutrients to the soil. The role of rice straw in improving organic carbon status of soil has been reported by many workers. Singh and Deka (1990) reported that incorporation of rice straw combined with N ensured substantial improvement of organic matter content. Rice straw could be used to substitute 25-50 per cent of the N needs of the monsoon rice crop in the rice-rice cropping system (Hegde, 1997).

Lee *et al.* (1998) reported that urea and lime greatly increased the rate and extent of rice straw decomposition in soil. Sarmah and Bordoloi (1994) have reported that rice straw caused N immobilization during the initial period of decomposition.

Tisdale *et al.* (1995) have stated that when organic materials have C:N ratio between 20 and 30 there will be neither mineralisation nor immobilization. Foth and Turk (1972) found that 35 per cent of the total carbon applied to the soil by way of organic manures could be humified if nitrogen is added to raise the level of C:N ratio to 10:1. Cereal straw and residues on maturity contained about 0.5 per cent N, 0.6 per cent P and 1.5 per cent K. Kumar *et al.* (1999) found that crop wastes improved the nutrient content of the soil. Crop yield and soil fertility was further improved when these organic materials were combined with inorganic fertilizers.

Aggarwal (1994) studied the effect of different crop residue management techniques like removal, burning and incorporation. Residue incorporation increased organic carbon, infiltration rate and other properties associated with soil erodability. Prasad *et al.* (1999) found that rice residues could be safely incorporated without any detrimental effects on the following crops. It improved soil fertility by improving organic carbon and available P and K contents. Residue incorporation was more beneficial than residue burning, which resulted in the loss of valuable plant nutrients.

Dhiman *et al.* (2000) reported that rice grain yield was superior with incorporation of rice residues than burning and removal. Organic carbon and total N in the soil increased with the incorporation of crop residues but decreased with their burning. Sistani *et al.* (1998) found that incorporation of rice straw significantly increased rice grain yields, while rice husk ash did not.

2.6.3. Green manure crops in the system

The importance of green manuring in agriculture has been recognized as early as 500 B.C. (Kadke, 1965) and since then it has been practiced by rice farmers. The benefits of green manuring included increase in available plant nutrient and organic matter content, improvement in physical and biological properties of soil and the overall impact in increased crop production (Singh, 1962).

Lohins (1926) reported primary action of organic matter wherein addition of easily decomposable organic matter leads to decomposition of native organic matter thus liberating more nutrients for crop growth. The increased P, K and trace elements due to green manuring had been attributed to the solubilising effect of decomposing organic matter (Shrikhande, 1948). Effects of green manuring on increased K availability and higher P content in soil solution had been attributed to the combined effect of green manure as well as the release of CO_2 and weak acids which could act on insoluble minerals (Agboola, 1974). He has also reported that green manure crops because of their deep penetrating root system absorbed nutrients from lower layers of the soil and enrich the top soil on decomposition to benefit the crops. He attributed the beneficial effects of green manures to this recycling effect.

Legumes with their adaptability to fit in the various cropping systems and their ability to fix atmospheric N, offer opportunities to increase and sustain productivity and income in rice based cropping system. The residue could supply N to rice and improve soil fertility which in turn increase the productivity of rice. John *et al.* (1989 a) found that use of dual purpose cowpea offered the advantage of 0.9 to 1.0 t ha^{-1} cowpea grain production with no significant reduction in N contribution to rice.

Sunhemp and daincha are popular legumes for green manuring in rice and could accumulate up to 100 kg N ha^{-1} in 50-55 days (Singh *et al.*, 1991). Incorporation of these green manures in situ before transplanting rice supplied about 45-60 kg N ha^{-1} besides providing a significant effect to the succeeding crops (Mohanty and Sharma, 2000). Vaiyapuri *et al.* (1998) and

Somasundaram *et al.* (1996) reported the advantages of green manuring with *Sesbania sp.* in improving chemical properties of soil and grain yield in rice-rice cropping sequence.

Thakur *et al.* (1999) observed that in a rice double cropping system, substitution of 25 per cent N in *Kharif* through Azolla produced comparable yields with standard 100 per cent NPK level. Soil status of nutrient showed a general increase in available P and organic carbon, but K level showed a decrease.

Mathew *et al.* (1991) have reported that intercropped cowpea is an ideal green manure for semi dry rice in Kerala and it resulted in an yield increase of 600 kg ha^{-1}. John *et al.* (1989 b) found that lentil residues benefited the succeeding rice. The effect of lentil residue incorporation was equivalent to 33 kg N ha^{-1} when 60 kg N ha^{-1} was applied to rice.

Fertiliser use efficiency was improved when a legume crop was introduced in rice-rice cropping system (Pradhan and Mondal, 1997). Mohanty and Sharma (2000) suggested that productivity of rice–rice cropping system could be increased by about 1 t ha^{-1} besides a net saving of 30 kg fertilizer N ha^{-1} by including a short duration legume such as cowpea or green gram and incorporating its residues into the soil after harvesting the grain.

Cowpea green manure N substituted for a nearly equivalent quantity of urea, whereas cowpea residue N was more effective than urea N. Residue released mineral N more slowly than did green manure and hence less N losses (John *et al.*, 1992).

A dual purpose grain legume with residue incorporation could increase the soil nutrient supply and rainfed rice system productivity (Kulkarni and Pandey, 1988). NPK contents of grain were maximum when rice was grown after cowpea residue incorporation (Jacob, 1994). John *et al.* (1989 c) found that incorporation of cowpea green manure or residue increased soil extractable ammonium and total plant N but it had no effect on N loss from urea applied to rice.

Studies on biomass production and N accumulation have shown that 60 day old cowpea produced 6.9 t ha^{-1} of dry matter and the corresponding N addition is 113 kg ha^{-1} (Beri *et al.*, 1989). Besides increasing the N supply to the rice crop, green manures enhanced the P use efficiency of rice (George and Prasad, 1989; Joseph, 1994) and increased the translocation of Zn and S to grain (Mythili *et al.*, 1993). The beneficial effects also included more favourable physical, chemical and biological conditions of the soil amended with green manures.

Jana and Ghosh (1996) studied the effect of integrated nutrient management in rice-rice crop sequence in a sandy clay loam soils in West Bengal and found that application of 100 per cent fertilizer alone or 75 per cent inorganic + 25 per cent organic fertilizer gave highest yield in rainy season whereas during the winter seasons yield was highest with 50 per cent NPK plus 50 per cent FYM. Pathak and Ghose (1996) also have stressed the importance of balanced fertilization in rice-rice systems and blending of organic and inorganic sources for sustainability and crop productivity.

2.7. Cropping system and soil organic carbon status

Changes in soil organic carbon status was influenced by cropping and tillage practices (Soon and Arshad, 1996). Tian *et al.* (1999) found that crop fallow maintained soil organic carbon status better than natural fallow. Kuo *et al.* (1997) also reported that cover crops increased soil carbon levels or reduce their rate of depletion. Including a legume in the cropping sequence increased soil organic carbon and available soil P level (Singh *et al.*, 1996). Armstrong *et al.* (1999) reported that soil organic carbon progressively increased under Siratro, Desmanthus and Sorghum, but remained unchanged under mungbean, Lucerne and lablab.

Beneficial effects of leguminous summer crops in improving the organic carbon in rice soil have been reported by Jacob (1994). Menon (1987) and Anilakumar and Sivakumar (1994) have reported that in a double cropped rice field, organic carbon status steadily increased when the field was occupied by a legume crop during summer; it declined under fallow.

Ploughing of pasture caused a large fall in the organic carbon. The soil organic carbon fell markedly during the first five years of the experiment and then seemed to have stabilized for all the rotations (Andriulo *et al.*, 1999). But continuous fertilizer application resulted in increase in soil organic carbon (Panda *et al.*, 1999). On the contrary, Belanger *et al.* (1999) reported that soil carbon was not affected by continuous fertilization in the long run. Soil carbon was negatively correlated to soil pH.

Kumar *et al.* (1999) reported that application of crop wastes improved the organic carbon. Inorganic fertilizer alone did not increase the organic carbon content of the soil. Integrated use of organic and inorganic fertilizer increased soil organic carbon (Hegde, 1997). Mathew and Nair (1997) also have found that balanced application of organic manures in combination with chemical fertilizer is important for improving soil organic carbon content and maintaining soil health and productivity.

The decomposition rate of organic matter is directly related to temperature, moisture regime and input of organic substances. According to Menon (1987), after legume crops there was an increase in the organic carbon content of soil and the increase was higher in the top 0-15 cm layer than in the lower 15-30 cm layer.

Cassman *et al.* (1995) found that in several long term experiments with continuous, irrigated double and triple crop rice systems in the tropics, a yield decline associated with decreasing effective soil N supplying capacity has occurred despite the conservation or increase in soil organic carbon and total N of whole soil. Changes in soil organic matter composition were causing a decline in the supply of N from non fertilizer sources when irrigated cropping is intensified (Dobermann, 1998; Kundu and Ladha, 1999). Olk *et al.* (1999) compared the chemical composition of soil organic matter from fields under different histories of rice cropping and he found that with increased frequency of irrigated rice cropping there was a large increase in phenolic content of soil organic matter. This increased phenolic content might influence N cycling and the N supplying capacity of lowland soils supporting two or three annual crops of irrigated rice. Increased phenol accumulation in the whole soil and also in the labile humic acid extract of the soil was known to inhibit N mineralisation of crop residues and green manures in flooded rice soil (Becker *et al.*, 1994).

Materials and methods

3. MATERIALS AND METHODS

The research project entitled, "Nutritional constraints of rice- legume system in laterite soils of humid tropics" was carried out from 1997-'98 to 1999-'00 at Regional Agricultural Research Station, Pattambi, Kerala. The details of materials used and methods adopted in the conduct of the experiments are presented in this chapter.

3.1. Location

Regional Agricultural Research Station, Pattambi is located at 10° N latitude and 76° E longitude and at an altitude of 25.4 m above mean sea level.

3.2. Weather and climate

The area experiences a humid tropical climate. The weekly averages of important meteorological parameters observed during the experimental period are presented in Appendix I to VII.

The mean maximum temperature during the *rabi* seasons was 31.9° c and the mean minimum temperature was 22.4°C. During the *kharif* seasons the corresponding temperatures were 29.7° C and 23.4° C respectively. The mean RH was higher during the *kharif* seasons. Though the RH values in general were low during *rabi* seasons, *rabi* 1998-'99 period had comparatively higher RH. The highest total rainfall of 2045 mm was received during *kharif* 1998-'99 crop period distributed in 84 rainy days. *Kharif* 1999-'00 received 1609 mm. Among the three *rabi* seasons, 1997-'98 period had the highest total rainfall of 461.9 mm. The amount of rainfall during *rabi* 1998-'99 and 1999-'00 were 332.1 mm and 268.4 mm, respectively.

Mean evaporation and wind speed were the highest during *rabi* 1999-'00 and it was the lowest during *kharif* 1998-'99. *Rabi* 1998-'99 recorded comparatively lower values for these parameters. The total amount of sunshine received was the highest during *rabi* 1997-'98 (863.1h). *Rabi* 1999-'00 received 783.3 h whereas during *rabi* 1998-'99 it was only 602 h. The amount of sunshine received during *kharif* 1998-'99 and 1999-'00 were 419.1 h and 563.5 h respectively.

3.3. Soil

The soil type is lateritic sandy loam of the oxisol group. The soil is acidic in reaction with pH of 5.17. The physico chemical characteristics of the soil of the experimental fields are presented in Table 3.1.

3.4. Crop and variety

A. Rice

The rice cv. Jyothi, a red kernelled, long, bold, short duration variety of 110-115 days was used for the experiment.

B. Legume

The cowpea variety Kanakamony which is a red grained dual purpose type with 70-75 days duration was used as the legume crop in summer.

3.5. Cropping history of the experimental site

The area is typical double cropped wetland. Field that was under bulk cultivation of paddy for the two previous seasons was selected for the trial.

3.6. Experimental methods

The research project consisted of the following two experiments carried out in a rice- rice- cowpea cropping system.

Experiment I. Soil-plant elemental status and productivity as influenced by crop residue recycling and nutrient supply in the rice-legume cropping system

The objective of the experiment was to study the impact of nutrient management practices as well as crop residue recycling on soil productivity and

Table 3.1. Physico chemical properties of the experimental field

A. Physical properties	Content
Bulk density (g cc^{-1})	1.24
Particle density (g cc^{-1})	2.68
Water holding capacity (%)	46.60
Porosity (%)	49.10
Mechanical composition (%)	
Sand	56.1
Silt	12.5
Clay	30.3
b. Chemical properties	
Soil reaction (pH)	5.17
Electrical conductivity (ds m^{-1})	0.67
Organic carbon (%)	1.22
Cation exchange capacity (c mol^{+} kg^{-1})	6.30
Available N (kg ha^{-1})	324.10
Available P_2O_5 (kg ha^{-1})	19.00
Available K_2O (NN- NH_4Ac extract) kg ha^{-1}	78.40
Exchangeable Ca (- do -) m.eq/100 g soil	0.84
Exchangeable Mg (-do -) m.eq/100 g soil	0.37
Available S (Sodium acetate extract) kg ha^{-1}	81.00
Available Fe (DTPA extract) kg ha^{-1}	660.00
Available Mn (DTPA extract) kg ha^{-1}	9.80
Available Zn (DTPA extract) kg ha^{-1}	2.80
Available Cu (DTPA extract) kg ha^{-1}	11.20

crop growth. The crop residues added in the system involved harvested left overs of grain cowpea crop as well as addition of 2/3 portion of rice straw of *kharif* crop to *rabi* crop.

The details of the experiments are given below.

The experiment covered seven seasons as shown in Table 3.2. Only during *rabi* season the straw incorporation of previous *kharif* crop was done. The *kharif* crop was harvested at 40 cm height from the base and the stubbles left were incorporated after broadcasting 20 kg N ha^{-1}. The average quantity of straw thus added to the field amounted to 1500 kg ha^{-1}.

Design: RBD; Replications : 3 ; Plot size : 19.8 m^2 (5.5 x 3.6)

Treatments (*rabi*)

1. Incorporation of *kharif* season straw alone
2. NPK at 70: 35: 35 kg ha^{-1} (Recommended dose)
3. Straw + NPK
4. Straw + NPK (higher dose of K of 70 kg ha^{-1})
5. Straw + NPK + silica 250 kg ha^{-1}
6. Straw + NPK (higher dose of K) + silica 250 kg ha^{-1}
7. Straw + NPK + silica 250 kg ha^{-1} + soil application of $ZnSO_4$ 20 kg ha^{-1}
8. Straw + NPK + silica 250 kg ha^{-1} + soil application of $ZnSO_4$ 20 kg ha^{-1} and $MgSO_4$ 20 kg ha^{-1}
9. Straw + NPK + silica 250 kg ha^{-1} + soil application of $ZnSO_4$ 20 kg ha^{-1}, $MgSO_4$ 20 kg ha^{-1} and $CuSO_4$ 12.5 kg ha^{-1}
10. Straw + NPK + silica 250 kg ha^{-1} + foliar spray of $ZnSO_4$, $MgSO_4$ and $CuSO_4$ @ 0.5, 0.5 and 0.2 %, respectively

11. Straw + NPK + silica 250 kg ha^{-1} + foliar spray of $ZnSO_4$, $MgSO_4$, $CuSO_4$ and boric acid @ 0.5, 0.5, 0.2 and 0.1 % respectively

12. Straw + NPK + silica 250 kg ha^{-1} + foliar spray of $ZnSO_4$, $MgSO_4$, $CuSO_4$, boric acid and sodium molybdate @ 0.5, 0.5, 0.2, 0.1 and 0.1 %, respectively

13. NPK + silica 250 kg ha^{-1} + foliar spray of $ZnSO_4$, $MgSO_4$, $CuSO_4$, boric acid and sodium molybdate @ 0.5, 0.5, 0.2, 0.1 and 0.1 %, respectively

14. T_{12} (without summer cowpea crop)

15. T_2 (without summer cowpea crop)

16. T_{13} (without summer cowpea crop)

In addition to individual treatment comparisons, for better understanding of the effects of various management practices followed in the experiment, grouping of the treatments were made and these treatment sets are separately analysed and discussed. The details of the groupings so made are furnished below:

Effect of cropping systems

Treatments

1. Rice –Rice – Fallow (R-R-F) - mean of treatments T_{14}, T_{15} and T_{16}
2. Rice –Rice – cowpea (R-R-cp) - mean of treatments T_2, T_{13} and T_{12}

Effect of *kharif* straw incorporation

Treatments

1. Without straw - mean of treatments T_2, T_{13} and T_{16}
2. With straw - mean of treatments T_3, T_{12} and T_{14}

Effect of silica

Treatments

1. Without silica - mean of treatments T_3 and T_4
2. With silica - mean of treatments T_5 and T_6

Effect of higher dose of K

Treatments

1. Normal dose of K (K_{35}) - mean of treatments T_3 and T_5
2. Higher dose of K (K_{70}) - mean of treatments T_4 and T_6

The general view of the experimental fields is given in plates 1.

Cowpea was raised during summer in treatment plots T_1 to T_{13} under uniform package of practices as recommended by KAU (1996). After harvest of grains, the crop residues were incorporated in the field. The plots under treatments T_{14} to T_{16} were left fallow during summer season. In the ensuing *kharif* crop (transplanted), the same set of treatments were imposed in the corresponding plots of *rabi* season except for the addition of straw.

Lime was applied uniformly for both the rice crops in two splits viz. 350 kg ha^{-1} as basal and 250 kg ha^{-1} one month after planting. Urea, mussoriephos and muriate of potash were used as sources of N, P and K. Silica was supplied as sodium silicate.

Experiment II. Effect of tillage and water management practices on soil-plant elemental status and productivity of rice in rice- legume cropping system

The objective of the experiment was to study the influence of ploughing the field to a depth of 30 cm instead of the normal ploughing depth of 15 cm as well as providing intermittent drainage on nutrient status of plant and soil as well as productivity of the crops in the system. The experiment started with the cowpea crop of summer 1998. This was followed by the transplanted *kharif* rice crop.

Plate 1. General view of the field under Experiment I

RICE CROP

COWPEA CROP

The experiment was continued till the end of the *rabi* crop in 1999-'00. Cowpea was raised in the plots during summer 1999. A new site was selected for conducting the trial during *kharif* 1999-'00 and *rabi* 1999-'00 after summer cowpea. As in experiment I, harvesting of *kharif* crop was done retaining 40 cm height of straw in the field which was incorporated in the field with 20 kg N ha^{-1}.

Design: RBD; Replications : 3 ; Plot size : 20 m^2 (5m x 4m)

Treatments

1. NPK at 70:35:35 kg ha^{-1}
2. NPK + silica 250 kg ha^{-1} + foliar spray of $ZnSO_4$, $MgSO_4$, $CuSO_4$, boric acid and sodium molybdate @ 0.5, 0.5, 0.2, 0.1 and 0.1 % respectively
3. T_1 + deep ploughing (30 cm)
4. T_1 + intermittent drainage
5. T_1 + deep ploughing + intermittent drainage
6. T_2 + deep ploughing
7. T_2 + intermittent drainage
8. T_2 + deep ploughing + intermittent drainage

In the intermittent drainage, the field was drained to hair line crack stage during three periods viz., tiller initiation stage, between active tillering to panicle initiation and between panicle initiation to flowering stage. Deep ploughing was done during *kharif* season only and its residual effect was studied in *rabi*.

In order to have a clear understanding of the effects of these practices, data of the relevant treatments were combined and their mean values were expressed as treatments effects. The combinations are described below.

Effect of deep ploughing

Without deep ploughing – mean of T_1, T_2, T_4 and T_7

With deep ploughing - mean of T_3, T_5, T_6 and T_8

Effect of intermittent drainage

Continuous submergence - mean of T_1, T_2, T_3 and T_6
Intermittent drainage - mean of T_4, T_5, T_7 and T_8

The general view of the experimental fields is given in plates 1I.

3.7. Cultivation aspects

a. Rice

The crop was raised as per the recommended practices. Dates of sowing and harvesting of various crops in the experiments are furnished in Table 3.2.

The experimental plots were ploughed well, puddled and levelled. The land was laid out with strong bunds of 30 cm x 30 cm with irrigation cum drainage channels in between. Seedlings were raised in wet nursery and transplanted on 20-25th day at 15 x 10 cm spacing with 2-3 seedlings per hill. Entire dose of P and half the dose of N and K were applied basally. One- fourth of the dose of N was supplied at tillering stage and the remaining N and K at panicle initiation stage. The entire dose of silica, $ZnSO_4$, $MgSO_4$ and $CuSO_4$ were applied basally. Foliar spray of $ZnSO_4$, $MgSO_4$, $CuSO_4$, boric acid and sodium molybdate was given at one month after planting as per treatments.

The fields were kept weed free by hand weeding. Plant protection measures were taken up as per the need. The crops were harvested on maturity. Four rows adjoining the border rows in one side were kept for destructive sampling. Plants in two border rows and the destructive sampling area were eliminated and the grain and straw yields from the net plot area were recorded. Weight of grain is expressed at 14 per cent moisture content and that of straw as air-dry weight.

Plate II. General view of the field under Experiment II

RICE CROP

COWPEA CROP

Table 3.2 sowing and harvesting dates and duration of crops in the experiments

Expt.	Season	Crop	Date of sowing/ transplanting		Date of harvest	Duration (days)
			Nursery	Main field		
I	*Rabi* 1997-'98	Rice	19-10-1997	22-11-1997	4-2-1998	109
I	Summer 1998	Cowpea	-	25-2-1998	6-5-1998	71
I & II	*Kharif* 1998-'99	Rice	5-6-1998	2-7-1998	26-9-1998	114
I & II	*Rabi* 1998-'99	Rice	10-10-1998	29-10-1998	16-1-1999	99
I & II	Summer 1999	Cowpea	-	15-2-1999	20-4-1999	65
I & II	*Kharif* 1999-'00	Rice	31-5-1999	22-6-1999	17-9-1999	110
I & II	*Rabi* 1999-'00	Rice	7-10-1999	27-10-1999	22-1-2000	107

B. Cowpea

Immediately after harvest of the *rabi* crops, the plots were ploughed, levelled and cowpea was dibbled in lines at a spacing of 25 cm x 15 cm. The crop was fertilized with 20:30:10 kg NPK ha^{-1}. Entire dose of P and K was applied basally while half the dose of N was supplied basally and the other half as foliar spray at 20 days after sowing. Two to three irrigations were given. Harvesting of the pods was done in 2-3 pickings and the residues were incorporated in the field after quantifying the weight. On an average, 3090 kg ha^{-1} residue was added to the field.

3.8. Observations

Ten hills/plot selected at random were used as observational plants for recording biometric observations. Five other hills were separately selected for chemical analysis from the destructive sampling area.

Observations at tillering stage were not recorded in *rabi* 1997-98 crop

1. Plant

A. Biometric observations

1. Height of plants (cm)	: At tillering stage, panicle initiation stage and maturity
2. Tiller count (No./plant)	: At tillering , panicle initiation and maturity stages
3. Dry matter production of shoot and root* (kg ha^{-1})	: At tillering , panicle initiation and maturity stages
4. Productive tillers (No./hill))	: At maturity
5. Length of panicle	: At maturity
6. No. of spikelets/panicle	
7. No. of filled grains/ panicle	
8. No. of unfilled grains/ panicle	
9. Grain yield	
10. Straw yield	

* For taking the root biomass, entire plant samples including the roots wer scooped out carefully to a depth of 25 cm and the roots were washed in runnin tap water by keeping in a 2 mm sized wire mesh sieve. All the soil particles wer removed and the roots were separated from the plant; the root pieces in the wir mesh also were added to it and they were dried in oven and weight recorded.

B. Chemical composition

i. Plant

Plant samples were dried in a hot air oven for 72 h at 60^{o} C $\pm$ 5^{o} C. They were powdered well by hand crushing and used for analysis. The total N content of the sample was determined by micro kjeldahl digestion and distillation method (Jackson, 1958). For the determination of P, K, Ca, Mg, S and micronutrient elements, di acid extract (HNO_3 : $HClO_4$ in the ratio of 2:1) of the plant material was made use of. Phosphorous was determined by Vanado-molybdo phosphoric yellow colour method (Jackson, 1958). Potassium was determined using EEL Flame photometer. Ca, Mg, Fe, Mn, Zn and Cu were determined using Atomic Absorption Spectrophotometer. Sulphur was determined by turbidimetric method using spectrophotometer (Hart, 1961). The residue from wet ashing was ignited in a muffle furnace and the silica content was determined gravimetrically (Yoshida, *et al.*, 1972)

Nutrient uptake was computed from nutrient content and dry matter accumulation.

ii. Soil

The pH and redox potential of the soil water suspension was determined using a pH meter (Hesse, 1971). Soil samples were dried, powdered and passed through 2 mm sieve for analysis. Walkley and Black's method was used for organic carbon determination (Jackson, 1958). Ammoniacal and nitrate nitrogen contents were determined in fresh samples by microkjeldhal method. Available P in soil was extracted by Bray No. 1 extractant and the P content was determined colorimetrically by the Ascorbic acid blue colour method (Watanabe and Olsen, 1965). Available K in soil was extracted by neutral normal ammonium acetate and was read in EEL flame photometer (Jackson, 1958). Exchangeable Ca and Mg were determined from the ammonium acetate extract by EDTA titration method. Available S was estimated by turbidimetric method (Hesse, 1971). For the determination of available micronutrients (Fe, Mn, Zn and Cu), the soil samples were extracted with DTPA and the elements were estimated in an Atomic Absorption Spectrophotometer (Lindsay and Norwell, 1978).

3.10. Statistical analysis

Statistical analysis was done as per the methods suggested by Panse and Sukhatme (1978). Duncans Multiple Range Test (DMRT) values were used for comparison of treatments whereas critical difference (CD) values were used for comparison of seasons. Multiple regression analysis was also done to work out the relationship between yield, yield attributes and nutrients. Microsoft Excel 2000 and MSTAT packages were used for computations.

Results

4. RESULTS

4.1. Experiment I. Soil-plant elemental status and productivity as influenced by crop residue recycling and nutrient supply in the rice- legume cropping system

The experiment was aimed to study the effect of crop residue recycling and nutrient supply on soil-plant elemental status and productivity of rice-legume cropping system in laterite soils of humid tropics. The experiment involved three *rabi* crops, two *kharif* crops and two crops of summer cowpea grown in sequence.

4.1.1. Effect of season and management practices on growth characters and yield attributes

4.1.1.1. Plant height

The data on plant height at tillering, panicle initiation (PI) and maturity stages are presented in Tables 4.1 a, b and c, respectively.

Tillering stage

The average height of the crop at tillering stage was 39.4 cm. It was significantly higher during *kharif* season. During *kharif* 1998-'99, the plant height was 36.7 cm while in *kharif 1999-'00* significantly higher plant height of 45.8 cm was recorded. In *rabi* , plant height during 1999-'00 (34.6 cm) was significantly lower than that of *rabi* 1998-'99 (40.6 cm)

Comparison of the treatment effects showed that during all the seasons, the height was lowest in straw alone treatment (T_1). During *kharif* 1998-'99, T_1 and T_{13} had significantly lower height than T_6 and T_{10}. During *kharif* 1999-'00, application of silica at 250 kg ha^{-1} resulted in significant increase in plant height (Sub table 4.1c). T_1, T_2 and T_{13} registered significantly shorter plants than T_5. During *rabi* 1998-'99 and *rabi* 1999-'00, plant height was lowest in T_1.

Table 4.1. Effect of season and treatments on plant height (cm) of rice

a. Tillering stage

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	33.3^{c}	41.8^{d}	37.6^{d}	36.7^{b}	31.3^{b}	34.0^{b}	35.8^{c}
2	NPK alone	36.2^{ab}	44.5^{cd}	40.4^{c}	39.4^{ab}	34.1^{ab}	36.8^{a}	38.6^{b}
3	Straw + NPK	36.9^{ab}	45.9^{abc}	41.4^{abc}	41.4^{ab}	34.0^{ab}	37.7^{a}	39.6^{ab}
4	Straw + NPK (higher dose of K)	37.5^{ab}	45.9^{abc}	41.7^{abc}	41.7^{a}	36.8^{a}	39.3^{a}	40.5^{a}
5	Straw + NPK + Si	37.3^{ab}	48.7^{a}	43.0^{a}	39.8^{ab}	35.8^{a}	37.8^{a}	40.4^{a}
6	Straw + NPK (higher dose of K)+ Si	38.3^{a}	45.7^{abc}	42.0^{abc}	41.4^{ab}	34.3^{ab}	37.9^{a}	39.9^{ab}
7	Straw + NPK + Si + Zn	37.6^{ab}	48.2^{ab}	42.9^{ab}	40.3^{ab}	35.0^{a}	37.7^{a}	40.3^{a}
8	Straw + NPK + Si + Zn +Mg	35.9^{ab}	46.7^{abc}	41.3^{abc}	39.6^{ab}	35.0^{a}	37.3^{a}	39.3^{ab}
9	Straw + NPK + Si + Zn +Mg+Cu	36.5^{ab}	47.4^{abc}	42.0^{abc}	41.4^{ab}	34.7^{ab}	38.1^{a}	40.0^{ab}
10	Straw+ NPK + Si +Foliar Zn,Mg,Cu	38.1^{a}	45.7^{abc}	41.9^{abc}	40.5^{ab}	35.8^{a}	38.2^{a}	40.0^{ab}
11	T_{10}+ Boron	36.8^{ab}	45.2^{abcd}	41.0^{abc}	39.7^{ab}	33.5^{ab}	36.6^{a}	38.8^{ab}
12	T_{11}+ Mo	36.1^{ab}	45.9^{abc}	41.0^{abc}	41.9^{a}	35.3^{a}	38.6^{a}	39.8^{ab}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	35.5^{bc}	44.7^{bcd}	40.1^{c}	41.1^{ab}	33.9^{ab}	37.5^{a}	38.8^{ab}
14	T_{12} (No summer cowpea)	37.3^{ab}	45.8^{abc}	41.6^{abc}	43.2^{a}	34.5^{ab}	38.9^{a}	40.2^{ab}
15	T_2 (No summer cowpea)	36.4^{ab}	45^{abcd}	40.7^{bc}	38.8^{ab}	34.5^{ab}	36.7^{a}	38.7^{ab}
16	T_{13} (No summer cowpea)	36.8^{ab}	45.4^{abc}	41.4^{abc}	41.9^{a}	35.5^{a}	38.7^{a}	39.7^{ab}
	Mean	**36.7**	**45.8**	**41.2**	**40.6**	**34.6**	**37.6**	**39.4**
CD for comparison of seasons				2.4			1.1	1.5
CD for comparison of *Kharif* vs *Rabi*					1.4			
Sub table 4.1 a. Effect of cropping system								
	R-R-Fallow	36.8	45.4	41.1	41.3	34.8	38.1	39.6
	R-R-cowpea	35.9	45.0	40.5	40.8	34.4	37.6	39.1
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.1b. Effect of *Kharif* straw incorporation								
	Without straw	36.2	44.9	40.5	40.8	34.5	37.7	39.1
	With straw	36.8	45.9	41.3	42.2	34.6	38.4	39.9
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.1 c. Effect of silica								
	Without silica	37.2	45.9	41.6	41.6	35.4	38.5	40.0
	With silica	37.8	47.2	42.5	40.6	35.1	37.8	40.2
		NS	Sig*	NS	NS	NS	NS	NS
Sub-table 4.1d. Effect of higher dose of K								
	K_{35}	37.1	47.3	42.2	40.6	34.9	37.8	40.0
	K_{70}	37.9	45.8	41.9	41.6	35.6	38.6	40.2
		NS	NS	NS	NS	NS	NS	NS

* Significant at 5 per cent level

PI stage

During PI stage, the mean plant height recorded in *kharif* (57.4 cm) was significantly higher than the plant height of *rabi* crop (52.4 cm). Comparison of the height between the two *kharif* seasons showed that 1999-'00 season produced taller plants (62.2 cm) than 1998-'99 season. But significant differences were not noticed among the three *rabi* seasons.

Plant height in T_1 was remarkably low during all the seasons. During *kharif* 1998-'99, T_2, T_3, T_8, T_{13} and T_{15} also had significantly lower height than T_{10}. During *rabi* 1997-'98 and 1999-'00 incorporation of *kharif* straw increased the plant height significantly (Sub table 4.1b). During *rabi* 1997-'98, Straw+NPK+silica (T_5) registered the plant height of 56.9 cm, which was significantly higher than T_1, T_6, T_8 and T_{13}. During *rabi* 1998-'99 T_1, T_2 and T_{11} had remarkably lower height than T_8 whereas in *rabi* 1999-'00 all other treatments except T_1 were on par in terms of plant height.

Maturity

The mean plant height during *kharif* and *rabi* seasons were 77.7 cm and 69.2 cm respectively. The seasons also differed among themselves in plant height. Thus *kharif* 1998-'99 crop had significantly higher plant height of 78.4 cm than *kharif* 1999-'00. In *rabi* 1999-'00, the plant height was 63.8 cm which was significantly lesser compared to the heights of *rabi* 1997-'98 and 1998-'99 crops.

During *kharif* 1998-'99, T_1 recorded significantly lower plant height of 69.2 cm. During *kharif* 1999-'00, silica application remarkably influenced plant height. It increased the height from 73.9 cm to 77.8 cm (Sub table 4.1c).

During *rabi* 1997-'98 all the treatments were on par in plant height. T_8 (Straw+NPK+silica+ soil application of $ZnSO_4$ and $MgSO_4$) recorded the highest plant height of 75.9 cm during *rabi* 1998-'99 while T_1 and T_2 produced significantly shorter plants. During *rabi* 1999-'00, incorporation of *kharif* straw increased the plant height from 62.6 cm to 64.9 cm (Sub table 4.1b). Heights in T_1, T_2 and T_5 were significantly low compared to T_{10} and T_{11}.

Table 4.1. Effect of season and treatments on plant height (cm) of rice

b. PI stage

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	47.1^{c}	55.9^{b}	51.5^{b}	49.3^{d}	48.3^{d}	46.2^{b}	47.9^{a}	49.4^{d}
2	NPK alone	51.8^{b}	63.0^{a}	57.4^{a}	52.8^{abcd}	50.4^{cd}	49.3^{ab}	50.8^{a}	53.5^{bc}
3	Straw + NPK	52.5^{b}	61.4^{a}	57.0^{a}	55.7^{ab}	54.0^{abc}	52.2^{a}	54.0^{a}	55.2^{abc}
4	Straw + NPK (higher dose of K)	54.1^{ab}	63.0^{a}	58.6^{a}	54.9^{abc}	52.3^{abcd}	50.2^{ab}	52.5^{a}	54.9^{abc}
5	Straw + NPK + Si	52.8^{ab}	62.4^{a}	57.6^{a}	56.9^{a}	52.1^{abcd}	52.2^{a}	53.7^{a}	55.3^{ab}
6	Straw + NPK (higher dose of K)+ Si	54.0^{ab}	64.7^{a}	59.4^{a}	51.8^{bcd}	54.8^{ab}	53.3^{a}	53.3^{a}	55.7^{a}
7	Straw + NPK + Si + Zn	53.0^{ab}	61.6^{a}	57.3^{a}	53.1^{abcd}	54.3^{abc}	51.7^{a}	53.0^{a}	54.7^{abc}
8	Straw + NPK + Si + Zn +Mg	51.7^{b}	64.6^{a}	58.2^{a}	51.3^{bcd}	55.7^{a}	50.5^{a}	52.5^{a}	54.8^{abc}
9	Straw + NPK + Si + Zn +Mg+Cu	52.9^{ab}	61.8^{a}	57.4^{a}	54.1^{abc}	53.3^{abc}	51.3^{a}	52.9^{a}	54.7^{abc}
10	Straw+ NPK + Si +Foliar Zn,Mg,Cu	56.0^{a}	62.3^{a}	59.2^{a}	54.1^{abc}	54.1^{abc}	51.7^{a}	53.3^{a}	55.6^{a}
11	T_{10}+ Boron	54.1^{ab}	61.9^{a}	58.0^{a}	52.3^{abcd}	51.3^{bcd}	52.2^{a}	51.9^{a}	54.4^{abc}
12	T_{11}+ Mo	53.0^{ab}	62.1^{a}	57.6^{a}	55.5^{ab}	55.6^{ab}	52.2^{a}	54.4^{a}	55.7^{a}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	52.0^{b}	62.3^{a}	57.2^{a}	50.4^{cd}	53.5^{abc}	49.0^{ab}	51.0^{a}	53.4^{c}
14	T_{12} (No summer cowpea)	53.0^{ab}	63.2^{a}	58.1^{a}	53.4^{abcd}	53.4^{abc}	53.0^{a}	53.3^{a}	55.2^{ab}
15	T_2 (No summer cowpea)	51.2^{b}	63.0^{a}	57.1^{a}	54.7^{abc}	53.4^{abc}	50.0^{ab}	52.7^{a}	54.5^{abc}
16	T_{13} (No summer cowpea)	53.2^{ab}	62.6^{a}	57.9^{a}	52.9^{abcd}	52.2^{abcd}	50.4^{a}	51.8^{a}	54.3^{abc}
	Mean	**52.7**	**62.2**	**57.4**	**53.3**	**53.0**	**51.0**	**52.4**	**54.4**
CD for comparison of seasons				1.6				NS	2.1
CD for comparison of *Kharif* vs *Rabi*						1.3			
Sub table 4.1 a. Effect of cropping system									
	R-R-Fallow	52.5	62.9	57.7	-	53.0	51.1	52.6	54.7
	R-R-cowpea	52.3	62.5	57.4	-	53.2	50.2	52.1	54.2
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.1b. Effect of *Kharif* straw incorporation									
	Without straw	52.3	62.6	57.5	52.0	52.0	49.6	50.8	54.1
	With straw	52.8	62.2	57.6	54.9	54.3	52.5	53.4	55.5
		NS	NS	NS	Sig	NS	Sig	Sig	Sig
Sub table 4.1 c. Effect of silica									
	Without silica	53.3	62.2	57.8	55.3	53.2	51.2	53.3	55.1
	With silica	53.4	63.6	58.5	54.4	53.5	52.8	53.5	55.5
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.1d. Effect of higher dose of K									
	K_{35}	52.7	61.9	57.3	56.3	53.1	52.2	53.9	55.3
	K_{70}	54.1	63.9	59.0	53.4	53.6	51.8	52.9	55.3
		NS	NS	NS	Sig	NS	NS	NS	NS

Table 4.1. Effect of season and treatments on plant height (cm) of rice

c. Maturity stage

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	69.2^{b}	71.2^{c}	70.2^{d}	69.4^{a}	65.3^{c}	58.6^{d}	64.4^{a}	66.7^{d}
2	NPK alone	78.6^{a}	76.8^{ab}	77.7^{abc}	71.1^{a}	71.4^{b}	60.8^{cd}	67.8^{a}	71.7^{c}
3	Straw + NPK	77.9^{a}	73.8^{bc}	75.9^{c}	71.9^{a}	72.6^{ab}	65.3^{ab}	69.9^{a}	72.3^{abc}
4	Straw + NPK (higher dose of K)	79.1^{a}	74.0^{bc}	76.6^{bc}	71.1^{a}	73.1^{ab}	63.9^{abc}	69.4^{a}	72.2^{bc}
5	Straw + NPK + Si	79.2^{a}	78.6^{a}	78.9^{ab}	70.6^{a}	72.7^{ab}	62.8^{bc}	68.7^{a}	72.8^{abc}
6	Straw + NPK (higher dose of K)+ Si	79.3^{a}	77.0^{ab}	78.2^{abc}	71.5^{a}	75.3^{ab}	65.1^{ab}	70.6^{a}	73.6^{ab}
7	Straw + NPK + Si + Zn	80.2^{a}	77.8^{a}	79.0^{ab}	71.4^{a}	73.0^{ab}	63.1^{abc}	69.2^{a}	73.1^{abc}
8	Straw + NPK + Si + Zn +Mg	78.5^{a}	78.0^{a}	78.3^{abc}	71.7^{a}	75.9^{a}	64.3^{ab}	70.6^{a}	73.7^{ab}
9	Str + NPK + Si + Zn +Mg+Cu	79.5^{a}	78.7^{a}	79.1^{ab}	71.7^{a}	74.4^{ab}	65.5^{ab}	70.5^{a}	74.0^{ab}
10	Str + NPK + Si +Foliar Zn,Mg,Cu	79.9^{a}	79.3^{a}	79.6^{a}	70.9^{a}	74.0^{ab}	66.3^{a}	70.4^{a}	74.1^{a}
11	T_{10}+ Boron	79.5^{a}	77.7^{a}	78.6^{ab}	72.5^{a}	73.0^{ab}	64.1^{ab}	69.9^{a}	73.4^{abc}
12	T_{11}+ Mo	77.6^{a}	78.1^{a}	77.9^{abc}	71.2^{a}	72.6^{ab}	66.1^{a}	70.0^{a}	73.1^{abc}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	78.0^{a}	77.6^{a}	77.8^{abc}	69.8^{a}	72.8^{ab}	63.3^{abc}	68.6^{a}	72.3^{abc}
14	T_{12} (No summer cowpea)	78.5^{a}	78.7^{a}	78.6^{ab}	68.1^{a}	74.0^{ab}	63.3^{abc}	68.5^{a}	72.5^{abc}
15	T_{2} (No summer cowpea)	79.1^{a}	77.9^{a}	78.5^{ab}	71.3^{a}	72.3^{ab}	64.8^{ab}	69.5^{a}	73.1^{abc}
16	T_{13} (No summer cowpea)	80.1^{a}	77.7^{a}	78.9^{ab}	69.0^{a}	73.1^{ab}	63.6^{abc}	68.6^{a}	72.7^{abc}
	Mean	**78.4**	**77.1**	**77.7**	**70.8**	**72.8**	**63.8**	**69.2**	**72.6**
CD for comparison of seasons				0.9				2.5	1.8
CD for comparison of *Kharif* vs *Rabi*		0.9							
Sub table 4.1 a. Effect of cropping system									
	R-R-Fallow	79.2	78.1	78.7	-	73.1	63.9	68.5	73.6
	R-R-cowpea	78.1	77.5	77.8	-	72.3	63.4	67.8	72.8
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.1b. Effect of *Kharif* straw incorporation									
	Without straw	78.9	77.4	78.1	70.0	72.4	62.6	68.3	72.2
	With straw	78.0	76.9	77.4	70.4	73.1	64.9	69.5	72.6
		NS	NS	NS	NS	NS	Sig	Sig	NS
Sub table 4.1 c. Effect of silica									
	Without silica	78.5	73.9	76.2	71.5	72.9	64.6	69.7	72.3
	With silica	79.3	77.8	78.5	71.1	74.0	64.0	69.7	73.2
		NS	Sig	Sig	NS	NS	NS	NS	NS
Sub table 4.1d. Effect of higher dose of K									
	K_{35}	78.6	76.2	77.4	71.3	72.7	64.1	69.3	72.5
	K_{70}	79.2	75.5	77.4	71.3	74.2	64.5	70.0	72.9
		NS	NS	NS	NS	NS	NS	NS	NS

4.1.1.2. Tiller production

The data on number of tillers per hill at tillering, PI and maturity stages of rice are presented in Tables 4.2 a, b and c, respectively.

Tillering stage

The mean tiller count was higher in *kharif* (6.2). *Rabi* season had a significantly lower count of 5.6. The two *kharif* seasons differed between themselves in the tiller production while *rabi* crops did not show any remarkable variation. During *kharif* 1998-'99, number of tillers per hill was 5.3 while during 1999-'00 it was 7.1.

During *kharif* 1998-'99, the highest tiller number of 6.4 was recorded in T_3 (Straw + NPK [illegible]). T_1, T_4, T_8, T_{11} and T_{15} had significantly lower counts. During *kharif* 1999-'00, application of higher K dose increased the tiller count significantly. It increased from 7.2 to 8.1 (Sub table 4.2.d). T_6 registered the highest tiller number of 8.2; T_1, T_8, T_{12}, T_{15} and T_{16} recorded lower counts.

During *rabi* 1998-'99, tiller count in T_3 (6.2) was higher compared to T_1, T_{13} and T_{15}. During *rabi* 1999-'00, T_6 and T_9 had a higher count of 6.3 compared to T_1, T_{11}, T_{14} and T_{16}.

PI stage

At PI stage, the mean tiller count did not show remarkable variation between *kharif* and *rabi* crops. The two *kharif* seasons showed variation in the tiller production. During *kharif* 1998-'99, the tiller number was 6.4 while during *kharif* 1999-'00 significantly higher count of 8.1 was recorded. *Rabi* 1997-'98 and 1998-'99 recorded tiller counts of 6.3 and 6.7, respectively whereas *rabi* 1999-'00 had significantly higher tiller number (7.5).

During *kharif* 1998-'99, the lowest tiller count was in T_1. T_6, T_{12} and T_{16} recorded significantly higher count. During *kharif* 99-00, tiller count in T_4 and T_9 was higher than T_{14}. During the *rabi* seasons T_1 registered lower count.

Table 4.2. **Effect of season and treatments on number of tillers per hill of rice**

a. Tillering stage

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-0	*Kharif* mean	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	4.1^{c}	6.2^{bc}	5.2^{bc}	4.7^{d}	4.6^{c}	4.7^{c}	4.9^{d}
2	NPK alone	5.4^{abcd}	6.8^{abc}	6.1^{abc}	5.4^{abcd}	5.6^{abc}	5.5^{abc}	5.8^{abc}
3	Straw + NPK	6.4^{a}	6.6^{abc}	6.5^{ab}	6.2^{a}	5.7^{ab}	6.0^{ab}	6.2^{ab}
4	Straw + NPK (higher dose of K)	4.9^{bcde}	7.9^{ab}	6.4^{ab}	5.8^{abc}	5.7^{ab}	5.8^{ab}	6.1^{ab}
5	Straw + NPK + Si	5.2^{abcde}	7.8^{ab}	6.5^{ab}	5.9^{abc}	5.5^{abc}	5.7^{ab}	6.1^{ab}
6	Straw + NPK (higher dose of K)+ Si	5.6^{abcd}	8.2^{a}	6.9^{a}	6.1^{ab}	6.3^{a}	6.2^{a}	6.6^{a}
7	Straw + NPK + Si + Zn	5.6^{abcd}	7.8^{ab}	6.7^{a}	5.4^{abcd}	5.5^{abc}	5.5^{abc}	6.1^{ab}
8	Straw + NPK + Si + Zn +Mg	4.6^{de}	6.2^{bc}	5.4^{abc}	5.4^{abcd}	5.9^{ab}	5.7^{abc}	5.5^{bcd}
9	Str + NPK + Si + Zn +Mg+Cu	5.3^{abcde}	7.7^{ab}	6.5^{ab}	6.0^{ab}	6.3^{a}	6.2^{a}	6.3^{ab}
10	Str + NPK + Si +Foliar Zn,Mg,Cu	5.8^{abcd}	7.4^{ab}	6.6^{ab}	5.8^{abc}	5.6^{abc}	5.7^{ab}	6.2^{ab}
11	T_{10}+ Boron	4.7^{cde}	7.8^{ab}	6.3^{abc}	5.6^{abcd}	5.2^{bc}	5.4^{abc}	5.8^{abc}
12	T_{11}+ Mo	6.0^{ab}	6.3^{bc}	6.2^{abc}	5.8^{abc}	5.7^{ab}	5.8^{abc}	6.0^{ab}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	5.6^{abcd}	7.2^{ab}	6.4^{ab}	5.0^{cd}	5.5^{abc}	5.3^{abc}	5.8^{abc}
14	T_{12} (No summer cowpea)	5.9^{abcd}	7.5^{ab}	6.7^{a}	5.5^{abcd}	5.2^{bc}	5.4^{abc}	6.0^{ab}
15	T_{2} (No summer cowpea)	4.1^{e}	5.6^{c}	4.9^{c}	5.3^{bcd}	5.4^{abc}	5.4^{bc}	5.1^{cd}
16	T_{13} (No summer cowpea)	6.0^{abc}	6.4^{bc}	6.2^{abc}	6.0^{ab}	5.0^{bc}	5.5^{abc}	5.9^{abc}
	Mean	**5.3**	**7.1**	**6.2**	**5.6**	**5.5**	**5.6**	**5.9**
CD for comparison of season				0.7			NS	0.5
CD for comparison of *kharif* vs *rabi*					0.4			
Sub table 4.2 a. Effect of cropping system								
	R-R-Fallow	5.3	6.5	5.9	5.6	5.2	5.4	5.7
	R-R-cowpea	5.7	6.8	6.2	5.4	5.6	5.5	5.9
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.2 b. Effect of *Kharif* straw incorporation								
	Without straw	5.7	6.8	6.2	5.5	5.4	5.4	5.8
	With straw	6.1	6.8	6.5	5.8	5.5	5.7	6.1
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.2 c. Effect of silica								
	Without silica	5.7	7.3	6.5	6.0	5.7	5.9	6.2
	With silica	5.4	8.0	6.7	6.0	5.9	6.0	6.3
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.2 d. Effect of higher dose of K								
	K_{35}	5.8	7.2	6.5	6.1	5.6	5.8	6.2
	K_{70}	5.3	8.1	6.7	6.0	6.0	6.0	6.3
		NS	Sig	NS	NS	NS	NS	NS

Table 4.2. Effect of season and treatments on number of tillers per hill of rice

b. PI stage

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	5.6^{d}	7.3^{ab}	6.5^{c}	5.4^{b}	5.3^{b}	6.5^{b}	5.7^{c}	6.0^{d}
2	NPK alone	6.1^{bcd}	8.3^{ab}	7.2^{abc}	6.4^{ab}	6.1^{ab}	7.4^{ab}	6.6^{ab}	6.9^{abc}
3	Straw + NPK	6.3^{bcd}	8.2^{ab}	7.3^{abc}	6.8^{a}	7.3^{a}	7.6^{ab}	7.2^{a}	7.2^{ab}
4	Straw + NPK (higher dose of K)	6.4^{abcd}	8.8^{a}	7.6^{ab}	6.7^{a}	6.6^{ab}	7.4^{ab}	6.9^{ab}	7.2^{ab}
5	Straw + NPK + Si	6.4^{bcd}	8.5^{ab}	7.5^{ab}	6.2^{ab}	6.6^{ab}	7.4^{ab}	6.7^{ab}	7.0^{abc}
6	Straw + NPK (higher dose of K)+ Si	7.0^{ab}	7.7^{ab}	7.4^{ab}	6.7^{a}	6.8^{a}	7.5^{ab}	7.0^{ab}	7.1^{ab}
7	Straw + NPK + Si + Zn	6.5^{abcd}	8.2^{ab}	7.4^{ab}	6.4^{ab}	7.6^{a}	7.0^{ab}	7.0^{ab}	7.1^{ab}
8	Straw + NPK + Si + Zn +Mg	6.5^{abcd}	8.2^{ab}	7.4^{ab}	6.6^{a}	7.0^{a}	7.6^{ab}	7.1^{a}	7.2^{ab}
9	Str + NPK + Si + Zn +Mg+Cu	5.9^{cd}	8.6^{a}	7.3^{abc}	6.8^{a}	6.9^{a}	7.6^{ab}	7.1^{a}	7.2^{ab}
10	Str + NPK + Si +Foliar Zn,Mg,Cu	6.6^{abcd}	8.4^{ab}	7.5^{ab}	6.6^{ab}	7.3^{a}	8.4^{a}	7.4^{a}	7.5^{a}
11	T_{10}+ Boron	5.8^{cd}	8.3^{ab}	7.1^{abc}	6.9^{a}	7.3^{a}	7.8^{ab}	7.3^{a}	7.2^{ab}
12	T_{11}+ Mo	6.8^{abc}	8.3^{ab}	7.6^{ab}	6.2^{ab}	6.5^{ab}	7.3^{ab}	6.7^{ab}	7.0^{abc}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	6.4^{bcd}	7.9^{ab}	7.2^{abc}	5.7^{ab}	6.3^{ab}	7.9^{ab}	6.6^{ab}	6.8^{bc}
14	T_{12} (No summer cowpea)	6.4^{bcd}	7.1^{b}	6.8^{bc}	6.3^{ab}	6.2^{ab}	7.7^{ab}	6.7^{ab}	6.7^{bc}
15	T_2 (No summer cowpea)	5.9^{cd}	7.6^{ab}	6.8^{bc}	5.9^{ab}	6.1^{ab}	6.7^{b}	6.2^{bc}	6.4^{cd}
16	T_{13} (No summer cowpea)	7.4^{a}	8.3^{ab}	7.9^{a}	5.8^{ab}	7.0^{a}	7.4^{ab}	6.7^{ab}	7.2^{ab}
	Mean	**6.4**	**8.1**	**7.2**	**6.3**	**6.7**	**7.5**	**6.8**	**7.0**
CD for comparison of seasons				1.2				0.8	0.8
CD for comparison of *Kharif* vs *Rabi*		NS							
Sub table 4.2 a. Effect of cropping system									
	R-R-Fallow	6.6	7.7	7.1	-	6.4	7.3	6.9	7.0
	R-R-cowpea	6.4	8.2	7.3	-	6.3	7.5	6.9	7.1
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.2 b. Effect of *Kharif* straw incorporation									
	Without straw	6.6	8.2	7.4	6.0	6.5	7.6	6.7	7.0
	With straw	6.5	7.9	7.2	6.4	6.7	7.5	6.9	7.0
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.2 c. Effect of silica									
	Without silica	6.4	8.5	7.4	6.8	7.0	7.5	7.1	7.2
	With silica	6.7	8.1	7.4	6.5	6.7	7.5	6.9	7.1
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.2d. Effect of higher dose of K									
	K_{35}	6.4	8.4	7.4	6.5	7.0	7.5	7.0	7.1
	K_{70}	6.7	8.3	7.5	6.7	6.7	7.5	7.0	7.2
		NS	NS	NS	NS	NS	NS	NS	NS

Table 4.2 Effect of season and treatments on number of tillers per hill of rice

c. Maturity stage

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	5.4^{ab}	5.5^{b}	5.5^{b}	6.8^{ab}	5.1^{c}	6.3^{b}	6.1^{d}	5.8^{c}
2	NPK alone	5.8^{ab}	7.1^{ab}	6.5^{ab}	7.2^{ab}	5.6^{abc}	7.1^{ab}	6.6^{abcd}	6.6^{abc}
3	Straw + NPK	5.8^{ab}	6.6^{ab}	6.2^{ab}	6.7^{ab}	6.1^{abc}	7.4^{a}	6.7^{abc}	6.5^{ab}
4	Straw + NPK (higher dose of K)	5.8^{ab}	8.1^{a}	7.0^{a}	7.3^{ab}	5.7^{abc}	6.9^{ab}	6.6^{abcd}	6.8^{ab}
5	Straw + NPK + Si	5.7^{ab}	6.9^{ab}	6.3^{ab}	7.0^{ab}	6.3^{ab}	7.1^{ab}	6.8^{abc}	6.6^{abc}
6	Straw + NPK (higher dose of K)+ Si	5.9^{a}	7.3^{a}	6.6^{a}	7.8^{a}	6.2^{ab}	7.7^{a}	7.2^{a}	7.0^{a}
7	Straw + NPK + Si + Zn	5.5^{ab}	7.6^{a}	6.6^{a}	7.6^{ab}	5.8^{abc}	7.8^{a}	7.1^{ab}	6.9^{ab}
8	Straw + NPK + Si + Zn +Mg	5.3^{ab}	7.3^{a}	6.3^{ab}	6.9^{ab}	6.0^{abc}	7.3^{ab}	6.7^{abc}	6.6^{abc}
9	Str + NPK + Si + Zn +Mg+Cu	5.6^{ab}	7.6^{a}	6.6^{a}	7.2^{ab}	6.5^{a}	6.9^{ab}	6.9^{abc}	6.8^{ab}
10	Str + NPK + Si +Foliar Zn,Mg,Cu	6.0^{a}	7.0^{ab}	6.5^{ab}	7.7^{a}	6.0^{abc}	7.6^{a}	7.1^{ab}	6.9^{ab}
11	T_{10}+ Boron	4.8^{b}	7.4^{a}	6.1^{ab}	7.5^{ab}	5.5^{abc}	7.6^{a}	6.9^{abc}	6.6^{abc}
12	T_{11}+ Mo	5.6^{ab}	8.1^{a}	6.9^{a}	6.9^{ab}	5.5^{abc}	7.3^{ab}	6.6^{bcd}	6.7^{ab}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	5.8^{ab}	7.1^{ab}	6.5^{ab}	7.7^{a}	6.1^{abc}	7.3^{ab}	7.0^{ab}	6.8^{ab}
14	T_{12} (No summer cowpea)	6.2^{a}	7.4^{a}	6.8^{a}	7.1^{ab}	6.2^{abc}	7.1^{ab}	6.8^{abc}	6.8^{ab}
15	T_2 (No summer cowpea)	5.6^{ab}	7.1^{ab}	6.4^{ab}	6.3^{b}	5.3^{bc}	7.4^{a}	6.3^{cd}	6.3^{b}
16	T_{13} (No summer cowpea)	5.7^{ab}	7.8^{a}	6.9^{a}	7.2^{ab}	5.5^{abc}	7.1^{ab}	6.6^{abcd}	6.7^{ab}
	Mean	**5.7**	**7.2**	**6.5**	**7.2**	**5.8**	**7.2**	**6.8**	**6.6**
CD for comparison of seasons				1.4				0.6	0.8
CD for comparison of *Kharif* vs *Rabi*		NS							
Sub table 4.2 a. Effect of cropping system									
	R-R-Fallow	5.9	7.4	6.7	-	5.7	7.2	6.4	6.6
	R-R-cowpea	5.7	7.4	6.6	-	5.7	7.2	6.5	6.5
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.2 b. Effect of *Kharif* straw incorporation									
	Without straw	5.8	7.3	6.6	7.4	5.7	7.2	6.8	6.7
	With straw	5.9	7.4	6.6	6.9	5.9	7.3	6.7	6.7
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.2 c. Effect of silica									
	Without silica	5.8	7.4	6.6	7.0	5.9	7.2	6.7	6.6
	With silica	5.8	7.1	6.5	7.4	6.3	7.4	7.0	6.8
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.2 d. Effect of higher dose of K									
	K_{35}	5.8	6.8	6.3	6.9	6.2	7.3	6.8	6.6
	K_{70}	5.9	7.7	6.8	7.6	6.0	7.3	6.9	6.9
		NS	Sig	NS	Sig	NS	NS	NS	NS

Maturity

At maturity the mean number of tillers produced during *kharif* and *rabi* were 6.5 and 6.8 respectively. *Kharif* 1998-'99 had a tiller count of 5.7 whereas in 1999-'00 it was significantly higher (7.2). During *rabi* 1997-'98 and 1999-'00 the tiller number was 7.2, but during *rabi* 1998-'99 it was significantly low (5.8).

During *kharif* 1998-'99, T_{10}, T_{14} and T_{16} had significantly higher tiller count compared to T_{11} which recorded tiller count of 4.8. During *kharif* 1999-'00, higher K dose brought about significant increase in tiller production (Sub table 4.2d). T_1 produced the lowest tiller number of 5.5. During *rabi* 1997-'98, NPK alone treatment (T_{15}) recorded tiller count of 6.3; T_6, T_{10} and T_{13} had significantly higher counts. Application of higher dose of K resulted in a significant increase in tiller production during the season also (Sub table 4.2d). During *rabi* 1998-'99, tiller count in T_1 was significantly lower compared to T_5, T_6 and T9. During *rabi* 1999-'00 also T_1 had a significantly lower count of 6.3 than the number recorded in T_3, T_6, T_7, T_{10}, T_{11} and T_{15}.

4.1.1.3. Biomass production

Shoot biomass

The data on biomass production of shoot at tillering and PI stages are given in Tables 4.3 a and b, respectively. The *kharif* and *rabi* seasons did not differ significantly in the shoot biomass at tillering stage. But significant variations were noticed between the two *kharif* and *rabi* seasons themselves. Among the *kharif* crops, biomass production was significantly higher during *kharif* 1999-'00 (1227 kg ha^{-1}). Comparison of the *rabi* crops showed that during *rabi* 1998-'99 biomass production was remarkably higher (1127 kg ha^{-1}). Towards PI stage, *kharif* and *rabi* seasons showed significant variations in the amount of shoot biomass accumulation; the *kharif* season had higher amount of biomass (2109 kg ha^{-1}). Among the two *kharif* crops, *kharif* 1999-'00 continued to be superior in terms of shoot biomass accumulation. Among the *rabi* seasons, significantly lower biomass was produced during *rabi* 1997-'98 (1481 kg ha^{-1}) whereas *rabi* 1998-'99 had 2187 kg ha^{-1}.

Table 4.3. Effect of season and treatment on shoot dry matter (kg ha^{-1}) of rice

a. Tillering stage

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	407^{b}	1163^{a}	785^{a}	1069^{ab}	539^{b}	804^{a}	795^{b}
2	NPK alone	630^{a}	1332^{a}	981^{a}	1065^{ab}	536^{b}	801^{a}	891^{ab}
3	Straw + NPK	574^{ab}	1187^{a}	881^{a}	1186^{ab}	568^{ab}	877^{a}	879^{ab}
4	Straw + NPK (higher dose of K)	573^{ab}	1181^{a}	877^{a}	1118^{ab}	633^{ab}	876^{a}	876^{ab}
5	Straw + NPK + Si	524^{ab}	1087^{a}	806^{a}	1103^{ab}	648^{ab}	876^{a}	841^{ab}
6	Straw + NPK (higher dose of K)+ Si	522^{ab}	1060^{a}	791^{a}	1172^{ab}	660^{ab}	916^{a}	854^{ab}
7	Straw + NPK + Si + Zn	617^{a}	1361^{a}	989^{a}	969^{b}	669^{ab}	819^{a}	904^{ab}
8	Straw + NPK + Si + Zn +Mg	485^{ab}	1195^{a}	840^{a}	1086^{ab}	577^{ab}	832a	836^{ab}
9	Str + NPK + Si + Zn +Mg+Cu	497^{ab}	1326^{a}	912^{a}	1269^{a}	604^{ab}	937^{a}	924^{ab}
10	Str + NPK + Si +Foliar Zn,Mg,Cu	540^{ab}	1373^{a}	957^{a}	1230^{ab}	664^{ab}	947^{a}	952^{a}
11	T_{10}+ Boron	656^{a}	1155^{a}	906^{a}	1170^{ab}	609^{ab}	890^{a}	898^{ab}
12	T_{11}+ Mo	504^{ab}	1187^{a}	846^{a}	1216^{ab}	732^{a}	974^{a}	910^{ab}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	564^{ab}	1106^{a}	835^{a}	1109^{ab}	571^{ab}	840^{a}	838^{ab}
14	T_{12} (No summer cowpea)	538^{ab}	1224^{a}	881^{a}	1132^{ab}	600^{ab}	866^{a}	874^{ab}
15	T_{2} (No summer cowpea)	505^{ab}	1418^{a}	961^{a}	1115^{ab}	633^{ab}	874^{a}	917^{ab}
16	T_{13} (No summer cowpea)	559^{ab}	1283^{a}	921^{a}	1016^{ab}	601^{ab}	809^{a}	865^{ab}
	Mean	**543**	**1227**	**885**	**1127**	**615**	**871**	**878**
CD for comparison of seasons				444			73	268
CD for comparison of *Kharif* vs *Rabi*		NS						
Sub table 4.3 a. Effect of cropping system								
	R-R-Fallow	534	1308	921	1088	611	850	885
	R-R-cowpea	566	1208	887	1130	613	872	879
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.3b. Effect of *Kharif* straw incorporation								
	Without straw	584	1240	912	1063	569	816	575
	With straw	539	1199	869	1178	633	906	887
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.3 c. Effect of silica								
	Without silica	574	1184	879	1152	601	876	878
	With silica	523	1074	798	1138	654	896	847
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.3 d. Effect of higher dose of K								
	K_{35}	549	1137	843	1145	608	876	860
	K_{70}	548	1121	834	1145	647	896	865
		NS	NS	NS	NS	NS	NS	NS

Table 4.3. Effect of season and treatment on shoot dry matter (kg ha^{-1}) of rice

b. PI stage

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	1447^{c}	2588^{ab}	2018^{abc}	1197^{d}	2024^{c}	1718^{bc}	1646^{c}	1795^{ef}
2	NPK alone	1911^{ab}	2150^{ab}	2031^{abc}	1397^{bcd}	2019^{c}	1745^{bc}	1720^{bc}	1844^{ef}
3	Straw + NPK	1908^{ab}	1950^{b}	1929^{bc}	1509^{abcd}	2289^{abc}	2069^{bc}	1956^{bc}	1945^{cde}
4	Straw + NPK (higher dose of K)	2135^{a}	2678^{ab}	2407^{ab}	1653^{ab}	2434^{abc}	1777^{bc}	1955^{abc}	2135^{abc}
5	Straw + NPK + Si	1792^{ab}	1976^{b}	1884^{c}	1486^{abcd}	1956^{c}	1576^{c}	1673^{c}	1757^{f}
6	Straw + NPK (higher dose of K)+ Si	1893^{ab}	2580^{ab}	2237^{abc}	1256^{cd}	2109^{bc}	1951^{bc}	1772^{bc}	1958^{bcde}
7	Straw + NPK + Si + Zn	1735^{bc}	2451^{ab}	2093^{abc}	1639^{ab}	2194^{abc}	1982^{bc}	1938^{bc}	2000^{abcd}
8	Straw + NPK + Si + Zn +Mg	2040^{ab}	2852^{ab}	2446^{a}	1703^{ab}	2697^{a}	1689^{bc}	2030^{ab}	2196^{ab}
9	Str + NPK + Si + Zn +Mg+Cu	1966^{ab}	2942^{a}	2454^{a}	1350^{bcd}	2239^{abc}	2065^{bc}	1885^{bc}	2113^{abc}
10	Str + NPK + Si +Foliar Zn,Mg,Cu	1952^{ab}	2462^{ab}	2207^{abc}	1353^{bcd}	1994^{c}	1889^{bc}	1779^{bc}	1950^{cde}
11	T_{10}+ Boron	1801^{ab}	2224^{ab}	2013^{abc}	1761^{a}	2173^{bc}	2150^{b}	2028^{ab}	2022^{abcd}
12	T_{11}+ Mo	1811^{ab}	2419^{ab}	2115^{abc}	1528^{abcd}	2623^{ab}	2683^{a}	2278^{a}	2213^{a}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	1709^{bc}	2073^{ab}	1891^{c}	1564^{abc}	2041^{c}	1759^{bc}	1788^{bc}	1829^{ef}
14	T_{12} (No summer cowpea)	1750^{bc}	2390^{ab}	2070^{abc}	1472^{abcd}	2046^{c}	1752^{bc}	1757^{bc}	1882^{def}
15	T_2 (No summer cowpea)	1772^{bc}	1978^{b}	1875^{c}	1486^{abcd}	2129^{bc}	1860^{bc}	1825^{bc}	1845^{ef}
16	T_{13} (No summer cowpea)	1881^{ab}	2281^{ab}	2081^{abc}	1342^{bcd}	2019^{c}	1677^{bc}	1679^{c}	1840^{ef}
	Mean	**1844**	**2375**	**2109**	**1481**	**2187**	**1903**	**1857**	**1958**
CD for comparison of seasons				219				189	173
CD for comparison of *Kharif* vs *Rabi*			150						
Sub table 4.3 a. Effect of cropping system									
	R-R-Fallow	1801	2216	2009	-	2065	1763	1914	1961
	R-R-cowpea	1810	2214	2012	-	2228	2062	2145	2079
		NS	NS	NS	-	NS	Sig	Sig	NS
Sub table 4.3 b. Effect of *Kharif* straw incorporation									
	Without straw	1834	2168	2001	1434	2026	1727	1729	1838
	With straw	1823	2253	2038	1503	2319	2168	1997	2013
		NS	NS	NS	NS	Sig	Sig	Sig	Sig
Sub table 4.3 c. Effect of silica									
	Without silica	2022	2314	2168	1581	2362	1923	1955	2040
	With silica	1843	2278	2060	1371	2033	1764	1722	1858
		NS	NS	NS	NS	Sig	NS	Sig	Sig
Sub table 4.3 d. Effect of higher dose of K									
	K_{35}	1850	1963	1907	1498	2123	1823	1814	1851
	K_{70}	2014	2629	2322	1455	2272	1864	1863	2047
		NS	Sig	Sig	NS	NS	NS	NS	Sig

At tillering stage, the treatments did not manifest any significant variations during the different seasons. During *kharif* 1998-'99, T_1 had the lowest biomass of 407 kg ha^{-1} while T_2, T_7 and T_{11} registered significantly higher biomass. During *kharif* 1999-'00, the treatments did not bring about any significant variation. During *rabi* 1998-'99, treatment receiving Straw + NPK + silica + soil application of $ZnSO_4$, $MgSO_4$ and $CuSO_4$ (T_9) produced significantly higher biomass (1269 kg ha^{-1}) than T_7 (Straw + NPK + silica + soil application of $ZnSO_4$ and $MgSO_4$) whereas in *rabi* 1999-'00, T_1 and T_2 produced lower dry matter compared to T_{12}.

At PI stage, during *kharif* 1998-'99, T_1 had lower amount of biomass whereas it was highest in treatment receiving Straw+ NPK (higher dose of K) (T_4). The other treatments did not bring about significant variation. During *kharif* 1999-'00, application of higher dose of K resulted in increasing dry matter production from 1963 kg ha^{-1} to 2629 kg ha^{-1} (Sub table 4.3 d). T_9 recorded the highest biomass and T_3, T_5 and T_{15} registered significantly lower weights. During *rabi* 1997-'98, highest biomass production was in T_{11} (Straw +NPK +Si +foliar application of Zn, Mg, Cu and B); T_1, T_2, T_6, T_9, T_{10} and T_{16} showed significantly lower values. During *rabi* 1998-'99, incorporation of *kharif* straw resulted in a remarkable increase whereas silica application decreased the dry matter production (Sub tables 4.3 b and c). Straw +NPK +Si + soil application of $ZnSO_4$ and $MgSO_4$ (T_8) produced the highest biomass and T_1, T_2, T_5, T_6, T_{10}, T_{11} and T_{13} to T_{16} had significantly lower biomass. During *rabi* 1999-'00, both raising of summer cowpea as well as *kharif* straw incorporation increased the biomass significantly (Sub table 4.3 a and b). T_{12} produced the highest biomass whereas others had significantly lower biomass production.

Root biomass

The data on root biomass production at tillering and PI stages of the crops are presented in Tables 4.4 a and b, respectively.

The mean seasonal differences in root biomass production were negligible at tillering and PI stages. But the significant variations were noticed among the *kharif* and *rabi* seasons themselves. The root biomass production at

Table 4.4. Effect of season and treatment on root dry matter (kg ha^{-1}) of rice

a. Tillering stage

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	165^{a}	594^{bc}	380^{bcd}	634^{abc}	236^{b}	435^{a}	407^{abc}
2	NPK alone	230^{a}	977^{a}	604^{a}	668^{abc}	244^{ab}	456^{a}	530^{ab}
3	Straw + NPK	200^{a}	570^{bc}	385^{bcd}	657^{abc}	297^{ab}	477^{a}	431^{abc}
4	Straw + NPK (higher dose of K)	221^{a}	462^{c}	342^{cd}	501^{bc}	345^{ab}	423^{a}	382^{abc}
5	Straw + NPK + Si	253^{a}	456^{c}	355^{cd}	534^{bc}	245^{ab}	390^{a}	372^{bc}
6	Straw + NPK (higher dose of K)+ Si	203^{a}	647^{abc}	425^{abcd}	657^{abc}	345^{ab}	501^{a}	463^{abc}
7	Straw + NPK + Si + Zn	245^{a}	901^{ab}	573^{ab}	614^{abc}	375^{a}	495^{a}	536^{a}
8	Straw + NPK + Si + Zn +Mg	166^{a}	421^{c}	294^{d}	564^{bc}	236^{b}	400^{a}	347^{c}
9	Str + NPK + Si + Zn +Mg+Cu	224^{a}	469^{c}	347^{cd}	696^{abc}	280^{ab}	488^{a}	417^{abc}
10	Str + NPK + Si +Foliar Zn,Mg,Cu	195^{a}	713^{abc}	454^{abcd}	877^{a}	319^{ab}	598^{a}	526^{ab}
11	T_{10}+ Boron	250^{a}	640^{abc}	445^{abcd}	754^{ab}	338^{ab}	546^{a}	496^{abc}
12	T_{11}+ Mo	184^{a}	570^{bc}	377^{bcd}	677^{abc}	288^{ab}	483^{a}	430^{abc}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	220^{a}	542^{bc}	381^{bcd}	757^{ab}	220^{b}	489^{a}	435^{abc}
14	T_{12} (No summer cowpea)	179^{a}	576^{bc}	378^{bcd}	727^{abc}	285^{ab}	506^{a}	442^{abc}
15	T_{2} (No summer cowpea)	182^{a}	607^{bc}	395^{bcd}	712^{abc}	246^{ab}	479^{a}	437^{abc}
16	T_{13} (No summer cowpea)	243^{a}	775^{abc}	509^{abc}	470^{c}	327^{ab}	399^{a}	454^{ab}
	Mean	**210**	**620**	**415**	**656**	**289**	**473**	**444**
CD for comparison of seasons				319			81	194
CD for comparison of *Kharif* vs *Rabi*		NS						
Sub table 4.4 a. Effect of cropping system								
	R-R-Fallow	201	653	427	636	286	461	444
	R-R-cowpea	211	696	454	701	251	476	465
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.4 b. Effect of *Kharif* straw incorporation								
	Without straw	231	765	498	632	264	448	473
	With straw	188	572	380	687	290	489	434
		NS	Sig	Sig	NS	NS	NS	NS
Sub table 4.4 c. Effect of silica								
	Without silica	211	516	363	579	321	450	407
	With silica	228	552	390	596	295	445	418
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.4 d. Effect of higher dose of K								
	K_{35}	227	513	370	596	271	433	402
	K_{70}	212	555	383	579	345	462	423
		NS	NS	NS	NS	NS	NS	NS

Table 4.4. Effect of season and treatment on root dry matter (kg ha^{-1}) of rice

b. PI stage

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	417^{a}	924^{ab}	671^{ab}	511^{b}	547^{bc}	551^{b}	536^{c}	590^{b}
2	NPK alone	463^{a}	862^{ab}	663^{ab}	486^{b}	576^{bc}	623^{ab}	562^{bc}	602^{b}
3	Straw + NPK	404^{a}	718^{ab}	611^{ab}	539^{b}	636^{abc}	646^{ab}	607bc	609^{b}
4	Straw + NPK (higher dose of K)	439^{a}	987^{a}	763^{a}	595^{b}	652^{abc}	639^{ab}	629^{bc}	682^{ab}
5	Straw + NPK + Si	519^{a}	720^{ab}	620^{ab}	692^{ab}	502^{c}	542^{b}	579^{bc}	595^{b}
6	Straw + NPK (higher dose of K)+ Si	579^{a}	901^{ab}	740^{a}	419^{b}	626^{abc}	708^{ab}	584^{bc}	647^{ab}
7	Straw + NPK + Si + Zn	464^{a}	764^{ab}	614^{ab}	589^{b}	727^{abc}	653^{ab}	656^{abc}	639^{b}
8	Straw + NPK + Si + Zn +Mg	531^{a}	916^{ab}	724^{ab}	908^{a}	753^{ab}	669^{ab}	777^{a}	755^{a}
9	Str + NPK + Si + Zn +Mg+Cu	513^{a}	996^{a}	755^{a}	478^{b}	671^{abc}	583^{b}	577^{bc}	648^{ab}
10	Str + NPK + Si +Foliar Zn,Mg,Cu	499^{a}	819^{ab}	659^{ab}	520^{b}	587^{bc}	636^{ab}	581^{bc}	612^{b}
11	T_{10}+ Boron	551^{a}	807^{ab}	679^{ab}	7.6^{ab}	623^{abc}	591^{b}	640^{abc}	656^{ab}
12	T_{11}+ Mo	527^{a}	743^{ab}	635^{ab}	600^{b}	624^{abc}	824^{a}	683^{abc}	664^{ab}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	443^{a}	637^{b}	540^{b}	708^{ab}	695^{c}	604^{ab}	602^{bc}	577^{b}
14	T_{12} (No summer cowpea)	483^{a}	779^{ab}	631^{ab}	537^{b}	788^{ab}	484^{b}	603^{bc}	614^{b}
15	T_2 (No summer cowpea)	441^{a}	703^{ab}	572^{ab}	661^{ab}	837^{a}	573^{b}	690^{ab}	643^{ab}
16	T_{13} (No summer cowpea)	577^{a}	704^{ab}	641^{ab}	588^{b}	602^{abc}	654^{ab}	615^{bc}	625^{b}
	Mean	**503**	**811**	**657**	**596**	**640**	**624**	**620**	**635**
CD for comparison of seasons				55				NS	105
CD for comparison of *Kharif* vs *Rabi*		NS							
Sub table 4.4 a. Effect of cropping system									
	R-R-Fallow	500	729	615	-	742	570	656	635
	R-R-cowpea	478	747	613	-	565	684	624	618
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.4 b. Effect of *Kharif* straw incorporation									
	Without straw	494	734	614	594	558	627	593	601
	With straw	505	747	626	559	683	651	631	629
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.4 c. Effect of silica									
	Without silica	522	853	687	567	644	643	618	646
	With silica	549	811	680	556	564	625	582	621
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.4d. Effect of higher dose of K									
	K_{35}	512	719	615	616	569	594	593	602
	K_{70}	559	944	752	507	639	674	607	665
		NS	Sig	NS	NS	NS	NS	NS	NS

tillering stage of *kharif* 1999-'00 was 620 kg ha^{-1} which was significantly higher than the biomass during *kharif* 1998-'99. At PI stage also the same trend was noticed. Among the *rabi* seasons, root biomass at tillering stage was significantly higher during *rabi* 1998-'99. But at PI, no appreciable variation was noticed among the three *rabi* seasons.

The treatments did not impart any variation in the root biomass production at tillering or PI stages of *kharif* 1998-'99 crop. During *kharif* 1999-'00, *kharif* straw incorporation has decreased the biomass at tillering stage . At PI stage, a significant increase was noticed with application of higher K dose (Sub tables 4.4). At tillering stage of *rabi* 1998-'99, root biomass was highest in Straw +NPK +Si +foliar application of Zn, Mg and Cu (T_{10}) (877 kg ha^{-1}). The lowest biomass of 470 kg ha^{-1} was produced in T_{16}. T_{10}, T_{11} and T_{13} had significantly higher biomass than T_{16}. During *rabi* 1999-'00, T_1, T_8 and T_{13} produced significantly lower biomass than T_7. At PI stage, T_8 had the highest biomass during *rabi* 1997-'98. T_5, T_{11}, T_{13} and T_{15} had comparable biomass while others produced significantly lower biomass. During *rabi* 1998-'99, T_{15} (NPK alone without summer cowpea) had the highest biomass. T_1, T_2, T_5, T_{10} and T_{13} had significantly lower root production. In *rabi* 1999-'00, T_{12} had the highest biomass of 824 kg ha^{-1} while T_1, T_5, T_9, T_{11}, T_{14} and T_{15} had significantly lower values.

Shoot root ratio

The ratio between shoot biomass and root biomass production at tillering and PI stages were worked out and the data obtained are depicted in Tables 4.5 a and b, respectively.

During both the stages, the mean values of shoot root ratio of *kharif* and *rabi* seasons did not show marked variations at tillering as well as PI stages. The two *kharif* seasons did not differ between themselves at tillering stage but at PI stage, *kharif* 1998-'99 registered significantly higher value (3.66). The *rabi* seasons differed among themselves at both the stages. At tillering stage, *rabi* 1999-'00 recorded significantly higher value of 2.13 while at PI stage, the value during 1997-'98 was significantly lower than the other two *rabi* seasons.

Table 4.5. Effect of season and treatment on shoot root ratio of rice

a. Tillering stage

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	2.47^{a}	1.96^{abcd}	2.07^{ab}	1.69^{abc}	2.28^{abcd}	1.85^{abcd}	2.10^{abc}
2	NPK alone	2.74^{a}	1.36^{d}	1.63^{b}	1.59^{bc}	2.20^{abcd}	1.76^{bcd}	1.97^{bc}
3	Straw + NPK	2.87^{a}	2.08^{abcd}	2.29^{ab}	1.81^{abc}	1.91^{cd}	1.84^{bcd}	2.17^{abc}
4	Straw + NPK (higher dose of K)	2.59^{a}	2.56^{abc}	2.57^{ab}	2.23^{a}	1.83^{cd}	2.07^{abcd}	2.3^{abc}
5	Straw + NPK + Si	2.07^{a}	2.38^{abc}	2.27^{ab}	2.07^{ab}	2.64^{a}	2.25^{a}	2.29^{ab}
6	Straw + NPK (higher dose of K)+ Si	2.57^{a}	1.64^{abcd}	1.86^{ab}	1.78^{abc}	1.91^{abcd}	1.83^{bcd}	1.98^{bc}
7	Straw + NPK + Si + Zn	2.52^{a}	1.51^{cd}	1.73^{b}	1.58^{bc}	1.78^{d}	1.66^{d}	1.85^{c}
8	Straw + NPK + Si + Zn +Mg	2.92^{a}	2.84^{a}	2.86^{a}	1.93^{abc}	2.44^{abc}	2.08^{abc}	2.53^{a}
9	Str + NPK + Si + Zn +Mg+Cu	2.22^{a}	2.83^{ab}	2.63^{ab}	1.82^{abc}	2.16^{abcd}	1.92^{abcd}	2.26^{abc}
10	Str + NPK + Si +Foliar Zn,Mg,Cu	2.77^{a}	1.93^{abcd}	2.11^{ab}	1.40^{c}	2.08^{abcd}	1.58^{cd}	2.04^{bc}
11	T_{10}+ Boron	2.62^{a}	1.8^{abcd}	2.03^{ab}	1.55^{bc}	1.80^{bcd}	1.63^{bcd}	1.95^{bc}
12	T_{11}+ Mo	2.74^{a}	2.08^{abcd}	2.24^{ab}	1.80^{abc}	2.54^{ab}	2.02^{ab}	2.29^{ab}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	2.56^{a}	2.04^{abcd}	2.19^{ab}	1.46^{c}	2.6^{ab}	1.72^{abcd}	2.17^{abc}
14	T_{12} (No summer cowpea)	3.01^{a}	2.13^{abcd}	2.33^{ab}	1.56^{bc}	2.11^{abcd}	1.71^{bcd}	2.2^{abc}
15	T_2 (No summer cowpea)	2.77^{a}	2.34^{abcd}	2.44^{ab}	1.57^{abc}	2.57^{ab}	1.82^{abcd}	2.31^{ab}
16	T_{13} (No summer cowpea)	2.30^{a}	1.66^{bcd}	1.81^{b}	2.16^{ab}	1.84^{cd}	2.03^{abcd}	1.99^{bc}
	Mean	**2.61**	**1.98**	**2.13**	**1.75**	**2.13**	**1.86**	**2.15**
CD for comparison of seasons				NS			0.31	0.38
CD for comparison of *Kharif* vs *Rabi*		NS						
Sub table 4.5 a. Effect of cropping system								
	R-R-Fallow	2.69	2.04	2.19	1.76	2.17	1.97	2.17
	R-R-cowpea	2.68	1.83	2.02	1.62	2.44	2.03	2.14
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.5b. Effect of *Kharif* straw incorporation								
	Without straw	2.53	1.69	1.88	1.74	2.21	1.83	2.04
	With straw	2.87	2.10	2.29	1.72	2.19	1.86	2.22
		NS	Sig	NS	NS	NS	NS	NS
Sub table 4.5 c. Effect of silica								
	Without silica	2.73	2.32	2.43	2.02	1.87	1.95	2.24
	With silica	2.32	2.01	2.07	1.92	2.28	2.04	2.13
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.5d. Effect of higher dose of K								
	K_{35}	2.47	2.23	2.28	1.94	2.28	2.04	2.23
	K_{70}	2.58	2.10	2.21	2.01	1.87	1.95	2.14
		NS	NS	NS	NS	NS	NS	NS

Table 4.5. Effect of season and treatment on shoot root ratio of rice

b. PI stage

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	3.47^{a}	2.80^{a}	3.01^{a}	2.34^{a}	3.70^{abc}	3.12^{ab}	3.07^{abc}	3.04^{a}
2	NPK alone	4.13^{a}	2.49^{a}	3.06^{a}	2.87^{a}	3.51^{bcd}	2.80^{ab}	3.06^{abc}	3.06^{a}
3	Straw + NPK	3.79^{a}	2.72^{a}	3.16^{a}	2.8^{a}	3.60^{abcd}	3.20^{ab}	3.22^{abc}	3.20^{a}
4	Straw + NPK (higher dose of K)	3.96^{a}	2.71^{a}	3.15^{a}	2.78^{a}	3.73^{abc}	2.78^{ab}	3.11^{abc}	3.13^{a}
5	Straw + NPK + Si	3.45^{a}	2.74^{a}	3.05^{a}	2.15^{a}	3.90^{abc}	2.91^{ab}	2.89^{abc}	2.95^{a}
6	Straw + NPK (higher dose of K)+ Si	3.27^{a}	2.86^{a}	3.02^{a}	3.0^{a}	3.37^{cd}	2.76^{ab}	3.03^{abc}	3.03^{a}
7	Straw + NPK + Si + Zn	3.74^{a}	3.21^{a}	3.41^{a}	2.78^{a}	3.02^{de}	3.04^{ab}	2.95^{abc}	3.13^{a}
8	Straw + NPK + Si + Zn +Mg	3.84^{a}	3.11^{a}	3.38^{a}	1.88^{a}	3.58^{abcd}	2.52^{b}	2.61^{abc}	2.91^{a}
9	Str + NPK + Si + Zn +Mg+Cu	3.83^{a}	2.95^{a}	3.25^{a}	2.82^{a}	3.34^{cd}	3.54^{a}	3.26^{cc}	3.26^{a}
10	Str + NPK + Si +Foliar Zn,Mg,Cu	3.91^{a}	3.01^{a}	3.35^{a}	2.60^{a}	3.40^{cd}	3.13^{ab}	3.06^{abc}	3.19^{a}
11	T_{10}+ Boron	3.27^{a}	2.76^{a}	2.96^{a}	2.49^{a}	3.49^{bcd}	3.64^{a}	3.17^{abc}	3.08^{a}
12	T_{11}+ Mo	3.44^{a}	3.26^{a}	3.33^{a}	2.55^{a}	4.20^{a}	3.26^{ab}	3.34^{a}	3.33^{a}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	3.86^{a}	3.25^{a}	3.50^{a}	2.21^{a}	4.12^{ab}	2.91^{ab}	2.97^{abc}	3.17^{a}
14	T_{12} (No summer cowpea)	3.62^{a}	3.07^{a}	3.28^{a}	2.74^{a}	2.60^{e}	3.62^{a}	2.91^{abc}	3.06^{a}
15	T_{2} (No summer cowpea)	4.02^{a}	2.81^{a}	3.28^{a}	2.25^{a}	2.54^{e}	3.25^{ab}	2.64^{bc}	2.87^{a}
16	T_{13} (No summer cowpea)	3.26^{a}	3.24^{a}	3.25^{a}	2.28^{a}	3.35^{cd}	2.56^{b}	2.73^{abc}	2.94^{a}
	Mean	**3.66**	**2.93**	**3.22**	**2.53**	**3.47**	**3.06**	**3.00**	**3.08**
CD for comparison of seasons				0.75				0.45	0.50
CD for comparison of *Kharif* vs *Rabi*		NS							
Sub table 4.5 a. Effect of cropping system									
	R-R-Fallow	3.60	3.00	3.27	-	2.83	3.14	2.99	3.23
	R-R-cowpea	3.80	3.00	3.30	-	3.94	2.99	3.47	3.50
		NS	NS	NS	-	Sig	NS	Sig	NS
Sub table 4.5 b. Effect of *Kharif* straw incorporation									
	Without straw	3.70	3.00	3.27	2.46	3.66	2.76	2.92	3.06
	With straw	3.60	3.00	3.26	2.70	3.47	3.36	3.16	3.20
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.5 c. Effect of silica									
	Without silica	3.87	2.72	3.16	2.79	3.67	2.99	3.17	3.16
	With silica	3.36	2.80	3.03	2.57	3.63	2.83	2.96	2.99
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.5 d. Effect of higher dose of K									
	K_{35}	3.60	2.70	3.10	2.47	3.75	3.06	3.06	3.07
	K_{70}	3.62	2.79	3.09	2.89	3.55	2.77	3.07	3.08
		NS	NS	NS	NS	NS	NS	NS	NS

During *kharif* 1998-'99, the treatments did not manifest any variation in the shoot root ratio values at both tillering and PI stages. During *kharif* 1999-'00, at tillering stage, incorporation of *kharif* straw resulted in increase of shoot root ratio from 1.7 to 2.1 (Sub table 4.5 b). The ratio was highest in T_8 (2.84). T_2, T_7 and T_{16} had significantly lower values. However, the treatments did not manifest any variation at PI stage. During *rabi* 1998-'99, T_4 (Straw +NPK with higher dose of K) had the highest ratio at tillering stage; T_2, T_7, T_{10}, T_{11}, T_{13} and T_{14} showed significantly lower values. During *rabi* 1999-'00, silica application increased the ratio from 1.91 to 2.64 (T_3 vs T_5) at tillering stage; but this increase was not noticed when silica application was combined with higher K dose. At PI stage of *rabi* 1997-'98, treatments did not show variation whereas during *rabi* 1998-'99 raising of summer cowpea increased the shoot root ratio significantly (Sub table 4.5 a). T_{12} showed the highest ratio and the values in T_2, T_6, T_7, T_9, T_{10}, T_{11}, T_{14}, T_{15} and T_{16} were significantly lower. During *rabi* 1999-'00, T9, T_{11} and T_{14} registered higher ratios compared to T_8 and T_{16}.

4.1.1.4. Effect of season and management practices on yield and panicle characters

Grain yield

The data on the effect of various treatments on grain yield during the five seasons are presented in Table 4.6.

The grain yield showed variations among the seasons and treatments. The variation ranged from 1671 kg ha^{-1} to 4477 kg ha^{-1} which worked out to 168 per cent. The mean productivity during *kharif* was higher and significantly superior to *rabi* season. The variation, however, was only 284 kg ha^{-1}. This small variability in the mean productivity between *kharif* and *rabi* seasons has been the result of very wide variability within the *kharif* and *rabi* themselves.

Between the two *kharif* seasons, yield was significantly higher during *kharif* 1998-'99. Among the three *rabi* seasons, the highest yield was recorded in *rabi* 1997-'98. During *rabi* 1998-'99 significantly lower yield of 2510 kg ha^{-1} was obtained.

Table 4.6. Effect of season and treatments on grain yield (kg ha^{-1}) of rice

Sl. No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	3161^{c}	2359^{d}	2760^{c}	3608^{d}	1671^{b}	2475^{d}	2585^{e}	2655^{f}
2	NPK alone	3906^{b}	3520^{abc}	3713^{ab}	3899^{cd}	2041^{e}	3077^{c}	3006^{d}	3829^{e}
3	Straw+NPK	4006^{ab}	3235^{c}	3621^{b}	4377^{abc}	2601^{abcd}	3727^{ab}	3568^{abc}	3589^{bcd}
4	Straw+NPK (higher dose of K)	3894^{b}	3420^{abc}	3651^{b}	4123^{abc}	2362^{cde}	3714^{ab}	3400^{bc}	3502^{cde}
5	Straw+NPK+ Si	4085^{ab}	3693^{ab}	3889^{ab}	4341^{abc}	2709^{abc}	4045^{ab}	3698^{ab}	3775^{abc}
6	Straw +NPK (higher dose of K)+ Si	3829^{b}	3593^{abc}	3711^{ab}	4120^{abc}	2506^{bcd}	4246^{a}	3624^{abc}	3659^{bcd}
7	Straw+NPK+Si+Zn	4007^{ab}	3687^{ab}	3847^{ab}	4062^{abcd}	2530^{abcd}	3854^{ab}	3482^{abc}	3628^{bcd}
8	Straw + NPK + Si + Zn +Mg	4229^{ab}	3785^{a}	4007^{a}	4004^{abcd}	2911^{a}	4053^{ab}	3656^{abc}	3769^{ab}
9	Straw + NPK + Si + Zn +Mg+Cu	4474^{a}	3596^{abc}	4035^{a}	4477^{a}	2876^{ab}	4230^{a}	3861^{a}	3931^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,C	4340^{ab}	3460^{abc}	3900^{ab}	4027^{abcd}	2578^{abcd}	4045^{ab}	3550^{abc}	3690^{abcd}
11	T_{10}+ Boron	4162^{ab}	3659^{ab}	3911^{ab}	4447^{ab}	2638^{abcd}	3803^{ab}	3629^{abc}	3742^{abc}
12	T_{11}+ Mo	4296^{ab}	3759^{ab}	4028^{a}	4123^{abc}	2554^{abcd}	4007^{ab}	3562^{abc}	3748^{abc}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	3850^{b}	3618^{abc}	3734^{ab}	3936^{bcd}	2637^{abcd}	3811^{ab}	3461^{bc}	3570^{bcd}
14	T_{12} (No summer cowpea)	4006^{ab}	3543^{abc}	3775^{ab}	4423^{ab}	2864^{ab}	3691^{ab}	3659^{abc}	3705^{abcd}
15	T_2 (No summer cowpea)	3962^{ab}	3379^{bc}	3671^{b}	4132^{abc}	2291^{de}	3487^{bc}	3303^{cd}	3450^{de}
16	T_{13} (No summer cowpea)	3984^{ab}	3544^{abc}	3764^{ab}	4249^{abc}	2387^{cde}	3630^{abc}	3422^{bc}	3559^{bcd}
	Mean	**4012**	**3491**	**3751**	**4147**	**2510**	**3743**	**3467**	**3581**
CD for comparison of seasons				108				328	238
CD for comparison of *Kharif* vs *Rabi*		141							
Sub table 4.6 a. Effect of cropping system									
	R-R-Fallow	3984	3489	3736	-	2514	3603	3058	3397
	R-R-cowpea	4017	3632	3825	-	2411	3632	3021	3423
		NS	NS	NS		NS	NS	NS	NS
Sub table 4.6b. Effect of *Kharif* straw incorporation									
	Without straw	3913	3561	3737	4028	2355	3506	3296	3473
	With straw	4103	3512	3808	4309	2673	3808	3597	3681
		NS	NS	NS	Sig	Sig	Sig	Sig	Sig
Sub table 4.6 c. Effect of silica									
	Without silica	3950	3328	3639	4250	2482	3721	3484	3546
	With silica	3657	3643	3800	4231	2608	4146	3661	3717
		NS	Sig	NS	NS	NS	Sig	Sig	Sig
Sub table 4.6 d. Effect of higher dose of K									
	K_{35}	4046	3464	3755	4359	2655	3886	3633	3682
	K_{70}	3862	3507	3684	4122	2434	3980	3512	3581
		NS	NS	NS	NS	NS	NS	NS	NS

The treatments exhibited variations in the grain yield recorded during different seasons. During *kharif* 1998-'99, T_9 (Straw +NPK +Si + soil application of $ZnSO_4$, $MgSO_4$ and Cu SO_4) registered the highest yield of 4474 kg ha^{-1}, whereas it was lowest in Straw alone treatment (3161 kg ha^{-1}). T_2, T_4, T_6 and T_{13} also recorded significantly lower yields. All other treatments produced yields on par with T_9. Raising of summer cowpea and its incorporation or incorporation of *kharif* straw in the previous *rabi* season did not bring about appreciable variation in yield. Application of silica or higher dose of K also did not produce any added advantage.

During *kharif* 1999-'00, the highest yield of 3785 kg ha^{-1} was recorded in T_8 (Straw +NPK +Si + soil application of $ZnSO_4$ and $MgSO_4$) Treatments except T_1, T_3 and T_{15} had yields on par with T_8. Inclusion of cowpea in the cropping system or incorporation of *kharif* straw did not produce any notable change in yield. But application of silica brought about significant increase in grain yield. Higher dose of K did not produce any effect.

During *rabi* 1997-'98 also, the highest yield of 4477 kg ha^{-1} was recorded in T_9 which was on par with all other treatments except T_1, T_2 and T_{13} which produced significantly lower yields. *Kharif* straw incorporation resulted in a significant increase in yield (Sub table 4.6 b). But silica application or higher K dose did not bring about any appreciable variation in yield.

During *rabi* 1998-'99, T_8 recorded the highest yield of 2911 kg ha^{-1}. Treatments T_3 to T_{14} produced yields on par with this treatment. T_1, T_2, T_{15} and T_{16} had significantly lower yields. During this season also *kharif* straw incorporation resulted in a significant increase in yield (Sub table 4.6 b).

During *rabi* 1999-'00 also T_1, T_2 and T_{15} differed from the rest of the treatments and the grain yield in these treatments were significantly lower. Apart from *kharif* straw incorporation, silica application also resulted in a significant yield increase during this season (Sub table 4.6 b and c).

The mean yield of *rabi* seasons as well as the overall pooled mean yield also showed the superiority of T_9. T_1, T_2, T_{15} and T_{16} had significantly lower yields. Advantages of *kharif* straw incorporation and silica application also are revealed.

When the yield level of each treatment during the *rabi* seasons are studied, it could be seen that yields are higher during *rabi* 1997-'98. *Rabi* 1998-'99 recorded considerably lower yields. Yield during *rabi* 1999-'00 also is lower, but a closer scrutiny of the deviation in yield between *rabi* 1997-'98 and 1999-'00 revealed treatment variations. Thus deviation in yield between *rabi* 1997-'98 and *rabi* 1999-'00 is 1133 kg ha^{-1} in T_1, 822 kg ha^{-1} in T_2, 650 kg ha^{-1} in T_3, 296 kg ha^{-1} in T_5 and so on. Deviation was comparatively lower in T_5, T_6, T_8, T_9, T_{10} and T_{12} whereas other treatments showed larger deviations.

Straw yield

The data on the effect of various treatments on straw yield during the five seasons are presented in Table 4.7.

The mean straw yield obtained during *kharif* season was 3418 kg ha^{-1}. *rabi* season recorded significantly lower yield of 3005 kg ha^{-1}. Significant variations were noticed within the two *kharif* seasons as well as the three *rabi* seasons studied. Thus straw yield during *kharif* 1998-'99 (3072 kg ha^{-1}) was significantly lower than *kharif* 1999-'00 yield (3764 kg ha^{-1}). Among the *rabi* crops, straw yield obtained during *rabi* 1997-'98 (3387 kg ha^{-1}) was significantly higher than the yield of *rabi* 1998-'99.

The treatments manifested significant variations in straw yield during all the seasons. During *kharif* 1998-'99, T_1 and T_2 recorded significantly lower yield compared to T_4, T_8 and T_{12}. *Kharif* straw incorporation produced a significant enhancement in yield (Sub table 4. 7 b). During *kharif* 1999-'00 also T_1 recorded the lowest yield. Significantly higher yields were noticed in T_4, T_7, T_9, T_{11} and T_{13}. During *rabi* 1997-'98, yield in T_2 to T_{16} were on par. T_1 alone recorded significantly lower yield of 2566 kg ha^{-1}. During *rabi* 1998-'99 also T_1 produced the lowest yield whereas T_9 recorded the highest yield. T_8, T_{10}, T_{11}, T_{12} and T_{14} produced comparable yields, while other treatments were significantly inferior to T_9. *Kharif* straw incorporation resulted in significant yield increase (Sub table 4.7 b). During *rabi* 1999-'00, the highest straw yield of 3497 kg ha^{-1} was recorded in T_9. Straw yield in T_3 to T_{12} was on

Table 4.7. Effect of season and treatments on straw yield (kg ha^{-1}) of rice

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	2637^{d}	3183^{c}	2910^{b}	2566^{b}	1716^{a}	2205^{f}	2162^{e}	2461^{f}
2	NPK alone	2715^{cd}	3658^{abc}	3187^{ab}	3363^{a}	2281^{c}	2611^{ef}	2752^{d}	2926^{e}
3	Straw + NPK	3241^{abc}	3211^{bc}	3226^{ab}	3435^{a}	2564^{bc}	3028^{abcde}	3009^{abcd}	3096^{cde}
4	Straw + NPK (higher dose of K)	3277^{ab}	3927^{ab}	3602^{a}	3291^{a}	2451^{bc}	3084^{abcde}	2942^{bcd}	3206^{abcd}
5	Straw + NPK + Si	3079^{abcd}	3896^{abc}	3487^{a}	3516^{a}	2583^{bc}	3296^{abc}	3132^{abc}	3274^{abcd}
6	Straw + NPK (higher dose of K)+ Si	3093^{abcd}	3770^{abc}	3432^{a}	3597^{a}	2621^{bc}	3452^{ab}	3223^{ab}	3307^{abcd}
7	Straw + NPK + Si + Zn	3079^{abcd}	4105^{a}	3592^{a}	3448^{a}	2564^{bc}	3272^{abcd}	3095^{abc}	3294^{abcd}
8	Straw + NPK + Si + Zn +Mg	3440^{a}	3714^{abc}	3577^{a}	3202^{a}	2790^{ab}	3418^{ab}	3137^{abc}	3313^{abc}
9	Straw + NPK + Si + Zn +Mg+Cu	3233^{abc}	3925^{ab}	3579^{a}	3390^{a}	3035^{a}	3497^{a}	3307^{a}	3416^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,C	3035^{abcd}	3732^{abc}	3384^{a}	3333^{a}	2735^{ab}	3377^{ab}	3148^{abc}	3242^{abcd}
11	T_{10}+ Boron	3020^{abcd}	3952^{a}	3486^{a}	3851^{a}	2753^{ab}	3270^{abcd}	3291^{a}	3369^{ab}
12	T_{11}+ Mo	3336^{a}	3561^{abc}	3449^{a}	3360^{a}	2734^{ab}	3245^{abcd}	3113^{abc}	3247^{abcd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	3060^{abcd}	4041^{a}	3550^{a}	3320^{a}	2507^{bc}	2995^{bcde}	2940^{bcd}	3184^{abcd}
14	T_{12} (No summer cowpea)	3056^{abcd}	3867^{abc}	3462^{a}	3577^{a}	2658^{abc}	2803^{cde}	3013^{abcd}	3192^{abcd}
15	T_2 (No summer cowpea)	2761^{bcd}	3901^{abc}	3331^{a}	3403^{a}	2394^{bc}	2805de	2867^{cd}	3053de
16	T_{13} (No summer cowpea)	3091^{abcd}	3776^{abc}	3433^{a}	3540^{a}	2452^{bc}	2863^{cde}	2952^{bcd}	3144^{bcde}
	Mean	**3072**	**3764**	**3418**	**3387**	**2552**	**3076**	**3005**	**3170**
CD for comparison of seasons				496				540	456
CD for comparison of *Kharif* vs *Rabi*		222							
Sub table 4.7 a. Effect of cropping system									
	R-R-Fallow	2969	3848	3409	-	2501	2824	2663	3036
	R-R-cowpea	3037	3753	3395	-	2507	2950	2729	3062
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.7 b. Effect of *Kharif* straw incorporation									
	Without straw	2955	3825	3390	3408	2413	2823	2881	3085
	With straw	3211	3546	3379	3457	2652	3025	3045	3178
		Sig	NS	NS	NS	Sig	NS	Sig	NS
Sub table 4.7 c. Effect of silica									
	Without silica	3259	3569	3414	3363	2508	3056	2976	3151
	With silica	3086	3833	3459	3557	2602	3374	3178	3290
		NS	NS	NS	NS	NS	Sig	Sig	NS
Sub table 4.7 d. Effect of higher dose of K									
	K_{35}	3160	3554	3357	3476	2574	3162	3070	3185
	K_{70}	3185	3849	3517	3444	2536	3268	3083	3256
		NS	NS	NS	NS	NS	NS	NS	NS

par with this. T_1, T_2 and T_{15} recorded significantly lower yields than these treatments. Application of silica resulted in significant yield increase (Sub table 4.7 c).

Grain-straw ratio

The data on ratio between yield of grain and straw during the five seasons are given in Table 4.8.

The mean value of grain-straw ratio during *kharif* was 1.10 and during *rabi* it was 1.15, the difference being non significant. However, the two *kharif* seasons and the three *rabi* seasons differed among themselves significantly. Grain-straw ratio recorded during *kharif* 1998-'99 was 1.31 whereas during *kharif* 1999-'00 it was significantly low (0.93). The ratio during *rabi* 1997-'98 and *rabi* 1999-'00 was 1.22. Significantly lower ratio of 0.98 was recorded during *rabi* 1998-'99.

The treatments did not manifest any significant variation in grain-straw ratio during *kharif* 1998-'99 and *rabi* 1999-'00. During *kharif* 1999-'00, T_1 recorded the lowest ratio of 0.74. T_3, T_5, T_6, T_8, T_{12} and T_{16} had significantly higher ratios. During *rabi* 1997-'98, T_1 had the highest ratio, whereas T_2, T_6, T_7, T_{10} and T_{16} registered significantly lower values. During *rabi* 1998-'99, T_2 had the lowest ratio whereas treatment receiving Straw +NPK +Si + foliar application of Zn, Mg, Cu, B and Mo and no summer cowpea (T_{14}) registered significantly higher value.

Panicle number

The data on the effect of treatments on panicle production during the five seasons are depicted in Table 4.9.

The mean number of panicles produced per m^2 was 378. During *kharif* the average panicle production was 362 while *rabi* crop registered a significantly higher number of 388. The two *kharif* seasons did not differ among themselves in the number of panicles produced. But significant variations were noticed among the *rabi* seasons. During *rabi* 1998-'99 the panicle number was only 295 which was significantly lower than the other two *rabi* seasons.

Table 4.8. Effect of season and treatments on grain straw ratio of rice

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	1.20^{a}	0.74^{b}	0.95^{a}	1.41^{a}	0.97^{ab}	1.12^{a}	1.20^{ab}	1.08^{a}
2	NPK alone	1.44^{a}	0.96^{a}	1.17^{a}	1.16^{b}	0.89^{b}	1.18^{a}	1.09^{b}	1.12^{a}
3	Straw + NPK	1.24^{a}	1.01^{a}	1.12^{ab}	1.27^{ab}	1.01^{ab}	1.23^{a}	1.19^{ab}	1.16^{a}
4	Straw + NPK (higher dose of K)	1.19^{a}	0.87^{ab}	1.02^{bc}	1.25^{ab}	0.96^{ab}	1.20^{a}	1.16^{ab}	1.09^{a}
5	Straw + NPK + Si	1.33^{a}	0.95^{a}	1.12^{ab}	1.23^{ab}	1.05^{ab}	1.23^{a}	1.18^{ab}	1.15^{a}
6	Straw + NPK (higher dose of K)+ Si	1.24^{a}	0.95^{a}	1.08^{abc}	1.15^{b}	0.96^{ab}	1.23^{a}	1.12^{b}	1.11^{a}
7	Straw + NPK + Si + Zn	1.30^{a}	0.90^{ab}	1.07^{abc}	1.18^{b}	0.99^{ab}	1.18^{a}	1.13^{b}	1.10^{a}
8	Straw + NPK + Si + Zn +Mg	1.23^{a}	1.02^{a}	1.12^{ab}	1.25^{ab}	1.04^{ab}	1.19^{a}	1.17^{ab}	1.15^{a}
9	Str + NPK + Si + Zn +Mg+Cu	1.38^{a}	0.92^{ab}	1.13^{ab}	1.32^{ab}	0.95^{ab}	1.21^{a}	1.17^{ab}	1.15^{a}
10	Str + NPK + Si +Foliar Zn,Mg,Cu	1.43^{a}	0.93^{ab}	1.15^{ab}	1.21^{b}	0.94^{ab}	1.20^{a}	1.13^{b}	1.14^{a}
11	T_{10}+ Boron	1.38^{a}	0.93^{ab}	1.12^{ab}	1.15^{b}	0.96^{ab}	1.16^{a}	1.10^{b}	1.11^{a}
12	T_{11}+ Mo	1.29^{a}	1.06^{a}	1.17^{ab}	1.23^{ab}	0.93^{ab}	1.23^{a}	1.14^{ab}	1.15^{a}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	1.26^{a}	0.90^{ab}	1.05^{abc}	1.19^{b}	1.05^{ab}	1.27^{a}	1.18^{ab}	1.12^{a}
14	T_{12} (No summer cowpea)	1.31^{a}	0.92^{ab}	1.09^{abc}	1.24^{ab}	1.08^{a}	1.32^{a}	1.21^{a}	1.16^{a}
15	T_2 (No summer cowpea)	1.43^{a}	0.87^{ab}	1.10^{ab}	1.21^{ab}	0.96^{ab}	1.24^{a}	1.15^{ab}	1.13^{a}
16	T_{13} (No summer cowpea)	1.29^{a}	0.94^{a}	1.10^{ab}	1.20^{b}	0.97^{ab}	1.27^{a}	1.16^{ab}	1.13^{a}
	Mean	**1.31**	**0.93**	**1.10**	**1.22**	**0.98**	**1.22^{a}**	**1.15**	**1.13**
CD for comparison of seasons				0.16				0.19	0.16
CD for comparison of *Kharif* vs *Rabi*		NS							
Sub table 4.8 a. Effect of cropping system									
	R-R-Fallow	1.34	0.91	1.10	-	1.00	1.28	1.14	1.13
	R-R-cowpea	1.33	0.97	1.13	-	0.96	1.23	1.09	1.12
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.8 b. Effect of *Kharif* straw incorporation									
	Without straw	1.33	0.93	1.10	1.18	0.97	1.24	1.14	1.13
	With straw	1.28	0.99	1.13	1.25	1.01	1.26	1.18	1.16
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.8 c. Effect of silica									
	Without silica	1.21	0.94	1.07	1.26	0.99	1.22	1.17	1.13
	With silica	1.28	0.95	1.10	1.19	1.00	1.23	1.15	1.13
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.8 d. Effect of higher dose of K									
	K_{35}	1.28	0.98	1.12	1.25	1.03	1.23	1.18	1.16
	K_{70}	1.21	0.91	1.05	1.20	0.96	1.22	1.14	1.10
		NS	NS	NS	NS	NS	NS	NS	NS

Table 4.9 Effect of season and treatments on panicles per m² of rice

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	340^{ab}	300^{b}	320^{c}	427^{ab}	233^{c}	340^{c}	333^{d}	328^{c}
2	NPK alone	380^{ab}	340^{ab}	360^{abc}	440^{ab}	287^{abc}	407^{ab}	378^{bc}	371^{ab}
3	Straw + NPK	380^{ab}	300^{b}	340^{abc}	427^{ab}	307^{ab}	440^{a}	391^{abc}	371^{ab}
4	Straw + NPK (higher dose of K)	373^{ab}	373^{ab}	373^{abc}	453^{ab}	280^{bc}	380^{bc}	371^{c}	372^{ab}
5	Straw + NPK + Si	367^{ab}	327^{ab}	347^{abc}	440^{ab}	307^{ab}	413^{ab}	387^{abc}	371^{ab}
6	Straw + NPK (higher dose of K)+ Si	373^{ab}	373^{ab}	373^{abc}	500^{a}	327^{ab}	433^{ab}	420^{a}	401^{a}
7	Straw + NPK + Si + Zn	353^{ab}	407^{a}	380^{ab}	460^{ab}	307^{ab}	420^{ab}	396^{abc}	389^{a}
8	Straw + NPK + Si + Zn +Mg	340^{ab}	367^{ab}	353^{abc}	440^{ab}	293^{abc}	427^{ab}	387^{abc}	373^{ab}
9	Str + NPK + Si + Zn +Mg+Cu	347^{ab}	380^{ab}	363^{abc}	440^{ab}	340^{a}	440^{ab}	407^{abc}	389^{a}
10	Str + NPK + Si +Foliar Zn,Mg,Cu	380^{ab}	360^{ab}	370^{abc}	500^{a}	287^{abc}	453^{a}	413^{ab}	396^{a}
11	T_{10}+ Boron	340^{ab}	367^{ab}	353^{abc}	467^{ab}	273^{bc}	440^{a}	393^{abc}	377^{ab}
12	T_{11}+ Mo	353^{ab}	420^{a}	387^{ab}	447^{ab}	273^{bc}	427^{ab}	382^{abc}	384^{ab}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	373^{ab}	360^{ab}	367^{abc}	480^{a}	313^{ab}	413^{ab}	402^{abc}	388^{a}
14	T_{12} (No summer cowpea)	393^{a}	393^{ab}	393^{a}	447^{ab}	340^{ab}	407^{ab}	398^{abc}	396^{a}
15	T_{2} (No summer cowpea)	327^{b}	360^{ab}	343^{bc}	387^{b}	280^{bc}	453^{a}	373^{c}	361^{b}
16	T_{13} (No summer cowpea)	373^{ab}	360^{ab}	367^{abc}	453^{ab}	273^{bc}	413^{ab}	380^{bc}	375^{ab}
	Mean	**362**	**362**	**362**	**450**	**295**	**419**	**388**	**378**
CD for comparison of seasons				NS				47	33
CD for comparison of *Kharif* vs *Rabi*						20			
Sub table 4.9 a. Effect of cropping system									
	R-R-Fallow	364	371	368	-	298	424	361	364
	R-R-cowpea	369	373	371	-	291	416	353	362
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.9 b. Effect of *Kharif* straw incorporation									
	Without straw	376	353	364	458	291	411	387	0
	With straw	376	371	373	440	307	424	390	384
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.9 c. Effect of silica									
	Without silica	377	337	357	440	293	410	381	371
	With silica	370	350	360	470	317	423	403	386
		NS	NS	NS	NS	NS	NS	Sig	NS
Sub table 4.9 d. Effect of higher dose of K									
	K_{35}	373	313	343	433	307	427	389	371
	K_{70}	373	373	373	477	303	407	396	387
		NS	Sig	NS	Sig	NS	NS	NS	NS

Panicle production showed variation with treatments during *kharif* 1998-'99. The highest number of 393 was produced in T_{14} whereas T_{15} which received NPK alone, registered significantly lower number. The other treatments were on par with these. During *kharif* 1999-'00, T_7 and T_{12} produced significantly higher number of panicles than T_1 and T_3. Higher K dose resulted in significant increase in panicle number (Sub table 4.9 d). There was no appreciable variation in the other treatments. During *rabi* 1997-'98, the panicle production in different treatments did not show significant variation except for a lower number in T_{15} compared to T_6, T_{10} and T_{13}. Greater variation in panicle production was observed during *rabi* 1998-'99. Number of panicles/ m^2 in T_9 was 340. The number in T_1 was considerably low (233). T_4, T_{11}, T_{12}, T_{15} and T_{16} also had significantly lower panicle number. Rest of the treatments had panicles on par with the number in T_9. During *rabi* 1999-'00 also, the lowest panicle number was seen in T_1. Panicle number in T_3, T_{10}, T_{11} and T_{15} was significantly higher than that in T_1 and T_4.

Spikelets per panicle

The data on the effect of treatments on number of spikelets per panicle during the five seasons are depicted in Table 4.10.

The mean number of spikelets per panicle in *kharif* season was 76.8, which was significantly higher than the spikelet number in *rabi* season (66.7). The spikelet number did not show appreciable variation between the two *kharif* seasons, but significant difference was noticed among the *rabi* crops. The number of spikelets per panicle in *rabi* 1997-'98 crop was 71.3 which was significantly higher than the spikelet number during *rabi* 1999-'00.

During *kharif* 1998-'99 and 1999-'00, the treatments did not manifest any significant variation in spikelet number. During *rabi* 1997-'98, significantly higher number of spikelets per panicle was noticed in treatment receiving Straw +NPK +Si + foliar application of Zn, Mg and Cu (T_{10}). Lower number was recorded in T_1 (66.0) and T_2 (57.5) whereas other treatments were on par. During *rabi* 1998-'99 also spikelet number differed with treatments. The highest number of 78.7 was recorded in T_{10}. T_1, T_2, T_5, T_6 and T_8 recorded significantly lower values. During *rabi* 1999-'00, T_{14} had

Table 4.10 Effect of season and treatments on spikelets per panicle of rice

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	71.0^{a}	71.0^{a}	71.0^{c}	66.0^{f}	57.6^{cd}	59.9^{b}	61.2^{bc}	65.1^{c}
2	NPK alone	76.0^{a}	76.9^{a}	76.5^{abc}	57.5^{g}	62.7^{bcd}	56.0^{b}	58.7^{c}	65.8^{c}
3	Straw + NPK	69.0^{a}	74.0^{a}	71.5^{bc}	70.5^{cdef}	74.0^{ab}	57.4^{d}	67.3^{ab}	69.0^{bc}
4	Straw + NPK (higher dose of K)	76.9^{a}	76.6^{a}	76.6^{abc}	73.2^{bcde}	65.4^{abcd}	66.6^{ab}	68.4^{ab}	71.7^{ab}
5	Straw + NPK + Si	80.0^{a}	82.5^{a}	81.2^{a}	68.3^{cdef}	62.3^{bcd}	57.2^{b}	62.6^{bc}	70.1^{bc}
6	Straw + NPK (higher dose of K)+ Si	75.3^{a}	77.5^{a}	76.4^{abc}	74.7^{bcd}	64.1^{bcd}	62.2^{ab}	67.2^{b}	70.9^{bc}
7	Straw + NPK + Si + Zn	77.0^{a}	80.5^{a}	78.7^{abc}	75.1^{bc}	73.3^{ab}	61.1^{ab}	69.6^{ab}	73.4^{ab}
8	Straw + NPK + Si + Zn +Mg	78.0^{a}	81.2^{a}	79.6^{abc}	68.9^{cdef}	57.0^{d}	60.6^{ab}	62.2^{bc}	69.1^{bc}
9	Str + NPK + Si + Zn +Mg+Cu	79.0^{a}	81.7^{a}	80.4^{a}	73.9^{bcde}	52.0^{ab}	62.7^{ab}	69.5^{ab}	73.9^{ab}
10	Str + NPK + Si +Foliar Zn,Mg,Cu	77.7^{a}	82.0^{a}	79.9^{ab}	87.1^{a}	78.7^{a}	58.2^{b}	74.7^{a}	76.7^{a}
11	T_{10}+ Boron	75.3^{a}	77.3^{a}	76.3^{abc}	71.6^{bcdef}	70.0^{abcd}	60.1^{b}	67.2^{bc}	70.9^{bc}
12	T_{11}+ Mo	72.7^{a}	74.3^{a}	73.5^{abc}	67.4^{ef}	74.3^{ab}	59.0^{b}	66.9^{b}	69.5^{bc}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	76.3^{a}	80.8^{a}	78.5^{abc}	78.1^{b}	69.6^{abcd}	62.2^{ab}	70.0^{ab}	73.4^{ab}
14	T_{12} (No summer cowpea)	75.7^{a}	76.5^{a}	76.9^{abc}	70.2^{cdef}	71.0^{abc}	72.3^{a}	71.2^{ab}	73.1^{bc}
15	T_{2} (No summer cowpea)	75.3^{a}	77.3^{a}	76.3^{abc}	67.8^{def}	67.7^{abcd}	60.8^{ab}	65.4^{bc}	69.8^{bc}
16	T_{13} (No summer cowpea)	78.7^{a}	72.8^{a}	75.8^{abc}	69.9^{cdef}	65.0^{abcd}	61.9^{ab}	65.6^{bc}	69.7^{bc}
	Mean	**75.9**	**77.7**	**76.8**	**71.3**	**67.8**	**61.1**	**66.7**	**70.8**
CD for comparison of seasons				NS				6.8	4.6
CD for comparison of *Kharif* vs *Rabi*		3.9							
Sub table 4.10 a. Effect of cropping system									
	R-R-Fallow	76.6	75.5	76.1	-	67.9	65.0	66.5	71.3
	R-R-cowpea	75.0	77.3	76.2	-	68.9	59.1	64.0	70.1
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.10 b. Effect of *Kharif* straw incorporation									
	Without straw	77.0	76.8	76.9	68.5	65.8	60.0	64.8	69.6
	With straw	72.5	74.9	73.7	69.4	73.1	62.9	68.5	70.6
		NS	NS	NS	NS	NS	NS	Sig	NS
Sub table 4.10 c. Effect of silica									
	Without silica	72.8	75.3	74.1	71.9	69.7	62.0	67.9	70.3
	With silica	77.7	80.0	78.8	71.5	63.5	59.7	64.9	70.5
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.10 d. Effect of higher dose of K									
	K_{35}	74.5	78.3	76.4	69.4	68.2	57.3	65.0	69.5
	K_{70}	76.0	77.1	76.5	74.0	65.1	64.4	67.8	71.3
		NS	NS	NS	Sig	NS	NS	NS	NS

a spikelet number of 72.3. T_1, T_2, T_3, T_5, T_{10}, T_{11} and T_{12} had significantly lower spikelet number.

Chaff percentage

The data on percentage of chaff recorded in different treatments during the five seasons are presented in Table 4.11.

The mean chaff percentage in *kharif* was 29.1 while in *rabi* it was 30.1. The values of chaff percentage showed no variations between the seasons.

During *kharif* 1998-'99, T_{16} had a chaff percentage of 34.4, which was on par with all other treatments except Straw +NPK +Si + foliar application of Zn, Mg, Cu, B and Mo (T_{12}), which registered a lower value of 25.0. During *kharif* 1999-'00, there was no appreciable difference between treatments in the chaff percentage.

During *rabi* 1997-'98, chaff percentage was highest in treatment receiving Straw and NPK with higher dose of K (32.8). T_1, T_9, T_{10}, T_{13}, T_{14} and T_{16} recorded values significantly lower than this. During *rabi* 1998-'99, Straw +NPK +Si + soil application of $ZnSO_4$ and $MgSO_4$ (T_8) had the highest chaff percentage. T_3 and T_{14} registered significantly lower percentage. During *rabi* 1999-'00 the treatments did not vary among themselves in chaff percentage values.

Thousand grain weight

The data on test weight of grains recorded in different treatments during the five seasons are presented in Table 4.12.

During *kharif*, the mean thousand grain weight was 28.9g, which was significantly higher than the *rabi* season value of 26.3g. Among the two *kharif* seasons, thousand grain weight recorded during *kharif* 1998-'99 was 28.4g while in *kharif* 1999-'00 it was significantly higher. But the *rabi* seasons did not show remarkable variations.

During *kharif* 1998-'99, the grain weight of 29.1g was recorded in treatment receiving Straw +NPK +Si + foliar application of Zn, Mg, Cu and B (T_{11}). T_1, T_{15} and T_{16} had significantly lower weights. During *kharif* 1999-'00,

Table 4.11 Effect of season and treatments on chaff percentage of rice

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	27.3^{ab}	29.2^{a}	28.2^{ab}	25.2^{cd}	33.6^{ab}	35.5^{a}	31.4^{ab}	30.2^{ab}
2	NPK alone	30.8^{ab}	30.6^{a}	30.7^{ab}	28.5^{abcd}	37.0^{ab}	29.9^{a}	31.8^{ab}	31.4^{a}
3	Straw + NPK	26.5^{ab}	30.6^{a}	28.5^{ab}	27.4^{abcd}	28.1^{b}	30.4^{a}	28.6^{ab}	28.6^{b}
4	Straw + NPK (higher dose of K)	32.2^{ab}	28.8^{a}	30.5^{ab}	32.8^{a}	29.8^{ab}	27.9^{a}	30.2^{ab}	30.3^{ab}
5	Straw + NPK + Si	28.1^{ab}	28.6^{a}	28.3^{ab}	26.2^{abcd}	35.6^{ab}	27.0^{a}	29.6^{ab}	29.1^{ab}
6	Straw + NPK (higher dose of K)+ Si	31.8^{ab}	30.3^{a}	31.1^{ab}	30.9^{abc}	31.9^{ab}	25.7^{a}	29.5^{ab}	30.1^{ab}
7	Straw + NPK + Si + Zn	27.6^{ab}	29.8^{a}	28.7^{ab}	28.0^{abcd}	30.5^{ab}	25.5^{a}	28.0^{ab}	28.3^{ab}
8	Straw + NPK + Si + Zn +Mg	27.4^{ab}	29.9^{a}	28.6^{ab}	28.3^{abcd}	37.9^{a}	33.4^{a}	33.2^{a}	31.4^{a}
9	Str + NPK + Si + Zn +Mg+Cu	25.1^{ab}	28.9^{a}	27.0^{b}	25.8^{bcd}	31.2^{ab}	29.8^{a}	28.9^{ab}	28.2^{ab}
10	Str + NPK + Si +Foliar Zn,Mg,Cu	18.0^{ab}	29.1^{a}	28.5^{ab}	25.0^{cd}	33.7^{ab}	31.1^{a}	29.9^{ab}	29.4^{ab}
11	T_{10}+ Boron	28.0^{ab}	30.8^{a}	29.4^{ab}	26.8^{abcd}	30.3^{ab}	29.9^{a}	29.0^{ab}	29.1^{ab}
12	T_{11}+ Mo	25.0^{b}	29.9^{a}	27.0^{b}	26.9^{abcd}	30.6^{ab}	37.7^{a}	31.7^{ab}	29.8^{ab}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	25.5^{ab}	29.4^{a}	27.4^{b}	22.3^{d}	33.8^{ab}	36.7^{a}	30.9^{ab}	29.5^{ab}
14	T_{12} (No summer cowpea)	27.4^{ab}	29.8^{a}	28.6^{ab}	23.6^{d}	27.7^{b}	33.5^{a}	28.3^{ab}	28.4^{ab}
15	T_2 (No summer cowpea)	29.8^{ab}	30.5^{a}	30.1^{ab}	31.6^{ab}	35.2^{ab}	30.5^{a}	32.4^{ab}	31.5^{a}
16	T_{13} (No summer cowpea)	34.4^{a}	30.4^{a}	32.4^{a}	25.0^{cd}	31.3^{ab}	26.4^{a}	27.6^{b}	29.5^{ab}
	Mean	**28.4**	**29.8**	**29.1**	**27.1**	**32.4**	**30.7**	**30.1**	**29.7**
CD for comparison of seasons				NS				NS	NS
CD for comparison of *Kharif* vs *Rabi*		NS							
Sub table 4.11 a. Effect of cropping system									
	R-R-Fallow	30.5	30.2	30.4	-	31.4	30.1	30.7	30.6
	R-R-cowpea	26.8	30.0	28.4	-	33.8	34.8	34.3	31.0
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.11b. Effect of *Kharif* straw incorporation									
	Without straw	30.2	30.1	30.2	25.3	34.0	31.0	30.1	30.1
	With straw	26.0	30.1	28.0	26.0	28.8	33.9	29.5	28.9
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.11 c. Effect of silica									
	Without silica	29.4	29.7	29.5	30.1	29.0	29.2	29.4	29.4
	With silica	30.0	29.5	29.7	28.6	33.8	26.4	29.6	29.6
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.11d. Effect of higher dose of K									
	K_{35}	27.3	29.6	28.4	26.8	31.9	28.7	29.1	28.8
	K_{70}	32.0	29.6	30.8	31.9	30.9	26.8	29.8	30.2
		NS	NS	NS	NS	NS	NS	NS	NS

Table 4.12 Effect of season and treatments on thousand grain weight (g) of rice

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	27.5^{c}	29.3^{ab}	28.4^{bc}	26.1^{b}	26.3^{a}	25.5^{b}	26.0^{a}	26.9^{c}
2	NPK alone	28.4^{abc}	29.4^{ab}	28.9^{abc}	26.3^{a}	26.5^{a}	26.3^{ab}	26.4^{a}	27.4^{abc}
3	Straw + NPK	28.1^{abc}	28.9^{ab}	28.5^{abc}	26.0^{ab}	26.5^{a}	26.9^{ab}	26.5^{a}	27.3^{abc}
4	Straw + NPK (higher dose of K)	28.8^{ab}	28.3^{b}	28.6^{abc}	25.3^{bc}	26.7^{a}	29.5^{ab}	26.2^{a}	27.1^{bc}
5	Straw + NPK + Si	28.4^{abc}	30.1^{ab}	29.3^{ab}	26.0^{ab}	27.0^{a}	27.1^{ab}	26.7^{a}	27.7^{a}
6	Straw + NPK (higher dose of K)+ Si	28.6^{ab}	29.3^{ab}	29.0^{abc}	26.0^{abc}	26.3^{a}	26.6^{ab}	26.3^{a}	27.4^{abc}
7	Straw + NPK + Si + Zn	28.7^{abc}	29.9^{ab}	29.3^{ab}	26.1^{ab}	26.5^{a}	27.4^{a}	26.7^{a}	27.7^{ab}
8	Straw + NPK + Si + Zn +Mg	27.9^{bc}	29.2^{ab}	28.6^{abc}	25.7^{abc}	26.9^{a}	26.8^{ab}	26.5^{a}	27.3^{abc}
9	Str + NPK + Si + Zn +Mg+Cu	28.5^{abc}	29.2^{ab}	28.9^{abc}	26.0^{ab}	26.3^{a}	26.9^{ab}	26.4^{a}	27.4^{abc}
10	Str + NPK + Si +Foliar Zn,Mg,Cu	28.4^{abc}	30.7^{a}	29.6^{a}	25.6^{abc}	26.9^{a}	26.1^{ab}	26.2^{a}	27.5^{abc}
11	T_{10}+ Boron	29.1^{a}	28.8^{ab}	29.0^{abc}	26.1^{ab}	26.9^{a}	26.2^{ab}	26.4^{a}	27.4^{abc}
12	T_{11}+ Mo	28.4^{abc}	29.5^{ab}	29.0^{abc}	24.8^{c}	26.9^{a}	27.5^{a}	26.4^{a}	27.4^{abc}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	29.1^{a}	30.1^{ab}	29.6^{a}	25.4^{abc}	27.0^{a}	26.5^{ab}	26.3^{a}	27.6^{abc}
14	T_{12} (No summer cowpea)	28.8^{ab}	29.6^{ab}	29.2^{abc}	25.5^{abc}	26.7^{a}	27.0^{ab}	26.4^{a}	27.5^{abc}
15	T_{2} (No summer cowpea)	28.0^{bc}	29.2^{ab}	28.6^{abc}	24.9^{c}	26.0^{a}	25.9^{ab}	25.6^{a}	26.8^{abc}
16	T_{13} (No summer cowpea)	27.5^{c}	28.7^{ab}	28.1^{c}	25.4^{abc}	26.1^{a}	27.0^{ab}	26.2^{a}	26.9^{c}
	Mean	**28.4**	**29.4**	**28.9**	**25.7**	**26.6**	**26.6**	**26.3**	**27.3**
CD for comparison of seasons				0.8				NS	0.6
CD for comparison of *Kharif* vs *Rabi*		0.5							
Sub table 4.12 a. Effect of cropping system									
	R-R-Fallow	28.1	29.2	28.6	-	26.3	26.6	26.5	27.5
	R-R-cowpea	28.6	29.7	29.2	-	26.8	26.8	26.8	28.0
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.12 b. Effect of *Kharif* straw incorporation									
	Without straw	28.3	29.4	28.9	25.7	26.5	26.6	26.3	27.3
	With straw	28.4	29.3	28.9	25.4	26.7	27.1	26.4	27.4
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.12 c. Effect of silica									
	Without silica	28.5	28.6	28.5	25.7	26.6	26.7	26.3	27.2
	With silica	28.5	29.7	29.1	26.0	26.7	26.9	26.5	27.5
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.12 d. Effect of higher dose of K									
	K_{35}	28.3	29.5	28.9	26.0	26.8	27.0	26.6	27.5
	K_{70}	28.7	28.8	28.8	25.7	26.5	26.6	26.2	27.2
		NS	NS	NS	NS	NS	NS	NS	NS

thousand grain weight was highest in T_{10} (30.7g). Other treatments except T_4 registered grain weight on par with this.

During *rabi* 1997-'98, thousand grain weight in NPK alone treatment (T_2) was 26.3g which was on par with other treatments excepting T_4, T_{12} and T_{15} which had significantly lower weights. During *rabi* 1998-'99, the treatment differences were non significant. During *rabi* 1999-'00, the highest thousand grain weight of 27.5g was expressed in T_{12} (Straw +NPK +Si +foliar application of Zn, Mg, Cu, B and Mo). T_1 alone had a significantly lower value than this.

Panicle length

The data on length of panicle recorded in different treatments during the five seasons are presented in Table 4.13.

During *kharif*, the mean panicle length of the crop was 20.2 cm. *Rabi* crop had a significantly lower length of 18.1 cm. Significant variation was noticed within *kharif* and *rabi* seasons themselves in panicle length. During *kharif* 1998-'99, the panicle length was 18.6 cm while *kharif* 1999-'00 had significantly longer panicles. Among the *rabi* seasons the panicle length during *rabi* 1997-'98 and *rabi* 1998-'99 were on par but the length was significantly lower in *rabi* 1999-'00 (17.3 cm).

During *kharif* 1998-'99, the treatments exhibited variation in panicle length. In T_4 (Straw +NPK with higher K dose) it was 20 cm and it was on par with the panicle length of T_5 and T_7. Other treatments exhibited significantly lower length. During *kharif* 1999-'00, panicle length in T_8 (Straw +NPK +Si + soil application of $ZnSO_4$ and $MgSO_4$) was 22.5 cm. T_1 alone recorded a significantly lower length (20.6 cm). During *rabi* 1997-'98, T_{10} (Straw +NPK +Si + foliar application of Zn, Mg and Cu) had the highest panicle length of 19.5 cm while T_1, T_2, T_3 and T_{14} had significantly lower values. During *rabi* 1998-'99, panicle length of 19.6 cm was recorded in T_8. Straw alone treatment showed a significantly lower value. During *rabi* 1999-'00, the differences among treatments were non significant.

Table 4.13 Effect of season and treatments on panicle length (cm) of rice

Sl.No.	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	18.2^{b}	20.6^{c}	19.4^{bcd}	18.0^{b}	16.9^{b}	17.2^{a}	17.4^{b}	18.2^{bcd}
2	NPK alone	18.6^{b}	21.5^{abc}	20.1^{ab}	17.8^{b}	18.2^{ab}	17.5^{a}	17.8ab	18.7^{bcd}
3	Straw + NPK	17.8^{b}	21.7^{abc}	19.8^{bc}	17.8^{b}	19.5^{ab}	17.7^{a}	18.3^{ab}	19.1^{ab}
4	Straw + NPK (higher dose of K)	20.0^{a}	21.5^{abc}	20.8^{a}	18.6^{ab}	18.4^{ab}	18.1^{a}	18.4^{a}	19.3^{a}
5	Straw + NPK + Si	19.7^{ab}	21.8^{abc}	20.8^{a}	18.6^{ab}	18.7^{ab}	16.4^{a}	17.9^{ab}	19.0^{ab}
6	Straw + NPK (higher dose of K)+ Si	18.4^{b}	22.1^{ab}	20.3^{ab}	19.0^{ab}	18.5^{ab}	17.0^{a}	18.2^{ab}	19.0^{ab}
7	Straw + NPK + Si + Zn	19.1^{ab}	22.3^{ab}	20.7^{ab}	18.9^{ab}	18.7^{ab}	17.3^{a}	18.3^{ab}	19.3^{a}
8	Straw + NPK + Si + Zn +Mg	17.9^{b}	22.5^{a}	20.2^{ab}	18.7^{ab}	19.6^{a}	17.8^{a}	18.7^{a}	19.3^{a}
9	Str + NPK + Si + Zn +Mg+Cu	18.8^{b}	21.8^{abc}	20.3^{ab}	18.1^{ab}	18.9^{ab}	17.8^{a}	18.3^{ab}	19.1^{ab}
10	Str + NPK + Si +Foliar Zn,Mg,Cu	18.1^{b}	21.7^{abc}	19.9^{bc}	19.5^{a}	18.6^{ab}	16.9^{a}	18.3^{ab}	19.0^{ab}
11	T_{10}+ Boron	18.6^{b}	21.6^{abc}	20.1^{bc}	18.5^{ab}	18.8^{ab}	17.3^{a}	18.2^{ab}	19.0^{ab}
12	T_{11}+ Mo	18.3^{b}	22.1^{ab}	20.2^{ab}	18.0^{ab}	18.8^{ab}	16.9^{a}	17.9^{ab}	18.8^{bcd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	18.5^{b}	21.9^{abc}	20.2^{ab}	18.7^{ab}	18.6^{ab}	17.6^{a}	18.3^{ab}	19.1^{ab}
14	T_{12} (No summer cowpea)	18.9^{b}	21.7^{abc}	20.3^{ab}	18.0^{b}	18.6^{ab}	18.3^{a}	18.3^{ab}	19.1^{ab}
15	T_{2} (No summer cowpea)	18.3^{b}	21.7^{abc}	20.0^{bc}	18.6^{ab}	19.0^{ab}	16.8^{a}	18.1^{ab}	18.9^{bcd}
16	T_{13} (No summer cowpea)	17.8^{b}	21.4^{abc}	19.6^{bc}	18.0^{ab}	18.4^{ab}	16.9^{a}	17.8^{ab}	18.5^{bcd}
	Mean	**18.6**	**21.7**	**20.2**	**18.4**	**18.6**	**17.3**	**18.1**	**19.0**
CD for comparison of seasons				0.7				0.7	0.5
CD for comparison of *Kharif* vs *Rabi*		0.4							
Sub table 4.13 a. Effect of cropping system									
	R-R-Fallow	18.3	21.6	20.0	-	18.7	17.3	18.0	19.0
	R-R-cowpea	18.5	21.8	20.2	-	18.5	17.3	17.9	19.0
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.13 b. Effect of *Kharif* straw incorporation									
	Without straw	18.3	21.6	20.0	18.2	18.4	17.3	18.0	18.8
	With straw	18.3	21.8	20.1	17.9	18.7	17.6	18.2	19.0
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.13 c. Effect of silica									
	Without silica	18.9	21.6	20.3	18.2	18.4	17.9	18.3	19.2
	With silica	19.1	22.0	20.5	18.8	18.6	16.7	18.0	19.0
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.13 d. Effect of higher dose of K									
	K_{35}	18.8	21.8	20.3	18.2	18.7	17.1	18.1	19.1
	K_{70}	19.2	21.8	20.5	18.8	18.5	17.6	18.3	19.2
		NS	NS	NS	NS	NS	NS	NS	NS

4.1.2. Interrelationships of growth and yield attributes with rice yield.

The coefficients of correlation of growth attributes and yield components with yield of rice are presented in Table 4.14. Total dry matter production at maturity and panicles/m^2 exerted the maximum influence on grain yield as indicated by the highly significant positive correlation of 0.806 and 0.622 respectively. The contribution of grains/panicle (r=0.292) ranked next to these. Tiller count at maturity showed positive significant correlation, but the tiller counts at the other stages did not show any promising relation with yield. Similar was the case with the dry matter production in the early stages.

On the other hand, straw yield showed significant positive relation with almost all the characters.

4.1.3. Effect of season and management practices on nutrient content of rice

4.1.3.1. Nitrogen

The data on effect of season and management practices on nitrogen content of rice at tillering, PI and maturity stages and in grain are given in Tables 4.15 a,b.c and d, respectively.

Tillering stage

At tillering stage, the average content of N in *kharif* crop was 2.01 per cent whereas *rabi* had a significantly higher content of 2.55 per cent. The two *kharif* seasons did not differ appreciably in N content but significant differences were noticed between the two *rabi* seasons. *Rabi* 1998-'99 registered 2.26 per cent whereas *rabi* 1999-'00 had a significantly higher content (2.83 %).

Treatment effects showed that during *kharif* 1998-'99, T_6 (Straw +NPK with higher K dose +Si) recorded the highest content of 2.72 per cent. Inclusion of cowpea in the cropping system as well as supply of higher K dose resulted in significant increase in N content (Sub table 4.15 a and d). During *kharif* 1999-'00, highest N content of 2.24 per cent was recorded in T_4. Silica

Table 4.14. Coefficients of correlation of growth attributes and yield components with yield of rice *

Attributes	Grain yield	Straw yield
Plant height at tillering stage	-0.161	0.471**
Plant height at PI stage	0.077	0.551**
Plant height at maturity	0.120	0.339**
Tiller count at tillering stage	0.104	0.552**
Tiller count at PI stage	0.035	0.357**
Tiller count at maturity	0.292**	0.492**
Shoot dry matter production at tillering stage	-0.422**	0.318**
Shoot dry matter production at PI stage	-0.285	0.151
Root dry matter production at tillering stage	-0.448**	0.225
Root dry matter production at PI stage	-0.125	0.296*
Total dry matter production at maturity	0.806**	0.623**
Length of panicle	-0.068	0.427**
Panicles per m^2	0.622**	0.374**
1000 grain weight	0.087	0.386**
Grains per panicle	0.292**	0.293**

* Data pooled over five seasons

Table 4.15. Effect of season and treatments on nitrogen content (%) of rice

a. Tillering stage

Sl.No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	1.95^{bc}	1.59^{bcd}	1.77^{c}	1.86^{bc}	1.93^{e}	1.90^{d}	1.84^{b}
2	NPK alone	2.16^{abc}	2.05^{abc}	2.11^{abc}	2.51^{a}	2.24^{e}	2.38^{bc}	2.24^{a}
3	Straw + NPK	2.04^{bc}	2.10^{ab}	2.07^{abc}	2.63^{a}	2.10^{e}	2.36^{c}	2.22^{a}
4	Straw + NPK (higher dose of K)	2.42^{ab}	2.24^{a}	2.33^{a}	2.35^{ab}	2.78^{d}	2.56^{abc}	2.45^{a}
5	Straw + NPK + Si	2.11^{abc}	1.77^{abcd}	1.94^{abc}	2.18^{abc}	3.20^{abc}	2.69^{ab}	2.31^{a}
6	Straw + NPK (higher dose of K)+ Si	2.72^{a}	1.44^{d}	2.08^{abc}	2.20^{abc}	2.87^{cd}	2.53^{abc}	2.31^{a}
7	Straw + NPK + Si + Zn	2.16^{abc}	1.60^{bcd}	1.88^{bc}	2.16^{abc}	3.22^{ab}	2.69^{ab}	2.29^{a}
8	Straw + NPK + Si + Zn +Mg	2.13^{abc}	1.96^{abcd}	2.04^{abc}	2.47^{a}	3.08^{abcd}	2.77^{a}	2.41^{a}
9	Straw + NPK + Si + Zn +Mg+Cu	2.52^{ab}	1.52^{cd}	2.02^{abc}	2.11^{abc}	3.34^{a}	2.73^{a}	2.37^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	2.29^{ab}	1.64^{bcd}	1.97^{abc}	2.39^{ab}	2.82^{d}	2.60^{abc}	2.28^{a}
11	T_{10}+ Boron	2.29^{ab}	1.44^{d}	1.86^{bc}	2.27^{abc}	2.85^{a}	2.56^{abc}	2.21^{a}
12	T_{11}+ Mo	2.29^{ab}	2.12^{ab}	2.20^{ab}	1.76^{c}	2.90^{bcd}	2.33^{c}	2.27^{a}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	2.28^{ab}	1.89^{abcd}	2.09^{abc}	2.25^{abc}	2.87^{cd}	2.56^{abc}	2.32^{a}
14	T_{12} (No summer cowpea)	1.61^{e}	1.84^{abcd}	1.72^{c}	2.29^{abc}	3.08^{abcd}	2.68^{ab}	2.20^{a}
15	T_{2} (No summer cowpea)	1.99^{bc}	2.03^{abc}	2.01^{abc}	2.39^{ab}	3.03^{abcd}	2.71^{a}	2.36^{a}
16	T_{13} (No summer cowpea)	2.11^{abc}	1.87^{abcd}	1.99^{abc}	2.35^{ab}	3.01^{abcd}	2.68^{ab}	2.34^{a}
	Mean	**2.19**	**1.82**	**2.01**	**2.26**	**2.83**	**2.55**	**2.28**
CD for comparison of seasons				NS			0.16	0.18
CD for comparison of *Kharif vs Rabi*					0.23			
Sub table 4.15 a. Effect of cropping system								
	R-R-Fallow	1.90	1.91	1.91	2.34	3.04	2.69	2.30
	R-R-cowpea	2.24	2.02	2.13	2.17	2.67	2.42	2.28
		Sig	NS	NS	NS	Sig	NS	NS
Sub table 4.15 b. Effect of Kharif straw incorporation								
	Without straw	2.18	1.94	2.06	2.37	2.71	2.54	2.30
	With straw	1.98	2.02	2.00	2.23	2.69	2.46	2.23
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.15 c. Effect of silica								
	Without silica	2.23	2.17	2.20	2.49	2.44	2.46	2.34
	With silica	2.42	1.61	2.01	2.19	3.04	2.61	2.31
		NS	Sig	NS	NS	Sig	NS	NS
Sub table 4.15d. Effect of higher dose of K								
	K35	2.08	2.04	2.06	2.41	2.65	2.53	2.30
	K70	2.57	1.84	2.21	2.28	2.83	2.56	2.38
		Sig	NS	NS	NS	NS	NS	NS

application resulted in a significant decrease in N content (Sub table 4.15 c). Other treatments did not manifest significant variation.

During *rabi* 1998-'99, T_1 and T_{12} had considerably lower content. N content in other treatments was statistically on par. During *rabi* 1999-'00, T_9 (Straw +NPK +Si + soil application of $ZnSO_4$, $MgSO_4$ and $CuSO_4$) recorded the highest content of 3.34 per cent. T_5, T_7, T_8, T_{14}, T_{15} and T_{16} had statistically similar concentration; other treatments registered significantly lower N content.

PI stage

At PI stage, the mean N content did not manifest any variations with seasons. However, treatment effects were reflected in the nutrient composition of each season.

During *kharif* 1998-'99, foliar application of Mo resulted in N concentration of 2.14 per cent. The content in T_1, T_2, T_7, T_9, T_{11} and T_{15} were significantly low. Growing of summer cowpea, *kharif* straw incorporation or silica application did not bring about any appreciable change. During *kharif* 1999-'00, foliar application of Zn, Mg and Cu resulted in significant decrease in N content over their soil application. Supply of normal dose of NPK along with straw and silica (T_5) registered significantly higher N concentration (2.01 %) over the addition of higher K dose with straw and silica.

During *rabi* 1997-'98, N content was lowest in T_1 (1.33%). Supply of NPK brought about significant increase in N content. Combined application of straw and NPK resulted in further increase. But application of silica brought about significant reduction in N content. Soil application of Mg increased the content from 1.75 per cent to 1.98 per cent. But the effect of soil application of Cu was negative. During *rabi* 1998-'99, T_9 registered the highest N content of 2.24 per cent. T_4 recorded significantly lower concentration while the contents in other treatments were on par with T_9.

During *rabi* 1999-'00, T_1 had the lowest N content of 1.61 per cent. Inclusion of cowpea or *kharif* straw incorporation did not bring about any appreciable change in N concentration.

Table 4.15. Effect of season and treatments on nitrogen content (%) of rice

b. PI stage

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	1.49^{d}	1.66^{cde}	1.58^{ef}	1.33^{b}	1.52^{ab}	1.61^{c}	1.49^{c}	1.52^{d}
2	NPK alone	1.49^{d}	1.61^{de}	1.55^{f}	1.62^{fg}	1.73^{ab}	1.93^{abc}	1.76^{ab}	1.67^{cd}
3	Straw + NPK	2.11^{ab}	1.61^{de}	1.86^{abcde}	1.97^{abc}	1.72^{ab}	1.79^{abc}	1.82^{ab}	1.84^{abc}
4	Straw + NPK (higher dose of K)	2.04^{abc}	1.89^{abcde}	1.96^{abc}	2.07^{a}	1.60^{ab}	2.10^{ab}	1.92^{ab}	1.94^{a}
5	Straw + NPK + Si	1.90^{abcd}	2.01^{abc}	1.96^{abcd}	1.81^{bcdef}	1.56^{ab}	1.82^{abc}	1.73^{b}	1.82^{abc}
6	Straw + NPK (higher dose of K)+ Si	1.69^{abcd}	1.59^{e}	1.64^{ef}	1.78^{defg}	1.59^{ab}	1.89^{abc}	1.75^{ab}	1.71^{cd}
7	Straw + NPK + Si + Zn	1.61^{cd}	1.72^{bcde}	1.66^{def}	1.75^{defg}	1.41^{b}	2.01^{ab}	1.72^{d}	1.70^{cd}
8	Straw + NPK + Si + Zn +Mg	1.93^{abcd}	2.03^{ab}	1.98^{ab}	1.98^{ab}	1.86^{ab}	1.98^{ab}	1.94^{ab}	1.96^{a}
9	Straw + NPK + Si + Zn +Mg+Cu	1.55^{d}	2.15^{a}	1.85^{abcde}	1.58^{g}	2.24^{a}	2.08^{ab}	1.97^{a}	1.92^{ab}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	1.72^{abcd}	1.73^{bcde}	1.73^{bcdef}	1.72^{efg}	1.69^{ab}	1.75^{bc}	1.72^{b}	1.72^{bc}
11	T_{10}+ Boron	1.61^{cd}	1.73^{bcde}	1.67^{cdef}	1.78^{cdefg}	1.78^{ab}	1.75^{bc}	1.77^{ab}	1.73^{bc}
12	T_{11}+ Mo	2.14^{a}	1.96^{abcd}	2.05^{a}	1.61^{g}	1.57^{ab}	2.01^{ab}	1.73^{b}	1.86^{abc}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	1.73^{abcd}	1.63^{de}	1.68^{cdef}	1.94^{abcd}	1.50^{ab}	1.80^{ab}	1.75^{ab}	1.72^{bc}
14	T_{12} (No summer cowpea)	1.67^{abcd}	1.72^{bcde}	1.69^{bcdef}	1.76^{defg}	1.87^{ab}	2.14^{a}	1.92^{ab}	1.83^{abc}
15	T_{2} (No summer cowpea)	1.65^{bcd}	1.66^{cde}	1.66^{ef}	1.82^{bcde}	2.10^{ab}	1.77^{bc}	1.90^{ab}	1.80^{abc}
16	T_{13} (No summer cowpea)	2.05^{abc}	1.70^{bcde}	1.87^{abcde}	1.77^{defg}	1.52^{ab}	2.14^{a}	1.81^{ab}	1.83^{abc}
	Mean	**1.77**	**1.78**	**1.77**	**1.77**	**1.70**	**1.91**	**1.79**	**1.79**
	CD for comparison of seasons			NS				NS	NS
	CD for comparison of *Kharif vs Rabi*	NS							
Sub table 4.15 a. Effect of cropping system									
	R-R-Fallow	1.79	1.69	1.74	-	1.83	2.02	1.88	1.83
	R-R-cowpea	1.79	1.73	1.76	-	1.60	1.91	1.75	1.76
		NS	NS	NS		NS	NS	NS	NS
Sub table 4.15b. Effect of Kharif straw incorporation									
	Without straw	1.75	1.64	1.70	1.78	1.58	1.95	1.77	1.74
	With straw	1.97	1.76	1.87	1.78	1.72	1.98	1.82	1.84
		NS	NS	Sig	NS	NS	NS	NS	NS
Sub table 4.15 c. Effect of silica									
	Without silica	2.07	1.75	1.95	2.02	1.66	1.94	1.87	1.89
	With silica	1.79	1.80	1.80	1.79	1.57	1.86	1.74	1.76
		NS	NS	NS	Sig	NS	NS	NS	NS
Sub table 4.15d. Effect of higher dose of K									
	K35	2.00	1.81	1.91	1.89	1.64	1.80	1.78	1.83
	K70	1.86	1.74	1.80	1.92	1.59	2.00	1.84	1.82
		NS	NS	NS	NS	NS	NS	NS	NS

Straw

N concentration of straw did not manifest any significant variation with seasons. The mean N content during *kharif* was 0.87 per cent while during *rabi* it was 0.92 per cent. The various treatments also did not exhibit any significant change in the N concentration during *kharif* 1998-'99, *kharif* 1999-'00 and *rabi* 1997-'98. During *rabi* 1998-'99, growing of summer cowpea resulted in significant increase in N concentration (Sub table 4.15 a). During *rabi* 1999-'00, T_1 registered the lowest N content of 0.72 per cent. Other treatments did not bring about any significant variation in the N concentration.

Grain

Seasonal variations were noticed in the grain N concentration. N content during *kharif* was 1.02 per cent whereas *rabi* registered significantly increased value of 1.16 per cent. Contents in the two *kharif* seasons were similar whereas in *rabi*, 1998-'99 and 1999-'00 seasons had significantly higher percentage over *rabi* 1997-'98.

During *kharif* 1998-'99 treatment receiving straw + NPK + silica recorded 1.09 per cent which was significantly higher to the content recorded in T_9 (0.83%). The other treatments did not show any remarkable variations. During *kharif* 1999-'00, straw alone treatment recorded low N content of 0.89 per cent. Foliar application of Mo resulted in significant increase of N concentration from 0.99 per cent to 1.20 per cent. Other treatments did not manifest any significant influence.

4.1.3.2. Phosphorous

The data on effect of season and management practices on phosphorous content of rice at tillering, PI and maturity stages and in grain are given in Tables 4.16 a,b.c and d, respectively.

Table 4.15. Effect of season and treatments on nitrogen content (%) of rice

C. Straw

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	0.90^{a}	0.88^{a}	0.89^{ab}	0.70^{a}	0.87^{bcde}	0.72^{e}	0.76^{d}	0.81^{c}
2	NPK alone	0.87^{a}	0.88^{a}	0.87^{ab}	0.83^{a}	1.03^{ab}	0.91^{abcde}	0.92^{abc}	0.90^{abc}
3	Straw + NPK	0.84^{a}	1.00^{a}	0.92^{ab}	0.85^{a}	0.90^{abcde}	0.98^{abcd}	0.91^{bc}	0.91^{ab}
4	Straw + NPK (higher dose of K)	0.85^{a}	0.88^{a}	0.86^{ab}	0.86^{a}	1.05^{ab}	1.10^{abc}	1.00^{ab}	0.95^{a}
5	Straw + NPK + Si	0.88^{a}	0.86^{a}	0.87^{ab}	0.89^{a}	1.02^{abc}	1.12^{ab}	1.01^{a}	0.95^{a}
6	Straw + NPK (higher dose of K)+ Si	0.85^{a}	0.77^{a}	0.81^{ab}	0.95^{a}	0.90^{abcde}	0.90^{bcde}	0.92^{abc}	0.87^{abc}
7	Straw + NPK + Si + Zn	0.81^{a}	0.96^{a}	0.89^{ab}	0.83^{a}	0.93^{abcd}	0.79^{de}	0.85^{c}	0.86^{abc}
8	Straw + NPK + Si + Zn +Mg	0.89^{a}	1.00^{a}	0.94^{a}	0.90^{a}	0.84^{cde}	0.86^{cde}	0.87^{c}	0.90^{abc}
9	Straw + NPK + Si + Zn +Mg+Cu	0.78^{a}	0.93^{a}	0.85^{ab}	0.96^{a}	0.86^{bcde}	0.93^{abcde}	0.92^{bc}	0.89^{abc}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	0.86^{a}	0.92^{a}	0.89^{ab}	0.87^{a}	1.00^{abc}	0.88^{bcde}	0.91^{bc}	0.90^{abc}
11	T_{10}+ Boron	0.90^{a}	0.92^{a}	0.91^{ab}	0.82^{a}	0.87^{bcde}	1.07^{abc}	0.92^{abc}	0.92^{ab}
12	T_{11}+ Mo	0.90^{a}	0.75^{a}	0.83^{ab}	0.91^{a}	0.92^{abcde}	1.00^{abcd}	0.94^{abc}	0.89^{abc}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	0.92^{a}	0.95^{a}	0.93^{ab}	0.94^{a}	1.06^{a}	0.93^{abcde}	0.98^{ab}	0.96^{a}
14	T_{12} (No summer cowpea)	0.80^{a}	0.79^{a}	0.79^{ab}	0.95^{a}	0.76^{de}	0.91^{abcde}	0.87^{c}	0.84^{bc}
15	T_2 (No summer cowpea)	0.96^{a}	0.82^{a}	0.89^{ab}	0.99^{a}	0.70^{e}	0.92^{abcde}	0.87^{c}	0.88^{abc}
16	T_{13} (No summer cowpea)	0.81^{a}	0.75^{a}	0.78^{b}	1.02^{a}	0.94^{abcd}	1.16^{a}	1.04^{ab}	0.90^{abc}
	Mean	**0.86**	**0.88**	**0.87**	**0.89**	**0.91**	**0.95**	**0.92**	**0.90**
CD for comparison of seasons				NS				NS	NS
CD for comparison of *Kharif* vs *Rabi*		NS							
Sub table 4.15 a. Effect of cropping system									
	R-R-Fallow	0.85	0.79	0.82	-	0.80	1.00	0.90	0.86
	R-R-cowpea	0.90	0.86	0.88	-	1.00	0.95	0.97	0.93
		NS	NS	NS		Sig	NS	NS	NS
Sub table 4.15b. Effect of Kharif straw incorporation									
	Without straw	0.87	0.86	0.86	0.93	1.01	1.00	0.98	0.93
	With straw	0.85	0.84	0.85	0.90	0.86	0.96	0.91	0.88
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.15 c. Effect of silica									
	Without silica	0.84	0.94	0.89	0.85	0.97	1.04	0.95	0.93
	With silica	0.87	0.81	0.84	0.92	0.96	1.01	0.96	0.91
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.15d. Effect of higher dose of K									
	K35	0.86	0.93	0.89	0.87	0.96	1.05	0.96	0.93
	K70	0.85	0.82	0.84	0.90	0.97	1.00	0.96	0.91
		NS	NS	NS	NS	NS	NS	NS	NS

Table 4.15. Effect of season and treatments on nitrogen content (%) of rice

d. Grain

l. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	1.05^{ab}	0.89^{d}	0.97^{ab}	0.89^{b}	1.14^{bc}	1.09^{c}	1.04^{fg}	1.01^{f}
2	NPK alone	0.95^{ab}	1.03^{abcd}	0.99^{ab}	0.93^{b}	1.26^{ab}	1.24^{bc}	1.14^{bcdef}	1.08^{bcde}
3	Straw + NPK	0.86^{ab}	1.10^{abc}	0.98^{ab}	0.91^{b}	1.38^{a}	1.40^{ab}	1.23^{ab}	1.13^{abcd}
4	Straw + NPK (higher dose of K)	0.92^{ab}	0.96^{bcd}	0.94^{b}	1.03^{ab}	1.38^{a}	1.56^{a}	1.32^{a}	1.17^{ab}
5	Straw + NPK + Si	1.09^{a}	1.12^{abc}	1.11^{a}	1.10^{ab}	1.26^{ab}	1.38^{ab}	1.25^{ab}	1.19^{a}
6	Straw + NPK (higher dose of K)+ Si	0.94^{ab}	1.05^{abcd}	0.99^{ab}	1.05^{ab}	1.19^{b}	1.26^{bc}	1.17^{bcde}	1.10^{abcde}
7	Straw + NPK + Si + Zn	1.04^{ab}	1.00^{bcd}	1.02^{ab}	1.04^{ab}	1.02^{c}	1.09^{c}	1.05^{efg}	1.04^{def}
8	Straw + NPK + Si + Zn +Mg	0.99^{ab}	1.14^{ab}	1.06^{ab}	1.04^{ab}	1.37^{a}	1.21^{bc}	1.21^{abcd}	1.15^{abc}
9	Straw + NPK + Si + Zn +Mg+Cu	0.83^{b}	1.09^{abcde}	0.96^{ab}	0.99^{ab}	1.37^{bc}	1.38^{ab}	1.25^{bcde}	1.13^{abcde}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	1.02^{ab}	1.05^{abcd}	1.03^{ab}	0.92^{b}	1.24^{ab}	1.16^{bc}	1.10^{cdefg}	1.08^{bcde}
11	T_{10}+ Boron	1.02^{ab}	0.99^{bcd}	1.00^{ab}	0.88^{b}	1.13^{bc}	1.21^{bc}	1.07^{efg}	1.05^{cdef}
12	T_{11}+ Mo	0.95^{ab}	1.20^{a}	1.07^{ab}	0.97^{ab}	1.02^{c}	1.30^{bc}	1.09^{defg}	1.09^{abcde}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	1.04^{ab}	1.14^{ab}	1.09^{ab}	0.97^{ab}	1.24^{ab}	1.23^{bc}	1.15^{bcdef}	1.12^{abcde}
14	T_{12} (No summer cowpea)	0.88^{ab}	1.12^{abc}	1.00^{ab}	1.07^{ab}	1.38^{a}	1.23^{bc}	1.22^{abc}	1.14^{abcd}
15	T_2 (No summer cowpea)	1.06^{ab}	0.92^{cd}	0.99^{ab}	1.26^{a}	1.14^{bc}	1.37^{ab}	1.25^{ab}	1.15^{abc}
16	T_{13} (No summer cowpea)	0.92^{ab}	1.14^{ab}	1.03^{ab}	0.93^{b}	1.02^{c}	1.07^{c}	1.00^{g}	1.01^{ef}
	Mean	**0.97**	**1.06**	**1.02**	**1.00**	**1.22**	**1.26**	**1.16**	**1.10**
CD for comparison of seasons				NS				0.13	0.09
CD for comparison of *Kharif vs Rabi*		0.11							
Sub table 4.15 a. Effect of cropping system									
	R-R-Fallow	0.95	1.06	1.01	-	1.18	1.22	1.20	1.10
	R-R-cowpea	0.98	1.12	1.05	-	1.17	1.25	1.21	1.13
		NS	NS	NS		NS	NS	NS	NS
Sub table 4.15b. Effect of Kharif straw incorporation									
	Without straw	0.97	1.10	1.04	0.94	1.17	1.18	1.10	1.07
	With straw	0.90	1.14	1.02	0.98	1.26	1.31	1.18	1.12
		NS	NS	NS	NS	Sig	NS	Sig	NS
Sub table 4.15 c. Effect of silica									
	Without silica	0.89	1.03	0.96	0.97	1.38	1.48	1.28	1.15
	With silica	1.02	1.09	1.05	1.08	1.23	1.32	1.21	1.14
		NS	NS	NS	NS	Sig	Sig	NS	NS
Sub table 4.15d. Effect of higher dose of K									
	K35	0.98	1.11	1.04	1.01	1.32	1.39	1.24	1.16
	K70	0.93	1.01	0.97	1.04	1.29	1.41	1.25	1.13
		NS	NS	NS	NS	NS	NS	NS	NS

Tillering stage

The mean P content did not exhibit variation between *kharif* and *rabi* seasons. But the two *kharif* seasons and *rabi* seasons showed variation among themselves. Thus during *kharif* 1998-'99, the mean P content was 0.38 per cent which was significantly higher than the content during *kharif* 1999-'00. Similarly *rabi* 1998-'99 had a content of 0.47 per cent while the content during *rabi* 1999-'00 was remarkably low.

During *kharif* 1998-'99, higher content was in T_3, T_7, T_9 and T_{10}. T_{14} and T_{15} had significantly lower values. During *kharif* 1999-'00, the treatment differences were not significant. During *rabi* 1998-'99, T_1, T_2 and T_{16} registered lower P content while there was no statistical differences between other treatments. During *rabi* 1999-'00 also the differences were non significant.

PI stage

During this stage, the mean P content of *kharif* and *rabi* crops did not exhibit variation. But there was variation among seasons themselves. *Kharif* 1998-'99 recorded a content of 0.43 per cent whereas *kharif* 1999-'00 registered significantly lower concentration. The P content of the plant in *rabi* 1999-'00 was considerably lower than its content in *rabi* 1997-'98 and *rabi* 1998-'99.

During *kharif* 1998-'99, P concentration in T_6 and T_{12} was higher than T_{14} and T_{16}. But the differences with other treatments were not significant. During *kharif* 1999-'00, P concentration in all the treatments was on par with each other.

During *rabi* 1997-'98, P content was highest (0.63%) in T_{11} (Straw +NPK +Si + foliar application of Zn, Mg, Cu and B). T_1, T_2, T_5, T_8 and T_{15} registered significantly lower values. During *rabi* 1998-'99, T_9 (Straw +NPK +Si + soil application of $ZnSO_4$, $MgSO_4$, and $CuSO_4$) registered the highest content (0.52%) while T_{13} alone had significantly lower content; other treatments had concentration on par with it. During *rabi* 1999-'00, content in T_3 was significantly lower compared to T_6 and T_{12}.

Table 4.16. Effect of season and treatments on phosphorous content (%) of rice

a. Tillering stage

I. No	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	0.37^{ab}	0.29^{a}	0.33^{ab}	0.41^{b}	0.27^{a}	0.34^{b}	0.33^{bc}
2	NPK alone	0.38^{ab}	0.30^{a}	0.34^{ab}	0.41^{b}	0.24^{a}	0.33^{b}	0.33^{bc}
3	Straw + NPK	0.44^{a}	0.28^{a}	0.36^{a}	0.50^{ab}	0.23^{a}	0.36^{ab}	0.36^{ab}
4	Straw + NPK (higher dose of K)	0.37^{ab}	0.29^{a}	0.33^{ab}	0.51^{ab}	0.22^{a}	0.36^{ab}	0.35^{ab}
5	Straw + NPK + Si	0.36^{ab}	0.28^{a}	0.32^{ab}	0.46^{ab}	0.26^{a}	0.36^{b}	0.34^{abc}
6	Straw + NPK (higher dose of K)+ Si	0.37^{ab}	0.29^{a}	0.33^{ab}	0.49^{ab}	0.28^{a}	0.39^{ab}	0.36^{ab}
7	Straw + NPK + Si + Zn	0.42^{a}	0.25^{a}	0.34^{ab}	0.44^{ab}	0.27^{a}	0.35^{b}	0.35^{abc}
8	Straw + NPK + Si + Zn +Mg	0.36^{ab}	0.27^{a}	0.32^{ab}	0.47^{ab}	0.24^{a}	0.36^{b}	0.34^{abc}
9	Straw + NPK + Si + Zn +Mg+Cu	0.43^{a}	0.30^{a}	0.36^{a}	0.47^{ab}	0.29^{a}	0.38^{ab}	0.37^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	0.43^{a}	0.31^{a}	0.37^{a}	0.45^{ab}	0.27^{a}	0.36^{b}	0.36^{ab}
11	T_{10}+ Boron	0.39^{ab}	0.30^{a}	0.34^{ab}	0.50^{ab}	0.24^{a}	0.37^{ab}	0.36^{ab}
12	T_{11}+ Mo	0.37^{ab}	0.28^{a}	0.33^{ab}	0.44ab	0.29^{a}	0.37^{ab}	0.35^{ab}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	0.38^{ab}	0.26^{a}	0.32^{ab}	0.49^{ab}	0.28^{a}	0.38^{ab}	0.35^{ab}
14	T_{12} (No summer cowpea)	0.30^{b}	0.27^{a}	0.29^{bc}	0.58^{a}	0.30^{a}	0.44^{a}	0.36^{ab}
15	T_2 (No summer cowpea)	0.28^{b}	0.25^{a}	0.27^{c}	0.46^{ab}	0.25^{a}	0.35^{b}	0.31^{c}
16	T_{13} (No summer cowpea)	0.39^{ab}	0.30^{a}	0.34^{ab}	0.42^{b}	0.28^{a}	0.35^{b}	0.34^{bc}
	Mean	**0.38**	**0.28**	**0.33**	**0.47**	**0.26**	**0.37**	**0.35**
CD for comparison of season				0.06			0.09	0.05
CD for comparison of *Kharif vs Rabi*		NS						
Sub table 4.16 a Effect of cropping system								
	R-R-Fallow	0.32	0.27	0.30	0.48	0.27	0.38	0.34
	R-R-cowpea	0.38	0.28	0.33	0.45	0.27	0.36	0.34
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.16b Effect of Kharif straw incorporation								
	Without straw	0.38	0.28	0.33	0.44	0.26	0.35	0.34
	With straw	0.37	0.28	0.32	0.51	0.27	0.39	0.36
		NS	NS	NS	NS	NS	Sig	NS
Sub table 4.16c Effect of silica application								
	Without silica	0.40	0.29	0.34	0.50	0.22	0.36	0.35
	With silica	0.36	0.29	0.32	0.48	0.27	0.37	0.35
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.16d Effect of higher dose of K								
	K_{35}	0.40	0.28	0.34	0.48	0.24	0.36	0.35
	K_{70}	0.37	0.29	0.33	0.50	0.25	0.38	0.35
		NS	NS	NS	NS	NS	NS	NS

Table 4.16. Effect of season and treatments on phosphorous content (%) of rice

b. PI stage

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	0.39^{abc}	0.27^{a}	0.34^{ab}	0.42^{bc}	0.46^{ab}	0.30^{ab}	0.39^{abc}	0.37^{abc}
2	NPK alone	0.42^{abc}	0.29^{a}	0.35^{ab}	0.38^{c}	0.44^{ab}	0.28^{ab}	0.37^{c}	0.36^{abc}
3	Straw + NPK	0.48^{ab}	0.28^{a}	0.38^{a}	0.56^{ab}	0.44^{ab}	0.24^{b}	0.41^{abc}	0.40^{abc}
4	Straw + NPK (higher dose of K)	0.41^{abc}	0.29^{a}	0.35^{ab}	0.53^{abc}	0.44^{ab}	0.30^{ab}	0.42^{abc}	0.39^{abc}
5	Straw + NPK + Si	0.48^{ab}	0.29^{a}	0.37^{a}	0.37^{c}	0.48^{ab}	0.27^{ab}	0.37^{bc}	0.38^{abc}
6	Straw + NPK (higher dose of K)+ Si	0.50^{a}	0.26^{a}	0.38^{a}	0.50^{abc}	0.50^{ab}	0.32^{a}	0.44^{a}	0.42^{ab}
7	Straw + NPK + Si + Zn	0.44^{abc}	0.26^{a}	0.36^{ab}	0.55^{ab}	0.44^{ab}	0.30^{ab}	0.43^{ab}	0.40^{abc}
8	Straw + NPK + Si + Zn +Mg	0.41^{abc}	0.28^{a}	0.34^{ab}	0.46^{bc}	0.50^{ab}	0.31^{ab}	0.42^{abc}	0.39^{abc}
9	Straw + NPK + Si + Zn +Mg+Cu	0.48^{ab}	0.27^{a}	0.35^{a}	0.55^{ab}	0.52^{a}	0.28^{ab}	0.45^{a}	0.42^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	0.48^{ab}	0.23^{a}	0.37^{ab}	0.52^{abc}	0.44^{ab}	0.29^{ab}	0.41^{abc}	0.39^{abc}
11	T_{10}+ Boron	0.39^{abc}	0.25^{a}	0.33^{ab}	0.63^{a}	0.44^{ab}	0.29^{ab}	0.45^{a}	0.40^{abc}
12	T_{11}+ Mo	0.51^{a}	0.27^{a}	0.38^{a}	0.49^{abc}	0.45^{ab}	0.32^{a}	0.42^{abc}	0.41^{abc}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	0.41^{abc}	0.25^{a}	0.33^{ab}	0.50^{abc}	0.41^{b}	0.31^{ab}	0.41^{abc}	0.38^{abc}
14	T_{12} (No summer cowpea)	0.32^{c}	0.25^{a}	0.29^{b}	0.49^{abc}	0.43^{ab}	0.28^{ab}	0.40^{abc}	0.35^{c}
15	T_2 (No summer cowpea)	0.44^{abc}	0.26^{a}	0.35^{ab}	0.46^{bc}	0.50^{ab}	0.27^{ab}	0.41^{abc}	0.39^{abc}
16	T_{13} (No summer cowpea)	0.34^{bc}	0.25^{a}	0.29^{b}	0.50^{abc}	0.42^{ab}	0.29^{ab}	0.40^{abc}	0.35^{bc}
	Mean	**0.43**	**0.27**	**0.35**	**0.49**	**0.46**	**0.29**	**0.41**	**0.39**
CD for comparison of season				NS				0.08	NS
CD for comparison of *Kharif vs Rabi*		NS							
Sub table 4.16 a Effect of cropping system									
	R-R-Fallow	0.37	0.26	0.31	-	0.45	0.28	0.39	0.34
	R-R-cowpea	0.45	0.27	0.36	-	0.43	0.30	0.37	0.36
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.16b Effect of Kharif straw incorporation									
	Without straw	0.39	0.26	0.33	0.46	0.42	0.29	0.39	0.37
	With straw	0.44	0.27	0.35	0.51	0.44	0.28	0.41	0.39
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.16c Effect of silica application									
	Without silica	0.45	0.28	0.37	0.54	0.44	0.27	0.42	0.40
	With silica	0.49	0.27	0.38	0.44	0.49	0.30	0.41	0.40
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.16d Effect of higher dose of K									
	K_{35}	0.48	0.28	0.38	0.47	0.46	0.25	0.39	0.39
	K_{70}	0.46	0.27	0.37	0.51	0.47	0.31	0.43	0.39
		NS	NS	NS	NS	NS	NS	NS	NS

Straw

The mean content of P in straw of *kharif* and *rabi* crops did not show appreciable variation. But there was significant variation among *kharif* and *rabi* seasons themselves. Thus *kharif* 1998-'99 recorded significantly higher P content (0.20%) than *kharif* 1999-'00 crop. The content in *rabi* 1999-'00 was 0.08 per cent which was significantly lower than the contents in 1997-'98 and 1998-'99 crops.

P content of plant was unaffected by treatments during *kharif* 1998-'99 and *kharif* 1999-'00. During *rabi* 1997-'98, there was remarkable difference among treatments. Higher content was recorded in T_9 (0.27%). T_4, T_5, T_7, T_{10}, T_{13} and T_{16} had contents on par with it whereas other treatments registered significantly lower concentration. During *rabi* 1998-'99, T_5 (Straw + NPK + Si) recorded significantly lower P content than T_8 and T_{15}; all other treatments registered P content on par with them. During *rabi* 1999-'00, there was no appreciable difference among treatments in the P content.

Grain

The mean P content of grain during *kharif* was 0.34 per cent whereas *rabi* had a significantly lower content. The two *kharif* crops also differed in the P content. It was higher during *kharif* 1998-'99 (0.40%). Among the three *rabi* crops, grain P concentration during *rabi* 1999-'00 was significantly lower than the other two *rabi* seasons. The treatments did not bring about any appreciable variation in the P content during any season.

4.1.3.4. Potassium

The data on effect of season and management practices on potassium content of rice at tillering, PI and maturity stages and in grain are given in Tables 4.17 a,b.c and d, respectively.

Table 4.16. Effect of season and treatments on phosphorous content (%) of rice

C. Straw

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	0.19^{a}	0.10^{a}	0.15^{a}	0.16^{de}	0.23^{ab}	0.06^{a}	0.15^{bc}	0.15^{a}
2	NPK alone	0.19^{a}	0.12^{a}	0.15^{a}	0.21^{bcd}	0.24^{ab}	0.08^{a}	0.18^{abc}	0.17^{a}
3	Straw + NPK	0.17^{a}	0.11^{a}	0.14^{a}	0.17^{de}	0.23^{ab}	0.08^{a}	0.16^{bc}	0.15^{a}
4	Straw + NPK (higher dose of K)	0.18^{a}	0.11^{a}	0.15^{a}	0.25^{ab}	0.25^{ab}	0.09^{a}	0.20^{a}	0.18^{a}
5	Straw + NPK + Si	0.21^{a}	0.11^{a}	0.16^{a}	0.24^{ab}	0.18^{b}	0.09^{a}	0.17^{abc}	0.17^{a}
6	Straw + NPK (higher dose of K)+ Si	0.20^{a}	0.11^{a}	0.16^{a}	0.16^{de}	0.22^{ab}	0.07^{a}	0.15^{bc}	0.15^{a}
7	Straw + NPK + Si + Zn	0.20^{a}	0.13^{a}	0.16^{a}	0.21^{abcd}	0.23^{ab}	0.06^{a}	0.17^{abc}	0.17^{a}
8	Straw + NPK + Si + Zn +Mg	0.20^{a}	0.13^{a}	0.16^{a}	0.17^{cde}	0.27^{a}	0.08^{a}	0.18^{abc}	0.17^{a}
9	Straw + NPK + Si + Zn +Mg+Cu	0.20^{a}	0.12^{a}	0.15^{a}	0.27^{a}	0.23^{ab}	0.09^{a}	0.20^{a}	0.18^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	0.20^{a}	0.11^{a}	0.16^{a}	0.23^{abc}	0.24^{ab}	0.08^{a}	0.18^{abc}	0.17^{a}
11	T_{10}+ Boron	0.24^{a}	0.11^{a}	0.17^{a}	0.13^{e}	0.21^{ab}	0.09^{a}	0.15^{c}	0.16^{a}
12	T_{11}+ Mo	0.20^{a}	0.11^{a}	0.16^{a}	0.20^{bcd}	0.20^{ab}	0.10^{a}	0.17^{abc}	0.16^{a}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	0.21^{a}	0.11^{a}	0.17^{a}	0.22^{abcd}	0.24^{ab}	0.09^{a}	0.18^{abc}	0.17^{a}
14	T_{12} (No summer cowpea)	0.19^{a}	0.12^{a}	0.15^{a}	0.16^{de}	0.20^{ab}	0.08^{a}	0.15^{bc}	0.15^{a}
15	T_{2} (No summer cowpea)	0.23^{a}	0.11^{a}	0.17^{a}	0.21^{bcd}	0.26^{a}	0.08^{a}	0.18^{abc}	0.18^{a}
16	T_{13} (No summer cowpea)	0.22^{a}	0.11^{a}	0.17^{a}	0.23^{abc}	0.24^{ab}	0.06^{a}	0.18^{abc}	0.17^{a}
	Mean	**0.20**	**0.11**	**0.15**	**0.20**	**0.23**	**0.08**	**0.17**	**0.17**
CD for comparison of season				0.03				NS	NS
CD for comparison of *Kharif vs Rabi*		NS							
Sub table 4.16 a Effect of cropping system									
	R-R-Fallow	0.21	0.01	0.01	-	0.23	0.07	0.17	0.17
	R-R-cowpea	0.20	0.11	0.16	-	0.23	0.09	0.18	0.10
		NS	NS	NS		NS	NS	NS	NS
Sub table 4.16b Effect of Kharif straw incorporation									
	Without straw	0.21	0.11	0.14	0.22	0.24	0.08	0.18	0.16
	With straw	0.19	0.11.	0.15	0.18	0.21	0.08	0.16	0.15
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.16c Effect of silica application									
	Without silica	0.18	0.11	0.14	0.21	0.24	0.09	0.18	0.16
	With silica	0.20	0.11	0.16	0.20	0.20	0.08	0.16	0.16
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.16d Effect of higher dose of K									
	K_{35}	0.19	0.11	0.15	0.21	0.20	0.09	0.16	0.16
	K_{70}	0.19	0.11	0.15	0.21	0.23	0.08	0.17	0.16
		NS	NS	NS	NS	NS	NS	NS	NS

Table 4.16. Effect of season and treatments on phosphorous content (%) of rice

d. Grain

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	0.41[a]	0.28[a]	0.35[a]	0.29[ab]	0.33[a]	0.21[a]	0.27[ab]	0.30[a]
2	NPK alone	0.41[a]	0.29[a]	0.34[a]	0.31[ab]	0.36[a]	0.22[a]	0.29[a]	0.32[a]
3	Straw + NPK	0.44[a]	0.27[a]	0.35[a]	0.37[a]	0.30[a]	0.20[a]	0.29[a]	0.32[a]
4	Straw + NPK (higher dose of K)	0.39[a]	0.27[a]	0.34[a]	0.35[a]	0.31[a]	0.18[a]	0.28[ab]	0.30[a]
5	Straw + NPK + Si	0.38[a]	0.29[a]	0.33[a]	0.25[b]	0.33[a]	0.20[a]	0.26[ab]	0.29[a]
6	Straw + NPK (higher dose of K)+ Si	0.41[a]	0.29[a]	0.35[a]	0.32[ab]	0.30[a]	0.19[a]	0.27[ab]	0.30[a]
7	Straw + NPK + Si + Zn	0.43[a]	0.28[a]	0.36[a]	0.31[ab]	0.32[a]	0.21[a]	0.28[ab]	0.31[a]
8	Straw + NPK + Si + Zn +Mg	0.40[a]	0.28[a]	0.34[a]	0.34[ab]	0.30[a]	0.22[a]	0.28[ab]	0.31[a]
9	Straw + NPK + Si + Zn +Mg+Cu	0.42[a]	0.27[a]	0.35[a]	0.34[ab]	0.29[a]	0.19[a]	0.28[ab]	0.31[a]
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	0.38[a]	0.28[a]	0.33[a]	0.34[ab]	0.30[a]	0.21[a]	0.28[ab]	0.30[a]
11	T_{10}+ Boron	0.39[a]	0.28[a]	0.34[a]	0.36[a]	0.32[a]	0.20[a]	0.29[a]	0.31[a]
12	T_{11}+ Mo	0.42[a]	0.29[a]	0.35[a]	0.35[a]	0.32[a]	0.20[a]	0.29[ab]	0.32[a]
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	0.36[a]	0.28[a]	0.32[a]	0.31[ab]	0.32[a]	0.20[a]	0.28[ab]	0.30[a]
14	T_{12} (No summer cowpea)	0.42[a]	0.27[a]	0.34[a]	0.30[ab]	0.29[a]	0.18[a]	0.26[b]	0.29[a]
15	T_2 (No summer cowpea)	0.40[a]	0.27[a]	0.33[a]	0.30[ab]	0.31[a]	0.20[a]	0.27[ab]	0.29[a]
16	T_{13} (No summer cowpea)	0.38[a]	0.28[a]	0.33[a]	0.29[ab]	0.31[a]	0.21[a]	0.27[ab]	0.29[a]
	Mean	**0.40**	**0.28**	**0.34**	**0.32**	**0.31**	**0.20**	**0.28**	**0.30**
CD for comparison of season				0.07				0.06	0.08
CD for comparison of *Kharif vs Rabi*		0.04							
Sub table 4.16 a Effect of cropping system									
	R-R-Fallow	0.40	0.28	0.34	-	0.30	0.20	0.25	0.29
	R-R-cowpea	0.40	0.29	0.34	-	0.33	0.21	0.27	0.31
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.16b Effect of Kharif straw incorporation									
	Without straw	0.39	0.28	0.33	0.30	0.33	0.21	0.28	0.30
	With straw	0.42	0.28	0.35	0.34	0.31	0.19	0.28	0.31
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.16c Effect of silica application									
	Without silica	0.41	0.27	0.35	0.36	0.31	0.19	0.29	0.31
	With silica	0.40	0.29	0.34	0.28	0.31	0.19	0.26	0.29
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.16d Effect of higher dose of K									
	K_{35}	0.41	0.28	0.34	0.31	0.32	0.20	0.28	0.30
	K_{70}	0.40	0.28	0.34	0.33	0.30	0.18	0.27	0.30
		NS	NS	NS	NS	NS	NS	NS	NS

Tillering stage

At the tillering stage of the crop, K content during *kharif* or *rabi* did not show much variation. Among the two *kharif* seasons also the differences were insignificant. But in *rabi* the content during *rabi* 1999-'00 was significantly lower than *rabi* 1998-'99.

The treatments exhibited variations in K content. During *kharif* 1998-'99 application of silica (Sub table 4.17 c) and Mg resulted in a decreased K concentration whereas soil application of Zn significantly increased the K content (T_5 vs T_7). During *kharif* 1999-'00, these effects were not prominent, but *kharif* straw incorporation significantly decreased K content in the plant (Sub table 4.17 b).

During *rabi* 1998-'99, also silica application depressed K concentration. However, the other treatments did not influence the K content. During *rabi* 1999-'00 none of the treatments brought about any influence on K concentration in the plant.

PI stage

K content of plant at PI stage differed with seasons. The mean content during *kharif* was 2.87 per cent while *rabi* had a significantly higher content of 3.41 per cent. Among the two *kharif* seasons, increased content was registered during *kharif* 1998-'99 (3.21%). During *rabi* the content was highest in 1997-'98 (4.13%); other two seasons had significantly lower values.

During *kharif* 1998-'99, application of K at the higher dose along with straw and silica registered K content of 3.75 per cent. T_1, T_8, T_{13} and T_{14} recorded significantly lower content. During *kharif* 1999-'00, T_4 (Straw + NPK with higher K dose) recorded the highest K content. T_7, T_8, T_{11}, T_{13} and T_{15} had significantly low values.

During *rabi* 1997-'98, T_3, T_4 and T_7 had higher K concentration in the plant compared to T_8 and T_{16}. The effects of other treatments were not significant. During *rabi* 1998-'99, also T_4 had the highest value (3.57%). T_{13} and T_{14} recorded significantly lower values; however, effects of other treatments remained insignificant. During *rabi* 1999-'00, application of higher

Table 4.17. Effect of season and treatments on potassium content (%) of rice

a. Tillering stage

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	3.42^{abc}	3.06^{bc}	3.24^{abcd}	3.60^{bc}	3.38^{a}	3.49^{bc}	3.37^{bc}
2	NPK alone	3.64^{ab}	3.46^{a}	3.55^{a}	3.94^{b}	3.19^{a}	3.57^{b}	3.56^{ab}
3	Straw + NPK	3.68^{ab}	3.19^{abc}	3.44^{abcd}	4.10^{ab}	3.23^{a}	3.66^{b}	3.55^{ab}
4	Straw + NPK (higher dose of K)	3.64^{ab}	3.34^{abc}	3.49^{abc}	4.73^{a}	3.46^{a}	4.09^{a}	3.79^{a}
5	Straw + NPK + Si	3.01^{c}	3.30^{abc}	3.16^{d}	3.53^{bc}	3.17^{a}	3.35^{bc}	3.25^{c}
6	Straw + NPK (higher dose of K)+ Si	3.42^{abc}	3.27^{abc}	3.35^{abcd}	3.42^{bc}	3.11^{a}	3.27^{bc}	3.31^{bc}
7	Straw + NPK + Si + Zn	3.87^{a}	3.01^{c}	3.44^{abcd}	3.57^{bc}	3.27^{a}	3.42^{bc}	3.43^{bc}
8	Straw + NPK + Si + Zn +Mg	3.19^{bc}	3.19^{abc}	3.19^{cd}	3.79^{bc}	3.12^{a}	3.45^{bc}	3.32^{bc}
9	Straw + NPK + Si + Zn +Mg+Cu	3.64^{ab}	3.19^{abc}	3.42^{abcd}	3.53^{bc}	3.11^{a}	3.32^{bc}	3.37^{bc}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	3.53^{abc}	3.45^{a}	3.49^{abc}	3.64^{bc}	3.08^{a}	3.36^{bc}	3.42^{bc}
11	T_{10}+ Boron	3.57^{abc}	3.49^{a}	3.53^{ab}	3.08^{c}	3.02^{a}	3.05^{c}	3.29^{bc}
12	T_{11}+ Mo	3.46^{abc}	3.27^{abc}	3.37^{abcd}	3.42^{bc}	3.42^{a}	3.42^{bc}	3.39^{bc}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	3.30^{abc}	3.30^{abc}	3.30^{abcd}	3.57^{bc}	3.19^{a}	3.38^{bc}	3.34^{bc}
14	T_{12} (No summer cowpea)	3.38^{abc}	3.04^{bc}	3.21^{bcd}	3.75^{bc}	3.19^{a}	3.47^{bc}	3.34^{bc}
15	T_2 (No summer cowpea)	3.22^{bc}	3.19^{abc}	3.21^{bcd}	3.76^{bc}	3.23^{a}	3.50^{bc}	3.35^{bc}
16	T_{13} (No summer cowpea)	3.34^{abc}	3.38^{ab}	3.36^{abcd}	3.42^{bc}	3.00^{a}	3.21^{bc}	3.29^{bc}
	Mean	**3.46**	**3.26**	**3.36**	**3.68**	**3.20**	**3.44**	**3.40**
CD for comparison of season				NS			0.38	NS
CD for comparison of *Kharif vs Rabi*					NS			
Sub table 4.17 a Effect of cropping system								
	R-R-Fallow	3.64	3.14	3.26	3.64	3.14	3.39	3.33
	R-R-cowpea	3.64	3.27	3.41	3.64	3.27	3.45	3.43
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.17 b Effect of Kharif straw incorporation								
	Without straw	3.43	3.38	3.40	3.64	3.13	3.39	3.39
	With straw	3.51	3.17	3.34	3.76	3.28	3.52	3.43
		NS	Sig	NS	NS	NS	NS	NS
Sub table 4.17 c Effect of silica application								
	Without silica	3.66	3.27	3.46	4.42	3.34	3.88	3.67
	Without silica	3.22	3.29	3.25	3.48	3.14	3.31	3.28
		Sig	NS	Sig	Sig	NS	Sig	Sig
Sub table 4.17 d Effect of higher dose of K								
	K_{35}	3.35	3.25	3.30	3.82	3.20	3.51	3.40
	K_{70}	3.53	3.31	3.42	4.08	3.28	3.68	3.55
		NS	NS	NS	NS	NS	NS	NS

Table 4.17. Effect of season and treatments on potassium content (%) of rice

b. PI stage

Sl. No	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	2.89^{bcd}	2.78^{ab}	2.84^{abc}	4.02^{abc}	3.42^{ab}	3.01^{a}	3.48^{ab}	3.22^{abcde}
2	NPK alone	3.19^{abc}	2.67^{abcd}	2.93^{abc}	4.02^{abc}	3.35^{ab}	2.63^{a}	3.33^{bc}	3.17^{bcdef}
3	Straw + NPK	3.64^{ab}	2.78^{ab}	3.21^{a}	4.47^{a}	3.27^{ab}	2.63^{a}	3.45^{ab}	3.36^{abc}
4	Straw + NPK (higher dose of K)	3.42^{abc}	2.82^{a}	3.12^{ab}	4.43^{a}	3.57^{a}	3.19^{a}	3.73^{a}	3.49^{a}
5	Straw + NPK + Si	3.31^{abc}	2.63^{abcd}	2.97^{abc}	4.21^{ab}	3.34^{ab}	2.59^{a}	3.38^{bc}	3.22^{abcde}
6	Straw + NPK (higher dose of K)+ Si	3.75^{a}	2.70^{abc}	3.23^{a}	4.03^{ab}	3.23^{ab}	3.30^{a}	3.52^{ab}	3.40^{ab}
7	Straw + NPK + Si + Zn	3.15^{abc}	2.33^{cd}	2.74^{bcd}	4.43^{a}	3.01^{ab}	2.78^{a}	3.41^{b}	3.14^{bcdef}
8	Straw + NPK + Si + Zn +Mg	2.89^{bcd}	2.33^{cd}	2.61^{cd}	3.87^{bc}	3.00^{ab}	3.16^{a}	3.34^{bc}	3.05^{def}
9	Straw + NPK + Si + Zn +Mg+Cu	3.26^{abc}	2.59^{abcd}	2.93^{abc}	4.20^{ab}	3.49^{ab}	2.89^{a}	3.53^{ab}	3.29^{abcd}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	3.72^{ab}	2.59^{abcd}	3.16^{ab}	4.32^{ab}	3.31^{ab}	2.93^{a}	3.52^{ab}	3.37^{abc}
11	T_{10}+ Boron	3.34^{abc}	2.25^{d}	2.80^{abc}	4.24^{ab}	3.30^{ab}	2.74^{a}	3.43^{b}	3.17^{bcdef}
12	T_{11}+ Mo	3.61^{abc}	2.44^{abcd}	3.03^{abc}	4.02^{abc}	3.30^{ab}	2.93^{a}	3.41^{b}	3.26^{abcd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	2.78^{cd}	2.35^{bcd}	2.57^{cd}	4.22^{ab}	2.93^{b}	2.82^{a}	3.32^{bc}	3.02^{def}
14	T_{12} (No summer cowpea)	2.22^{b}	2.48^{abcd}	2.35^{d}	4.06^{ab}	2.93^{b}	2.97^{a}	3.32^{bc}	2.93^{f}
15	T_2 (No summer cowpea)	3.19^{abc}	2.25^{d}	2.72^{bcd}	4.08^{ab}	3.38^{ab}	2.67^{a}	3.38^{bc}	3.11^{cdef}
16	T_{13} (No summer cowpea)	3.05^{abc}	2.41^{abcd}	2.73^{bcd}	3.57^{c}	3.08^{ab}	2.63^{a}	3.09^{c}	2.95^{ef}
	Mean	**3.21**	**2.53**	**2.87**	**4.13**	**3.24**	**2.86**	**3.41**	**3.20**
CD for comparison of season				0.25				0.42	0.40
CD for comparison of *Kharif vs Rabi*		0.41							
Sub table 4.17 a Effect of cropping system									
	R-R-Fallow	2.82	2.38	2.60	-	3.13	2.75	2.94	2.77
	R-R-cowpea	3.19	2.49	2.84	-	3.19	2.79	2.99	2.92
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.17 b Effect of Kharif straw incorporation									
	Without straw	3.01	2.48	2.74	3.93	3.12	2.69	3.25	3.04
	With straw	3.16	2.57	2.86	4.18	3.17	2.84	3.39	3.18
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.17 c Effect of silica application									
	Without silica	3.53	2.80	3.17	4.45	3.42	2.91	3.59	3.42
	Without silica	3.53	2.67	3.10	4.12	3.29	2.95	3.45	3.31
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.17 d Effect of higher dose of K									
	K_{35}	3.48	2.71	3.09	4.34	3.31	2.61	3.42	3.29
	K_{70}	3.59	2.76	3.17	4.23	3.40	3.25	3.62	3.44
		NS	NS	NS	NS	NS	Sig	NS	NS

dose of K significantly increased K concentration in the plant (Sub table 4.17 d). Other treatments did not manifest any variation.

Straw

Rabi crop had higher K concentration in straw compared to *kharif* crop. Among the two *kharif* seasons, *kharif* 1999-'00 registered higher content of 2.29 per cent. During *rabi*, the highest content was in *rabi* 1997-'98 (3.17%).

The treatments did not manifest any variation during *kharif* 1998-'99. During *kharif* 1999-'00, T_5 (Straw + NPK +Si) had the highest content of 2.66 per cent. T_9, T_{10}, T_{11}, T_{13} and T_{15} registered significantly lower contents. During *rabi* 1997-'98, though T_{13} had higher K content, all other treatments except T_3,. T_7, T_8 and T_{12} registered significantly lower concentration. In the following *rabi* seasons, treatments did not manifest any change in K concentration.

Grain

During *kharif*, the K concentration in the grain was 0.21 per cent whereas *rabi* had a significantly higher concentration of 0.33 per cent. Among the *kharif* seasons, *kharif* 1998-'99 registered an average of 0.30 per cent while *kharif* 1999-'00 had a significantly lower value. During *rabi*, the content was higher in 1997-'98 (0.43 %). The treatments did not manifest any variation in the K content of grain in all the seasons.

4.1.3.4. Calcium

The data on the effects of season and management practices on calcium content of rice at tillering, PI and maturity stages and in grain are given in Tables 4.18 a,b.c and d, respectively.

Tillering stage

Kharif and *rabi* seasons did not show variation in the Ca content. The difference in the content was insignificant between the two *kharif* seasons also. But *rabi* seasons showed variations. Ca content during *rabi* 1998-'99,

Table 4.17. Effect of season and treatments on potassium content (%) of rice

C. Straw

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	1.72^{a}	2.37^{abcde}	2.04^{a}	2.97^{cd}	2.52^{a}	2.74^{a}	2.74^{ab}	2.46^{ab}
2	NPK alone	2.25^{a}	2.34^{abcde}	2.29^{a}	2.85^{d}	2.63^{a}	2.70^{a}	2.73^{ab}	2.55^{ab}
3	Straw + NPK	2.18^{a}	2.29^{abcde}	2.24^{a}	3.30^{abc}	2.63^{a}	2.56^{a}	2.83^{ab}	2.59^{ab}
4	Straw + NPK (higher dose of K)	2.25^{a}	2.44^{abcd}	2.35^{a}	3.00^{bcd}	2.63^{a}	2.82^{a}	2.82^{ab}	2.63^{ab}
5	Straw + NPK + Si	1.99^{a}	2.66^{a}	2.32^{a}	3.19^{bcd}	2.81^{a}	2.60^{a}	2.87^{ab}	2.65^{a}
6	Straw + NPK (higher dose of K)+ Si	2.25^{a}	2.56^{ab}	2.40^{a}	3.23^{bcd}	2.78^{a}	2.55^{a}	2.83^{ab}	2.67^{a}
7	Straw + NPK + Si + Zn	2.07^{a}	2.29^{abcde}	2.18^{a}	3.34^{abc}	2.63^{a}	2.33^{a}	2.77^{ab}	2.53^{ab}
8	Straw + NPK + Si + Zn +Mg	2.11^{a}	2.52^{abc}	2.31^{a}	3.30^{abc}	2.59^{a}	2.58^{a}	2.82^{ab}	2.61^{ab}
9	Straw + NPK + Si + Zn +Mg+Cu	1.80^{a}	2.15^{bcde}	1.97^{a}	3.03^{bcd}	2.70^{a}	2.59^{a}	2.77^{ab}	2.45^{ab}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	1.80^{a}	2.14^{bcde}	1.97^{a}	3.16^{bcd}	2.74^{a}	2.37^{a}	2.76^{ab}	2.44^{ab}
11	T$_{10}$+ Boron	2.14^{a}	1.95^{de}	2.05^{a}	3.12^{bcd}	2.48^{a}	2.59^{a}	2.73^{ab}	2.46^{ab}
12	T$_{11}$+ Mo	2.07^{a}	2.43^{abcd}	2.25^{a}	3.38^{ab}	2.89^{a}	2.59^{a}	2.95^{a}	2.67^{a}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	1.84^{a}	1.88^{e}	1.86^{a}	3.64^{a}	2.55^{a}	2.27^{a}	2.82^{ab}	2.43^{ab}
14	T$_{12}$ (No summer cowpea)	2.11^{a}	2.18^{abcde}	2.14^{a}	2.97^{bcd}	2.71^{a}	2.63^{a}	2.77^{ab}	2.52^{ab}
15	T$_{2}$ (No summer cowpea)	1.88^{a}	2.03^{cde}	1.96^{a}	3.04^{bcd}	2.52^{a}	2.22^{a}	2.59^{b}	2.34^{b}
16	T$_{13}$ (No summer cowpea)	1.99^{a}	2.40^{abcd}	2.20^{a}	3.23^{bcd}	2.55^{a}	2.22^{a}	2.67^{b}	2.48^{ab}
	Mean	**2.03**	**2.29**	**2.16**	**3.17**	**2.65**	**2.52**	**2.78**	**2.53**
CD for comparison of season				0.18				0.42	0.40
CD for comparison of *Kharif vs Rabi*		0.29							
Sub table 4.17 a Effect of cropping system									
	R-R-Fallow	1.99	2.20	2.10	-	2.59	2.35	2.47	2.29
	R-R-cowpea	2.05	2.21	2.13	-	2.69	2.52	2.60	2.37
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.17 b Effect of Kharif straw incorporation									
	Without straw	2.03	2.20	2.12	3.24	2.58	2.39	2.74	2.49
	With straw	2.12	2.30	2.21	3.22	2.74	2.59	2.85	2.59
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.17 c Effect of silica application									
	Without silica	2.22	2.37	2.29	3.15	2.63	2.69	2.82	2.61
	Without silica	2.12	2.61	2.36	3.21	2.80	2.58	2.86	2.66
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.17 d Effect of higher dose of K									
	K$_{35}$	2.09	2.47	2.28	3.25	2.72	2.58	2.85	2.62
	K$_{70}$	2.25	2.50	2.37	3.12	2.71	2.68	2.83	2.65
		NS	NS	NS	NS	NS	NS	NS	NS

Table 4.17. Effect of season and treatments on potassium content (%) of rice

d. Grain

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	0.31^{a}	0.14^{a}	0.23^{a}	0.39^{a}	0.27^{a}	0.34^{a}	0.33^{ab}	0.29^{a}
2	NPK alone	0.29^{a}	0.12^{a}	0.20^{a}	0.39^{a}	0.27^{a}	0.31^{a}	0.32^{ab}	0.28^{a}
3	Straw + NPK	0.32^{a}	0.14^{a}	0.23^{a}	0.49^{a}	0.28^{a}	0.29^{a}	0.35^{ab}	0.30^{a}
4	Straw + NPK (higher dose of K)	0.30^{a}	0.13^{a}	0.22^{a}	0.51^{a}	0.29^{a}	0.28^{a}	0.36^{a}	0.30^{a}
5	Straw + NPK + Si	0.32^{a}	0.16^{a}	0.24^{a}	0.40^{a}	0.25^{a}	0.25^{a}	0.30^{b}	0.28^{a}
6	Straw + NPK (higher dose of K)+ Si	0.33^{a}	0.11^{a}	0.22^{a}	0.39^{a}	0.25^{a}	0.29^{a}	0.31^{ab}	0.27^{a}
7	Straw + NPK + Si + Zn	0.29^{a}	0.12^{a}	0.20^{a}	0.44^{a}	0.27^{a}	0.31^{a}	0.34^{ab}	0.29^{a}
8	Straw + NPK + Si + Zn +Mg	0.29^{a}	0.12^{a}	0.20^{a}	0.40^{a}	0.27^{a}	0.29^{a}	0.32^{ab}	0.27^{a}
9	Straw + NPK + Si + Zn +Mg+Cu	0.29^{a}	0.11^{a}	0.20^{a}	0.39^{a}	0.25^{a}	0.35^{a}	0.33^{ab}	0.28^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	0.28^{a}	0.14^{a}	0.21^{a}	0.42^{a}	0.25^{a}	0.26^{a}	0.31^{ab}	0.27^{a}
11	T_{10}+ Boron	0.32^{a}	0.12^{a}	0.22^{a}	0.48^{a}	0.28^{a}	0.25^{a}	0.34^{ab}	0.29^{a}
12	T_{11}+ Mo	0.29^{a}	0.13^{a}	0.21^{a}	0.43^{a}	0.27^{a}	0.25^{a}	0.32^{ab}	0.27^{a}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	0.27^{a}	0.12^{a}	0.19^{a}	0.43^{a}	0.23^{a}	0.28^{a}	0.31^{ab}	0.26^{a}
14	T_{12} (No summer cowpea)	0.32^{a}	0.12^{a}	0.22^{a}	0.47^{a}	0.23^{a}	0.29^{a}	0.33^{ab}	0.28^{a}
15	T_2 (No summer cowpea)	0.29^{a}	0.12^{a}	0.20^{a}	0.43^{a}	0.28^{a}	0.30^{a}	0.34^{ab}	0.28^{a}
16	T_{13} (No summer cowpea)	0.29^{a}	0.11^{a}	0.20^{a}	0.44^{a}	0.29^{a}	0.31^{a}	0.35^{ab}	0.29^{a}
	Mean	**0.30**	**0.12**	**0.21**	**0.43**	**0.26**	**0.29**	**0.33**	**0.28**
CD for comparison of season				0.06				0.07	0.32
CD for comparison of *Kharif vs Rabi*		0.02							
Sub table 4.17 a Effect of cropping system									
	R-R-Fallow	0.30	0.11	0.21	-	0.27	0.30	0.28	0.24
	R-R-cowpea	0.28	0.12	0.20	-	0.26	0.28	0.27	0.23
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.17 b Effect of Kharif straw incorporation									
	Without straw	0.28	0.11	0.20	0.42	0.26	0.30	0.33	0.28
	With straw	0.31	0.13	0.22	0.46	0.26	0.28	0.33	0.29
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.17 c Effect of silica application									
	Without silica	0.31	0.14	0.22	0.50	0.29	0.28	0.36	0.30
	Without silica	0.33	0.13	0.23	0.40	0.25	0.27	0.30	0.27
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.17 d Effect of higher dose of K									
	K_{35}	0.32	0.15	0.23	0.45	0.27	0.27	0.33	0.29
	K_{70}	0.32	0.12	0.22	0.45	0.27	0.28	0.33	0.29
		NS	NS	NS	NS	NS	NS	NS	NS

was 1066 ppm, which was significantly higher than the content recorded during *rabi* 1999-'00.

The treatments manifested variations in the Ca content. During *kharif* 1998-'99, application of higher K dose along with straw tended to decrease the Ca content of the plant (Sub table 4.18 d). But this effect was not seen when higher K dose was supplied along with straw and silica. Soil application of Zn, Mg and Cu along with straw, NPK and silica also resulted in significant decrease in Ca content over the foliar supply of Zn, Mg and Cu. Application of straw alone (T_1) registered a higher Ca content in the plant (1050 ppm).

During *kharif* 1999-'00 also higher K dose brought about significant reduction in Ca content in T_6. But this effect was not seen in T_4 where higher K dose was supplied with straw and NP alone. Soil application of Mg has increased Ca content whereas Cu application decreased it. Foliar spray of boron enhanced Ca content while the effect of Mo was reverse.

During *rabi* 1998-'99, raising of summer cowpea, *kharif* straw incorporation as well as higher K dose significantly increased Ca content in the plant whereas silica application decreased the content (Sub tables 4.18). Soil application of Zn and Mg increased Ca content while Cu resulted in its decrease.

During *rabi* 1999-'00 also summer cowpea in the system increased the Ca content, while silica application resulted in a decrease (Sub tables 4.18). This decrease was seen when silica application was combined with higher K dose application (T_6). Foliar spray of Mo increased Ca content.

PI stage

The mean Ca content during *kharif* and *rabi* did not show significant variation. But among the *kharif* and *rabi* seasons themselves, remarkable variations were noticed. Thus *kharif* 1998-'99 registered significantly lower Ca content (813 ppm) than *kharif* 1999-'00. Among the three *rabi* seasons significantly higher content was noticed during *rabi* 1998-'99.

During *kharif* 1998-'99, T_{11} registered the highest Ca content. T_7 had significantly lower content. During *kharif* 1999-'00, raising of summer cowpea and higher K application brought about significant increase, whereas

Table 4.18. Effect of season and treatments on calcium content (ppm) of rice

a. Tillering stage

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	1050^{a}	760^{cdef}	905^{a}	1300^{bc}	507^{abc}	904^{bc}	904^{a}
2	NPK alone	950^{ab}	767^{cdef}	859^{ab}	1300^{bc}	564^{ab}	932^{abc}	895^{a}
3	Straw + NPK	1050^{a}	784^{bcde}	917^{a}	1150^{cd}	517^{abc}	834^{cde}	875^{a}
4	Straw + NPK (higher dose of K)	650^{c}	706^{defg}	678^{e}	1450^{ab}	581^{a}	1016^{a}	847^{a}
5	Straw + NPK + Si	750^{bc}	909^{a}	830^{abcd}	850^{fgh}	464^{abcde}	657^{gh}	743^{b}
6	Straw + NPK (higher dose of K)+ Si	750^{bc}	680^{fg}	715^{bcde}	1600^{a}	344^{de}	972^{ab}	844^{a}
7	Straw + NPK + Si + Zn	725^{bc}	630^{g}	678^{e}	1150^{cd}	439^{abcde}	795^{def}	736^{b}
8	Straw + NPK + Si + Zn +Mg	900^{abc}	790^{bcd}	845^{abc}	1450^{ab}	308^{e}	879^{bcd}	862^{a}
9	Straw + NPK + Si + Zn +Mg+Cu	650^{c}	655^{g}	653^{e}	1050^{de}	363^{cde}	707^{fg}	680^{bc}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	1100^{a}	705^{defg}	903^{a}	800^{ghi}	315^{e}	558^{hi}	730^{b}
11	T_{10}+ Boron	850^{abc}	828^{abc}	839^{abc}	850^{fgh}	307^{e}	579^{hi}	709^{b}
12	T_{11}+ Mo	650^{c}	697^{defg}	674^{e}	950^{efg}	499^{abcd}	725^{fg}	699^{bc}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	750^{bc}	691^{efg}	721^{bcde}	800^{ghi}	501^{abcd}	651^{gh}	686^{bc}
14	T_{12} (No summer cowpea)	600^{c}	776^{bcde}	688^{de}	1000^{def}	480^{abcd}	740^{efg}	714^{b}
15	T_2 (No summer cowpea)	600^{c}	808^{bc}	704^{cde}	650^{i}	388^{cde}	519^{i}	612^{c}
16	T_{13} (No summer cowpea)	850^{abc}	860^{ab}	855^{ab}	700^{hi}	405^{bcde}	553^{hi}	704^{b}
	Mean	**805**	**753**	**779**	**1066**	**436**	**751**	**765**
CD for comparison of season				NS			110	77
CD for comparison of *Kharif vs Rabi*					NS			
Sub table 4.18a Effect of cropping system								
	R-R-Fallow	683	815	749	783	424	604	676
	R-R-cowpea	783	718	751	1017	521	769	760
		NS	NS	NS	Sig	Sig	Sig	Sig
Sub table 4.18b Effect of Kharif straw incorporation								
	Without straw	850	773	811	933	490	712	762
	Without straw	767	752	760	1033	499	766	763
		NS	NS	NS	Sig	NS	NS	NS
Sub table 4.18 c Effect of silica application								
	Without silica	850	745	798	1300	549	925	861
	Without silica	750	795	772	1225	404	815	793
		NS	NS	NS	Sig	Sig	Sig	Sig
Sub table 4.18 d Effect of higher dose of K								
	K_{35}	900	847	873	1000	491	745	809
	K_{70}	700	693	697	1525	463	994	845
		Sig	Sig	Sig	Sig	NS	Sig	NS

Table 4.18. Effect of season and treatments on calcium content (ppm) of rice

b. PI stage

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	650^{ab}	1250^{cde}	950^{b}	950^{abc}	2000^{a}	1400^{a}	1450^{a}	1250^{ab}
2	NPK alone	650^{ab}	1700^{a}	1175^{ab}	1000^{abc}	1850^{ab}	1050^{abc}	1300^{a}	1250^{ab}
3	Straw + NPK	900^{ab}	1200^{cdef}	1050^{ab}	950^{abc}	1400^{cd}	1000^{bcd}	1117^{b}	1090^{bcde}
4	Straw + NPK (higher dose of K)	850^{ab}	1300^{cd}	1075^{ab}	1350^{a}	1700^{b}	1150^{ab}	1400^{a}	1270^{a}
5	Straw + NPK + Si	750^{ab}	1000^{ef}	875^{b}	800^{c}	1200^{def}	900^{bcd}	967^{bcd}	930^{def}
6	Straw + NPK (higher dose of K)+ Si	650^{ab}	1450^{bc}	1050^{ab}	1150^{abc}	1600^{bc}	1150^{ab}	1300^{a}	1200^{abc}
7	Straw + NPK + Si + Zn	500^{b}	1350^{bcd}	925^{b}	800^{c}	900^{gh}	1000^{bcd}	900^{cd}	910^{ef}
8	Straw + NPK + Si + Zn +Mg	750^{ab}	1000^{ef}	875^{b}	1250^{ab}	850^{gh}	950^{bcd}	1017^{bcd}	960^{def}
9	Straw + NPK + Si + Zn +Mg+Cu	700^{ab}	1600^{ab}	1150^{ab}	950^{abc}	1400^{cd}	900^{bcd}	1083^{bc}	1110^{abcd}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	1000^{ab}	1400^{bc}	1200^{ab}	1350^{a}	750^{h}	650^{d}	917^{cd}	1030^{cdef}
11	T_{10}+ Boron	1150^{a}	1400^{bc}	1275^{a}	850^{bc}	1100^{efg}	700^{cd}	883^{d}	1040^{cdef}
12	T_{11}+ Mo	900^{ab}	950^{f}	925^{b}	750^{c}	1100^{efg}	1050^{abc}	967^{bcd}	950^{def}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	950^{ab}	1300^{cd}	1125^{ab}	900^{bc}	1300^{de}	900^{bcd}	1033^{bcd}	1070^{bcdef}
14	T_{12} (No summer cowpea)	950^{ab}	950^{f}	950^{b}	1100^{abc}	1000^{fgh}	850^{bcd}	983^{bcd}	970^{def}
15	T_2 (No summer cowpea)	700^{ab}	1100^{def}	900^{b}	900^{bc}	900^{gh}	900^{bcd}	900^{cd}	900^{f}
16	T_{13} (No summer cowpea)	950^{ab}	1300^{cd}	1125^{ab}	1100^{abc}	900^{gh}	1200^{ab}	1067^{bcd}	1090^{abcde}
	Mean	**813**	**1266**	**1039**	**1009**	**1247**	**984**	**1080**	**1064**
CD for comparison of season				321				167	160
CD for comparison of *Kharif vs Rabi*		NS							
Sub table 4.18a Effect of cropping system									
	R-R-Fallow	867	1117	992	-	933	983	958	975
	R-R-cowpea	833	1317	1075	-	1417	1000	1208	1142
		NS	Sig	NS	-	Sig	NS	NS	Sig
Sub table 4.18b Effect of Kharif straw incorporation									
	Without straw	850	1433	1142	1000	1350	1050	1133	1137
	Without straw	917	1033	975	933	1167	967	1022	1003
		NS	Sig	NS	NS	Sig	NS	NS	Sig
Sub table 4.18 c Effect of silica application									
	Without silica	875	1250	1063	1150	1550	1075	1258	1180
	Without silica	700	1225	963	975	1400	1025	1133	1065
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.18 d Effect of higher dose of K									
	K_{35}	825	1100	963	875	1300	950	1042	1010
	K_{70}	750	1375	1063	1250	1650	1150	1350	1235
		NS	Sig	NS	Sig	Sig	NS	Sig	Sig

kharif straw incorporation decreased the content. The increase in Ca content with increased K dose was seen only when it was combined with silica application (T_5 vs T_6). Soil application of Mg decreased Ca content while Zn and Cu resulted in its increase. Foliar spray of Mo also decreased the content.

During *rabi* 1997-'98, also higher K dose along with silica application resulted in an increase in Ca content of the plant. Ca content was highest in T_{10} and T_4. Soil application of Mg increased the content whereas foliar spray of boron brought about a decrease.

During *rabi* 1998-'99, *kharif* straw incorporation decreased the Ca concentration in the plant whereas raising of summer cowpea and higher K dose combined with silica application increased the content (Sub table 4.18). Soil application of Zn decreased whereas Cu increased the content in the plant. The content was highest in T_1 (2000 ppm). During *rabi* 1999-'00 also, T_1 recorded higher Ca content (1400 ppm) than T_3, T_5, T_7,T_8, T_9,T_{10}, T_{11}, T_{13} and T_{15}.

Straw

The mean Ca content of straw was higher during *rabi* (3079 ppm). Among the two *kharif* seasons, the content was higher during *kharif* 1999-'00. The mean Ca content during the three *rabi* seasons also showed remarkable variation. Ca concentration was highest in *rabi* 1998-'99 (4059 ppm) and the lowest was during *rabi* 1999-'00.

During *kharif* 1998-'99, silica application remarkably decreased the Ca content. This effect was not pronounced when silica application was combined with higher K dose. Application of higher K dose also resulted in decreased Ca content, however, combination with silica application (T_6) did not produce this effect. Foliar application of boron increased the content while other treatments did not manifest any significant effect.

During *kharif* 1999-'00, the highest content was in T_{11} (Straw + NPK+Si +foliar application of Zn, Mg, Cu and B) while T_1, T_2, T_4, T_9, T_{12}, T_{14} and T_{15} were on par with this. Combined application of straw and NPK (T_3) decreased Ca content over T_1 and T_2.

Table 4.18. Effect of season and treatments on calcium content (ppm) of rice

C. Straw

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	1694^{bcd}	2223^{ab}	1959^{abcd}	3650^{abc}	4315^{abcd}	2144^{ab}	3370^{abc}	2805^{ab}
2	NPK alone	2011^{ab}	2224^{ab}	2118^{ab}	4050^{ab}	4532^{abcd}	2244^{ab}	3609^{a}	3012^{a}
3	Straw + NPK	2482^{a}	2088^{cde}	2285^{a}	4100^{a}	3963^{bcde}	2300^{ab}	3454^{ab}	2987^{a}
4	Straw + NPK (higher dose of K)	1526^{bcd}	2169^{abcd}	1848^{bcd}	3200^{abc}	4008^{bcde}	2976^{a}	3395^{abc}	2776^{abc}
5	Straw + NPK + Si	1325^{bcd}	2057^{de}	1691^{cd}	2650^{cd}	3568^{de}	2157^{ab}	2792^{de}	2351^{d}
6	Straw + NPK (higher dose of K)+ Si	1507^{bcd}	2035^{e}	1771^{bcd}	2750^{cd}	3776^{cde}	1819^{b}	2782^{de}	2377^{cd}
7	Straw + NPK + Si + Zn	1221^{cd}	2002^{e}	1612^{d}	3050^{abcd}	4613^{abc}	1744^{b}	3136^{abcde}	2526^{bcd}
8	Straw + NPK + Si + Zn +Mg	1300^{bcd}	2010^{e}	1655^{cd}	2800^{bcd}	3876^{bcde}	1728^{b}	2801^{de}	2343^{d}
9	Straw + NPK + Si + Zn +Mg+Cu	1357^{bcd}	2122^{abcde}	1740^{cd}	3400^{abc}	4217^{abcd}	1682^{b}	3100^{abcde}	2556^{bcd}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	1150^{d}	2032^{e}	1591^{d}	3000^{abcd}	4778^{ab}	2107^{ab}	3295^{abcd}	2613^{abcd}
11	T_{10}+ Boron	1313^{bcd}	2250^{a}	1782^{bcd}	3450^{abc}	3563^{de}	2019^{b}	3011^{bcde}	2519^{bcd}
12	T_{11}+ Mo	1412^{bcd}	2231^{ab}	1822^{bcd}	2450^{cd}	3603^{de}	1907^{b}	2653^{e}	2321^{d}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	1400^{bcd}	2113^{bcde}	1757^{bcd}	3650^{abc}	4282^{abcd}	1782^{b}	3238^{abcd}	2645^{abcd}
14	T_{12} (No summer cowpea)	1256^{bcd}	2187^{abc}	1722^{bcd}	3100^{abc}	3107^{e}	1844^{b}	2684^{e}	2299^{d}
15	T_2 (No summer cowpea)	1563^{bcd}	2222^{ab}	1893^{bcd}	2900^{abcde}	3603^{de}	2200^{ab}	2901^{cde}	2498^{bcd}
16	T_{13} (No summer cowpea)	1943^{abc}	2114^{bcde}	2029^{abc}	1800^{d}	5133^{a}	2219^{ab}	3051^{bcde}	2642^{abcd}
	Mean	**1529**	**2130**	**1829**	**3125**	**4059**	**2055**	**3079**	**2579**
CD for comparison of seasons				285				520	341
CD for comparison of *Kharif vs Rabi*		98							
Sub table 4.18a Effect of cropping system									
	R-R-Fallow	1587	2174	1881	-	3948	2088	3018	2449
	R-R-cowpea	1608	2189	1899	-	4139	1978	3058	2478
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.18b Effect of Kharif straw incorporation									
	Without straw	1785	2150	1968	3167	4649	2082	3299	2766
	Without straw	1717	2169	1943	3217	3558	2017	2930	2535
		NS	NS	NS	NS	Sig	NS	Sig	NS
Sub table 4.18 c Effect of silica application									
	Without silica	2004	2129	2066	3650	3986	2638	3425	2881
	Without silica	1416	2046	1731	2700	3672	1988	2787	2364
		Sig	NS	Sig	NS	NS	Sig	Sig	Sig
Sub table 4.18 d Effect of higher dose of K									
	K_{35}	1904	2073	1988	3375	3766	2229	3123	2669
	K_{70}	1517	2102	1809	2975	3892	2398	3088	2577
		NS	NS	NS	NS	NS	NS	NS	NS

During *rabi* 1997-'98, silica application significantly decreased Ca content when silica was combined with normal dose of K. T_5, T_{12} and T_{16} recorded significantly lower concentration compared to T_3 (Straw+ NPK).

During *rabi* 1998-'99, *kharif* straw incorporation significantly decreased Ca content. The highest content of 5133 ppm was recorded in T_{16} and T_1, T_2, T_7, T_9, T_{10} and T_{13} registered on par values while others had significantly lower contents.

During *rabi* 1999-'00, application of silica along with higher K dose significantly decreased Ca content. Effects of other treatments were not significant.

Grain

The mean content of Ca in the grain during *kharif* and *rabi* season did not show remarkable variation. The content in the two *kharif* seasons also remained similar while variations were noticed during *rabi* season. *Rabi* 1998-'99 crop had higher Ca content in the grain. It was significantly lower during the other two *rabi* seasons.

During *kharif* 1998-'99, foliar application of Zn, Mg and Cu recorded significantly lower content than their soil application. T_{12} (Straw + NPK+Si +foliar application of Zn, Mg, Cu, B and Mo) registered the highest concentration of 81 ppm while T_2, T_{10}, T_{14} and T_{16} had significantly lower contents. During *kharif* 1999-'00, the treatments did not manifest any variation in the Ca content. During *rabi* 1997-'98, T_9 (Straw +NPK +Si + soil application of $ZnSO_4$, $MgSO_4$, and $CuSO_4$) recorded significantly higher Ca content in the grain than T_{11}, T_{12}, T_{13}, T_{14}, T_{15} and T_{16}. During *rabi* 1998-'99, content in T_6 (Straw +NPK +Si with higher K dose) was comparatively lower; others remained on par. During *rabi* 1999-'00, T_1 recorded lower content than T_6 whereas others were on par with each other.

4.1.3.5. Magnesium

The data on the effects of season and management practices on magnesium content of rice at tillering, PI and maturity stages and in grain are given in Tables 4.19 a,b.c and d, respectively.

Table 4.18. Effect of season and treatments on calcium content (ppm) of rice

d. Grain

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	58^{abcd}	57^{a}	58^{bc}	187^{abc}	204^{ab}	80^{b}	157^{ab}	117^{ab}
2	NPK alone	53^{cd}	58^{a}	56^{c}	178^{abc}	219^{ab}	90^{ab}	162^{ab}	120^{ab}
3	Straw + NPK	61^{abcd}	61^{a}	61^{abc}	178^{abc}	193^{ab}	105^{ab}	159^{ab}	120^{ab}
4	Straw + NPK (higher dose of K)	68^{abcd}	67^{a}	68^{abc}	204^{ab}	219^{ab}	100^{ab}	174^{a}	132^{a}
5	Straw + NPK + Si	80^{abc}	67^{a}	74^{abc}	152^{bcd}	213^{ab}	87^{ab}	151^{ab}	120^{ab}
6	Straw + NPK (higher dose of K)+ Si	66^{abcd}	68^{a}	67^{abc}	159^{bcd}	165^{b}	115^{a}	146^{ab}	115^{ab}
7	Straw + NPK + Si + Zn	79^{abc}	75^{a}	77^{ab}	187^{abc}	179^{ab}	82^{ab}	149^{ab}	120^{ab}
8	Straw + NPK + Si + Zn +Mg	76^{abc}	78^{a}	79^{ab}	174^{abcd}	189^{ab}	83^{ab}	149^{ab}	121^{ab}
9	Straw + NPK + Si + Zn +Mg+Cu	80^{ab}	83^{a}	82^{a}	229^{a}	176^{ab}	95^{ab}	167^{a}	133^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	47^{d}	71^{a}	59^{bc}	162^{abcd}	245^{a}	93^{ab}	167^{a}	124^{ab}
11	T_{10}+ Boron	56^{abcd}	72^{a}	64^{abc}	160^{bcd}	233^{ab}	107^{ab}	167^{a}	126^{ab}
12	T_{11}+ Mo	81^{a}	81^{a}	81^{a}	135^{bcd}	217^{ab}	92^{ab}	148^{ab}	121^{ab}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	75^{abc}	60^{a}	68^{abc}	108^{d}	191^{ab}	95^{ab}	131^{b}	106^{b}
14	T_{12} (No summer cowpea)	53^{bcd}	70^{a}	62^{abc}	120^{cd}	198^{ab}	84^{ab}	134^{b}	105^{b}
15	T_2 (No summer cowpea)	62^{abcd}	61^{a}	62^{abc}	144^{bcd}	247^{a}	95^{ab}	162^{ab}	122^{ab}
16	T_{13} (No summer cowpea)	53^{cd}	70^{a}	62^{abc}	154^{bcd}	244^{a}	85^{ab}	161^{ab}	121^{ab}
	Mean	**66**	**69**	**67**	**164**	**208**	**93**	**155**	**120**
CD for comparison of season				NS				39	25
CD for comparison of *Kharif vs Rabi*		NS							
Sub table 4.18a Effect of cropping system									
	R-R-Fallow	56	67	62	-	230	88	159	110
	R-R-cowpea	70	66	68	-	209	92	151	109
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.18b Effect of Kharif straw incorporation									
	Without straw	60	63	62	147	218	90	152	116
	Without straw	65	71	68	144	203	94	147	115
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.18 c Effect of silica application									
	Without silica	65	64	64	191	206	103	167	126
	Without silica	73	68	70	156	189	101	149	117
		NS	NS	NS	NS	NS	NS	Sig	NS
Sub table 4.18 d Effect of higher dose of K									
	K_{35}	71	64	67	165	203	96	155	120
	K_{70}	67	68	67	182	192	108	160	123
		NS	NS	NS	NS	NS	NS	NS	NS

Tillering stage

At the tillering stage the mean value of Mg content in *kharif* was significantly higher than *rabi* crop. Among the *kharif* seasons, *kharif* 1998-'99 had higher content than *kharif* 1999-'00 crop. The content of Mg during *rabi* 1998-'99 was 1898 ppm, which was remarkably higher than the content during *rabi* 1999-'00.

During *kharif* 1998-'99, summer cowpea in the cropping system resulted in decreasing the Mg content. Silica application also decreased the content when its application was combined with higher K dose (Sub tables 4.19). Foliar application of Zn, Mg and Cu registered lower Mg content than their soil application. Lower contents were recorded in T_1 and T_{12} also.

During *kharif* 1999-'00, higher K dose reduced the Mg content when the K application was combined with silica. When no silica was supplied, higher K dose did not produce this effect. Silica application increased Mg content (Sub table 4.19). Soil application of Cu and foliar application of boron (T_{11}) increased Mg content whereas Mo application decreased it.

During *rabi* 1998-'99, *kharif* straw incorporation significantly reduced the Mg content (Sub table 4.19). T_2, T_9 and T_{15} had concentration similar to T_{16}, which recorded the highest content.

During *rabi* 1999-'00, summer cowpea resulted in significant increase in Mg content. Application of higher K dose brought about significant reduction in Mg content; when the higher K dose was combined with silica application (T_6), this decrease was not noticed. Mg content in straw alone (T_1) was 1438 ppm, which was lower than the content in NPK alone treatment (T_2).

PI stage

Seasonal variations were noticed in the Mg content of the crops at this stage also. The mean content in *rabi* was significantly higher than *kharif* crop. Among the two *kharif* seasons, *kharif* 1998-'99 recorded higher Mg concentration. The content in *rabi* 1997-'98 was 2829 ppm, which was significantly higher than the other two *rabi* seasons. *rabi* 1998-'99 had the lowest content.

Table 4.19. Effect of season and treatments on magnesium content (ppm) of rice

a. Tillering stage

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	1470^{e}	1875^{efg}	1673^{h}	1680^{ef}	1438^{cd}	1559^{e}	1616^{g}
2	NPK alone	2790^{bc}	2313^{abc}	2552^{ab}	2190^{abc}	1750^{ab}	1970^{a}	2261^{ab}
3	Straw + NPK	2940^{ab}	1625^{g}	2283^{cde}	1860^{cdef}	1840^{a}	1850^{abcd}	2066^{cde}
4	Straw + NPK (higher dose of K)	3180^{a}	1750^{fg}	2465^{abc}	1770^{cdef}	1500^{bcd}	1635^{de}	2050^{cde}
5	Straw + NPK + Si	2700^{bc}	2438^{ab}	2569^{ab}	1680^{ef}	1688^{abc}	1684^{cde}	2127^{bc}
6	Straw + NPK (higher dose of K)+ Si	2760^{bc}	1938^{def}	2349^{bcde}	1800^{cdef}	1625^{abcd}	1713^{bcde}	2031^{cde}
7	Straw + NPK + Si + Zn	2670^{bc}	2188^{bcd}	2429^{abc}	1470^{f}	1500^{bcd}	1485^{e}	1957^{de}
8	Straw + NPK + Si + Zn +Mg	2760^{bc}	1625^{g}	2193^{ef}	1770^{cdef}	1625^{abcd}	1698^{cde}	1945^{e}
9	Straw + NPK + Si + Zn +Mg+Cu	2970^{ab}	1938^{def}	2454^{abc}	2160^{abcd}	1625^{abcd}	1893^{abc}	2173^{abc}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	1800^{de}	2063^{cde}	1932^{g}	1740^{def}	1438^{cd}	1589^{e}	1760^{f}
11	T_{10}+ Boron	2640^{bc}	2375^{ab}	2508^{abc}	1860^{cdef}	1500^{bcd}	1680^{cde}	2094^{cde}
12	T_{11}+ Mo	2110^{d}	2000^{def}	2055^{fg}	1980^{bcde}	1688^{abc}	1834^{abcde}	1945^{e}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	2520^{c}	2313^{abc}	2417^{abcd}	1830^{cdef}	1875^{a}	1853^{abcd}	2135^{bc}
14	T_{12} (No summer cowpea)	2760^{bc}	2375^{ab}	2568^{ab}	1770^{def}	1563^{bcd}	1667^{cde}	2117^{bcd}
15	T_{2} (No summer cowpea)	2730^{bc}	2500^{a}	2615^{a}	2310^{ab}	1688^{abc}	1999^{a}	2307^{a}
16	T_{13} (No summer cowpea)	2760^{bc}	1625^{g}	2193^{def}	2500^{a}	1375^{d}	1938^{ab}	2065^{cde}
	Mean	**2598**	**2059**	**2328**	**1898**	**1607**	**1753**	**2040**
CD for comparison of season				74			203	99
CD for comparison of *Kharif vs Rabi*		124						
Sub table 4.19 a Effect of cropping system								
	R-R-Fallow	2750	2167	2458	2193	1542	1868	2163
	R-R-cowpea	2473	2209	2341	2000	1771	1886	2113
		Sig	NS	NS	NS	Sig	NS	NS
Sub table 4.19 b Effect of kharif straw incorporation								
	No straw	2690	2084	2387	2173	1667	1920	2153
	Without straw	2603	2000	2302	1870	1697	1784	2043
		NS	NS	NS	Sig	NS	NS	NS
Sub table 4.19 c Effect of silica application								
	No silica	3060	1688	2374	1815	1670	1743	2058
	Silica	2730	2188	2459	1740	1657	1698	2079
		Sig	Sig	NS	NS	NS	NS	NS
Sub table 4.19 d Effect of higher dose of K								
	K_{35}	2820	2032	2426	1770	1764	1767	2096
	K_{70}	2970	1844	2407	1785	1563	1674	2040
		NS	Sig	NS	NS	NS	NS	NS

Table 4.19. Effect of season and treatments on magnesium content (ppm) of rice

b. PI stage

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	3210^{a}	1938^{a}	2574^{a}	2790^{ab}	2040^{cdef}	2375^{abc}	2402^{cd}	2471^{ab}
2	NPK alone	3120^{ab}	1563^{bc}	2342^{ab}	2940^{ab}	1710^{f}	2563^{ab}	2404^{cd}	2379^{abc}
3	Straw + NPK	3150^{a}	1250^{ef}	2200^{bcd}	3120^{a}	2550^{ab}	2250^{abc}	2640^{ab}	2464^{ab}
4	Straw + NPK (higher dose of K)	2790^{ab}	1438^{bcde}	2114^{bcde}	2940^{ab}	1860^{def}	2370^{abc}	2390^{cd}	2280^{bcde}
5	Straw + NPK + Si	2640^{abcd}	1563^{bc}	2102^{bcde}	2940^{ab}	2240^{bc}	2375^{abc}	2518^{abc}	2352^{bc}
6	Straw + NPK (higher dose of K)+ Si	2970^{abc}	1625^{b}	2298^{abc}	2730^{ab}	1860^{def}	2625^{ab}	2405^{cd}	2362^{bc}
7	Straw + NPK + Si + Zn	2700^{abc}	1125^{f}	1913^{def}	2790^{ab}	2100^{cde}	1750^{c}	2213^{d}	2093^{e}
8	Straw + NPK + Si + Zn +Mg	3150^{a}	1500^{bcd}	2325^{abc}	2880^{ab}	1710^{f}	2440^{ab}	2343^{cd}	2336^{bcd}
9	Straw + NPK + Si + Zn +Mg+Cu	3180^{a}	1563^{bc}	2372^{ab}	2940^{ab}	2760^{a}	2438^{ab}	2713^{a}	2576^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	2040^{d}	1250^{ef}	1645^{f}	2760^{ab}	2580^{ab}	2188^{abc}	2509^{abc}	2164^{cde}
11	T_{10}+ Boron	2580^{abcd}	1125^{f}	1853^{ef}	2520^{b}	2040^{cdef}	2375^{abc}	2312^{cd}	2128^{de}
12	T_{11}+ Mo	2460^{bcd}	1438^{bcde}	1949^{def}	2820^{ab}	1890^{cdef}	2375^{abc}	2362^{cd}	2197^{cde}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	2430^{cd}	1375^{cde}	1903^{def}	2730^{ab}	2580^{ab}	2313^{abc}	2541^{abc}	2286^{bcde}
14	T_{12} (No summer cowpea)	2670^{abcd}	1438^{bcde}	2054^{bcde}	2640^{b}	2180^{cd}	2188^{abc}	2336^{cd}	2223^{cde}
15	T_2 (No summer cowpea)	2890^{abc}	1563^{bc}	2227^{bcd}	2790^{ab}	2520^{ab}	2125^{bc}	2478^{bc}	2378^{abc}
16	T_{13} (No summer cowpea)	2670^{abcd}	1313^{def}	1992^{cde}	2940^{ab}	1770^{ef}	2813^{a}	2508^{abc}	2301^{bcde}
	Mean	**2791**	**1442**	**2116**	**2829**	**2149**	**2348**	**2442**	**2312**
CD for comparison of season				236				127	119
CD for comparison of Kharif vs Rabi		89							
Sub table 4.19 a Effect of cropping system									
	R-R-Fallow	2743	1438	2091	-	2157	2375	2266	2178
	R-R-cowpea	2670	1459	2064	-	2060	2417	2239	2151
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.19 b Effect of kharif straw incorporation									
	No straw	2740	1417	2079	2870	2020	2563	2484	2322
	Without straw	2760	1375	2068	2860	2207	2271	2446	2295
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.19 c Effect of silica application									
	No silica	2970	1344	2157	3030	2205	2310	2515	2372
	Silica	2805	1594	2200	2835	2050	2500	2462	2357
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.19 d Effect of higher dose of K									
	K_{35}	2895	1407	2151	3030	2395	2313	2579	2408
	K_{70}	2880	1532	2206	2835	1860	2498	2398	2321
		NS	NS	NS	NS	Sig	NS	NS	NS

During *kharif* 1998-'99, content was lowest in T_{10} (Straw +NPK +Si + foliar application of Zn, Mg and Cu) which was significantly lower than the content in T_1, T_2, T_3, T_4, T_6, T_7, T_8, T_9 and T_{15}.

During *kharif* 1999-'00, application of silica remarkably increased Mg content (T_3 vs T_5). But when silica application was combined with higher K dose, no change was noticed. T_1 had the highest Mg content. T_7, T_{10} and T_{11} recorded lower contents. Application of NPK alone or straw + NPK significantly reduced Mg content.

During *rabi* 1997-'98, T_3 (Straw + NPK) recorded the highest content. T_{11} and T_{14} produced significantly lower content.

During *rabi* 1998-'99, application of higher K dose resulted in significant decrease in Mg content in the plant. Soil application of Mg did not increase Mg content, however, Cu application brought about an increase whereas foliar spray of boron decreased the content.

During *rabi* 1999-'00, Mg application increased its content in the plant. T_9 (Straw +NPK +Si + soil application of $ZnSO_4$, $MgSO_4$, and $CuSO_4$) had the highest content. Treatments except T_3, T_{10}, T_{13} and T_{15} had significant lower contents.

Straw

During *kharif*, the mean value of Mg content in straw was 1895 ppm whereas *rabi* had significantly higher concentration of 2928 ppm. Among the two *kharif* seasons, *kharif* 1998-'99 had higher content than *kharif* 1999-'00. *Rabi* 1998-'99 crop had Mg concentration of 3672 ppm while the content in other two *rabi* seasons were considerably low.

During *kharif* 1998-'99, T_1, T_2, T_{11} had significantly higher content than T_{13}. During *kharif* 1999-'00, T_{13} and T_{15} recorded higher Mg content. T_2, T_4, T_5, T_7 and T_8 had significantly lower contents. Other treatments were on par.

During *rabi* 1997-'98, T_{14} and T_{16} recorded Mg content of 3060 ppm. Other treatments were on par with these except T_1, T_{10} and T_{11}, which had significantly lower content of Mg.

Table 4.19. Effect of season and treatments on magnesium content (ppm) of rice

C. Straw

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	2625^{a}	1563^{ab}	2094^{a}	1800^{c}	3250^{efg}	2313^{ab}	2454^{e}	2310^{b}
2	NPK alone	2563^{a}	1438^{bc}	2001^{a}	2910^{ab}	3813^{bcdef}	2688^{ab}	3137^{bc}	2682^{ab}
3	Straw + NPK	2188^{ab}	1500^{abc}	1844^{a}	2490^{abc}	3563^{bcdef}	2813^{ab}	2955^{abcd}	2511^{ab}
4	Straw + NPK (higher dose of K)	2313^{ab}	1250^{c}	1782^{a}	2580^{abc}	3063^{fg}	3125^{a}	2923^{abcd}	2466^{ab}
5	Straw + NPK + Si	2250^{ab}	1375^{bc}	1813^{a}	2970^{ab}	2625^{g}	2375^{ab}	2657^{de}	2319^{b}
6	Straw + NPK (higher dose of K)+ Si	2125^{ab}	1500^{abc}	1813^{a}	3000^{ab}	3375^{defg}	2000^{ab}	2792^{bcde}	2400^{ab}
7	Straw + NPK + Si + Zn	2188^{ab}	1438^{bc}	1813^{a}	2880^{ab}	3438^{cdefg}	2313^{ab}	2877^{abcde}	2451^{ab}
8	Straw + NPK + Si + Zn +Mg	2188^{ab}	1438^{bc}	1813^{a}	2670^{abc}	4375^{ab}	2313^{ab}	3119^{abc}	2597^{ab}
9	Straw + NPK + Si + Zn +Mg+Cu	2250^{ab}	1563^{ab}	1907^{a}	2250^{abc}	4813^{a}	2750^{ab}	3271^{a}	2725^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	2000^{ab}	1563^{ab}	1782^{a}	2130^{bc}	4125^{abcde}	2500^{ab}	918abc	2464^{ab}
11	T_{10}+ Boron	2625^{a}	1563^{ab}	2094^{a}	2130^{bc}	3250^{efg}	2438^{ab}	2606^{de}	2401^{ab}
12	T_{11}+ Mo	2313^{ab}	1625^{ab}	1969^{a}	2370^{abc}	3688^{bcdef}	2563^{ab}	2874^{abcde}	2512^{ab}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	1625^{b}	1750^{a}	1688^{a}	2940^{ab}	3625^{bcdef}	2875^{ab}	3147^{abc}	2563^{ab}
14	T_{12} (No summer cowpea)	2188^{ab}	1625^{ab}	1907^{a}	3060^{a}	3250^{efg}	1875^{b}	2728^{cde}	2400^{ab}
15	T_2 (No summer cowpea)	2250^{ab}	1750^{a}	2000^{a}	2550^{abc}	4313^{abc}	2813^{ab}	3225^{ab}	2735^{a}
16	T_{13} (No summer cowpea)	2375^{ab}	1625^{ab}	2000^{a}	3060^{a}	4188^{abcd}	2250^{ab}	3166^{abc}	2700^{a}
	Mean	**2254**	**1535**	**1895**	**2612**	**3672**	**2500**	**2928**	**2515**
CD for comparison of season				206				528	338
CD for comparison of *Kharif vs Rabi*		125							
Sub table 4.19 a Effect of cropping system									
	R-R-Fallow	2271	1667	1969		3917	2313	3115	2542
	R-R-cowpea	**2167**	1604	1886		3709	2709	3209	2547
		NS	NS	NS		NS	NS	NS	NS
Sub table 4.19 b Effect of kharif straw incorporation									
	No straw	**2188**	**1604**	1896	2970	3875	2604	3150	2648
	Without straw	2230	1583	1907	2640	3500	2417	2852	2474
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.19 c Effect of silica application									
	No silica	2251	1375	1813	2535	3313	2969	2939	2489
	Silica	2188	1438	1813	2985	3000	2188	2724	2360
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.19 d Effect of higher dose of K									
	K_{35}	2219	1438	1828	2730	3094	2594	2806	2415
	K_{70}	2219	1375	1797	2790	3219	2563	2857	2433
		NS	NS	NS	NS	NS	NS	NS	NS

During *rabi* 1998-'99, T_9 (Straw +NPK +Si + soil application of $ZnSO_4$, $MgSO_4$, and $CuSO_4$) had the highest Mg concentration of 4813 ppm. Soil application of Mg resulted in increased content of the element in the straw.

During *rabi* 1999-'00, T_4 (Straw + NPK with higher K dose) registered the highest content of 3125 ppm whereas T_{14} had significantly lower content.

Grain

Magnesium content of grain did not exhibit any variation with seasons. The concentration in the grain among the *kharif* and *rabi* seasons themselves also had no appreciable changes.

During *kharif* 1998-'99, T_{15} recorded the highest content. Treatments T_1, T_2, T_3, T_5, T_7 and T_{10} had significantly lower content. During *kharif* 1999-'00 T_8 and T_9 registered significantly higher content than T_4, T_{10}, T_{14}, T_{15} and T_{16}.

During *rabi* 1997-'98, application of silica brought about significant reduction in Mg content. But when silica application was combined with higher K dose this reduction was not noticed. Content in T_9 was lower compared to T_1, T_2, T_3, T_4, T_{11} and T_{16}.

During *rabi* 1998-'99 and *rabi* 1999-'00 no remarkable changes in Mg content of grain was noticed between treatments.

4.1.3.6. Sulphur

The data on the effects of season and management practices on sulphur content of rice at tillering, PI and maturity stages and in grain are given in Tables 4.20 a,b.c and d, respectively.

Tillering stage

Sulphur content at tillering stage of the crop was higher in *rabi* (4555 ppm). Among the *kharif* seasons, the content was significantly higher in *kharif* 1998-'99. In case of *rabi*, mean S content was 5912 ppm in *rabi* 1998-'99 while *rabi* 1999-'00 had only 3198 ppm.

Table 4.19. Effect of season and treatments on magnesium content (ppm) of rice

d. Grain

Sl. No	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	930[bc]	1125[ab]	1028[c]	1070[ab]	1375[a]	1310[a]	1252[abc]	1162[a]
2	NPK alone	960[bc]	1250[ab]	1105[bc]	1110[ab]	1438[a]	1313[a]	1287[a]	1214[a]
3	Straw + NPK	860[bc]	1313[ab]	1087[bc]	1350[a]	1250[a]	1188[a]	1263[ab]	1192[a]
4	Straw + NPK (higher dose of K)	1090[abc]	1063[b]	1077[bc]	1080[ab]	1313[a]	1250[a]	1214[abc]	1159[a]
5	Straw + NPK + Si	810[c]	1375[ab]	1093[bc]	950[bc]	1813[a]	1188[a]	1317[a]	1227[a]
6	Straw + NPK (higher dose of K)+ Si	1010[abc]	1375[ab]	1193[abc]	900[bc]	1188[a]	1063[a]	1050[bc]	1107[a]
7	Straw + NPK + Si + Zn	900[bc]	1250[ab]	1075[bc]	810[bc]	1438[a]	1313[a]	1187[abc]	1142[a]
8	Straw + NPK + Si + Zn +Mg	1120[ab]	1813[a]	1467[a]	930[bc]	1188[a]	1125[a]	1081[abc]	1235[a]
9	Straw + NPK + Si + Zn +Mg+Cu	1020[abc]	1813[a]	1417[ab]	630[c]	1438[a]	1188[a]	1085[abc]	1218[a]
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	880[bc]	1063[b]	972[c]	840[bc]	1250[a]	1188[a]	1093[abc]	1044[a]
11	T_{10}+ Boron	1080[abc]	1188[ab]	1134[abc]	1020[ab]	1313[a]	1125[a]	1153[abc]	1145[a]
12	T_{11}+ Mo	1020[abc]	1188[ab]	1104[bc]	930[bc]	1313[a]	1125[a]	1123[abc]	1115[a]
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	1020[abc]	1188[ab]	1104[bc]	870[bc]	1375[a]	1250[a]	1165[abc]	1141[a]
14	T_{12} (No summer cowpea)	1090[abc]	1063[b]	1077[bc]	870[bc]	1125[a]	1063[a]	1019[c]	1042[a]
15	T_2 (No summer cowpea)	1260[a]	1063[b]	1162[abc]	990[b]	1375[a]	1188[a]	1184[abc]	1175[a]
16	T_{13} (No summer cowpea)	1050[abc]	1063[b]	1057[bc]	1080[ab]	1313[a]	1250[a]	1214[abc]	1151[a]
	Mean	**1006**	**1262**	**1134**	**964**	**1344**	**1195**	**1168**	**1154**
CD for comparison of season				NS				NS	202
CD for comparison of *Kharif vs Rabi*		NS							
Sub table 4.19 a Effect of cropping system									
	R-R-Fallow	1133	1063	1098	-	1271	1167	1219	1159
	R-R-cowpea	1000	1209	1104	-	1375	1229	1302	1203
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.19 b Effect of kharif straw incorporation									
	No straw	1010	1167	1089	1020	1375	1271	1222	1169
	Without straw	990	1188	1089	1050	1229	1125	1135	1117
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.19 c Effect of silica application									
	No silica	975	1188	1082	1215	1282	1219	1239	1176
	Silica	910	1375	1143	925	1501	1126	1184	1167
		NS	NS	NS	Sig	NS	NS	NS	NS
Sub table 4.19 d Effect of higher dose of K									
	K_{35}	835	1344	1090	1150	1532	1188	1290	1210
	K_{70}	1050	1219	1135	990	1251	1157	1132	1133
		NS	NS	NS	NS	NS	NS	NS	NS

During *kharif* 1998-'99, application of silica brought about significant reduction in S content. However, supply of silica with higher K dose did not affect the S content. Content in T_5, T_8, T_{11}, T_{15} and T_{16} were significantly lower than T_3.

During *kharif* 1999-'00, *kharif* straw incorporation brought about significant reduction in S content (Sub table 4.20 b). Application of silica with normal K dose resulted in an increased content. Soil application of Cu also increased S concentration in the plant. T_1 (Straw alone) recorded the lowest concentration of 1806 ppm; all other treatments except T_3, T_7, T_8, T_{12} and T_{13} registered significantly lower concentration.

During *rabi* 1998-'99, T_8 (Straw +NPK +Si + soil application of $ZnSO_4$ and $MgSO_4$) had the highest content. T_1 alone recorded significantly lower content. During *rabi* 1999-'00, application of higher K dose significantly reduced S content, but when silica application was combined with higher K dose, this effect was not noticed. Soil application of Zn resulted in increasing S content. Treatment receiving foliar application of Zn, Mg and Cu (T_{10}) registered significantly lower content than their soil application.

PI stage

At PI stage, *kharif* crop had a mean S content of 2805 ppm whereas *rabi* crop had a higher content of 3455 ppm. Among the *kharif* seasons, *kharif* 1998-'99 had significantly higher content than *kharif* 1999-'00. In *rabi*, the content was highest in *rabi* 1998-'99. Lower values were recorded during *rabi* 1997-'98 and *rabi* 1999-'00 and they also differed among themselves significantly in S content of the crop.

During *kharif* 1998-'99, combined application of straw and NPK (T_3) resulted in significant increase in S content over application of straw alone. Content in T_8, T_{11}, T_{14} and T_{16} also was significantly lower than T_3. Foliar spray of boron decreased the S concentration in the plant.

During *kharif* 1999-'00, also T_3 (Straw + NPK) had significantly higher S content than T_1. T_{11} also had lower content whereas other treatments were on par with each other.

Table 4.20. Effect of season and treatments on sulphur content (ppm) of rice

a. Tillering stage

Sl.No	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	4809^{abc}	1806^{c}	3308^{bcd}	4730^{b}	3208^{bcdef}	3969^{c}	3638^{e}
2	NPK alone	6206^{ab}	2737^{a}	4472^{a}	5728^{ab}	3577^{bc}	4653^{abc}	4562^{ab}
3	Straw + NPK	6298^{a}	2143^{bc}	4221^{abc}	6351^{ab}	3768^{ab}	5060^{ab}	4640^{a}
4	Straw + NPK (higher dose of K)	5099^{abc}	2381^{ab}	3740^{abcd}	6482^{ab}	3010^{cdefg}	4746^{abc}	4243^{abcde}
5	Straw + NPK + Si	4361^{bc}	2751^{a}	3556^{abcd}	5942^{ab}	3382^{bcd}	4662^{abc}	4109^{abcde}
6	Straw + NPK (higher dose of K)+ Si	4427^{abc}	2362^{ab}	3395^{bcd}	5665^{ab}	3069^{cdefg}	4367^{abc}	3881^{de}
7	Straw + NPK + Si + Zn	5152^{abc}	2155^{bc}	3654^{abcd}	5955^{ab}	4227^{a}	5091^{a}	4372^{abcd}
8	Straw + NPK + Si + Zn +Mg	4085^{c}	2134^{bc}	3110^{d}	6798^{a}	3257^{bcde}	5028^{ab}	4069^{abcde}
9	Straw + NPK + Si + Zn +Mg+Cu	5705^{abc}	2785^{a}	4245^{ab}	5995^{ab}	3724^{ab}	4860^{abc}	4552^{abc}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	4625^{abc}	2375^{ab}	3500^{bcd}	5982^{ab}	2663^{efg}	4323^{abc}	3911^{cde}
11	T_{10}+ Boron	3953^{c}	2360^{ab}	3157^{d}	6105^{ab}	2797^{defg}	4451^{abc}	3804^{de}
12	T_{11}+ Mo	4414^{abc}	2123^{bc}	3269^{cd}	5969^{ab}	2463^{g}	4216^{abc}	3742^{de}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	4967^{abc}	2130^{bc}	3549^{abcd}	6038^{ab}	3349^{bcd}	4694^{abc}	4121^{abcde}
14	T_{12} (No summer cowpea)	5231^{abc}	2257^{b}	3744^{abcd}	5710^{ab}	2576^{fg}	4143^{bc}	3944^{bcde}
15	T_2 (No summer cowpea)	4320^{bc}	2385^{ab}	3353^{bcd}	5692^{ab}	2831^{defg}	4262^{abc}	3807^{de}
16	T_{13} (No summer cowpea)	4269^{c}	2534^{ab}	3402^{bcd}	5455^{ab}	3261^{bcde}	4358^{abc}	3880^{de}
	Mean	**4870**	**2339**	**3604**	**5912**	**3198**	**4555**	**4080**
CD for comparison of season				240			1894	871
CD for comparison of *Kharif vs Rabi*					690			
Sub table 4.20 a. Effect of cropping system								
	R-R-Fallow	4607	2392	3499	5619	2889	4254	3877
	R-R-cowpea	5196	2330	3763	5912	3130	4521	4142
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.20b. Effect of Kharif straw incorporation								
	Without straw	5147	2467	3807	5740	3396	4568	4188
	With straw	5314	2174	3744	6010	2936	4473	4109
		NS	Sig	NS	NS	NS	NS	NS
Sub table 4.20 c. Effect of silica								
	Without silica	5699	2262	3980	6417	3389	4903	4442
	With silica	4394	2557	3475	5804	3226	4515	3995
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.20d. Effect of higher dose of K								
	K35	5330	2447	3888	6147	3575	4861	4375
	K70	4763	2372	3567	6074	3040	4557	4062
		NS	NS	NS	NS	NS	NS	NS

Table 4.20. Effect of season and treatments on sulphur content (ppm) of rice

b. PI stage

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	2714^{cde}	1961^{c}	2338de	2798^{b}	4449^{ab}	1811^{bc}	3019^{h}	2747^{f}
2	NPK alone	3001^{abcde}	2525^{ab}	2763^{abcd}	3808^{a}	4701^{ab}	1710^{c}	3406^{efg}	3149^{bcde}
3	Straw + NPK	4098^{a}	2634^{a}	3366^{a}	4299^{a}	4480^{ab}	2144^{abc}	3641^{b}	3531^{a}
4	Straw + NPK (higher dose of K)	3399^{abcd}	2353^{abc}	2876^{abcd}	3947^{a}	4804^{ab}	2174^{abc}	3642^{b}	3335^{abcd}
5	Straw + NPK + Si	3742^{abc}	2644^{a}	3193^{ab}	3962^{a}	4467^{ab}	1792^{bc}	3407^{efg}	3321^{abcd}
6	Straw + NPK (higher dose of K)+ Si	3729^{abc}	2225^{abc}	2977^{abc}	3795^{a}	4944^{a}	2148^{abc}	3629^{b}	3368^{abc}
7	Straw + NPK + Si + Zn	3057^{abcde}	2237^{abc}	2647^{bcde}	3732^{a}	5061^{a}	1790^{bc}	3528^{bcd}	3175^{abcde}
8	Straw + NPK + Si + Zn +Mg	2912^{bcde}	2632^{a}	2772^{abcd}	3623^{ab}	4361^{ab}	1986^{abc}	3323^{g}	3103^{bcde}
9	Straw + NPK + Si + Zn +Mg+Cu	3124^{abcde}	2622^{a}	2873^{abcd}	4096^{a}	5152^{a}	2157^{abc}	3802^{a}	3430^{ab}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	4019^{ab}	2511^{ab}	3265^{a}	3813^{a}	4480^{ab}	2107^{abc}	3467^{cde}	3386^{abc}
11	T_{10}+ Boron	2174^{e}	2104^{bc}	2139^{e}	3815^{a}	4743^{ab}	1800^{bc}	3453^{def}	2927^{ef}
12	T_{11}+ Mo	3716^{abc}	2237^{abc}	2977^{abc}	3501^{ab}	3825^{b}	1917^{abc}	3081^{h}	3039^{cdef}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	3004^{abcde}	2654^{a}	2829^{abcd}	3403^{ab}	4321^{ab}	2345^{a}	3356^{efg}	3145^{bcde}
14	T_{12} (No summer cowpea)	2714^{cde}	2219^{abc}	2467^{cde}	3535^{ab}	4929^{a}	2264^{ab}	3576^{bc}	3132^{bcde}
15	T_2 (No summer cowpea)	3268^{abcde}	2629^{a}	2949^{abc}	3543^{ab}	5120^{a}	2194^{abc}	3619^{b}	3351^{abcd}
16	T_{13} (No summer cowpea)	2570de	2317^{abc}	2444^{cde}	3417^{ab}	4480^{ab}	2112^{abc}	3336^{fg}	2979^{def}
	Mean	**3203**	**2407**	**2805**	**3693**	**4645**	**2028**	**3455**	**3195**
CD for comparison of season				242				495	321
CD for comparison of *Kharif vs Rabi*		212							
Sub table 4.20 a. Effect of cropping system									
	R-R-Fallow	2851	2388	2620		4843	2190	3517	3068
	R-R-cowpea	3240	2472	2856		4282	1991	3137	2996
		NS	NS	NS		NS	NS	Sig	NS
Sub table 4.20b. Effect of Kharif straw incorporation									
	Without straw	2858	2499	2679	3543	4501	2056	3366	3091
	With straw	3509	2363	2936	3778	4411	2108	3433	3234
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.20 c. Effect of silica									
	Without silica	3749	2494	3121	4123	4642	2159	3641	3433
	With silica	3736	2435	3085	3879	4706	1970	3518	3345
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.20d. Effect of higher dose of K									
	K35	3920	2639	3280	4131	4474	1968	3524	3426
	K70	3564	2289	2927	3871	4874	2161	3635	3352
		NS	NS	NS	NS	NS	NS	NS	NS

During *rabi* 1997-'98, straw alone (T_1) had lower S content. The S content of other treatments were on par with each other. During *rabi* 1998-'99 T_{12} had the lowest content while other treatments were on par. During *rabi* 1999-'00, T_2 recorded 1710 ppm which was significantly lower to T_{13} and T_{14}.

Straw

The mean S content of straw was significantly higher in *rabi* (2376 ppm) than *kharif* season. Among the *kharif* seasons, higher content was recorded in *kharif* 1998-'99. Sulphur content in the three *rabi* seasons also differed significantly. The lowest content was registered during *rabi* 1999-'00. It was significantly higher in *rabi* 1998-'99 and *rabi* 1997-'98.

During *kharif* 1998-'99, foliar spray of boron was found to result in significant increase in S content. T_{13} registered the lowest content. Other treatments were on par in S content. During *kharif* 1999-'00 and *rabi* 1998-'99 the treatments did not manifest any variation. During *rabi* 1997-'98, T_{13} and T_1 differed significantly whereas others were on par. During *rabi* 1999-'00, T_{12} (Straw +NPK +Si + foliar application of Zn, Mg, Cu, B and Mo) registered significantly higher concentration than T_1 whereas other treatments did not show any statistical difference.

Grain

S content of grain was found to be higher in *kharif* crop (1266 ppm). Among the two *kharif* seasons, the content was significantly higher during *kharif* 1998-'99. *Rabi* 1997-'98 and 1998-'99 had comparable values but the content in *rabi* 1999-'00 crop was significantly lower.

During *kharif* 1998-'99, application of silica with higher K dose (T_6) resulted in significantly increased S concentration in grain. The effects of other treatments were not remarkable. During *kharif* 1999-'00, T_5 (Straw +NPK +Si) recorded the highest concentration while T_{10} and T_{15} had significantly lower content.

During *rabi* 1997-'98, higher K dose increased S content, but combined application of silica did not bring about this increase. Silica

Table 4.20. Effect of season and treatments on sulphur content (ppm) of rice

C. Straw

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	1964^{abc}	1328^{a}	1646^{abc}	1845^{b}	2411^{a}	1924^{b}	2060^{c}	1894^{b}
2	NPK alone	1924^{abc}	1408^{a}	1666^{abc}	2465^{ab}	2678^{a}	2187^{ab}	2443^{ab}	2132^{ab}
3	Straw + NPK	2003^{abc}	1441^{a}	1722^{abc}	2569^{ab}	2253^{a}	2029^{ab}	2284^{bc}	2059^{ab}
4	Straw + NPK (higher dose of K)	1871^{abc}	1573^{a}	1722^{abc}	2359^{ab}	2757^{a}	2385^{ab}	2500^{ab}	2189^{ab}
5	Straw + NPK + Si	2148^{abc}	1456^{a}	1802^{abc}	2406^{ab}	2430^{a}	2161^{ab}	2332^{abc}	2120^{ab}
6	Straw + NPK (higher dose of K)+ Si	1713^{bc}	1415^{a}	1564^{bc}	2609^{ab}	2724^{a}	2029^{ab}	2454^{ab}	2098^{ab}
7	Straw + NPK + Si + Zn	1898^{abc}	1720^{a}	1809^{abc}	2503^{ab}	2675^{a}	2346^{ab}	2508^{ab}	2228^{a}
8	Straw + NPK + Si + Zn +Mg	2082^{abc}	1616^{a}	1849^{abc}	2279^{ab}	2663^{a}	2029^{ab}	2324^{abc}	2134^{ab}
9	Straw + NPK + Si + Zn +Mg+Cu	2108^{abc}	1591^{a}	1850^{abc}	2398^{ab}	2517^{a}	2292^{ab}	2402^{ab}	2181^{ab}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	1660^{bc}	1316^{a}	1488^{c}	2293^{ab}	2635^{a}	2201^{ab}	2376^{abc}	2021^{ab}
11	T_{10}+ Boron	2424^{a}	1481^{a}	1953^{ab}	2286^{ab}	2345^{a}	2214^{ab}	2282^{bc}	2150^{ab}
12	T_{11}+ Mo	1990^{abc}	1433^{a}	1712^{abc}	2187^{ab}	2570^{a}	2504^{a}	2420^{ab}	2137^{ab}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	1463^{c}	1662^{a}	1563^{bc}	3018^{a}	2978^{a}	1950^{b}	2649^{a}	2214^{a}
14	T_{12} (No summer cowpea)	1937^{abc}	1492^{a}	1715^{abc}	2346^{ab}	2413^{a}	2069^{ab}	2276^{bc}	2051^{ab}
15	T_2 (No summer cowpea)	1924^{abc}	1589^{a}	1757^{abc}	2227^{ab}	2345^{a}	2174^{ab}	2249^{bc}	2052^{ab}
16	T_{13} (No summer cowpea)	2306^{ab}	1720^{a}	2013^{a}	2492^{ab}	2852^{a}	2029^{ab}	2458^{ab}	2280^{a}
	Mean	**1963**	**1515**	**1739**	**2393**	**2578**	**2158**	**2376**	**2121**
CD for comparison of season				422				130	177
CD for comparison of *Kharif vs Rabi*						222			
Sub table 4.20 a. Effect of cropping system									
	R-R-Fallow	2056	1600	1828	-	2537	2091	2314	2071
	R-R-cowpea	1792	1501	1647	-	2742	2214	2478	2062
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.20b. Effect of Kharif straw incorporation									
	Without straw	1898	1597	1747	2658	2836	2055	2517	2209
	With straw	1977	1455	1716	2367	2412	2201	2327	2082
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.20 c. Effect of silica									
	Without silica	1937	1507	1722	2464	2505	2207	2392	2124
	With silica	1931	1436	1683	2508	2577	2095	2393	2109
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.20d. Effect of higher dose of K									
	K35	2076	1449	1762	2488	2342	2095	2308	2090
	K70	1792	1494	1643	2484	2741	2207	2477	2144
		NS	NS	NS	NS	NS	NS	NS	NS

Table 4.20. Effect of season and treatments on sulphur content (ppm) of rice

d. Grain

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	1291^{bc}	1047^{ab}	1169^{b}	673^{e}	1467^{abc}	725^{ab}	955^{f}	1041^{d}
2	NPK alone	1450^{bc}	1133^{ab}	1292^{ab}	1175^{cde}	1529^{abc}	791^{ab}	1165^{cdef}	1216^{bcd}
3	Straw + NPK	1456^{bc}	1268^{ab}	1362^{ab}	1208^{cde}	1199^{bc}	712^{b}	1040^{ef}	1169^{bcd}
4	Straw + NPK (higher dose of K)	1489^{bc}	1174^{ab}	1332^{ab}	2039^{a}	1280^{bc}	826^{ab}	1382^{bc}	1362^{abc}
5	Straw + NPK + Si	1371^{bc}	1397^{a}	1384^{ab}	1041^{de}	1095^{c}	923^{ab}	1020^{ef}	1165^{bcd}
6	Straw + NPK (higher dose of K)+ Si	2069^{a}	1226^{ab}	1648^{a}	1041^{de}	1387^{abc}	804^{ab}	1077^{def}	1305^{abc}
7	Straw + NPK + Si + Zn	1242^{bc}	1226^{ab}	1234^{b}	993^{de}	1383^{abc}	1058^{a}	1145^{cdef}	1180^{bcd}
8	Straw + NPK + Si + Zn +Mg	1344^{bc}	1187^{ab}	1266^{ab}	1004^{de}	1714^{abc}	896^{ab}	1205^{bcdef}	1229^{bcd}
9	Straw + NPK + Si + Zn +Mg+Cu	1054^{c}	1210^{ab}	1132^{b}	1911^{ab}	2214^{a}	1054^{a}	1726^{a}	1489^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	1160^{bc}	936^{b}	1048^{b}	1136^{cde}	1056^{c}	699^{b}	964^{f}	997^{d}
11	T_{10}+ Boron	1370^{bc}	1028^{ab}	1199^{b}	1594^{abcd}	1226^{bc}	883^{ab}	1234^{bcdef}	1220^{bcd}
12	T_{11}+ Mo	1555^{b}	1184^{ab}	1370^{ab}	1779^{abc}	1357^{abc}	809^{ab}	1315^{bcde}	1337^{abc}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	1081^{c}	1067^{ab}	1074^{b}	1135^{cde}	1222^{bc}	751^{ab}	1036^{ef}	1051^{d}
14	T_{12} (No summer cowpea)	1331^{bc}	1134^{ab}	1233^{b}	1173^{cde}	1294^{bc}	620^{b}	1029^{ef}	1110^{cd}
15	T_{2} (No summer cowpea)	1449^{bc}	975^{b}	1212^{b}	1581^{abcd}	2021^{ab}	843^{ab}	1482^{ab}	1374^{ab}
16	T_{13} (No summer cowpea)	1371^{bc}	1226^{ab}	1299^{ab}	1397^{bcd}	1886^{abc}	778^{ab}	1354^{bcd}	1332^{abc}
	Mean	**1380**	**1151**	**1266**	**1305**	**1458**	**823**	**1195**	**1224**
CD for comparison of season				191				402	260
CD for comparison of *Kharif vs Rabi*		170							
Sub table 4.20 a. Effect of cropping system									
	R-R-Fallow	1384	1112	1248	-	1734	747	1240	1244
	R-R-cowpea	1362	1128	1245	-	1369	784	1077	1161
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.20b. Effect of Kharif straw incorporation									
	Without straw	1301	1142	1221	1236	1546	773	1185	1199
	With straw	1447	1195	1321	1387	1283	714	1128	1205
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.20 c. Effect of silica									
	Without silica	1473	1221	1347	1624	1240	769	1211	1265
	With silica	1720	1312	1516	1041	1241	864	1049	1235
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.20d. Effect of higher dose of K									
	K35	1414	1333	1373	1125	1147	818	1030	1167
	K70	1779	1200	1490	1540	1334	815	1230	1334
		NS	NS	NS	NS	NS	NS	NS	NS

application on the contrary, decreased the S content when it was applied along with higher dose of K. Soil application of Cu increased S concentration. But foliar application of Zn, Mg and Cu resulted in a decreased content of S over their soil application.

During *rabi* 1998-'99 also soil application of Zn, Mg and Cu registered significantly higher content in the grain over their foliar application. The other treatments had similar concentration. During *rabi* 1999-'00, T_7 and T_9 registered higher S concentration whereas T_3, T_{10} and T_{14} had significantly lower content.

4.1.3.7. Iron

The data on the effects of season and management practices on iron content of rice at tillering, PI and maturity stages and in grain are given in Tables 4.21 a,b.c and d, respectively.

Tillering stage

The mean Fe content of the crop at tillering stage was 3872 ppm in *kharif* while *rabi* crop had a significant lower content of 3600 ppm. Variations were much wider among the *kharif* and *rabi* seasons themselves. Thus *kharif* 1998-'99 crop had Fe content of 927 ppm while *kharif* 1999-'00 crop registered 6817 ppm. Similarly during *rabi* 1998-'99 the concentration of Fe in the plant was 972 ppm while *rabi* 1999-'00 crop registered 6228 ppm.

During *kharif* 1998-'99, application of higher dose of K resulted in decreasing Fe content from 944 ppm to 853 ppm. This decrease was not seen when higher K dose was associated with silica application. T_{15} and T_{16} recorded the highest concentration of 978 ppm while T_1, T_2, T_4, and T_7 had significantly lower contents.

During *kharif* 1999-'00, *kharif* straw incorporation brought about significant increase in Fe content whereas silica application decreased the concentration, but combination of silica and higher K dose did not show any influence. Foliar application of boron increased Fe content. Incorporation of cowpea residues did not bring about any remarkable change.

Table 4.21. Effect of season and treatments on iron content (ppm) of rice

a. Tillering stage

Sl.No	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	863^{cd}	7169^{cd}	4016^{cd}	962^{ab}	9050^{a}	5006^{a}	4511^{a}
2	NPK alone	902^{bcd}	6844^{cd}	3873^{cde}	1051^{a}	5851^{bcde}	3451^{bcde}	3662^{bcdef}
3	Straw + NPK	944^{ab}	9681^{a}	5313^{a}	954^{ab}	5782^{bcde}	3368^{bcde}	4340^{ab}
4	Straw + NPK (NK 1:1)	853^{d}	8313^{abc}	4583^{bc}	969^{ab}	5069^{cde}	3019^{cde}	3801^{bcde}
5	Straw + NPK + Silica	913^{abcd}	5132^{f}	3023^{f}	901^{b}	7813^{ab}	4357^{ab}	3690^{bcde}
6	Straw + NPK (NK 1:1)+ Silica	913^{abcd}	8763^{ab}	4838^{ab}	969^{ab}	4955^{de}	2962^{de}	3000^{abcd}
7	Straw + NPK + Silica + Zn	894^{bcd}	6357^{def}	3626^{def}	932^{ab}	5915^{bcde}	3424^{bcde}	3525^{cdef}
8	Straw + NPK + Silica + Zn +Mg	925^{abc}	7282^{cd}	4104^{cd}	963^{ab}	7433^{abc}	4198^{abc}	4151^{abc}
9	Straw + NPK + Si + Zn +Mg+Cu	945^{ab}	5813^{def}	3379^{def}	969^{ab}	5725^{bcde}	3347^{bcde}	3363^{def}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	936^{ab}	5219^{ef}	3078^{f}	957^{ab}	7338^{abcde}	4148^{abcd}	3613^{cdef}
11	T_{10}+ Boron	932^{ab}	7432^{bcd}	4182^{bcd}	975^{ab}	8013^{ab}	4494^{abc}	4338^{ab}
12	T_{11}+ Mo	944^{ab}	7554^{bcd}	4249^{bcd}	1007^{ab}	5726^{bcde}	3367^{bcde}	3808^{bcd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	963^{ab}	5213^{ef}	3088^{f}	1013^{ab}	5257^{cde}	3135^{cde}	3112^{ef}
14	T_{12} (No summer cowpea)	944^{ab}	6400^{def}	3672^{def}	968^{ab}	6155^{bcde}	3562^{bcde}	3617^{cdef}
15	T_2 (No summer cowpea)	978^{a}	6700^{de}	3839^{de}	969^{ab}	4650^{e}	2810^{e}	3324^{def}
16	T_{13} (No summer cowpea)	978^{a}	5207^{ef}	3093^{ef}	999^{ab}	4919^{de}	2959^{de}	3026^{f}
	Mean	**927**	**6817**	**3872**	**972**	**6228**	**3600**	**3736**
CD for comparison of season				235			199	264
CD for comparison of *Kharif vs Rabi*					103			
Sub table 4.21 a. Effect of cropping system								
	R-R-Fallow	967	6102	3535	979	5241	3110	3322
	R-R-cowpea	936	6537	3737	1024	5611	3318	3527
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.21b. Effect of Kharif straw incorporation								
	Without straw	948	5755	3351	1021	5342	3182	3266
	With straw	944	7878	4411	976	5888	3432	3922
		NS	Sig	NS	NS	NS	NS	Sig
Sub table 4.21 c. Effect of silica								
	Without silica	899	8997	4948	962	5426	3194	4071
	With silica	913	6948	3930	935	6384	3660	3795
		NS	Sig	NS	NS	NS	NS	NS
Sub table 4.21d. Effect of higher dose of K								
	K35	929	7407	4168	928	6798	3863	4015
	K70	883	8538	4711	969	5012	2991	3851
		NS	Sig	NS	NS	Sig	NS	NS

During *rabi* 1998-'99, T_2 (NPK alone) had the highest content. T_5 (Straw + NPK + Si) showed lowest content. The other treatments did not vary remarkably.

During *rabi* 1999-'00, Fe content was highest in T_1. Application of higher K dose brought about significant reduction in Fe concentration only when the K application was associated with silica application. Incorporation of *kharif* straw or summer cowpea residues did not influence Fe concentration in the plant.

PI stage

At PI stage the mean Fe concentration in *kharif* and *rabi* crops did not show significant variation. But the variations within the *kharif* and *rabi* seasons were highly significant. *Kharif* 1998-'99 crop registered Fe concentration of 953 ppm whereas in *kharif* 1999-'00 it was as high as 4228 ppm. The contents showed significant variations in *rabi* also. The Fe concentration during *rabi* 1997-'98, 1998-'99 and 1999-'00 were 6208 ppm, 1017 ppm and 4401 ppm respectively.

During *kharif* 1998-'99, the lowest content was in T_1 (863 ppm) whereas T_6 (Straw +NPK +Si with higher K dose) recorded significantly higher concentration of 1019 ppm. The contents in other treatments were on par with each other.

During *kharif* 1999-'00, higher K application resulted in increased Fe concentration. Content was significantly lower in T_8, T_{12}, T_{13} and T_{14}.

During *rabi* 1997-'98, highest content was in T_7 (Straw +NPK +Si + soil application of $ZnSO_4$). T_1, T_2, T_3, T_4, T_8, T_9, T_{15} and T_{16} had significantly lower content. During *rabi* 1998-'99, treatments did not show any remarkable difference. During *rabi* 1999-'00, T_6 registered the highest content of 6151 ppm; T_{12} alone had a significantly low concentration. Other treatments showed contents similar to these.

Straw

The mean Fe content of straw during *kharif* and *rabi* did not show remarkable variation. But differences existed between *kharif* and *rabi* seasons

Table 4.21. Effect of season and treatments on iron content (ppm) of rice

b. PI stage

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	863^{c}	5357^{abc}	3110^{abc}	6056^{bcde}	999^{a}	3532^{ab}	3529^{cde}	3361^{bcd}
2	NPK alone	951^{b}	4069^{cde}	2510^{cde}	5982^{bcde}	1038^{a}	3888^{ab}	3636^{bcd}	3186^{bcd}
3	Straw + NPK	957^{b}	3769de	2363de	5650^{bcde}	1013^{a}	4332^{ab}	3665^{bcd}	3144^{bcd}
4	Straw + NPK (higher dose of K)	952^{b}	6100^{ab}	3526^{ab}	3813^{e}	1049^{a}	2926^{b}	2596^{e}	2968^{d}
5	Straw + NPK + Si	938^{b}	4588^{cde}	2763^{cde}	7263^{abc}	1044^{a}	5613^{ab}	4640^{ab}	3889^{ab}
6	Straw + NPK (higher dose of K)+ Si	1019^{a}	6425^{a}	3722^{a}	6269^{abcde}	1013^{a}	6151^{a}	4478^{abc}	4175^{a}
7	Straw + NPK + Si + Zn	957^{ab}	3569de	2263de	8744^{a}	1052^{a}	5032^{ab}	4943^{a}	3871^{abc}
8	Straw + NPK + Si + Zn +Mg	975^{ab}	3288^{e}	2132^{e}	5163^{cde}	988^{a}	4475^{ab}	3542^{cde}	2978^{d}
9	Straw + NPK + Si + Zn +Mg+Cu	948^{b}	4644^{cde}	2796^{cde}	4582de	1001^{a}	3657^{ab}	3080de	2966^{d}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	957^{b}	3575de	2266de	6244^{abcde}	1001^{a}	3482^{ab}	3576^{cde}	3052^{cd}
11	T_{10}+ Boron	951^{b}	3875de	2413^{cde}	6532^{abcd}	1038^{a}	4301^{ab}	3957^{abcd}	3339^{bcd}
12	T_{11}+ Mo	944^{b}	3394^{e}	2169^{e}	8269^{ab}	974^{a}	2901^{b}	4048^{abcd}	3296^{bcd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	969^{ab}	3269^{e}	2119^{e}	7232^{abcd}	994^{a}	3988^{ab}	4071^{abcd}	3290^{bcd}
14	T_{12} (No summer cowpea)	938^{b}	3282^{e}	2110^{e}	6926^{abcd}	1057^{a}	5644^{ab}	4542^{abc}	3569^{abcd}
15	T_2 (No summer cowpea)	994^{ab}	3482de	2238de	5282^{cde}	1013^{a}	4850^{ab}	3715^{bcd}	3124^{bcd}
16	T_{13} (No summer cowpea)	935^{b}	4969^{bcd}	2952^{bcd}	5313^{cde}	1001^{a}	5644^{ab}	3986^{abcd}	3572^{abcd}
	Mean	**953**	**4228**	**2591**	**6208**	**1017**	**4401**	**3875**	**3361**
CD for comparison of season				509				520	1042
CD for comparison of *Kharif vs Rabi*		NS							
Sub table 4.21 a. Effect of cropping system									
	R-R-Fallow	956	3911	2433		1024	5379	3202	2817
	R-R-cowpea	955	3577	2266		1002	3592	2297	2282
		NS	NS	NS		NS	NS	NS	NS
Sub table 4.21b. Effect of Kharif straw incorporation									
	Without straw	952	4102	2527	6176	1011	4507	3898	3349
	With straw	946	3482	2214	6948	1015	4292	4085	3337
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.21 c. Effect of silica									
	Without silica	955	4935	2945	4732	1031	3629	3131	3056
	With silica	979	5507	3243	6766	1029	5882	4559	4032
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.21d. Effect of higher dose of K									
	K35	948	4179	2563	6457	1029	4973	4153	3517
	K70	986	6263	3624	5041	1031	4539	3537	3572
		NS	Sig	Sig	NS	NS	NS	NS	NS

Table 4.21. Effect of season and treatments on iron content (ppm) of rice

C. Straw

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	1159^{a}	1357^{e}	1258^{ef}	1288^{ab}	1879^{cde}	988^{bcd}	1385^{ab}	1334^{c}
2	NPK alone	1075^{a}	1369^{e}	1222^{f}	1188^{ab}	2076^{bcde}	969^{bcd}	1411^{ab}	1335^{c}
3	Straw + NPK	1257^{a}	1407^{e}	1332^{def}	1038^{ab}	2494^{abc}	1588^{ab}	1707^{a}	1557^{abc}
4	Straw + NPK (higher dose of K)	1188^{a}	1644^{de}	1416^{def}	1038^{ab}	1745^{de}	1188^{bcd}	1324^{b}	1361^{c}
5	Straw + NPK + Si	1007^{a}	1548^{de}	1278^{ef}	1225^{ab}	1769^{de}	888^{d}	1294^{b}	1287^{c}
6	Straw + NPK (higher dose of K)+ Si	1216^{a}	1688^{de}	1452^{def}	1157^{ab}	2144^{abcde}	1032^{bcd}	1444^{ab}	1447^{bc}
7	Straw + NPK + Si + Zn	1211^{a}	1900^{cde}	1556^{cdef}	1413^{ab}	1550^{e}	1325^{bcd}	1429^{ab}	1280^{abc}
8	Straw + NPK + Si + Zn +Mg	1052^{a}	1788^{de}	1420^{def}	1532^{a}	1913^{bcde}	938^{bcd}	1461^{ab}	1445^{bc}
9	Straw + NPK + Si + Zn +Mg+Cu	1119^{a}	2101^{cde}	1610^{cdef}	1044^{ab}	1849^{cde}	1113^{bcd}	1335^{b}	1445^{bc}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	1279^{a}	1538^{de}	1409^{def}	975^{ab}	1907^{bcde}	1563^{abc}	1482^{ab}	1452^{bc}
11	T10+ Boron	1312^{a}	3094^{ab}	2203^{ab}	850^{ab}	1663^{de}	1969^{a}	1494^{ab}	1778^{a}
12	T11+ Mo	1147^{a}	2490^{abcd}	1819^{abcd}	963^{ab}	1832^{cde}	1276^{bcd}	1357^{b}	1542^{abc}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	1226^{a}	3238^{ab}	2232^{ab}	851^{ab}	2259^{abcd}	1094^{bcd}	1401^{ab}	1734^{ab}
14	T12 (No summer cowpea)	1201^{a}	3422^{a}	2312^{a}	1150^{ab}	1738^{de}	1069^{bcd}	1319^{b}	1716^{ab}
15	T2 (No summer cowpea)	1122^{a}	2807^{abc}	1965^{abc}	688^{b}	2563^{ab}	813^{d}	1355^{b}	1599^{abc}
16	T13 (No summer cowpea)	1224^{a}	2313^{cde}	1769^{bcde}	688^{b}	2744^{a}	925^{cd}	1452^{ab}	1579^{abc}
	Mean	**1175**	**2107**	**1641**	**1068**	**2008**	**1171**	**1416**	**1506**
CD for comparison of season				460				756	571
CD for comparison of *Kharif vs Rabi*		NS							
Sub table 4.21 a. Effect of cropping system									
	R-R-Fallow	1182	2847	2015	-	2348	936	1642	1828
	R-R-cowpea	1149	2366	1758	-	2056	1113	1584	1671
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.21b. Effect of Kharif straw incorporation									
	Without straw	1175	2307	1741	909	2360	996	1422	1549
	With straw	1202	2440	1821	1050	2021	1311	1461	1605
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.21 c. Effect of silica									
	Without silica	1223	1526	1374	1038	2120	1388	1515	1459
	With silica	1112	1618	1365	1191	1957	960	1369	1367
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.21d. Effect of higher dose of K									
	K35	1132	1478	1305	1132	2132	1238	1500	1422
	K70	1202	1666	1434	1098	1945	1110	1384	1404
		NS	NS	NS	NS	NS	NS	NS	NS

themselves. *Kharif* 1998-'99 crop had a significantly lower Fe content of 1175 ppm as against 2107 ppm in *kharif* 1999-'00. During *rabi* 1998-'99, the content was 2008 ppm whereas in *rabi* 1997-'98 and 1999-'00 the concentrations were 1068 ppm and 1171 ppm respectively.

During *kharif* 1998-'99, Fe content in the treatments did not show statistical difference. During *kharif* 1999-'00,. T_{14} (Straw +NPK +Si + foliar application of Zn, Mg, Cu, B and Mo with no summer cowpea) registered the highest Fe content of 3422 ppm. T_{11}, T_{12}, T_{13} and T_{15} had concentration on par with it while others were significantly lower.

During *rabi* 1997-'98, T_8 (Straw +NPK +Si + soil application of $ZnSO_4$ and $MgSO_4$) had the highest Fe concentration while T_{15} and T_{16} had significantly lower values. During *rabi* 1998-'99, T_{16} registered Fe content of 2744 ppm while T_3, T_6, T_{13} and T_{14} had concentration on par with it. T_7, T_4, T_5, T_{11} and T_{14} recorded lower content.

During *rabi* 1999-'00, silica application significantly reduced Fe content. When silica was supplied along with higher dose of K, this decrease was not pronounced. T_{11} (Straw +NPK +Si + foliar application of Zn, Mg, Cu and B) registered the highest content of 1969 ppm. T_{10} was on par with this while others were significantly lower.

Grain

The mean content of Fe in the grain of *kharif* crop was 222 ppm whereas *rabi* crop had a significantly higher content of 391 ppm. *Kharif* 1998-'99 and *kharif* 1999-'00 registered Fe content of 200 ppm and 245 ppm respectively whereas during *rabi*, significant variations were noticed. Concentration of Fe during *rabi* 1997-'98 was 771 ppm whereas *rabi* 1998-'99 and 1999-'00 recorded significantly lower values of 237 ppm and 164 ppm respectively.

During *kharif* 1998-'99, the lowest Fe concentration (157 ppm) was in T_{11} (Straw +NPK +Si + foliar application of Zn, Mg, Cu and B). T_{10} and T_{12} showed significantly higher concentration whereas others recorded contents similar to T_{11}. During *kharif* 1999-'00, silica application along with higher K

Table 4.21. Effect of season and treatments on iron content (ppm) of rice

d. Grain

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	194^{abc}	157^{b}	176^{b}	744^{bcde}	219^{abc}	253^{a}	405^{bcd}	313^{bcd}
2	NPK alone	181^{bc}	232^{b}	207^{b}	769^{abcde}	138^{c}	157^{ab}	355^{def}	259^{d}
3	Straw + NPK	200^{abc}	201^{b}	201^{b}	716^{de}	219^{abc}	207^{ab}	381^{def}	309^{bcd}
4	Straw + NPK (higher dose of K)	186^{abc}	213^{b}	200^{b}	763^{abcde}	175^{bc}	175^{ab}	371^{def}	302^{cd}
5	Straw + NPK + Si	212^{abc}	282^{b}	247^{b}	775^{abcd}	351^{a}	257^{a}	461^{a}	375^{a}
6	Straw + NPK (higher dose of K)+ Si	196^{abc}	488^{a}	342^{a}	800^{abc}	251^{abc}	126^{b}	392^{cde}	372^{a}
7	Straw + NPK + Si + Zn	202^{abc}	257^{b}	230^{b}	688^{e}	163^{bc}	129^{b}	327^{ef}	288^{d}
8	Straw + NPK + Si + Zn +Mg	216^{abc}	282^{b}	249^{b}	719^{cde}	169^{bc}	213^{ab}	367^{def}	320^{abcd}
9	Straw + NPK + Si + Zn +Mg+Cu	175^{bc}	244^{b}	210^{b}	744^{bcde}	219^{abc}	107^{b}	357^{def}	298^{cd}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	242^{ab}	151^{b}	197^{b}	807^{ab}	282^{abc}	125^{b}	405^{bcde}	321^{abcd}
11	T10+ Boron	157^{c}	313^{b}	235^{b}	775^{abcd}	231^{abc}	151^{ab}	386^{de}	325^{abcd}
12	T11+ Mo	259^{a}	219^{b}	239^{b}	763^{abcde}	250^{abc}	164^{ab}	392^{cde}	331^{abcd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	208^{abc}	201^{b}	205^{b}	776^{abcd}	157^{bc}	113^{b}	349^{ef}	291^{d}
14	T12 (No summer cowpea)	175^{bc}	157^{b}	166^{b}	825^{ab}	307ab	100^{b}	411^{abcd}	313^{bcd}
15	T2 (No summer cowpea)	222^{abc}	225^{b}	224^{b}	832^{a}	294^{ab}	197^{ab}	441^{abc}	354^{abc}
16	T13 (No summer cowpea)	172^{bc}	300^{b}	236^{b}	838^{a}	363^{a}	157^{ab}	453^{ab}	366^{ab}
	Mean	**200**	**245**	**222**	**771**	**237**	**164**	**391**	**323**
CD for comparison of season				NS				60	46
CD for comparison of *Kharif vs Rabi*		18							
Sub table 4.21 a. Effect of cropping system									
	R-R-Fallow	190	227	209	-	321	151	236	222
	R-R-cowpea	216	217	217	-	182	145	163	190
		NS	NS	NS	-	Sig	NS	NS	NS
Sub table 4.21b. Effect of Kharif straw incorporation									
	Without straw	187	244	216	794	219	142	385	317
	With straw	211	192	202	768	259	157	395	317
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.21 c. Effect of silica									
	Without silica	193	207	200	740	197	191	376	306
	With silica	204	385	295	788	301	192	427	374
		Ns	Sig	NS	NS	Sig	NS	NS	NS
Sub table 4.21d. Effect of higher dose of K									
	K35	206	242	224	746	285	232	421	342
	K70	191	351	271	782	213	151	382	337
		NS	NS	NS	782	NS	NS	NS	NS

dose resulted in increasing Fe concentration, whereas other treatments had similar but significantly lower concentration. During *rabi* 1997-'98, T_{15} and T_{16} had higher concentration; T_1, T_3, T_7, T_8 and T_9 registered significantly lower concentration. During *rabi* 1998-'99, content was lowest in T_2 (138 ppm). T_5, T_{14}, T_{15} and T_{16} alone had contents higher than this. During *rabi* 1999-'00, T_1 and T_5 had concentration higher than T_{13} and T_{14} whereas other treatments remained on par with these.

4.1.3.8. Manganese

The data on the effects of season and management practices on manganese content of rice at tillering, PI and maturity stages and in grain are given in Tables 4.22 a,b.c and d, respectively.

Tillering stage

During *kharif*, the mean Mn content was 138 ppm whereas *rabi* registered significantly lower content of 89 ppm. Among the two *kharif* seasons, during *kharif* 1998-'99, the Mn level in the plant was 180 ppm while in *kharif* 1999-'00 it was 96 ppm. Significant differences were noticed among *rabi* seasons also. During *rabi* 1998-'99, the Mn content was 130 ppm. A lower content of 49 ppm was recorded in *rabi* 1999-'00.

During *kharif* 1998-'99, T_3 (Straw + NPK) registered higher content of 238 ppm, while T_{15} had significantly lower content. Other treatments remained on par with these. During *kharif* 1999-'00, the treatments did not manifest any significant influence on Mn content.

During *rabi* 1998-'99, the content in T_8 (Straw +NPK +Si + soil application of $ZnSO_4$ and $MgSO_4$) had the lowest content of 86 ppm while T_1, T_2, T_3, T_4, T_{13} and T_{15} had significantly higher contents.

During *rabi* 1999-'00, application of higher K dose significantly reduced Mn content, but when K was combined with silica application, this influence was not noticed. T_{12} also recorded lower concentration.

Table 4.22. Effect of season and treatments on manganese content (ppm) of rice

a. Tillering stage

Sl.No	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	178[ab]	95[a]	137[ab]	153[ab]	64[ab]	109[ab]	123[ab]
2	NPK alone	228[ab]	99[a]	164[a]	153[ab]	62[abc]	108[ab]	136[a]
3	Straw + NPK	238[a]	93[a]	166[a]	153[ab]	71[a]	112[a]	139[a]
4	Straw + NPK (higher dose of K)	193[ab]	97[a]	145[ab]	173[a]	32[c]	103[abc]	124[ab]
5	Straw + NPK + Si	151[ab]	99[a]	125[ab]	122[bc]	41[abc]	82[bcde]	103[b]
6	Straw + NPK (higher dose of K)+ Si	151[ab]	99[a]	125[ab]	126[abc]	42[abc]	84[abcde]	105[b]
7	Straw + NPK + Si + Zn	170[ab]	113[a]	142[ab]	114[bc]	58[abc]	86[abcde]	114[ab]
8	Straw + NPK + Si + Zn +Mg	175[ab]	106[a]	141[ab]	86[c]	36[bc]	61[e]	101[b]
9	Straw + NPK + Si + Zn +Mg+Cu	212[ab]	80[a]	146[ab]	119[bc]	54[abc]	87[abcde]	116[ab]
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	187[ab]	108[a]	148[ab]	128[abc]	44[abc]	86[abcde]	117[ab]
11	T10+ Boron	152[ab]	109[a]	131[ab]	106[bc]	44[abc]	75[cde]	103[b]
12	T11+ Mo	176[ab]	92[a]	134[ab]	112[bc]	32[c]	72[de]	103[b]
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	171[ab]	97[a]	134[ab]	139[ab]	46[abc]	93[abcd]	113[ab]
14	T12 (No summer cowpea)	185[ab]	77[a]	131[ab]	131[abc]	49[abc]	90[abcd]	111[ab]
15	T2 (No summer cowpea)	136[b]	73[a]	105[b]	142[ab]	49[abc]	96[abcd]	100[b]
16	T13 (No summer cowpea)	183[ab]	95[a]	139[ab]	118[bc]	63[abc]	91[abcde]	115[ab]
	Mean	**180**	**96**	**138**	**130**	**49**	**89**	**114**
CD for comparison of season				21			26	15
CD for comparison of *Kharif vs Rabi*					26			
Sub table 4.22 a. Effect of cropping system								
	R-R-Fallow	168	82	125	130	54	92	108
	R-R-cowpea	192	96	144	135	47	91	117
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.22b. Effect of Kharif straw incorporation								
	Without straw	194	97	146	137	57	97	121
	With straw	200	87	144	132	51	91	117
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.22 c. Effect of silica								
	Without silica	216	95	155	163	52	107	131
	With silica	151	99	125	124	42	83	104
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.22d. Effect of higher dose of K								
	K35	195	96	145	138	56	97	121
	K70	172	98	135	150	37	93	114
		NS	NS	NS	NS	NS	NS	NS

PI stage

The mean Mn content in the plant at PI stage in *kharif* crop was 132 ppm whereas *rabi* registered significantly lower content of 117 ppm. Among the two *kharif* seasons, Mn content during *kharif* 1998-'99 was 169 ppm as compared to a lower level of 95 ppm in *kharif* 1999-'00. Among the *rabi* seasons, during *rabi* 1997-'98 the Mn content was 128 ppm. The content was significantly higher in *rabi* 1998-'99 whereas it was low in *rabi* 1999-'00 (57 ppm).

During *kharif* 1998-'99, silica application resulted in a significant reduction in Mn content (Sub table 4.22 c). Foliar application of boron also resulted in a remarkable decrease. During *kharif* 1999-'00, Mn content was highest in T_1, T_3 and T_4 while T_9, T_{13} and T_{14} registered significantly lower content.

During *rabi* 1997-'98, higher dose of K application along with silica increased the content of Mn. Foliar application of Mo decreased the Mn level from 144 ppm to 85 ppm. During *rabi* 1998-'99, T_1 had the highest content of 248 ppm while T_{10}, T_{14} and T_{16} registered significantly lower values, whereas during *rabi* 99-00, T_1 had the lowest content. T_4, T_9, T_{11} and T_{15} registered significantly higher contents.

Straw

The mean content of Mn in the straw did not exhibit difference between *kharif* and *rabi* seasons. During *kharif* 1998-'99, the content of Mn was 370 ppm, while in *kharif* 1999-'00 significantly higher content was recorded. Significant variation was noticed among *rabi* seasons also. During *rabi* 1997-'98, the content was 246 ppm while significantly higher levels of 486 ppm and 933 ppm were registered during *rabi* 1998-'99 and *rabi* 1999-'00 respectively.

During *kharif* 1998-'99, the content was highest in T_1. T_3, T_5 and T_{16} registered contents on par with it while all others had significantly lower content. During *kharif* 1999-'00, silica application resulted in significant decrease of Mn content in the straw (Sub table 4.22 c). Foliar application of Zn, Mg and Cu brought about significant reduction in Mn level as compared to

Table 4.22. Effect of season and treatments on manganese content (ppm) of rice

b. PI stage

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	214^{abc}	122^{a}	168^{abc}	123^{abcde}	248^{a}	31^{c}	134^{ab}	148^{ab}
2	NPK alone	203^{abcd}	86^{abc}	145^{bcd}	107^{cde}	181^{ab}	41^{bc}	110^{abc}	124^{bcd}
3	Straw + NPK	265^{a}	120^{a}	193^{a}	131^{abcde}	177^{ab}	44^{abc}	117^{abc}	147^{ab}
4	Straw + NPK (higher dose of K)	236^{ab}	121^{a}	179^{ab}	147^{abcd}	201^{ab}	67^{ab}	138^{a}	154^{a}
5	Straw + NPK + Si	161^{cdef}	107^{abc}	134^{cd}	99^{cde}	154^{ab}	59^{abc}	104^{bc}	116^{cd}
6	Straw + NPK (higher dose of K)+ Si	173^{bcde}	97^{abc}	135^{cd}	174^{a}	155^{ab}	56^{abc}	128^{abc}	131^{abc}
7	Straw + NPK + Si + Zn	162^{cdef}	111^{ab}	137^{cd}	166^{ab}	176^{ab}	53^{abc}	132^{ab}	134^{abc}
8	Straw + NPK + Si + Zn +Mg	132^{def}	88^{abc}	110^{de}	130^{abcde}	145^{b}	64^{abc}	113^{abc}	112^{cd}
9	Straw + NPK + Si + Zn +Mg+Cu	135^{def}	74^{bc}	105^{de}	136^{abcde}	202^{ab}	77^{a}	138^{a}	125^{bc}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	180^{bcde}	108^{abc}	144^{bcd}	137^{abcde}	116^{b}	61^{abc}	105^{bc}	120^{bcd}
11	T10+ Boron	98^{ef}	85^{abc}	92^{e}	144^{abcd}	170^{ab}	77^{a}	130^{abc}	115^{cd}
12	T11+ Mo	161^{cdef}	83^{abc}	122^{de}	85^{e}	161^{ab}	51^{abc}	99^{c}	108^{cd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	145^{cdef}	73^{bc}	109^{de}	150^{abc}	167^{ab}	53^{abc}	123^{abc}	118^{cd}
14	T12 (No summer cowpea)	118^{ef}	66^{c}	92^{e}	115^{bcde}	126^{b}	54^{abc}	98^{c}	96^{d}
15	T2 (No summer cowpea)	154^{cdef}	93^{abc}	124^{de}	94^{de}	153^{ab}	67^{ab}	105^{bc}	112^{cd}
16	T13 (No summer cowpea)	166^{bcdef}	92^{abc}	129^{de}	105^{cde}	133^{b}	58^{abc}	99^{c}	111^{cd}
	Mean	**169**	**95**	**132**	**128**	**167**	**57**	**117**	**123**
CD for comparison of season				33				11	14
CD for comparison of *Kharif vs Rabi*		11							
Sub table 4.22 a. Effect of cropping system									
	R-R-Fallow	146	84	115	-	137	60	99	107
	R-R-cowpea	170	81	125	-	170	48	109	117
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.22b. Effect of Kharif straw incorporation									
	Without straw	171	84	128	121	160	51	111	117
	With straw	181	90	136	110	155	50	105	117
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.22 c. Effect of silica									
	Without silica	251	121	186	139	189	56	128	151
	With silica	167	102	135	137	155	58	116	124
		Sig	NS	Sig	NS	NS	NS	NS	NS
Sub table 4.22d. Effect of higher dose of K									
	K35	213	114	163	115	166	52	111	132
	K70	205	109	157	161	178	62	133	143
		NS	NS	NS	Sig	NS	NS	NS	NS

Table 4.22. Effect of season and treatments on manganese content (ppm) of rice

C. Straw

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	608^{a}	648^{abc}	628^{ab}	261^{a}	708^{a}	1397^{a}	789^{a}	724^{a}
2	NPK alone	310^{c}	663^{ab}	487^{cd}	279^{a}	473^{bc}	1151^{ab}	634^{b}	575^{bc}
3	Straw + NPK	581^{ab}	702^{a}	642^{a}	292^{a}	553^{ab}	1080^{ab}	642^{b}	642^{ab}
4	Straw + NPK (higher dose of K)	366^{bc}	677^{a}	522^{abc}	256^{a}	524^{bc}	936^{b}	572^{bcd}	552^{bcd}
5	Straw + NPK + Si	478^{abc}	554^{abcde}	516^{abc}	328^{a}	441^{bc}	855^{b}	541^{bcd}	531^{cde}
6	Straw + NPK (higher dose of K)+ Si	266^{c}	445^{de}	356^{d}	268^{a}	441^{bc}	897^{b}	535^{bcd}	463^{de}
7	Straw + NPK + Si + Zn	285^{c}	469^{cde}	377^{cd}	261^{a}	511^{bc}	934^{b}	569^{bcd}	492^{cde}
8	Straw + NPK + Si + Zn +Mg	347^{c}	538^{abcde}	443^{cd}	286^{a}	514^{bc}	936^{b}	579^{bc}	524^{cde}
9	Straw + NPK + Si + Zn +Mg+Cu	349^{c}	651^{abc}	500^{bcd}	188^{a}	519^{bc}	796^{b}	501^{cd}	501^{cde}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	298^{c}	426^{e}	362^{d}	234^{a}	552^{ab}	844^{b}	543^{bcd}	471^{de}
11	T_{10}+ Boron	319^{c}	635^{abcd}	477^{cd}	205^{a}	379^{bc}	789^{b}	458^{d}	465^{de}
12	T_{11}+ Mo	335^{c}	425^{e}	380^{cd}	159^{a}	405^{bc}	881^{b}	482^{cd}	441^{e}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	304^{c}	462^{cde}	383^{cd}	181^{a}	452^{bc}	823^{b}	485^{cd}	444^{e}
14	T_{12} (No summer cowpea)	303^{c}	567^{abcde}	435^{cd}	266^{a}	520^{bc}	888^{b}	558^{bcd}	509^{cde}
15	T_2 (No summer cowpea)	357^{c}	480^{bcde}	419^{cd}	271^{a}	360^{c}	859^{b}	497^{cd}	465^{de}
16	T_{13} (No summer cowpea)	415^{abc}	605^{abcde}	510^{abc}	208^{a}	416^{bc}	855^{b}	493^{cd}	500^{cde}
	Mean	**370**	**559**	**465**	**246**	**486**	**933**	**555**	**519**
CD for comparison of season				120				96	124
CD for comparison of *Kharif vs Rabi*		NS							
Sub table 4.22 a. Effect of cropping system									
	R-R-Fallow	358	551	455	-	432	867	650	552
	R-R-cowpea	316	517	417	-	443	952	698	557
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.22b. Effect of Kharif straw incorporation									
	Without straw	343	577	460	223	447	943	538	506
	With straw	406	565	486	239	493	950	560	530
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.22 c. Effect of silica									
	Without silica	474	690	582	274	539	1008	607	597
	With silica	372	500	436	298	441	876	538	497
		NS	Sig	Sig	NS	NS	NS	NS	Sig
Sub table 4.22d. Effect of higher dose of K									
	K35	530	628	579	310	497	968	592	586
	K70	316	561	439	262	483	917	554	508
		NS	NS	Sig	NS	NS	NS	NS	Sig

their soil application. Foliar spray of boron increased the content whereas Mo decreased.

During the *rabi* 1997-'98, the treatments did not manifest any effect on Mn level in straw. During *rabi* 1998-'99, T_1 registered the highest content of 708 ppm. All other treatments except T_3 and T_{10} had significantly lower content. During *rabi* 1999-'00 also T_1 had the highest content. T_2 and T_3 were on par with it while other treatments recorded significantly lower values.

Grain

The mean content of Mn in the grain was higher in *rabi* (49 ppm). There was no remarkable difference in the Mn content of *kharif* 1998-'99 and *kharif* 1999-'00. During *rabi* 1999-'00, the Mn level was 78 ppm, which was significantly higher than the content recorded during *rabi* 1997-'98 and *rabi* 1998-'99.

During *kharif* 1998-'99, application of NPK alone recorded lower Mn content than supply of straw alone. Silica application brought about significant reduction in Mn concentration (Sub table 4.22 c). This was noticed during *kharif* 1999-'00 also.

During *rabi* 1997-'98, T_8 recorded Mn content of 29 ppm whereas soil application of Cu increased the level to 49 ppm. Contents were lower in T_1, T_2, T_5 and T_{16} also.

During *rabi* 1998-'99, T_1 had the highest content of 41 ppm while T_6 registered significantly lower content. The other treatments were on par with these. During *rabi* 1999-'00, T_1 and T_3 recorded significantly higher content than T_{15} and T_{16}. Other treatments showed similar Mn contents.

4.1.3.9. Zinc

The data on the effects of season and management practices on zinc content of rice at tillering, PI and maturity stages and in grain are given in Tables 4.23 a,b.c and d, respectively.

Table 4.22. Effect of season and treatments on manganese content (ppm) of rice

d. Grain

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	59[a]	32[ab]	46[ab]	28[d]	41[a]	97[a]	55[ab]	51[a]
2	NPK alone	41[cd]	30[b]	36[abc]	27[d]	39[ab]	91[ab]	52[abcd]	46[abcd]
3	Straw + NPK	54[ab]	42[ab]	48[a]	31[cd]	39[ab]	97[a]	56[ab]	53[a]
4	Straw + NPK (higher dose of K)	46[bc]	44[a]	45[ab]	33[bcd]	37[ab]	91[ab]	54[abc]	50[ab]
5	Straw + NPK + Si	35[d]	32[ab]	34[bc]	25[d]	36[ab]	61[ab]	41[de]	38[d]
6	Straw + NPK (higher dose of K)+ Si	30[d]	30[ab]	30[c]	32[bcd]	23[b]	84[ab]	46[bcde]	40[cd]
7	Straw + NPK + Si + Zn	39[cd]	32[ab]	36[abc]	37[bcd]	29[ab]	83[ab]	50[abcde]	44[abcd]
8	Straw + NPK + Si + Zn +Mg	31[d]	30[ab]	31[c]	29[d]	28[ab]	92[ab]	50[abcde]	42[bcd]
9	Straw + NPK + Si + Zn +Mg+Cu	39[cd]	34[ab]	37[abc]	49[ab]	32[ab]	73[ab]	51[abcd]	45[abcd]
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	34[d]	29[b]	32[c]	55[a]	33[ab]	87[ab]	58[a]	48[abc]
11	T_{10}+ Boron	33[d]	37[ab]	35[abc]	48[abc]	26[ab]	61[ab]	45[bcde]	41[bcd]
12	T_{11}+ Mo	38[cd]	34[ab]	36[abc]	37[abc]	30[ab]	63[ab]	43[cde]	40[cd]
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	29[d]	37[ab]	33[bc]	47[abc]	31[ab]	82[ab]	53[abc]	45[abcd]
14	T_{12} (No summer cowpea)	34[d]	35[ab]	35[bc]	40[abcd]	25[ab]	62[ab]	42[cde]	39[cd]
15	T_2 (No summer cowpea)	32[d]	30[ab]	31[c]	31[cd]	33[ab]	59[b]	41[de]	37[d]
16	T_{13} (No summer cowpea)	37[cd]	33[ab]	35[abc]	28[d]	31[ab]	59[b]	39[e]	38[d]
	Mean	**38**	**34**	**36**	**36**	**32**	**78**	**49**	**44**
CD for comparison of season				NS				12	9
CD for comparison of *Kharif vs Rabi*		10							
Sub table 4.22 a. Effect of cropping system									
	R-R-Fallow	34	33	34	-	30	60	45	39
	R-R-cowpea	36	34	35	-	33	79	56	45
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.22b. Effect of Kharif straw incorporation									
	Without straw	36	33	35	34	34	77	48	43
	With straw	42	37	40	36	31	74	47	44
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.22 c. Effect of silica									
	Without silica	50	43	47	32	38	94	55	51
	With silica	33	31	32	29	30	73	44	39
		Sig	Sig	Sig	NS	NS	NS	Sig	Sig
Sub table 4.22d. Effect of higher dose of K									
	K35	45	37	41	28	38	79	48	45
	K70	38	37	38	33	30	88	50	45
		NS	NS	NS	NS	NS	NS	NS	NS

Tillering stage

The mean value of Zn in the plant at tillering stage during *kharif* was 66.3 ppm whereas *rabi* crop had 58.2 ppm. During *kharif* 1998-'99, the Zn content was 37.8 ppm; during *kharif* 1999-'00 significantly higher content of 94.8 ppm was recorded. During *rabi* 1998-'99 the mean value of Zn content was 29.7 ppm while in *rabi* 1999-'00 the content was 86.7 ppm.

During *kharif* 1998-'99, T_9 (Straw +NPK +Si + soil application of $ZnSO_4$, $MgSO_4$, and $CuSO_4$) had higher Zn concentration. T_5, T_6 and T_{15} recorded significantly lower concentration while other treatments were on par with these. During *kharif* 1999-'00, T_7 (Straw +NPK +Si + soil application of $ZnSO_4$) had significantly higher content than other treatments. During *rabi* 1998-'99, Zn content was highest in T_8; T_6, T_{11}, T_{12}, T_{13}, T_{14}, T_{15} and T_{16} had lower contents. During *rabi* 1999-'00, content was higher in T_9.

PI stage

The mean contents of Zn in *kharif* and *rabi* were 66.0 ppm and 56.1 ppm respectively. During *kharif* 1998-'99, the cocentration of Zn in the plant was 59.6 ppm while in *kharif* 1999-'00 it was 72.4 ppm. During *rabi* 1997-'98 and 1998-'99, the contents were comparable while *rabi* 1999-'00 had significantly higher content.

During *kharif* 1998-'99, T_9 recorded Zn concentration of 39.8 ppm whereas in T_{10} the content was significantly higher (84.6 ppm). Other treatments had concentrations similar to T_9. During *kharif* 1999-'00 the content was higher in T_7 and T_8. T_4, T_{10}, T_{12}, T_{13}, T_{14} and T_{15} registered significantly lower contents.

During *rabi* 1997-'98, the treatments did not manifest any influence. During *rabi* 1998-'99, T_6 (Straw +NPK +with higher K dose) had the highest content. The lowest content was in T_2. T_6, T_{10}, T_{13} and T_{14} were superior to it. During *rabi* 1999-'00, T_{12} had the highest content of 115 ppm whereas T_1, T_5, T_6, T_{10} and T_{15} recorded significantly lower content.

Table 4.23. Effect of season and treatments on zinc content (ppm) of rice

a. Tillering stage

Sl.No	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	34.9^{ab}	60.0^{cd}	47.5^{cd}	30.6^{abcd}	55.0^{d}	42.8^{c}	45.1^{c}
2	NPK alone	34.4^{ab}	17.0^{bcd}	52.2^{cd}	36.0^{abc}	55.0d	45.5^{c}	48.9^{c}
3	Straw + NPK	41.7^{ab}	60.0^{cd}	50.9^{cd}	30.0^{abcd}	70.0^{cd}	50.0^{c}	50.4^{c}
4	Straw + NPK (higher dose of K)	35.4^{ab}	85.0^{bcd}	60.2^{bcd}	35.8^{abc}	77.5^{bcd}	56.7^{bc}	58.4^{c}
5	Straw + NPK + Si	31.8^{b}	97.0^{bcd}	64.4^{bcd}	27.4^{abcd}	60.0^{d}	43.7^{c}	54.1^{c}
6	Straw + NPK (higher dose of K)+ Si	30.9^{b}	90.0^{bcd}	60.5^{bcd}	25.9^{bcd}	85.0^{bcd}	55.5^{bc}	58.0^{c}
7	Straw + NPK + Si + Zn	44.4^{ab}	255.0^{a}	149.7^{a}	37.9^{ab}	145.0^{abc}	91.5^{ab}	120.6^{a}
8	Straw + NPK + Si + Zn +Mg	40.0^{ab}	115.0^{bc}	77.5^{bc}	40.2^{a}	150.0^{ab}	95.1^{a}	86.3^{b}
9	Straw + NPK + Si + Zn +Mg+Cu	48.1^{a}	125.0^{b}	86.6^{b}	36.5^{abc}	180.0^{a}	108.3^{a}	97.4^{b}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	35.5^{ab}	85.0^{bcd}	60.3^{bcd}	29.3^{abcd}	90.0^{bcd}	59.7^{bc}	60.0^{c}
11	T_{10}+ Boron	37.3^{ab}	95.0^{bcd}	66.2^{bcd}	21.8^{d}	90.0^{bcd}	55.9^{bc}	61.0^{c}
12	T_{11}+ Mo	42.4^{ab}	90.0^{bcd}	66.2^{bcd}	25.6^{bcd}	75.0^{bcd}	50.3^{c}	58.3^{c}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	38.1^{ab}	55.0^{d}	46.6^{cd}	24.6^{bcd}	75.0^{bcd}	49.8^{c}	48.2^{c}
14	T_{12} (No summer cowpea)	38.9^{ab}	70.0^{bcd}	54.5^{cd}	25.2^{bcd}	60.0^{d}	42.6^{c}	48.5^{c}
15	T_2 (No summer cowpea)	30.9^{b}	75.0^{bcd}	53.0^{cd}	24.5^{bcd}	65.0^{d}	44.8^{c}	48.9^{c}
16	T_{13} (No summer cowpea)	39.4^{ab}	90.0^{bcd}	64.7^{bcd}	24.1^{cd}	55.0^{d}	39.6^{c}	52.1^{c}
	Mean	**37.8**	**94.8**	**66.3**	**29.7**	**86.7**	**58.2**	**62.3**
CD for comparison of season				18.5			13.8	10.6
CD for comparison of *Kharif vs Rabi*		NS						
Sub table 4.23 a. Effect of cropping system								
	R-R-Fallow	36.4	78.3	57.4	24.6	60.0	42.3	49.8
	R-R-cowpea	38.3	71.7	55.0	28.7	68.3	48.5	51.8
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.23b. Effect of Kharif straw incorporation								
	Without straw	37.3	71.7	54.5	28.2	61.7	45.0	49.7
	With straw	41.0	73.3	57.2	26.9	68.3	47.6	52.4
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.23 c. Effect of silica								
	Without silica	38.6	72.5	55.5	32.9	73.8	53.3	54.4
	With silica	31.4	93.5	62.4	26.7	72.5	49.6	56.0
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.23d. Effect of higher dose of K								
	K35	36.8	78.5	57.6	28.7	65.0	46.9	52.2
	K70	33.2	87.5	60.3	30.9	81.3	56.1	58.2
		NS	NS	NS	NS	NS	NS	NS

Table 4.23. Effect of season and treatments on zinc content (ppm) of rice

b. PI stage

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	49.5^{bc}	75.0^{abcd}	62.3^{ab}	42.6^{a}	45.7^{abcd}	65.0^{bc}	53.8^{bcd}	58.0^{ab}
2	NPK alone	53.0^{bc}	80.0^{abc}	66.5^{ab}	42.0^{a}	28.2^{d}	85.0^{abc}	51.7^{bcd}	57.6^{ab}
3	Straw + NPK	68.0^{abc}	85.0^{abc}	76.5^{a}	40.8^{a}	32.6^{cd}	85.0^{abc}	52.8^{bcd}	62.3^{a}
4	Straw + NPK (higher dose of K)	54.2^{abc}	70.0^{bcde}	62.1^{ab}	42.7a	38.4^{abcd}	72.5^{abc}	51.2^{bcd}	55.6^{ab}
5	Straw + NPK + Si	60.0^{abc}	75.0^{abcd}	67.5^{ab}	47.7^{a}	34.2^{cd}	60.0^{c}	47.3^{cd}	55.4^{ab}
6	Straw + NPK (higher dose of K)+ Si	62.4^{abc}	75.0^{abcd}	68.7^{ab}	53.0^{a}	60.9^{a}	70.0^{bc}	61.3^{abc}	64.3^{a}
7	Straw + NPK + Si + Zn	58.9^{abc}	95.0^{a}	77.0^{a}	40.6^{a}	41.9^{abcd}	105.0^{ab}	62.5^{abc}	68.3^{a}
8	Straw + NPK + Si + Zn +Mg	57.2^{abc}	95.0^{a}	76.1^{a}	36.9^{a}	36.5^{bcd}	85.0^{abc}	52.8^{bcd}	62.1^{a}
9	Straw + NPK + Si + Zn +Mg+Cu	39.8^{abc}	79.0^{abc}	59.4^{ab}	56.2^{a}	47.9^{abcd}	75.0^{abc}	59.7^{abc}	59.6^{ab}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	84.6^{abc}	55.0^{de}	69.8^{ab}	44.9^{a}	58.9^{ab}	70.0^{bc}	57.9^{abc}	62.7^{a}
11	T_{10}+ Boron	52.8^{abc}	75.0^{abcd}	63.9^{ab}	51.6^{a}	51.0^{abcd}	80.0^{abc}	60.9^{abc}	62.1^{a}
12	T_{11}+ Mo	74.1^{ab}	50.0^{e}	62.1^{ab}	47.2^{a}	51.6^{abcd}	115.0^{a}	71.3^{a}	67.6^{a}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	62.8^{abc}	60.0^{cde}	60.4^{ab}	37.1^{a}	55.2^{abc}	75.0^{abc}	55.8^{bcd}	58.0^{ab}
14	T_{12} (No summer cowpea)	46.5^{bc}	60.0^{cde}	53.3^{b}	51.4^{a}	54.2^{abc}	85.0^{abc}	63.5^{ab}	59.4^{ab}
15	T_2 (No summer cowpea)	61.1^{abc}	55.0^{de}	58.1^{ab}	34.1^{a}	35.5^{bcd}	55.0^{c}	41.5^{d}	48.1^{b}
16	T_{13} (No summer cowpea)	69.3^{abc}	75.0^{abcd}	72.2^{a}	30.5^{a}	52.2^{abcd}	80.0^{abc}	54.2^{bcd}	61.4^{a}
	Mean	**59.6**	**72.4**	**66.0**	**43.7**	**45.3**	**78.9**	**56.1**	**60.2**
CD for comparison of season				19.5				10.7	9.9
CD for comparison of *Kharif vs Rabi*		NS							
Sub table 4.23 a. Effect of cropping system									
	R-R-Fallow	59.0	63.3	61.2	-	47.3	73.3	60.3	60.7
	R-R-cowpea	63.3	63.3	63.3	-	45.0	91.7	68.3	65.8
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.23b. Effect of Kharif straw incorporation									
	Without straw	61.7	71.7	66.7	36.5	45.2	80.0	53.9	59.0
	With straw	62.9	65.0	63.9	46.5	46.1	95.0	62.5	63.1
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.23 c. Effect of silica									
	Without silica	61.1	77.5	69.3	41.8	35.5	78.8	52.0	58.9
	With silica	61.2	75.0	68.1	50.4	47.6	65.0	54.3	59.8
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.23d. Effect of higher dose of K									
	K35	64.0	80.0	72.0	44.3	33.4	72.5	50.1	58.8
	K70	58.3	72.5	65.4	47.9	49.7	71.3	56.3	59.9
		NS	NS	NS	NS	NS	NS	NS	NS

Straw

The mean Zn content of straw during *kharif* was 75.9 ppm and during *rabi* it was 68.8 ppm. During *kharif* 1998-'99, the mean content was 71.4 ppm while during *kharif* 1999-'00 it was 80.5 ppm. During *rabi* 1997-'98 the content was 75.5 ppm. During *rabi* 1998-'99 significantly lower content of 42.4 ppm was recorded while *rabi* 1999-'00 had higher content of 88.4 ppm.

During *kharif* 1998-'99, the treatment effects were non-significant. During *kharif* 1999-'00, T_7 (Straw +NPK +Si + soil application of $ZnSO_4$) had a higher Zn content of 95.0 ppm. T_4 (Straw +NPK with higher K dose) had significantly lower content while others were on par with these two treatments.

During *rabi* 1997-'98, higher contents were recorded in T_{13} and T_{14} while others had significantly lower content. During *rabi* 1998-'99, T_{11} and T_{16} registered higher Zn content. Incorporation of *kharif* straw and summer cowpea residues resulted in a significant decrease in Zn content during the season. During *rabi* 1999-'00 T_7, T_8 and T_{12} recorded higher Zn while others showed amounts significantly lesser than these.

Grain

Mean content of Zn in grain during *kharif* was 48.9 ppm. During *rabi* it was 78.3 ppm. During *kharif* 1998-'99, the Zn content was 27.2 ppm while during *kharif* 1999-'00, it was 70.6 ppm. Zn content of grain during *rabi* 1997-'98, 1998-'99 and 1999-'00 were 21.0 ppm, 64.1 ppm and 149.7 ppm respectively.

During *kharif* 1998-'99, T_7 (Straw +NPK +Si + soil application of $ZnSO_4$) recorded the highest content of 35.3 ppm; T_4, T_{12}, T_{13}, T_{14}, T_{15} and T_{16} had significantly lower contents. During *kharif* 1999-'00, T_{13} (NPK +Si + foliar application of Zn, Mg, Cu, B and Mo) differed from T_3, T_4 and T_6 while other treatments were on par with these. During *rabi* 1997-'98, T_{13} had the highest content of 29.7 ppm; contents were lower in T_1 and T_2. During *rabi* 1998-'99, T_9 recorded higher content of 105 ppm; T_7 and T_8 had similar concentrations while others registered significantly lower contents. During *rabi* 1999-'00, the highest content was in T_8 (Straw +NPK +Si + soil

Table 4.23. Effect of season and treatments on zinc content (ppm) of rice

C. Straw

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	57.5^{a}	82.5^{ab}	70.0^{a}	49.0^{gh}	37.0^{cdef}	55.0^{cd}	47.0^{f}	56.2^{e}
2	NPK alone	84.5^{a}	70.0^{ab}	77.3^{a}	41.3^{gh}	34.6^{cdef}	65.0^{cd}	47.0^{f}	59.1^{de}
3	Straw + NPK	69.2^{a}	80.0^{ab}	74.6^{a}	48.2^{gh}	31.9^{def}	90.0^{bcd}	56.7^{f}	63.9^{cde}
4	Straw + NPK (higher dose of K)	74.6^{a}	65.0^{ab}	69.8^{a}	39.6^{gh}	30.9^{ef}	60.0^{cd}	43.5^{f}	54.0^{e}
5	Straw + NPK + Si	66.4^{a}	70.0^{ab}	68.2^{a}	43.5^{gh}	37.9^{cdef}	60.0^{cd}	47.1^{f}	55.6^{e}
6	Straw + NPK (higher dose of K)+ Si	76.6^{a}	85.0^{ab}	80.8^{a}	35.0^{gh}	28.0^{f}	55.0^{cd}	39.3^{f}	55.9^{e}
7	Straw + NPK + Si + Zn	70.9^{a}	95.0^{a}	83.0^{a}	51.6^{gh}	47.0^{bcde}	175.0^{a}	91.2^{abc}	87.9^{ab}
8	Straw + NPK + Si + Zn +Mg	78.2^{a}	80.0^{ab}	78.1^{a}	60.0^{fgh}	48.2^{bcd}	145.0^{ab}	84.4^{abcd}	81.9^{ab}
9	Straw + NPK + Si + Zn +Mg+Cu	75.4^{a}	85.0^{ab}	80.2^{a}	68.9^{efg}	46.2^{bcde}	125.0^{abc}	80.0^{bcd}	80.1^{ab}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	69.6^{a}	90.0^{ab}	79.8^{a}	92.0^{cde}	44.2^{bcdef}	70.0^{cd}	68.7^{de}	73.2^{bcd}
11	T_{10}+ Boron	82.4^{a}	90.0^{ab}	86.2^{a}	81.9^{def}	55.9^{ab}	125.0^{abc}	87.6^{abcd}	87.0^{ab}
12	T_{11}+ Mo	58.1^{a}	80.0^{ab}	69.1^{a}	113.0^{c}	40.0^{bcdef}	145.0^{ab}	99.3^{ab}	87.2^{ab}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	68.2^{a}	75.0^{ab}	71.6^{a}	188.0^{a}	47.7^{bcde}	75.0^{cd}	103.6^{a}	90.8^{a}
14	T_{12} (No summer cowpea)	64.4^{a}	80.0^{ab}	72.2^{a}	144.0^{b}	50.2^{abc}	65.0^{cd}	86.4^{abcd}	80.7^{ab}
15	T_2 (No summer cowpea)	66.1^{a}	85.0^{ab}	75.6^{a}	44.0^{gh}	32.9^{def}	45.0^{d}	40.6^{f}	54.6^{e}
16	T_{13} (No summer cowpea)	82.5^{a}	75.0^{ab}	78.8^{a}	107.8^{cd}	65.8^{a}	60.0^{cd}	77.9^{cd}	78.2^{abc}
	Mean	**71.4**	**80.5**	**75.9**	**75.5**	**42.4**	**88.4**	**68.8**	**71.6**
CD for comparison of season				NS				12.4	8.4
CD for comparison of *Kharif vs Rabi*		4.8							
Sub table 4.23 a. Effect of cropping system									
	R-R-Fallow	71.0	80.0	75.5	-	49.6	56.7	53.2	64.3
	R-R-cowpea	70.3	75.0	72.6	-	40.8	95.0	67.9	70.3
		NS	NS	NS	-	Sig	NS	NS	NS
Sub table 4.23b. Effect of Kharif straw incorporation									
	Without straw	78.4	73.3	75.9	112.4	49.4	66.7	76.1	76.0
	With straw	63.9	80.0	72.0	101.7	40.7	100.0	80.8	77.3
		NS	NS	NS	NS	Sig	NS	NS	NS
Sub table 4.23 c. Effect of silica									
	Without silica	71.9	72.5	72.2	43.9	31.4	75.0	50.1	58.9
	With silica	71.5	77.5	74.5	39.3	33.0	57.5	43.2	55.7
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.23d. Effect of higher dose of K									
	K35	67.8	75.0	71.4	45.9	34.9	75.0	51.9	59.7
	K70	75.6	75.0	75.3	37.3	29.5	57.5	41.4	55.0
		NS	NS	NS	NS	NS	NS	NS	NS

Table 4.23. Effect of season and treatments on zinc content (ppm) of rice

d. Grain

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	30.5^{ab}	65.0^{ab}	47.8^{abc}	9.3^{d}	37.5^{f}	130.0^{b}	58.9^{f}	54.5^{d}
2	NPK alone	29.8^{ab}	65.0^{ab}	47.4^{abc}	17.5^{bcd}	64.0^{bcde}	160.0^{b}	80.8^{b}	64.3^{b}
3	Straw + NPK	27.9^{abc}	52.5^{ab}	40.2^{bc}	28.3^{ab}	66.5^{bcde}	130.0^{b}	74.9^{def}	61.0^{d}
4	Straw + NPK (higher dose of K)	26.4^{bcd}	50.0^{b}	38.2^{c}	19.4^{abcd}	60.0^{cdef}	180.0^{b}	86.5^{cde}	67.2^{cd}
5	Straw + NPK + Si	30.3^{ab}	55.0^{ab}	42.7^{abc}	14.2^{cd}	65.0^{bcde}	105.0^{b}	61.4^{f}	53.9^{d}
6	Straw + NPK (higher dose of K)+ Si	30.1^{ab}	50.0^{b}	40.1^{bc}	16.6^{bcd}	85.0^{abc}	100.0^{b}	67.2^{ef}	56.3^{d}
7	Straw + NPK + Si + Zn	35.3^{a}	90.0^{ab}	62.7^{a}	22.9^{abc}	80.0^{abcd}	180.0^{b}	94.3^{bcd}	81.6^{bc}
8	Straw + NPK + Si + Zn +Mg	30.4^{ab}	85.0^{ab}	57.7^{abc}	19.8^{abcd}	90.0^{ab}	320.0^{a}	143.3^{a}	109.0^{a}
9	Straw + NPK + Si + Zn +Mg+Cu	27.8^{abc}	90.0^{ab}	58.9^{ab}	25.1^{abc}	105.0^{a}	160.0^{b}	96.7^{bc}	81.6^{bc}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	28.8^{ab}	75.0^{ab}	51.9^{abc}	25.4^{abc}	55.0^{def}	140.0^{b}	73.5^{def}	64.8^{cd}
11	T_{10}+ Boron	27.9^{abc}	75.0^{ab}	51.5^{abc}	27.6^{ab}	65.0^{bcde}	105.0^{b}	65.9^{ef}	60.1^{d}
12	T_{11}+ Mo	26.0^{bcd}	72.5^{ab}	49.3^{abc}	21.9^{abc}	49.0^{ef}	100.0^{b}	57.0^{f}	53.9^{d}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	19.9^{cd}	95.0^{a}	57.5^{abc}	29.7a	48.5^{ef}	115.0^{b}	64.4^{ef}	61.6^{d}
14	T_{12} (No summer cowpea)	19.9^{cd}	85.0^{ab}	52.5^{abc}	18.1^{abcd}	45.0^{ef}	145.0^{b}	69.4^{ef}	62.6^{d}
15	T_2 (No summer cowpea)	24.7^{bcd}	60.0^{ab}	42.4^{abc}	19.0^{abcd}	65.0^{bcde}	125.0^{b}	69.7^{ef}	58.7^{d}
16	T_{13} (No summer cowpea)	19.4^{d}	65.0^{ab}	42.2^{abc}	21.7^{abc}	45.0^{ef}	100.0^{b}	55.6^{f}	50.2^{d}
	Mean	**27.2**	**70.6**	**48.9**	**21.0**	**64.1**	**149.7**	**78.3**	**66.5**
CD for comparison of season				NS				39.4	31.6
CD for comparison of *Kharif vs Rabi*		NS							
Sub table 4.23 a. Effect of cropping system									
	R-R-Fallow	21.3	70.0	45.7	-	51.7	123.3	87.5	66.6
	R-R-cowpea	25.2	77.5	51.4	-	53.8	158.3	106.1	78.7
		NS	NS	NS	-	NS	NS	Sig	NS
Sub table 4.23b. Effect of Kharif straw incorporation									
	Without straw	23.0	75.0	49.0	23.0	52.5	158.3	77.9	66.4
	With straw	24.6	70.0	47.3	22.8	53.5	125.0	67.1	59.2
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.23 c. Effect of silica									
	Without silica	27.2	51.3	39.2	23.9	63.3	155.0	80.7	64.1
	With silica	30.2	52.5	41.4	15.4	75.0	102.5	64.3	55.1
		NS	NS	NS	Sig	NS	Sig	NS	NS
Sub table 4.23d. Effect of higher dose of K									
	K35	29.1	53.8	41.4	21.3	65.8	117.5	68.2	57.5
	K70	28.3	50.0	39.1	18.0	72.5	140.0	76.8	61.8
		NS	NS	NS	NS	NS	NS	NS	NS

application of $ZnSO_4$ and $MgSO_4$) whereas other treatments had similar but significantly lower levels.

4.1.3.10. Copper

The data on the effects of season and management practices on copper content of rice at tillering, PI and maturity stages and in grain are given in Tables 4.24 a,b.c and d, respectively.

Tillering stage

The mean content of Cu in the plant during *kharif* was 18.2 ppm. *Rabi* crop recorded significantly lower level of 11.3 ppm. Among the two *kharif* seasons and *rabi* seasons themselves, the difference in the contents was not remarkable.

During *kharif* 1998-'99, silica application resulted in significant decrease in Cu content. Inclusion of summer cowpea in the cropping system brought about an increase in Cu content of the plant. Soil application of Cu increased its content in the plant, however, the effect of foliar application was not pronounced. During *kharif* 1999-'00 also Cu content increased with its soil application. T_4 had the highest Cu content; T_7, T_8, T_{10}, T_{15} and T_{16} registered significantly lower concentration.

During *rabi* 1998-'99, the highest content was in T_9 (Straw +NPK +Si + soil application of $ZnSO_4$, $MgSO_4$, and $CuSO_4$); T_1, T_{12} and T_{14} had significantly lower content whereas other treatments were on par with these treatments. During *rabi* 1999-'00, T_{11} (Straw +NPK +Si + foliar application of Zn, Mg, Cu and B) recorded the highest Cu content of 18.0 ppm; T_2, T_4, T_9, T_{10} and T_{16} had similar values whereas other treatments had lower concentration than T_{11}.

PI stage

The mean content of Cu in the plant at PI stage was 15.6 ppm during *kharif* while *rabi* crop recorded a lower value of 14.3 ppm. During *kharif* 1998-'99, the Cu content was 14.2 ppm while during *kharif* 1999-'00 a higher

Table 4.24. Effect of season and treatments on copper content (ppm) of rice

a. Tillering stage

Sl.No	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	19.4^{b}	16.5^{abcd}	18.0^{bc}	7.2^{b}	13.5^{bcde}	10.4^{cd}	14.2^{bcd}
2	NPK alone	20.8^{b}	16.5^{abcd}	18.7^{bc}	8.7^{ab}	14.5^{abcde}	11.6^{abcd}	15.1^{bcd}
3	Straw + NPK	22.7^{b}	16.5^{abcd}	19.6^{b}	8.2^{ab}	13.0^{bcde}	10.6^{cd}	15.1^{bcd}
4	Straw + NPK (higher dose of K)	19.6^{b}	20.5^{a}	20.1^{b}	9.5^{ab}	14.0^{abcde}	11.8^{abcd}	15.9^{bc}
5	Straw + NPK + Si	17.8^{bc}	17.0^{abcd}	17.4^{bcd}	10.5^{ab}	11.0^{de}	10.8^{bcd}	14.1^{bcd}
6	Straw + NPK (higher dose of K)+ Si	18.9^{b}	19.5^{ab}	19.2^{b}	9.0^{ab}	10.5^{e}	9.8^{d}	14.5^{bcd}
7	Straw + NPK + Si + Zn	19.3^{b}	14.0^{d}	16.7^{bcd}	9.2^{ab}	12.5^{bcde}	10.9^{bcd}	13.8^{cd}
8	Straw + NPK + Si + Zn +Mg	17.4^{bc}	14.0^{d}	15.7^{cd}	9.6^{ab}	12.0^{cde}	10.8^{bcd}	13.3^{d}
9	Straw + NPK + Si + Zn +Mg+Cu	29.8^{a}	19.0^{abc}	24.4^{a}	12.6^{a}	15.0^{abcd}	13.8^{ab}	19.1^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	19.6^{b}	15.0^{cd}	17.3^{bcd}	10.2^{ab}	16.5^{ab}	13.4^{abc}	15.3^{bcd}
11	T_{10}+ Boron	19.2^{b}	17.0^{abcd}	18.1^{bc}	10.1^{ab}	18.0^{a}	14.1^{a}	16.1^{b}
12	T_{11}+ Mo	18.7^{b}	19.5^{ab}	19.1^{bc}	7.1^{b}	11.0^{de}	9.1^{d}	14.1^{bcd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	19.2^{b}	16.5^{abcd}	17.9^{bc}	9.2^{ab}	11.5^{cde}	10.4^{cd}	14.1^{bcd}
14	T_{12} (No summer cowpea)	17.5^{bc}	16.5^{abcd}	17.0^{bcd}	7.4^{b}	12.5^{bcde}	10.0^{d}	13.5^{d}
15	T_{2} (No summer cowpea)	12.7^{c}	16.0^{bcd}	14.4^{d}	10.6^{ab}	13.5^{bcde}	12.1^{abcd}	13.2^{d}
16	T_{13} (No summer cowpea)	18.4^{b}	16.0^{bcd}	17.2^{bcd}	8.4^{ab}	15.5^{abc}	12.0^{abcd}	14.6^{bcd}
	Mean	**19.4**	**16.9**	**18.2**	**9.2**	**13.4**	**11.3**	**14.7**
CD for comparison of season				NS			NS	2.4
CD for comparison of *Kharif vs Rabi*		2.5						
Sub table 4.24 a. Effect of cropping system								
	R-R-Fallow	16.2	16.2	16.2	8.8	13.8	11.3	13.8
	R-R-cowpea	19.6	17.5	18.5	8.3	12.3	10.3	14.4
		Sig	NS	NS	NS	NS	NS	NS
Sub table 4.24b. Effect of Kharif straw incorporation								
	Without straw	19.5	16.3	17.9	8.8	13.8	11.3	14.6
	With straw	19.6	17.5	18.6	7.6	12.2	9.9	14.2
		NS	NS	NS	NS	NS	NS	NS
Sub table 4.24 c. Effect of silica								
	Without silica	21.2	18.5	19.8	8.9	13.5	11.2	15.5
	With silica	18.4	18.3	18.3	9.8	10.8	10.3	14.3
		Sig	NS	NS	NS	Sig	NS	NS
Sub table 4.24d. Effect of higher dose of K								
	K35	20.3	16.8	18.5	9.4	12.0	10.7	14.6
	K70	19.3	20.0	19.6	9.3	12.3	10.8	15.2
		NS	NS	NS	NS	NS	NS	NS

Table 4.24. Effect of season and treatments on copper content (ppm) of rice

b. PI stage

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	9.8^{de}	20.0^{abc}	14.9^{bcdef}	8.3^{c}	10.8^{bc}	12.5^{abcd}	10.5^{c}	12.3^{c}
2	NPK alone	7.1^{e}	13.5^{c}	10.3^{f}	11.5^{bc}	8.9^{bc}	14.0^{abcd}	11.5^{c}	11.0^{c}
3	Straw + NPK	13.7^{bcde}	15.0^{bc}	14.4^{bcdef}	11.8^{bc}	7.8^{c}	12.0^{bcd}	10.5^{c}	12.1^{c}
4	Straw + NPK (higher dose of K)	9.9^{de}	16.0^{abc}	13.0^{ef}	11.6^{bc}	9.7^{bc}	16.5^{abcd}	12.6^{bc}	12.7^{c}
5	Straw + NPK + Si	12.4^{bcde}	14.5^{bc}	13.5^{def}	10.7^{bc}	10.8^{bc}	16.5^{abcd}	12.7^{bc}	13.0^{c}
6	Straw + NPK (higher dose of K)+ Si	11.2^{cde}	15.0^{bc}	13.1^{ef}	12.7^{bc}	9.6^{bc}	12.5^{abcd}	11.6^{c}	12.2^{c}
7	Straw + NPK + Si + Zn	10.9^{de}	13.5^{bc}	12.2^{ef}	9.5^{bc}	9.5^{bc}	9.5^{d}	9.5^{c}	10.6^{c}
8	Straw + NPK + Si + Zn +Mg	10.2^{de}	14.5^{bc}	13.4^{ef}	8.5^{c}	6.6^{c}	11.5^{cd}	8.9^{c}	10.3^{c}
9	Straw + NPK + Si + Zn +Mg+Cu	14.6^{bcde}	17.0^{abc}	15.8^{bcdef}	11.0^{bc}	12.0^{bc}	14.5^{abcd}	12.5^{bc}	13.8^{c}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	25.9^{a}	18.5^{abc}	22.2^{a}	14.2^{bc}	26.3^{a}	21.0^{abc}	20.5^{a}	21.2^{ab}
11	T_{10}+ Boron	16.6^{ab}	18.0^{abc}	17.3^{ab}	15.0^{abc}	14.2^{bc}	19.5^{abcd}	16.2^{b}	16.7^{b}
12	T_{11}+ Mo	21.3^{abc}	18.5^{abc}	19.9^{ab}	23.4^{a}	23.3^{a}	23.0^{a}	23.2^{a}	21.9^{a}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	19.1^{abcd}	20.0^{abc}	19.6^{abc}	18.3^{ab}	25.0^{a}	21.0^{abc}	21.4^{a}	20.7^{ab}
14	T_{12} (No summer cowpea)	13.9^{bcde}	22.0^{a}	18.0^{abcde}	18.4^{ab}	25.1^{a}	22.5^{ab}	22.0^{a}	20.4^{ab}
15	T_2 (No summer cowpea)	12.0^{bcde}	15.5^{abc}	13.8^{cdef}	7.9^{c}	7.8^{c}	12.0^{bcd}	9.2^{c}	11.0^{c}
16	T_{13} (No summer cowpea)	17.8^{abcd}	20.5^{ab}	19.2^{abcd}	8.7^{c}	18.3^{bc}	22.0^{abc}	16.3^{b}	17.5^{b}
	Mean	**14.2**	**17.0**	**15.6**	**12.6**	**14.1**	**16.3**	**14.3**	**14.8**
CD for comparison of season				2.3				NS	1.8
CD for comparison of *Kharif vs Rabi*		1.1							
Sub table 4.24 a. Effect of cropping system									
	R-R-Fallow	14.6	19.3	17.0	-	17.1	18.8	18.0	17.5
	R-R-cowpea	15.8	17.3	16.6	-	19.1	19.3	19.2	17.9
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.24b. Effect of Kharif straw incorporation									
	Without straw	14.7	18.0	16.3	12.8	17.4	19.0	16.4	16.4
	With straw	16.3	18.5	17.4	17.9	18.7	19.2	18.6	18.1
		NS	NS	NS	Sig	NS	NS	NS	NS
Sub table 4.24 c. Effect of silica									
	Without silica	11.8	15.5	13.7	11.7	8.8	14.3	11.6	12.4
	With silica	11.8	14.8	13.3	11.7	10.2	14.5	12.1	12.6
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.24d. Effect of higher dose of K									
	K35	13.1	14.8	13.9	11.2	9.3	14.3	11.6	12.5
	K70	10.6	15.5	13.0	12.2	9.7	14.5	12.1	12.5
		NS	NS	NS	NS	NS	NS	NS	NS

content of 17.0 ppm was recorded. The three *rabi* seasons did not show significant variation.

During *kharif* 1998-'99, foliar application of Cu resulted in increased Cu content of 25.9 ppm in the plant while soil application had only a lower concentration of 14.6 ppm. Such an increase with foliar spray was not noticed during *kharif* 1999-'00.

During the *rabi* 1997-'98, T_{12} (Straw +NPK +Si + foliar application of Zn, Mg, Cu, B and Mo) recorded the highest concentration of 23.4 ppm. T_{11}, T_{13} and T_{14} also showed similar concentration whereas others had significantly lower levels. During *rabi* 1998-'99, T_{10}, T_{12}, T_{13}, T_{14} and T_{16} had similar contents while other treatments showed significantly lower concentration. During *rabi* 1999-'00, T_{12} had the highest content; treatments except T_3, T_7, T_8 and T_{15} registered Cu levels similar to it.

Straw

The mean content of Cu in the straw did not show variation between *kharif* or *rabi* season. But among the three *rabi* seasons, significant difference was noticed. During *rabi* 1997-'98 the content was 16.3 ppm while *rabi* 1998-'99 and *rabi* 1999-'00 recorded significantly lower contents of 5.8 ppm and 9.6 ppm respectively. The two *kharif* seasons did not show remarkable variation.

During *kharif* 1998-'99 and 1999-'00, the treatments did not have any remarkable influence in Cu content.

During *rabi* 1997-'98, T_{12}, T_{13} and T_{14} registered significantly higher Cu concentration. During *rabi* 1998-'99, T_{13} had the highest concentration; T_1, T_4, T_5, T_6, T_7, T_9 and T_{15} recorded significantly lower Cu level. During *rabi* 1999-'00, T_{10}, T_{11}, T_{12}, T_{13}, T_{14} and T_{16} registered similar contents while other treatments were significantly inferior.

Grain

The mean value of Cu in the grain during *kharif* was 13.2 ppm and during *rabi* it was 12.6 ppm. Cu content recorded during *kharif* 1998-'99 was 4.3 ppm whereas significantly higher concentration of 22.2 ppm was

Table 4.24. Effect of season and treatments on copper content (ppm) of rice

C. Straw

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	9.6^{a}	11.5^{a}	10.6^{ab}	10.5^{b}	4.4^{b}	8.0^{c}	7.6^{cd}	8.8^{ef}
2	NPK alone	8.8^{a}	11.0^{a}	9.9^{b}	15.7^{b}	5.7^{ab}	6.5^{c}	9.3^{bcd}	9.5^{def}
3	Straw + NPK	10.9^{a}	9.5^{a}	10.2^{ab}	13.3^{b}	5.6^{ab}	7.5^{c}	8.8^{bcd}	9.4^{ef}
4	Straw + NPK (higher dose of K)	10.1^{a}	11.5^{a}	10.8^{ab}	15.4^{b}	4.0^{b}	9.0^{bc}	9.5^{bcd}	10.0^{def}
5	Straw + NPK + Si	16.6^{a}	9.5^{a}	13.1^{ab}	11.4^{b}	3.9^{b}	7.0^{c}	7.4^{d}	9.7^{def}
6	Straw + NPK (higher dose of K)+ Si	10.3^{a}	10.0^{a}	10.2^{ab}	12.7^{b}	5.5^{b}	6.5^{c}	8.2^{cd}	9.0^{ef}
7	Straw + NPK + Si + Zn	9.5^{a}	9.5^{a}	9.5^{b}	11.6^{b}	4.6^{b}	7.5^{c}	7.9^{cd}	8.5^{f}
8	Straw + NPK + Si + Zn +Mg	11.4^{a}	10.5^{a}	11.0^{ab}	13.2^{b}	6.6^{ab}	9.0^{bc}	9.6^{bcd}	10.1^{def}
9	Straw + NPK + Si + Zn +Mg+Cu	14.2^{a}	12.0^{a}	13.1^{ab}	13.3^{b}	4.6^{b}	9.0^{bc}	9.0^{bcd}	10.6^{def}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	18.2^{a}	12.5^{a}	15.4^{a}	12.8^{b}	7.2^{ab}	12.0^{ab}	10.7^{bc}	12.5^{bcd}
11	T_{10}+ Boron	10.7^{a}	12.0^{a}	11.4^{ab}	16.3^{b}	6.3^{ab}	12.5^{a}	11.7^{b}	11.6^{cdef}
12	T_{11}+ Mo	9.3^{a}	13.5^{a}	11.4^{ab}	28.1^{a}	6.5^{ab}	14.5^{a}	16.4^{a}	14.4^{abc}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	14.5^{a}	13.5^{a}	14.0^{ab}	29.3^{a}	9.8^{a}	12.0^{ab}	17.0^{a}	15.8^{a}
14	T_{12} (No summer cowpea)	9.9^{a}	10.5^{a}	10.2^{ab}	34.0^{a}	6.3^{ab}	12.0^{ab}	17.4^{a}	14.5^{ab}
15	T_2 (No summer cowpea)	12.1^{a}	11.5^{a}	11.8^{ab}	11.5^{b}	5.1^{b}	8.0^{c}	8.2^{cd}	9.6^{def}
16	T_{13} (No summer cowpea)	11.6^{a}	12.0^{a}	11.8^{ab}	16.3^{b}	7.2^{ab}	12.0^{ab}	11.8^{b}	11.8^{bcde}
	Mean	**11.7**	**11.3**	**11.5**	**16.3**	**5.8**	**9.6**	**10.7**	**10.9**
CD for comparison of season				NS				3.4	1.5
CD for comparison of *Kharif vs Rabi*		NS							
Sub table 4.24 a. Effect of cropping system									
	R-R-Fallow	11.2	11.3	11.3	-	6.2	10.7	8.4	9.9
	R-R-cowpea	10.9	12.7	11.8	-	7.3	11.0	9.2	10.5
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.24b. Effect of Kharif straw incorporation									
	Without straw	11.6	12.2	11.9	20.4	7.6	10.2	12.7	12.4
	With straw	10.0	11.2	10.6	25.1	6.1	11.3	14.2	12.8
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.24 c. Effect of silica									
	Without silica	10.5	10.5	10.5	14.4	4.8	8.3	9.1	9.7
	With silica	13.5	9.8	11.6	12.1	4.7	6.8	7.8	9.3
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.24d. Effect of higher dose of K									
	K35	13.8	9.5	11.6	12.4	4.8	7.3	8.1	9.5
	K70	10.2	10.8	10.5	14.1	4.8	7.8	8.9	9.5
		NS	NS	NS	NS	NS	NS	NS	NS

Table 4.24. Effect of season and treatments on copper content (ppm) of rice

d. Grain

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	4.2^{a}	16.5^{b}	10.4^{c}	8.9^{d}	17.0^{ab}	8.5^{ab}	11.5^{bc}	11.0^{c}
2	NPK alone	3.5^{a}	18.5^{b}	11.0^{c}	7.9^{d}	19.0^{ab}	9.5^{ab}	12.1^{abc}	11.7^{bc}
3	Straw + NPK	4.8^{a}	11.0^{b}	7.9^{c}	9.6^{d}	22.5^{a}	9.5^{ab}	13.9^{abc}	11.5^{bc}
4	Straw + NPK (higher dose of K)	4.6^{a}	11.5^{b}	8.1^{abc}	11.1^{bcd}	11.5^{ab}	10.5^{ab}	11.0^{c}	9.8^{c}
5	Straw + NPK + Si	4.1^{a}	23.5^{ab}	13.8^{abc}	11.4^{bcd}	11.5^{ab}	8.0^{b}	10.3^{c}	11.7^{bc}
6	Straw + NPK (higher dose of K)+ Si	5.3^{a}	24.0^{ab}	14.7^{abc}	8.3^{d}	14.5^{ab}	8.0^{b}	10.3^{c}	12.0^{bc}
7	Straw + NPK + Si + Zn	4.8^{a}	24.5^{ab}	14.7^{abc}	10.5^{cd}	16.0^{ab}	9.5^{ab}	12.0^{abc}	13.1^{bc}
8	Straw + NPK + Si + Zn +Mg	4.7^{a}	22.0^{ab}	13.4^{abc}	12.2^{bcd}	10.5^{b}	10.0^{ab}	10.9^{c}	11.9^{bc}
9	Straw + NPK + Si + Zn +Mg+Cu	4.1^{a}	15.0^{b}	9.6^{c}	24.4^{a}	14.5^{ab}	8.5^{ab}	15.8^{ab}	13.3^{bc}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	4.2^{a}	30.0^{ab}	17.1^{abc}	10.9^{bcd}	17.0^{ab}	8.5^{ab}	12.1^{abc}	14.1^{abc}
11	T_{10}+ Boron	4.0^{a}	25.5^{ab}	14.8^{abc}	15.1^{abcd}	14.0^{ab}	8.0^{b}	12.4^{abc}	13.3^{bc}
12	T_{11}+ Mo	5.3^{a}	22.0^{ab}	13.7^{abc}	22.4^{ab}	10.5^{b}	8.5^{ab}	13.8^{abc}	13.6^{bc}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	4.4^{a}	39.0^{a}	21.7^{a}	22.0^{abc}	18.0^{ab}	9.0^{ab}	16.3^{a}	18.5^{a}
14	T_{12} (No summer cowpea)	4.1^{a}	38.5^{a}	21.3^{ab}	11.6^{bcd}	18.0^{ab}	10.0^{ab}	13.2^{abc}	16.4^{ab}
15	T_{2} (No summer cowpea)	2.6^{a}	20.5^{ab}	11.6^{bc}	14.3^{abcd}	12.0^{ab}	11.0^{a}	12.4^{abc}	12.1^{bc}
16	T_{13} (No summer cowpea)	3.6^{a}	26.5^{ab}	15.1^{abc}	12.7^{bcd}	19.5^{ab}	9.5^{ab}	13.9^{abc}	14.4^{abc}
	Mean	**4.3**	**22.2**	**13.2**	**13.3**	**15.4**	**9.2**	**12.6**	**12.9**
CD for comparison of season				15.2				3.4	6.1
CD for comparison of *Kharif vs Rabi*		NS							
Sub table 4.24 a. Effect of cropping system									
	R-R-Fallow	3.4	28.5	16.0	-	16.5	10.2	13.3	14.7
	R-R-cowpea	4.4	26.5	15.5	-	15.8	9.0	12.4	13.9
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.24b. Effect of Kharif straw incorporation									
	Without straw	3.8	28.0	15.9	14.2	18.8	9.3	14.1	14.8
	With straw	4.7	23.8	14.3	14.5	17.0	9.3	13.6	13.9
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.24 c. Effect of silica									
	Without silica	4.7	11.3	8.0	10.4	17.0	10.0	12.5	10.7
	With silica	4.7	17.0	10.9	9.9	13.0	8.0	10.3	10.5
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.24d. Effect of higher dose of K									
	K35	4.5	14.5	9.5	10.5	17.0	8.8	12.1	11.0
	K70	5.0	13.8	9.4	9.7	13.0	9.3	10.7	10.1
		NS	NS	NS	NS	NS	NS	NS	NS

registered in *kharif* 1999-'00. During *rabi* 1997-'98 the content was 13.3 ppm, and 15.4 ppm during *rabi* 1998-'99. But *rabi* 1999-'00 had significantly lower content of 9.2 ppm.

During *kharif* 1998-'99, the treatments did not manifest any variation in Cu content. During *kharif* 1999-'00, T_{13} and T_{14} registered significantly higher content than T_1, T_2, T_3, T_4 and T_9.

During *rabi* 1997-'98, soil application of Cu along with straw + NPK + silica + soil application of Zn + Mg registered the highest concentration of 24.4 ppm; T_{11}, T_{12}, T_{13} and T_{15} had similar contents while others had significantly lower concentration. During *rabi* 1998-'99, content was highest in T_3 (22.5 ppm) while T_8 and T_{12} had significantly lower content. Other treatments remained on par with these. During *rabi* 1999-'00, content was highest in T_{15} whereas T_5, T_6 and T_{11} recorded significantly lower content. Other treatments remained on par with these.

4.1.3.11. Silica

The data on the effects of season and management practices on silica content of rice at tillering, PI and maturity stages and in grain are given in Tables 4.25 a,b.c and d, respectively.

Tillering stage

The mean value of silica content in the plant during *kharif* was 7.4 per cent while *rabi* had a significantly lower content of 6.7 per cent. Within *kharif* and *rabi* seasons themselves, the contents did not differ significantly.

During *kharif* 1998-'99, raising of summer cowpea resulted in significant increase of silica content from 6.8 per cent to 7.5 per cent. *Kharif* straw incorporation as well as silica addition also brought about significant increase whereas higher K dose significantly decreased the content (Sub tables 4.25).

During *kharif* 1999-'00, also raising of summer cowpea and silica application increased the content of silica. Application of higher K dose also brought about a significant increase in silica content during this season. The

Table 4.25. Effect of season and treatments on silica content (%) of rice

a. Tillering stage

Sl.No	Treatment	Kharif 1998-99	Kharif 1999-0	Kharif mean	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	6.5^{bcd}	5.7^{b}	6.1^{e}	5.2^{de}	6.4^{ab}	5.8^{cde}	6.0^{fg}
2	NPK alone	6.5^{bcd}	6.3^{fgh}	6.4^{cde}	4.9^{e}	5.0^{bc}	5.0^{e}	5.7^{g}
3	Straw + NPK	6.5^{bcd}	5.9^{gh}	6.2^{e}	6.0^{cde}	4.9^{bc}	5.4^{de}	5.8^{fg}
4	Straw + NPK (higher dose of K)	5.9^{a}	6.6^{efgh}	6.3^{de}	7.8^{abc}	4.5^{bc}	6.2^{bcde}	6.2^{efg}
5	Straw + NPK + Si	8.4^{a}	6.7^{efgh}	7.5^{abcde}	7.5^{abc}	6.4^{ab}	7.0^{abc}	7.3^{abc}
6	Straw + NPK (higher dose of K)+ Si	8.0^{ab}	8.5^{bc}	8.2^{ab}	8.2^{ab}	6.6^{ab}	7.4^{ab}	7.8^{ab}
7	Straw + NPK + Si + Zn	7.5^{abc}	9.0^{a}	8.2^{ab}	7.7^{abc}	6.4^{ab}	7.0^{abc}	7.7^{ab}
8	Straw + NPK + Si + Zn +Mg	7.9^{ab}	8.2^{abcd}	8.0^{abc}	9.0^{ab}	6.1^{abc}	7.5^{a}	7.8^{ab}
9	Straw + NPK + Si + Zn +Mg+Cu	8.9^{a}	7.6^{bcde}	8.2^{ab}	9.1^{a}	5.8^{abc}	7.5^{ab}	7.8^{ab}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	8.4^{a}	7.7^{bcde}	8.0^{abcd}	7.7^{abc}	5.6^{abc}	6.7^{abcd}	7.4^{a}
11	T_{10}+ Boron	8.3^{a}	8.6^{abc}	8.4^{a}	8.5^{ab}	5.8^{abc}	7.2^{abc}	7.8^{abc}
12	T_{11}+ Mo	8.5^{a}	8.9^{ab}	8.7^{a}	7.8^{abc}	6.6^{ab}	7.2^{abc}	8.0^{a}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	7.5^{abc}	7.6^{de}	7.5^{abcde}	7.4^{abc}	5.5^{abc}	6.5^{abcd}	7.0^{bcd}
14	T_{12} (No summer cowpea)	8.3^{a}	6.1^{gh}	7.2^{abcde}	7.5^{abc}	7.2^{a}	7.4^{ab}	7.2^{abc}
15	T_2 (No summer cowpea)	5.9^{d}	7.1^{defg}	6.5^{bcde}	7.0^{abcd}	5.9^{abc}	6.5^{abcd}	6.4^{def}
16	T_{13} (No summer cowpea)	6.30^{ab}	7.5^{cdef}	6.9^{abcde}	6.9^{bcde}	6.3^{ab}	6.6^{abcd}	6.7^{cde}
	Mean	**7.46**	**7.38**	**7.42**	**7.39**	**5.94**	**6.66**	**7.04**
CD for comparison of season				NS			NS	1.60
CD for comparison of *Kharif vs Rabi*					0.20			
Sub table 4.25 a. Effect of cropping system								
	R-R-Fallow	6.83	6.90	6.87	7.13	6.47	6.80	6.83
	R-R-cowpea	7.50	7.60	7.55	6.70	5.70	6.20	6.88
		Sig	Sig	NS	NS	NS	NS	NS
Sub table 4.25b. Effect of Kharif straw incorporation								
	Without straw	6.77	7.13	6.95	6.40	5.60	6.00	6.48
	With straw	7.77	6.97	7.37	7.10	6.23	6.67	7.02
		Sig	NS	NS	NS	NS	NS	NS
Sub table 4.25 c. Effect of silica								
	Without silica	6.20	6.25	6.23	6.90	4.70	5.80	6.01
	With silica	8.20	7.60	7.90	7.85	6.50	7.18	7.54
		Sig	Sig	Sig	NS	Sig	Sig	Sig
Sub table 4.25d. Effect of higher dose of K								
	K35	7.5	6.3	6.9	6.8	5.7	6.2	6.5
	K70	7.0	7.6	7.3	8.0	5.6	6.8	7.0
		Sig	Sig	NS	Sig	NS	NS	NS

highest content was in T_7 (Straw +NPK +Si + soil application of $ZnSO_4$ and $MgSO_4$) whereas T_1 (Straw alone) had the lowest content of 5.7 per cent.

During *rabi* 1998-'99, higher K dose increased silica content. Other treatments did not manifest any significant variation. During *rabi* 1999-'00 also, silica application increased its content in the plant.

PI stage

The mean silica content during *kharif* was 7.1 per cent whereas during *Rabi* significantly higher content of 8.0 per cent was recorded. During *kharif* 1998-'99, the mean content was 6.5 per cent while during *kharif* 1999-'00, a higher value of 7.6 per cent was recorded. Among the *rabi* seasons, the content was lowest during *rabi* 1999-'00 (6.9 %) whereas *rabi* 1997-'98 and 1998-'99 had significantly higher contents.

During *kharif* 1998-'99, application of silica resulted in significant increase in its content in the plant. During *rabi* 1997-'98, the lowest content was in T_1 and T_3 while others were on par in silica content. During *rabi* 1998-'99 application of silica and higher K dose increased the silica content in the plant whereas soil application of Mg resulted in a significant decrease of the content from 10.7 per cent to 8.2 per cent. Content was lower in T_2 and T_{15}.

During *rabi* 1999-'00 also silica content of the plant increased with silica application. Lower contents were recorded in T_1, T_2, T_3, T_4 and T_{15}. .

Straw

The mean content of silica in straw during *kharif* was 11.7 per cent whereas in *rabi* it was low (9.8 %). The contents during *kharif* 1998-'99 and *kharif* 1999-'00 were 12.6 per cent and 10.9 per cent respectively. The silica concentration during *rabi* seasons showed remarkable variation. The content was 10.7 per cent during *rabi* 1997-'98. *Rabi* 1998-'99 and *rabi* 1999-'00 had significantly lower values of 9.8 per cent and 8.8 per cent.

During *kharif* 1998-'99, application of silica increased the silica content in the straw from 11.3 per cent to 14.5 per cent (Subtable 4.25 c). During *kharif* 1999-'00, T_8 (Straw +NPK +Si + soil application of $ZnSO_4$ and $MgSO_4$) registered the highest content of silica; treatments except T_3, T_{15} and

Table 4.25. Effect of season and treatments on silica content (%) of rice

b. PI stage

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	6.0^{abc}	7.3^{cde}	6.7^{bcd}	7.1^{c}	10.0^{abc}	6.0^{cdef}	7.7^{cde}	7.3^{def}
2	NPK alone	5.4^{cd}	7.1^{de}	6.3^{cd}	7.8^{abc}	7.2^{d}	5.5^{ef}	6.8^{ef}	6.6^{f}
3	Straw + NPK	5.9^{abcd}	8.0^{abc}	6.9^{abcd}	7.3^{bc}	7.6^{cd}	4.5^{f}	6.5^{f}	6.7^{f}
4	Straw + NPK (higher dose of K)	4.2^{d}	8.1^{abc}	6.2^{d}	7.7^{abc}	9.0^{bcd}	5.7^{def}	7.5^{de}	6.9^{ef}
5	Straw + NPK + Si	7.1^{abc}	8.0^{abc}	7.6^{ab}	7.7^{abc}	9.1^{abcd}	8.7^{a}	8.5^{bc}	8.1^{abc}
6	Straw + NPK (higher dose of K)+ Si	7.7^{a}	7.7^{abcd}	7.7^{a}	8.5^{abc}	11.4^{a}	8.5^{a}	9.5^{a}	8.8^{a}
7	Straw + NPK + Si + Zn	7.2^{abc}	8.3^{ab}	7.8^{a}	9.3^{ab}	10.7^{ab}	7.0^{abcde}	9.0^{ab}	8.5^{ab}
8	Straw + NPK + Si + Zn +Mg	6.9^{abc}	7.5^{bcd}	7.2^{abc}	8.4^{abc}	8.2^{cd}	7.9^{abc}	8.2^{bcd}	7.8^{bcd}
9	Straw + NPK + Si + Zn +Mg+Cu	6.5^{abc}	7.6^{bcd}	7.1^{abcd}	8.2^{abc}	8.4^{bcd}	7.5^{abcde}	8.0^{bcd}	7.6^{cde}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	7.0^{abc}	7.0^{de}	7.0^{abcd}	8.2^{abc}	9.0^{bcd}	7.4^{abcde}	8.2^{bcd}	7.7^{bcde}
11	T_{10}+ Boron	6.7^{abc}	7.6^{bcd}	7.1^{abcd}	9.8^{a}	8.5^{bcd}	6.3^{bcdef}	8.2^{bcd}	7.8^{bcd}
12	T_{11}+ Mo	7.6^{a}	6.6^{e}	7.1^{abcd}	9.0^{abc}	9.0^{bcd}	7.9^{abc}	8.6^{abc}	8.0^{abcd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	6.2^{abc}	8.5^{a}	7.4^{ab}	8.7^{abc}	9.2^{abcd}	6.7^{abcde}	8.2^{bcd}	7.9^{bcd}
14	T_{12} (No summer cowpea)	6.0^{abc}	7.3^{ab}	6.7^{bcd}	8.3^{abc}	9.3^{abcd}	8.1^{ab}	8.6^{abc}	7.8^{bcd}
15	T_2 (No summer cowpea)	7.5^{ab}	7.5^{cd}	7.5^{ab}	9.5^{a}	6.9^{d}	5.5^{ef}	7.3^{def}	7.4^{cdef}
16	T_{13} (No summer cowpea)	5.7^{bcd}	8.1^{abc}	6.9^{abcd}	8.1^{abc}	8.0^{cd}	7.6^{abcd}	7.9^{cd}	7.5^{cde}
	Mean	**6.5**	**7.6**	**7.1**	**8.3**	**8.8**	**6.9**	**8.0**	**7.6**
CD for comparison of season				0.30				0.70	0.50
CD for comparison of *Kharif vs Rabi*		0.20							
Sub table 4.25 a. Effect of cropping system									
	R-R-Fallow	6.4	7.6	7.0	-	8.1	7.1	7.6	7.3
	R-R-cowpea	6.4	7.4	6.9	-	8.5	6.7	7.6	7.2
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.25b. Effect of Kharif straw incorporation									
	Without straw	5.8	7.9	6.8	8.2	8.1	6.6	7.6	7.3
	With straw	6.5	7.3	6.9	8.2	8.6	6.8	7.9	7.5
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.25 c. Effect of silica									
	Without silica	5.1	8.0	6.5	7.5	8.3	5.1	7.0	6.8
	With silica	7.4	7.9	7.6	8.1	10.3	8.6	9.0	8.4
		Sig	NS	Sig	NS	Sig	Sig	Sig	Sig
Sub table 4.25d. Effect of higher dose of K									
	K35	6.5	8.0	7.2	7.5	8.4	6.6	7.5	7.4
	K70	6.0	7.9	6.9	8.1	10.2	7.1	8.5	7.9
		NS	NS	NS	NS	Sig	NS	NS	NS

Table 4.25. Effect of season and treatments on silica content (%) of rice

C. Straw

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	11.8^{abc}	11.1^{abc}	11.5^{abcde}	11.3^{abcd}	9.7^{abcde}	8.8^{abc}	9.9^{bcd}	10.5^{bcde}
2	NPK alone	10.5^{bc}	10.2^{abc}	10.4^{de}	11.2^{abcd}	7.7^{d}	6.8^{c}	8.6^{e}	9.3^{fg}
3	Straw + NPK	10.1^{c}	9.7^{bc}	9.9^{e}	9.7^{bcde}	8.1^{cd}	6.9^{bc}	8.2^{e}	8.9^{g}
4	Straw + NPK (higher dose of K)	12.4^{abc}	11.7^{ab}	12.1^{abcd}	9.5^{cde}	7.4^{d}	6.9^{bc}	7.9^{e}	9.6^{efg}
5	Straw + NPK + Si	14.9^{a}	11.5^{ab}	13.2^{a}	11.7^{ab}	10.1^{abcd}	9.7^{a}	10.5^{ab}	11.6^{ab}
6	Straw + NPK (higher dose of K)+ Si	14.0^{ab}	11.7ab	12.9^{ab}	10.7^{abcde}	9.3^{abcd}	9.7^{a}	9.9^{bcd}	11.1^{abc}
7	Straw + NPK + Si + Zn	14.0^{ab}	10.9^{abc}	12.5^{abcd}	9.3^{de}	8.7^{bcd}	8.9^{abc}	9.0^{de}	10.4^{cdef}
8	Straw + NPK + Si + Zn +Mg	13.0^{abc}	12.1^{a}	12.7^{abc}	10.8^{abcde}	11.4^{ab}	9.9^{a}	10.7^{ab}	11.5^{abc}
9	Straw + NPK + Si + Zn +Mg+Cu	14.3^{ab}	11.2^{abc}	12.8^{ab}	11.7^{ab}	12.1^{a}	10.0^{a}	11.3^{a}	11.9^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	11.9^{abc}	11.5^{ab}	11.7^{abcde}	12.0^{a}	9.8^{abcd}	8.9^{abc}	10.2^{abc}	10.8^{abcd}
11	T_{10}+ Boron	13.9^{abc}	11.1^{abc}	12.5^{abcd}	10.5^{abcde}	10.5^{abcd}	9.5^{ab}	10.2^{abc}	11.1^{abc}
12	T_{11}+ Mo	11.2^{abc}	10.7^{abc}	11.0^{bcde}	11.0^{abcde}	11.9^{a}	9.7^{a}	10.9^{ab}	10.9^{abcd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	11.7^{abc}	10.7^{abc}	11.2^{abcde}	11.9^{a}	11.0^{abc}	9.2^{abc}	10.7^{abc}	10.9^{abcd}
14	T_{12} (No summer cowpea)	13.2^{abc}	11.5^{ab}	12.4^{abcd}	11.5^{abc}	11.0^{abcd}	9.7^{abc}	10.7^{abc}	11.4^{abc}
15	T_2 (No summer cowpea)	11.9^{abc}	9.3^{c}	10.6^{cde}	9.0^{e}	8.5^{bcd}	8.4^{abc}	8.6^{e}	9.4^{efg}
16	T_{13} (No summer cowpea)	11.8^{abc}	9.7^{bc}	10.7^{bcde}	9.6^{bcde}	9.6^{abcd}	8.0^{abc}	9.1^{cde}	9.7^{defg}
	Mean	**12.6**	**10.9**	**11.7**	**10.7**	**9.8**	**8.8**	**9.8**	**10.6**
CD for comparison of season				NS				0.40	1.20
CD for comparison of *Kharif vs Rabi*		0.30							
Sub table 4.25 a. Effect of cropping system									
	R-R-Fallow	12.3	10.2	11.2	-	9.7	8.7	9.2	10.2
	R-R-cowpea	11.1	10.5	10.8	-	10.2	8.6	9.4	10.1
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.25b. Effect of Kharif straw incorporation									
	Without straw	11.3	10.2	10.8	10.9	9.4	8.0	9.4	10.0
	With straw	11.5	10.6	11.1	10.7	10.3	8.8	9.9	10.4
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.25 c. Effect of silica									
	Without silica	11.3	10.7	11.0	9.6	7.8	6.9	8.1	9.2
	With silica	14.5	11.6	13.0	11.2	9.7	9.7	10.2	11.3
		Sig	NS	Sig	Sig	Sig	NS	Sig	Sig
Sub table 4.25d. Effect of higher dose of K									
	K35	12.5	10.6	11.6	10.7	9.1	8.3	9.4	10.2
	K70	13.2	11.7	12.5	10.1	8.4	8.3	8.9	10.3
		NS	NS	NS	NS	NS	NS	NS	NS

Table 4.25. Effect of season and treatments on silica content (%) of rice

d. Grain

Sl. No.	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Pooled mean
1	Straw alone	2.1^{bc}	3.0^{ab}	2.6^{ab}	3.7^{ab}	3.5^{a}	4.6^{ab}	3.9^{ab}	3.4^{ab}
2	NPK alone	2.4^{abc}	2.5^{ab}	2.5^{ab}	2.5^{e}	3.0^{a}	2.9^{cd}	2.8^{f}	2.7^{ef}
3	Straw + NPK	2.4^{abc}	2.9^{ab}	2.7^{ab}	3.0^{bcde}	3.2^{a}	2.4^{d}	2.9^{ef}	2.8^{def}
4	Straw + NPK (higher dose of K)	1.7^{c}	2.6^{ab}	2.2^{b}	3.4^{abcd}	3.5^{a}	2.9^{cd}	3.3^{cdef}	2.8^{cdef}
5	Straw + NPK + Si	2.0^{bc}	2.6^{ab}	2.3^{ab}	2.9^{bcde}	3.6^{a}	3.0^{cd}	3.2^{cdef}	2.8^{def}
6	Straw + NPK (higher dose of K)+ Si	2.5^{abc}	2.9^{ab}	2.7^{ab}	3.4^{abcd}	3.5^{a}	3.7^{abcd}	3.5^{bcd}	3.2^{abcd}
7	Straw + NPK + Si + Zn	3.0^{ab}	3.0^{ab}	3.0^{a}	2.9^{bcde}	3.6^{a}	4.0^{abc}	3.5^{bcd}	3.3^{abc}
8	Straw + NPK + Si + Zn +Mg	2.1^{bc}	3.4^{a}	2.8^{ab}	2.6^{de}	3.7^{a}	3.9^{abc}	3.4^{cd}	3.1^{bcde}
9	Straw + NPK + Si + Zn +Mg+Cu	2.5^{abc}	2.5^{ab}	2.5^{ab}	3.3^{abcde}	3.6^{a}	3.3^{bcd}	3.4^{cd}	3.0^{bcdef}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	2.9^{ab}	2.3^{ab}	2.6^{ab}	3.0^{bcde}	3.7^{a}	4.0^{abc}	3.6^{bc}	3.2^{abcd}
11	T_{10}+ Boron	2.6^{abc}	3.1^{ab}	2.9^{ab}	4.1^{a}	3.6^{a}	4.8^{a}	4.2^{a}	3.6^{a}
12	T_{11}+ Mo	2.6^{abc}	2.9^{ab}	2.8^{ab}	3.0^{bcde}	3.4^{a}	3.0^{cd}	3.1^{cdef}	3.0^{bcdef}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	3.2^{a}	2.4^{b}	2.8^{ab}	3.4^{abcd}	3.3^{a}	3.2^{bcd}	3.3^{cdef}	3.1^{bcdef}
14	T_{12} (No summer cowpea)	2.7^{abc}	3.0^{ab}	2.9^{ab}	3.5^{abc}	3.3^{a}	3.0^{cd}	3.3^{cdef}	3.1^{bcdef}
15	T_2 (No summer cowpea)	2.4^{abc}	2.3^{ab}	2.4^{ab}	2.5^{e}	3.1^{a}	3.0^{cd}	2.9^{ef}	2.7^{f}
16	T_{13} (No summer cowpea)	2.2^{abc}	3.0^{ab}	2.6^{ab}	2.7^{cde}	3.3^{a}	3.1^{cd}	3.0^{def}	2.9^{cdef}
	Mean	**2.5**	**2.8**	**2.6**	**3.1**	**3.4**	**3.4**	**3.3**	**3.0**
CD for comparison of season				NS				0.20	0.20
CD for comparison of *Kharif vs Rabi*		0.10							
Sub table 4.25 a. Effect of cropping system									
	R-R-Fallow	2.4	2.8	2.6	-	3.2	3.0	3.1	2.9
	R-R-cowpea	2.7	2.6	2.7	-	3.2	3.0	3.1	2.9
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.25b. Effect of Kharif straw incorporation									
	Without straw	2.6	2.6	2.6	2.9	3.2	3.1	3.0	2.9
	With straw	2.6	2.9	2.8	3.2	3.3	2.8	3.1	3.0
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.25 c. Effect of silica									
	Without silica	2.1	2.8	2.4	3.2	3.4	2.7	3.1	2.8
	With silica	2.3	2.8	2.5	3.2	3.6	3.4	3.4	3.0
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.25d. Effect of higher dose of K									
	K35	2.2	2.8	2.5	3.0	3.4	2.7	3.0	2.8
	K70	2.1	2.8	2.4	3.4	3.5	3.3	3.4	3.0
		NS	NS	NS	NS	NS	NS	NS	NS

T_{16} had similar concentration. During *rabi* 1997-'98 and *rabi* 1998-'99, application of silica increased silica concentration in the straw. During *rabi* 1999-'00, the effect was insignificant.

Grain

The mean content of silica in grain during *kharif* was 2.6 per cent. During *rabi* it was higher (3.3 %). The two *kharif* seasons did not differ in the content of silica, but differences were observed among the *rabi* seasons. The content was higher during *rabi* 1998-'99 and *rabi* 1999-'00 whereas *rabi* 1997-'98 recorded a lower concentration of 3.1 per cent.

During *kharif* 1998-'99, T_{13} (NPK +Si + foliar application of Zn, Mg, Cu, B and Mo) recorded the highest content of 3.2 per cent. T_1, T_4, T_5 and T_8 had significantly lower concentration while others were similar to T_{13}. During *kharif* 1999-'00, no appreciable variations were noticed among the treatments. During *rabi* 1997-'98, T_2, T_8 and T_{15} had lower contents whereas T_{11} registered the highest content of 4.1 per cent. During *rabi* 1998-'99, the treatments did not manifest any appreciable variation in silica content of grain. During *rabi* 1999-'00, T_{11} (Straw +NPK +Si + foliar application of Zn, Mg, Cu and B) recorded the highest content of 4.8 per cent; T_1, T_6, T_7, T_8 and T_{10} showed similar contents while others had significantly lower contents.

4.1.4. Plant nutrient interrelations and productivity

The correlations among nutrient composition at PI stage, yield components and grain yield during the five seasons are given in Tables 4.26 to 4.30.

During *rabi* 1997-'98, the season in which the highest yields were obtained, grain yield showed significant positive correlation with P and S. The mean contents of these nutrients in the plant were 0.49 and 0.37 per cent respectively. Effect of P was significant in improving the grains/ panicle as evident by the high positive correlation between the two (0.575). Magnesium was showing a negative relation (-0.407) with panicles/m^2 while the relation between Mn and panicle number was highly positive. There was a significant positive correlation of S with N and K, whereas Fe showed negative relation with Ca (-0.383) and S (-0.402).

The second *rabi* season had a significantly lower yield compared to *rabi* 1997-'98. Contents of N and P were almost similar during both seasons; but *rabi* 1998-'99 had lower K, Mg and Fe and a higher level of Mn, Ca and S. A perusal of the interrelations of the season showed that the nature and extent of the correlations were similar to the previous *rabi* season in some respects. Phosphorous and S continued to have a positive effect. The negative effect of Ca assumed a significant level of –0.379 during the season. Manganese also showed a significant negative correlation (-0.344).

Phosphorous favorably influenced the number of panicles/m^2 whereas S influenced both panicles/m^2 and grains/panicle. Manganese, on the contrary, had a negative influence on panicles/m^2. Magnesium exhibited a significant role in increasing grains/panicle.

The correlation study of *rabi* 1999-'00 revealed the continued negative effect of Ca on yield. Calcium had a significant negative relation with panicles/m^2. The role of Si was more pronounced during the season. It had a significant positive correlation with yield and there was significant yield increase with Si application during this season. Silica appeared to have a positive correlation with Fe, which could be due to the higher silica uptake for counteracting Fe. The effect of Ca on Mn was highly negative in nature. The reduction in the Mn content has resulted to turn its effect to positive.

Correlation values of *kharif* 1998-'99 revealed the significant role of Cu. Sulphur had a significant positive relation with N, P, K, Mn and Zn. Mn also had a significant positive effect on P and K. The relations of P with Zn and Si also were significant besides the positive significant relations of Zn with S and Cu.

The data of *kharif* 1999-'00 showed that there were remarkable differences in the content of the elements, possibly due to weather effects. This has brought about appreciable changes in the correlation pattern. The

Table 4.26. Coefficients of correlation of nutrient contents at PI stage of rice with grain yield during *Rabi* 1997-98

	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	Si	Panicles per m^2	Grains per panicle	Test wt	Yield
N	1.000														
P	0.078	1.000													
K	0.331	0.220	1.000												
Ca	0.256	-0.060	-0.207	1.000											
Mg	0.100	0.060	0.113	-0.091	1.000										
S	0.445**	0.122	0.471**	0.007	0.293*	1.000									
Fe	-0.267	0.166	-0.115	-0.383**	-0.114	-0.402**	1.000								
Mn	0.171	0.345**	0.288	0.151	-0.247	0.023	0.059	1.000							
Cu	-0.025	0.182	-0.050	-0.044	-0.319*	-0.134	0.462**	-0.082	1.000						
Zn	-0.185	0.210	0.330	-0.208	-0.042	0.180	0.018	0.200	0.061	1.000					
Si	0.084	0.220	0.060	-0.136	-0.306*	-0.036	0.284	-0.073	0.193	0.169	1.000				
Panicles per m^2	0.068	0.176	0.281	0.036	-0.407*	0.166	-0.002	0.540**	0.167	0.188	-0.118	1.000			
Grains per panicle	0.103	0.575**	0.130	0.052	-0.134	-0.050	0.279	0.327*	0.274	-0.045	-0.021	0.317	1.000		
Test wt	-0.213	-0.207	0.013	-0.178	-0.012	0.204	0.021	0.215	-0.265	-0.051	-0.262	0.132	-0.178	1.000	
Yield	0.253	0.389**	0.102	-0.156	0.112	0.426 **	-0.024	0.023	0.048	0.154	-0.051	0.073	0.188	0.176	1.000

Table 4.27. Coefficients of correlation of nutrient contents at PI stage of rice with grain yield during *Rabi* 1998-99

	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	Si	Panicles per m^2	Grains per panicle	Test wt	Yield
N	1.000														
P	-0.002	1.000													
K	-0.055	0.653**	1.000												
Ca	-0.080	0.119	0.436**	1.000											
Mg	0.297*	0.036	0.115	-0.132	1.000										
S	-0.067	0.450**	0.335*	0.097	0.172	1.000									
Fe	0.028	-0.052	0.108	-0.001	-0.093	0.125	1.000								
Mn	-0.153	-0.099	0.020	0.557**	0.002	0.186	-0.255	1.000							
Cu	0.040	-0.356**	-0.228	-0.311*	0.217	-0.247	-0.135	-0.261	1.000						
Zn	-0.083	-0.002	-0.013	-0.139	0.126	0.081	-0.209	-0.147	0.659**	1.000					
Si	-0.246	-0.090	-0.242	0.099	-0.150	-0.075	-0.066	0.100	0.071	0.284	1.000				
Panicles per m^2	-0.051	0.298*	-0.069	-0.153	0.224	0.432**	0.047	-0.200	0.120	0.163	0.082	1.000			
Grains per panicle	-0.106	-0.019	0.202	-0.080	0.401**	0.272	-0.197	0.118	0.212	0.285	0.061	0.146	1.000		
Test wt	-0.021	0.124	0.130	-0.029	0.227	0.083	-0.257	0.036	-0.082	0.068	0.136	0.021	0.447**	1.000	
Yield	0.084	0.361**	0.033	-0.379**	0.319	0.239	-0.131	-0.344**	0.171	0.201	-0.018	0.539	0.328*	0.530**	1.000

Table 4.28. Coefficients of correlation of nutrient contents at PI stage of rice with grain yield during *Rabi* 1999-00

	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	Si	Panicles per m^2	Grains per panicle	Test wt	Yield
N	1.000														
P	-0.011	1.000													
K	0.053	0.724**	1.000												
Ca	0.153	0.165	0.079	1.000											
Mg	0.183	0.148	0.019	0.266	1.000										
S	0.163	0.192	0.296*	-0.169	0.171	1.000									
Fe	0.223	-0.297*	-0.316*	0.101	0.015	-0.089	1.000								
Mn	0.235	0.002	0.134	-0.413**	-0.013	0.134	-0.139	1.000							
Cu	-0.030	0.166	0.079	-0.307*	0.035	0.222	-0.274	0.257	1.000						
Zn	0.170	0.042	-0.059	-0.116	-0.235	-0.306*	-0.207	-0.034	0.165	1.000					
Si	0.277	0.248	0.093	-0.192	0.101	0.035	0.424**	0.101	0.229	0.016	1.000				
Panicles per m^2	-0.061	-0.218	-0.239	-0.532**	-0.251	0.072	0.255	0.313*	-0.041	0.039	0.184	1.000			
Grains per panicle	0.243	-0.068	0.036	0.093	-0.214	0.090	0.268	0.060	0.078	-0.085	0.198	-0.010	1.000		
Test wt	0.262	0.124	0.061	-0.230	-0.049	0.102	-0.174	0.185	0.353**	0.517**	0.295*	0.033	0.282	1.000	
Yield	0.187	0.154	0.175	-0.343**	-0.010	0.279	0.097	0.262	0.218	0.057	0.470**	0.368*	0.181	0.464**	1.000

Table 4.29. Coefficients of correlation of nutrient contents at PI stage of rice with grain yield during *Kharif* 1998-99

	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	Si	Panicles per m^2	Grains per panicle	Test wt	Yield
N	1.000														
P	0.133	1.000													
K	0.129	0.740**	1.000												
Ca	0.302*	-0.188	0.000	1.000											
Mg	-0.137	-0.017	-0.091	-0.532**	1.000										
S	0.396**	0.774**	0.567**	-0.173	-0.060	1.000									
Fe	-0.025	0.213	0.229	-0.041	-0.043	0.040	1.000								
Mn	0.228	0.381**	0.371**	-0.162	0.181	0.529**	-0.175	1.000							
Cu	0.174	0.086	0.109	0.562**	-0.660**	0.106	-0.020	-0.215	1.000						
Zn	0.256	0.476**	0.427**	0.066	-0.331*	0.552**	0.179	0.331*	0.462**	1.000					
Si	-0.097	0.522**	0.315*	-0.196	-0.074	0.253	0.298	-0.322*	0.204	0.268	1.000				
Panicles per m^2	0.166	-0.150	-0.227	0.018	-0.072	0.268	-0.16	0.139	0.000	0.041	-0.291	1.000			
Grains per panicle	-0.009	0.156	0.052	0.150	-0.179	0.061	0.088	-0.15	0.064	0.159	0.129	-0.079	1.000		
Test wt	-0.128	0.154	0.042	0.216	-0.366**	-0.1	0.188	-0.246	0.069	-0.144	0.082	-0.093	0.285	1.000	
Yield	0.255	0.127	0.084	0.126	-0.162	0.210	0.300	-0.206	0.399**	0.186	0.083	0.179	0.179	-0.041	1.000

Table 4.30. Coefficients of correlation of nutrient contents at PI stage of rice with grain yield during *Kharif* 1999-00

	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	Si	Panicles per m^2	Grains per panicle	Test wt	Yield
N	1.000														
P	0.280	1.000													
K	0.002	0.324*	1.000												
Ca	-0.120	-0.007	0.344**	1.000											
Mg	0.137	0.321*	0.426**	0.028	1.000										
S	0.319*	0.290*	0.107	0.115	-0.030	1.000									
Fe	0.044	0.190	0.482**	0.393**	0.359**	-0.222	1.000								
Mn	0.037	0.201	0.579**	0.185	0.215	0.009	0.358**	1.000							
Cu	-0.044	-0.241	-0.044	-0.152	0.016	-0.294*	-0.121	-0.105	1.000						
Zn	0.135	0.367*	0.082	0.129	-0.100	0.111	0.093	0.115	-0.487**	1.000					
Si	-0.064	-0.003	-0.036	0.092	-0.219	0.135	0.219	0.101	-0.135	0.333*	1.000				
Panicles per m^2	0.187	-0.056	-0.236	-0.049	-0.214	-0.030	-0.128	-0.366**	0.059	-0.185	-0.188	1.000			
Grains per panicle	0.235	-0.010	-0.137	0.008	-0.054	0.406**	-0.013	-0.050	-0.160	-0.138	0.139	0.269	1.000		
Test wt	-0.043	-0.070	-0.510**	-0.276	-0.102	0.056	-0.377**	-0.351**	0.047	-0.297*	-0.199	0.125	0.172	1.000	
Yield	0.261	-0.020	-0.441**	-0.070	-0.473**	0.362**	-0.297	-0.397**	-0.137	-0.103	0.170	0.457**	0.430**	0.169	1.000

season expressed lower yield than *kharif* 1998-'99 and was characterized by a decreased content of P, K, Mg, S and Mn in the plant system, whereas Ca, Fe, Zn, Cu and Si showed an increase. The changes have resulted in a positive correlation of S. The influence of N on yield remained the same during both the *kharif* seasons; but other elements viz. K, Mg, Mn and Fe had a high negative correlation value. Sulphur was found to have pronounced effect on increasing grains per panicle as indicated by its high 'r' value of 0.406.

4.1.5. Effect of season and management practices on nutrient uptake of rice

4.1.5.1. Nitrogen

The data on the effects of management practices on the uptake pattern of nitrogen during the five seasons are presented in Table 4.31.

The mean uptake during *kharif* and *rabi* were 77.8 kg ha^{-1} and 71.5 kg ha^{-1} respectively. *Kharif* and *rabi* seasons themselves did not differ significantly in the amount of N uptake.

During *kharif* 1998-'99, silica application increased the N uptake; however, when this was combined with higher K dose this increase was not seen. During 1998-'99 *rabi* soil application of Zn and Cu and foliar spray of Mo decreased N uptake while Mg application brought about a significant increase. During *rabi* 1999-'00, higher K dose increased N uptake (T_3 vs T_4) but when this was combined with silica application this increase was not noticed. *Kharif* straw incorporation also resulted in a significantly higher N uptake. In the straw alone treatment (T_1) uptake was low.

4.1.5.2. Phosphorous

The data on the effects of management practices on the uptake pattern of phosphorous during the five seasons are presented in Table 4.32.

The mean uptake of P during *kharif* and *rabi* were 20.2 kg ha^{-1} and 15.6 kg ha^{-1} respectively. Significant variations were observed among the *kharif* and *rabi* seasons themselves.

Table 4.31 Effect of season and treatments on nitrogen uptake (kg ha^{-1}) of rice

Sl.No	Treatments	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	66.9^{de}	56.8^{b}	61.9^{d}	52.7^{a}	43.8^{f}	42.7^{g}	46.4^{g}	52.6^{f}
2	NPK alone	71.9^{bcde}	75.8^{ab}	73.9^{bcd}	63.4^{bc}	56.4^{def}	56.8^{f}	58.9^{f}	64.9^{e}
3	Straw + NPK	65.9^{e}	71.4^{ab}	68.7^{cd}	69.6^{abc}	79.4^{a}	85.5^{bc}	78.2^{abc}	74.4^{cd}
4	Straw + NPK (higher dose of K)	74.4^{bcde}	73.6^{ab}	74.0^{bcd}	75.7^{ab}	69.9^{abc}	101.3^{a}	82.3^{a}	79.0^{abc}
5	Straw + NPK + Si	91.6^{a}	83.9^{a}	87.8^{a}	82.1^{ab}	70.0^{abc}	94.2^{ab}	82.1^{a}	84.4^{a}
6	Straw + NPK (higher dose of K)+ Si	73.7^{bcde}	78.7^{a}	76.2^{abc}	82.0^{ab}	64.6^{bcde}	81.7^{bcd}	76.1^{abcd}	76.1^{bcd}
7	Straw + NPK + Si + Zn	82.6^{abcd}	85.6^{a}	84.1^{ab}	72.6^{abc}	53.5^{ef}	68.7^{def}	64.9^{ef}	72.6^{cd}
8	Straw + NPK + Si + Zn +Mg	87.0^{abc}	87.4^{a}	87.2^{a}	73.7^{ab}	78.6^{a}	82.9^{bcd}	78.4^{abc}	81.9^{ab}
9	Straw + NPK + Si + Zn +Mg+Cu	76.8^{abcde}	82.9^{a}	79.9^{abc}	83.5^{ab}	65.4^{bcde}	88.7^{abc}	79.2^{ab}	79.5^{abc}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	87.4^{ab}	78.3^{a}	82.9^{ab}	65.6^{bc}	74.6^{ab}	76.2^{cde}	72.1^{bcde}	76.4^{bcd}
11	T_{10}+ Boron	80.0^{abcde}	78.5^{a}	79.3^{abc}	71.1^{abc}	57.5^{cde}	79.7^{bcde}	69.4^{cde}	73.4^{cd}
12	T_{11}+ Mo	78.5^{abcde}	81.8^{a}	80.2^{abc}	70.6^{abc}	52.0^{ef}	90.3^{abc}	71.0^{bcde}	74.6^{bcd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	81.3^{abcde}	83.0^{a}	82.2^{ab}	70.9^{abc}	69.6^{abcd}	79.9^{bcde}	73.5^{abcde}	76.9^{bcd}
14	T_{12} (No summer cowpea)	75.4^{abcde}	74.7^{ab}	75.1^{abc}	87.9^{a}	63.7^{bcde}	75.2^{cde}	75.6^{abcde}	75.4^{bcd}
15	T_2 (No summer cowpea)	87.4^{ab}	69.5^{ab}	78.5^{abc}	86.7^{a}	53.3^{ef}	65.8^{ef}	68.6^{de}	72.5^{cd}
16	T_{13} (No summer cowpea)	70.4^{cde}	76.8^{a}	73.6^{bcd}	72.4^{abc}	54.1^{ef}	75.3^{cde}	67.3^{de}	69.8^{de}
	Mean	**78.2**	**77.4**	**77.8**	**73.8**	**62.9**	**77.8**	**71.5**	**74.0**
CD for comparison of seasons				NS				NS	10.9
Sub table 4.31 a. Effect of cropping system									
	R-R-Fallow	77.7	73.7	75.7	-	57.0	72.1	70.5	72.6
	R-R-cowpea	77.2	80.2	78.7	-	59.3	75.7	67.8	72.1
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.31b. Effect of *Kharif* straw incorporation									
	Without straw	74.5	78.5	76.5	68.9	60.0	70.7	66.5	70.5
	With straw	73.3	76.0	74.6	76.0	65.0	83.7	74.9	74.8
		NS	NS	NS	NS	NS	Sig	Sig	NS
Sub table 4.31 c. Effect of silica									
	Without silica	70.2	72.5	71.3	72.7	74.7	93.4	80.2	76.7
	With silica	82.7	81.3	82.0	82.1	67.3	88.0	79.1	80.3
		Sig	NS	Sig	NS	NS	NS	NS	NS
Sub table 4.31d. Effect of higher dose of K									
	K_{35}	78.8	77.7	78.2	75.9	74.7	89.9	80.1	79.4
	K_{70}	74.1	76.2	75.1	78.9	67.3	91.5	79.2	77.6
		NS	NS	NS	NS	NS	NS	NS	NS

During *kharif* 1998-'99, the mean uptake was 25.4 kg ha^{-1} whereas *kharif* 1999-'00 recorded significantly lower uptake of 15.1 kg ha^{-1}. During *rabi* 1997-'98 P uptake was 20.7 kg ha^{-1}. The following *rabi* seasons registered significantly lower uptake values of 16.1 kg ha^{-1} and 10.0 kg ha^{-1} respectively.

During *kharif* 1999-'00, silica application increased P uptake significantly. During *rabi* 1997-'98, soil application of Cu has increased P uptake. During *rabi* 1998-'99, soil application of Mg significantly increased P uptake while Cu resulted in decreasing it. Treatment 'straw alone' registered low P uptake during all the seasons.

4.1.5.3. Potassium

The data on the effects of management practices on the uptake pattern of potassium during the five seasons are presented in Table 4.33.

The mean uptake of K in *kharif* was 106.5 kg ha^{-1} while in *rabi* it was 108.1 kg ha^{-1}. The two *kharif* seasons did not differ in the mean uptake; but variations were noticed between *rabi* seasons. During *rabi* 1997-'98 K uptake was 132.8 kg ha^{-1} while *rabi* 1998-'99 and 1999-'00 registered significantly lower values.

During *kharif* 1998-'99, the uptake in Straw alone treatment (T_1) was significantly lower than T_5, T_7, T_8 and T_{14}. During *kharif* 1999-'00, T_1 was significantly inferior to T_6. T_3, T_{10}, T_{13} and T_{15} also were inferior to T_6.

During *rabi* 1998-'99, *kharif* straw incorporation as well as soil application of Mg brought about significant increase in K uptake. *Kharif* straw incorporation increased uptake during *rabi* 1999-'00 also. During *rabi* 1997-'98, T_1 and T_2 registered lower uptake than all other treatments except T_{10}.

4.1.5.4. Calcium

The data on the effects of management practices on the uptake pattern of calcium during the five seasons are presented in Table 4.34.

The mean Ca uptake during *kharif* was 8.5 kg ha^{-1} and during *rabi* it was 11.2 kg ha^{-1}. Among the two *kharif* seasons, 1998-'99 registered uptake

Table 4.32 Effect of season and treatments on phosphorous uptake (kg ha^{-1}) of rice

Sl.No	Treatments	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	20.3^{c}	10.7^{c}	15.5^{d}	15.1^{c}	12.0^{c}	6.3^{c}	11.1^{e}	12.9^{e}
2	NPK alone	23.9^{abc}	15.5^{ab}	19.7^{abc}	18.8^{bc}	14.3^{de}	8.2^{bc}	13.8^{de}	16.1^{b}
3	Straw + NPK	24.0^{abc}	12.9^{bc}	18.5^{c}	22.1^{ab}	19.2^{ab}	10.3^{ab}	17.2^{abc}	17.7^{bcd}
4	Straw + NPK (higher dose of K)	23.6^{abc}	14.3^{ab}	19.0^{bc}	24.5^{ab}	16.1^{bcd}	10.1^{ab}	16.9^{abc}	17.7^{bcd}
5	Straw + NPK + Si	26.5^{ab}	16.3^{a}	21.4^{abc}	19.9^{bc}	15.3^{cde}	11.2^{ab}	15.5^{bcd}	17.8^{bcd}
6	Straw + NPK (higher dose of K)+ Si	24.7^{abc}	16.1^{ab}	20.4^{abc}	19.7^{bc}	16.0^{bcd}	10.3^{ab}	15.3^{bcd}	17.4^{bcd}
7	Straw + NPK + Si + Zn	26.8^{ab}	16.7^{a}	21.8^{ab}	20.3^{abc}	15.3^{def}	10.3^{ab}	15.3^{bcd}	17.9^{bcd}
8	Straw + NPK + Si + Zn +Mg	27.3^{ab}	16.0^{ab}	21.7^{ab}	19.6^{abc}	21.3^{a}	12.0^{a}	17.6^{bc}	19.2^{abc}
9	Straw + NPK + Si + Zn +Mg+Cu	29.0^{a}	15.7^{ab}	22.4^{a}	26.5^{a}	17.1^{bcd}	11.2^{ab}	18.3^{a}	19.9^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	26.7^{ab}	14.7^{ab}	20.7^{abc}	21.2^{abc}	18.1^{abc}	11.0^{ab}	16.8^{abc}	18.3^{abc}
11	T_{10}+ Boron	25.7^{ab}	15.4^{ab}	20.6^{abc}	21.4^{abc}	15.0^{cde}	10.3^{ab}	15.6^{bcd}	17.6^{bcd}
12	T_{11}+ Mo	26.3^{ab}	16.3^{a}	21.3^{abc}	20.9^{abc}	13.9^{de}	11.8^{a}	15.5^{bcd}	17.8^{bcd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	23.4^{bc}	15.6^{ab}	19.5^{abc}	19.9^{bc}	16.8^{bcd}	10.7^{ab}	15.8^{abcd}	17.3^{bcd}
14	T_{12} (No summer cowpea)	26.5^{ab}	14.9^{ab}	20.7^{abc}	20.3^{abc}	15.0^{cde}	9.0^{abc}	14.8^{cd}	17.1^{cd}
15	T_2 (No summer cowpea)	26.6^{ab}	14.3^{ab}	20.5^{abc}	19.7^{bc}	17.0^{bcd}	8.4^{bc}	15.0^{bcd}	17.2^{bcd}
16	T_{13} (No summer cowpea)	24.4^{abc}	15.5^{ab}	20.0^{abc}	21.7^{ab}	15.2^{cde}	9.6^{ab}	15.5^{bcd}	17.3^{bcd}
	Mean	**25.4**	**15.1**	**20.2**	**20.7**	**16.1**	**10.0**	**15.6**	**17.5**
CD for comparison of season				3.8				4.2	3.2
Sub table 4.32 a. Effect of cropping system									
	R-R-Fallow	25.8	14.9	20.4	-	15.7	9.0	15.1	17.2
	R-R-cowpea	24.5	15.8	20.2	-	15.0	10.2	15.0	17.1
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.32b. Effect of *Kharif* straw incorporation									
	Without straw	23.9	15.5	19.7	20.1	15.4	9.5	15.0	16.9
	With straw	25.6	14.7	20.2	21.1	16.0	10.4	15.8	17.6
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.32 c. Effect of silica									
	Without silica	23.8	13.6	18.7	23.3	17.7	10.2	17.1	17.7
	With silica	25.6	16.2	20.9	19.8	15.7	10.7	15.4	17.6
		NS	Sig	Sig	Sig	NS	NS	Sig	NS
Sub table 4.32d. Effect of higher dose of K									
	K_{35}	25.3	14.6	19.9	21.0	17.3	10.8	16.3	17.8
	K_{70}	23.8	13.6	18.7	23.3	17.7	10.2	17.1	17.7
	CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.33. Effect of season and treatments on potassium uptake (kg ha^{-1}) of rice

Sl.No	Treatments	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	73.9^{b}	100.8^{bcd}	87.4^{de}	104.5^{c}	72.9^{e}	73.4^{cd}	83.6^{e}	85.1^{g}
2	NPK alone	101.1^{ab}	109.6^{abcd}	105.4^{abcde}	108.8^{c}	82.6^{de}	75.3^{cd}	88.9^{de}	95.5^{fg}
3	Straw + NPK	95.9^{ab}	88.3^{cd}	92.1^{cde}	137.3^{ab}	131.2^{a}	102.9^{abc}	123.8^{a}	111.1^{abcd}
4	Straw + NPK (higher dose of K)	110.1^{ab}	117.5^{abcd}	113.8^{abcd}	133.1^{ab}	95.2^{bcde}	121.3^{a}	116.5^{ab}	115.4^{abcd}
5	Straw + NPK + Si	120.9^{a}	135.8^{ab}	128.4^{a}	131.9^{ab}	104.2^{abc}	94.8^{abcd}	110.3^{abc}	117.5^{abc}
6	Straw + NPK (higher dose of K)+ Si	110.2^{ab}	141.8^{a}	126.0^{ab}	143.9^{ab}	106.1^{abc}	92.6^{abcd}	114.2^{abc}	118.9^{ab}
7	Straw + NPK + Si + Zn	129.5^{a}	121.3^{abc}	125.4^{ab}	136.7^{ab}	83.2^{de}	91.4^{abcd}	103.8^{bcd}	112.4^{abcde}
8	Straw + NPK + Si + Zn +Mg	115.1^{a}	119.1^{abcd}	117.1^{abc}	135.4^{ab}	121.0^{ab}	116.0^{ab}	124.1^{a}	121.3^{a}
9	Straw + NPK + Si + Zn +Mg+Cu	102.2^{ab}	104.3^{abcd}	103.3^{abcde}	140.3^{ab}	103.9^{abc}	103.8^{abc}	116.0^{ab}	110.9^{abcd}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	99.3^{ab}	102.2^{bcd}	100.8^{abcde}	123.6^{bc}	117.2^{abc}	88.7^{abcd}	109.8^{abc}	106.2^{bcdef}
11	T_{10}+ Boron	104.8^{ab}	95.1^{cd}	100.0^{bcde}	139.2^{ab}	87.7^{cde}	91.0^{abcd}	106.0^{bc}	103.6^{cdef}
12	T_{11}+ Mo	94.0^{ab}	122.4^{abc}	108.2^{abcde}	130.6^{ab}	90.8^{bcde}	107.0^{abc}	109.5^{abc}	109.0^{abcdef}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	89.8^{ab}	81.9^{d}	85.8^{c}	143.1^{ab}	89.9^{cde}	91.5^{abcd}	108.2^{abc}	99.2^{ef}
14	T_{12} (No summer cowpea)	117.1^{a}	104.6^{abcd}	110.9^{abcde}	146.4^{a}	89.4^{cde}	103.2^{abc}	113.0^{abc}	112.1^{abcde}
15	T_2 (No summer cowpea)	97.7^{ab}	95.3^{cd}	96.5^{cde}	130.4^{ab}	101.6^{abc}	64.8^{d}	98.9^{cd}	98.0^{efg}
16	T_{13} (No summer cowpea)	91.7^{ab}	114.9^{abcd}	10.3^{abcde}	139.7^{ab}	85.1^{de}	82.0^{bcd}	102.3^{bcd}	102.7^{def}
	Mean	**103.3**	**109.7**	**106.5**	**132.8**	**97.6**	**93.7**	**108.1**	**107.4**
CD for comparison of season				NS				3.3	4.2
Sub table 4.33 a. Effect of cropping system									
	R-R-Fallow	102.2	104.9	103.6	-	92.0	83.3	104.7	104.3
	R-R-cowpea	95.0	104.6	99.8	-	87.8	91.3	102.2	101.2
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.33 b. Effect of *Kharif* straw incorporation									
	Without straw	94.2	102.1	98.2	130.5	85.9	82.9	99.8	99.1
	With straw	102.3	105.1	103.7	138.1	103.8	104.4	115.4	110.7
		NS	NS	NS	NS	Sig	Sig	Sig	Sig
Sub table 4.33 c. Effect of silica									
	Without silica	103.0	102.9	103.0	135.2	113.2	112.1	120.2	113.3
	With silica	115.6	138.8	127.2	137.9	105.1	93.7	112.2	118.2
		NS	Sig	Sig	NS	NS	NS	NS	NS
Sub table 4.33 d. Effect of higher dose of K									
	K_{35}	108.4	112.1	110.2	134.6	117.7	98.8	117.0	114.3
	K_{70}	110.2	129.7	119.9	138.5	100.6	106.9	115.4	117.2
		NS	Sig	NS	NS	NS	NS	NS	NS

of 7.0 kg ha^{-1} whereas in 1999-'00 a significantly higher uptake of 10.0 kg ha^{-1} was observed. Among the *rabi* seasons, uptake was lowest in 1999-'00 season while 1997-'98 and 1998-'99 registered 12.0 kg ha^{-1} and 14.5 kg ha^{-1} respectively.

During *kharif* 1999-'00, silica application and higher K dose resulted in significant increase in Ca uptake (Sub tables 4.34 c and d).

During *rabi* 1997-'98, silica application along with normal dose of K decreased the uptake, while during *rabi* 1998-'99, foliar application of boron resulted in reduced Ca uptake. The highest uptake was in treatment receiving Straw +NPK +Si+ foliar application of Zn, Mg and Cu (T_{10}) whereas T_1, T_2, T_4, T_5, T_6, T_7, T_{11}, T_{12}, T_{14} and T_{15} had significant lower values. During *rabi* 1999-'00, silica application reduced Ca uptake from 10.4 kg ha^{-1} to 6.9 kg ha^{-1} (Sub table 4.34 c).

4.1.5.5. Magnesium

The data on the effects of management practices on the uptake pattern of magnesium during the five seasons are presented in Table 4.35.

The mean uptake of Mg during *kharif* was 12.9 kg ha^{-1} while in *rabi* it was 14.1 kg ha^{-1}. Among the two *kharif* seasons, 1998-'99 recorded significantly higher content of 14.2 kg ha^{-1} while in 1999-'00 it was 11.5 kg ha^{-1}. *Rabi* 1998-'99 had an uptake of 16.2 kg ha^{-1} Mg while other two *rabi* seasons had significantly lower levels.

During *kharif* 1999-'00, silica application increased Mg uptake. During *rabi* 1997-'98 T_1 had the lowest uptake whereas T_{14} (Straw +NPK +Si+ foliar application of Zn, Mg, Cu, B and Mo without summer cowpea) had significantly higher uptake than T_1, T_9, T_{10}, T_{11} and T_{12}. During *rabi* 1998-'99 application of higher K dose resulted in significant reduction, but when it was combined with silica application there was no influence. Application of silica along with normal dose of K decreased Mg uptake while when it was along with higher dose of K it was ineffective. During *rabi* 1999-'00, silica application has reduced the Mg uptake. Straw alone treatment recorded the lowest uptake.

Table 4.34. Effect of season and treatments on calcium uptake (kg ha^{-1}) of rice

Sl.No	Treatments	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	6.4^{b}	9.3^{ab}	7.9^{a}	11.8^{abcd}	12.1^{cde}	5.3^{b}	9.7^{de}	9.0^{cd}
2	NPK alone	8.2^{ab}	10.2^{a}	9.2^{a}	14.0^{ab}	13.7^{bcde}	5.9^{b}	11.2^{bcde}	10.4^{abcd}
3	Straw + NPK	9.2^{a}	7.8^{b}	8.5^{a}	15.2^{a}	19.3^{ab}	8.7^{b}	14.4^{a}	12.0^{a}
4	Straw + NPK (higher dose of K)	7.0^{ab}	10.3^{a}	8.7^{a}	12.7^{abc}	14.2^{bcde}	12.1^{a}	13.0^{ab}	11.3^{ab}
5	Straw + NPK + Si	7.8^{ab}	10.3^{a}	9.1^{a}	10.2^{bcd}	12.9^{cde}	7.4^{b}	10.2^{cde}	9.7^{bcd}
6	Straw + NPK (higher dose of K)+ Si	6.7^{ab}	11.2^{a}	9.0^{a}	11.5^{abcd}	14.2^{bcde}	6.4^{b}	10.7^{bcde}	10.0^{bcd}
7	Straw + NPK + Si + Zn	6.7^{ab}	10.5^{a}	8.6^{a}	11.6^{abcd}	13.9^{bcde}	6.1^{b}	10.5^{bcde}	9.8^{bcd}
8	Straw + NPK + Si + Zn +Mg	6.8^{ab}	9.4^{ab}	8.1^{a}	10.7^{abcd}	17.5^{abc}	7.6^{b}	11.9^{abcd}	10.4^{abcd}
9	Straw + NPK + Si + Zn +Mg+Cu	7.0^{ab}	10.2^{a}	8.6^{a}	14.8^{ab}	15.6^{abcde}	6.2^{b}	12.2^{abcd}	10.8^{abc}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	5.8^{b}	9.5^{ab}	7.7^{a}	10.9^{abcd}	20.0^{a}	7.3^{b}	12.8^{abc}	10.7^{abc}
11	T_{10}+ Boron	5.9^{b}	10.7^{a}	8.3^{a}	13.7^{ab}	12.0^{cde}	7.1^{b}	10.9^{bcde}	9.9^{bcd}
12	T_{11}+ Mo	6.2^{b}	11.1^{a}	8.7^{a}	8.6^{cd}	11.0^{de}	7.5^{b}	9.0^{e}	8.9^{d}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	6.4^{b}	9.0^{ab}	7.7^{a}	13.0^{abc}	14.6^{abcde}	6.8^{b}	11.5^{bcde}	10.0^{bcd}
14	T_{12} (No summer cowpea)	6.4^{b}	10.3^{a}	8.4^{a}	13.7^{ab}	10.0^{e}	6.7^{b}	10.1^{cde}	9.4^{cd}
15	T_2 (No summer cowpea)	7.4^{ab}	10.1^{a}	8.8^{a}	11.4^{abcd}	14.2^{bcde}	5.7^{b}	10.4^{bcde}	9.8^{bcd}
16	T_{13} (No summer cowpea)	8.0^{ab}	10.0^{a}	9.0^{a}	7.4^{d}	16.6^{abcd}	7.4^{b}	10.5^{bcde}	9.9^{bcd}
	Mean	**7.0**	**10.0**	**8.5**	**12.0**	**14.5**	**7.1**	**11.2**	**10.1**
CD for comparison of season					2.6			3.3	2.4
Sub table 4.34 a. Effect of cropping system									
	R-R-Fallow	7.3	10.1	8.7	-	13.6	6.6	10.4	9.7
	R-R-cowpea	6.9	10.1	8.5	-	13.1	6.7	10.6	9.7
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.34 b. Effect of *Kharif* straw incorporation									
	Without straw	7.5	9.7	8.6	11.5	15.0	6.7	11.0	10.1
	With straw	7.3	9.7	8.5	12.5	13.4	7.6	11.2	10.1
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.34 c. Effect of silica									
	Without silica	8.1	9.1	8.6	13.9	16.8	10.4	13.7	11.6
	With silica	7.3	10.8	9.0	10.9	13.6	6.9	10.4	9.9
		NS	Sig	NS	NS	NS	Sig	Sig	Sig
Sub table 4.34 d. Effect of higher dose of K									
	K_{35}	8.5	9.1	8.8	12.7	16.1	8.0	12.3	10.9
	K_{70}	6.9	10.8	8.8	12.1	14.2	9.3	11.9	10.6
		NS	Sig	NS	NS	NS	NS	NS	NS

Table 4.35. Effect of season and treatments on magnesium uptake (kg ha^{-1}) of rice

Sl.No	Treatments	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	12.6^{a}	9.1^{c}	10.9^{b}	9.1^{e}	11.2^{d}	8.7^{c}	9.7^{e}	10.1^{d}
2	NPK alone	14.0^{a}	10.9^{abc}	12.5^{ab}	13.9^{abcd}	14.1^{d}	10.4^{bc}	12.8^{d}	12.7^{c}
3	Straw + NPK	11.8^{a}	9.7^{bc}	10.8^{b}	14.7^{abc}	20.4[illegible]	14.6^{ab}	16.5^{ab}	14.2^{abc}
4	Straw + NPK (higher dose of K)	14.7^{a}	9.4^{bc}	12.1^{ab}	14.2^{abcde}	13.7^{d}	17.0^{a}	15.0^{abcd}	13.8^{abc}
5	Straw + NPK + Si	16.0^{a}	11.9^{abc}	14.0^{ab}	14.9^{abc}	13.9^{d}	12.7^{abc}	13.8^{cd}	13.9^{bc}
6	Straw + NPK (higher dose of K)+ Si	13.3^{a}	12.9^{abc}	13.1^{ab}	15.6^{abc}	15.5^{cd}	11.1^{bc}	14.1^{bcd}	13.7^{bc}
7	Straw + NPK + Si + Zn	14.9^{a}	11.9^{abc}	13.4^{ab}	13.5^{abcd}	13.8^{d}	12.9^{abc}	13.4^{cd}	13.4^{bc}
8	Straw + NPK + Si + Zn +Mg	15.7^{a}	13.3^{ab}	14.5^{a}	13.4^{abcd}	22.8^{a}	14.1^{ab}	16.8^{a}	15.9^{a}
9	Straw + NPK + Si + Zn +Mg+Cu	15.8^{a}	13.9^{a}	14.9^{a}	11.9^{cde}	21.5^{a}	14.4^{ab}	15.9^{abc}	15.5^{ab}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	13.8^{a}	10.8^{abc}	12.3^{ab}	10.5^{de}	19.9^{abc}	13.1^{abc}	14.5^{abcd}	13.6^{bc}
11	T_{10}+ Boron	15.7^{a}	11.5^{abc}	13.6^{ab}	12.8^{bcde}	13.8^{d}	12.2^{abc}	12.9^{d}	13.2^{c}
12	T_{11}+ Mo	13.8^{a}	12.3^{abc}	13.1^{ab}	11.7^{cde}	14.0^{d}	14.1^{ab}	13.3^{cd}	13.2^{c}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	11.1^{a}	11.9^{abc}	11.5^{ab}	13.7^{abcd}	15.7^{bcd}	15.0^{ab}	14.8^{abcde}	13.5^{bc}
14	T_{12} (No summer cowpea)	15.2^{a}	11.1^{abc}	13.2^{ab}	16.9^{a}	13.2^{d}	10.2^{bc}	13.4^{cd}	13.3^{c}
15	T_2 (No summer cowpea)	15.5^{a}	11.6^{abc}	13.6^{ab}	13.5^{abcd}	19.5^{abc}	10.7^{bc}	14.6^{abcd}	14.2^{abc}
16	T_{13} (No summer cowpea)	13.9^{a}	11.4^{abc}	12.7^{ab}	16.2^{ab}	15.9^{bcd}	11.8^{bc}	14.6^{abcd}	13.8^{abc}
	Mean	**14.2**	**11.5**	**12.9**	**13.5**	**16.2**	**12.7**	**14.1**	**13.6**
CD for comparison of season				NS				2.8	1.9
Sub table 4.35 a. Effect of cropping system									
	R-R-Fallow	14.9	11.4	13.1	-	16.2	10.9	14.2	13.8
	R-R-cowpea	13.0	11.7	12.3	-	14.6	13.2	13.6	13.1
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.35 b. Effect of *Kharif* straw incorporation									
	Without straw	13.0	11.4	12.2	14.6	15.2	12.4	14.1	13.3
	With straw	13.6	11.0	12.3	14.4	15.9	13.0	14.4	13.6
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.35 c. Effect of silica									
	Without silica	13.3	9.6	11.4	14.4	17.1	15.8	15.8	14.0
	With silica	14.7	12.4	13.5	15.2	14.7	11.9	13.9	13.8
		NS	Sig	Sig	NS	NS	Sig	Sig	NS
Sub table 4.35 d. Effect of higher dose of K									
	K_{35}	13.9	10.8	12.4	14.8	17.2	13.6	15.2	14.1
	K_{70}	14.0	11.2	12.6	14.9	14.6	14.0	14.5	13.7
		NS	NS	NS	NS	NS	NS	NS	NS

4.1.5.6. Sulphur

The data on the effects of management practices on the uptake pattern of sulphur during the five seasons are presented in Table 4.36.

The mean S uptake during *kharif* and *rabi* were 12.7 kg ha^{-1} and 12.3 kg ha^{-1} respectively. Among the *kharif* seasons, higher uptake of 14.4 kg ha^{-1} was recorded in 1998-'99. During *rabi* 1999-'00, the uptake was 10.2 kg ha^{-1} which was significantly lower than the uptake in the other two seasons.

During *rabi* 1998-'99, soil application of Mg increased the S uptake. During *rabi* 1999-'00, higher K dose significantly increased S uptake but when silica was applied along with higher K dose this increase was not seen. Raising of summer cowpea as well as incorporation of *kharif* straw led to increased S uptake by the plant (Sub tables 4.36 a and b). The treatments of straw alone had the lowest uptake during all the seasons.

4.1.5.7. Iron

The data on the effects of management practices on the uptake pattern of iron during the five seasons are presented in Table 4.37.

During *kharif*, the mean Fe uptake was 8.3 kg ha^{-1} while *rabi* had 6.4 kg ha^{-1}. Among the *kharif* seasons, 1998-'99 season had a mean uptake of 6.1 kg ha^{-1} while in 1999-'00, the uptake was significantly higher (10.5 kg ha^{-1}). The variation between the *rabi* seasons was not significant.

During *kharif* 1999-'00, raising of summer cowpea had significantly decreased Fe uptake. Uptake was higher in T_{11} and T_{14} whereas T_1 to T_{10} registered significantly lower uptake values.

During *rabi* 1998-'99, higher K dose has significantly decreased Fe uptake, but when silica application was combined with it no influence was seen. The uptake in straw alone was lesser than straw and NPK. During *rabi* 1999-'00, silica application has reduced Fe uptake. T_{11} (Straw +NPK +Si+ foliar application of Zn, Mg, Cu and B) had the highest uptake of 7.0 kg ha^{-1}. T_3, T_4, T_{10} and T_{12} had comparable Fe uptake while in other treatments, it was significantly lower.

Table 4.36. Effect of season and treatments on sulphur uptake (kg ha^{-1}) of rice

Sl.No	Treatments	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	11.4^{bc}	7.9^{c}	9.7^{d}	8.0^{c}	9.2^{d}	6.3^{g}	7.8^{d}	8.6^{f}
2	NPK alone	13.3^{abc}	10.3^{abc}	11.8^{bcd}	12.7^{bc}	11.1^{cd}	7.8^{fg}	10.5^{c}	11.0^{e}
3	Straw + NPK	13.5^{abc}	9.4^{abc}	11.5^{bcd}	14.3^{ab}	14.0^{abc}	9.8^{def}	12.7^{bc}	12.2^{bcde}
4	Straw + NPK (higher dose of K)	14.3^{abc}	11.3^{abc}	12.8^{abc}	17.0^{ab}	12.5^{bcd}	12.5^{ab}	14.0^{ab}	13.5^{abc}
5	Straw + NPK + Si	17.3^{a}	12.4^{ab}	14.9^{a}	13.4^{ab}	11.4^{cd}	10.9^{abcde}	11.9^{bc}	13.1^{abcd}
6	Straw + NPK (higher dose of K)+ Si	15.5^{ab}	12.0^{ab}	13.8^{abc}	14.6^{ab}	13.6^{abc}	9.9^{cdef}	12.7^{bc}	13.1^{abcd}
7	Straw + NPK + Si + Zn	14.6^{abc}	13.3^{a}	14.0^{ab}	13.0^{bc}	11.3^{cd}	12.0^{abcd}	12.1^{bc}	12.8^{bcd}
8	Straw + NPK + Si + Zn +Mg	16.0^{a}	11.8^{abc}	13.9^{ab}	12.3^{bc}	16.6^{a}	12.0^{abcd}	13.6^{ab}	13.7^{ab}
9	Straw + NPK + Si + Zn +Mg+Cu	15.3^{ab}	11.8^{abc}	13.5^{abc}	18.3^{a}	15.6^{ab}	12.2^{abc}	15.4^{a}	14.6^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	13.3^{abc}	9.2^{bc}	11.3^{bcd}	12.2^{bc}	13.7^{abc}	10.1^{bcdef}	12.0^{bc}	11.7^{de}
11	T_{10}+ Boron	16.1^{a}	10.6^{abc}	13.3^{abc}	15.9^{ab}	10.7^{cd}	10.4^{abcde}	12.3^{bc}	12.7^{bcde}
12	T_{11}+ Mo	14.6^{abc}	11.4^{abcd}	13.0^{abc}	14.7^{ab}	10.8^{cd}	12.7^{a}	12.7^{bc}	12.8^{bcd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	10.7^{c}	10.0^{abc}	10.4^{cd}	14.9^{ab}	13.2^{abc}	9.9^{cdef}	12.7^{bc}	11.7^{cde}
14	T_{12} (No summer cowpea)	14.9^{abc}	10.8^{abc}	12.9^{abc}	15.2^{ab}	11.1^{cd}	9.5^{ef}	11.9^{bc}	12.3^{bcde}
15	T_2 (No summer cowpea)	14.7^{abc}	10.5^{abc}	12.6^{abc}	14.7^{ab}	13.6^{abc}	8.0^{fg}	12.1^{bc}	12.3^{bcde}
16	T_{13} (No summer cowpea)	14.9^{abc}	12.5^{ab}	13.7^{abc}	15.5^{ab}	13.1^{abc}	9.2^{ef}	12.6^{bc}	13.0^{abcd}
	Mean	**14.4**	**10.9**	**12.7**	**14.2**	**12.6**	**10.2**	**12.3**	**12.5**
CD for comparison of season				1.9				2.2	1.7
Sub table 4.35 a. Effect of cropping system									
	R-R-Fallow	14.8	11.3	13.1	-	12.6	8.9	12.2	12.5
	R-R-cowpea	12.9	10.6	11.7	-	11.7	10.1	12.0	11.9
		NS	NS	Sig	-	NS	Sig	NS	NS
Sub table 4.35 b. Effect of *Kharif* straw incorporation									
	Without straw	13.0	10.9	12.0	14.4	12.5	9.0	11.9	11.9
	With straw	14.3	10.5	12.4	14.7	12.0	10.7	12.5	12.4
		NS	NS	NS	NS	NS	Sig	NS	NS
Sub table 4.35 c. Effect of silica									
	Without silica	13.9	10.4	12.1	15.7	13.3	11.1	13.3	12.9
	With silica	16.4	12.2	14.3	14.0	12.5	10.4	12.3	13.1
		NS	NS	Sig	NS	NS	NS	NS	NS
Sub table 4.35 d. Effect of higher dose of K									
	K_{35}	15.4	10.9	13.2	13.9	12.7	10.4	12.3	12.6
	K_{70}	14.9	11.7	13.3	15.8	13.1	11.2	13.4	13.3
		NS	NS	NS	NS	NS	NS	NS	NS

Table 4.37 Effect of season and treatments on iron uptake (kg ha^{-1}) of rice

No	Treatments	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	4.9^{a}	6.0^{g}	5.4^{e}	6.6^{a}	5.5^{cd}	3.0^{ef}	5.0^{d}	5.2^{d}
2	NPK alone	5.0^{a}	7.0^{fg}	6.0^{e}	6.9^{a}	6.4^{bcd}	2.9^{ef}	6.4^{cd}	5.6^{cd}
3	Straw + NPK	5.6^{a}	5.7^{g}	5.7^{e}	6.9^{a}	12.6^{a}	6.4^{ab}	8.6^{a}	7.4^{ab}
4	Straw + NPK (higher dose of K)	6.0^{a}	8.3^{efg}	7.2^{de}	7.2^{a}	6.3^{cd}	5.3^{abcd}	6.3^{bcd}	6.6^{bc}
5	Straw + NPK + Si	6.3^{a}	8.6^{defg}	7.5^{de}	7.9^{a}	7.0^{bcd}	4.0^{cdef}	6.3^{bcd}	6.8^{bc}
6	Straw + NPK (higher dose of K)+ Si	6.1^{a}	10.9^{bcdef}	8.5^{bcd}	7.9^{a}	8.5^{bcd}	3.7^{cdef}	6.7^{bcd}	7.4^{ab}
7	Straw + NPK + Si + Zn	7.1^{a}	10.6^{bcdef}	8.9^{bcd}	7.9^{a}	4.9^{d}	4.9^{bcde}	5.9^{bcd}	7.1^{ab}
8	Straw + NPK + Si + Zn +Mg	6.2^{a}	9.2^{cdefg}	7.7^{de}	7.6^{a}	8.9^{abcd}	4.8^{bcde}	7.1^{ab}	7.3^{ab}
9	Straw + NPK + Si + Zn +Mg+Cu	6.3^{a}	10.6^{bcdef}	8.5^{cd}	6.5^{a}	7.3^{bcd}	4.3^{cdef}	6.0^{bcd}	7.0^{ab}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	7.3^{a}	7.5^{efg}	7.4^{de}	6.6^{a}	8.6^{bcd}	5.7^{abc}	7.0^{bc}	7.1^{ab}
11	T_{10}+ Boron	6.3^{a}	15.7^{a}	11.0^{ab}	6.7^{a}	6.0^{cd}	7.0^{a}	6.6^{bcd}	8.3^{a}
12	T_{11}+ Mo	5.9^{a}	12.9^{abcd}	9.4^{abcd}	6.3^{a}	5.9^{cd}	5.4^{abcd}	5.9^{bcd}	7.3^{ab}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	6.3^{a}	14.4^{ab}	10.4^{abc}	6.1^{a}	7.9^{bcd}	4.3^{cdef}	6.1^{bcd}	7.8^{ab}
14	T_{12} (No summer cowpea)	6.6^{a}	16.1^{a}	11.4^{a}	8.6^{a}	6.2^{cd}	4.1^{cdef}	6.3^{bcd}	8.3^{a}
15	T_2 (No summer cowpea)	6.0^{a}	13.2^{abc}	9.6^{abcd}	5.9^{a}	10.4^{ab}	2.7^{f}	6.3^{bcd}	7.6^{ab}
16	T_{13} (No summer cowpea)	5.6^{a}	11.7^{abcde}	8.7^{bcd}	6.3^{a}	9.3^{abc}	3.5^{def}	6.4^{bcd}	7.3^{ab}
	Mean	**6.1**	**10.5**	**8.3**	**7.0**	**7.6**	**4.5**	**6.4**	**7.1**
	CD for comparison of season			1.7				NS	2.5
Sub table 4.37 a. Effect of cropping system									
	R-R-Fallow	6.1	13.7	9.9	-	8.6	3.5	6.3	7.8
	R-R-cowpea	5.7	11.4	8.6	-	6.7	4.2	5.8	6.9
		NS	Sig	NS	-	NS	NS	NS	NS
Sub table 4.37 b. Effect of *Kharif* straw incorporation									
	Without straw	5.6	11.0	8.3	6.4	7.9	3.6	6.0	6.9
	With straw	6.0	11.6	8.8	7.3	8.2	5.3	6.9	7.7
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.37 c. Effect of silica									
	Without silica	5.8	7.0	6.4	7.1	9.5	5.9	7.5	7.0
	With silica	6.2	9.8	8.0	7.9	7.8	3.9	6.5	7.1
		NS	NS	NS	NS	NS	Sig	NS	NS
Sub table 4.37 d. Effect of higher dose of K									
	K_{35}	6.0	7.2	6.6	7.4	9.8	5.2	7.5	7.1
	K_{70}	6.1	9.6	7.8	7.6	7.4	4.5	6.5	7.0
		NS	NS	NS	NS	Sig	NS	NS	NS

4.1.5.8. Manganese

The data on the effects of management practices on the uptake pattern of manganese during the five seasons are presented in Table 4.38.

The mean Mn uptake during *kharif* was 2.2 kg ha^{-1} while it was 2.0 kg ha^{-1} in *rabi*. Mean uptake during the two *kharif* seasons of 1998-'99 and 1999-'00 were 1.8 kg ha^{-1} and 2.7 kg ha^{-1} respectively. Uptake showed significant differences between the *rabi* seasons. Thus *rabi* 1997-'98 had uptake of 1.0 kg ha^{-1}, while in 1998-'99 and 1999-'00 uptake were 1.8 kg ha^{-1} and 3.3 kg ha^{-1} respectively.

During *kharif* 1998-'99, NPK alone (T_2) and T_6 had the lowest Mn uptake while T_1, T_3 and T_5 had significantly higher uptake.

During *rabi* 1998-'99, incorporation of *kharif* straw brought about significant increase in Mn uptake while silica application reduced it. Soil application of Mg increased Mn uptake while foliar spray of boron resulted in significant reduction. Straw + NPK treatment had the highest uptake. During *rabi* 1999-'00 also straw + NPK and T_8 registered the highest uptake while T_{15} had significantly lower value.

4.1.5.9. Zinc

The data on the effects of management practices on the uptake pattern of zinc during the five seasons are presented in Table 4.39.

The mean Zn uptake during *kharif* and *rabi* seasons were 0.53 kg ha^{-1} and 0.51 kg ha^{-1} respectively. During *kharif* 1998-'99 the mean Zn uptake was 0.43 kg ha^{-1} and in *kharif* 1999-'00 it was 0.62 kg ha^{-1}. During *rabi* 1997-'98, and 1998-'99 the uptake was significantly lower than the uptake recorded in *rabi* 1999-'00 (0.85 kg ha^{-1}).

During *kharif* 1999-'00, silica application significantly increased Zn uptake, while during *rabi* 1999-'00 growing of summer cowpea increased the amount of uptake. During both the seasons of 1999-'00, soil application of Zn resulted in significant increase in its uptake by the plant.

During *kharif* 1998-'99, T_7 and T_8 recorded the highest uptake whereas T_{12} and T_1 had significantly lower values.

Table 4.38 Effect of season and treatments on manganese uptake (kg ha^{-1}) of rice

Sl.No	Treatments	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	2.4^{ab}	2.7^{a}	2.6^{abc}	0.9^{a}	1.9^{bc}	3.6^{ab}	2.1^{abcd}	2.3^{abc}
2	NPK alone	1.4^{c}	3.1^{a}	2.3^{abc}	1.0^{a}	1.5^{cde}	3.1^{ab}	1.9^{cd}	2.0^{bcd}
3	Straw + NPK	2.4^{ab}	2.7^{a}	2.6^{abc}	1.2^{a}	2.7^{a}	4.3^{a}	2.7^{a}	2.6^{a}
4	Straw + NPK (higher dose of K)	1.8^{abc}	3.3^{a}	2.6^{abc}	1.1^{a}	1.9^{bcd}	4.0^{ab}	2.3^{a}	2.4^{ab}
5	Straw + NPK + Si	2.6^{a}	2.8^{a}	2.7^{a}	1.3^{a}	1.6^{cde}	3.0^{ab}	2.0^{bcd}	2.3^{abcd}
6	Straw + NPK (higher dose of K)+ Si	1.3^{c}	2.5^{a}	1.9^{bc}	1.2^{a}	1.7^{cde}	3.3^{ab}	2.1^{bcd}	2.0^{bcd}
7	Straw + NPK + Si + Zn	1.6^{bc}	2.5^{a}	2.1^{abc}	1.1^{a}	1.6^{cde}	3.5^{ab}	2.1^{bcd}	2.1^{bcd}
8	Straw + NPK + Si + Zn +Mg	1.8^{abc}	2.6^{a}	2.2^{abc}	1.1^{a}	2.3^{ab}	4.2^{a}	2.6^{ab}	2.4^{ab}
9	Straw + NPK + Si + Zn +Mg+Cu	1.9^{abc}	3.2^{a}	2.6^{abc}	1.0^{a}	1.9^{bc}	3.0^{ab}	2.0^{bcd}	2.2^{abcd}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	1.6^{bc}	2.0^{a}	1.8^{bc}	1.0^{a}	2.3^{ab}	3.1^{ab}	2.2^{abcd}	2.0^{bcd}
11	T_{10}+ Boron	1.5^{bc}	3.1^{a}	2.3^{abc}	1.0^{a}	1.3^{de}	2.8^{ab}	1.7^{cd}	1.9^{bcd}
12	T_{11}+ Mo	1.5^{bc}	2.2^{a}	1.9^{bc}	0.7^{a}	1.3^{e}	3.6^{ab}	1.9^{cd}	1.9^{cd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	1.5^{bc}	2.0^{a}	1.8^{c}	0.8^{a}	1.5^{cde}	3.4^{ab}	1.9^{bcd}	1.8^{cd}
14	T_{12} (No summer cowpea)	1.6^{bc}	2.7^{a}	2.2^{abc}	1.3^{a}	1.7^{cde}	3.3^{ab}	2.1^{abcd}	2.1^{bcd}
15	T_2 (No summer cowpea)	1.8^{abc}	2.2^{a}	2.0^{abc}	1.2^{a}	1.4^{cde}	2.3^{b}	1.6^{d}	1.8^{d}
16	T_{13} (No summer cowpea)	1.8^{abc}	2.9^{a}	2.4^{abc}	0.9^{a}	1.4^{cde}	2.9^{ab}	1.7^{cd}	2.0^{bcd}
	Mean	**1.8**	**2.7**	**2.2**	**1.0**	**1.8**	**3.3**	**2.0**	**2.1**
CD for comparison of season				NS				0.5	0.6
Sub table 4.38 a. Effect of cropping system									
	R-R-Fallow	1.8	2.6	2.2	-	1.5	2.8	1.8	2.0
	R-R-cowpea	1.5	2.4	2.0	-	1.4	3.4	1.9	1.9
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.38 b. Effect of *Kharif* straw incorporation									
	Without straw	1.6	2.7	2.1	0.9	1.5	3.1	1.8	2.0
	With straw	1.8	2.5	2.2	1.1	1.9	3.7	2.2	2.2
		NS	NS	NS	NS	Sig	NS	Sig	NS
Sub table 4.38 c. Effect of silica									
	Without silica	2.1	3.0	2.6	1.1	2.3	4.1	2.5	2.5
	With silica	2.0	2.7	2.3	1.3	1.7	3.2	2.0	2.1
		NS	NS	NS	NS	Sig	NS	Sig	Sig
Sub table 4.38 d. Effect of higher dose of K									
	K_{35}	2.5	2.8	2.6	1.2	2.2	3.6	2.4	2.5
	K_{70}	2.5	2.8	2.6	1.2	2.2	3.6	2.4	2.5
		NS	NS	NS	NS	NS	NS	NS	NS

Table 4.39 Effect of season and treatments on zinc uptake (kg ha^{-1}) of rice

Sl.No	Treatments	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	0.31^{c}	0.49^{c}	0.40^{e}	0.18^{e}	0.16^{e}	0.45^{e}	0.27^{f}	0.32^{f}
2	NPK alone	0.45^{abc}	0.55^{bc}	0.50^{bcde}	0.20^{e}	0.24^{de}	0.90^{bcde}	0.45^{cde}	0.47^{defg}
3	Straw + NPK	0.38^{abc}	0.46^{c}	0.42^{de}	0.29^{cde}	0.33^{bcd}	0.80^{cde}	0.47^{cde}	0.45^{efg}
4	Straw + NPK (higher dose of K)	0.43^{abc}	0.47^{c}	0.45^{cde}	0.22^{e}	0.26^{bcd}	0.92^{bcde}	0.47^{cde}	0.46^{defg}
5	Straw + NPK + Si	0.48^{ab}	0.55^{bc}	0.52^{bcde}	0.22^{e}	0.31^{bcd}	0.63^{cde}	0.39^{def}	0.44^{fg}
6	Straw + NPK (higher dose of K)+ Si	0.45^{abc}	0.64^{abc}	0.55^{abcd}	0.21^{e}	0.33^{bcd}	0.62^{cde}	0.39^{def}	0.45^{fg}
7	Straw + NPK + Si + Zn	0.51^{a}	0.81^{a}	0.66^{a}	0.27^{de}	0.35^{bc}	1.32^{b}	0.64^{b}	0.65^{b}
8	Straw + NPK + Si + Zn +Mg	0.50^{a}	0.68^{abc}	0.59^{ab}	0.30^{cde}	0.48^{a}	1.85^{a}	0.88^{a}	0.76^{a}
9	Straw + NPK + Si + Zn +Mg+Cu	0.50^{ab}	0.73^{ab}	0.62^{ab}	0.39^{bcd}	0.49^{a}	1.09^{bc}	0.66^{b}	0.64^{bc}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	0.47^{ab}	0.67^{abc}	0.57^{abc}	0.42^{bc}	0.32^{bcd}	0.81^{cde}	0.52^{bcd}	0.54^{def}
11	T_{10}+ Boron	0.47^{ab}	0.69^{abc}	0.58^{abc}	0.44^{b}	0.35^{bc}	0.82^{cde}	0.54^{bcd}	0.55^{cde}
12	T_{11}+ Mo	0.35^{bc}	0.66^{abc}	0.51^{bcde}	0.47^{b}	0.24^{cde}	0.95^{bcd}	0.55^{bc}	0.53^{def}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	0.38^{abc}	0.68^{abc}	0.53^{bcde}	0.77^{a}	0.29^{bcd}	0.70^{cde}	0.59^{bc}	0.56^{bcd}
14	T_{12} (No summer cowpea)	0.40^{abc}	0.66^{abc}	0.53^{abcde}	0.69^{a}	0.29^{bcd}	0.75^{cde}	0.58^{bc}	0.56^{bcd}
15	T_2 (No summer cowpea)	0.40^{abc}	0.59^{abc}	0.50^{bcde}	0.24^{e}	0.28^{bcd}	0.51^{de}	0.34^{ef}	0.40^{gh}
16	T_{13} (No summer cowpea)	0.41^{abc}	0.59^{abc}	0.50^{bcde}	0.50^{b}	0.32^{bcd}	0.54^{de}	0.45^{cde}	0.47^{defg}
	Mean	**0.43**	**0.62**	**0.53**	**0.36**	**0.31**	**0.85**	**0.51**	**0.52**
CD for comparison of season				NS				0.27	0.22
Sub table 4.39 a. Effect of cropping system									
	R-R-Fallow	0.40	0.61	0.51	-	0.30	0.60	0.46	0.48
	R-R-cowpea	0.39	0.63	0.51	-	0.26	0.85	0.53	0.52
		NS	NS	NS	-	NS	Sig	NS	NS
Sub table 4.39 b. Effect of *Kharif* straw incorporation									
	Without straw	0.41	0.61	0.51	0.49	0.28	0.71	0.50	0.50
	With straw	0.38	0.59	0.49	0.49	0.29	0.83	0.54	0.52
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.39 c. Effect of silica									
	Without silica	0.41	0.47	0.44	0.26	0.30	0.86	0.47	0.46
	With silica	0.47	0.60	0.53	0.21	0.32	0.63	0.39	0.44
		NS	Sig	Sig	NS	NS	NS	NS	NS
Sub table 4.39 d. Effect of higher dose of K									
	K_{35}	0.43	0.51	0.47	0.26	0.32	0.72	0.43	0.45
	K_{70}	0.43	0.51	0.47	0.26	0.32	0.72	0.43	0.45
	CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS

During *rabi* 1997-'98, T_9 to T_{14} and T_{16} had higher uptake of Zn whereas T_1, T2, T_4, T_5, T_6, T_7 and T_{15} had significantly lower values. During *rabi* 1998-'99, uptake was lowest in T_1 and T_2. T_9 and T_{10} had higher uptake values.

4.1.5.10. Copper

The data on the effects of management practices on the uptake pattern of copper during the five seasons are presented in Table 4.40.

The mean value of Cu uptake during *kharif* was 0.10 kg ha^{-1} while in *rabi* it was 0.08 kg ha^{-1}. *Kharif* 1998-'99 had a mean uptake of 0.07 kg ha^{-1} while *kharif* 1999-'00 registered significantly higher uptake of 0.13 kg ha^{-1}. In *rabi* 1997-'98 the uptake value was 0.12 kg ha^{-1}; significantly lower values of 0.06 kg ha^{-1} and 0.07 kg ha^{-1} were recorded during the following *rabi* seasons.

During *kharif* 1999-'00, silica application significantly increased Cu uptake. The highest uptake of 0.21 kg ha^{-1} was recorded in T_{13} (NPK +Si+ foliar application of Zn, Mg, Cu, B and Mo). During *rabi* 1997-'98, T_{14} had the highest uptake. It was significantly lower in T_1 to T_8 and also T_{10}, T_{15} and T_{16}.

4.1.5.11. Silica

The data on the effects of management practices on the uptake pattern of silica during the five seasons are presented in Table 4.41.

The mean silica uptake showed a higher value of 636 kg ha^{-1} during *kharif* than *rabi* (453 kg ha^{-1}). During *kharif* 1998-'99, the mean uptake was 673 kg ha^{-1} while it was 599 kg ha^{-1} in *kharif* 1999-'00. During *rabi* 1997-'98, silica uptake was 519 kgha^{-1}. *Rabi* 1998-'99 and 1999-'00 recorded significantly lower values.

Soil application of silica increased its uptake by the plant during all the seasons except *rabi* 1998-'99. During this season, application of higher K dose brought about significant reduction in silica uptake by the plant. During *rabi* 1997-'98, soil application of Cu increased silica uptake. Uptake was lower in T_1, T_2, T_3, T_{15} and T16. In *rabi* 1998-'99, a significant increase was observed with soil application of Mg.

Table 4.40 Effect of season and treatments on copper uptake (kg ha^{-1}) of rice

Sl.No	Treatments	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	0.05^{a}	0.09^{cd}	0.07^{de}	0.06^{d}	0.04^{a}	0.04^{a}	0.05^{d}	0.06^{e}
2	NPK alone	0.05^{a}	0.11^{bcd}	0.08^{bcde}	0.08^{d}	0.06^{a}	0.04^{a}	0.06^{cd}	0.07^{de}
3	Straw + NPK	0.06^{a}	0.07^{d}	0.07^{e}	0.09^{cd}	0.09^{a}	0.06^{a}	0.08^{abcd}	0.08^{cde}
4	Straw + NPK (higher dose of K)	0.06^{a}	0.09^{cd}	0.08^{cde}	0.10^{cd}	0.04^{a}	0.07^{a}	0.07^{abcd}	0.07^{cde}
5	Straw + NPK + Si	0.11^{a}	0.14^{abcd}	0.13^{abc}	0.09^{cd}	0.05^{a}	0.06^{a}	0.07^{bcd}	0.09^{bcde}
6	Straw + NPK (higher dose of K)+ Si	0.07^{a}	0.14^{abcd}	0.13^{abcde}	0.08^{d}	0.06^{a}	0.05^{a}	0.07^{bcd}	0.08^{cde}
7	Straw + NPK + Si + Zn	0.07^{a}	0.14^{abcd}	0.11^{abcde}	0.08^{d}	0.05^{a}	0.06^{a}	0.07^{bcd}	0.08^{cde}
8	Straw + NPK + Si + Zn +Mg	0.08^{a}	0.13^{bcd}	0.11^{abcde}	0.10^{cd}	0.06^{a}	0.08^{a}	0.08^{abcd}	0.09^{bcde}
9	Straw + NPK + Si + Zn +Mg+Cu	0.09^{a}	0.11^{bcd}	0.10^{abcde}	0.16^{abc}	0.06^{a}	0.07^{a}	0.10^{abc}	0.10^{abcd}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	0.11^{a}	0.16^{abc}	0.13^{ab}	0.09^{d}	0.07^{a}	0.07^{a}	0.08^{abcd}	0.10^{abcd}
11	T_{10}+ Boron	0.06^{a}	0.15^{abc}	0.11^{abcde}	0.13^{abcd}	0.06^{a}	0.07^{a}	0.08^{abcd}	0.09^{bcde}
12	T_{11}+ Mo	0.06^{a}	0.15^{abcd}	0.11^{abcde}	0.19^{ab}	0.05^{a}	0.09^{a}	0.11^{ab}	0.11^{abc}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	0.09^{a}	0.21^{a}	0.15^{a}	0.19^{ab}	0.08^{a}	0.08^{a}	0.12^{a}	0.13^{a}
14	T_{12} (No summer cowpea)	0.07^{a}	0.18^{ab}	0.12^{abcd}	0.20^{a}	0.07^{a}	0.08^{a}	0.12^{a}	0.12^{ab}
15	T_2 (No summer cowpea)	0.07^{a}	0.12^{bcd}	0.09^{abcde}	0.10^{cd}	0.05^{a}	0.06^{a}	0.07^{bcd}	0.06^{abcd}
16	T_{13} (No summer cowpea)	0.06^{a}	0.15^{abc}	0.11^{abcde}	0.11^{bcd}	0.07^{a}	0.07^{a}	0.08^{abcd}	0.09^{bcde}
	Mean	**0.07**	**0.13**	**0.10**	**0.12**	**0.06**	**0.07**	**0.08**	**0.09**
CD for comparison of season				0.05				0.03	0.02
Sub table 4.40 a. Effect of cropping system									
	R-R-Fallow	0.07	0.15	0.11	-	0.06	0.07	0.09	0.10
	R-R-cowpea	0.07	0.16	0.11	-	0.06	0.07	0.09	0.10
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.40 b. Effect of *Kharif* straw incorporation									
	Without straw	0.07	0.16	0.11	0.13	0.07	0.06	0.09	0.10
	With straw	0.06	0.13	0.10	0.16	0.07	0.08	0.10	0.10
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.40 c. Effect of silica									
	Without silica	0.06	0.08	0.07	0.10	0.06	0.07	0.08	0.07
	With silica	0.09	0.14	0.11	0.09	0.05	0.05	0.07	0.09
		NS	Sig	Sig	NS	NS	NS	NS	NS
Sub table 4.40 d. Effect of higher dose of K									
	K_{35}	0.09	0.11	0.10	0.09	0.07	0.06	0.07	0.08
	K_{70}	0.09	0.11	0.10	0.09	0.07	0.06	0.07	0.08
		NS	NS	NS	NS	NS	NS	NS	NS

Table 4.41 Effect of season and treatments on silica uptake (kg ha^{-1}) of rice

Sl.No	Treatments	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	Pooled mean
1	Straw alone	497^{c}	528^{bc}	512^{ef}	474^{def}	325^{cd}	317^{cde}	372^{fg}	428^{e}
2	NPK alone	511^{c}	551^{ab}	531^{def}	464^{ef}	289^{d}	251^{e}	335^{g}	413^{e}
3	Straw + NPK	503^{c}	445^{c}	474^{f}	472^{def}	420^{abcd}	335^{bcde}	409^{cdef}	435^{e}
4	Straw + NPK (higher dose of K)	622^{abc}	631^{abc}	627^{bcdef}	497^{cdef}	339^{cd}	380^{bcde}	406^{efg}	494^{cde}
5	Straw + NPK + Si	886^{a}	661^{ab}	773^{a}	548^{bcde}	456^{abcd}	440^{abcd}	482^{abcde}	598^{ab}
6	Straw + NPK (higher dose of K)+ Si	716^{abc}	735^{a}	726^{abc}	565^{abcd}	432^{abcd}	469^{abc}	489^{abcde}	584^{ab}
7	Straw + NPK + Si + Zn	854^{ab}	666^{ab}	760^{ab}	450^{ef}	346^{cd}	459^{abc}	412^{cdef}	555^{abc}
8	Straw + NPK + Si + Zn +Mg	755^{abc}	678^{ab}	717^{abc}	493^{cdef}	611^{a}	569^{a}	558^{a}	621^{a}
9	Straw + NPK + Si + Zn +Mg+Cu	825^{ab}	615^{abc}	720^{abc}	623^{ab}	541^{ab}	481^{ab}	549^{ab}	617^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	711^{abc}	603^{abc}	657^{abcde}	625^{cdef}	511^{abc}	458^{abc}	498^{abc}	525^{abc}
11	T_{10}+ Boron	709^{abc}	628^{abc}	669^{abcde}	583^{abc}	438^{abcd}	489^{ab}	503^{abc}	569^{abc}
12	T_{11}+ Mo	569^{bc}	626^{abc}	598^{bcdef}	495^{cdef}	431^{abcd}	486^{ab}	470^{bcde}	521^{bcd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	650^{abc}	518^{abc}	584^{bcdef}	547^{bcde}	452^{abcd}	449^{abcd}	482^{abcde}	523^{bcd}
14	T_{12} (No summer cowpea)	760^{abc}	629^{abc}	694^{abcd}	646^{a}	416^{bcd}	412^{bcd}	491^{abcd}	573^{abc}
15	T_2 (No summer cowpea)	642^{abc}	502^{bc}	572^{cdef}	436^{ef}	393^{bcd}	302^{de}	377^{fg}	455^{de}
16	T_{13} (No summer cowpea)	562^{bc}	569^{abc}	566^{def}	479^{def}	379^{bcd}	369^{bcde}	409^{defg}	471^{de}
	Mean	**673**	**599**	**636**	**519**	**424**	**417**	**453**	**526**
CD for comparison of season				NS				78	79
Sub table 4.41 a. Effect of cropping system									
	R-R-Fallow	655	566	611	-	396	361	426	500
	R-R-cowpea	576	565	571	-	391	395	429	486
		NS	NS	NS	-	NS	NS	NS	NS
Sub table 4.41 b. Effect of *Kharif* straw incorporation									
	Without straw	574	546	560	497	373	356	409	469
	With straw	611	567	589	537	422	411	457	510
		NS	NS	NS	NS	NS	NS	Sig	Sig
Sub table 4.41 c. Effect of silica									
	Without silica	563	538	550	485	380	358	407	464
	With silica	801	698	749	557	444	455	485	591
		Sig	Sig	Sig	Sig	NS	Sig	Sig	Sig
Sub table 4.41 d. Effect of higher dose of K									
	K_{35}	694	553	624	510	438	388	445	517
	K_{70}	669	683	676	531	386	425	447	539
		NS	NS	NS	NS	Sig	NS	NS	NS

During *kharif* 1998-'99, uptake was lower in T_1, T_2 and T_3 while straw + NPK + silica treatment (T_5), T_7 and T_9 had significantly higher uptake. During *kharif* 1999-'00, T_6 had the highest uptake of 735 kg ha^{-1} while T_L, T_2, T_3, T_{13} and T_{15} registered significantly lower uptake.

4.1.6. Effect of season and management practices on soil nutrient status

4.1.6.1. Organic carbon

The data pertaining to the soil status of organic carbon at the end of each crop are depicted in Table 4.42.

The mean content of organic carbon at the end of *kharif* was 1.52 per cent. *Rabi* and summer season registered significantly lower values of 1.26 per cent and 1.35 per cent respectively.

Growing of summer cowpea in the cropping system was found to maintain a significantly higher level of organic carbon during *rabi* 1998-'99 and summer 1999 (Sub table 4.42 a). The other treatments did not manifest any significant variations in organic carbon status.

4.1.6.2. Ammoniacal nitrogen

The data pertaining to the soil status of ammoniacal nitrogen at the end of each crop are depicted in Table 4.43.

The mean values of soil ammoniacal nitrogen status showed that in *kharif* season it was 27.2 kg ha^{-1}, whereas *rabi* had significantly low level of 13.0 kg ha^{-1}. During summer it was 26.3 kg ha^{-1}.

The content showed variations among seasons themselves. Thus *rabi* 1997-'98 recorded 17.6 kg ha^{-1} whereas in *rabi* 1998-'99 it was significantly low (8.3 kg ha^{-1}). Similarly in summer 1998 the content was 34 kg ha^{-1} while in summer 1999 significantly lower level of 18.6 kg ha^{-1} was recorded. The variation between the two *kharif* seasons was negligible.

Table 4. 42. Effect of season and treatments on organic carbon content (%) in the soil at the end of each crop

Sl.No	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	*Summer* 1998	*Summer* 1999	*Summer* mean	pooled mean
1	Straw alone	1.55^{a}	1.42^{a}	1.48^{a}	1.43^{ab}	1.39^{a}	1.14^{a}	1.32^{ab}	1.29^{b}	1.35^{ab}	1.32^{ab}	1.37^{abc}
2	NPK alone	1.60^{a}	1.35^{a}	1.47^{a}	1.29^{ab}	1.29^{ab}	1.04^{a}	1.21^{bc}	1.37^{ab}	1.37^{a}	1.37^{ab}	1.33^{bcd}
3	Straw + NPK	1.58^{a}	1.38^{a}	1.48^{a}	1.34^{ab}	1.32^{ab}	1.16^{a}	1.27^{abc}	1.39^{ab}	1.32^{ab}	1.36^{ab}	1.36^{abcd}
4	Straw + NPK (higher dose of K)	1.64^{a}	1.41^{a}	1.52^{a}	1.39^{ab}	1.25^{abc}	1.15^{a}	1.26^{abc}	1.44^{ab}	1.30^{ab}	1.37^{ab}	1.37^{abc}
5	Straw + NPK + Si	1.67^{a}	1.45^{a}	1.56^{a}	1.35^{ab}	1.32^{ab}	1.10^{a}	1.25^{abc}	1.46^{ab}	1.28^{ab}	1.37^{ab}	1.37^{abc}
6	Straw + NPK (higher dose of K)+ Si	1.62^{a}	1.41^{a}	1.52^{a}	1.41^{ab}	1.26^{abc}	1.16^{a}	1.27^{abc}	1.45^{ab}	1.24^{ab}	1.34^{ab}	1.36^{abc}
7	Straw + NPK + Si + Zn	1.62^{a}	1.46^{a}	1.54^{a}	1.41^{ab}	1.37^{a}	1.16^{a}	1.31^{ab}	1.41^{ab}	1.33^{ab}	1.37^{ab}	1.39^{ab}
8	Straw + NPK + Si + Zn +Mg	1.57^{a}	1.52^{a}	1.54^{a}	1.43^{ab}	1.27^{ab}	1.13^{a}	1.28^{abc}	1.32^{ab}	1.37^{a}	1.35^{ab}	1.37^{abc}
9	Straw + NPK + Si + Zn +Mg+Cu	1.59^{a}	1.56^{a}	1.58^{a}	1.43^{ab}	1.28^{ab}	1.10^{a}	1.27^{abc}	1.45^{ab}	1.43^{a}	1.44^{a}	1.40^{ab}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	1.70^{a}	1.48^{a}	1.59^{a}	1.36^{ab}	1.37^{a}	1.12^{a}	1.28^{abc}	1.40^{ab}	1.40^{a}	1.40^{ab}	1.40^{ab}
11	T_{10}+ Boron	1.61^{a}	1.60^{a}	1.60^{a}	1.53^{a}	1.37^{a}	1.18^{a}	1.36^{a}	1.43^{ab}	1.43^{ab}	1.42^{a}	1.45^{a}
12	T_{11}+ Mo	1.65^{a}	1.50^{a}	1.57^{a}	1.36^{ab}	1.31^{ab}	1.05^{a}	1.24^{abc}	1.31^{ab}	1.31^{ab}	1.31^{ab}	1.35^{abcd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	1.56^{a}	1.46^{a}	1.51^{a}	L25^{b}	1.35^{a}	1.08^{a}	1.23^{abc}	1.55^{a}	1.16^{ab}	1.35^{ab}	1.34^{bcd}
14	T_{12} (No summer cowpea)	1.55^{a}	1.40^{a}	1.48^{a}	1.35^{ab}	1.30^{ab}	1.06^{a}	1.24^{abc}	1.46^{ab}	1.23^{ab}	1.35^{ab}	1.34^{bcd}
15	T_{2} (No summer cowpea)	1.55^{a}	1.27^{a}	1.41^{a}	1.28^{ab}	1.06^{c}	1.07^{a}	1.14^{c}	1.39^{ab}	1.22^{ab}	1.30^{ab}	1.26^{d}
16	T_{13} (No summer cowpea)	1.52^{a}	1.40^{a}	1.46^{a}	1.35^{ab}	1.13^{bc}	1.13^{a}	1.20^{bc}	1.38^{ab}	1.08^{b}	1.23^{b}	1.28^{cd}
	Mean	**1.60**	**1.44**	**1.52**	**1.37**	**1.29**	**1.11**	**1.26**	**1.40**	**1.30**	**1.35**	**1.36**
	CD for comparison of season			NS				0.11			0.25	0.13
Sub table 4.42 a. Effect of cropping system												
	R-R-Fallow	1.54	1.36	1.45	-	1.16	1.09	1.18	1.41	1.18	1.29	1.29
	R-R-cowpea	1.60	1.43	1.52	-	1.32	1.06	1.19	1.41	1.28	1.34	1.35
		NS	NS	NS	-	Sig	NS	NS	NS	Sig	NS	Sig
Sub table 4.42b. Effect of Kharif straw incorporation												
	Without straw	1.56	1.40	1.48	1.28	1.26	1.08	1.21	1.43	1.20	1.32	1.32
	With straw	1.59	1.43	1.51	1.35	1.31	1.09	1.25	1.39	1.29	1.34	1.35
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.42 c. Effect of silica												
	Without silica	1.61	1.40	1.50	1.37	1.28	1.15	1.27	1.42	1.31	1.36	1.36
	With silica	1.64	1.43	1.54	1.38	1.29	1.13	1.26	1.45	1.26	1.36	1.37
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.42d. Effect of higher dose of K												
	K35	1.62	1.41	1.52	1.35	1.32	1.13	1.26	1.42	1.30	1.36	1.36
	K70	1.63	1.41	1.52	1.40	1.25	1.15	1.27	1.44	1.27	1.36	1.36
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4. 43. Effect of season and treatments on ammonical nitrogen content (kg ha^{-1}) in the soil at the end of each crop

Sl.No	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* mean	*Summer* 1998	*Summer* 1999	*Summer* mean	pooled mean
1	Straw alone	28.4^{ab}	18.6^{a}	23.5^{a}	22.7^{a}	7.7^{bcde}	15.2^{a}	35.4^{abc}	18.4^{a}	26.9^{abc}	21.9^{a}
2	NPK alone	18.6^{b}	22.0^{a}	20.3^{a}	21.6^{a}	10.6^{ab}	16.1^{a}	32.6^{bc}	17.5^{a}	25.0^{abc}	20.5^{a}
3	Straw + NPK	23.9^{ab}	24.2^{a}	24.0^{a}	18.3^{a}	7.7^{bcde}	13.0^{a}	32.6^{bc}	13.9^{a}	23.2^{c}	20.1^{a}
4	Straw + NPK (higher dose of K)	30.0^{ab}	29.3^{a}	29.7^{a}	21.4^{a}	10.8^{a}	16.1^{a}	30.8^{bc}	25.8^{a}	28.3^{abc}	24.7^{a}
5	Straw + NPK + Si	27.1^{ab}	23.5^{a}	25.3^{a}	16.0^{a}	9.7^{abc}	12.9^{a}	33.2^{bc}	14.8^{a}	24.0^{c}	20.7^{a}
6	Straw + NPK (higher dose of K)+ Si	23.9^{ab}	34.2^{a}	24.0^{a}	15.0^{a}	6.7^{de}	10.9^{a}	36.3^{abc}	15.7^{a}	26.0^{abc}	20.3^{a}
7	Straw + NPK + Si + Zn	37.3^{a}	21.2^{a}	29.2^{a}	18.1^{a}	7.7^{abcde}	12.9^{a}	27.9^{c}	16.6^{a}	22.2^{c}	21.5^{a}
8	Straw + NPK + Si + Zn +Mg	19.4^{b}	33.3^{a}	26.4^{a}	20.7^{a}	8.6^{abcde}	14.6^{a}	37.1^{ab}	16.6^{a}	26.8^{abc}	22.6^{a}
9	Straw + NPK + Si + Zn +Mg+Cu	18.8^{b}	34.3^{a}	26.5^{a}	19.4^{a}	6.8^{cde}	13.1^{a}	43.1^{a}	21.3^{a}	32.2^{ab}	23.9^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	35.6^{ab}	23.0^{a}	29.3^{a}	14.9^{a}	6.7cde	10.8^{a}	30.8^{bc}	16.6^{a}	23.7^{c}	21.3^{a}
11	T_{10}+ Boron	27.7^{ab}	25.0^{a}	26.3^{a}	14.4^{a}	7.7bcde	11.1^{a}	37.2^{ab}	27.8^{a}	32.5^{a}	23.3^{a}
12	T_{11}+ Mo	36.0^{ab}	29.1^{a}	32.5^{a}	15.7^{a}	7.7^{bcde}	11.7^{a}	37.2^{bc}	20.4^{a}	28.8^{abc}	24.3^{a}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	29.6^{ab}	35.5^{a}	32.5^{a}	13.7^{a}	8.6^{abcde}	11.1^{a}	31.4^{bc}	15.7^{a}	23.5^{c}	22.4^{a}
14	T_{12} (No summer cowpea)	28.7^{ab}	30.0^{a}	29.3^{a}	17.2^{a}	5.7^{e}	11.5^{a}	36.1^{abc}	19.3^{a}	27.7^{abc}	22.8^{a}
15	T_2 (No summer cowpea)	34.3^{ab}	30.5^{a}	32.4^{a}	15.0^{a}	10.6^{ab}	12.8^{a}	28.3^{c}	20.4^{a}	24.4^{bc}	23.2^{a}
16	T_{13} (No summer cowpea)	21.7^{ab}	26.9^{a}	24.3^{a}	17.9^{a}	9.5^{abcd}	13.7^{a}	33.4^{bc}	17.5^{a}	25.4^{abc}	21.1^{a}
	Mean	**26.9**	**27.5**	**27.2**	**17.6**	**8.3**	**13.0**	**34.0**	**18.6**	**26.3**	**22.2**
	CD for comparison of season			NS			3.1			7.0	11.5
Sub table 4.43 a. Effect of cropping system											
	R-R-Fallow	28.2	29.1	28.7	-	8.6	8.6	32.6	19.0	25.8	23.5
	R-R-cowpea	28.0	28.9	28.4	-	9.0	9.0	33.7	17.8	25.8	23.5
		NS	NS	NS	-	NS	NS	NS	NS	NS	NS
Sub table 4.43b. Effect of Kharif straw incorporation											
	Without straw	23.3	28.1	25.7	17.7	9.6	13.7	32.4	16.9	24.7	21.3
	With straw	29.5	27.8	28.6	13.7	7.1	10.4	35.3	17.8	26.6	21.9
		Sig	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.43 c. Effect of silica											
	Without silica	26.9	26.8	26.9	19.8	9.2	12.0	31.7	19.8	25.8	21.6
	With silica	25.5	28.8	24.7	15.5	8.2	11.9	34.7	15.2	25.0	20.5
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.43d. Effect of higher dose of K											
	K35	25.5	23.9	24.7	17.2	8.7	10.4	32.9	14.3	23.6	19.6
	K70	27.0	31.8	26.9	18.2	8.7	13.5	33.5	20.7	27.1	22.5
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

During *kharif* 1998-'99, soil application of Mg decreased NH_4-N of the soil from 37.3 kg ha^{-1} to 19.4 kg ha^{-1}. Incorporation of *kharif* straw brought about significant increase in the NH_4-N status (Sub table 4.43 b).

During *rabi* 1998-'99, application of higher dose of K increased the NH_4 -N content, but when the higher dose was combined with silica, NH_4-N content in soil showed a significant decrease. During summer 1998, T_9 (Straw +NPK +Si + soil application of $ZnSO_4$, $MgSO_4$ and $CuSO_4$) registered higher NH_4-N than T_2, T_3, T_4, T_5, T_7, T_{10}, T_{13}, T_{15} and T_{16} whereas T_{13} had lower NH_4-N than T_8, T_9, T_{11} and T_{12}. The treatments did not impart remarkable influence on NH_4-N content of soil during the other seasons

4.1.6.3. Nitrate nitrogen

The data pertaining to the soil status of nitrate nitrogen at the end of each crop are depicted in Table 4.44.

The mean values of NO_3- N content in the soil showed that at the end of *kharif* season it was 29.0 kg ha^{-1}. The values were 15.2 kg ha^{-1} and 16.9 kg ha^{-1} respectively in *rabi* and summer.

During *kharif* 1999-'00, incorporation of *kharif* straw brought about a significant reduction in NO_3-N content of soil (Sub table 4.44 b). Also application of silica along with higher K dose decreased the content.

The various treatments did not manifest any significant influence during the other seasons.

4.1.6.4. Available phosphorous

The data pertaining to the soil status of available phosphorous at the end of each crop are depicted in Table 4.45.

The mean value of available P at the end of *kharif* crop was 51.3 kg ha^{-1}. At the end of *rabi* it was 37.2 kg ha^{-1} and in summer it was 45.0 kg ha^{-1}.

In summer 1998, *kharif* straw incorporation brought about significant increase in available P content of soil. During *kharif* 1998-'99, silica application resulted in a decrease of P content (Sub tables 4.45). In summer 1999, application of silica along with higher K dose resulted in significant increase in soil available P status. Foliar application of Zn, Mg and Cu

Table 4.44. Effect of season and treatments on nitrate nitrogen content (kg ha^{-1}) in the soil at the end of each crop

Sl.No	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1998-99	*Summer* 1998
1	Straw alone	22.5^{abc}	21.7^{b}	22.1^{b}	10.8^{bc}	12.5^{a}
2	NPK alone	22.7^{abc}	37.6^{ab}	30.2^{ab}	11.9^{bc}	13.3^{a}
3	Straw + NPK	27.4^{abc}	36.5^{ab}	32.0^{ab}	17.5^{abc}	18.1^{a}
4	Straw + NPK (higher dose of K)	14.2^{c}	52.2^{a}	33.2^{ab}	15.7^{abc}	17.8^{a}
5	Straw + NPK + Si	15.0^{bc}	47.7^{ab}	31.4^{ab}	14.4^{abc}	24.1^{a}
6	Straw + NPK (higher dose of K)+ Si	24.3^{abc}	21.7^{b}	23.0^{b}	17.6^{abc}	10.3^{a}
7	Straw + NPK + Si + Zn	31.6^{abc}	28.3^{ab}	30.0^{ab}	16.5^{abc}	19.4^{a}
8	Straw + NPK + Si + Zn +Mg	21.3^{abc}	37.4^{ab}	29.3^{ab}	12.5^{abc}	17.0^{a}
9	Straw + NPK + Si + Zn +Mg+Cu	21.4^{abc}	35.6^{ab}	28.5^{ab}	15.6^{abc}	13.0^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	14.3^{c}	21.8^{b}	18.1^{b}	13.4^{abc}	15.5^{a}
11	T_{10}+ Boron	25.9^{abc}	34.5^{ab}	30.2^{ab}	16.4^{abc}	12.8^{a}
12	T_{11}+ Mo	32.0^{a}	22.1^{b}	27.0^{ab}	10.6^{c}	18.3^{a}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	34.0^{a}	48.8^{ab}	41.4^{a}	16.6^{abc}	26.5^{a}
14	T_{12} (No summer cowpea)	31.5^{abc}	41.2^{ab}	36.4^{ab}	19.0^{a}	14.1^{a}
15	T_{2} (No summer cowpea)	24.0^{abc}	29.6^{ab}	26.8^{ab}	17.6^{abc}	19.4^{a}
16	T_{13} (No summer cowpea)	36.0^{ab}	31.4^{ab}	33.7^{ab}	17.7^{ab}	18.9^{a}
	Mean	**23.6**	**34.3**	**29.0**	**15.2**	**16.9**
	CD for comparison of season			8.0		
Sub table 4.44 a. Effect of cropping system						
	R-R-Fallow	30.5	34.0	32.3	18.1	17.5
	R-R-cowpea	29.6	36.2	32.9	13.0	19.4
		NS	NS	NS	NS	NS
Sub table 4.44b. Effect of Kharif straw incorporation						
	Without straw	30.9	39.3	35.1	15.4	19.6
	With straw	30.3	33.3	31.8	15.7	16.8
		NS	Sig	NS	NS	NS
Sub table 4.44 c. Effect of silica						
	Without silica	20.8	44.4	32.6	16.6	18.0
	With silica	19.7	34.7	27.2	16.0	17.2
		NS	Sig	Sig	NS	NS
Sub table 4.44d. Effect of higher dose of K						
	K35	21.2	42.1	31.7	16.0	21.1
	K70	19.3	37.0	28.1	16.6	14.1
		NS	NS	NS	NS	NS

Table 4. 45. Effect of season and treatments on available phosphorous (kg ha^{-1}) in the soil at the end of each crop

Sl.No	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	*Summer* 1998	*Summer* 1999	*Summer* mean	pooled mean
1	Straw alone	51.1^{a}	49.4^{a}	50.2^{a}	21.2^{c}	46.9^{a}	37.7^{a}	35.3^{a}	43.6^{a}	48.4^{bcde}	46.0^{ab}	42.6^{abc}
2	NPK alone	57.3^{a}	49.3^{a}	53.3^{a}	22.8^{bc}	43.7^{a}	37.4^{a}	34.6^{a}	36.2^{a}	49.1^{bcde}	42.6^{b}	42.3^{abc}
3	Straw + NPK	59.6^{a}	49.7^{a}	54.7^{a}	32.6^{abc}	46.1^{a}	37.0^{a}	38.6^{a}	47.4^{a}	51.5^{bc}	49.4^{ab}	46.3^{ab}
4	Straw + NPK (higher dose of K)	61.8^{a}	51.9^{a}	56.8^{a}	26.3^{abc}	50.8^{a}	37.6^{a}	38.3^{a}	46.6^{a}	48.5^{bcde}	47.4^{ab}	46.2^{ab}
5	Straw + NPK + Si	49.3^{a}	51.3^{a}	50.3^{a}	33.4^{ab}	43.5^{a}	34.5^{a}	37.1^{a}	39.9^{a}	48.3^{bcde}	44.2^{ab}	42.9^{abc}
6	Straw + NPK (higher dose of K)+ Si	56.4^{a}	48.0^{a}	52.2^{a}	29.4^{abc}	48.5^{a}	37.4^{a}	38.4^{a}	49.7^{a}	59.1^{a}	54.4^{a}	47.0^{a}
7	Straw + NPK + Si + Zn	52.6^{a}	47.6^{a}	50.1^{a}	32.4^{abc}	41.2^{a}	37.0^{a}	36.8^{a}	42.9^{a}	50.8^{bcd}	46.9^{ab}	43.5^{abc}
8	Straw + NPK + Si + Zn +Mg	55.3^{a}	47.2^{a}	51.2^{a}	37.2^{a}	42.3^{a}	37.3^{a}	38.9^{a}	45.8^{a}	48.8^{bcde}	47.3^{ab}	44.8^{abc}
9	Straw + NPK + Si + Zn +Mg+Cu	51.5^{a}	48.0^{a}	49.8^{a}	32.8^{abc}	43.9^{a}	38.3^{a}	38.3^{a}	38.3^{a}	43.9^{de}	41.1^{b}	42.4^{abc}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	58.9^{a}	52.4^{a}	55.7^{a}	33.5^{ab}	48.5^{a}	40.0^{a}	40.7^{a}	33.5^{a}	54.5^{ab}	44.0^{ab}	45.9^{ab}
11	T_{10}+ Boron	50.2^{a}	46.6^{a}	48.4^{a}	25.8^{abc}	45.8^{a}	35.3^{a}	35.6^{a}	40.5^{a}	48.9^{bcde}	44.7^{ab}	41.9^{abc}
12	T_{11}+ Mo	53.3^{a}	42.3^{a}	47.8^{a}	27.6^{abc}	45.0^{a}	34.9^{a}	35.9^{a}	43.5^{a}	47.4^{cde}	45.4^{ab}	42.0^{abc}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	49.7^{a}	47.4^{a}	48.6^{a}	35.7^{a}	45.2^{a}	34.2^{a}	38.6^{a}	32.3^{a}	50.1^{bcd}	41.2^{b}	42.2^{abc}
14	T_{12} (No summer cowpea)	59.1^{a}	48.9^{a}	54.0^{a}	31.0^{abc}	41.3^{a}	38.0^{a}	36.8^{a}	41.6^{a}	49.5^{bcde}	45.5^{ab}	44.2^{abc}
15	T_{2} (No summer cowpea)	52.0^{a}	47.4^{a}	49.7^{a}	30.5^{abc}	38.9^{a}	34.9^{a}	34.8^{a}	33.4^{a}	42.8^{e}	38.1^{b}	40.0^{c}
16	T_{13} (No summer cowpea)	54.4^{a}	42.8^{a}	48.6^{a}	32.3^{abc}	41.8^{a}	33.7^{a}	35.9^{a}	39.0^{a}	44.8^{cde}	41.9^{b}	41.2^{bc}
	Mean	**54.5**	**48.1**	**51.3**	**30.3**	**44.7**	**36.6**	**37.2**	**40.9**	**49.2**	**45.0**	**43.5**
	CD for comparison of season			NS				NS			4.3	7.9
Sub table 4.45 a. Effect of cropping system												
	R-R-Fallow	55.2	46.4	50.8	-	40.7	35.5	38.1	38.0	45.7	41.8	43.6
	R-R-cowpea	53.5	46.3	49.9	-	45.0	35.5	40.2	37.3	48.8	43.1	44.4
		NS	NS	NS	-	NS	NS	NS	NS	NS	NS	NS
Sub table 4.45b. Effect of Kharif straw incorporation												
	Without straw	53.8	46.5	50.2	30.3	43.8	35.1	36.4	35.8	48.0	41.9	41.9
	With straw	57.3	47.0	52.2	30.4	44.2	36.6	37.1	44.1	49.5	46.8	44.2
		NS	NS	NS	NS	NS	NS	NS	Sig	NS	Sig	NS
Sub table 4.45 c. Effect of silica												
	Without silica	60.7	50.8	55.7	29.5	48.5	37.3	38.4	47.0	49.9	48.4	46.2
	With silica	52.9	49.7	51.3	31.4	46.0	36.0	37.8	44.8	53.8	49.3	44.9
		Sig	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.45d. Effect of higher dose of K												
	K35	54.4	50.5	52.5	33.0	44.8	35.7	37.8	43.6	50.0	46.8	44.6
	K70	59.1	50.0	54.5	27.9	49.7	37.5	37.0	48.2	53.7	50.9	46.0
		NS	NS	NS	NS	NS	NS	NS	NS	NS	Sig	NS

increased the P status significantly compared to their soil application. The treatments did not manifest any significant variation in P status of soil during the other seasons.

4.1.6.5. Available potassium

The data pertaining to the soil status of available potassium at the end of each crop are depicted in Table 4.46.

The mean content of available K at the end of *kharif* crop was 94 kg ha^{-1}. In *rabi* and summer the contents were 77 kg ha^{-1} and 58 kg·ha^{-1} respectively. Significant variations in the K status were noticed among the three *rabi* seasons. In *rabi* 1997-'98 K content recorded was 101 kg ha^{-1}. Other two *rabi* seasons registered significantly lower values.

During *kharif* 1998-'99, both silica application as well as higher K dose resulted in significant increase in K content of the soil. During *kharif* 1999-'00 also, higher K dose increased the K status of soil (Sub tables 4.46).

During *rabi* 1997-'98, *kharif* straw incorporation as well as silica application increased the K status of the soil significantly (Sub table 4.46 b). During *rabi* 1999-'00 also application of higher K dose brought about increase in K content of the soil from 60 kg ha^{-1} to 83 kg ha^{-1}. During *rabi* 1998-'99, T_{15} which received NPK alone had a significantly lower content of 44 kg ha^{-1} than T_4, T_5 and T_{10}.

4.1.6.6. Exchangeable calcium

The data pertaining to the soil status of exchangeable calcium at the end of each crop are depicted in Table 4.47.

The mean level of exchangeable Ca in the soil at the end of *kharif* season was 2.12 m.eq/100g soil. In *rabi* it was 1.48 m.eq/100 g and in summer 1.36 m.eq./100 g.

The *kharif* seasons did not show any variations among themselves, but significant variations were noticed among *rabi* and summer seasons. Thus during *rabi* 1997-'98, the amount of exchangeable Ca recorded was 1.44 m.eq. In *rabi* 1998-'99, it was significantly lower whereas in *rabi* 1999-'00 significantly higher content of 1.89 m.eq was observed.

Table 4. 46. Effect of season and treatments on available potassium (kg ha^{-1}) in the soil at the end of each crop

Sl.No	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	*Summer* 1998	*Summer* 1999	*Summer* mean	pooled mean
1	Straw alone	92^{ab}	109^{a}	100^{ab}	99^{abc}	69^{ab}	83^{a}	84^{ab}	73^{ab}	69^{a}	71^{a}	85^{abc}
2	NPK alone	88^{ab}	99^{a}	94^{ab}	71^{bc}	59^{ab}	59^{ab}	63^{bc}	63^{ab}	60^{ab}	62^{ab}	71^{bcd}
3	Straw + NPK	81^{ab}	88^{a}	85^{ab}	94^{abc}	56^{ab}	55^{ab}	68^{abc}	83^{a}	44^{bcd}	63^{ab}	71^{abcd}
4	Straw + NPK (higher dose of K)	103^{ab}	110^{a}	106^{a}	108^{abc}	75^{a}	83^{a}	89^{a}	71^{ab}	60^{ab}	66^{ab}	87^{a}
5	Straw + NPK + Si	100^{ab}	96^{a}	98^{ab}	132^{a}	73^{a}	66^{ab}	90^{a}	67^{ab}	44^{bcd}	55^{ab}	82^{abc}
6	Straw + NPK (higher dose of K)+ Si	109^{ab}	105^{a}	107^{a}	125^{ab}	65^{ab}	83^{a}	91^{a}	75^{ab}	43^{bcd}	59^{ab}	86^{ab}
7	Straw + NPK + Si + Zn	92^{ab}	92^{a}	92^{ab}	112^{abc}	60^{ab}	64^{ab}	79^{ab}	67^{ab}	37^{d}	52^{b}	75^{abcd}
8	Straw + NPK + Si + Zn +Mg	77^{ab}	94^{a}	86^{ab}	102^{abc}	53^{ab}	63^{ab}	73^{abc}	59^{ab}	38^{cd}	49^{b}	70^{cd}
9	Straw + NPK + Si + Zn +Mg+Cu	123^{a}	95^{a}	109^{a}	102^{abc}	68^{ab}	67^{ab}	79^{ab}	74^{ab}	52^{abcd}	63^{ab}	83^{abc}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	112^{a}	90^{a}	101^{ab}	114^{abc}	81^{a}	71^{ab}	88^{a}	64^{ab}	57^{abc}	60^{ab}	84^{abc}
11	T_{10}+ Boron	81^{ab}	100^{a}	90^{ab}	99^{abc}	62^{ab}	73^{ab}	78^{ab}	63^{ab}	52^{abcd}	57^{ab}	75^{abcd}
12	T_{11}+ Mo	94^{ab}	86^{a}	90^{ab}	91^{abc}	57^{ab}	76^{ab}	75^{ab}	63^{ab}	54^{abcd}	58^{ab}	74^{abcd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	90^{ab}	94^{a}	92^{ab}	108^{abc}	56^{ab}	60^{ab}	75^{ab}	69^{ab}	38^{cd}	54^{ab}	74^{abcd}
14	T_{12} (No summer cowpea)	101^{ab}	95^{a}	98^{ab}	116^{abc}	60^{ab}	65^{ab}	81^{ab}	68^{ab}	46^{bcd}	57^{ab}	79^{abcd}
15	T_2 (No summer cowpea)	58^{b}	76^{a}	67^{b}	63^{c}	44^{ab}	47^{b}	51^{a}	53^{b}	44^{bcd}	48^{b}	55^{e}
16	T_{13} (No summer cowpea)	93^{ab}	86^{a}	90^{ab}	74^{abc}	56^{ab}	58^{ab}	63^{bc}	59^{ab}	37^{d}	48^{b}	66^{de}
	Mean	**93**	**95**	**94**	**101**	**62**	**67**	77	67	**48**	**58**	**76**
	CD for comparison of season			NS				21			NS	16
Sub table 4.46 a. Effect of cropping system												
	R-R-Fallow	84	86	85	-	53	57	55	60	42	51	64
	R-R-cowpea	91	93	92	-	57	65	61	65	51	58	70
		NS	NS	NS	-	NS	NS	NS	NS	NS	Sig	NS
Sub table 4.46b. Effect of Kharif straw incorporation												
	Without straw	90	93	92	85	57	59	67	64	45	55	70
	With straw	92	90	91	100	58	65	75	71	48	60	75
		NS	NS	NS	Sig	NS	NS	NS	NS	NS	Sig	NS
Sub table 4.46 c. Effect of silica												
	Without silica	92	99	95	101	66	69	78	77	52	64	79
	With silica	104	101	102	128	69	74	91	71	43	57	84
		Sig	NS	NS	Sig	NS	NS	NS	NS	NS	Sig	NS
Sub table 4.46d. Effect of higher dose of K												
	K35	90	92	91	113	64	60	79	75	44	59	77
	K70	106	108	107	116	70	83	90	73	52	62	87
		Sig	Sig	Sig	NS	NS	Sig	NS	NS	NS	NS	Sig

Table 4. 47. Effect of season and treatments on exchangeable calcium (m.eq./100g) in the soil at the end of each crop

Sl.No	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Summer 1998	Summer 1999	Summer mean	pooled mean
1	Straw alone	2.20^{a}	1.50^{d}	1.85^{c}	1.80^{a}	1.14^{ab}	2.04^{a}	1.66^{a}	1.79^{ab}	1.00^{abcd}	1.40^{abc}	1.64^{abcd}
2.	NPK alone	2.12^{a}	2.32^{ab}	2.22^{abc}	1.43^{abc}	1.22^{ab}	2.02^{a}	1.55^{ab}	1.72^{abc}	1.09^{abc}	1.40^{abc}	1.70^{abc}
3	Straw + NPK	2.23^{a}	2.05^{abcd}	2.14^{abc}	1.21^{c}	1.22^{ab}	1.80^{ab}	1.41^{abc}	1.80^{ab}	1.00^{abcd}	1.40^{abc}	1.61^{abcd}
4	Straw + NPK (higher dose of K)	2.42^{a}	2.60^{a}	2.51^{a}	1.33^{abc}	1.04^{ab}	1.96^{a}	1.44^{abc}	1.63^{abc}	0.99^{abcd}	$.31^{abcd}$	1.71^{ab}
5	Straw + NPK + Si	2.03^{a}	2.44^{ab}	2.23^{abc}	1.22^{bc}	1.08^{ab}	2.00^{a}	1.43^{abc}	1.84^{a}	1.07^{abcd}	1.45^{ab}	1.67^{abc}
6	Straw + NPK (higher dose of K)+ Si	2.37^{a}	2.43^{ab}	2.40^{ab}	1.74^{ab}	1.03^{ab}	1.88^{ab}	1.55^{ab}	1.93^{a}	0.97^{abcd}	1.45^{ab}	1.76^{a}
7	Straw + NPK + Si + Zn	2.15^{a}	2.18^{abcd}	2.16^{abc}	1.72^{abc}	1.28^{a}	1.94^{ab}	1.65^{ab}	1.78^{ab}	1.04^{abcd}	1.41^{abc}	1.73^{a}
8	Straw + NPK + Si + Zn +Mg	1.97^{a}	2.13^{abcd}	2.05^{bc}	1.29^{abc}	1.20^{ab}	2.05^{a}	1.51^{abc}	1.65^{abc}	0.97^{abcd}	$.31^{abcd}$	1.61^{abcd}
9	Straw + NPK + Si + Zn +Mg+Cu	2.29^{a}	1.85^{bcd}	2.07^{abc}	1.38^{abc}	1.09^{ab}	1.85^{ab}	1.44^{abc}	1.60^{abc}	1.05^{abcd}	$.33^{abcd}$	1.59^{abcde}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	2.12^{a}	1.88^{bcd}	2.00^{bc}	1.24^{bc}	1.07^{ab}	1.96^{a}	1.42^{abc}	1.75^{ab}	1.12^{ab}	1.43^{abc}	1.59^{abcde}
11	T_{10}+ Boron	2.08^{a}	1.77^{bcd}	1.92^{c}	1.58^{abc}	1.20^{ab}	2.05^{a}	1.61^{ab}	1.79^{ab}	1.15^{a}	1.50^{a}	1.66^{abc}
12	T_{11}+ Mo	1.82^{a}	1.96^{abcd}	1.89^{c}	1.27^{bc}	1.04^{ab}	1.47^{b}	1.26^{c}	1.38^{bc}	0.88^{cd}	1.15^{de}	1.40^{f}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	2.17^{a}	2.01^{abcd}	2.13^{abc}	1.20^{c}	0.95^{ab}	1.61^{ab}	1.25^{c}	1.85^{a}	0.88^{cd}	1.39^{abcd}	1.53^{bcdef}
14	T_{12} (No summer cowpea)	1.95^{a}	1.63^{cd}	1.79^{c}	1.36^{abc}	1.13^{ab}	1.79^{ab}	1.42^{abc}	1.55^{abc}	0.85^{d}	1.22^{cde}	1.46^{def}
15	T_2 (No summer cowpea)	1.87^{a}	1.86^{bcd}	1.86^{c}	1.33^{abc}	0.85^{b}	1.64^{ab}	1.27^{c}	1.54^{abc}	0.90^{bcd}	1.24^{bcde}	1.43^{ef}
16	T_{13} (No summer cowpea)	2.08^{a}	2.20^{abc}	2.14^{abc}	1.52^{abc}	1.02^{ab}	1.63^{ab}	1.39^{bc}	1.32^{c}	0.92^{bcd}	1.14^{e}	1.52^{cdef}
	Mean	**2.11**	**2.05**	**2.08**	**1.41**	**1.09**	**1.85**	**1.45**	**1.68**	**0.99**	**1.36**	**1.60**
	CD for comparison of season			NS			0.10				0.21	0.19
Sub table 4.47 a. Effect of cropping system												
	R-R-Fallow	1.96	1.90	1.93	-	1.00	1.68	1.34	1.47	0.89	1.18	1.48
	R-R-cowpea	2.03	2.12	2.08	-	1.07	1.70	1.38	1.65	0.95	1.30	1.59
		NS	Sig	NS		NS	NS	NS	Sig	NS	Sig	Sig
Sub table 4.47b. Effect of Kharif straw incorporation												
	Without straw	2.12	2.20	2.16	1.38	1.06	1.75	1.40	1.63	0.96	1.29	1.59
	With straw	2.00	1.88	1.94	1.28	1.13	1.69	1.36	1.58	0.91	1.24	1.49
		NS	Sig	Sig	NS	NS	NS	NS	NS	NS	NS	Sig
Sub table 4.47 c. Effect of silica												
	Without silica	2.32	2.32	2.32	1.27	1.13	1.88	1.42	1.71	0.99	1.35	1.66
	With silica	2.20	2.43	2.31	1.48	1.05	1.94	1.49	1.88	1.02	1.45	1.71
		NS	NS	NS	Sig	NS	NS	NS	Sig	NS	Sig	NS
Sub table 4.47d. Effect of higher dose of K												
	K35	2.13	2.25	2.19	1.21	1.15	1.90	1.42	1.82	1.03	1.43	1.64
	K70	2.39	2.51	2.45	1.53	1.03	1.92	1.49	1.78	0.98	1.38	1.73
		NS	NS	Sig	Sig	NS	NS	NS	NS	NS	NS	NS

During *kharif* 1998-'99, treatments did not manifest any significant difference, while in *kharif* 1999-'00 raising of summer cowpea in the system resulted in a significant increase in the content. On the contrary, incorporation of *kharif* straw decreased the Ca level in the soil (Sub table 4.47 b).

During *rabi* 1997-'98, application of silica as well as higher K dose brought about significant increase in the exchangeable Ca level of the soil (Sub tables 4.47). During *rabi* 1999-'000 foliar spray of Mo decreased the Ca content from 2.09 m.eq to 1.50 m.eq/100 g soil.

During summer 1998, raising of summer cowpea as well as silica application brought about a significant increase in exchangeable Ca of soil (Sub tables 4.47). In summer 1999 foliar spray of Mo decreased the Ca content from 1.17 m.eq to 0.89 m.eq/100 g soil.

4.1.6.7. Exchangeable magnesium

The data pertaining to the soil status of exchangeable magnesium at the end of each crop are depicted in Table 4.48.

The mean values of exchangeable Mg at the end of *kharif*, *rabi* and summer seasons were 0.31 m.eq, 0.30 m.eq and 0.23 meg/100g soil.

The mean contents within the *kharif* and summer seasons themselves did not show any variation, but *rabi* seasons showed differences. Thus *rabi* 1997-'98 and *rabi* 1998-'99 had exchangeable Mg of 0.31 m.eq and 0.19 m.eq respectively whereas a significantly higher level of 0.41 m.eq was reported in *rabi* 1999-'00.

During *kharif* 1998-'99, *kharif* straw incorporation significantly decreased the exchangeable Mg status of the soil. During *kharif* 1999-'00, application of silica as well as higher dose of K decreased Mg level (Sub table 4.48). Soil application of Mg also decreased Mg level.

During *rabi* 1999-'00, raising of summer cowpea resulted in increased content of exchangeable Mg in the soil (Sub tables 4.48).

During *rabi* 1997-'98 and summer 1999, the treatments did not manifest any variations. During *rabi* 1998-'99 T_3 and T_{12} had significantly lower Mg status than T_6 (Straw +NPK +Si with higher K dose). During

Table 4. 48. Effect of season and treatments on exchangeable magnesium (m.eq./100g) in the soil at the end of each crop

Sl.No	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	*Summer* 1998	*Summer* 1999	*Summer* mean	pooled mean
1	Straw alone	0.29^{b}	0.20^{cd}	0.24^{def}	0.25^{a}	0.17^{abc}	0.28^{a}	0.23^{a}	0.26^{ab}	0.18^{a}	0.22^{abc}	0.23^{ab}
2	NPK alone	0.23^{bc}	0.13^{d}	0.18^{f}	0.43^{a}	0.15^{abc}	0.34^{a}	0.30^{a}	0.241^{ab}	0.23^{a}	0.24^{abc}	0.24^{ab}
3	Straw + NPK	0.20^{bc}	0.72^{a}	0.46^{a}	0.32^{a}	0.11^{c}	0.41^{a}	0.28^{a}	0.27^{ab}	0.16^{a}	0.21^{abc}	0.31^{ab}
4	Straw + NPK (higher dose of K)	0.28^{bc}	0.36^{bcd}	0.32^{bcde}	0.25^{a}	0.18^{abc}	0.33^{a}	0.25^{a}	0.23^{ab}	0.22^{a}	0.22^{abc}	0.26^{ab}
5	Straw + NPK + Si	0.24^{bc}	0.41^{bc}	0.33^{abcd}	0.33^{a}	0.20^{abc}	0.36^{a}	0.29^{a}	0.29^{ab}	0.18^{a}	0.23^{abc}	0.28^{abc}
6	Straw + NPK (higher dose of K)+ Si	0.31^{ab}	0.13^{d}	0.22^{ef}	0.22^{a}	0.27^{a}	0.22^{a}	0.24^{a}	0.27^{ab}	0.20^{a}	0.23^{abc}	0.22^{ab}
7	Straw + NPK + Si + Zn	0.30^{ab}	0.47^{b}	0.39^{abc}	0.28^{a}	0.16^{abc}	0.50^{a}	0.32^{a}	0.42^{a}	0.21^{a}	0.31^{a}	0.34^{a}
8	Straw + NPK + Si + Zn +Mg	0.27^{bc}	0.16^{d}	0.21^{ef}	0.25^{a}	0.20^{abc}	0.38^{a}	0.28^{a}	0.18^{b}	0.17^{a}	0.17^{c}	0.23^{ab}
9	Straw + NPK + Si + Zn +Mg+Cu	0.27^{bc}	0.34^{bcd}	0.30^{bcde}	0.29^{a}	0.18^{abc}	0.53^{a}	0.33^{a}	0.34^{ab}	0.24^{a}	0.29^{ab}	0.31^{ab}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	0.33^{ab}	0.42^{bc}	0.38^{abcd}	0.31^{a}	0.18^{abc}	0.55^{a}	0.34^{a}	0.23^{ab}	0.22^{a}	0.23^{abc}	0.31^{ab}
11	T_{10}+ Boron	0.29^{b}	0.44^{b}	0.36^{abcd}	0.37^{a}	0.20^{abc}	0.46^{a}	0.34^{a}	0.33^{ab}	0.21^{a}	0.27^{abc}	0.32^{ab}
12	T_{11}+ Mo	0.27^{bc}	0.30^{bcd}	0.29^{cdef}	0.33^{a}	0.11^{c}	0.53^{a}	0.33^{a}	0.25^{ab}	0.21^{a}	0.23^{abc}	0.28^{ab}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	0.44^{a}	0.43^{bc}	0.43^{ab}	0.26^{a}	0.23^{abc}	0.45^{a}	0.31^{a}	0.17^{b}	0.21^{a}	0.19^{bc}	0.31^{ab}
14	T_{12} (No summer cowpea)	0.14^{c}	0.28^{bcd}	0.21^{ef}	0.33^{a}	0.14^{bc}	0.33^{a}	0.27^{a}	0.15^{b}	0.17^{a}	0.16^{c}	0.21^{ab}
15	T_{2} (No summer cowpea)	0.28^{bc}	0.17^{d}	0.23^{ef}	0.38^{a}	0.26^{ab}	0.20^{a}	0.28^{a}	0.17^{b}	0.19^{a}	0.18^{c}	0.23^{ab}
16	T_{13} (No summer cowpea)	0.33^{ab}	0.41^{bc}	0.37^{abcd}	0.38^{a}	0.17^{abc}	0.43^{a}	0.32^{a}	0.30^{ab}	0.20^{a}	0.25^{abc}	0.31^{ab}
	Mean	**0.28**	**0.33**	**0.31**	**0.31**	**0.18**	**0.39**	**0.29**	**0.26**	**0.20**	**0.23**	**0.28**
	CD for comparison of season			NS				0.15			NS	0.09
Sub table 4.48 a. Effect of cropping system												
	R-R-Fallow	0.25	0.29	0.27	-	0.19	0.32	0.25	0.21	0.18	0.20	0.24
	R-R-cowpea	0.31	0.28	0.30	-	0.16	0.44	0.30	0.22	0.22	0.22	0.27
		NS	NS	NS		NS	Sig	NS	NS	NS	NS	NS
Sub table 4.48b. Effect of Kharif straw incorporation												
	Without straw	0.33	0.32	0.33	0.35	0.18	0.41	0.31	0.24	0.21	0.23	0.29
	With straw	0.20	0.43	0.32	0.33	0.12	0.42	0.29	0.22	0.18	0.20	0.27
		Sig	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.48 c. Effect of silica												
	Without silica	0.24	0.54	0.39	0.28	0.14	0.37	0.27	0.25	0.19	0.22	0.29
	With silica	0.28	0.27	0.27	0.27	0.24	0.29	0.27	0.28	0.19	0.23	0.26
		NS	Sig	Sig	NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.48d. Effect of higher dose of K												
	K35	0.22	0.57	0.39	0.32	0.16	0.38	0.29	0.28	0.17	0.22	0.30
	K70	0.30	0.24	0.27	0.23	0.22	0.28	0.24	0.25	0.21	0.23	0.25
		NS	Sig	Sig	NS	NS	NS	NS	NS	NS	NS	Sig

summer 1998 T_7 (Straw +NPK +Si + soil application of $ZnSO_4$) registered significantly higher content than T_8, T_{13}, T_{14} and T_{15}.

4.1.6.8. Available Sulphur

The data pertaining to the soil status of available sulphur at the end of each crop are depicted in Table 4.49.

The mean values of available sulphur in the soil at the end of *kharif*, *rabi* and summer seasons were 96 kg ha^{-1}, 74 kg ha^{-1} and 87 kg ha^{-1} respectively.

The two *kharif* seasons did not differ between themselves in the mean content of S whereas *rabi* and summer seasons showed variations. Thus *rabi* 1997-'98 and 1998-'99 had S status of 87 and 89 kg ha^{-1} respectively while significantly lower content of 46 kg ha^{-1} was recorded in *rabi* 1999-'00. Similarly in summer 1998 S status of soil was 74 kg ha^{-1} while summer 1999 had 101 kg ha^{-1}.

During *kharif* 1998-'99, raising of summer cowpea significantly reduced the S status of the soil whereas *kharif* straw incorporation resulted in increasing the content. During *kharif* 1999-'00, *kharif* straw incorporation has decreased the S level while silica application increased the S status from 79 kg ha^{-1} to 102 kg ha^{-1} (Sub table 4.49). Mg application resulted in a significant increase.

During *rabi* 1999-'00, *kharif* straw incorporation significantly reduced S content while silica application resulted in increasing the level. On the contrary, higher dose of K decreased the available S status of the soil (Sub table 4.48). Soil application of Mg significantly reduced the available S in the soil.

During *rabi* 1997-'98, S content in T_6 (117 kg ha^{-1}) was significantly higher than T_1, T_2, T_3, T_5, T_{10} and T_{11}. In summer 1999, the straw alone treatment was inferior to T_3, T_6, T_7 and T_8 in the S status of soil.

4.1.6.9. Available iron

The data pertaining to the soil status of available iron at the end of each crop are depicted in Table 4.50.

Table 4. 49. Effect of season and treatments on available sulphur (kg ha^{-1}) in the soil at the end of each crop

Sl.No	Treatment	*Kharif* 998-9	*Kharif* 1999-0	*Kharif* mean	*Rabi* 1997-9	*Rabi* 1998-9	*Rabi* 999-0	*Rabi* mean	*Summer* 1998	*Summer* 1999	*Summer* mean	pooled mean
1	Straw alone	83^{bc}	101^{abc}	92^{bcd}	71^{b}	82^{a}	45^{bcde}	65^{abcd}	53^{a}	67^{b}	60^{b}	72^{d}
2	NPK alone	99^{abc}	105^{ab}	102^{abc}	74^{b}	90^{a}	53^{abc}	72^{abcd}	82^{a}	99^{ab}	90^{a}	86^{abc}
3	Straw + NPK	91^{abc}	78^{c}	85^{cd}	76^{b}	94^{a}	50^{bc}	73^{abcd}	82^{a}	115^{a}	98^{a}	84^{abcd}
4	Straw + NPK (higher dose of K)	101^{abc}	80^{bc}	90^{bcd}	79^{ab}	74^{a}	34^{e}	62^{d}	87^{a}	99^{ab}	93^{a}	79^{bcd}
5	Straw + NPK + Si	101^{abc}	95^{abc}	98^{abcd}	69^{b}	96^{a}	62^{a}	76^{abcd}	77^{a}	96^{ab}	86^{a}	85^{abc}
6	Straw + NPK (higher dose of K)	101^{abc}	110^{a}	106^{ab}	117^{a}	86^{a}	45^{bcde}	83^{ab}	77^{a}	126^{a}	101^{a}	95^{a}
7	Straw + NPK + Si + Zn	107^{abc}	78^{c}	93^{abcd}	82^{ab}	96^{a}	62^{a}	80^{abc}	82^{a}	123^{a}	102^{a}	90^{ab}
8	Straw + NPK + Si + Zn +Mg	110^{ab}	113^{a}	112^{a}	97^{ab}	86^{a}	37^{de}	74^{abcd}	74^{a}	113^{a}	94^{a}	90^{ab}
9	Straw + NPK + Si + Zn +Mg+C	106^{abc}	95^{abc}	100^{abc}	98^{ab}	97^{a}	36^{de}	77^{abcd}	69^{a}	103^{ab}	86^{a}	86^{abc}
10	Straw + NPK + Si +Foliar Zn,M	116^{a}	96^{abc}	106^{ab}	76^{b}	89^{a}	42^{cde}	69^{bcd}	64^{a}	89^{ab}	76^{ab}	82^{bcd}
11	T_{10}+ Boron	108^{abc}	78^{c}	93^{abcd}	72^{b}	90^{a}	37^{de}	66^{cd}	79^{a}	106^{ab}	92^{a}	81^{bcd}
12	T_{11}+ Mo	115^{a}	78^{c}	97^{abcd}	83^{ab}	94^{a}	47^{bcd}	75^{abcd}	74^{a}	89^{ab}	82^{ab}	83^{bcd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,	80^{c}	82^{bc}	81^{d}	83^{ab}	87^{a}	45^{bcde}	72^{abcd}	55^{a}	96^{ab}	76^{ab}	76^{cd}
14	T_{12} (No summer cowpea)	116^{a}	82^{bc}	99^{abcd}	107^{ab}	81^{a}	37^{de}	75^{abcd}	76^{a}	98^{ab}	87^{a}	85^{abc}
15	T_{2} (No summer cowpea)	116^{a}	78^{c}	97^{abcd}	102^{ab}	96^{a}	45^{bcde}	81^{abc}	69^{a}	93^{ab}	81^{ab}	86^{abc}
16	T_{13} (No summer cowpea)	97^{abc}	91^{abc}	94^{abcd}	108^{ab}	93^{a}	56^{ab}	85^{a}	82^{a}	104^{ab}	93^{a}	90^{ab}
	Mean	**103**	**90**	**96**	**87**	**89**	**46**	**74**	**74**	**101**	**87**	**84**
	CD for comparison of season			NS				20			19	21
Sub table 4.49 a. Effect of cropping system												
	R-R-Fallow	110	84	97	-	90	46	68	76	98	87	84
	R-R-cowpea	98	88	93	-	90	49	69	70	95	83	82
		Sig	NS	NS	-	NS	NS	NS	NS	NS	NS	NS
Sub table 4.49b. Effect of Kharif straw incorporation												
	Without straw	92	93	92	88	90	52	77	73	100	86	84
	With straw	108	79	93	89	89	45	74	77	101	89	84
		Sig	Sig	NS	NS	NS	Sig	NS	NS	NS	NS	NS
Sub table 4.49 c. Effect of silica												
	Without silica	96	79	87	78	84	42	68	84	107	95	81
	With silica	101	102	102	93	91	53	79	77	111	94	90
		NS	Sig	Sig	NS	NS	Sig	Sig	NS	NS	NS	Sig
Sub table 4.49d. Effect of higher dose of K												
	K35	96	86	91	73	95	56	75	79	105	92	84
	K70	101	95	98	98	80	39	73	82	112	97	87
		NS	NS	NS	NS	NS	Sig	NS	NS	NS	NS	NS

The mean level of available Fe content in the soil at the end of *kharif*, *rabi* and summer seasons were 426 kg ha^{-1}, 536 kg ha^{-1} and 349 kg ha^{-1} respectively.

In *kharif* 1998-'99, the mean content of Fe was 481 kg ha^{-1} while *kharif* 1999-'00 had a significantly low level of 372 kg ha^{-1}. In *rabi* 1997-'98 the content was 394 kg ha^{-1}; *rabi* 1998-'99 and 1999-'00 registered higher contents of 739 kg ha^{-1} and 475 kg ha^{-1} respectively.

During *kharif* 1999-'00, application of silica along with higher dose of K drastically reduced Fe content from 491 kg ha^{-1} to 296 kg ha^{-1}. During *kharif* 1998-'99, T_{14} registered significantly higher Fe content than T_4.

During *rabi* 1998-'99, silica application has increased the Fe level in the soil (Sub table 4.50). During *rabi* 1999-'00, application of silica along with higher K dose reduced the Fe content from 477 kg ha-1 to 358 kg ha^{-1}. During *rabi* 1997-'98, T_6 had higher Fe status than T_{11} and T_{13}. T_3 and T_8 registered higher Fe level than T_4, T_5 and T_{10} during summer 1998 whereas in summer 1999 no variation was noticed.

4.1.6.10. Available Manganese

The data pertaining to the soil status of available manganese at the end of each crop are depicted in Table 4.51.

The mean value of available Mn content of soil during *kharif*, *rabi* and summer were 5.3 kg ha^{-1}, 4.9 kg ha^{-1} and 4.9 kg ha^{-1} respectively. Among the two *kharif* seasons, *kharif* 1998-'99 recorded significantly higher content of 6.5 kg ha^{-1} as compared to 3.5 kg ha^{-1} in *kharif* 1999-'00. During *rabi* 1997-'98, the mean Mn content was 6.1 kg ha^{-1}. *Rabi* 1998-'99 and 1999-'00 registered significantly lower contents. Summer seasons also showed significant variation among themselves. In summer 1998 the available status of Mn was 6.8 kg ha^{-1} while in summer 1999 it was 3.5 kg ha^{-1}.

During *kharif* 1998-'99 and 1999-'00 the treatments did not impart any significant variation in the soil Mn level. During *rabi* 1997-'98 incorporation

Table 4. 50. Effect of season and treatments on available iron (kg ha^{-1}) in the soil at the end of each crop

Sl.No	Treatment	*Kharif* 998-9	*Kharif* 1999-0	*Kharif* mean	*Rabi* 1997-9	*Rabi* 1998-9	*Rabi* 999-0	*Rabi* mean	*Summe* 1998	*Summe* 1999	*Summe* mean	pooled mean
1	Straw alone	468^{ab}	302^{c}	385^{bc}	486^{ab}	607^{ab}	432^{fghi}	508^{a}	271^{ab}	293^{a}	282^{a}	409^{ab}
2	NPK alone	531^{ab}	345^{abc}	438^{abc}	338^{abc}	905^{ab}	423^{ghij}	556^{a}	269^{ab}	542^{a}	405^{a}	479^{ab}
3	Straw + NPK	412^{ab}	332^{abc}	372^{bc}	361^{abc}	578^{ab}	323^{j}	420^{a}	363^{a}	376^{a}	370^{a}	392^{b}
4	Straw + NPK (higher dose of K)	401^{b}	491^{a}	446^{abc}	394^{abc}	553^{ab}	477^{cdefg}	475^{a}	224^{b}	361^{a}	292^{a}	414^{ab}
5	Straw + NPK + Si	502^{ab}	430^{abc}	466^{abc}	441^{abc}	885^{ab}	338^{ij}	555^{a}	226^{b}	484^{a}	355^{a}	472^{ab}
6	Straw + NPK (higher dose of K)	412^{ab}	296^{c}	354^{c}	508^{abc}	1015^{ab}	358^{hij}	627^{a}	280^{ab}	441^{a}	361^{a}	473^{ab}
7	Straw + NPK + Si + Zn	502^{ab}	323^{abc}	412^{abc}	345^{abc}	1124^{a}	450^{efgh}	640^{a}	269^{ab}	457^{a}	363^{a}	496^{ab}
8	Straw + NPK + Si + Zn +Mg	457^{ab}	405^{abc}	431^{abc}	421^{abc}	654^{ab}	558^{abcd}	544^{a}	363^{a}	392^{a}	377^{a}	464^{ab}
9	Straw + NPK + Si + Zn +Mg+C	493^{ab}	385^{abc}	439^{abc}	432^{abc}	1030^{ab}	412^{ghij}	625^{a}	289^{ab}	452^{a}	371^{a}	499^{ab}
10	Straw + NPK + Si +Foliar Zn,M	558^{ab}	486^{ab}	522^{a}	396^{abc}	988^{ab}	477^{defg}	620^{a}	242^{b}	399^{a}	320^{a}	507^{a}
11	T_{10}+ Boron	466^{ab}	372^{abc}	419^{abc}	327^{bc}	699^{ab}	580^{abc}	535^{a}	291^{ab}	459^{a}	375^{a}	456^{ab}
12	T_{11}+ Mo	511^{ab}	365^{abc}	438^{abc}	345^{abc}	567^{ab}	533^{bcdef}	482^{a}	264^{ab}	459^{a}	362^{a}	435^{ab}
13	NPK + Si +Foliar Zn,Mg,Cu,B,	531^{ab}	421^{abc}	476^{ab}	291^{c}	479^{b}	452^{efgh}	408^{a}	316^{ab}	452^{a}	384^{a}	420^{ab}
14	T_{12} (No summer cowpea)	571^{a}	394^{abc}	483^{ab}	473^{ab}	493^{b}	549^{abcde}	505^{a}	255^{ab}	401^{a}	328^{a}	448^{ab}
15	T_2 (No summer cowpea)	455^{ab}	284^{c}	370^{bc}	338^{abc}	549^{ab}	591^{ab}	493^{a}	255^{ab}	334^{a}	295^{a}	401^{ab}
16	T_{13} (No summer cowpea)	428^{ab}	314^{bc}	371^{bc}	408^{abc}	690^{ab}	643^{a}	580^{a}	316^{ab}	361^{a}	338^{a}	451^{ab}
	Mean	**481**	**372**	**426**	**394**	**739**	**475**	**536**	**281**	**417**	**349**	**451**
	CD for comparison of season			28				146			NS	111
Sub table 4.50 a. Effect of cropping system												
	R-R-Fallow	485	331	408	-	577	594	586	276	365	320	438
	R-R-cowpea	524	377	451	-	650	470	560	283	485	384	465
		NS	NS	NS	-	NS	NS	NS	NS	NS	Sig	NS
Sub table 4.50b. Effect of Kharif straw incorporation												
	Without straw	497	360	428	346	691	506	514	300	452	376	450
	With straw	498	364	431	393	546	468	469	294	412	353	425
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.50 c. Effect of silica												
	Without silica	407	411	409	377	566	400	448	293	368	331	403
	With silica	457	363	410	475	950	348	591	253	463	358	473
		NS	NS	NS	NS	Sig	NS	Sig	NS	NS	NS	NS
Sub table 4.50d. Effect of higher dose of K												
	K35	457	381	419	401	731	330	488	295	430	362	432
	K70	407	393	400	451	784	418	551	252	401	326	444
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4. 51. Effect of season and treatments on available manganese (kg ha^{-1}) in the soil at the end of each crop

Sl.No	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	*Summer* 1998	*Summer* 1999	*Summer* mean	pooled mean
1	Straw alone	6.2^{a}	3.5^{a}	4.8^{ab}	5.7^{abc}	5.5^{a}	3.6^{ab}	4.9^{abc}	5.2^{d}	3.7^{ab}	4.4^{abc}	4.8^{bcd}
2	NPK alone	5.3^{a}	3.3^{a}	4.3^{b}	5.6^{abc}	5.3^{a}	3.9^{a}	4.9^{abc}	5.8^{bcd}	3.5^{ab}	4.6^{abc}	4.7^{bcd}
3	Straw + NPK	7.1^{a}	2.8^{a}	4.9^{ab}	7.0^{a}	7.2^{a}	3.1^{abcd}	5.8^{a}	6.5^{abcd}	3.4^{ab}	4.9^{abc}	5.3^{abcd}
4	Straw + NPK (higher dose of K)	6.7^{a}	4.4^{a}	5.5^{ab}	7.0^{a}	5.6^{a}	3.5^{abc}	5.4^{a}	7.3^{ab}	3.2^{ab}	5.3^{abc}	5.4^{abc}
5	Straw + NPK + Si	8.0^{a}	3.0^{a}	5.5^{ab}	6.3^{abc}	5.7^{a}	3.8^{ab}	5.3^{ab}	6.4^{abcd}	2.9^{b}	4.6^{abc}	5.2^{abcd}
6	Straw + NPK (higher dose of K)+ Si	8.6^{a}	2.8^{a}	5.7^{ab}	6.4^{ab}	5.7^{a}	3.6^{ab}	5.2^{ab}	5.9^{bcd}	2.8^{b}	4.4^{abc}	5.1^{abcd}
7	Straw + NPK + Si + Zn	9.6^{a}	4.6^{a}	7.1^{a}	7.4^{a}	7.3^{a}	2.5^{d}	5.7^{a}	6.9^{abc}	2.8^{b}	4.9^{abc}	5.9^{a}
8	Straw + NPK + Si + Zn +Mg	7.4^{a}	4.0^{a}	5.7^{ab}	6.7^{ab}	6.4^{a}	3.9^{a}	5.7^{a}	6.3^{abcd}	4.5^{a}	5.4^{abc}	5.6^{ab}
9	Straw + NPK + Si + Zn +Mg+Cu	9.5^{a}	3.5^{a}	6.5^{ab}	5.8^{abc}	5.5^{a}	3.4^{abc}	4.9^{abc}	6.3^{abcd}	2.8^{b}	4.5^{abc}	5.2^{abcd}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	7.2^{a}	4.4^{a}	5.8^{ab}	6.8^{a}	5.9^{a}	3.5^{abc}	5.4^{a}	4.9^{bcd}	4.5^{a}	4.7^{abc}	5.3^{abcd}
11	T_{10}+ Boron	8.0^{a}	4.0^{a}	6.0^{ab}	7.3^{a}	6.0^{a}	3.4^{abc}	5.6^{a}	4.3^{d}	3.8^{ab}	4.0^{c}	5.2^{abcd}
12	T_{11}+ Mo	7.5^{a}	5.0^{a}	6.3^{ab}	7.0^{a}	5.2^{a}	3.1^{abcd}	5.1^{abc}	4.8^{cd}	3.5^{ab}	4.1^{bc}	5.2^{abcd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	5.9^{a}	3.1^{a}	4.5^{ab}	3.7^{c}	4.5^{a}	3.2^{abcd}	3.8^{bc}	6.6^{bcd}	2.8^{b}	4.7^{abc}	4.3^{d}
14	T_{12} (No summer cowpea)	7.6^{a}	3.2^{a}	5.4^{ab}	5.8^{abc}	5.2^{a}	3.6^{ab}	4.9^{abc}	8.5^{a}	2.8^{b}	5.7^{a}	5.2^{abcd}
15	T_{2} (No summer cowpea)	7.1^{a}	3.5^{a}	5.3^{ab}	4.1^{bc}	4.3^{a}	2.7^{cd}	3.7^{c}	6.5^{abcd}	3.0^{ab}	4.8^{abc}	4.4^{cd}
16	T_{13} (No summer cowpea)	7.3^{a}	3.8^{a}	5.5^{ab}	5.3^{abc}	4.6^{a}	3.0^{bcd}	4.3^{abc}	6.2^{abcd}	2.8^{b}	4.5^{abc}	4.7^{bcd}
	Mean	**6.5**	**3.5**	**5.3**	**6.1**	**4.5**	**4.5**	**4.9**	**6.8**	**3.5**	**4.9**	**5.1**
	CD for comparison of season			3.3				0.7			0.9	1.1
Sub table 4.51 a. Effect of cropping system												
	R-R-Fallow	7.3	3.5	5.4	-	4.7	3.1	3.9	7.1	2.9	5.0	4.8
	R-R-cowpea	6.2	3.8	5.0	-	5.0	3.4	4.2	5.7	3.2	4.5	4.6
		NS	NS	Sig	-	NS	NS	NS	Sig	NS	Sig	NS
Sub table 4.51b. Effect of Kharif straw incorporation												
	Without straw	6.2	3.4	4.8	4.8	4.8	3.4	4.3	6.2	3.0	4.6	4.5
	With straw	7.4	3.7	5.5	6.6	5.8	3.3	5.2	6.6	3.2	4.9	5.2
		NS	NS	NS	Sig	NS	NS	Sig	NS	NS	NS	Sig
Sub table 4.51 c. Effect of silica												
	Without silica	6.9	3.6	5.2	7.0	6.4	3.3	5.6	6.9	3.3	5.1	5.3
	With silica	8.3	2.9	5.6	6.3	5.7	3.7	5.2	6.2	2.9	4.5	5.1
Sub table 4.51d. Effect of higher dose of K		NS	NS	NS	NS	NS	NS	NS	NS	NS	Sig	NS
	K35	7.5	2.9	5.2	6.7	6.4	3.5	5.5	6.4	3.1	4.8	5.2
	K70	7.7	3.6	5.6	6.7	5.7	3.5	5.3	6.6	3.0	4.8	5.3
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

of *kharif* straw brought about significant increase in Mn content (Sub table 4.51).

During *rabi* 1999-'00, soil application of zinc brought about significant reduction in Mn content whereas application of Mg increased the content from 2.5 kg ha^{-1} to 3.9 kg ha^{-1}. In *rabi* 1998-'99, treatment differences were non significant.

During summer 1998, growing of summer cowpea resulted in significant decrease in Mn status of soil (Sub table 4.51). During summer 1999 soil application of Mg increased the Mn level whereas Cu resulted in bringing about significant decrease.

4.1.6.11. Available Zinc

The data pertaining to the soil status of available zinc at the end of each crop are depicted in Table 4.52.

The mean value of Zn in the soil during *kharif*, *rabi* and summer were 5.5 kg ha^{-1}, 2.2 kg ha^{-1} and 3.6 kg ha^{-1} respectively.

Soil application of Zn has increased the content in the soil during all the seasons. The other treatments did not manifest any significant influence in Zn status of the soil.

4.1.6.11. Available Copper

The data pertaining to the soil status of available copper at the end of each crop are depicted in Table 4.53.

The mean content of available copper in the soil during *kharif*, *rabi* and summer were 13.2 kg ha^{-1}, 11.3 kg ha^{-1} and 10.5 kg ha^{-1}. *Kharif* and *rabi* seasons showed significant variations among themselves. During *kharif* 1998-'99, the Cu content was 13.6 kg ha^{-1} while 1999-'00 season had a remarkably low level of 12.9 kg ha^{-1}. *Rabi* 1997-'98 recorded 10.2 kg ha^{-1} while *rabi* 1998-'99 and *rabi* 1999-'00 had significantly higher content of 12.5 kg ha^{-1} and 11.2 kg ha^{-1} respectively.

During *kharif* 1998-'99 and 1999-'00 and *rabi* 1998-'99, soil application of copper brought about significant increase in available copper

Table 4. 52. Effect of season and treatments on available zinc (kg ha^{-1}) in the soil at the end of each crop

Sl.No	Treatment	Kharif 1998-99	Kharif 1999-00	Kharif mean	Rabi 1997-98	Rabi 1998-99	Rabi 1999-00	Rabi mean	Summer 1998	Summer 1999	Summe mean	pooled mean
1	Straw alone	2.5^{de}	2.5^{bc}	2.5^{d}	1.3^{b}	1.6^{de}	1.3^{e}	1.4^{d}	1.6^{c}	1.6^{c}	1.6^{d}	1.8^{d}
2	NPK alone	2.7^{de}	2.7^{bc}	2.7^{cd}	1.3^{b}	1.6^{de}	1.8^{cde}	1.6^{cd}	1.6^{c}	1.8^{c}	1.7^{d}	1.9^{d}
3	Straw + NPK	2.5^{de}	3.1^{bc}	2.8^{bcd}	1.8^{b}	1.6^{de}	2.0^{cde}	1.8^{bcd}	2.0^{c}	2.8^{c}	2.4^{d}	2.3^{d}
4	Straw + NPK (higher dose of K)	1.8^{e}	2.5^{bc}	2.1^{d}	1.1^{b}	1.6^{de}	2.5^{e}	1.7^{bcd}	1.6^{c}	2.0^{c}	1.8^{d}	1.9^{d}
5	Straw + NPK + Si	1.8^{e}	2.5^{bc}	2.1^{d}	1.1^{b}	1.6^{de}	2.2^{cd}	1.6^{bcd}	1.6^{c}	2.0^{c}	1.8^{d}	1.8^{d}
6	Straw + NPK (higher dose of K)+ Si	2.0^{e}	1.8^{c}	1.9^{d}	1.6^{b}	1.6^{de}	1.8^{cde}	1.6^{bcd}	2.0^{c}	2.9^{c}	2.5^{d}	2.0^{d}
7	Straw + NPK + Si + Zn	11.6^{a}	9.9^{bc}	10.8^{ab}	3.6^{a}	5.8^{a}	3.8^{ab}	4.4^{a}	9.0^{a}	13.7^{a}	11.3^{b}	8.2^{b}
8	Straw + NPK + Si + Zn +Mg	11.2^{a}	11.4^{b}	11.3^{ab}	3.6^{a}	4.0^{b}	4.3^{a}	4.0^{a}	6.7^{b}	9.0^{b}	7.8^{c}	7.2^{b}
9	Straw + NPK + Si + Zn +Mg+Cu	9.4^{ab}	20.2^{a}	14.8^{a}	3.6^{a}	4.7^{b}	3.4^{b}	3.9^{a}	9.9^{a}	15.7^{a}	12.8^{a}	9.5^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	7.2^{bc}	8.7^{bc}	8.0^{bc}	2.0^{b}	2.0^{cde}	2.5^{c}	2.2^{b}	2.0^{c}	2.2^{a}	2.1^{d}	3.8^{c}
11	T_{10}+ Boron	5.6^{cd}	4.3^{bc}	4.9^{cd}	1.8^{b}	2.2^{cde}	1.8^{cde}	1.9^{bcd}	1.6^{c}	1.8^{c}	1.7^{d}	2.7^{cd}
12	T_{11}+ Mo	4.0^{cde}	6.5^{bc}	5.3^{cd}	1.6^{b}	1.8^{cde}	1.8^{cde}	1.7^{bcd}	1.6^{c}	2.7^{c}	4.1^{d}	2.8^{cd}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	4.9^{cde}	4.9^{bc}	4.9^{cd}	1.8^{b}	2.7^{c}	1.6^{de}	2.0^{bc}	2.0^{c}	1.8^{c}	1.9^{d}	2.8^{cd}
14	T_{12} (No summer cowpea)	5.2^{cde}	6.3^{bc}	5.7^{cd}	1.3^{b}	2.5^{cd}	2.0^{cde}	1.9^{bcd}	2.0^{c}	2.9^{c}	2.5^{d}	3.2^{cd}
15	T_2 (No summer cowpea)	4.3^{cde}	4.9^{bc}	4.6^{cd}	1.6^{b}	1.3^{e}	1.3^{e}	1.4^{d}	2.0^{c}	1.6^{c}	1.8^{d}	2.4^{d}
16	T_{13} (No summer cowpea)	3.1^{de}	3.8^{bc}	3.5^{cd}	1.3^{b}	1.8^{cde}	1.3^{e}	1.5^{cd}	1.6^{c}	2.0^{c}	1.8^{d}	2.1^{d}
	Mean	**5.0**	**6.0**	**5.5**	**1.9**	**2.4**	**2.2**	**2.2**	**3.0**	**4.2**	**3.6**	**3.5**
	CD for comparison of season			NS			NS				NS	0.9
Sub table 4.53 a. Effect of cropping system												
	R-R-Fallow	4.2	5.0	4.6	-	1.9	1.6	1.7	1.9	2.2	2.0	2.8
	R-R-cowpea	3.9	4.7	4.3	-	2.0	1.7	1.9	1.7	2.1	1.9	2.7
		NS	NS	NS	-	NS	NS	NS	NS	NS	NS	NS
Sub table 4.53b. Effect of Kharif straw incorporation												
	Without straw	3.6	3.8	3.7	1.5	2.0	1.6	1.7	1.7	1.9	1.8	2.3
	With straw	3.9	5.3	4.6	1.6	1.9	1.9	1.8	1.9	2.8	2.3	2.8
		NS	NS	NS	NS	NS	NS	NS	NS	NS	Sig	NS
Sub table 4.53 c. Effect of silica												
	Without silica	2.1	2.8	2.5	1.5	1.6	2.2	1.8	1.8	2.4	2.1	2.1
	With silica	1.9	2.1	2.0	1.3	1.6	2.0	1.6	1.8	2.5	2.1	1.9
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.53d. Effect of higher dose of K												
	K35	2.1	2.8	2.5	1.5	1.6	2.1	1.7	1.8	2.4	2.1	2.0
	K70	1.9	2.1	2.0	1.3	1.6	2.1	1.7	1.8	2.5	2.1	1.9
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4. 53. Effect of season and treatments on available copper (kg ha $^{-1}$) in the soil at the end of each crop

Sl.No	Treatment	*Kharif* 1998-99	*Kharif* 1999-00	*Kharif* mean	*Rabi* 1997-98	*Rabi* 1998-99	*Rabi* 1999-00	*Rabi* mean	*Summer* 1998	*Summer* 1999	*Summer* mean	pooled mean
1	Straw alone	13.2^{b}	14.2^{b}	13.7^{bc}	10.5^{ab}	13.0^{ab}	11.6^{a}	11.7^{abc}	10.3^{bcde}	10.8^{ab}	10.5^{abc}	11.9^{bcde}
2	NPK alone	12.2^{b}	11.6^{b}	11.9^{bc}	10.2^{ab}	12.0^{abc}	11.2^{a}	11.1^{abcd}	10.9^{bcd}	10.9^{ab}	10.9^{abc}	11.3^{cdef}
3	Straw + NPK	12.5^{b}	11.3^{b}	11.9^{bc}	8.4^{b}	11.9^{abc}	10.8^{a}	10.3^{bcd}	9.5^{ef}	11.4^{ab}	10.5^{abc}	10.8^{defg}
4	Straw + NPK (higher dose of K)	11.9^{b}	13.2^{b}	12.5^{bc}	10.1^{ab}	11.5^{bc}	11.4^{a}	11.0^{abcd}	10.0^{cdef}	10.4^{ab}	10.2^{abc}	11.2^{cdef}
5	Straw + NPK + Si	13.6^{b}	12.3^{b}	12.9^{bc}	10.8^{ab}	13.1^{ab}	11.2^{a}	11.7^{abc}	9.7^{def}	13.0^{a}	11.4^{ab}	12.0^{bcde}
6	Straw + NPK (higher dose of K)+ Si	14.1^{b}	12.0^{b}	13.0^{bc}	11.1^{ab}	12.8^{ab}	11.6^{a}	11.8^{ab}	9.9^{def}	10.9^{ab}	10.4^{abc}	11.8^{bcdef}
7	Straw + NPK + Si + Zn	14.0^{b}	13.3^{b}	13.7^{bc}	10.4^{ab}	13.6^{ab}	12.8^{a}	12.2^{ab}	11.2^{abc}	12.2^{a}	11.7^{a}	12.5^{bc}
8	Straw + NPK + Si + Zn +Mg	13.7^{b}	12.7^{b}	13.2^{bc}	10.8^{ab}	11.5^{bc}	11.2^{a}	11.2^{abcd}	9.5^{ef}	10.0^{ab}	9.7^{abc}	11.3^{bcdef}
9	Straw + NPK + Si + Zn +Mg+Cu	21.5^{a}	19.0^{a}	20.3^{a}	10.3^{ab}	15.3^{a}	12.8^{a}	12.8^{a}	10.5^{bcde}	12.1^{ab}	11.3^{ab}	14.5^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	13.9^{b}	13.1^{b}	13.5^{bc}	10.3^{ab}	13.0^{ab}	12.4^{a}	11.9^{ab}	10.6^{bcde}	11.5^{ab}	11.1^{ab}	12.1^{bcd}
11	T_{10}+ Boron	13.9^{b}	13.3^{b}	13.6^{bc}	12.0^{a}	13.0^{ab}	13.2^{a}	12.7^{a}	12.2^{a}	11.2^{ab}	11.7^{a}	12.7^{b}
12	T_{11}+ Mo	15.3^{b}	13.6^{b}	14.4^{b}	9.8^{ab}	11.5^{bc}	9.5^{a}	10.3^{bcd}	8.7^{f}	10.2^{ab}	9.5^{bc}	11.2^{cdef}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	11.6^{b}	11.9^{b}	11.8^{bc}	9.1^{ab}	10.2^{bc}	9.5^{a}	9.6^{cd}	11.3^{ab}	9.6^{ab}	10.5^{abc}	10.5^{fg}
14	T_{12} (No summer cowpea)	12.3^{b}	12.5^{b}	12.4^{bc}	9.4^{ab}	11.3^{bc}	9.9^{a}	10.2^{bcd}	10.2^{bcde}	11.1^{ab}	10.6^{abc}	11.0^{defg}
15	T_2 (No summer cowpea)	12.0^{b}	10.1^{b}	11.0^{c}	9.9^{ab}	15.6^{c}	9.1^{a}	11.5^{d}	9.6^{def}	8.2^{b}	8.9^{c}	10.6^{fg}
16	T_{13} (No summer cowpea)	12.2^{b}	11.4^{b}	11.8^{bc}	9.7^{ab}	10.8^{bc}	10.3^{a}	10.3^{bcd}	10.4^{bcde}	9.4^{ab}	9.9^{abc}	10.6^{efg}
	Mean	**13.6**	**12.9**	**13.2**	**10.2**	**12.5**	**11.2**	**11.3**	**10.3**	**10.8**	**10.5**	**11.6**
	CD for comparison of season			0.4			0.8				NS	0.5
Sub table 4.53 a. Effect of cropping system												
	R-R-Fallow	12.2	11.3	11.8	-	12.5	9.7	11.1	10.1	9.6	9.8	10.9
	R-R-cowpea	13.1	12.4	12.7	-	11.2	10.1	10.7	10.3	10.2	10.3	11.2
		NS	NS	NS	-	NS	NS	NS	NS	NS	NS	NS
Sub table 4.53b. Effect of Kharif straw incorporation												
	Without straw	12.0	11.6	11.8	9.7	11.0	10.3	10.3	10.9	10.0	10.4	10.8
	With straw	13.4	12.5	12.9	9.2	11.6	10.0	10.3	9.5	10.9	10.2	11.0
		NS	NS	NS	NS	NS	NS	NS	Sig	Sig	NS	NS
Sub table 4.53 c. Effect of silica												
	Without silica	12.2	12.3	12.2	9.2	11.7	11.1	10.7	9.7	10.9	10.3	11.0
	With silica	13.8	12.2	13.0	11.0	12.9	11.4	11.8	9.8	11.9	10.9	11.9
		NS	NS	NS	Sig	NS	NS	NS	NS	NS	NS	0.8
Sub table 4.53d. Effect of higher dose of K												
	K35	13.0	11.8	12.4	9.6	12.5	11.0	11.0	9.6	12.2	10.9	11.4
	K70	13.0	12.6	12.8	10.6	12.2	11.5	11.4	9.9	10.6	10.3	11.5
		NS	NS	NS	NS	NS	NS	NS	NS	Sig	NS	NS

status of soil. During *rabi* 1997-'98, application of silica had increased Cu content from 9.2 kg ha^{-1} to 11.0 kg ha-1.

4.1.7. Interrelations between soil nutrient status and grain yield

The correlation coefficients between the soil available nutrients and grain yield pooled over different seasons are presented in Table 4.54. Available status of K, Ca, Mg and Mn exerted a strong positive correlation with grain yield. At the same time, there was a significant negative relationship (r = -0.404) between soil available Fe and grain yield. The influence of S, Zn and Cu were not much pronounced.

Available N status had a significant positive correlation with yield (0.589**). Its relation with K, Ca, Mg and Zn also was positive and remarkable. However, it exhibited a strong negative relation with available Fe of the soil. Available Mn also showed a negative relation.

Available P content did not have any remarkable influence on yield. There was a significant positive relationship of P with Ca, S, Zn and Cu. K had a negative interaction (r = -0.242) with Fe, while its relation was positive with Ca, S and Cu.

Similar to K, Ca also exhibited a significant negative correlation (r = -0.34) with available Fe of soil. Interrelation between Ca and Mg was found to be positive (r = 0.281), whereas the influence of Mg on S and Fe was highly negative (r = -0.369 and –0.249).

Sulphur had a positive relation with Mn, Zn and Cu. The relations of Cu with Mn and Zn was positive and significant.

4.1.8 . Effect of management practices on yield of succeeding cowpea crop

During summer 1998 and summer 1999, cowpea was raised in the treatment plots T_1 to T_{13}. The seed yield and dry haulm yield are presented in Table 4.55.

Table 4.54 Coefficients of correlation of soil available nutrient status and grain yield of rice *

	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	Yield
N	1										
P	0.188	1									
K	0.504**	0.115	1								
Ca	0.657**	0.383**	0.333**	1							
Mg	0.422**	-0.128	0.049	0.281**	1						
S	0.096	0.41**	0.280**	0.007	-0.369	1					
Fe	-0.529**	0.058	-0.242**	-0.340**	-0.249**	0.082	1				
Mn	-0.231**	0.068	0.192	-0.102	-0.220*	0.344**	0.133	1			
Zn	0.364**	0.318**	0.124	0.288**	0.065	0.225*	-0.049	0.114	1		
Cu	0.101	0.405**	0.283**	0.352**	-0.017	0.252**	0.184	0.311**	0.520*	1	
Yield	0.589**	-0.132	0.434**	0.362**	0.316**	0.034	-0.404**	0.206*	0.156	-0.033	1

* Data pooled over five seasons

Table 4.55. **Effect of management practices in rice crop on yield of summer cowpea**

l. No	Treatments in previous rice crop	Seed yield (kg ha^{-1})		Haulm yield (kg ha^{-1})	
		1998 summer	1999 summer	1998 summer	1999 summer
1	Straw alone	892^{ab}	806^{a}	2823^{a}	3113^{a}
2	NPK alone	760^{b}	771^{a}	3105^{a}	3003^{a}
3	Straw+NPK	839^{ab}	981^{a}	2954^{a}	3183^{a}
4	Straw+NPK (higher dose of K)	897^{ab}	973^{a}	2762^{a}	3323^{a}
5	Straw+NPK+ Si	855^{ab}	921^{a}	3595^{a}	3310^{a}
6	Straw +NPK (higher dose of K)+ Si	891^{ab}	819^{a}	3462^{a}	3187^{a}
7	Straw+NPK+Si+Zn	692^{b}	898^{a}	2649^{a}	2967^{a}
8	Straw + NPK + Si + Zn +Mg	752^{b}	939^{a}	2710^{a}	3423^{a}
9	Straw + NPK + Si + Zn +Mg+Cu	1097^{a}	1012^{a}	2800^{a}	3347^{a}
10	Straw + NPK + Si +Foliar Zn,Mg,Cu	872^{ab}	951^{a}	2929^{a}	3153^{a}
11	T_{10}+ Boron	755^{b}	784^{a}	3575^{a}	3050^{a}
12	T_{11}+ Mo	953^{ab}	1027^{a}	2897^{a}	3000^{a}
13	NPK + Si +Foliar Zn,Mg,Cu,B,Mo	742^{b}	749^{a}	3026^{a}	2993^{a}
	Mean	**846**	**895**	**3022**	**3158**

The crop produced a mean seed yield of 846 kg ha^{-1} and haulm yield of 3022 kg ha^{-1} during summer 1998. During summer 1999, the yields of seed and haulm were 895 kg ha^{-1} and 3158 kg ha^{-1} respectively.

During 1998 season, the yield of cowpea showed significant variations with the management treatments followed in *rabi* crop. During summer 1998 the highest yield of 1097 kg ha^{-1} was from the plot which received *harif* straw incorporation and soil application of Si, Mg, Zn and Cu along with recommended fertilizers (T_9). T_2, T_7, T_8, T_{11} and T_{13} produced significantly lower yields. Other treatments were on par with this.

During summer 1999, all the treatments were on par. During both the seasons the yield of dry haulm from the different plots did not vary markedly.

4.2. Experiment II. Effect of tillage and water management practices on soil- plant elemental status and productivity of rice in rice- legume cropping system

The experiment was carried out during 1998-2000 to study the influence of deep ploughing (30 cm) over shallow tillage and the effect of providing intermittent drainage during three stages of crop growth viz., tiller initiation stage, active tillering to panicle initiation and panicle initiation to flowering stage. Data on crop growth and panicle characters as well as soil and plant elemental composition are presented here.

4.2.1. Effect of deep ploughing and intermittent drainage on growth characters, yield attributes and yield of rice

The data are presented in Table 4.56 to 4.59. During *kharif* 1998-'99 (Table 4.56) the two methods of ploughing or the water management practices did not bring about any change in plant height. Tiller production at tillering stage showed differences with treatments. T_3 (NPK + deep ploughing) registered tiller count of 8.0 which was higher than that of T_8 (NPK + Si + foliar application of Zn, Mg, Cu, B and Mo + deep ploughing + intermittent drainage). At tillering and PI stages significantly higher count was observed

Table 4.56 Effect of deep ploughing and intermittent drainage on growth attributes, panicle characters and yield of rice during *Kharif* 1998 - 99

No.	Treatments	Plant height (cm)			Tiller number			Shoot dry matter (kg ha^{-1})		Panicles/ m^2	Spikelets/panicle	Chaff %	1000 gr wt (g)	Panicle length (cm)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
		Tillering stage	PI stage	maturity	Tillering stage	PI stage	maturity	Tillering stage	PI stage							
1	NPK alone	33.3^{a}	54.4^{a}	79.3^{a}	7.7^{ab}	7.4^{a}	5.9^{a}	525^{a}	1870^{ab}	340^{a}	51.4^{a}	29.9^{a}	28.5^{a}	17.5^{a}	2846^{a}	3746^{ab}
2	NPK+Si+foliar*	33.6^{a}	55.6^{a}	80.6^{a}	7.6^{ab}	7.2^{a}	6.6^{a}	500^{a}	1907^{ab}	387^{a}	54.3^{a}	27.6^{a}	27.8^{a}	17.2^{a}	3011^{a}	3514^{ab}
3	T_1+ DP	34.2^{a}	54.9^{a}	79.6^{a}	8.0^{a}	7.4^{a}	6.6^{a}	533^{a}	2002^{ab}	380^{a}	48.0^{a}	27.2^{a}	28.5^{a}	17.6^{a}	3023^{a}	3812^{ab}
4	T_1+ ID	35.4^{a}	56.3^{a}	82.5^{a}	7.2^{ab}	7.4^{a}	6.5^{a}	476^{a}	2065^{a}	373^{a}	45.4^{a}	32.4^{a}	29.1^{a}	18.3^{a}	2693^{a}	3980^{a}
5	T_1+ DP+ ID	33.4^{a}	55.9^{a}	83.2^{a}	6.8^{ab}	6.6^{a}	6.1^{a}	491^{a}	1819^{ab}	347^{a}	48.0^{a}	30.6^{a}	29.0^{a}	18.0^{a}	2817^{a}	3436^{b}
6	T_2 + DP	34.0^{a}	55.9^{a}	81.3^{a}	7.4^{ab}	7.1^{a}	6.0^{a}	581^{a}	2039^{a}	340^{a}	46.7^{a}	29.4^{a}	28.7^{a}	18.0^{a}	2691^{a}	3665^{ab}
7	T_2 + ID	33.7^{a}	57.8^{a}	81.4^{a}	6.8^{ab}	6.5^{a}	6.1^{a}	584^{a}	1826^{ab}	340^{a}	49.5^{a}	26.4^{a}	28.6^{a}	17.8^{a}	2883^{a}	3534^{ab}
8	T_2 + DP+ ID	33.8^{a}	55.3^{a}	81.0^{a}	6.7^{b}	6.3^{a}	6.4^{a}	552^{a}	1747^{b}	380^{a}	48.0^{a}	26.5^{a}	27.8^{a}	17.6^{a}	2747^{a}	3619^{ab}
	Mean	**33.9**	**55.8**	**81.1**	**7.3**	**7.0**	**6.3**	**530**	**1909**	**361**	**48.9**	**28.8**	**28.5**	**17.8**	**2839**	**3663**
Sub table 4.56 a. Effect of deep ploughing																
	Without DP	34.0	56.0	81.0	7.3	7.1	6.3	521	1917	360	50.2	29.1	28.5	17.7	2858	3694
	With DP	33.9	55.5	81.3	7.2	6.9	6.3	539	1902	362	47.7	28.4	28.5	17.8	2820	3633
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.56 b. Effect of intermittent drainage																
	CS	33.8	55.2	80.2	7.7	7.3	6.3	535	1955	362	50.1	28.6	28.4	17.6	2893	3684
	ID	34.1	56.3	82.0	6.9	6.7	6.3	526	1864	360	47.7	29.0	28.6	17.9	2785	3642
		NS	NS	NS	Sig	Sig	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

* foliar application of Zn, Mg, Cu, B, Mo; DP- Deep ploughing; CS-Continuous submergence; ID-Intermittent drainage

Table 4.57 Effect of deep ploughing and intermittent drainage on growth attributes, panicle characters and yield of rice during *Rabi* 1998 - 99

No.	Treatments	Plant height (cm)			Tiller number			Shoot dry matter (kg ha^{-1})		Panicles/ m^2	Spikelets/p anicle	Chaff %	1000 gr wt (g)	Panicle length (cm)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
		Tillering stage	PI stage	maturity	Tillering stage	PI stage	maturity	Tillering stage	PI stage							
1	NPK alone	38.2^a	51.2^a	72.8^{abc}	5.5^{ab}	7.3^{abc}	5.8^{ab}	1026^a	1747^b	340^a	54.0^a	29.9^a	26.2^a	18.5^a	2414^a	2116^a
2	NPK+Si+foliar*	37.3^a	50.8^a	74.8^{ab}	4.9^b	6.1^c	5.5^{ab}	885^a	2059^{ab}	320^a	51.2^a	25.0^a	26.3^a	17.9^a	2345^a	2048^a
3	T_1+ DP	37.7^a	49.7^a	75.4^a	5.0^b	6.7^{bc}	5.8^{ab}	1011^a	1902^{ab}	360^a	49.6^a	29.4^a	26.8^a	18.4^a	2142^a	2128^a
4	T_1+ ID	38.7^a	49.4^a	70.1^c	5.6^{ab}	7.9^{ab}	5.8^{ab}	765^a	1718^b	367^a	50.7^a	28.8^a	26.3^a	17.6^a	2094^a	1974^a
5	T_1+ DP+ ID	36.7^a	50.9^a	72.7^{abc}	5.3^b	7.8^{ab}	5.4^b	809^a	1882^{ab}	320^a	51.9^a	31.4^a	26.5^a	18.3^a	2481^a	1974^a
6	T_2 + DP	38.2^a	52.2^a	72.7^{abc}	5.2^b	7.1^{bc}	6.2^a	931^a	2001^{ab}	360^a	54.3^a	28.5^a	26.4^a	18.3^a	2283^a	2096^a
7	T_2 + ID	37.9^a	50.4^a	73.4^{ab}	5.4^b	8.5^a	5.6^{ab}	862^a	1618^b	327^a	57.7^a	29.5^a	27.0^a	18.2^a	2541^a	2271^a
8	T_2 + DP+ ID	38.5^a	51.0^a	72.0^{bc}	6.3^a	7.9^{ab}	5.9^{ab}	790^a	2488^a	333^a	49.7^a	29.4^a	26.9^a	17.6^a	2486^a	2375^a
	Mean	**37.9**	**50.7**	**73.0**	**5.4**	**7.4**	**5.8**	**885**	**1927**	**341**	**52**	**29.0**	**26.6**	**18.1**	**2311**	**2123**
Sub table 4.57 a. Effect of deep ploughing																
	Without DP	38.0	50.5	72.8	5.4	7.5	5.7	885	1786	338	53.4	28.3	26.5	18.1	2349	2102
	With DP	37.8	51.0	73.2	5.5	7.4	5.8	885	2068	343	51.4	29.7	26.7	18.2	2273	2143
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.57 b. Effect of intermittent drainage																
	CS	37.9	51.0	73.9	5.2	6.8	5.8	963	1927	345	52.3	28.2	26.4	18.3	2296	2097
	ID	38.0	50.4	72.1	5.7	8.0	5.7	807	1927	337	52.5	29.8	26.7	17.9	2326	2149
		NS	NS	NS	NS	Sig	NS	Sig	NS	NS	NS	NS	NS	NS	NS	NS

* foliar application of Zn, Mg, Cu, B, Mo; DP- Deep ploughing; CS-Continuous submergence; ID-Intermittent drainage

in continuous submergence plots (Sub table 4.56 b). However, towards maturity no difference was noticed.

Shoot dry matter production at tillering stage was not influenced by the treatments. At PI stage T_4 and T_6 were superior to T_8.

The yield attributes viz. panicles/m^2, spikelets/panicle, panicle length, chaff percentage and 1000 grain weight did not vary with treatments. Grain yield recorded in all the treatments also were on par with each other. NPK+ intermittent drainage (T_4) produced the highest straw yield of 3980 kg ha^{-1} and it was significantly higher to the yield obtained in T_5.

During *rabi* 1998-'99 (Table 4.57) plant height upto PI stage remained unaffected by the treatments. At maturity T_3 had significantly taller plants than T_4 and T_8. Other treatments were on par with each other. Tiller count during different stages varied with treatments. At tillering stage T_8 recorded the highest tiller number of 6.3 whereas T_2, T_3, T_5, T_6 and T_7 registered significantly lower counts. At PI stage, the highest count was in T_7 (8.5). T_2 and T_3 recorded significantly lower counts. During this stage intermittent drainage resulted in significant increase of tiller count (Sub table 4.57). At maturity the highest count was in T_6 (NPK + Si + foliar application of Zn, Mg, Cu, B and Mo + deep ploughing). Other treatments were on par with this except T_5 which had significantly lower count.

Dry matter production of shoot remained unaffected by treatments at tillering stage whereas at PI stage T_8 (NPK + Si + foliar application of Zn, Mg, Cu, B and Mo + deep ploughing + intermittent drainage) registered the highest biomass of 2488 kg ha^{-1}. T_1, T_4 and T_7 had significantly lower biomass production.

The different treatments did not bring about any change in yield attributes or grain and straw yield.

During *kharif* 1999-'00 (Table 4.58) plant height at tillering and maturity stages did not vary with treatments. At PI stage, T_6 (NPK + Si + foliar application of Zn, Mg, Cu, B and Mo + deep ploughing) recorded higher

Table 4.58. *Effect of deep ploughing and intermittent drainage on growth attributes, panicle characters and yield of rice during Kharif 1999-00*

No.	Treatments	Plant height (cm)			Tiller number			Shoot dry matter (kg ha^{-1})		Panicles/ m^2	Spikelets/panicle	Chaff %	1000 gr wt (g)	Panicle length (cm)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
		Tillering stage	PI stage	maturity	Tillering stage	PI stage	maturity	Tillering stage	PI stage							
1	NPK alone	48.1^a	61.8^{ab}	82.7^a	6.2^a	6.9^{ab}	5.8^{ab}	1391^a	3140^a	327^{ab}	73.7^{ab}	15.1^a	29.1^a	21.0^a	4424^{ab}	3975^a
2	NPK+Si+foliar*	45.3^a	63.5^{ab}	80.6^a	5.4^a	6.4^{ab}	5.3^{ab}	1287^{ab}	3055^{ab}	307^b	65.6^b	17.4^a	29.3^a	20.2^a	4264^{ab}	3729^a
3	T_1+ DP	45.6^a	62.9^{ab}	80.5^a	5.7^a	6.5^{ab}	5.4^{ab}	1287^{ab}	3109^{ab}	300^b	65.4^b	14.84^a	29.1^a	20.3^a	4656^a	3575^a
4	T_1+ ID	45.8^a	62.8^{ab}	82.6^a	6.1^a	6.8^{ab}	5.8^{ab}	1283^{ab}	2551^{ab}	327^{ab}	82.4^a	18.2^a	29.7^a	21.0^a	4535^{ab}	4202^a
5	T_1+ DP+ ID	46.5^a	61.0^b	81.9^a	5.6^a	6.7^{ab}	5.8^{ab}	1051^b	2477^{ab}	327^{ab}	69.9^{ab}	22.3^a	29.8^a	20.0^a	4236^{ab}	3078^a
6	T_2 + DP	48.6^a	65.5^a	81.5^a	5.1^a	7.0^a	5.3^{ab}	1302^{ab}	2466^b	293^b	82.1^a	14.8^a	29.8^a	21.0^a	4542^{ab}	3783^a
7	T_2 + ID	43.9^a	61.2^b	81.0^a	5.7^a	6.1^b	5.2^b	1033^b	3035^{ab}	280^b	62.0^b	20.3^a	29.6^a	20.0^a	4022^b	3410^a
8	T_2 + DP+ ID	46.9^a	62.2^{ab}	81.9^a	6.1^a	6.3^{ab}	6.0^a	1327^{ab}	2833^{ab}	360^a	75.5^{ab}	14.5^a	30.0^a	20.7^a	4413^{ab}	3486^a
	Mean	**46.3**	**62.6**	**81.6**	**5.7**	**6.6**	**5.6**	**1245**	**2833**	**315**	**72.1**	**17.2**	**29.6**	**20.5**	**4387**	**3655**
Sub table 4.58 a. Effect of deep ploughing																
	Without DP	45.8	62.3	81.7	5.9	6.6	5.5	1249	2945	310	70.9	17.8	29.4	20.6	4311	3829
	With DP	46.9	62.9	81.5	5.6	6.6	5.6	1242	2721	320	73.2	16.6	29.7	20.5	4462	3481
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	Sig
Sub table 4.58 b. Effect of intermittent drainage																
	CS	46.9	63.4	81.3	5.6	6.7	5.5	1317	2943	307	71.7	15.5	29.3	20.6	4472	3766
	ID	45.8	61.8	81.9	5.9	6.5	5.7	1174	2724	323	72.5	18.8	29.8	20.4	4302	3544
		NS	NS	NS	NS	NS	NS	Sig	NS	NS	NS	NS	NS	NS	NS	NS

* foliar application of Zn, Mg, Cu, B, Mo; DP- Deep ploughing; CS-Continuous submergence; ID-Intermittent drainage

plant height compared to T_5 and T_7. Tiller count did not vary at tillering stage. At PI stage T_6 registered the highest count of 7.0 whereas T_7 had significantly lower count. At maturity stage also T_7 (NPK + Si + foliar application of Zn, Mg, Cu, B and Mo +intermittent drainage) registered the lowest count. T_8 had significantly higher tiller number of 6.0.

Shoot dry matter production at tillering stage was significantly higher in T_1 than T_5 and T_7. Intermittent drainage resulted in a significant reduction in the amount of dry matter produced (Sub table 4.58). At PI stage also dry matter was higher in T_1 whereas T_6 had significantly lower biomass.

The number of panicles per m^2 was highest in T_8 (NPK + Si + foliar application of Zn, Mg, Cu, B and Mo + deep ploughing + intermittent drainage). T_2, T_3, T_6 and T_7 had significantly lower number. T_4 and T_6 recorded higher spikelets per panicle whereas T_2, T_3 and T_7 had significantly lower number. Chaff per cent, thousand-grain weight and panicle length as well as straw yield did not show variation with treatments. Grain yield was highest in T_3 (4656 kg ha^{-1}). T_7 (NPK + Si + foliar application of Zn, Mg, Cu, B and Mo + intermittent drainage) registered significantly lower values.

During *rabi* 1999-'00 (Table 4.59) plant height at tillering stage was highest in T_6 (38.5 cm). T_4, T_5, T_7 and T_8 registered significantly lower values. Intermittent drainage has resulted in a remarkable reduction in the height (Sub table 4.59). At PI stage T_1 recorded the highest plant height. T_4, T_7 and T_8 had significantly lower heights. At maturity T_1, T_3 and T_6 had higher values. T_7 registered significantly lower height. The data from the Sub table 4.59b indicate that intermittent drainage resulted in significant decrease in plant height.

Tiller number at tillering stage was found higher in T_3 (NPK + deep ploughing). T_6 recorded significantly lower count. At PI and maturity stages no variations were noticed with treatments.

Number of panicles/m^2 was highest in T_2 (353) whereas T_7 registered significantly lower value. The Sub table 4.59 showed that intermittent drainage results in significant reduction in panicle number. Number of spikelets per panicle also was higher in T_2 and T_3 compared to T_5 and T_7 which recorded significantly lower counts. Intermittent drainage is responsible for the reduction. Panicle length, chaff per cent and 1000 grain weight remained unaffected by the treatments.

Grain and straw yield also were significantly reduced by intermittent drainage (Sub table 4.59). Providing intermittent drainage thrice during the crop period resulted in a decrease in grain yield by 15 per cent and straw yield by 11 per cent.

4.2.1. Effect of deep ploughing and intermittent drainage on plant elemental composition

The effect of the practices of deep ploughing and intermittent drainage on elemental composition of plant at different stages were studied during *kharif* 1999-'00 and *rabi* 1999-'00. The data are presented in Tables 4.60 and 4.61.

4.2.1.1. Nitrogen

During *kharif* 1999-'00, the mean N content at tillering stage was 2.53 per cent which decreased to 1.46 per cent towards PI stage. The content in grain and straw were 0.60 per cent and 0.99 per cent respectively. At tillering stage the treatments did not influence N content. At PI stage T_4 and T_5 had higher N content whereas T_8 (NPK + Si + foliar application of Zn, Mg, Cu, B and Mo + deep ploughing + intermittent drainage) recorded significantly lower value. The N content of straw was higher in T_3. T_7 and T_8 had contents on par with this while it was lower in other treatments. The grain N content did not vary remarkably with treatments.

During *rabi* 1999-'00, straw N content was higher in T_1 (NPK alone). T_3 (NPK + deep ploughing) had significantly lower content while others were on par. Grain N content showed significantly higher content in T_8 than T_7.

Table 4.59. Effect of deep ploughing and intermittent drainage on growth attributes, panicle characters and yield of rice during Rabi 1999-00

No.	Treatments	Plant height (cm) Tillering stage	Plant height (cm) PI stage	Plant height (cm) maturity	Tiller number Tillering stage	Tiller number PI stage	Tiller number maturity	Panicles/m 2	Spikelets/panicle	Chaff %	1000 gr wt (g)	Panicle length (cm)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
1	NPK alone	36.3^{ab}	48.8^{a}	63.6^{a}	5.6^{ab}	7.1^{a}	5.9^{a}	333^{ab}	56.8^{ab}	24.4^{a}	27.1^{a}	16.4^{a}	3319^{ab}	2990^{a}
2	NPK+Si+foliar*	35.5^{abc}	46.6^{abcd}	61.0^{ab}	5.7^{ab}	6.4^{a}	6.2^{a}	353^{a}	61.1^{a}	23.8^{a}	28.0^{a}	17.0^{a}	3313^{ab}	2857^{abc}
3	T_1+ DP	36.4^{ab}	47.8^{abc}	62.9^{a}	6.0^{a}	6.7^{a}	5.6^{a}	307^{bc}	61.3^{a}	26.6^{a}	28.2^{a}	16.9^{a}	3471^{a}	2948^{ab}
4	T_1+ ID	33.2^{bc}	46.4^{bcd}	60.4^{abc}	5.0^{ab}	6.7^{a}	5.4^{a}	313^{abc}	51.7^{abc}	20.2^{a}	28.1^{a}	16.3^{a}	2963^{bc}	2697^{abcd}
5	T_1+ DP+ ID	33.9^{bc}	47.8^{abc}	57.9^{bc}	5.3^{ab}	6.8^{a}	6.0^{a}	320^{abc}	46.3^{c}	17.3^{a}	27.8^{a}	15.3^{a}	2878^{bc}	2536^{cd}
6	T_2 + DP	38.5^{a}	48.3^{ab}	64.3^{a}	4.6^{b}	6.6^{a}	5.6^{a}	320^{abc}	58.8^{ab}	27.2^{a}	28.1^{a}	16.6^{a}	3152^{ab}	2750^{abcd}
7	T_2 + ID	32.5^{a}	45.7^{cd}	56.6^{c}	5.3^{ab}	6.8^{a}	5.4^{a}	280^{c}	51.1^{bc}	27.6^{a}	27.5^{a}	15.7^{a}	2701^{c}	2423^{d}
8	T_2 + DP+ ID	34.0^{bc}	44.7^{d}	60.3^{abc}	5.1^{ab}	6.6^{a}	6.1^{a}	320^{abc}	51.5^{abc}	23.1^{a}	27.3^{a}	15.9^{a}	2965^{bc}	2622^{bcd}
	Mean	**35.0**	**47.0**	**60.9**	**5.3**	**6.7**	**5.8**	**318**	**55**	**24**	**28**	**16**	**3095**	**2728**
Sub table 4.59 a. Effect of deep ploughing														
	Without DP	34.4	46.9	60.4	5.4	6.8	5.7	320	55.2	24.0	27.7	16.4	3074	2742
	With DP	35.7	47.2	61.4	5.3	6.7	5.8	317	54.5	23.6	27.9	16.2	3117	2714
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.59 b. Effect of intermittent drainage														
	CS	36.7	47.9	63.0	5.5	6.7	5.8	328	59.5	25.5	27.9	16.7	3314	2886
	ID	33.4	46.2	58.8	5.2	6.7	5.7	308	50.2	22.1	27.7	15.8	2877	2570
		Sig	NS	Sig	NS	NS	NS	Sig	Sig	NS	NS	NS	Sig	Sig

* application of Zn, Mg, Cu, B, Mo; DP- Deep ploughing; CS-Continuous submergence; ID-Intermittent drainage

4.2.1.2. Phosphorous

During *kharif* 1999-'00, the average P content was 0.29 per cent at tillering stage and 0.27 per cent at PI stage. Straw and grain recorded 0.10 per cent and 0.26 per cent respectively. The plant contents showed that there was no difference in their concentration with ploughing methods. Intermittent drainage also did not register any remarkable variation.

Similar results were obtained during *rabi* 1999-'00 also.

4.2.1.3. Potassium

During *kharif* 1999-'00 K content at tillering stage was 3.46 per cent which decreased to 2.7 per cent towards PI. The concentration in straw was 2.62 per cent while grain registered 0.24 per cent.

The content did not vary with treatments at tillering stage or in straw and grain. At PI stage NPK alone had K concentration of 2.89 per cent whereas in T_5 (NPK + deep ploughing + intermittent drainage) a significant reduction was noticed. T_7 (NPK + Si + foliar application of Zn, Mg, Cu, B and Mo + intermittent drainage) also showed decreased content.

During *rabi* 1999-'00, the mean contents in straw and grain were 2.34 per cent and 0.37 per cent respectively. In straw T_6 (NPK + Si + foliar application of Zn, Mg, Cu, B and Mo + deep ploughing) showed the highest content while T_7 and T_8 recorded significantly lower value. In the grain the content was higher in T_7 and T_8 whereas T_2 registered significantly lower value.

4.2.1.4. Calcium

During *kharif* 1999-'00, Ca concentration of plant tissue at tillering, PI and maturity stages were 822, 992 and 1342 ppm respectively. Grain registered only 74 ppm. At tillering stage T_7 had the highest content while lowest content was recorded in T_1. All other treatments showed similar values. Content at PI stage or in straw and grain did not show any significant difference with treatments.

Table 4.60. Effect of deep ploughing and intermittent drainage on nutrient composition of rice during *Kharif* 1999-00

No.	Treatments	N %				P %				K %				Ca ppm				S ppm			
		Tillering stage	PI stage	Straw	Grain	Tillering stage	PI stage	Straw	Grain	Tillering stage	PI stage	Straw	Grain	Tillering stage	PI stage	Straw	Grain	Tillering stage	PI stage	Straw	Grain
1	NPK alone	2.40^{a}	1.46^{ab}	0.57^{c}	1.02^{a}	0.29^{a}	0.28^{a}	0.12^{a}	0.28^{a}	3.12^{a}	2.89^{a}	2.70^{a}	0.27^{a}	519^{b}	830^{a}	1169^{a}	80^{a}	2008^{a}	1497^{a}	683^{b}	932^{ab}
2	NPK+Si+foliar*	2.58^{a}	1.42^{ab}	0.57^{bc}	1.02^{a}	0.31^{a}	0.27^{a}	0.09^{a}	0.24^{a}	3.53^{a}	2.74^{abc}	2.33^{a}	0.20^{a}	838^{ab}	988^{a}	1226^{a}	68^{a}	2232^{a}	1536^{a}	525^{b}	841^{b}
3	T_1+ DP	2.51^{a}	1.48^{ab}	0.67^{a}	0.80^{a}	0.28^{a}	0.27^{a}	0.10^{a}	0.26^{a}	3.49^{a}	2.67^{abc}	2.63^{a}	0.22^{a}	788^{ab}	1132^{a}	1369^{a}	75^{a}	1982^{a}	1470^{a}	814^{a}	972^{ab}
4	T_1+ ID	2.60^{a}	1.54^{a}	0.57^{bc}	1.08^{a}	0.29^{a}	0.28^{a}	0.09^{a}	0.28^{a}	3.42^{a}	2.78^{abc}	2.85^{a}	0.23^{a}	738^{ab}	957^{a}	1288^{a}	74^{a}	2127^{a}	1497^{a}	761^{ab}	972^{ab}
5	T_1+ DP+ ID	2.63^{a}	1.55^{a}	0.56^{c}	0.99^{a}	0.30^{a}	0.24^{a}	0.10^{a}	0.25^{a}	3.57^{a}	2.52^{bc}	2.33^{a}	0.24^{a}	863^{ab}	1026^{a}	1451^{a}	62^{a}	2021^{a}	1300^{a}	748^{ab}	945^{ab}
6	T_2 + DP	2.50^{a}	1.44^{ab}	0.59^{bc}	1.00^{a}	0.29^{a}	0.29^{a}	0.09^{a}	0.25^{a}	3.64^{a}	2.86^{ab}	3.08^{a}	0.24^{a}	863^{ab}	938^{a}	1407^{a}	77^{a}	2231^{a}	1641^{a}	827^{a}	841^{b}
7	T_2 + ID	2.62^{a}	1.47^{ab}	0.65^{ab}	1.09^{a}	0.27^{a}	0.24^{a}	0.11^{a}	0.26^{a}	3.45^{a}	2.48^{c}	2.48^{a}	0.23^{a}	1026^{a}	994^{a}	1444^{a}	82^{a}	1890^{a}	1510^{a}	827^{a}	1077^{a}
8	T_2 + DP+ ID	2.42^{a}	1.40^{b}	0.60^{abc}	0.89^{a}	0.27^{a}	0.25^{a}	0.11^{a}	0.26^{a}	3.49^{a}	2.63^{abc}	2.52^{a}	0.25^{a}	938^{ab}	1069^{a}	1382^{a}	71^{a}	1628^{a}	1365^{a}	748^{b}	801^{b}
	Mean	**2.53**	**1.47**	**0.60**	**0.99**	**0.29**	**0.27**	**0.10**	**0.26**	**3.46**	**2.70**	**2.62**	**0.24**	**822**	**992**	**1342**	**74**	**2015**	**1477**	**742**	**923**
Sub table 4.60 a. Effect of deep ploughing																					
	Without DP	2.55	1.47	0.59	1.05	0.29	0.27	0.10	0.26	3.38	2.72	2.59	0.23	780	942	1282	76	2064	1510	699	956
	With DP	2.52	1.44	0.61	0.92	0.29	0.26	0.10	0.26	3.55	2.67	2.64	0.24	863	1041	1402	71	1966	1444	784	890
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.60 b. Effect of intermittent drainage																					
	CS	2.50	1.45	0.60	0.96	0.29	0.28	0.10	0.26	3.45	2.79	2.69	0.23	752	972	1293	75	2113	1536	712	897
	ID	2.57	1.47	0.60	1.01	0.28	0.25	0.10	0.26	3.48	2.60	2.55	0.24	891	1012	1391	72	1917	1418	771	949
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

* foliar application of Zn, Mg, Cu, B, Mo; DP- Deep ploughing; CS-Continuous submergence; ID-Intermittent drainage

Table 4.61 Effect of deep ploughing and intermittent drainage on nutrient composition of rice during Rabi 1999-00

		N %		P %				Ca ppm		S ppm	
No.	Treatments	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain
1	NPK alone	0.73^{a}	0.92^{ab}	0.09^{a}	0.26^{a}	2.48^{ab}	0.37^{ab}	1863^{a}	122^{a}	1300^{ab}	1391^{a}
2	NPK+Si+foliar*	0.66^{ab}	0.98^{ab}	0.08^{a}	0.24^{a}	2.18^{ab}	0.30^{b}	1932^{a}	94^{b}	985^{b}	1392^{a}
3	T_1+ DP	0.60^{b}	0.98^{ab}	0.08^{a}	0.24^{a}	2.33^{ab}	0.38^{ab}	1932^{a}	95^{b}	1693^{a}	1365^{a}
4	T_1+ ID	0.68^{ab}	0.91^{ab}	0.05^{a}	0.22^{a}	2.52^{ab}	0.32^{ab}	1913^{a}	85^{b}	1051^{b}	1221^{a}
5	T_1+ DP+ ID	0.71^{ab}	1.01^{ab}	0.06^{a}	0.26^{a}	2.41^{ab}	0.35^{ab}	2038^{a}	101^{ab}	1116^{b}	1116^{a}
6	T_2 + DP	0.62^{ab}	0.91^{ab}	0.07^{a}	0.23^{a}	2.71^{a}	0.37^{ab}	1657^{a}	105^{ab}	1234^{ab}	1103^{a}
7	T_2 + ID	0.71^{ab}	0.90^{b}	0.08^{a}	0.25^{a}	2.03^{b}	0.43^{a}	1663^{a}	103^{ab}	1352^{ab}	1076^{a}
8	T_2 + DP+ ID	0.71^{ab}	1.02^{a}	0.06^{a}	0.24^{a}	2.07^{b}	0.43^{a}	1876^{a}	94^{b}	1234^{ab}	1326^{a}
	Mean	**0.68**	**0.95**	**0.07**	**0.24**	**2.34**	**0.37**	**1859**	**100**	**1246**	**1249**
Sub table 4.61 a. Effect of deep ploughing											
	Without DP	0.70	0.93	0.08	0.24	2.30	0.36	1843	101	1172	1270
	With DP	0.66	0.98	0.07	0.24	2.38	0.38	1876	99	1319	1228
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.61 b. Effect of intermittent drainage											
	CS	0.65	0.95	0.08	0.24	2.43	0.36	1846	104	1303	1313
	ID	0.70	0.96	0.06	0.24	2.26	0.38	1873	96	1188	1185
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

* foliar application of Zn, Mg, Cu, B, Mo; DP- Deep ploughing; CS-Continuous submergence;

During *rabi* 1999-'00, Ca content of straw did not vary remarkably. In the grain the content was highest in T_1. T_5, T_6 and T_7 registered contents on par with it while others had significantly lower contents.

4.2.1.5. Sulphur

S content in the plant tissue at tillering, PI and maturity stages of *kharif* 1999-'00 crop were 2015 ppm, 1477 ppm and 742 ppm respectively. The content in the grain was 923 ppm. At tillering and PI stages the treatments did not influence the contents. In case of straw the content was higher in T_3, T_6 and T_7 while T_2 showed significantly lower value. Grain S content was higher in T_7 compared to T_2.

During *rabi* 1999-'00, T_3 (NPK + deep ploughing) showed significantly higher content than T_2. T_4 and T_5 also had lower values. The content of S in grain did not vary appreciably with the treatments.

4.2.3. Effect of deep ploughing and intermittent drainage on soil pH and Eh

a. Soil pH

During *kharif* 1998-'99, pH of rice soil was measured at 30 DAT and 70 DAT and during *rabi* 1998-'99 and *kharif* 1999-'00 it was recorded at 30 DAT. The figures are presented in Table 4.62.

The pH of soil during *kharif* 1998-'99 at 30 days after transplanting (DAT) was in the range 5.83 to 6.45 with an average of 6.16. T_2 (NPK + Si + foliar application of Zn, Mg, Cu, B and Mo) registered significantly higher pH than T_1 (NPK alone). The ploughing practices did not show any effect on soil pH, but the water management practices showed remarkable variation. pH was higher in the plots receiving continuous submergence (6.35) whereas in case of intermittent drainage, it was 5.97 (Sub table 4.62). At 70 DAT the pH raised to a higher level, the mean value being 6.76. The two practices did not show any variation in pH at this stage.

Table 4.62. Effect of deep ploughing and intermittent drainage on pH of rice soil

Sl. No.	Treatments	*Kharif* 1998-99		*Rabi* 1998-99 30 DAT	*Kharif* 1999-00 30 DAT
		30 DAT	70 DA		
1	NPK alone	6.23^{bc}	6.74^{a}	6.30^{a}	5.90^{a}
2	NPK+Si+foliar*	6.45^{a}	6.75^{a}	6.42^{a}	5.90^{a}
3	T1+ DP	6.33^{ab}	6.75^{a}	6.28^{a}	5.90^{a}
4	T1+ ID	6.01^{de}	6.80^{a}	5.47^{b}	5.80^{a}
5	T1+ DP+ ID	5.94^{de}	6.74^{a}	5.74^{b}	5.74^{a}
6	T2 + DP	6.39^{ab}	6.71^{a}	6.44^{a}	5.81^{a}
7	T2 + ID	5.83^{a}	6.77^{a}	5.80^{b}	5.95^{a}
8	T2 + DP+ ID	6.08^{cd}	6.79^{a}	5.54^{b}	5.88^{a}
	Mean	**6.16**	**6.76**	**6.00**	**5.86**
Sub table 4.62 a. Effect of deep ploughing					
	Without DP	6.13	6.77	6.00	5.89
	With DP	6.19	6.75	6.00	5.83
		NS	NS	NS	NS
Sub table 4.62 b. Effect of intermittent drainage					
	CS	6.35	6.74	6.36	5.88
	ID	5.97	6.78	5.64	5.84
		Sig	NS	Sig	NS

* foliar application of Zn, Mg, Cu, B, Mo; DP- Deep ploughing; CS-Continuous submergence; ID-Intermittent drainage; DAT-Days after transplanting

Table 4. 63. Effect of deep ploughing and intermittent drainage on Eh (mv) of rice soil

Sl. No.	Treatments	*Kharif* 1998-99		*Rabi* 1998-99 30 DAT	*Kharif* 1999-00 30 DAT
		30 DAT	70 DAT		
1	NPK alone	41.7[cd]	15.3[a]	42.0[c]	70.0[a]
2	NPK+Si+foliar*	32.7[d]	17.0[a]	33.0[c]	59.0[a]
3	T1+ DP	38.3[cd]	14.0[a]	58.0[bc]	67.0[a]
4	T1+ ID	52.7[bc]	15.3[a]	95.0[a]	66.7[a]
5	T1+ DP+ ID	79.3[a]	15.0[a]	71.0[ab]	74.7[a]
6	T2 + DP	35.0[cd]	18.0[a]	84.0[ab]	66.3[a]
7	T2 + ID	72.3[a]	14.3[a]	71.0[ab]	64.0[a]
8	T2 + DP+ ID	65.7[ab]	15.7[a]	33.0[c]	61.3[a]
	Mean	**52.2**	**15.6**	**60.9**	**66.1**
Sub table 4.63 a. Effect of deep ploughing					
	Without DP	49.9	15.5	60.3	64.9
	With DP	54.6	15.7	61.5	67.3
		NS	NS	NS	NS
Sub table 4.63 b. Effect of intermittent drainage					
	CS	36.9	16.1	54.3	65.6
	ID	67.5	15.1	67.5	66.7
		Sig	NS	NS	NS

* foliar application of Zn, Mg, Cu, B, Mo; DP- Deep ploughing; CS Continuous submergence; ID-Intermittent drainage; DAT-Days after

During *rabi* 1998-'99, the average pH of rice soil at 30 DAT was 6.0 which was lower than the previous *kharif* season. During this season also, the ploughing practices did not result in any soil pH variation, but continuous submergence registered a significantly higher pH (6.36) as against 5.64 in intermittent drainage plots (Sub table 4.62). During *kharif* 1999-'00, no appreciable variation in soil pH was noticed among the treatments.

b. Eh of rice soil

The data on Eh of rice soil measured at different periods are presented in Table 4.63. During *kharif* 1998-'99, the mean soil Eh at 30 DAT was 52.2 mv whereas at 70 DAT it decreased to 15.6 mv. The redox potential at 30 DAT was unaffected by ploughing methods, but it showed variations with the water management practices. The Eh value in case of continuous submergence was 36.9 mv (Sub table 4.36) which was significantly lower than that recorded in intermittent drainage plots (67.5 mv). But such a variation was not noticed at 70 DAT.

During *rabi* 1998-'99 also, the water management treatments showed variations in redox potential, it being lower in continuous submergence plots. But during *kharif* 1999-'00, the Eh value did not show any remarkable variation with any of the practices.

4.2.4. Effect of deep ploughing and intermittent drainage on soil nutrient status

The effect of the practices of deep ploughing and intermittent drainage on nutrient status of soil at the end of *kharif* 1999-'00 and *rabi* 1999-'00 are presented in Tables 4.64 and 4.65.

4.2.4.1. Organic carbon

Organic carbon content at the end of *kharif* 1999-'00 crop was 1.25 per cent. Either of the practices of deep ploughing or intermittent drainage did not bring about a change in organic carbon over the normal practices.

The status of organic carbon showed a decreased value of 1.09 per cent towards the end of *rabi* season. During this season also, the content of organic carbon in the soil remained unaffected by ploughing methods or the water management practices.

4.2.4.2.. Ammoniacal and nitrate nitrogen

Both the treatments of ploughing or water management did not bring about a change in the NH_4-N and NO_3-N content of soil during *kharif* 1999-'00 except a decrease in NO_3- N in T_7 (NPK + Si + foliar application of Zn, Mg, Cu, B and Mo + intermittent drainage). Treatments did not show variation in *rabi* 1999-'00 also.

4.2.4.3. Phosphorous

Available P content at the end of *kharif* 1999-'00 was 43 kg ha^{-1} whereas it was only 36.4 kg ha^{-1} towards the end of *rabi* 1999-'00.

During *kharif* 1999-'00, deep ploughing resulted in a decrease in available P of soil from 47 kg ha^{-1} to 39 kg ha^{-1}. Intermittent drainage also showed significantly lower value of available P as compared to the practice of continuous submergence (Sub table 4.64).

During *rabi* season, the residual effect of deep ploughing was not pronounced in changing the P status. The P level was unaffected by water management practices also.

4.2.4.4. Potassium

The mean K status recorded during *kharif* 1999-'00 was 102 kg ha^{-1} while at the end of *rabi* 1999-'00 it was 91 kg ha^{-1}. The treatments did not manifest any variation on K status during both the seasons.

4.2.4.5. Calcium

Exchangeable Ca status at the end of *kharif* 1999-'00 was 1.72 m.eq/100 g soil. The available status during *rabi* was 1.70 m.eq/100 g soil.

Table 4.64. Effect of deep ploughing and intermittent drainage on soil nutrient status at the end of rice crop during *Kharif* 1999-00

No.	Treatments	Organic carbon (%)	NH_4^+N (kg ha^{-1})	NO_3^-N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available Ca (m.eq/100g)	Available Mg (m.eq/100g)	Available S (kg ha^{-1})
1	NPK alone	1.17^a	10.9^a	21.7^{ab}	52.3^a	111^a	1.91^a	0.34^a	157^a
2	NPK+Si+foliar	1.26^a	10.2^a	26.0^a	53.4^a	101^a	1.81^a	0.27^a	135^b
3	T_1+ DP	1.26^a	9.2^a	23.5^a	47.8^{ab}	93^a	1.59^a	0.37^a	118^c
4	T_1+ ID	1.32^a	12.8^a	23.3^a	36.7^{ab}	127^a	1.63^a	0.32^a	127^{bc}
5	T_1+ DP+ ID	1.23^a	12.8^a	21.1^{ab}	31.0^b	97^a	1.73^a	0.34^a	130^{bc}
6	T_2 + DP	1.30^a	9.0^a	17.9^{ab}	36.6^{ab}	83^a	1.72^a	0.35^a	132^b
7	T_2 + ID	1.17^a	12.1^a	13.2^b	46.8^{ab}	94^a	1.85^a	0.47^a	134^b
8	T_2 + DP+ ID	1.25^a	9.5^a	24.9^a	39.1^{ab}	108^a	1.51^a	0.46^a	154^a
	Mean	**1.25**	**10.8**	**21.5**	**43.0**	**102**	**1.72**	**0.37**	**136**
Sub table 4.64 a. Effect of deep ploughing									
	Without DP	1.23	12	21	47	108	1.79	0.35	138
	With DP	1.26	10	22	39	95	1.64	0.38	134
		NS	NS	NS	Sig	NS	NS	NS	NS
Sub table 4.64 b. Effect of intermittent drainage									
	CS	1.25	10	22	48	97	1.76	0.33	136
	ID	1.24	12	21	38	107	1.68	0.40	136
		NS	NS	NS	Sig	NS	NS	NS	NS

* foliar application of Zn, Mg, Cu, B, Mo; DP- Deep ploughing; CS-Continuous submergence;

Table 4.65. Effect of deep ploughing and intermittent drainage on soil nutrient status at the end of rice crop during *Rabi* 1999-00

No.	Treatments	Organic carbon (%)	NH_4^+N (kg ha^{-1})	NO_3^-N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available Ca (m.eq/100g)	Available Mg (m.eq/100g)	Available S (kg ha^{-1})
1	NPK alone	1.06^{a}	9.9^{a}	11.6^{a}	38.8^{a}	83^{a}	1.46^{b}	0.48^{a}	85^{ab}
2	NPK+Si+foliar*	1.10^{a}	10.8^{a}	12.5^{a}	33.7^{a}	94^{a}	1.67^{ab}	0.38^{ab}	91^{ab}
3	T_1+ DP	1.04^{a}	11.6^{a}	14.3^{a}	40.4^{a}	86^{a}	1.67^{ab}	0.29^{bc}	91^{ab}
4	T_1+ ID	1.10^{a}	11.0^{a}	11.6^{a}	39.1^{a}	93^{a}	1.72^{ab}	0.27^{bc}	86^{ab}
5	T_1+ DP+ ID	1.11^{a}	9.0^{a}	11.6^{a}	31.5^{a}	90^{a}	1.83^{a}	0.32^{bc}	67^{b}
6	T_2 + DP	1.03^{a}	15.2^{a}	8.1^{a}	40.4^{a}	95^{a}	1.85^{a}	0.25^{bc}	95^{ab}
7	T_2 + ID	1.15^{a}	11.8^{a}	16.0^{a}	32.8^{a}	95^{a}	1.75^{ab}	0.21^{c}	100^{a}
8	T_2 + DP+ ID	1.12^{a}	12.8^{a}	14.8^{a}	34.1^{a}	88^{a}	1.63^{ab}	0.26^{bc}	89^{ab}
	Mean	**1.09**	**11.5**	**12.6**	**36.4**	**91**	**1.70**	**81**	**88**
Sub table 4.65 a. Effect of deep ploughing									
	Without DP	1.10	10.9	12.9	36.1	91	1.65	0.34	91
	With DP	1.08	12.2	12.2	36.6	90	1.74	0.27	86
		NS	NS	NS	NS	NS	NS	NS	NS
Sub table 4.65 b. Effect of intermittent drainage									
	CS	1.06	11.9	11.6	38.3	90	1.66	0.35	91
	ID	1.12	11.2	13.5	34.4	92	1.73	0.27	86
		NS	NS	NS	NS	NS	NS	Sig	NS

* foliar application of Zn, Mg, Cu, B, Mo; DP- Deep ploughing; CS-Continuous submergence;

Both deep ploughing and intermittent drainage did not affect the Ca status during *kharif* 1999-'00. During *rabi* 1999-'00 T_1 had significantly lower content than T_5 and T_6.

4.2.4.6. Magnesium

Soil status of Mg was 0.37 m.eq/100 g soil at the end of *kharif* season and 0.32 m.eq/100 g in *rabi*.

During *kharif*, deep ploughing registered a Mg level of 0.38 m.eq/100 g as against 0.35 m.eq/100 g with normal ploughing (Sub table 4.64). Among the two water management schedules, continuous submergence had 0.33 m.eq/100 g while intermittent drainage resulted in a higher level of Mg (0.40 m.eq/100 g). However the differences in the Mg level were not significant. During *rabi* T_1 recorded the highest content. All others except T_2 had significantly lower values. Intermittent drainage plots had a significantly lesser Mg level (0.27 m.eq/100 g) as compared to continuous submergence (0.35 m.eq/100 g).

4.2.4.7. Sulphur

The S status of soil during *kharif* was 136 kg ha^{-1} whereas in *Rabi* it was only 88 kg ha^{-1}.

During *kharif* 1999-'00, T_1 and T_8 registered higher content. Significantly lower values were recorded in the other treatments. During *Rabi* 1999-'00 T_7 (NPK + Si + foliar application of Zn, Mg, Cu, B and Mo + intermittent drainage) registered the highest content of 100 kg ha^{-1} whereas T_5 (NPK + deep ploughing + intermittent drainage) had significantly lower value.

4.2.5. Influence of deep ploughing and intermittent drainage on yield of succeeding summer cowpea

Cowpea was raised in the treatment plots of rice during summer 1999. The seed yield is given in Table 4.66. The seed yield from the plot which received deep ploughing during *kharif was* 1114 kg ha^{-1} whereas it was 1050 kg ha^{-1} with the normal practice of ploughing. However, the yield differences were not significant. The two systems of water management also produced comparable yields.

Table 4.66. Effect of deep ploughing and intermittent drainage on seed yield of summer cowpea

Sl. No.	Treatments in previous rice crop	Seed yield (kg ha^{-1})
1	NPK alone	1131[a]
2	NPK+Si+foliar*	1037[a]
3	T_1+ DP	1186[a]
4	T_1+ ID	962[a]
5	T_1+ DP+ ID	1108[a]
6	T_2 + DP	1102[a]
7	T_2 + ID	1070[a]
8	T_2 + DP+ ID	1059[a]
Sub table 4.66 a. Effect of deep ploughing		
	Without DP	1050
	With DP	1114
		NS
Sub table 4.66 b. Effect of intermittent drainage		
	CS	1114
	ID	1050
		NS

* foliar application of Zn, Mg, Cu, B, Mo; DP- Deep ploughing;
CS-Continuous submergence; ID-Intermittent drainage

Discussion

5. DISCUSSION

5.1. Experiment I. Soil–plant elemental status and productivity as influenced by crop residue recycling and nutrient supply in the rice- legume cropping system

The experiment was carried out at Regional Agricultural Research Station, Pattambi during the period 1997-'00. The experiment covered seven seasons where three *rabi* rice crops, two *kharif* rice crops and two summer cowpea were raised in rice-rice-cowpea sequence. The data obtained are critically analysed and discussed in this chapter.

5.1.1. Influence of season and management practices on growth and yield

5.1.1.1. Growth attributes

Comparison of the growth habits of *kharif* and *rabi* crops revealed that significantly taller plants are produced during *kharif.* It also had higher tiller count and biomass production during the early stages. The favourable weather condition during the rainy season might have resulted in better growth of plants during *kharif* season. Temperature that prevail in rainy weather are conducive to excessive tillering, leafy growth and tallness (Murata, 1967).

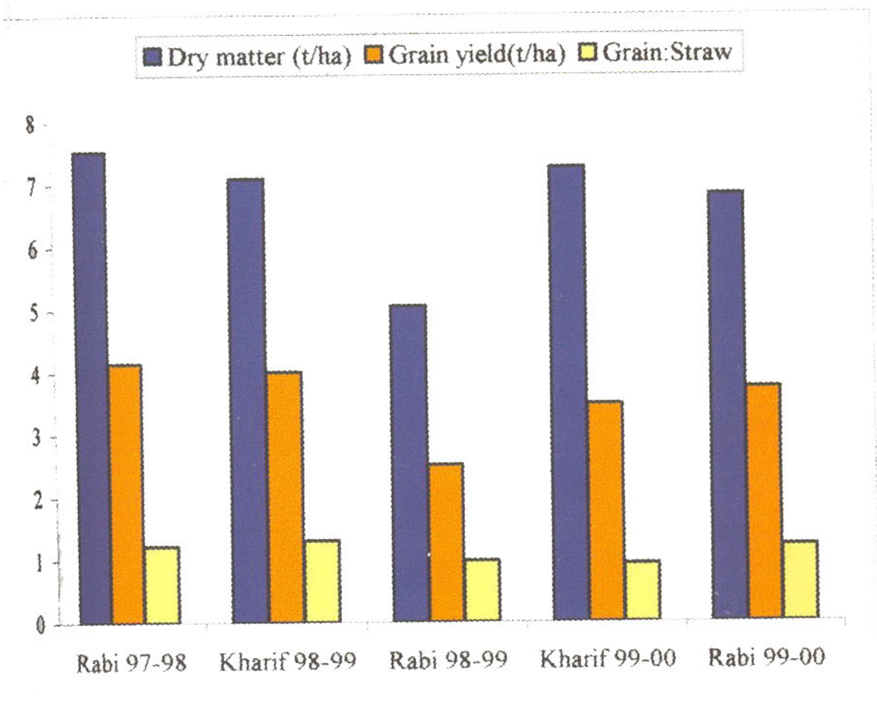
In the *rabi* season, 1999-'00 crop produced shorter plants; but it had higher tiller number of 7.5 at panicle initiation stage. The lesser amount of rainfall might have resulted in stunted growth of *rabi* 1999-'00 crop as compared with the other two *rabi* seasons. The influence of moderate water stress in inducing tiller production has been well established (Burbey and Zaini, 1990). Though the tiller count remained to be low in *rabi* 1997-'98 crop upto PI stage, towards maturity it maintained a higher count. Number of productive tillers also was higher during this season. Contrary to this, a reduction in tiller number was noticed from PI to maturity stage of the crops of the other seasons. The extent of tiller decline and the number of productive tillers per hill have been found to be closely related with yield. Musthafa (1995) has reported that destruction of tillers after the PI stage, which is designated as tiller decline, is one of the main reason for low productivity of rice crop in laterite soils.

Kharif 1998-'99 and *rabi* 1999-'00 crops had lower shoot dry matter production at tillering stage and PI stages. However, no direct relationship was noticed between yield and dry matter production in the early stages. The percentage increase in dry matter production at maturity over PI of the five seasons in the order beginning from *rabi* 1997-'98 were 408, 284, 131, 205 and 258 per cent respectively (Table 4.3 and 4.6). Higher grain yield was found to be a combined effect of higher dry matter production towards later stages and a higher grain : straw ratio (Fig 1). The correlation values also indicated this. De Datta (1981) has reported that increase in dry matter between PI and harvest is highly correlated with grain yield. This suggests that management programmes for higher yields should aim at higher photosynthesis of the crop as well as better translocation in the grain formation stage.

The different treatments have influenced the growth of the crop. The treatment 'straw alone' (T_1) was found to be significantly inferior, which could be due to inadequate supply of nutrients. Plant height of *kharif* crop increased with silica application @ 250 kg ha^{-1}. Similar results have been reported earlier (Ma *et al.*, 1989; Wang *et al.*, 1999). This is attributed to the role of silica in promotion of photosynthetic activity (Agarie *et al.*, 1992). Incorporation of straw of *kharif* crop enhanced plant height and biomass production of *rabi* crop. Since *rabi* is the season immediately following the straw addition, the crop could have benefitted more.

Application of K at 70 kg ha^{-1} increased tiller count at maturity stage of *kharif* 1999-'00 and *rabi* 1997-'98 crops over normal rate of application ie. 35 kg ha^{-1}. Increased K application was found to

Fig. 1. Total biomass, grain yield and grain straw ratio during different seasons



enhance N absorption which might have favoured tiller production as reported by De Datta (1981).

5.1.1.2. Yield

Grain yield over the five seasons varied from 1671 kg ha^{-1} (in T_1 of *rabi* 1998-'99) to 4477 kg ha^{-1} in T_9 of *rabi* 1997-'98) (Table 4.6). This wide variability may be attributed to the influence of season and treatments. It could be seen that the contribution of weather was much higher than the effect of treatments (Fig 2 and 3). The mean values showed that grain yield and straw yield were significantly higher during *kharif* season. But the highest grain yield among the five seasons was recorded during *rabi* 1997-'98. The *rabi* season of the following year yielded only 2510 kg ha^{-1}, thus registering a yield variation of about 65 per cent between *rabi* seasons. But it could be seen that the variation in grain yield between the two *kharif* seasons was comparatively low. In case of straw yield also the variation was higher during *rabi* season. This shows that the yields are more stable in *kharif.* Though dry matter accumulation in vegetative plant parts were not much influenced by weather variations, the translocation to the sink was adversely affected especially in *rabi*..

The wide changes noticed in the yield of grain and straw during different seasons appear to be the combined effect of the weather parameters viz. sunshine hours, temperature and rainfall (Appendix I to VIII and Fig 4 and 5). Higher the duration of sunshine hours and rainfall greater the dry matter accumulation. The lowest yield was obtained during *rabi* 1998-'99 and this crop period was characterized by higher mean RH as well as lower evaporation and wind speed and sunshine hours than the other two *rabi* seasons up to flowering stage. The cloudy weather prevailed during the season might have reduced the N metabolism resulting in a decreased yield. Similar observations have been made by Murty *et al.* (1983).

Fig. 2. Mean grain yield of rice during different seasons

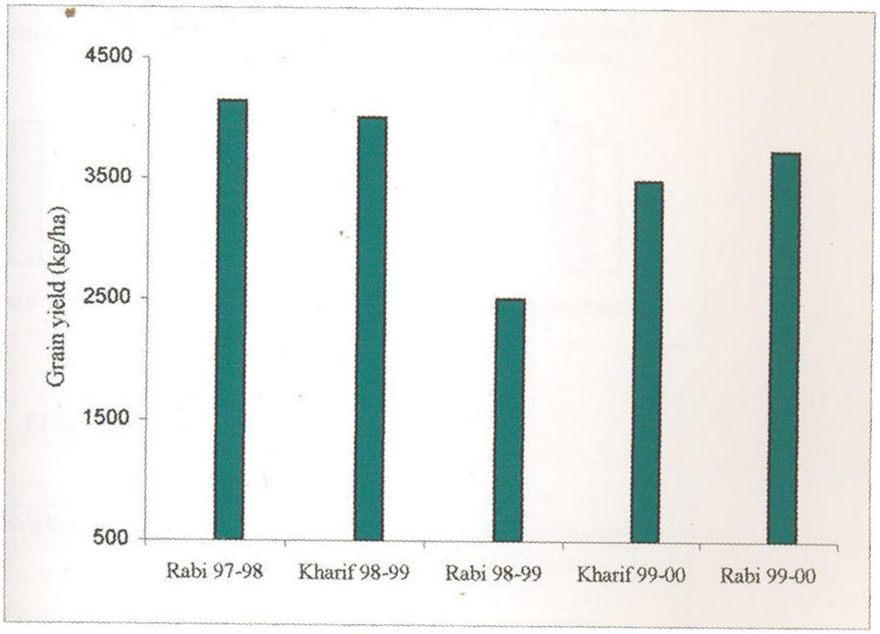


Fig. 3. Mean effect of treatments on grain yield of rice

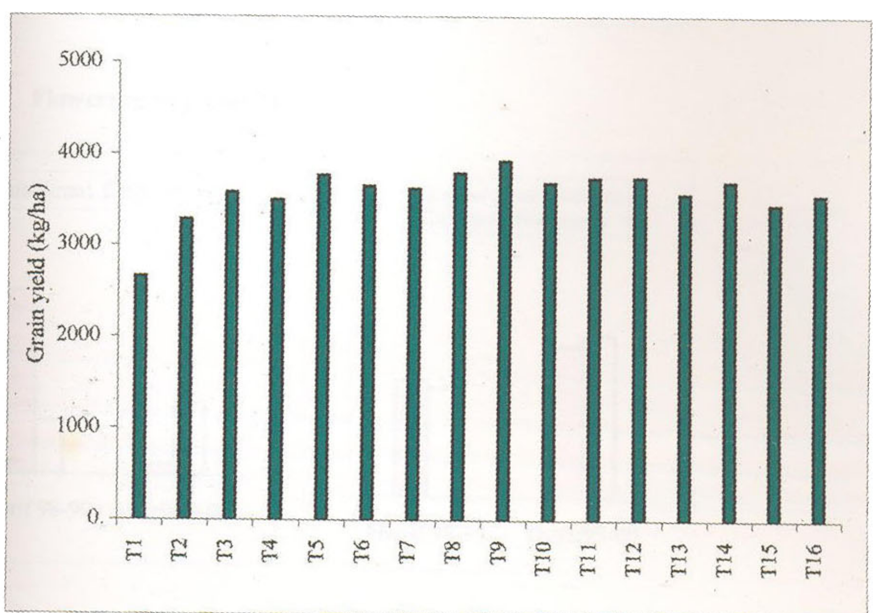
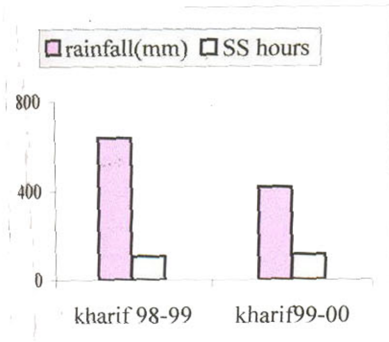
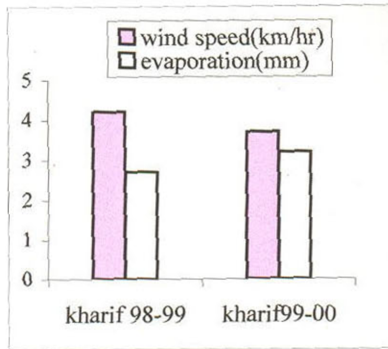


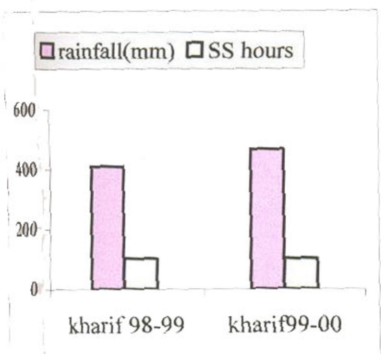
Fig 4. Mean weather parameters during the *Kharif* seasons

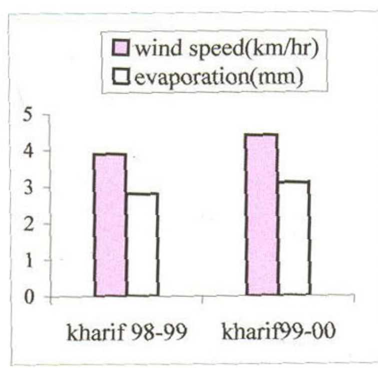
Tillering stage



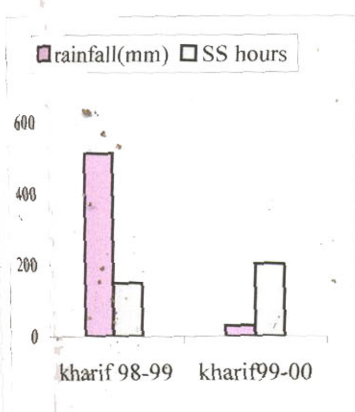


PI to flowering





Flowering to maturity



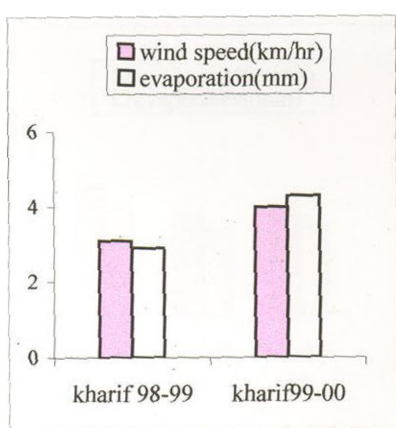
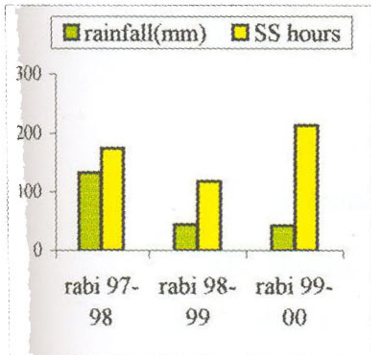
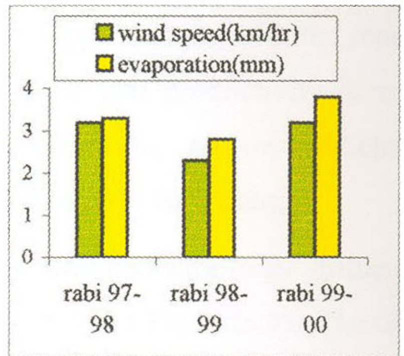


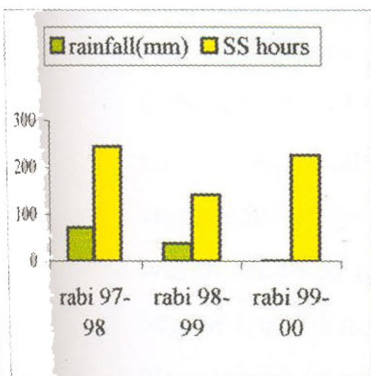
Fig 5. Mean weather parameters during the *Rabi* seasons

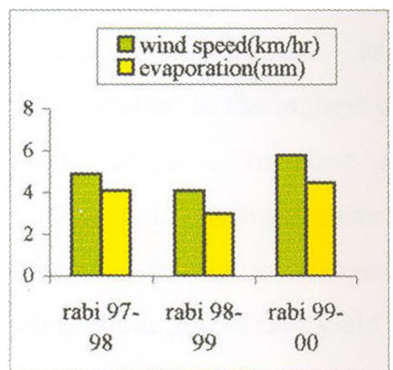
Tillering stage



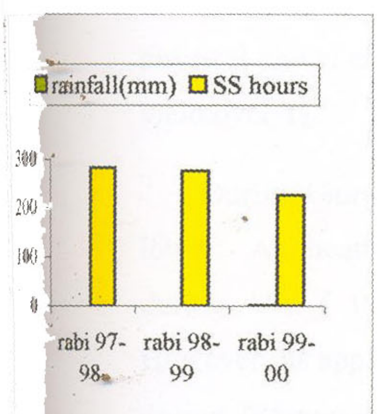


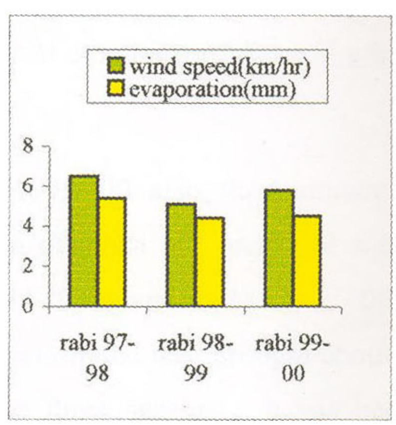
PI to flowering





Flowering to maturity





The higher yield in *rabi* 1997-'98 is attributable to the high solar radiation (863.1 h) and total rainfall (461.9 mm) whereas during the other two *rabi* seasons, rainfall and solar radiation was lower. During *kharif*, though solar radiation was low, the accompanied low temperature resulted in a favourable balance between photosynthesis and respiration. This goes in tune with the reports of Oldeman *et al.* (1986). This revealed that productivity is related to the weather situations of the prevailing season and changes in weather can bring about remarkable yield variations.

The treatments exhibited significant influence on grain and straw yield (Table 4.6 and 4.7 and Fig. 6 to 9). The treatment which did not receive any inorganic fertilizers (T_1) registered the lowest yield during all the seasons. During *kharif* 1998-'99 application of recommended dose of NPK fertilizers along with application of 250 kg ha^{-1} silica and soil application of $ZnSO_4$ 20 kg ha^{-1}, $MgSO_4$ 20 kg ha^{-1} and $CuSO_4$ 12.5 kg ha^{-1} (T_9) resulted in the highest grain yield of 4474 kg ha^{-1}. Application of inorganic fertilizer alone (T_2) produced significantly lower yields; but was higher than straw alone treatment which received no inorganic fertilizers. Progressive addition of Zn, Mg or Cu did not bring about significant yield increase at each step. Hence individually none of the treatments produced any remarkable effect over its non-application. However, the integrated supply of nutrients as well as application of silica might have resulted in better physical and chemical condition of the soil which led to higher grain yield over T_2.

During *kharif* 1999-'00 also, the treatment 'straw alone' yielded lower. Application of silica has produced significant yield increase during *kharif* 1999-'00 and *rabi* 1999-'00. (Sub table 4.6 c). However, its application had not brought about any marked influence during the previous three seasons. It has been reported that silica functions mainly as an ameliorant and it modifies soil characteristics (Padmaja and Varghese, 1966). Continued application of silica

Fig. 6. Effect of cropping system on grain yield of rice

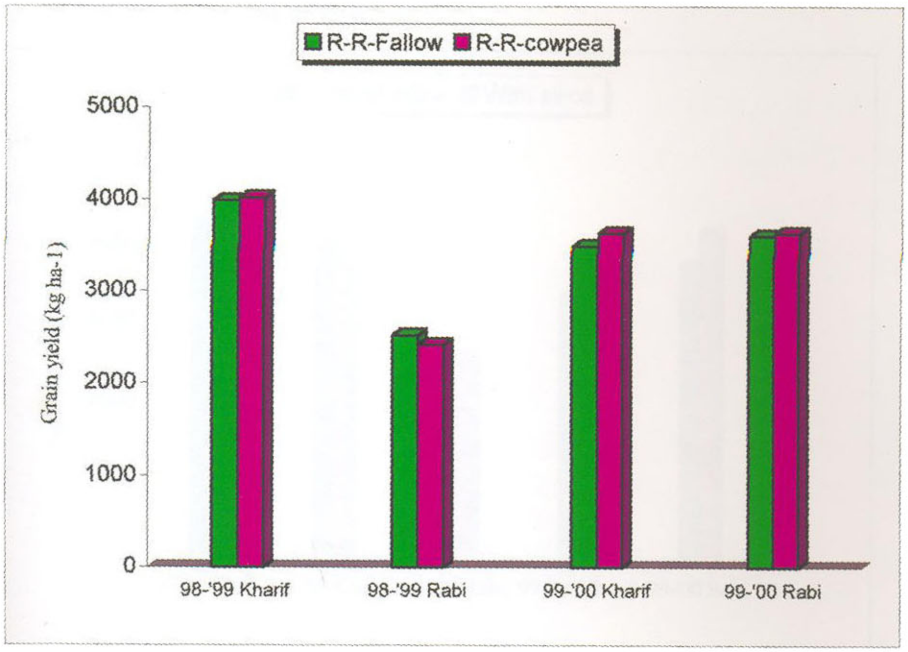


Fig. 7. Effect of *kharif* straw incorporation on grain yield of rice

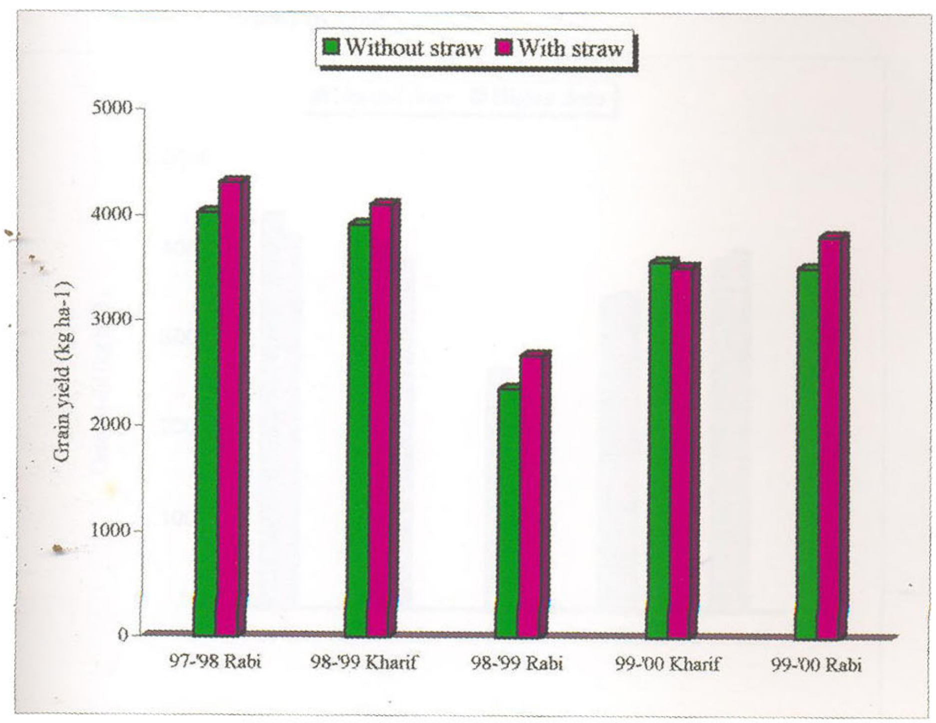


Fig. 8. Effect of silica application on grain yield of rice

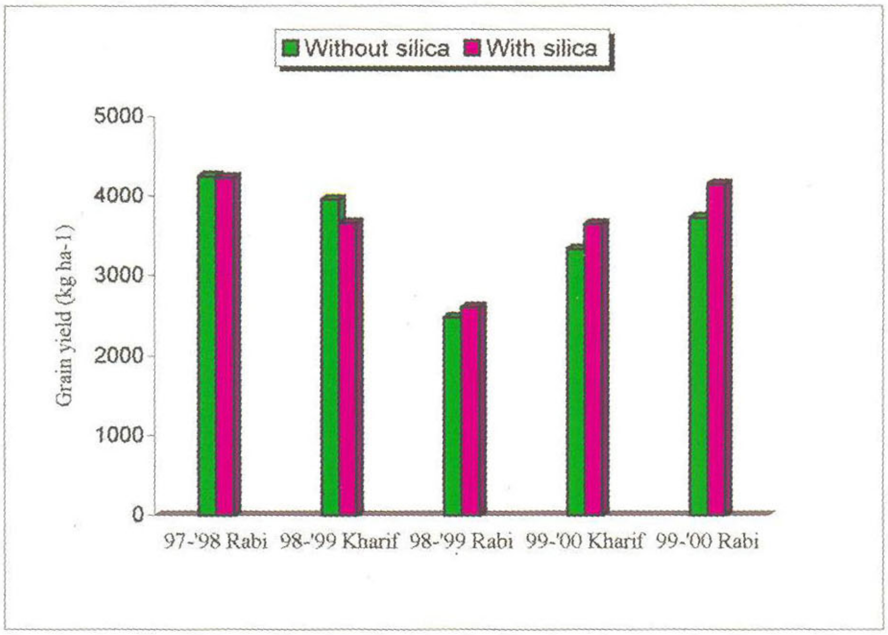
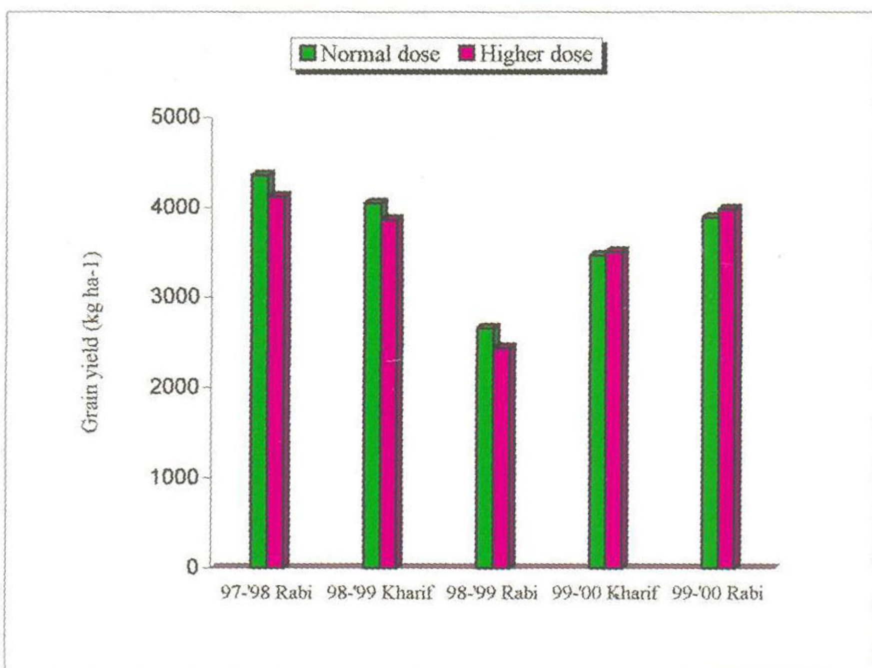


Fig. 9. Effect of higher dose of K on grain yield of rice



might be required for the amelioration and hence initial applications did not bring about significant yield increase.

Incorporation of *kharif* straw brought about significant increase of grain yield during the three *rabi* seasons (Sub table 4.6 b). In the present experiment, harvest of *kharif* crop was done retaining two third portion of straw which was incorporated in the field. The additional straw recycling from this practice amounted to about 1500 kg ha^{-1}. Rice straw contains a good amount of K, Ca, Si, N, P and S absorbed by the crop and its application might have resulted in slow and steady availability of nutrients. Since *rabi* is the season immediately following the straw incorporation, the crop was benefited more. The plant showed a significantly increased plant height, shoot dry matter production and spikelets per panicle. Reports of Hegde (1996) also revealed that integration of straw with inorganic fertilizers is beneficial.

Application of straw has resulted in increasing the yield from 4028 kg ha^{-1} to 4309 kg ha^{-1} during *rabi* 1997-'98 which worked out to 7 per cent increase (Sub table 4.6 b). In the following *rabi* seasons the increases were 13.5 per cent and 9.0 per cent, respectively. The variation during *kharif* 1998-'99 and *kharif* 1999-'00 were 5.0 per cent and –1.0 per cent respectively. Application of silica at 250 kg ha^{-1} has not brought about any significant yield variation during *rabi* 1997-'98. However, in the succeeding *rabi* seasons there was progressive increase by 5.0 per cent and 11 per cent respectively. The change in *kharif* 1998-'99 and 1999-'00 worked out to -8.0 per cent and 9.5 per cent respectively (Fig 10 to 12). This showed that the *rabi* seasons respond better to management practices compared to *kharif* season. The gradual increase in yield indicates that the practice of straw recycling and silica application can improve the productivity of the soil over years.

Fig. 10. Variation in grain yield between treatments (Straw+NPK) and (NPK alone) over seasons

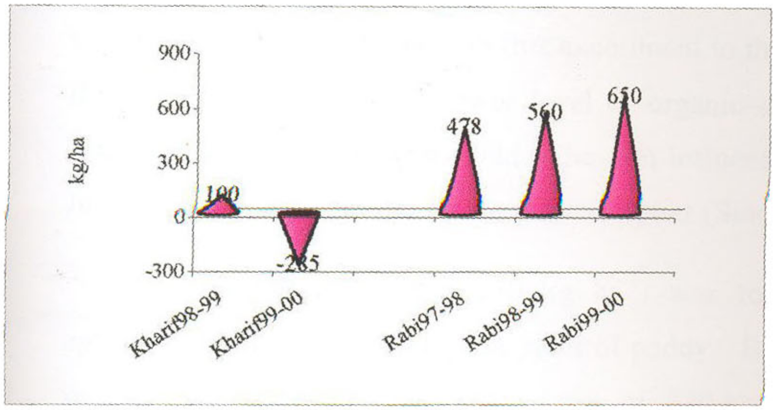


Fig.11. Variation in grain yield between treatments (Straw+NPK+Si) and (NPK alone) over seasons

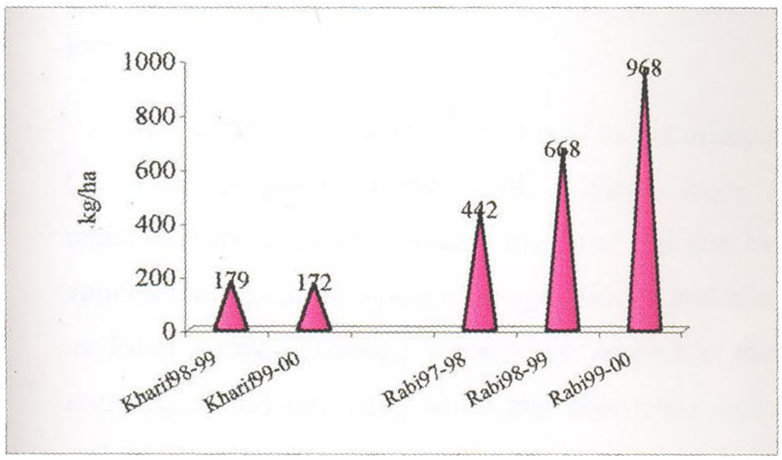
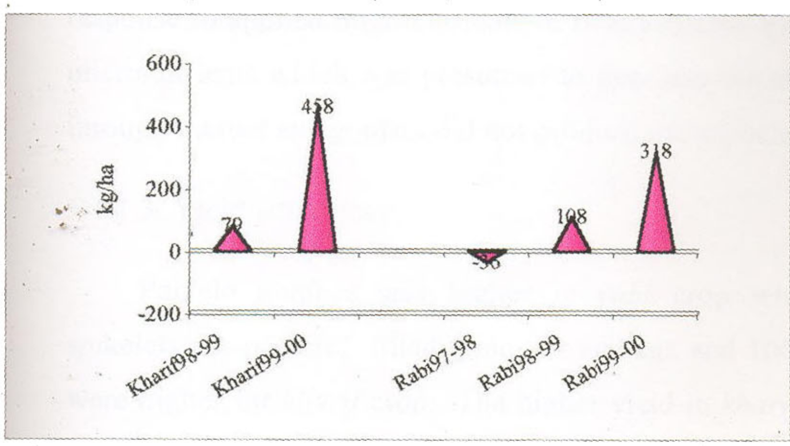


Fig.12 Variation in grain yield between treatments (Straw+NPK+Si) and (Straw+NPK) over seasons



Raising cowpea during summer and incorporation of its residues had no influence on grain or straw yield. Inclusion of cowpea in the cropping system and its residue addition is practised to improve the nitrogen supply and organic carbon status of the soil. However, the absence of response observed in this experiment to this practice shows that either lack of N or a lower level of organic carbon is not the limiting factor for the low yield. The non-influence of N in yield limiting process of rice has been reported earlier (Sindhu, 2002).

The higher dose of K (70 kg ha^{-1}) was found to have no appreciable effect on growth and yield of paddy. Bridgit (1999) has reported yield advantage with application of 120 kg ha^{-1} of K in iron rich laterite soils where the benefit was due to its indirect effect on absorption of other elements like iron. The lack of response at the tested level might be because response can be expected only at higher levels of K application.

The secondary nutrient, Mg as well as the micro nutrients, Zn and Cu were supplied through soil. Since there are chances of unavailability of these elements from the soil due to competition, its application was done through foliage also. B and Mo also were given as foliar spray. Though these were applied continuously for five seasons, it did not bring about any significant influence on growth and yield of paddy. Hence the deficiency of these elements as a nutritional constraint in laterite soils can be ruled out. Mariam and Koshy (1977) and Muralidharan (1992) also have reported absence of response to applied micronutrients in rice. External application of the micronutrients which was presumed to decrease the absorption of Fe through mutual antagonism did not produce the expected effect.

5.1.1.3. Yield attributes

Panicle number was higher in *rabi* crop while number of spikelets per panicle, filled grain per centage and 1000 grain weight were higher for *kharif* crop. The higher yield in *kharif* crop could be accounted for the increased number of spikelets per panicle, lesser chaff per centage and 1000 grain weight. The reduced 1000 grain weight during *rabi* reveal that translocation might be inhibited during the season.

Among the treatments, the panicle number and spikelets per panicle during different seasons were lower in straw alone applied plots. This could be attributed to the decreased dry matter production which in turn resulted in lower sink capacity.

5.1.2. Influence of season and management practices on plant nutrient content and uptake

The variation in plant elemental status due to the effect of season and treatments are shown in Fig 13 a to 13 k and 14 a to 14 f respectively.

The nitrogen content was higher in *rabi* crop which could be due to better N use efficiency and absorption during the season. But since the total biomass was low, the increase was not reflected in the total uptake. The increase in N content at tillering stage of 1998-'99 *kharif* crop with higher dose of K application could be due to the positive correlation between N and K (Tisdale et al., 1995). It was observed that during *kharif* 1999-'00 silica application decreased N content. Application of silica has increased its concentration in the plant and this might have led to decreased N absorption due to the negative correlation between the two elements as reported by Sumida (1992). However, during *rabi* 1999-'00, N content has recorded an increase which could be due to better availability of N during the season.

At PI stage of *kharif* 1998-'99 crop, the increased N content with foliar spray of Mo is attributed to the favourable effect of Mo on N metabolism as reported by Dasgupta and Basuchoudhary (1974). Increased N uptake with *kharif* straw incorporation is attributable to the higher grain and straw yield produced by this treatment.

Fig 13 a. Nitrogen content (%) of plant at PI stage during different seasons

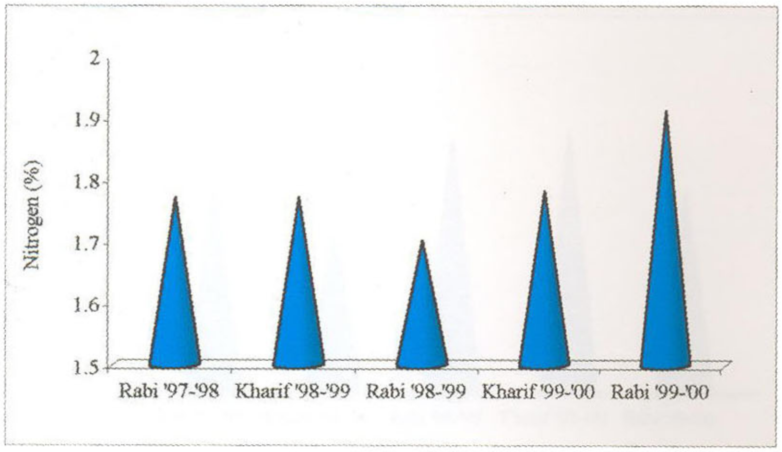


Fig 13 b. Phosphorous content (%) of plant at PI stage during different seasons

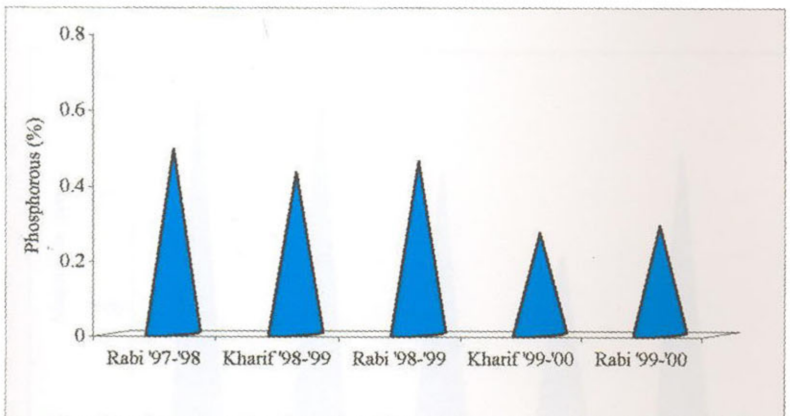


Fig 13 c. Potassium content (%) of plant at PI stage during different seasons

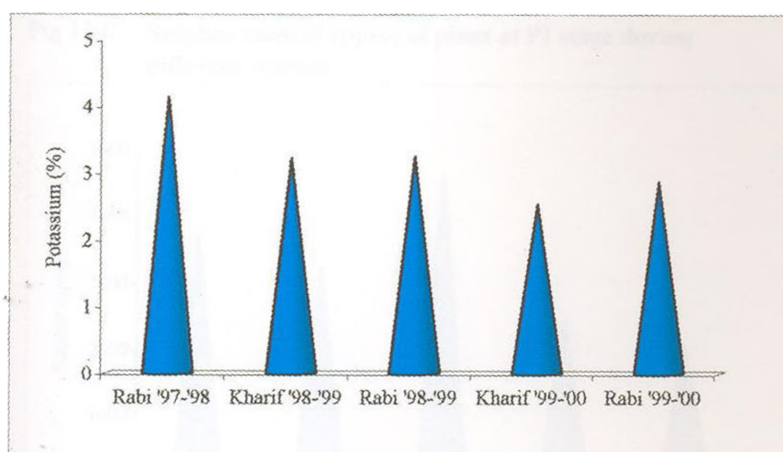


Fig 13 d. Calcium content (ppm) of plant at PI stage during different seasons

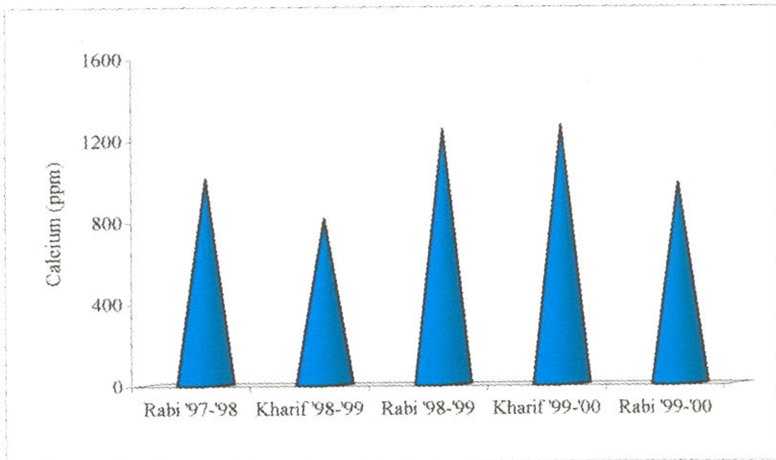


Fig 13 e. Magnesium content (ppm) of plant at PI stage during different seasons

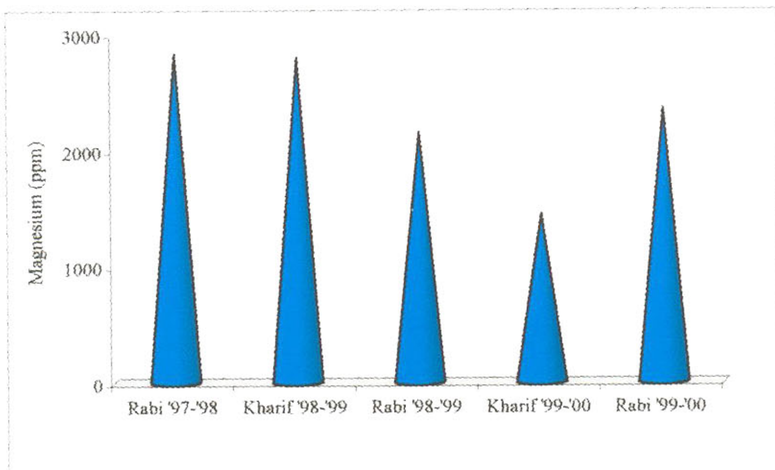


Fig 13 f. Sulphur content (ppm) of plant at PI stage during different seasons

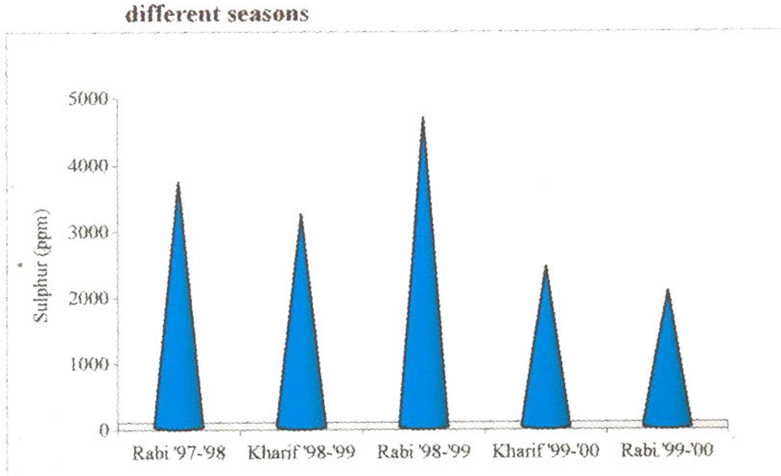


Fig 13 g. **Iron content (ppm) of plant at PI stage during different seasons**

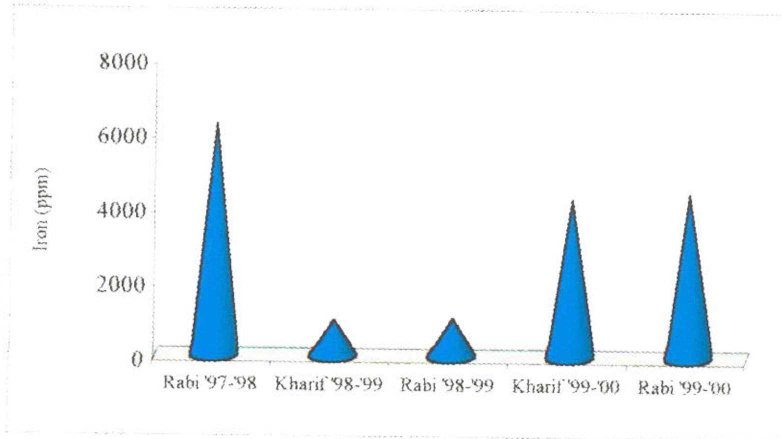


Fig 13 h. **Manganese content (ppm) of plant at PI stage during different seasons**

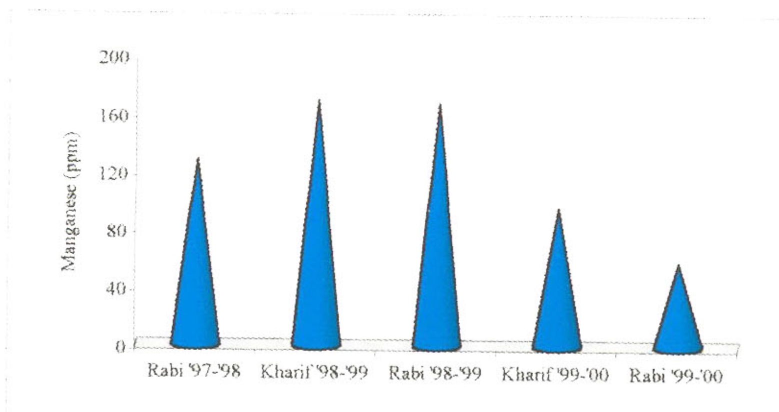


Fig 13 i. **Zinc content (ppm) of plant at PI stage during different seasons**

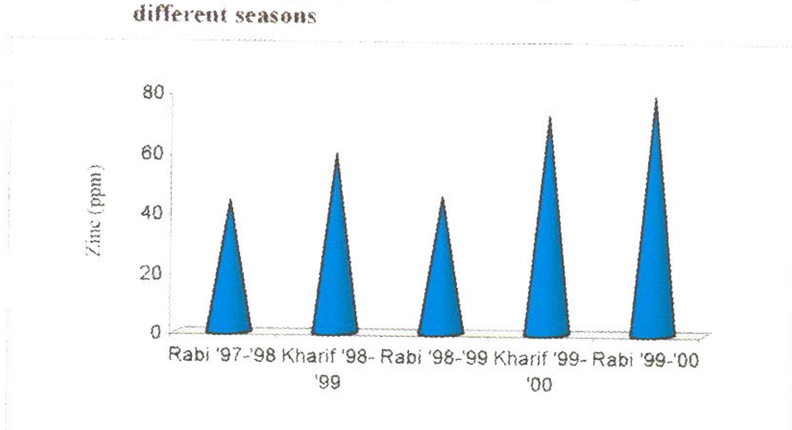


Fig 13 j. Copper content (ppm) of plant at PI stage during different seasons

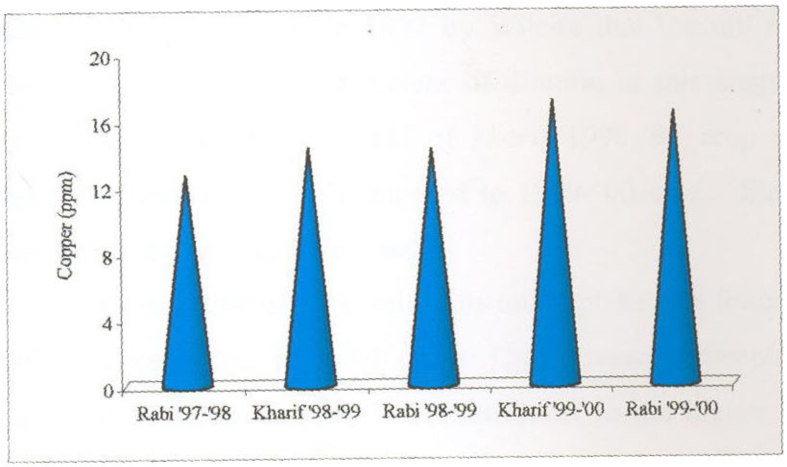
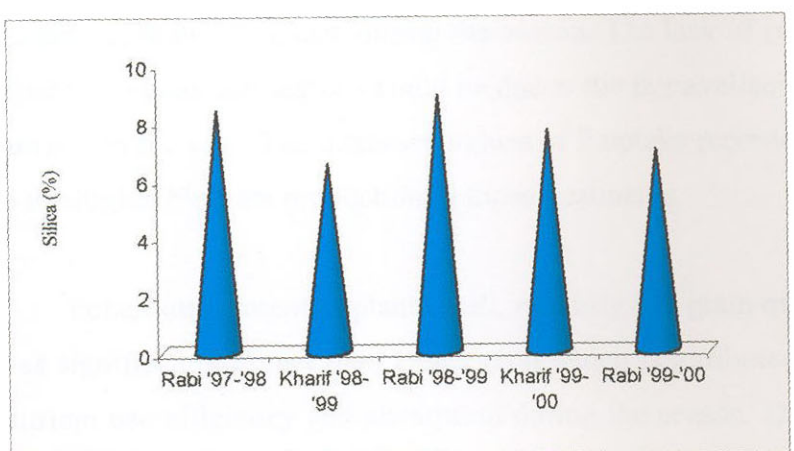


Fig 13 k. Silica content (%) of plant at PI stage during different seasons



The percentage dilution of N from tillering to PI stage of the plants is 19.2 per cent and 4 per cent respectively during *kharif* 1998-'99 and *kharif* 1999-'00 and it is 21.7 per cent and 32.5 per cent respectively during *rabi* 1998-'99 and *rabi* 1999-'00. It has been established as early as in 1937 by Wilcox that the utilization of a nutrient is related with the extent of dilution at this stage. This is evidenced by the higher yield of *kharif* 1998-'99 crop which has shown higher N dilution compared to 1999-'00 crop. Similar yield variation is noticed in *Rabi* also.

Concentration of P as well as its total uptake was found higher in 1998-'99 crops than 1999-'00 crops. The increased concentration of P during 1998-'99 over 1999-'00 is attributed to the higher amount of rainfall during 1998-'99 crop period. The prolonged period of submergence would have decreased the Eh and increased the concentration of water soluble and available P as reported by Jenne (1977). The higher yield in silica applied plots of *kharif* 1999-'00 has resulted in higher P uptake during the season. The lack of response in other treatments and seasons could be due to the fair availability of the nutrient in the soil. The increased values of P uptake recorded are due to the higher biomass production in those treatments.

Potassium content of plants at PI, maturity and grain of *rabi* crop was significantly higher than *kharif* crop which is attributed to better nutrient use efficiency and absorption during the season. Decrease in the content of K observed with Mg application is attributed to the antagonism of K with this element. K-Mg antagonism has been reported by many workers (Varughese and Jose, 1994: Muralidharan and Jose, 1994 a). K content is also found to decrease with silica application which could be attributed to the formation of potassium silicate which render K unavailable. The decreased K uptake with application of silica has been observed by Islam and Saha (1969). The decrease in K content due to *kharif* straw incorporation could be also due to the release of Si from decomposed straw and the resultant potassium silicate formation. The increased K content due to Zn application is assumed to be due to release of K from the exchange complex consequent to application of soluble Zn salts. Though K content decreases with Mg, the increased uptake of K due to Mg application during *rabi* 1998-'99 is attributed to the higher production of grain and straw. The increased content as well as higher yield with *kharif* straw incorporation is responsible for higher K uptake in the treatment. The lower biomass production as well as reduced content in straw and grain is responsible for the low K uptake in straw alone treatment.

Ca uptake by the crop was higher in *rabi*. This is due to increased content of the element in the plant during the season due to better use efficiency of the nutrient. Ca content of plant showed variation with treatments. The decrease in Ca content due to soil application of Zn, Mg and Cu is assumed to be due to mutual competition between these cations. During *rabi* 1998-'99 raising of summer cowpea and *kharif* straw incorporation increased the Ca content which could be due to better availability of the nutrient from the decomposed residues. At tillering stage of the crop higher dose of K resulted in decreased Ca content of plants during the *kharif* seasons which could be due to antagonism between K and divalent cation Ca which is in conformity with the reports of Muralidharan and Jose (1994 a). However, during *rabi* 1998-'99 there was an increase. The K dose has influenced the content of Ca at different stages of the various seasons due to mutual interactions. It is reported that the absorption of an element is influenced by elemental interactions in the soil and the relative influences are governed by a number of factors (Lindsay, 1979). The higher absorption of Ca has increased the content of the element during *rabi* and lower absorption of the element resulted in decreased uptake. Increased Ca uptake with application of silica and higher K dose during *kharif* 1999-'00 is due to the increased yield obtained in this treatment.

Fig 14 a. Efffect of summer cowpea on N content of rice at tillering stage

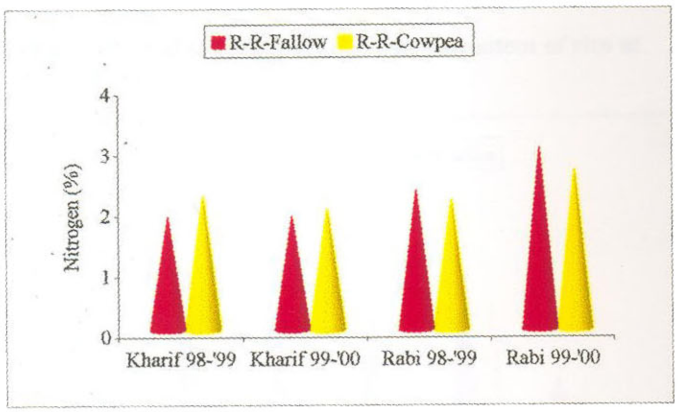


Fig 14 b. Efffect of kharif straw incorporation on silica content of rice at tillering stage

Fig 14 c. Efffect of silica application on K content of rice at tillering stage

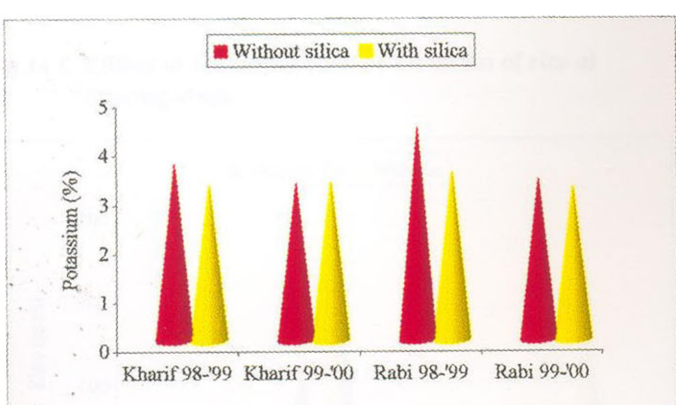


Fig 14 d. Efffect of silica application on Mn content of rice at PI stage

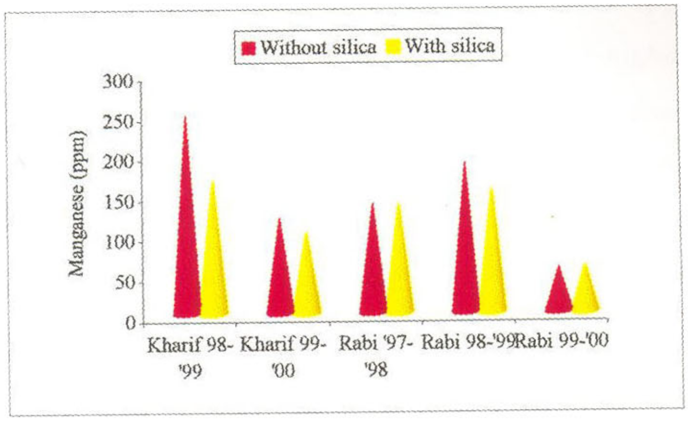


Fig 14 e. Efffect of silica application on silica content of rice at tillering stage

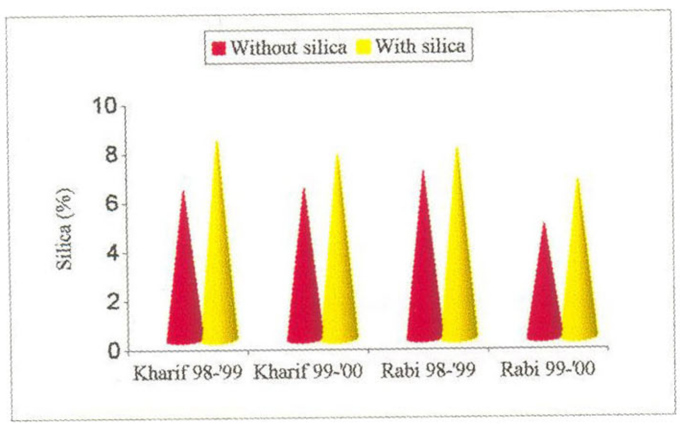
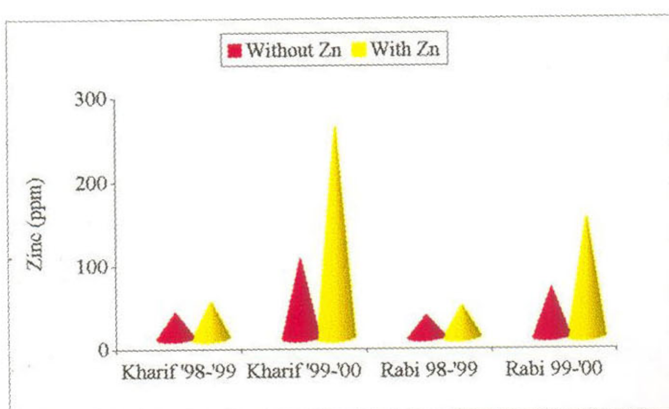


Fig 14 f. Efffect of soil application of Zn on Zn of rice at tillering stage



Content and uptake of Mg also showed differences with seasons and treatments. The higher uptake of Mg during *kharif* 1999-'00 due to silica application is due to higher biomass production whereas the lower Mg content of plants with higher K application resulted in decreased Mg uptake in *rabi* 1998-'99. Si + higher K dose resulted in a decrease which is possibly by their antagonism with Mg. Foliar spray of B has enhanced Mg content. Muralidharan (1992) also have observed similar results. Soil application of Mg has resulted in higher Mg content than its foliar supply which is evidently due to the higher availability of the nutrient from soil application.

The S content of plants during *rabi* was higher than *kharif* season crop which is attributed to the better efficiency of the nutrient during the season. It could also be noticed that the S content during *kharif* and *rabi* seasons of 1998-'99 was higher than the content of the corresponding seasons of 1999-'00. Sulphur reacts with Fe in the soil and its availability decreases. It is observed that during 1998-'99 absorption of Fe was remarkably lower than 1999-'00. It is probable that due to low content of Fe the chance of reaction of S with Fe was less which might have increased the availability of S and hence its increased content and uptake. Sulphur content and uptake differed with treatments also. The increased content of S noticed in the plant system at different stages with soil application of $ZnSO_4$ and $CuSO_4$ would be due to the higher availability of S from these salts. The increased S uptake due to application of *kharif* straw and raising of summer cowpea could be due to better availability of the nutrient from these residues and the increased biomass in these treatments.

The content of Fe in the initial stages of 1998-'99 *kharif* and *rabi* crops is found to be remarkably low compared to 1999-'00 season. This is assumed to be due to the influence of weather, especially rainfall. The higher amount of rainfall (2377.1 mm) during 1998-'99 crop season compared to 1877.4 during 1999-'00 might have continuously washed off the soluble iron and hence absorption has decreased. *kharif* 1999-'00 crop had higher Fe content in the plant parts at maturity also and hence it registered higher Fe uptake. Influence of the applied treatments on Fe content showed variation with seasons. During *rabi* 1999-'00 higher K dose decreased Fe content in the plant system. On the contrary, application of higher dose of K increased Fe content of plant at tillering stage of *kharif* 1999-'00 whereas silica application decreased the content; but when silica and higher dose of K were combined it was ineffective during both the seasons. This may due to nutrient interactions arising out of combined application of nutrients. The influence of K and Si in decreasing Fe content through mutual competition has been well established (Singh and Singh, 1987; Lakshmikanthan, 2000).

Unlike Fe content, Mn content of the plants at tillering and PI stages of 1998-'99 crop was significantly higher than 1999-'00 crop. This could be due to the low Fe content in the plant system. When Mn concentration is higher, Fe absorption will be lower and vice versa which is due to sequential reduction of their compounds in the soil and the resultant availability (Ponnamperuma, 1972). Concentration of Mn in the plant system is also influenced by treatments. Silica is found to decrease Mn content of plants during PI stage of *kharif* 1998-'99 and at maturity of *kharif* 1999-'00. Grain content also showed reduction during both the seasons. It also reduced total Mn uptake during *rabi* 1998-'99. Silica application creates an alkaline environment thus reducing the availability of Mn (Wallace,1992). The relatively higher content of Mn in straw alone treatment could be due to the unhindered absorption of this native element in the absence of added nutrients.

Zinc content in the plant was found lower during 1998-'99 than 1999-'00. This could be accounted for the variability in weather as described earlier. The prolonged flooding due to higher rainfall might have reduced the availability and absorption of Zn during 1998-'99 since flooding decreases the availability of Zn. The treatments that received either soil or foliar application of $ZnSO_4$ has higher Zn content in the plant.

Copper content of plant system was higher during *kharif* season. Among the treatments, silica application brought reduction in Cu content at tillering stage of *kharif* 1998-'99 and *rabi* 1999-'00. This reduction might have resulted form the mutual competition between these elements at the absorption sites. During *kharif* 1999-'00 Cu uptake was higher in silica applied plots which is due to the higher biomass production in this treatment. Foliar application of $CuSO_4$ has increased its content in the plant system during *rabi* season; during *kharif* it had no effect. This may be due to the ineffectiveness of foliar spray in *kharif* seasons owing to the frequent rains that may wash off the spray solution. Soil application resulted in increased uptake during *kharif* season. The lack of response during *rabi* may be due to higher concentration of other elements in the soil solution and the resultant competition.

Silica application has brought about significant increase in silica content of the plant. During *kharif* 1998-'99, raising of summer cowpea, silica addition as well as straw incorporation in the previous *rabi* has brought about increase in silica content. The release of silica from the decomposition of the straw may be responsible for the increased silica content in the straw applied plots. Silica uptake is found higher in *kharif* crop since plant content of silica and biomass production during the season is higher than *rabi* crop. External application of silica increased its content in the plant as well as its total uptake.

5.1.3. Soil nutrient status and productivity

The data on soil nutrient status showed seasonal and treatment variations (Fig 15 a to 15 k and 16 a to 16 d respectively).

The seasonal changes were regulated by weather indicating differential availability of the nutrients to plants. It is understood that soil temperature and soil moisture are the most important parameters regulating the availability of elements (Rao, 2000).

Fig 15 a. Soil organic carbon in treatment NPK alone (T_2) at the end of the crops

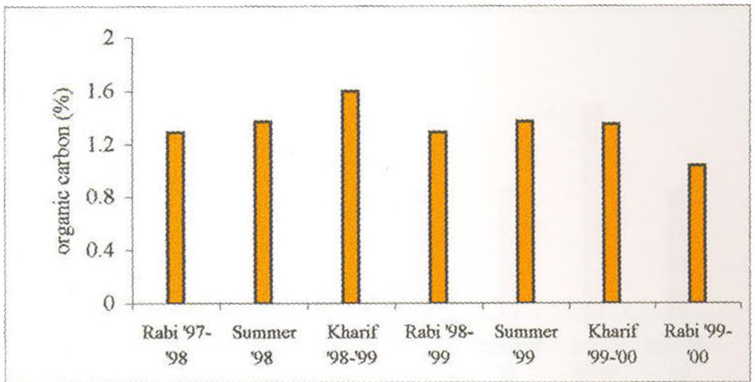


Fig 15 b. Ammoniacal N of soil in treatment NPK alone (T_2) at the end of the crops

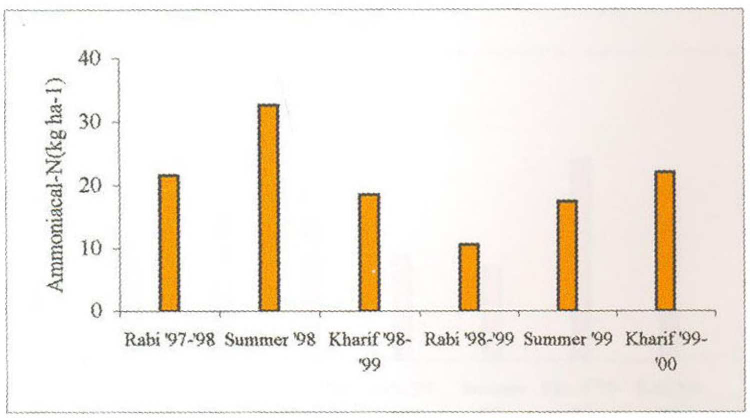


Fig 15 c. Soil available P in treatment NPK alone (T_2) at the end of the crops

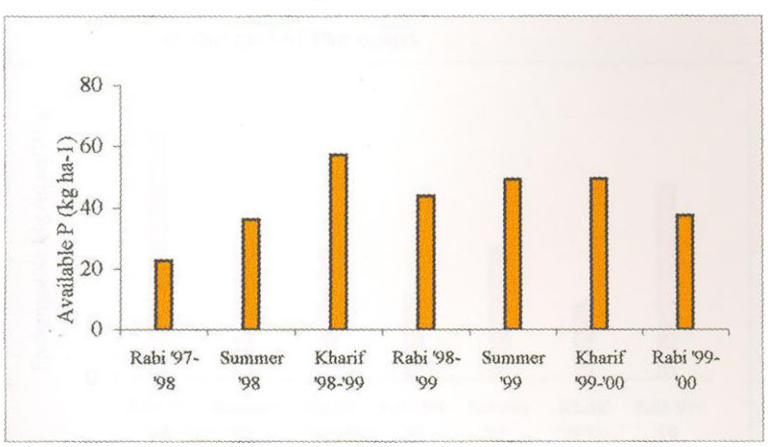


Fig 15 d. Soil available K in treatment NPK alone (T_2) at the end of the crops

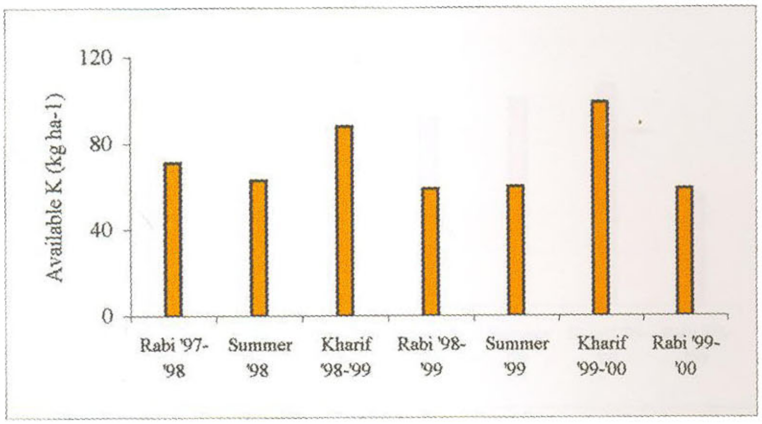


Fig 15 e. Soil exchangeable Ca in treatment NPK alone (T_2) at the end of the crops

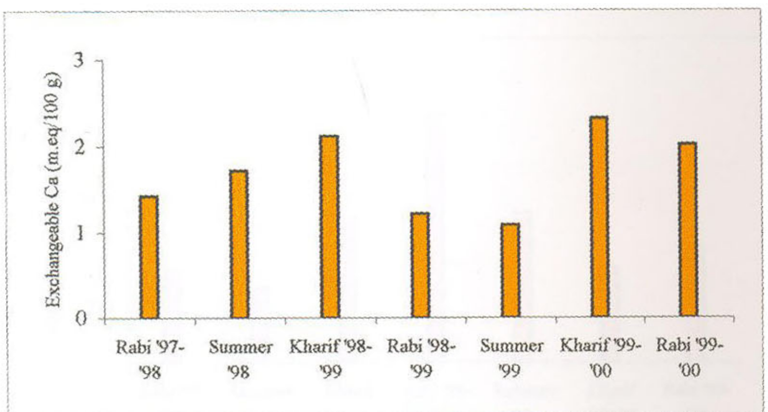


Fig 15 f. Soil exchangeable Mg in treatment NPK alone (T_2) at the end of the crops

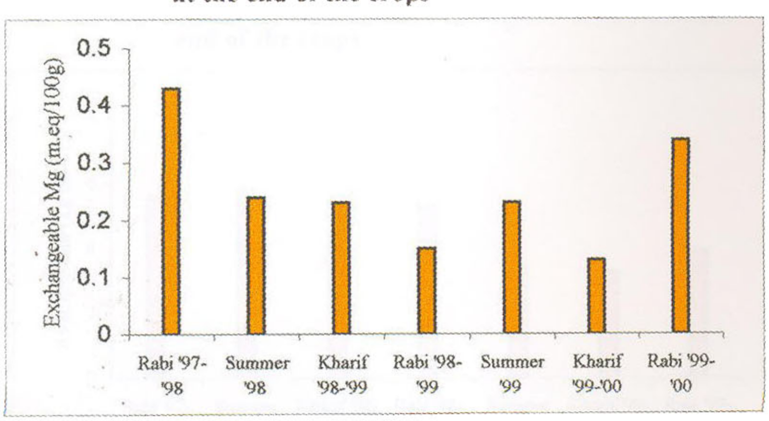


Fig 15 g. Soil available S in treatment NPK alone (T_2) at the end of the crops

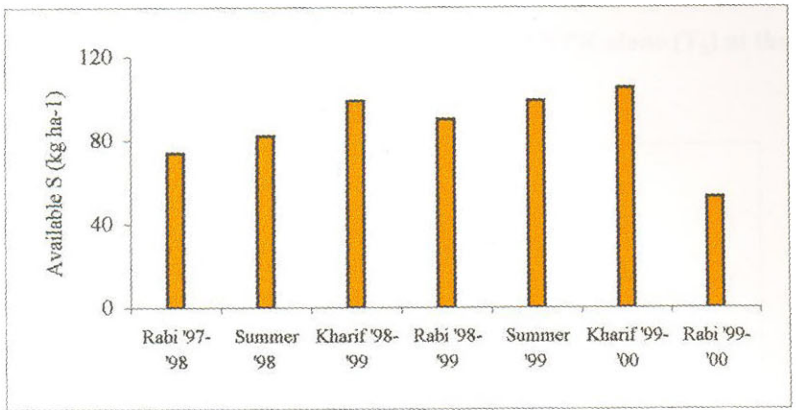


Fig 15 h. Soil available Fe in treatment NPK alone (T_2) at the end of the crops

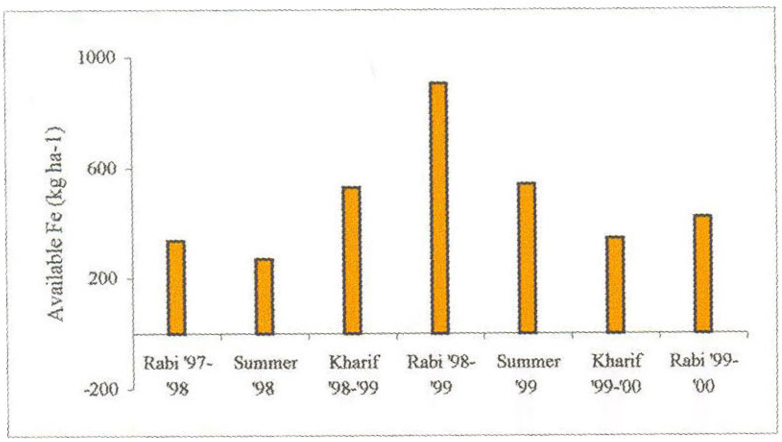


Fig 15 i. Soil available Mn in treatment NPK alone (T_2) at the end of the crops

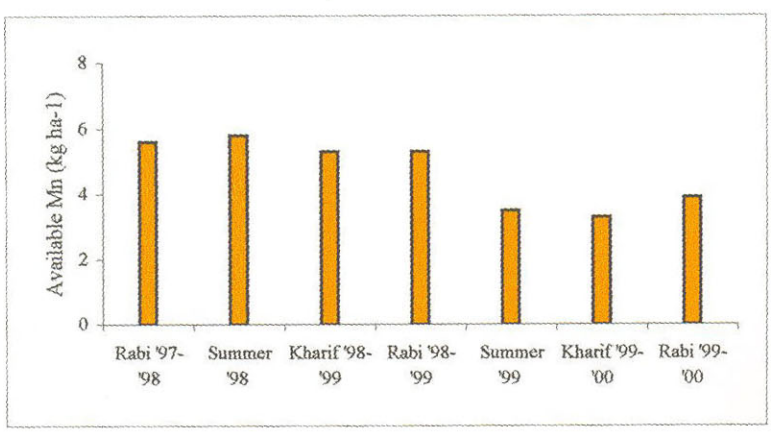


Fig 15 j. **Soil available Zn in treatment NPK alone (T_2) at the end of the crops**

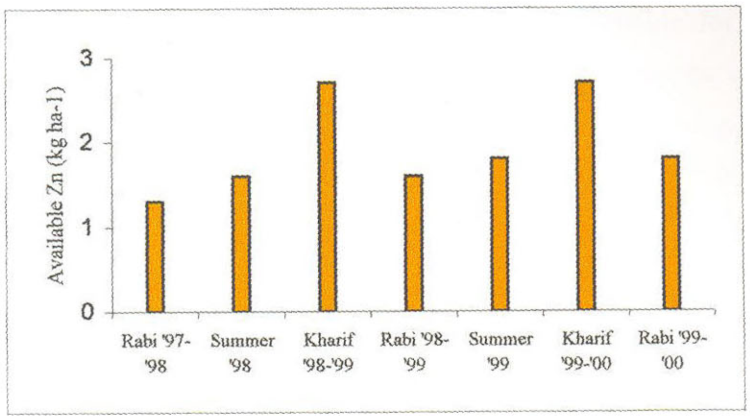
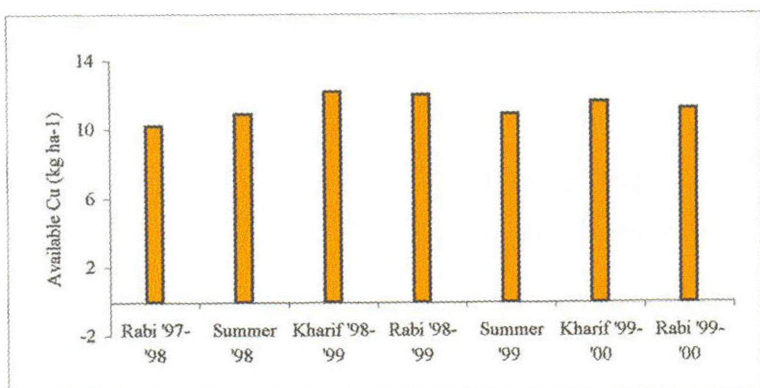


Fig 15 k. **Soil available Cu in treatment NPK alone (T2) at the end of the crops**



The organic carbon content of soil showed a cyclic increase and decrease. The content was high at the end of *kharif* season; it showed decreased values at the end of *rabi* and summer seasons. Organic carbon status of soil is linked to temperature, moisture regime and cropping. Continuous submerged condition and reduced temperature during *kharif* season might have been responsible for low oxidative loss of organic carbon. Growing of summer cowpea in the cropping system resulted in maintaining a higher level of organic carbon. Menon (1987) and Anilakumar and Sivakumar (1994) also have reported that dynamics of organic carbon in soils is linked to cropping. The other treatments did not influence the content of organic carbon.

Though variations were noticed in the organic carbon of the soil at different seasons, it could be seen that the level was high (>0.75%) throughout. Though the level of organic carbon is high, its favourable advantage is not reflected in plant growth or yield. Cassman *et al.* (1995) have reported a yield decline despite the conservation or increase in soil organic carbon and total N of whole soil. The reasons for this phenomenon needs detailed investigation.

The changes in the contents of N, P, K, S and Cu were similar to the organic carbon fluctuations. This is evidently due to the close interrelations that exist between organic carbon and these elements (Tisdale *et al.*, 1995).

The available P status of soil showed an increase from the initial level of 19 kg ha^{-1}. The mean level of P recorded during the experimental period in NPK alone treatment was 42.3 kg ha^{-1}. The experimental crops had received lime at the rate of 600 kg ha^{-1} per season and it was probable that this liming resulted in making P more available by converting part of Al and Fe phosphates to more available Calcium phosphate. It was also probable that liming resulted in the liberation of organic P in the soil through stimulation of the decomposition process which is in line with the findings of Khan *et al.* (1992). The significant positive correlation of Ca with P (r = 0.383**) confirms this. The increase in available P content of soil at the end of summer 1998 with *kharif* straw incorporation could be due to the decomposition and mineralisation of P from the crop residue. The presence of higher dose of K has increased the P status which could be the result of maintenance of the specific relation between the nutrients.

The available K content of soil showed variation among the seasons. The level of available K falls under the rating 'low'. Fe rich soils record low available K. Similar results were reported earlier by Suresh (1996). The significant negative correlation between available K and Fe (=-0.242*) indicated this. The data on plant uptake of K shows that cropping results in continuous depletion of K reserve of the soil. The total uptake of K by the crop per season is about 110 kg ha^{-1} whereas the maximum amount of the nutrient added as per the existing recommendation is 35 kg ha^{-1}. The influence of rice cropping in K depletion has been reported by Sindhu (2002). Higher dose of inorganic K application as well as *kharif* straw addition has increased available K content of the soil which is evidently due to the higher availability from these sources.

All the five crops had received lime application at the rate of 600 kg ha^{-1} per crop. This has raised the available Ca status of the soil in NPK alone treatment to 2.20 meq/100g from an initial level of 0.83 meq/100g. As a consequence of this, the plant system also has shown a high accumulation of Ca amounting to 1250 ppm at PI stage. Increase in Ca content of the soil due to raising of summer cowpea and silica application might be because of the better soil physical condition by these treatments which decreased the loss of Ca.

The higher level of Mg in the soil after *rabi* 1999-'00 might be due to lesser amount of rainfall during the season which decreased the leaching loss of Mg. Higher K dose was found to decrease soil available status of Mg. This might be due to displacement of Mg from the exchange sites and the leaching loss of Mg.

Fig 16 a. Efffect of summer cowpea on soil organic carbon at the end of the crops

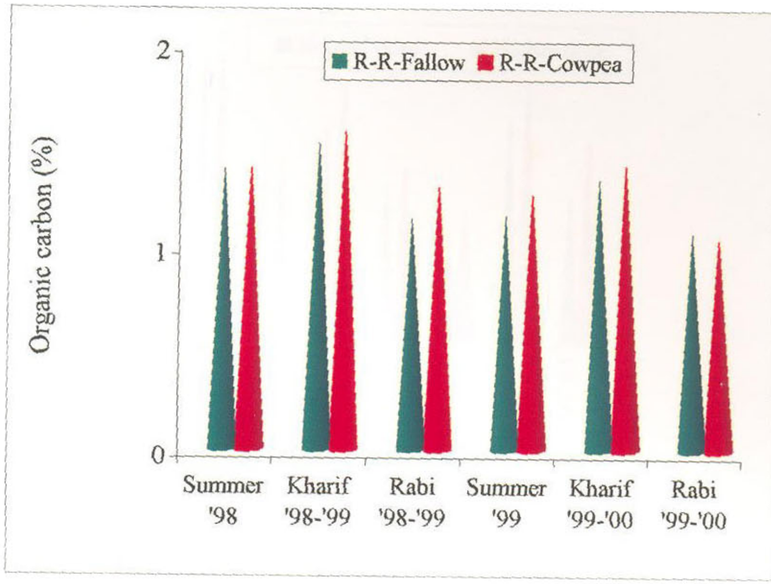


Fig 16 b. Efffect of silica application on available soil K at the end of the crops

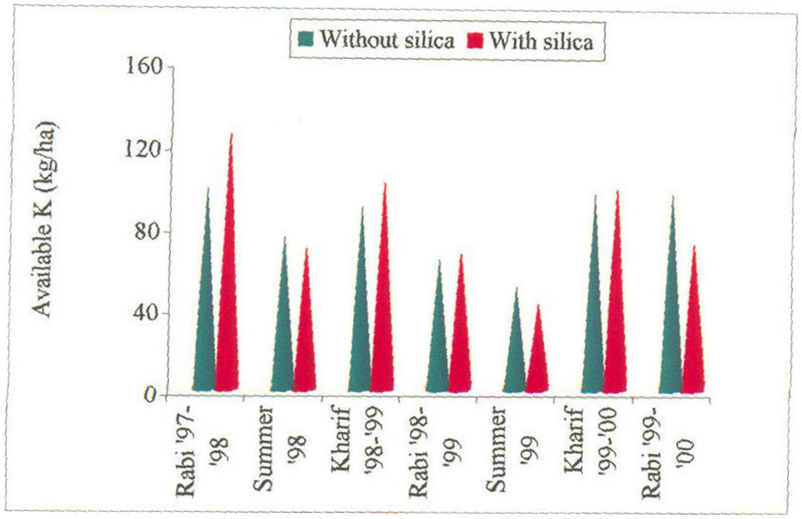


Fig 16 c. Efffect of higher K dose on available soil K at the end of the crops

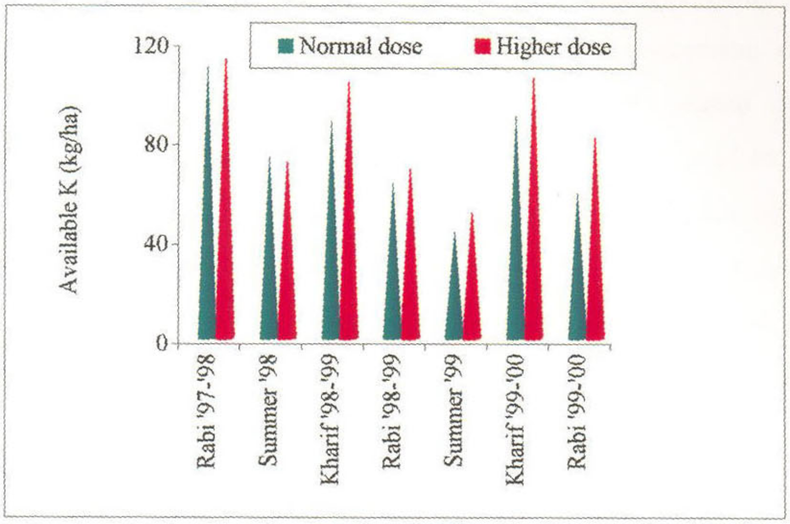
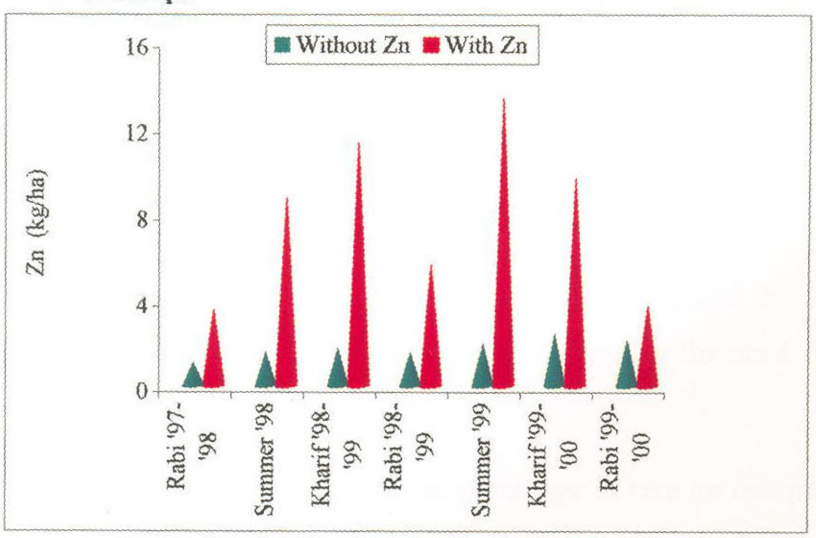


Fig 16 d. Efffect of soil aplication of Zn on available Zn at the end of the crops



The available Fe content was lower during *kharif* seasons which could be due to the heavy rains which resulted in washing off released Fe. The content was higher in *rabi* since the situation of water stagnation facilitates formation and accumulation of ferrous form. The aerobic condition during summer results in conversion of ferrous form to ferric state and hence availability decreased during the season. The increased availability of Fe in the soil lead to excessive uptake by the plant which in turn adversely affects rice yield. The significant negative correlation between soil available iron and grain yield (r = -0.404**) confirms this. This is in line with the reports of many workers (Potty *et al.*, 1992; Musthafa, 1995). The various treatments did not bring about any appreciable change in available Fe status of soil.

The available Mn level in the soil is in the range of 3.5 to 6.8 kg ha^{-1}. Rajagopal *et al.* (1977) have reported Mn deficiency in the soils of Trichur, Ernakulam, Palghat, Calicut and Trivandrum districts. The graded topography of the experimental region is conducive for constant washing off solution Mn and this might have resulted in low level of Mn in the soil. When the Mn level is low, reduction of Fe is faster (Ponnamperuma, 1972) and this can lead to greater level of Fe toxicity.

External application of Cu as well as Zn increased the soil status of the elements. Their contents were not influenced by other treatments.

5.1.3. Influence of management practices of rice on cowpea yield

The rice crops imparted some positive influences on the performance of succeeding cowpea crops. Cowpea yield during summer 1998 was highest in the plot which received the treatment T_9 in *rabi* 1997-'98. This treatment had produced the highest yield of rice during the *rabi* season. The increased amount of left over residues might have improved the productivity of the soil which resulted in higher cowpea yield.

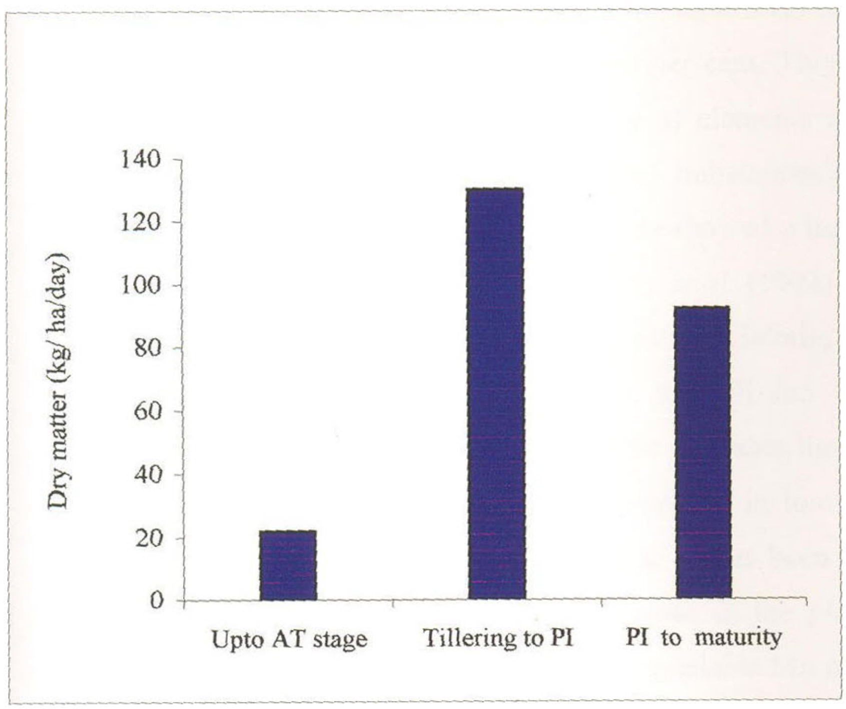
5.1.4. Constraints in productivity

In the present experiment, in spite of providing the recommended package of practices and additional management schedules, the mean yield averaged over five seasons was 3581 kg ha^{-1}. When the reasons for this low yield were analysed, it could be seen that the plant exhibited comparatively slower growth in the early growth stages than that of a normal healthy crop. This is evident from the data on plant height and tiller production. The decreased yield can be considered as a direct consequence of low tiller production itself. The average tiller count at the initial phase was 5.9, which has increased to 7.0 at PI. But towards maturity there was a decline in tiller number where it dropped down to 6.6.

The dry matter accumulation pattern also showed the picture of slow early growth (Fig. 17). The crop up to 40 days corresponding to the maximum tillering stage has produced a total of only 878 kg ha^{-1} shoot dry matter, while in the next 15 days, which corresponded to panicle initiation and differentiation, it accumulated additional 1080 kg ha^{-1} and attained 1958 kg ha^{-1}. In the next 55 days, where flowering and ripening take place, it gained a total of 7506 kg ha^{-1} which included 3925 kg ha^{-1} straw and 3581 kg ha^{-1} grain. Thus the per day production during the above three periods were 22, 130 and 101 kg ha^{-1} day^{-1}, respectively.

The low expression of the vegetative parameters is reflected in the reproductive phase also. Analysis of the yield components showed that the low yield is also attributable to the decreased production of panicle bearing tillers. The average number of productive tillers per hill was only 5.7 when computed back from the mean panicles per m^2 of 378 (Table 4.9). The tiller decline coupled with this low productive tiller formation is the factor responsible for decreased yield. The lower

Fig. 17. Mean per day production of dry matter in rice



number of spikelets per panicle and higher chaff percentage also contributed to the decreased yield.

A perusal of the elemental composition of the plant showed that there is no deficiency for any of the elements analysed in the plant system. Among the major nutrients, the plant contents of N, P and K were estimated as 1.79, 0.39 and 3.20 per cent respectively which is much higher than the sufficiency level as reported by De Datta (1981). Bridgit (1999) also has reported that the minimal level of N, P and K for a 7 t ha^{-1} crop is 1.65, 0.10 and 1.60 per cent. This showed that low yield could not be due to deficiency of elements in the soil or plant system, but due to their excesses, imbalances or metabolic unavailability. Further probing into the data showed a high content of non-applied elements particularly Fe. Potty *et al.* (1992) has reported that one of the major problem associated with the laterite soil is due to high content of total and soluble iron in the soil and the resultant accumulation in the plant system above the tolerable limits. The high content of this element can result in imbalance in ionic charge and create unfavourable situations in the plant. It has been reported that Mn also accumulates in toxic concentrations in the plant grown in laterite soils. But in the present study, the available Mn content in soil was low and hence the plant content also was lesser. The low yield recorded in this trial indicates that the nutrients absorbed were not effectively utilized for grain production. The incapability of the crops to transform nitrogen and carbohydrates to economic yield under the given soil conditions is suspected. A perusal of the N composition in straw and grain shows that the average N content in straw and grain is 0.9 and 1.1 per cent respectively. Maintenance of high level of N in the straw could be due to the ineffective transformation of photosynthates to economic produce. Sindhu (2002) also has made similar observations in rice crop grown in laterite soils.

The sluggish growth of the crop as well as the tiller decline could be the influence of the high concentration of Fe in the plant system. Musthafa (1995) has reported the decline in tiller as an unfavourable influence of this element which is a mechanism to shed excess accumulation of the element.

The correlations between plant composition with yield showed that P and S contents of the plant at PI stage have a significant positive effect on yield. Phosphorous has a key role in the energy metaboilism of the plants whereas S forms a component of amino acids (Tisdale *et al.*, 1995). The significant positive effects of the anionic elements viz. P and S may be due to their counteracting influences on cationic accumulation. The findings of Bridgit (1999) and Sindhu (2002) also agree with this.

The data on plant uptake of K shows that cropping results in continuous depletion of K reserve of the soil. The total uptake of K by the crop per season is about 110 kg ha^{-1} whereas the amount of the nutrient added as per the recommendation is 35 kg ha^{-1}. In spite of this the available soil status does not show a significant reduction over the seven seasons. It is probable that the depletion is made good from the mineral soil reserve which may result in gradual degradation of these minerals.

The application of lime was not effective in serving as an ameliorant for Fe toxicity. This is evident by the ineffectiveness of lime in reducing Fe content of the plant system which points to the fact that in the laterite soils lime application can only produce a temporary change in soil pH due to washing off H^+ ions. The Fe toxicity problem resulting from the high content of native Fe is not appreciably reduced by lime application. Marykutty (1986) also has reported similar results. Calcium on the other hand, was negatively correlated with yield. Hence lime application may be reduced to restrict the possible negative effects the element manifests on productivity.

The experimental results showed that straw incorporation is beneficial. The yield improvement is reflected mainly in the crop that follows immediately. Silica application did not produce any response in the initial season, but it resulted in a gradual increase in yield with the advancement of the season. Application of Mg or micronutrients like Zn, Cu, B or Mo along with straw, NPK and silica did not bring about any remarkable yield advantage. Raising of summer cowpea in the system or application of double the dose of recommended K fertilizer also failed to improve the yield.

The results indicated that apart from the management aspects evaluated in the experiment, related strategies are to be explored to break the yield barriers in the laterite soils.

5.2. Experiment II. Effect of tillage and water management practices on soil plant elemental status and productivity of rice in rice- legume cropping system

5.2.1. Tillage and water management effects on growth of rice and succeeding cowpea crop

Studies on the effect of deep digging during *kharif* season revealed that either its direct effect or its residual effect on grain yield or growth and yield attributes for the following *rabi* season was negligible indicating that in puddled soil condition deep ploughing will not be of much advantage. Pearce *et al.* (1999) also has reported that deep tillage was not superior to conventional tillage. The loose soil structure and availability of sufficient water and nutrients in the root zone of the plots subjected to normal ploughing depth as well could be the reasons for the low response. However, straw yield was lower in deep ploughed plots during *kharif* 1999-’00. The dry matter production recorded at PI stage also was lower in this treatment which indicated that vegetative growth was affected which could be due to lesser availability of nutrients due to probable greater percolation loss in deep ploughed plots.

The influence of intermittent drainage showed variation between *kharif* and *rabi* as well as between the two *rabi* seasons. The two water management practices did not produce any appreciable difference in growth or yield of the crops during the *kharif* seasons. It was observed that though the treatment plots were subjected to intermittent drainage, the continuous monsoonic rains caused to retain sufficient moisture to the extent of saturation in the soil almost throughout the crop period and hence the drainage practice was not effective to create an aerobic situation. Vergara (1976) also has found that dry winds cause desiccation of rice leaves and thus adversely affect photosynthesis and dry matter production.

Contrary to this, intermittent drainage resulted in a considerable decrease in the growth attributes, panicle characters as well as grain yield of *rabi* 1999-'00 crop. The *rabi* 1998-'99 period, however, produced an opposite effect. Intermittent drainage during this season resulted in a slight improvement in tiller number and dry matter production. The influence of water stress on improving tiller production has been reported earlier (Burbey and Zaini, 1990). A perusal of the weather parameters may explain the variation in the effect of the treatment between the two *rabi* seasons.

It could be seen that during *rabi* 1999-'00, the weather had been much drier than *rabi* 1998-'99. *Rabi* 1998-'99 received a total rainfall of 81.6 mm during the crop period whereas *rabi* 1999-'00 experienced only 44.3 mm. Besides, the wind speed, sunshine hours and evaporation were much higher during *rabi* 1999-'00. The season also exhibited a low RH value throughout the crop period. As a whole, the crop experienced a drier climate during *rabi* 1999-'00. Due to the dry atmospheric condition, the continuous submergence became instrumental in creating a more favourable environment to the *rabi* 1999-'00 crop. During *rabi* 1998-'99, the desiccating effect was considerably low and hence the drainage did not affect the growth of the crop. These observations prove that the effect of intermittent drainage depends on seasons as well as the current weather situations and these factors have to be taken into consideration when adopting the practice of intermittent drainage.

The yield of cowpea crop which was raised during summer was not influenced by ploughing or water management practices followed in the previous rice crops. This suggests that the practice of ploughing followed in the *kharif* season or the intermittent drainage adopted in the previous season rice crops have no influence on growth of summer cowpea.

5.2.2. Effect of tillage and water management practices on soil and plant nutrient status

It has been established that submergence leads to increase in pH of acidic soils due to various transformations which occur due to flooding (Ponnamperuma, 1972). Variations in soil pH and Eh were noticed by the water management practices followed in the experiment. It could be seen that with increased period of submergence, the soil pH reached a near neutral value. This also brought about a reduction in the Eh value which is evidently due to soil reduction to a greater extent. In case of intermittent drainage, a reduction in soil pH and correspondingly an increase in redox potential values were noticed due to increased oxidation state of the soil.

Variations in the available soil nutrient contents were observed under submergence and drainage treátments. Available P fraction of the soil increased with submergence during *kharif* 1999-'00 which could be due to change in pH towards neutral level and this has resulted in an increased P content in the plant. This is in conformity with the reports of Jenne (1977). Intermittent drainage reduced the

P status of the soil which could be due to the conversion of P to insoluble fractions under reduced pH conditions.

Deep ploughing results in an increase in the soil volume available for the root growth. The slightly increased content of Ca and K in the plant consequent to deep ploughing could be due to the availability of the nutrient from a higher volume of soil.

Summary and conclusions

6. SUMMARY AND CONCLUSIONS

Experiments of the research project entitled "Nutritional constraints of rice- legume system in laterite soils of humid tropics" were carried out from 1997-'98 to 1999-'00 at Regional Agricultural Research Station, Pattambi. The salient research results obtained are presented here.

1. In Experiment I entitled "Soil- plant elemental status and productivity as influenced by crop residue recycling and nutrient supply in the rice-legume cropping system" grain yield over the five seasons varied from 1671 kg ha^{-1} to 4477 kg ha^{-1}. This wide variability has been due to the influence of season and treatments. The contribution of weather was much higher than the effect of treatments

2. The mean values showed that grain yield and straw yield were significantly higher during *kharif* season. The variation in grain yield between the two *kharif* seasons was comparatively low indicating higher yield stability during *kharif.*

3. Weather influenced the extent of contribution of the different yield components to grain yield. *Rabi* crop had higher number of panicles/m^2 whereas the increased number of spikelets per panicle, lesser chaff percentage and higher grain weight were the important contributing factors for the higher yield during *kharif* seasons.

4. Variability in yield with seasons was wider with the grain yield than straw yield which showed that though dry matter accumulation in vegetative plant parts were not much influenced by weather variations, the translocation to the sink was adversely affected.

5. The pattern of dry matter accumulation in the various seasons showed That no direct relationship existed between yield and dry matter production in the early stages. Higher grain yield was found to be a

combined effect of higher dry matter production towards later stages and a higher grain : straw ratio

6. The treatments exhibited significant influence on grain and straw yield. The treatment which did not receive any inorganic fertilizers registered the lowest yield during all the seasons

7. Application of silica at 250 kg ha^{-1} produced significant yield increase from the fourth season and hence continued application might be required. Initial applications of the same did not bring about significant yield increase. Silica application has brought about significant increase in silica content of the plant.

8. Harvest of *kharif* crop was done retaining two third portion of straw which was incorporated to *rabi* crop. The additional straw recycling from this practice amounted to about 1500 kg ha^{-1}. *Kharif* harvest coincides with north east monsoon and the straw is usually wasted since its drying is difficult and hence this can be effectively recycled in rice system. Incorporation of *kharif* straw brought about significant increase of grain yield during the three *rabi* seasons. The plant showed a significantly increased plant height, shoot dry matter production and spikelets per panicle.

9. Raising of cowpea during summer and incorporation of its residues had no influence on grain or straw yield. The absence of response to addition of summer cowpea residues confirms the contention that either lack of N or a lower level of organic carbon is not the limiting factor for the low rice yield.

10. Application of potassium even at 70 kg ha^{-1} was found to have no appreciable effect on growth and yield of paddy. Though response for higher K dose is usually expected, the lack of response in this laterite soil might be because response can be expected only at higher levels.

11. The secondary nutrient, Mg as well as the micro nutrients, Zn and Cu were supplied through soil as well as foliage. B and Mo were given

only as foliar spray. Though these were applied continuously for five seasons, it did not bring about any significant influence on growth and yield of paddy. Hence the deficiency of these elements as a nutritional constraint in laterite soils can be ruled out. External application of the micronutrients which was presumed to decrease the absorption of Fe through mutual antagonism did not produce the expected effect. Application of Zn. increased the soil available fraction. Hence its continuous application may result in its accumulation in the soil.

12. In the present experiment, the mean yield averaged over five seasons was 3581 kg ha^{-1}. It could be seen that the plant exhibited comparatively slower growth in the early growth stages than that of a normal healthy crop. The dry matter accumulation pattern also showed the picture of slow early growth.

13. The observed low yield was attributable to the decreased production of panicle bearing tillers. The average number of productive tillers per hill was only 5.7. The tiller decline coupled with this low productive tiller formation might be responsible for decreased yield. The lower number of spikelets per panicle and higher chaff percentage also contributed to decreased yield.

14. The elemental composition of the plant showed that there was no deficiency of any element in the plant system. The low yield could be due to excesses, imbalances and metabolic unavailability of elements. The plant had high content of non-applied elements particularly Fe. This excess absorption of iron might be the resultant of high content of available iron in the soil. The absorbed nutrients, particularly N was not effectively utilized for grain production as evidenced by the relatively high content of 0.9 per cent N in straw as against 1.1 per cent in grain.

15. Weather exerted a significant influence on the plant elemental composition. The wide range in the content of elements in the plant during different seasons suggests the strong influence of weather on plant elemental composition.

16. The concentration of N, P, K, Ca and S was in general higher in *rabi* crops. However, it had no relation with yield confirming that the deficiency of these nutrients in the plant system is not the nutritional constraint in yield expression.

17. Decrease in the content of K observed with Ca and Mg application is attributed to the antagonism of K with these elements.

18. Concentration of P as well as its total uptake was found higher in 1998-'99 crops than 1999-'00 crops. The increased concentration of P during 1998-'99 over 1999-'00 could be attributed to the higher amount of rainfall during 1998-'99 crop period. The prolonged period of submergence would have decreased the Eh and increased the concentration of water soluble and available P

19. The content of Fe at tillering and PI stages of 1998-'99 *kharif* and *rabi* crops was found to be remarkably low compared to 1999-'00 season. The higher amount of rainfall (2377.1 mm) during 1998-'99 crop season compared to 1877.4 mm during 1999-'00 might have continuously washed off the soluble iron and hence absorption has decreased.

20. The S content during *kharif* and *rabi* seasons of 1998-'99 was higher than the content of the corresponding seasons of 1999-'00. Due to low content of Fe the chance of reaction of S with Fe was less which might have increased the availability of S and hence its increased content.

21. When the content of Fe in the plant was lower Mn content was found higher and *vice versa* which is attributable to the sequential reduction of their compounds in the soil and the resultant change in availability.

22. Soil as well as foliar application of $CuSO_4$ and $ZnSO_4$ has increased its content in the plant. The increase in Cu content with foliar application is more pronounced in *rabi*. This may be due to the ineffectiveness of

foliar spray in *kharif* seasons owing to the frequent rains that may wash off the spray solution.

23. Soil nutrient status also showed seasonal variations. The seasonal changes were regulated by weather indicating differential availability of the nutrients to plants. It was seen that soil temperature and soil moisture are the most important parameters regulating the availability of elements.

24. The organic carbon content of soil showed a cyclic increase and decrease. The content was high at the end of *kharif* season; it showed decreased values at the end of *rabi* and summer seasons. Growing of summer cowpea in the cropping system resulted in maintaining a higher level of organic carbon.

25. The changes in the contents of N, P, K, S and Cu were similar to the organic carbon fluctuations which could be due to the close interrelations that exist between organic carbon and these elements

26. The available P status of soil showed an increase from the initial level of 19 kg ha^{-1}. Liming might have resulted in making P more available by converting part of Al and Fe phosphates to more available Calcium phosphate. Also it could be due to the liberation of organic P in the soil through stimulation of the decomposition process.

27. The level of soil available K was rated as 'low'. The total uptake of K by the crop per season was about 110 kg ha^{-1} whereas the amount of the nutrient added as per the recommendation was 35 kg ha^{-1}. In spite of this the available soil status did not show a significant reduction over the seven seasons, probably because the depletion was made good from the mineral soil reserve.

28. The available Fe content of soil was lower during *kharif* season compared to *rabi* season which could be due to the heavy rains during *kharif* which resulted in washing off of released iron.

29. The available Mn level in the soil was in the range of 3.5 to 6.8 kg ha^{-1}. The graded topography of the experimental region is conducive for constant washing off of solution Mn and this might have resulted in low level of Mn in the soil.

30. The correlations between plant composition with yield showed that P and S contents of the plant at PI stage have a significant positive effect on yield. The significant positive effects of these anionic elements may be due to their counteracting influences on cationic accumulation.

31. All the five crops had received lime application at the rate of 600 kg ha^{-1} per crop. This has raised the available Ca status of the soil to 1.73 m.eq./ 100 g from an initial level of 0.83 meq/100g soil. The application of lime was not effective in serving as an ameliorant for Fe toxicity. The Fe toxicity problem resulting from the high content of native Fe was not appreciably reduced by lime application. Ca, on the other hand, was negatively correlated with yield. Hence Ca application may be reduced to restrict the possible negative effects the element manifests on productivity.

32. Results of Experiment II on 'Effect of tillage and water management practices on soil-plant elemental status and productivity of rice in rice legume cropping system' revealed that the direct effect of deep digging during *kharif* season or its residual effect for the following *rabi* season was negligible indicating that in puddled soil condition deep ploughing will not be of much advantage

33. The influence of intermittent drainage showed variation between *kharif* and *rabi* as well as between the two *rabi* seasons. The two water management practices did not produce any appreciable difference in growth or yield of the crops during the *kharif* seasons. Intermittent

drainage resulted in a considerable decrease in the growth attributes, panicle characters as well as grain yield of *rabi* 1999-00 crop.

34. Submergence increased the soil pH and reduced Eh value. In case of intermittent drainage, a reduction in soil pH and correspondingly an increase in redox potential values were noticed which is attributable to the increased oxidation state of the soil.

35. Variations in the available soil nutrient contents were observed under submergence and drainage treatments. Available P fraction of the soil increased with submergence. Intermittent drainage reduced the P status of the soil which reduced P absorption by the plant. Continuous submergence also resulted in better availability and absorption of nutrients like Ca and S and hence their content in the plant showed higher concentration.

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* Originals not seen

Appendices

Appendix I. Weekly weather data from 15-10-1997 to 4-2-1998 (*Rabi* 1997-98)

Std. Week	Mean Temperature °C		Mean RH %		Total Rainfall (mm)	No. of rainy days	Mean evaporation (mm)	Mean wind speed (km hr-1)	Total sunshine hours
	Max	Min	I	II					
42	32.9	23.2	91	62	47.8	3	3.7	2.9	45.5
43	31.9	23.6	93	64	16.2	3	3.0	2.1	31.5
44	31.9	23.2	93	68	127.2	4	3.7	3.2	52.5
45	31.5	23.2	93	65	66.2	2	3.5	2.9	42.7
46	32.7	23.3	96	62	41.3	2	3.3	2.5	54.6
47	31.6	23.3	94	64	91.2	3	1.9	1.5	34.3
48	32.9	23.7	86	58	0.0	0	3.5	4.2	62.3
49	31.5	23.5	89	68	17.8	2	3.3	4.9	42.7
50	32.7	23.6	89	54	3.6	1	3.2	2.9	54.6
51	32.6	23.5	93	58	50.6	1	3.7	3.5	55.3
52	32.3	21.8	85	46	0.0	0	4.9	5.9	66.5
1	32.2	22.2	75	42	0.0	0	6.0	10.1	60.2
2	32.8	21.8	77	41	0.0	0	5.7	8.7	67.2
3	34.0	20.9	95	45	0.0	0	3.7	2.4	60.2
4	34.5	22.4	85	42	0.0	0	4.9	3.9	63.7
5	34.8	22.3	76	33	0.0	0	7.2	9.1	69.3
Mean/Total	**32.7**	**22.8**	**88.1**	**54.5**	**461.9**	**21.0**	**4.1**	**4.4**	**863.1**

Appendix II. Weekly weather data from 26-2-1998 to 6-5-1998 (Summer 1998)

Std. Week	Mean Temperature °C		Mean RH %		Total Rainfall (mm)	No. of rainy days	Mean evaporation (mm)	Mean wind speed (km hr-1)	Total sunshine hours
	Max	Min	I	II					
9	35.6	23.4	89	43	0.0	0	5.5	3.6	62.3
10	36.4	22.1	91	39	0.0	0	6.2	4.2	68.6
11	35.6	22.4	89	43	0.0	0	6.7	5.1	67.9
12	37.3	23.4	91	42	0.0	0	6.6	3.9	66.5
13	36.2	25.1	89	46	0.0	0	5.7	3.9	58.1
14	37.2	25.3	87	51	17.8	1	5.8	4.5	58.1
15	35.6	26.5	87	54	0.0	0	5.4	3.9	60.9
16	36.5	27.0	84	49	0.0	0	6.3	4.7	63.7
17	36.5	25.6	85	49	22.4	2	6.1	4.5	63.0
18	35.9	25.9	86	54	11.2	2	5.2	3.8	67.2
Mean/Total	**36.3**	**24.7**	**87.8**	**47.0**	**51.4**	**5.0**	**6.0**	**4.2**	**699.9**

Appendix III. Weekly weather data from 4-6-1999 to 23-9-1999 (*Kharif* 1998-99)

Std. Week	Mean Temperature °C		Mean RH %		Total Rainfall (mm)	No. of rainy days	Mean evaporation (mm)	Mean wind speed (km hr-1)	Total sunshine hours
	Max	Min	I	II					
23	32.7	24.5	93	65	52.9	5	3.9	3.4	46.2
24	30.3	23.7	95	77	86.8	6	2.2	2.3	6.3
25	29.5	23.1	97	77	271.6	7	2.5	3.1	18.9
26	27.9	23.0	97	91	311.6	7	2.3	4.8	1.4
27	28.9	22.9	95	77	196.9	6	2.3	3.7	18.2
28	29.7	23.6	93	77	121.4	5	2.5	4.3	19.6
29	29.5	23.7	95	75	46.4	4	3.1	3.7	39.9
30	29.1	23.5	95	80	136.0	6	2.7	4.3	25.2
31	30.3	23.9	96	73	81.2	5	3.0	4.5	33.6
32	29.3	23.5	96	75	99.9	6	2.7	4.3	21.0
33	30.8	24.6	93	71	41.4	2	3.4	3.1	35.7
34	28.8	23.3	96	79	197.2	6	1.9	3.4	15.4
35	30.3	23.7	93	67	5.0	1	3.2	3.3	45.5
36	29.3	23.5	95	82	147.8	6	2.7	2.8	18.9
37	28.9	23.1	96	79	163.0	7	2.7	3.1	23.1
38	30.3	23.3	96	67	85.9	5	3.2	3.2	50.4
Mean/Total	**29.7**	**23.6**	**95.1**	**75.8**	**2045.0**	**84.0**	**2.8**	**3.6**	**419.3**

Appendix IV. Weekly weather data from 8-10-1998 to 14-1-1999 (*Rabi* 1998-99)

Std. Week	Mean Temperature °C		Mean RH %		Total Rainfall (mm)	No. of rainy days	Mean evaporation (mm)	Mean wind speed (km hr-1)	Total sunshine hours
	Max	Min	I	II					
41	27.8	23.1	96	84	178.8	7	1.7	2.1	4.9
42	29.5	22.5	95	72	65.6	4	2.7	2.5	36.4
43	30.8	22.8	95	62	4.9	1	3.2	2.7	56.7
44	30.9	23.3	93	70	2.7	0	2.6	2.2	35.0
45	30.9	23.7	93	65	41.2	5	2.4	2.4	28.7
46	31.6	22.5	94	63	1.6	0	3.2	2.5	60.9
47	32.0	22.1	95	57	0.0	0	3.1	2.1	57.4
48	32.7	22.5	92	53	1.0	0	3.0	2.4	49.0
49	31.4	22.0	85	53	0.0	0	3.2	4.0	38.5
50	30.3	22.7	89	62	36.1	2	3.0	7.3	21.0
51	31.6	20.9	86	49	0.2	0	3.1	3.2	23.8
52	31.0	19.3	85	49	0.0	0	4.3	4.9	61.6
1	31.7	20.5	80	44	0.0	0	5.0	6.6	65.1
2	32.6	19.7	85	42	0.0	0	4.3	4.3	63.0
Mean/Total	**31.1**	**22.0**	**90.2**	**58.9**	**332.1**	**19.0**	**3.2**	**3.5**	**602.0**

Appendix V. Weekly weather data from 12-2-1999 to 22-4-1999 (Summer 1999)

Std. Week	Mean Temperature °C		Mean RH %		Total Rainfall (mm)	No. of rainy days	Mean evaporation (mm)	Mean wind speed (km hr-1)	Total sunshine hours
	Max	Min	I	II					
7	35.5	21.7	85	31	0.0	0	6.4	4.7	65.1
8	34.8	21.8	73	28	0.0	0	7.9	7.9	48.3
9	36.7	19.7	87	21	0.0	0	7.1	4.5	69.3
10	36.6	22.6	89	34	0.0	0	6.2	3.6	64.4
11	36.0	24.2	89	45	0.4	0	6.0	3.9	58.1
12	35.5	23.9	89	49	0.0	0	5.8	3.8	55.3
13	35.4	24.4	88	50	0.0	0	5.7	3.7	53.9
14	35.0	24.1	89	49	7.4	2	5.4	4.6	55.3
15	33.8	23.9	90	54	22.2	2	5.6	5.1	54.6
16	33.4	25.7	85	57	0.8	0	5.6	5.5	39.2
Mean/Total	**35.3**	**23.2**	**86.4**	**41.8**	**30.8**	**4.0**	**6.2**	**4.7**	**563.5**

Appendix VI. Weekly weather data from 28-5-1999 to 16-9-1999 *(Kharif* 1999-00)

Std. Week	Mean Temperature °C		Mean RH %		Total Rainfall (mm)	No. of rainy days	Mean evaporation (mm)	Mean wind speed (km hr-1)	Total sunshine hours
	Max	Min	I	II					
22	30.3	23.7	95	69	104.5	5	3.6	3.3	37.8
23	30.0	23.0	93	72	85.2	6	4.1	4.1	39.9
24	28.4	23.1	95	83	344.1	7	2.5	2.9	10.5
25	29.5	23.1	95	73	199.1	5	3.1	3.6	28.0
26	31.1	23.1	93	63	0.2	0	4.2	3.3	61.6
27	29.5	23.2	94	79	134.1	5	2.9	3.5	25.9
28	29.3	22.7	94	72	86.8	7	3.0	4.0	18.2
29	27.1	22.5	95	91	238.6	7	2.2	3.6	2.1
30	28.0	22.6	94	80	161.4	6	2.2	4.5	7.0
31	28.9	23.0	94	78	145.4	7	2.5	4.5	15.4
32	29.5	23.3	93	72	79.6	5	3.5	4.8	32.9
33	30.5	23.3	91	67	0.4	0	4.5	4.4	55.3
34	30.5	23.4	93	66	1.6	0	4.3	4.3	48.3
35	30.1	23.6	92	67	10.8	1	3.7	3.7	44.8
36	30.5	22.7	93	66	12.0	3	4.1	4.0	34.3
37	31.1	23.1	92	62	5.2	1	4.7	3.6	50.4
Mean/Total	**29.6**	**23.1**	**93.5**	**72.5**	**1609.0**	**65.0**	**3.4**	**3.9**	**512.4**

Appendix VII. Weekly weather data from 8-10-1999 to 21-1-2000 (*Rabi* 1999-00)

Std. Week	Mean Temperature °C		Mean RH %		Total Rainfall (mm)	No. of rainy days	Mean evaporation (mm)	Mean wind speed (km hr-1)	Total sunshine hours
	Max	Min	I	II					
41	31.8	23.6	91	65	36.9	3	4.0	2.6	43.4
42	29.6	23.4	93	74	125.2	6	2.7	1.9	21.0
43	31.5	23.8	92	68	30.4	2	2.9	1.8	36.4
44	29.6	22.8	93	72	32.4	3	2.7	2.3	37.8
45	31.5	22.2	91	57	31.3	2	3.3	1.7	52.5
46	32.1	21.0	84	47	0.0	0	4.0	2.9	64.4
47	31.7	22.9	82	56	11.4	1	4.5	5.2	45.5
48	32.3	22.2	87	51	0.0	0	4.7	5.7	60.9
49	32.1	20.9	84	44	0.0	0	3.5	4.7	64.4
50	32.3	21.6	85	50	0.8	0	4.1	4.1	53.2
51	32.0	21.2	76	43	0.0	0	5.5	7.6	60.9
52	32.1	21.7	73	39	0.0	0	7.3	10.1	63.0
1	32.7	22.1	72	39	0.0	0	6.4	8.5	63.7
2	33.0	23.9	73	45	0.0	0	6.8	9.4	49.7
3	34.5	20.7	83	32	0.0	0	6.5	5.8	66.5
Mean/Total	**31.9**	**22.3**	**83.9**	**52.1**	**268.4**	**17.0**	**4.6**	**5.0**	**783.3**

Appendix VIII. Mean weather parameters at different growth stages

Tillering stage

Season	Mean Temperature Maximum	Mean Temperature Minimum	Mean RH (%) I	Mean RH (%) II	Mean evaporation (mm)	Mean wind (km hr-1)	Total rainfall (mm)	Total rainy days	Total SS hours
Rabi 1997-98	32.3	23.5	91	61	3.3	3.2	132.5	5	174.0
Kharif 1998-99	29.2	23.4	95	79	2.7	4.2	639.3	24	107.9
Rabi 1998-99	31.1	22.8	93	64	2.8	2.3	44.1	5	118.3
Kharif 1999-00	29.6	22.9	94	74	3.2	3.7	419.8	17	115.3
Rabi 1999-00	31.7	22.1	87	56	3.8	3.2	42.7	3	213.2

PI to Flowering

Season	Maximum	Minimum	I	II	Evaporation	Wind	Rainfall	Rainy days	SS hours
Rabi 1997-98	32.3	23.7	87	54	4.1	4.9	72.0	4	244.9
Kharif 1998-99	29.8	23.8	95	74	2.8	3.9	409.5	18	103.1
Rabi 1998-99	31.6	22.5	89	56	3.0	4.1	37.3	2	142.2
Kharif 1999-00	28.9	23.0	82	77	3.1	4.4	465.8	21	103.0
Rabi 1999-00	32.1	21.6	82	46	4.5	5.8	0.8	0	227.1

Flowering to harvest

Season	Maximum	Minimum	I	II	Evaporation	Wind	Rainfall	Rainy days	SS hours
Rabi 1997-98	33.9	21.8	83	40	5.4	6.5	0.0	0	284.1
Kharif 1998-99	29.6	23.4	95	75	2.9	3.1	514.1	22	149.1
Rabi 1998-99	31.8	20.2	84	46	4.4	5.1	0.2	0	276.6
Kharif 1999-00	30.6	23.3	92	65	4.3	4.0	29.6	5	203.3
Rabi 1999-00	32.1	21.6	82	46	4.5	5.8	0.8	0	227.1

NUTRITIONAL CONSTRAINTS OF RICE –LEGUME SYSTEM IN LATERITE SOILS OF HUMID TROPICS

By

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ABSTRACT OF THE THESIS

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Abstract

A research programme entitled "Nutritional constraints of rice- legume system in laterite soils of humid tropics" was carried out from 1997-'98 to 1999-'00 at Regional Agricultural Research Station, Pattambi. The objectives of the programme were to study the effect of crop residue recycling, nutrient management practices and tillage and water management practices on soil and plant elemental status and productivity of rice-rice-legume cropping system

There were two experiments in the programme. The first experiment entitled, "Soil- plant elemental status and productivity as influenced by crop residue recycling and nutrient supply in the rice-legume cropping system" was taken up to study the impact of nutrient management practices as well as crop residue recycling on soil productivity and crop growth. The crop residues added in the system involved harvested left overs of grain cowpea crop during summer as well as addition of two-third portion of straw of *kharif* crop to *rabi* season crop. Silica at 250 kg ha^{-1}, higher K dose of 70 kg ha^{-1} and soil/foliar supply of Mg, Zn, Cu, B and Mo were also included in various treatment combinations.

The treatments exhibited significant influence on grain and straw yield. The treatment which did not receive any inorganic fertilizers registered the lowest yield during all the seasons. Straw addition did not bring about yield advantage in *kharif*, but in *rabi* there was steady and significant increase over the seasons. Silica application was not beneficial in initial seasons, but from fourth rice crop onwards, significant increase was noticed. Though there was an improvement in organic carbon of soil during some seasons, summer cowpea raising did not bring about specific yield improvement. The absence of response to addition of summer cowpea residues revealed that either lack of N or a lower level of organic carbon may not be the limiting factors for low yield in these laterite soils.

Potassium application even at the higher dose of 70 kg ha^{-1} was found to have no appreciable effect on growth and yield of paddy. Foliar application of

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boron and molybdenum and soil as well as foliar spray of Mg, Zn and Cu continuously for five seasons did not bring about any significant influence on growth and yield of paddy

The second experiment, " Effect of tillage and water management practices on soil-plant elemental status and productivity of rice in rice- rice legume cropping system" was aimed to study the influence of deep ploughing and intermittent drainage. Deep ploughing during *kharif* season had no significant influence during the current season or for the following *rabi* crop indicating that in puddled soil condition deep ploughing will not be of much advantage. The two water management practices did not produce any appreciable difference in growth or yield of the crops during the *kharif* seasons; but it adversely affected the performance of *rabi* 1999-'00 crop which could be due to the dry atmospheric condition during the season. During *rabi* 1998-'99, the desiccating effect was considerably low and hence the drainage did not affect the growth of the crop. Hence the effect of intermittent drainage depends on season as well as the current weather situation.

The elemental composition of the plant showed that there was no deficiency of any of the elements analysed in the plant system and hence the general low yield obtained from these soils could be due to nutritional constraints owing to excesses, imbalances or metabolic unavailability of elements. The plant had high content of non-applied elements particularly Fe. This excess absorption of iron might be due to the high content of available iron in the soil. The absorbed nutrients, particularly N was not effectively utilized for grain production as evidenced by the relatively high content of 0.9 per cent N in straw as against 1.1 per cent in grain. Management practices like addition of cowpea residues, supply of nutrients, adoption of deep tillage or intermittent drainage did not show any advantage. Recycling of paddy straw as well as continuous addition of silica were effective in improving yield.