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# Effect of organic and inorganic sources of nitrogen on Fe, Mn, Cu and Zn uptake and content of rice grain at harvest and straw at different stages of rice (*Oryza sativa*) crop growth

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## ABSTRACT

*The present investigation was carried out at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during Kharif seasons of 2001 and 2002, in agro–ecological zone V of India. The soil of experimental site was sandy clay loam in texture with normal pH, low in nitrogen and phosphorus and medium in organic carbon and potassium contents. The experiment was laid out in Randomised Block Design with nine treatments replicated thrice. The treatments were applied to rice crop during kharif season. Incorporation of chemical fertilizer ($T_9$) enhanced the contents of micronutrients in plants and, obviously, their uptake in plant and grain and straw at harvest in comparison to rest of the N sources. Though various organic N sources significantly increased the contents and the uptake of respective micronutrients in plant at various stages over the control ($T_1$), the maximum improvement in the contents and uptake of micronutrients were recorded in the treatment receiving all the organics @ 40 kg N $ha^{-1}$ each ($T_8$) among the treatments receiving organics alone or in combination. Application of N through chemical fertilizer ($T_9$) brought about significant improvement in grain and straw yields of rice crop and established superiority over rest of the treatments. Among organic N sources, supplication of N through combination of D.S + P.M + C.W @ 40 kg N $ha^{-1}$each ($T_8$) increased the grain and straw yield significantly as against the application of rest of the organic N sources and the control ($T_1$) except the straw yield due to incorporation of P.M alone ($T_3$) which remained at par.*

**Key Words:** Organic sources, Fe, Mn, Cu, Zn uptake, content, grain yield, rice.

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## INTRODUCTION

Rice (*Oryza sativa*), the prince among cereals is the premier food crop not only in India but world too (Chhabra, 2002 ). It is grown over an area of 44.6 m ha (Anonymous, 2003) under highly diverse agro-ecological conditions ranging from below sea level in Kutanad district of Kerala to a height of 2000 meters in high hills under low temperature Considering the heavy demand of rice and the scope of quality rice in international market, interactive research work in almost all aspects of rice is needed.

The unbalanced use of N fertilizers has at times led to environmental confrontations, disturbance in soil nutrient balance and depletion of soil fertility **(**Kimmo, 1993**).** Even the introduction of high yielding varieties and intensive cultivation with excess and imbalanced use of chemical fertilizers and irrigation showed reduction in the soil fertility status and yield by 38 per cent of rice crop (Singh *et al.*, 2001). These causes have led to renewed interest in the use of renewable sources (organic manures/wastes) and prompted the scientists to find out an alternative agricultural system which involves the farming i.e. crop and animal husbandry in a way that harmonize rather than conflict with natural processes operating in a natural eco-system (Sharma[1], 2001). Organic farming approach is only an alternative agriculture taking care of all including ecological aspects.

Rice is a heavy nitrogen feeder, however, fertilizer N efficiency in rice is very low under tropical conditions where it rarely exceeds 50 per cent and usually ranges between 15 to 35 per cent (De Dutta, 1984). Most of the N taken up by rice plant is supplied through soils own natural resources. In wetland rice cultivation, the significance of native soil N is apparent from the fact that 60-80 per cent of N absorbed by the crop is derived from native pool (Broadbent, 1979). A major portion of N in wetland soils occur in organic pool, though this is usually very low. Conclusive evidences indicate that in production of irrigated rice, improvement in organic carbon content of soil and initial soil nitrogen content and efficiency of applied nutrient are more important. Several hypotheses were proposed: (i) high N uptake crops take up ammonium, amino acids or relatively high molecules of organic N preferentially; (ii) rice has stronger activity in competing with soil microorganisms than the other crops; (iii) rice secretes organic substances that support multiplication of microfauna, resulting in rapid decomposition of organic matter; and (iv) rice has superior Km (Michaelis constant), Vmax (maximum uptake velocity) and Cmin (minimum concentration of nutrient) for N uptake (Yamagata *et al.*, 1996).

Since the organic wastes (press mud, digested sludge and carpet wastes) are the source of primary, secondary and micronutrients to the plant growth and constant source of energy for heterotrophic microorganisms which help in increasing availability of nutrients, quality and quantity of crop produce, it can be hypothesized that the use of proper combination of these locally available organic wastes which are narrow in C:N ratio and safe to apply for agricultural purposes, is as critical as that for integrated use.

Keeping these facts in consideration, the present investigation entitled, *"Effect of organic and inorganic sources of nitrogen on Fe, Mn, Cu and Zn uptake and content of rice grain at harvest and straw at different stages of rice (Oryza sativa) crop growth"* was undertaken during 2001 and 2002 at the Agricultural Research Farm, Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, with an objective to study the nutrient acquisition efficiency of rice under organics in comparison to synthetic N source.

## MATERIALS AND METHODS

The present investigation was undertaken during 2001 and 2002 at the Agricultural Research Farm, Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, in agro-ecological zone V of India with an objective to study the effect of organic and inorganic sources of N on yield attributes and yield of rice grain.

Varanasi enjoys sub-tropical climate and is often subjected to extremes of weather conditions i.e., very hot in summer and very cold in winter. In Indian agro-ecological zone, the area falls under V – eastern plain zone. The soil of Varanasi region formed due to deposition of alluvium by river Ganges have predominance of illite, quartz and feldspar minerals.. Most of the soils of the Varanasi division have been classified in the soil order of Inceptisol (Udic, Ustochrept). However, the soils of the experimental site fall under Inceptisol.

The normal annual rainfall of this region is about 1100 mm. In terms of percentage of total rainfall, about 87.3 per cent is received from June to September (monsoon season), 5.9 per cent from October to December (winter season), 3.9 per cent from January to February and 2.8 per cent from March to May as pre-monsoon rain. The minimum and maximum relative humidity of this area varies in between 38 per cent during April to early June and 81 per cent during July to September with a mean of about 68 per cent. The highest mean temperature recorded was 34.475 and $37.35^0$ C in the month of June during both the years of experimentation.

The soil of experimental site was sandy clay loam in texture with normal pH, low in nitrogen and phosphorus and medium in organic carbon and potassium contents. The experiment was laid out in Randomised Block Design with nine treatments replicated thrice. The treatments were applied to rice crop during *kharif* season.

The treatments are $T_1$- Control (without chemical fertilizers and organics), $T_2$-120 kg N through digested sludge (D.S, 6936.4 kg), $T_3$-120 kg N through press mud (P.M, 11428.6 kg), $T_4$-120 kg N through woolen carpet wastes (C.W, 960 kg), $T_5$-60 kg N through D.S (3468.2 kg) + 60 kg N through P.M (5714.29 kg), $T_6$-60 kg N through D.S (3468.2 kg) + 60 kg N through C.W (480 kg), $T_7$-60 kg N through P.M (5714.29 kg) + 60 kg N through C.W (480 kg), $T_8$-40 kg N through D.S (2312.1 kg) + 40 kg N through P.M (3809.5 kg) + 40 kg N through C.W (320 kg), $T_9$-Recommended doses of fertilizers [120 : 60 : 60 :: N (209.8 kg Urea) : P (130.4 kg D.A.P) : K (100 kg M.O.P)].

Nitrogen was applied at the rate of 120 kg $ha^{-1}$ through different organic sources along with two additional treatments which were recommended doses of NPK through chemical fertilizer (120 kg N : 60 kg $P_2O_5$ : 60 kg $K_2O$) and without N (control). The organic sources of N were digested sludge, press mud and carpet wastes and inorganic N source was urea. Phosphorus and potassium were applied through diammonium phosphate and muriate of potash, respectively. The half of recommended dose of nitrogen with full doses of phosphorus and potassium were applied as basal at the time of transplanting and rest 50 % N was top dressed in two equal splits (coinciding maximum tillering and panicle initiation stage) at the interval of one month after transplanting of rice seedlings. The total amount of organic manures/wastes viz. digested sludge, press mud and woolen carpet wastes were applied 14 days before transplanting of the rice var. Sarju-52 at a spacing of 20 cm x 10 cm.

Grain yield was recorded (kg plot$^{-1}$) after threshing, winnowing and cleaning. The difference of the bundle weight and grain yield gave the straw yield (kg plot$^{-1}$) of the crop per plot. Thereafter, both the yields were computed to kilogram per hectare for each of the plot.

Composite plant samples of rice were collected randomly at 40 and 65 days after transplanting (DAT) and at the time of harvesting. The plant samples (straw and grain) were , then, dried in oven at 65$^{0}$ C for 48 hours, powdered with the help of willey mill and were digested and analyzed for micronutrients (Fe, Mn, Zn and Cu) as per procedure described in the following paragraphs.

For the estimation of micronutrients (Fe, Mn, Zn and Cu) the straw and grain samples were digested in diacid mixture of conc. $HNO_3$ and $HClO_4$ in the ratio of 10 : 4 as described by Jackson (1967). After digestion, the plant and grain samples were analyzed with the help of Atomic Absorption Spectrophotometer (Tandon, 1998).

Nutrient uptake in grain and straw of rice was calculated in kg ha$^{-1}$ for N, P, K and S in relation to dry matter production and their nutrient contents by using the following formula:

Nutrient (Fe, Mn, Zn and Cu) uptake (g ha$^{-1}$) =

$$= \frac{\text{Nutrient content in dry matter (ppm) x Yield of dry matter (kg)}}{1000}$$

**Fe content (ppm) of rice straw at different stages and grain at harvest**

Data on Fe content in plant at successive growth stages and in grain at harvest are presented in Table 1. Scrutiny of the data showed significant variation in the Fe content in plant of different stages and in grain at harvest due to different treatments. Fe – content was noticed to be highest at 40 DAT and thereafter there was a decreasing trend with same pattern in the subsequent growth stages (65 DAT and straw at harvest).

It is obvious from the pooled data that application of N through chemical fertilizer ($T_9$) induced significant improvement in Fe content showing its superiority over other N sources and the control ($T_1$) at all the growth stages except in grain at harvest in which it remained at par with application of D.S, P.M and C.W @ 40 kg N ha$^{-1}$($T_8$). Similar case was observed by Duhan and Singh (2002). Adinarayana and Tiwari (1989) also reported that the increasing N rate increased the Fe concentration in rainfed barley crop.

Among organic N sources, combination of D.S, C.W and P.M @ 40 kg N ha$^{-1}$each ($T_8$) increased Fe content against other organic N sources significantly along with control ($T_1$) excluding in grain at harvest where Fe content due to $T_8$ was found at par with the Fe content due to incorporation of P.M alone ($T_3$) and P.M + C.W @ 60 kg N ha$^{-1}$each ($T_7$). Easy availability of Fe in organics (P.M./D.S) during mineralization might have increased its uptake by rice resulting increased plant height, leaf area, straw and grain yield.

However, the Fe content due to application of N through organic sources improved significantly over control ($T_1$). Organic materials supply chelating agents, which helps in maintaining the solubility of micronutrients including Fe and Mn. In addition organic matter improves soil structure which provides better soil aeration resulting increase in the availability of Fe. The presence of organic matter showed a profound influence on the solubility of Fe in waterlogged soils (Das, 2000).

**Mn content (ppm) of rice straw at different stages and grain at harvest**

Data on Mn content in rice plant recorded at successive growth stages and in grain are presented in Table 2. Initially, higher Mn content in straw at 40 DAT was observed and decreased with the advancement in age indicating the dilution effect. The difference in Mn concentration between straw and grain may be due to the slow movement of Mn in plants (Duhan and Singh, 2002). Perusal of data revealed significant variations due to various treatments during both the years of field trial.

It is perceptible from the pooled data that Mn contents due to different treatments had significant difference among the treatments at all the stages except the treatments $T_5$ (D.S + P.M) and $T_6$ (D.S + C.W) at 65 DAT and $T_3$ (P.M alone) and $T_7$ (P.M + C.W), $T_5$ (D.S + P.M) and $T_6$ (D.S + C.W) in grain at harvest which remained at par within treatments. Application of N through chemical fertilizers ($T_9$) induced significant improvement on Mn content over rest of the treatments. Application of urea enhanced the content Mn by the plant and the interaction between Mn and N was found to be positive (Das, 2000). Duhan and Singh (2002) also observed significantly increased Mn content in rice straw and grain with the application of fertilizer N.

While comparing N sources through organics alone or in combination, application of combination of D.S, P.M and C.W @ 40 kg N $ha^{-1}$ each increased Mn content significantly over rest of N sources through organics. However, application of all the N sources through organics improved Mn content significantly over the control ($T_1$) and incorporation of N through chemical fertilizers ($T_9$) remained superior to other treatments. Application of organics (P.M, D.S and C.W) might have increased the water soluble plus exchangeable and easily reducible fractions of Mn. Das and Mandal (1986) also reported that the application of organic matter enhanced the initial decrease in redox potential and increases water soluble and exchangeable $Mn^{+2}$ in soil. A sharp decrease in the content of reducible Mn was found to be totally reflected in the increase in the content of water soluble plus exchangeable form during the period of submergence (Mandal and Mitra, 1982). The Mn contents in plants were in decreasing order as: $T_9 > T_8 > T_3 > T_7 > T_5 > T_6 > T_2 > T_4 > T_1$.

Mn is soluble under relatively acid and reducing conditions like Fe. Solubility for Mn is much broader than that for Fe, which accounts for the separation of one element from the other in weathering environments (Krauskopf, 1967). Most of the total Mn in soils was found in the Mn – oxide and organic fractions (Shuman, 1985). The later are more soluble and therefore, easier to redistribute plant available forms than the Fe – oxide and residual forms, as it is very sensitive to pH and Eh changes (Das, 2000).

Several investigators reported increased concentration of Mn in soils particularly under submerged conditions with the application of organic matter (Ponnamperuma, 1972 and Das, 2000).

**Zn content in rice plant at different stages of growth and grain at harvest**

The data pertaining to Zn content in plant at different stages of growth and in grain at harvest are presented in Table 3. Analysis of pooled data showed significant variations as affected by different treatments. The higher Zn content was recorded at 40 DAT but decreased slightly at successive stages of rice straw.

Application of N through chemical fertilizer ($T_9$) resulted in significantly higher Zn content in straw and grain over rest of the treatments. The findings of Duhan and Singh (2002) confirms increased Zn content in rice grain and straw due to application of fertilizer N. Abdul salam and Subramanian (1988) reported that the interaction between Zn and N was synergistic. Various organic sources of N also increased Zn significantly as compared to the control ($T_1$). The Zn content due to supplication of D.S, P.M and C.W @ 40 kg N $ha^{-1}$ each ($T_8$) improved significantly as against the application of N through organics except application of P.M alone ($T_3$) at 40 DAT which remained at par. Application of P.M alone ($T_3$) and P.M + C.W @ 60 kg N $ha^{-1}$ each ($T_7$) differed significantly with respect to Zn content in grain at harvest. Almost similar trend was noticed at all the stages and grain at harvest with a small variation at 65 DAT where the Zn content due to application of P.M + C.W @ 60 kg N $ha^{-1}$ ($T_7$) each was more than the Zn content due to application of P.M alone ($T_3$).

According to Stevenson and Ardakani (1972) on an average 60 per cent of the soluble Zn in soil occurs in soluble Zn – organic complexes. Soluble Zn – organic complexes are mainly associated with amino, organic and fulvic acids while insoluble Zn – organic complexes are derived from humic acids.

Das (2000) reported that the DTPA – extractable – Zn has been found to be increased in the treatment receiving organic matter (well rotten FYM) 14 and 28 days before puddling or non-puddling the soil. In majority of studies, there were significant positive correlationship (De *et al.*, 1994) existed in between organic matter and available Zn in soils. This might be the reason of increasing Zn content in the rice straw and grain.

**Cu content in plant at different growth stages and in grain at harvest**

Data on Cu content in plant at different stages and in grain at harvest are summarized in Table 4. As the age of rice crops advanced, the Cu content gradually decreased in straw. The scanning of pooled data revealed significant variations in Cu content due to various treatments. Incorporation of N through chemical fertilizers increased the Cu content significantly against incorporation of N though organics and control ($T_1$) at all the stages except application of D.S, P.M and C.W @ 40 kg N $ha^{-1}$ each ($T_8$) at 40 DAT and in grain at harvest which was at par to the treatment receiving N through chemical fertilizer ($T_9$). The increase in Cu content may be due to increase in grain yield and better root proliferation which helps in the absorption of Cu from native source under favourable reduced conditions. The organic N sources improved the Cu content significantly over control ($T_1$). The addition of D.S, P.M and C.W @ 40 kg N $ha^{-1}$ each ($T_8$), P.M alone ($T_3$) and P.M + C.W @ 60 kg N

$ha^{-1}$ each ($T_7$) being at par among each other significantly increased the Cu content over the rest of the organic N sources.

In all the cases almost similar trend was observed with the only exception that application of D.S + C.W @ 60 kg N $ha^{-1}$ ($T_6$) gave more Cu content in comparison to supplying D.S + P.M @ 60 kg N ha $^{-1}$ each (T5) in straw and grain at harvest. The Cu content at 40 and 65 DAT in decreasing order was as follows: $T_9 > T_8 > T_3 > T_7 > T_5 > T_6 > T_2 > T_4 > T_1$.

The organic fraction, in particular, seems to be a source of specific Cu – sorption sites in the soil, because of its unique ability to form inner – sphere complexes at a wide range of pH levels. On the other hand, the mobility of Cu in soils has been found to be increased due to formation of organic – Cu complexes with fulvic acid (Mclaren and Crawford, 1973). The organic matter present in the soil may increase the availability of Cu in soils due to the formation of soluble complexing agents resulting decrease in the fixation of Cu in soils. Grewal *et al.* (1969) observed that the amount of exchangeable Cu increased with an increase in the organic matter content of the soils and recorded a significant positive correlation between organic matter and exchangeable Cu.

Loneragan *et al.* (1981) showed that Cu has a strong affinity for the N atom of amino groups and it appears quite likely that soluble N compounds like amino acids act as Cu carriers in xylem and phloem.

Das and Mandal (1986) reported that the uptake of Cu by the rice root, straw and grains was found to be more in the rice plants grown under waterlogged condition than that in saturated soil condition. The higher Cu uptake by the different plant parts of rice (root, straw and grain) under waterlogged condition may be explained due to favourable chemical environment of the root medium leading to higher root proliferation and nutrient absorption by the rice due to healthy reducing conditions.

**Fe uptake by grain and straw**

Data on Fe uptake by straw and grain and its total uptake due to various treatments are presented in Table 5.

It is evident from the pooled data that application of N through chemical fertilizer ($T_9$) significantly improved the Fe uptake in grain and straw over rest of the treatments. Increasing rate of N increased the Fe uptake by rice (Adinarayana and Tiwari, 1989 and Duhan and Singh, 2002).

Incorporation of N through all the three organics @ 40 kg N $ha^{-1}$ each ($T_8$) increased Fe uptake as against the application of other organics alone or in combination along with control ($T_1$). However, maximum Fe uptake was recorded in all the cases due to application of N through chemical fertilizer ($T_9$) followed by N application through combination of three organics @ 40 kg N $ha^{-1}$ each ($T_8$). Similar trend was found in the uptake of Fe by grain and straw in decreasing order: $T_9 > T_8 > T_3 > T_7 > T_5 > T_6 > T_2 > T_4 > T_1$. Easy availability of Fe in organics (P.M./D.S) during mineralization might have increased its uptake by rice due to increased plant height, leaf area, straw and grain yield.

The uptake of Fe by rice plant was higher under flooded conditions as compared to saturated conditions (Satyanarayana and Ghildayal, 1970).

**Mn uptake by grain and straw**

Data on Mn uptake by straw and grain due to various treatments are presented in Table 6 which show significant variations on Mn uptake during both the years of field experimentation. On going through the pooled data, it is evident that application of N through chemical fertilizer ($T_9$) improved Mn uptake significantly over rest of the treatments. Application of fertilizer N increased the Mn uptake by rice crop over control (Duhan and Singh, 2002). Among organic N sources, incorporation of D.S + P.M + C.W @ 40 kg N $ha^{-1}$ ($T_8$) each increased Mn uptake as against incorporation of organics alone or in combination along with control ($T_1$). All the treatments differed significantly on total Mn uptake except the treatments $T_5$ and $T_6$, which remained at par with each other. However, application of N through chemical fertilizer ($T_9$) was found to be superior in case of Mn uptake followed by N applied through all the three organics @ 40 kg N $ha^{-1}$ each ($T_8$) over rest of the treatments. Application of urea enhance the uptake of Mn by the plant and the interaction between Mn and N was found to be positive (Das, 2000). There are ample evidences that uptake of Mn is metabolically mediated (More, 1972).

**Zn uptake by grain and straw**

Data pertaining to effect of organics and inorganics on Zn uptake (g $ha^{-1}$) by rice grain and straw are presented in Table 7 which reveal that there is significant variations during both the years of experimentations. It is obvious from the pooled data that application of N through chemical fertilizer ($T_9$) resulted in significantly higher Zn uptake by rice grain and straw over rest of the treatments. Increased Zn uptake due to application of fertilizer N was also reported by Duhan and Singh (2002).

Application of D.S + P.M + C.W @ 40 kg N $ha^{-1}$ each ($T_8$) proved to increase the Zn uptake significantly by rice straw and grain as against the application of organics and control ($T_1$). Application of organics increased the Zn uptake which might be due to greater availability of micronutrients present in the soil as well as in the organics except C.W due to variation in mineralization. In majority of studies, there has been a significant positive correlationship (De *et al.*, 1994) in between organic matter and available Zn in soils.

**Cu uptake by grain and straw**

Data on Cu uptake by grain, straw and its total uptake by rice crop pertaining to various treatments are presented in table 8. A critical observation of the data revealed significant variation in Cu uptake by grain and straw during both the years of experimentation. It is obvious from the pooled data that application on N through chemical fertilizer ($T_9$) brought about significant improvement in Cu uptake by rice over rest of the treatments. Duhan and Singh (2002) reported that Cu uptake by rice crop increased with increasing dose of fertilizer N up to 120 kg $ha^{-1}$ and this increase was mainly due to the increase in grain yield of rice.

Among organic N carriers, supplying D.S + P.M + C.W in combination @ 40 kg N $ha^{-1}$ each ($T_8$) increased significantly Cu uptake as against rest of the organic N sources along with control ($T_1$) except application of P.M + C.W @ 60 kg N $ha^{-1}$ each ($T_7$) and P.M alone ($T_3$) in case of straw uptake which were at par among themselves. However, application of N through chemical fertilizer was superior over others and all the organic N sources increased Cu uptake by grain and straw.

Das and Mandal (1986) reported that the uptake of Cu by the rice root, straw and grains was found to be more in the rice plants grown under waterlogged condition than that of water saturated soil condition. The higher Cu uptake by the different plant parts of rice (root, straw and grain) under waterlogged condition may be explained due to favourable chemical environment of the root medium leading to higher root proliferation and nutrient absorption by the rice due to reducing conditions.

**Grain Yield**

Data on grain yield (kg $ha^{-1}$) are presented in Table 9. Data on grain yield revealed significant variation due to experimental variables during both the years of field experimentation.

Economic yield is a complex inter-relationships of its components, which are determined from the growth rhythm in vegetative phase and its subsequent reflection in reproductive phase. Grain yield is the manifestation of yield attributing characters in rice (Matsushima, 1976). It is quite obvious from the pooled data that application of N through chemical fertilizer ($T_9$) brought about significant improvement in grain yield and established superiority over the application of organic N source and the control ($T_1$). Among organic N sources, supplying N through combination of D.S, P.M and C.W @ 40 kg N $ha^{-1}$each ($T_8$) significantly increased the grain yield as against the application of rest of the organic N sources. The addition of N through chemical fertilizers ($T_9$) and different combination of organic N sources ($T_{8,}$ $T_{7,}$ $T_{6,}$ $T_5$) produced significantly more grain yield over the incorporation of organic N sources alone ($T_2$, $T_4$) with the exception of the addition of P.M alone ($T_3$) and the control ($T_1$). However, all the treatments increased the grain yield significantly as against no fertilizer/manure ($T_1$). The trend observed in increasing order was: $T_1 > T_4 > T_2 > T_6 > T_5 > T_7 > T_8 > T_{9.}$

It is, by and large, true that dwarf indica rice varieties have high rate of responsiveness towards fertilizer application and more particularly for N because of their conducive genetic make up. The findings of the present investigation revealed profound effect of N on yield and yield attributes of rice. It was noticed that the grain yield due to application of N through chemical fertilizer and various organics was associated with the number of grains per panicle, effective tillers $m^{-2}$ and test weight of 1000 grains. Correlation studies have shown that grain yield is highly correlated with yield attributes (Hernandez, 1956 and Shastri *et al.*, 1967).

In physiological term, yield of most cereals is largely governed by source (photosynthesis) and sink (grain growth) relationship (Evans and Wardlaw, 1976). However, capacity of system transporting the photosynthates and partitioning of assimilates between their sites of utilization i.e., sink, are the major determinants of crop yield (Gifford and Evans, 1981).

The present investigations revealed significant increase in the yield attributes under N application through chemical fertilizer ($T_9$) followed by N through D.S + P.M + C.W ($T_8$) due to increased absorption of nutrients and their assimilation. Supply of N in balanced quantity enabled the rice plants to assimilate sufficient photosynthetic products and, thus, increased the dry matter accumulation. With increased dry matter and photosynthetic products, coupled with efficient translocation, plant produced more panicles with more number of fertile grains with increased test weight and ultimately higher grain yield. Increase in grain yield due to application of D.S, P.M and C.W were observed by various workers (Tiwari, 2002).

## Straw Yield

Yield of straw pertaining to the various treatments are summarized in the Table 9. Statistical analysis of straw yield data manifested profound variation due to different treatments during both the years of field trials. Application of N through chemical fertilizer ($T_9$) enhanced the straw yield significantly as against organic N sources and no N ($T_1$), which might be attributed due to quicker conversion of urea making N available to rice plants easily as compared to organics which release most of N after mineralization.

Straw yield of a crop is closely related to the vegetative growth viz. plant height, tiller numbers, leaf numbers and final stand of a crop (Singh and Verma, 1971). The beneficial effect of any treatment on one or more of these characters without a corresponding decrease in one or more of them will result in increased straw yield. In the present investigation, the N application through any means enhanced the growth attributes that ultimately led to higher straw yield.

**Table 1: Effect of organics and inorganics on Fe content (ppm) of rice straw at different stages and grain at harvest**

| Treatments | 2001 | 2002 | Pooled | 2001 | 2002 | Pooled | Straw at harvest | | Pooled | Grain at harvest | | Pooled |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 40 DAT | 40 DAT | | 65 DAT | 65 DAT | | 2001 | 2002 | | 2001 | 2002 | |
| $T_1$ | 120.20 | 147.77 | 133.98 | 106.47 | 120.50 | 113.48 | 96.47 | 108.5 | 102.48 | 51.50 | 54.1 | 52.80 |
| $T_2$ | 156.90 | 173.43 | 165.17 | 129.67 | 153.80 | 141.73 | 111.90 | 120.9 | 116.40 | 62.33 | 68.3 | 65.33 |
| $T_3$ | 179.47 | 212.77 | 196.12 | 150.30 | 188.40 | 169.35 | 121.20 | 136.2 | 128.70 | 68.60 | 73.7 | 71.15 |
| $T_4$ | 150.70 | 169.27 | 159.98 | 127.50 | 149.80 | 138.65 | 111.17 | 121.1 | 116.13 | 61.83 | 67.6 | 64.72 |
| $T_5$ | 165.60 | 197.53 | 181.57 | 137.93 | 168.9 | 153.42 | 116.30 | 128.7 | 122.50 | 65.27 | 71.2 | 68.23 |
| $T_6$ | 166.80 | 190.23 | 178.52 | 138.77 | 160.8 | 149.78 | 115.77 | 126.3 | 121.03 | 65.70 | 70.8 | 68.25 |
| $T_7$ | 177.20 | 210.40 | 193.80 | 145.17 | 183.4 | 164.28 | 119.90 | 134.6 | 127.25 | 67.97 | 72.9 | 70.43 |
| $T_8$ | 197.77 | 239.17 | 218.47 | 159.40 | 197.5 | 178.45 | 127.50 | 140.4 | 133.95 | 71.60 | 75.1 | 73.35 |
| $T_9$ | 204.30 | 247.20 | 225.75 | 162.70 | 210.3 | 186.50 | 133.70 | 144.1 | 138.90 | 74.70 | 78.8 | 76.75 |
| C.D. (P=0.05) | 4.70 | 10.66 | 5.60 | 7.36 | 10.36 | 6.11 | 5.46 | 7.30 | 4.38 | 4.07 | 7.73 | 4.20 |

**Table 2: Effect of organics and inorganics on Mn content (ppm) of rice straw at different stages and grain at harvest**

| Treatments | 2001 | 2002 | Pooled | 2001 | 2002 | Pooled | Straw at harvest | | Pooled | Grain at harvest | | Pooled |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 40 DAT | 40 DAT | | 65 DAT | 65 DAT | | 2001 | 2002 | | 2001 | 2002 | |
| $T_1$ | 224.80 | 231.00 | 227.90 | 161.73 | 169.37 | 165.55 | 90.50 | 96.30 | 93.40 | 77.03 | 78.03 | 77.53 |
| $T_2$ | 253.67 | 284.93 | 269.30 | 173.60 | 195.77 | 184.68 | 119.43 | 138.90 | 129.17 | 79.10 | 82.20 | 80.65 |
| $T_3$ | 288.73 | 360.87 | 324.80 | 198.77 | 227.70 | 213.23 | 143.60 | 160.70 | 152.15 | 83.27 | 89.43 | 86.35 |
| $T_4$ | 252.10 | 271.60 | 261.85 | 172.90 | 191.43 | 182.17 | 117.90 | 130.67 | 124.28 | 77.80 | 80.17 | 78.98 |
| $T_5$ | 264.93 | 325.50 | 295.22 | 180.20 | 207.50 | 193.85 | 127.50 | 152.40 | 139.95 | 80.07 | 85.77 | 82.92 |
| $T_6$ | 269.30 | 311.40 | 290.35 | 181.80 | 204.10 | 192.95 | 126.83 | 147.70 | 137.27 | 79.90 | 85.57 | 82.73 |
| $T_7$ | 275.40 | 355.13 | 315.27 | 190.37 | 221.80 | 206.08 | 136.97 | 158.13 | 147.55 | 82.93 | 88.70 | 85.82 |
| $T_8$ | 323.87 | 381.87 | 352.87 | 218.30 | 246.3 | 232.22 | 149.77 | 163.87 | 156.82 | 86.77 | 90.10 | 88.43 |
| $T_9$ | 329.70 | 393.90 | 361.80 | 234.70 | 250.57 | 242.63 | 158.40 | 171.50 | 164.95 | 89.30 | 91.47 | 90.38 |
| C.D. (P=0.05) | 3.58 | 4.36 | 2.71 | 2.82 | 2.88 | 1.94 | 2.62 | 2.06 | 1.60 | 1.93 | 1.55 | 1.19 |

Among organic N sources, incorporation of D.S, P.M and C.W @ 40 kg N $ha^{-1}$ each ($T_8$) being at par with incorporation of P.M alone ($T_3$) significantly improved the straw yield over rest of the treatments treated with organics along with control ($T_1$). The availability of mineralizable N and other nutrients might be more in case of the treatment $T_8$ followed by the treatment $T_3$ than the treatments with organics due to differential rate of organic N mineralization in soil (Mukherjee *et al.*, 1995).

Incorporation of organics such as D.S, P.M and C.W increased the straw yield of rice (Tiwari, 2002).

**Table 3: Effect of organics and inorganics on Zn content (ppm) of rice straw at different stages and grain at harvest**

| Treatments | 2001 | 2002 | Pooled | 2001 | 2002 | Pooled | Straw at harvest | | Pooled | Grain at harvest | | Pooled |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 40 DAT | 40 DAT | | 65 DAT | 65 DAT | | 2001 | 2002 | | 2001 | 2002 | |
| $T_1$ | 33.87 | 37.10 | 35.48 | 24.23 | 26.60 | 25.42 | 14.90 | 15.43 | 15.17 | 28.20 | 29.80 | 29.00 |
| $T_2$ | 37.63 | 40.53 | 39.08 | 28.30 | 29.80 | 29.05 | 19.37 | 22.80 | 21.08 | 33.83 | 37.43 | 35.63 |
| $T_3$ | 44.00 | 48.40 | 46.20 | 31.10 | 32.80 | 31.95 | 24.10 | 27.27 | 25.68 | 37.10 | 41.60 | 39.35 |
| $T_4$ | 37.30 | 39.47 | 38.38 | 27.97 | 29.13 | 28.55 | 19.80 | 20.70 | 20.25 | 33.40 | 36.20 | 34.80 |
| $T_5$ | 40..70 | 43.77 | 42.23 | 29.40 | 31.27 | 30.33 | 21.70 | 25.90 | 23.80 | 34.77 | 39.27 | 37.02 |
| $T_6$ | 41.03 | 43.30 | 42.17 | 29.67 | 31.10 | 30.38 | 22.30 | 25.13 | 23.72 | 35.23 | 38.07 | 36.65 |
| $T_7$ | 43.67 | 47.53 | 45.60 | 30.97 | 33.47 | 32.22 | 23.63 | 26.87 | 25.25 | 36.60 | 40.00 | 38.30 |
| $T_8$ | 45.77 | 48.87 | 47.32 | 32.57 | 35.20 | 33.88 | 25.97 | 28.20 | 27.08 | 39.50 | 42.70 | 41.10 |
| $T_9$ | 47.10 | 51.30 | 49.20 | 34.73 | 36.97 | 35.85 | 28.90 | 30.80 | 29.85 | 41.37 | 44.90 | 43.13 |
| C.D. (P=0.05) | 2.29 | 1.93 | 1.44 | 1.99 | 1.59 | 1.23 | 1.28 | 1.71 | 1.03 | 1.57 | 1.26 | 0.97 |

**Table 4: Effect of organics and inorganics on Cu content (ppm) of rice straw at different stages and grain at harvest**

| Treatments | 2001 | 2002 | Pooled | 2001 | 2002 | Pooled | Straw at harvest | | Pooled | Grain at harvest | | Pooled |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 40 DAT | 40 DAT | | 65 DAT | 65 DAT | | 2001 | 2002 | | 2001 | 2002 | |
| $T_1$ | 18.13 | 21.20 | 19.67 | 16.53 | 17.13 | 16.83 | 7.60 | 8.20 | 7.90 | 17.57 | 19.20 | 18.38 |
| $T_2$ | 23.20 | 26.80 | 25.00 | 19.60 | 21.70 | 20.65 | 9.43 | 11.30 | 10.37 | 19.60 | 22.63 | 21.12 |
| $T_3$ | 27.40 | 30.23 | 28.82 | 22.20 | 25.10 | 23.65 | 11.50 | 13.63 | 12.57 | 21.90 | 24.70 | 23.30 |
| $T_4$ | 22.37 | 25.90 | 24.13 | 19.17 | 20.93 | 20.05 | 8.97 | 10.70 | 9.83 | 18.93 | 22.17 | 20.55 |
| $T_5$ | 25.20 | 29.37 | 27.28 | 20.70 | 23.10 | 21.90 | 10.20 | 12.60 | 11.40 | 20.37 | 23.50 | 21.93 |
| $T_6$ | 24.97 | 28.83 | 26.90 | 21.03 | 22.47 | 21.75 | 10.60 | 12.27 | 11.43 | 20.70 | 23.80 | 22.25 |
| $T_7$ | 26.80 | 29.17 | 28.25 | 21.80 | 24.50 | 23.15 | 11.17 | 13.67 | 12.42 | 21.30 | 24.37 | 22.83 |
| $T_8$ | 29.70 | 31.40 | 30.55 | 23.97 | 26.37 | 25.17 | 12.40 | 13.40 | 12.90 | 22.97 | 25.40 | 24.18 |
| $T_9$ | 31.10 | 32.60 | 31.85 | 26.20 | 28.80 | 27.5 | 13.80 | 15.07 | 14.43 | 24.50 | 26.60 | 25.55 |
| C.D. (P=0.05) | 4.54 | 2.93 | 2.60 | 3.67 | 2.62 | 2.17 | 2.13 | 1.58 | 1.27 | 3.21 | 2.03 | 1.83 |

**Table 5: Effect of organics and inorganics on Fe uptake (g $ha^{-1}$) by rice grain and straw**

| Treatments | 2001 | 2002 | Pooled | 2001 | 2002 | Pooled | 2001 | 2002 | Pooled |
|---|---|---|---|---|---|---|---|---|---|
| | Grain Uptake | Grain Uptake | | Straw Uptake | Straw Uptake | | Total Uptake | Total Uptake | |
| $T_1$ | 91.79 | 106.37 | 99.08 | 319.95 | 381.32 | 350.63 | 411.74 | 487.69 | 449.71 |
| $T_2$ | 203.54 | 261.65 | 232.59 | 567.30 | 681.06 | 624.18 | 770.82 | 942.71 | 856.77 |
| $T_3$ | 263.07 | 326.56 | 294.81 | 645.85 | 838.45 | 742.15 | 908.92 | 1165.01 | 1036.97 |
| $T_4$ | 192.60 | 251.44 | 222.02 | 525.94 | 672.61 | 599.28 | 718.56 | 924.05 | 821.30 |
| $T_5$ | 229.53 | 295.34 | 262.43 | 583.94 | 762.64 | 673.29 | 746.80 | 1057.98 | 902.39 |
| $T_6$ | 234.28 | 288.88 | 261.58 | 590.78 | 747.79 | 669.28 | 758.40 | 1036.66 | 897.53 |
| $T_7$ | 257.28 | 314.66 | 285.97 | 639.50 | 806.09 | 722.80 | 896.78 | 1120.75 | 1008.77 |
| $T_8$ | 302.90 | 354.50 | 328.70 | 728.78 | 884.77 | 806.78 | 1031.58 | 1239.27 | 1135.43 |
| $T_9$ | 349.85 | 416.64 | 383.24 | 827.01 | 987.61 | 907.31 | 1176.87 | 1404.25 | 1290.56 |
| C.D. (P=0.05) | 17.39 | 32.51 | 17.72 | 57.15 | 76.92 | 46.05 | 140.20 | 72.96 | 75.96 |

**Table 6: Effect of organics and inorganics on Mn uptake (g ha$^{-1}$) by rice grain and straw**

| Treatments | 2001 Grain Uptake | 2002 Grain Uptake | Pooled | 2001 Straw Uptake | 2002 Straw Uptake | Pooled | 2001 Total Uptake | 2002 Total Uptake | Pooled |
|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | 137.37 | 153.50 | 145.43 | 300.14 | 338.76 | 319.45 | 437.51 | 492.25 | 464.89 |
| $T_2$ | 258.42 | 315.08 | 286.75 | 607.35 | 782.35 | 694.85 | 859.10 | 1097.43 | 978.27 |
| $T_3$ | 319.07 | 396.52 | 357.79 | 765.90 | 990.65 | 878.27 | 1085.03 | 1387.16 | 1236.10 |
| $T_4$ | 242.51 | 297.93 | 270.22 | 557.97 | 725.13 | 641.55 | 800.49 | 1023.05 | 911.77 |
| $T_5$ | 281.67 | 355.90 | 318.79 | 639.51 | 904.39 | 771.95 | 921.18 | 1260.30 | 1090.74 |
| $T_6$ | 285.05 | 349.41 | 317.23 | 646.73 | 873.82 | 760.28 | 931.78 | 1223.23 | 1077.51 |
| $T_7$ | 313.73 | 382.90 | 348.32 | 730.41 | 945.10 | 838.21 | 1044.14 | 1328.90 | 1186.52 |
| $T_8$ | 367.32 | 424.95 | 396.13 | 856.16 | 1032.26 | 944.21 | 1223.48 | 1457.20 | 1340.34 |
| $T_9$ | 418.19 | 483.25 | 450.72 | 979.57 | 1175.70 | 1077.64 | 1397.50 | 1658.95 | 1528.22 |
| C.D. (P=0.05) | 18.98 | 17.65 | 12.46 | 63.68 | 74.42 | 47.08 | 69.00 | 67.74 | 46.47 |

**Table 7: Effect of organics and inorganics on Zn uptake (g ha$^{-1}$) by rice grain and straw**

| Treatments | 2001 Grain Uptake | 2002 Grain Uptake | Pooled | 2001 Straw Uptake | 2002 Straw Uptake | Pooled | 2001 Total Uptake | 2002 Total Uptake | Pooled |
|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | 50.30 | 58.61 | 54.45 | 49.40 | 54.22 | 51.81 | 99.70 | 112.83 | 106.26 |
| $T_2$ | 110.52 | 143.52 | 127.02 | 100.43 | 116.47 | 108.45 | 210.95 | 259.99 | 235.47 |
| $T_3$ | 142.18 | 184.45 | 163.32 | 128.39 | 167.95 | 148.17 | 270.57 | 352.40 | 311.49 |
| $T_4$ | 103.99 | 134.56 | 119.28 | 91.62 | 126.39 | 109.00 | 195.61 | 260.95 | 228.28 |
| $T_5$ | 122.28 | 162.99 | 142.63 | 108.80 | 153.49 | 131.14 | 231.08 | 316.47 | 273.78 |
| $T_6$ | 125.65 | 155.45 | 140.55 | 113.77 | 148.71 | 131.24 | 239.42 | 304.16 | 271.79 |
| $T_7$ | 138.50 | 172.67 | 155.59 | 126.05 | 160.81 | 143.43 | 264.56 | 333.48 | 299.02 |
| $T_8$ | 167.09 | 201.48 | 184.29 | 148.47 | 177.72 | 163.09 | 315.56 | 379.20 | 347.38 |
| $T_9$ | 193.72 | 237.26 | 215.49 | 178.62 | 211.20 | 194.91 | 372.34 | 448.46 | 410.40 |
| C.D. (P=0.05) | 7.06 | 11.83 | 6.62 | 9.54 | 14.17 | 8.21 | 12.47 | 11.64 | 8.20 |

**Table 8: Effect of organics and inorganics on Cu uptake (g ha$^{-1}$) by rice grain and straw**

| Treatments | 2001 Grain Uptake | 2002 Grain Uptake | Pooled | 2001 Straw Uptake | 2002 Straw Uptake | Pooled | 2001 Total Uptake | 2002 Total Uptake | Pooled |
|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | 31.28 | 37.72 | 34.50 | 25.14 | 28.78 | 26.96 | 56.42 | 66.50 | 61.46 |
| $T_2$ | 64.09 | 86.82 | 75.46 | 48.44 | 63.65 | 56.05 | 112.53 | 150.48 | 131.51 |
| $T_3$ | 83.95 | 109.46 | 96.70 | 61.49 | 84.06 | 72.77 | 145.44 | 193.50 | 169.47 |
| $T_4$ | 58.83 | 82.31 | 70.57 | 42.37 | 59.40 | 50.89 | 101.20 | 141.71 | 121.46 |
| $T_5$ | 71.62 | 97.58 | 84.60 | 51.02 | 74.91 | 62.97 | 122.64 | 172.49 | 147.56 |
| $T_6$ | 73.94 | 97.17 | 85.55 | 53.90 | 72.48 | 63.19 | 127.84 | 169.65 | 148.74 |
| $T_7$ | 80.64 | 105.15 | 92.89 | 59.52 | 81.71 | 70.61 | 140.16 | 186.85 | 163.50 |
| $T_8$ | 97.15 | 119.71 | 108.43 | 70.82 | 84.36 | 77.59 | 167.97 | 204.07 | 186.02 |
| $T_9$ | 114.59 | 140.63 | 127.61 | 85.22 | 103.24 | 94.23 | 199.81 | 243.87 | 221.84 |
| C.D. (P=0.05) | 12.40 | 9.74 | 7.58 | 11.62 | 11.18 | 7.75 | 18.24 | 12.67 | 10.67 |

**Table 9: Effect of organics and inorganics on grain and straw yield of rice**

| Treatments | 2001 Grain Yield (kg ha$^{-1}$) | 2002 Grain Yield (kg ha$^{-1}$) | Pooled | 2001 Straw yield (kg ha$^{-1}$) | 2002 Straw yield (kg ha$^{-1}$) | Pooled |
|---|---|---|---|---|---|---|
| $T_1$ | 1783.3 | 1966.7 | 1875.0 | 3316.7 | 3516.7 | 3416.7 |
| $T_2$ | 3266.7 | 3833.3 | 3550.0 | 4883.3 | 5633.3 | 5258.3 |
| $T_3$ | 3833.3 | 4433.3 | 4133.3 | 5333.3 | 6166.7 | 5750.0 |
| $T_4$ | 3116.7 | 3716.7 | 3416.7 | 4733.3 | 5550.0 | 5141.7 |
| $T_5$ | 3516.7 | 4150.0 | 3833.3 | 5016.7 | 5933.3 | 5475.0 |
| $T_6$ | 3566.7 | 4083.3 | 3825.0 | 5100.0 | 5916.7 | 5508.3 |
| $T_7$ | 3783.3 | 4316.7 | 4050.0 | 5333.3 | 5983.3 | 5658.3 |
| $T_8$ | 4233.3 | 4716.7 | 4475.0 | 5716.7 | 6300.0 | 6008.3 |
| $T_9$ | 4683.3 | 5283.3 | 4983.3 | 6183.3 | 6850.0 | 6516.7 |
| C.D. (P=0.05) | 198.0 | 190.0 | 131.9 | 363.3 | 530.0 | 308.8 |

## CONCLUSION

Incorporation of chemical fertilizer ($T_9$) enhanced the contents of micronutrients in plants and, obviously, their uptake in plant and grain and straw at harvest in comparison to rest of the N sources. Though various organic N sources significantly increased the contents and the uptake of respective micronutrients in plant at various stages over the control ($T_1$), the maximum improvement in the contents and uptake of micronutrients were recorded in the treatment receiving all the organics @ 40 kg N $ha^{-1}$ each ($T_8$) among the treatments receiving organics alone or in combination. Application of N through chemical fertilizer ($T_9$) brought about significant improvement in grain and straw yields of rice crop and established superiority over rest of the treatments. Among organic N sources, supplication of N through combination of D.S + P.M + C.W @ 40 kg N $ha^{-1}$each ($T_8$) increased the grain and straw yield significantly as against the application of rest of the organic N sources and the control ($T_1$) except the straw yield due to incorporation of P.M alone ($T_3$) which remained at par.

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