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Research Article

EFFECT OF INTEGRATION OF ORGANIC AND INORGANIC SOURCES OF NITROGEN ON GROWTH, YIELD AND NUTRIENT UPTAKE BY MAIZE (*Zea mays* L.)

S. Kafle[1*] and P. K. Sharma[2]

[1]Department of Agronomy, Punjab Agricultural University, Ludhiana, India
[2]Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana, India

*Corresponding author email: sagarkafle23@gmail.com

Abstract

A field study was conducted at Agronomy Research Farm of Punjab Agricultural University during *kharif* 2013 to evaluate the effect of organic and inorganic sources of nitrogen on maize. Experiment was laid out in split plot design with four replications comprising three farmyard manure levels (0, 15 and 20 t/ha) in main-plots and five nitrogen levels 0, 75, 100, 125 and 150% of recommended dose (125 kg/ha) through inorganic fertilizer in sub-plots. Plant growth and yield characters and nutrient content as well as uptake were recorded. Number of leaves, leaf area index, chlorophyll content and leaf nitrogen content at periodic intervals increased significantly with the application of farmyard manure and nitrogen. Increase in nutrient uptake *viz*., nitrogen, phosphorus and potassium uptake along with micronutrient uptake by grain was also observed with incremental farmyard manure and nitrogen levels. Growth variables were correlated positively with each other and with grain yield. A fairly negative correlation was observed between micronutrient content and growth and yield variables.

Key words: Farmyard manure; Inorganic nitrogen; Nutrient uptake; Micronutrient content

Introduction

Maize ranks third in India in terms of production among cereals (Anonymous 2013). It is emerging as a favorable diversification option for farmers in South Asia as a non-traditional component crop in rice-wheat cropping system (Majumdar et al 2012), mainly because of higher productivity and profitability, lesser water requirement and better resilient to biotic and abiotic stresses than rice and wheat. High yielding maize is considered as an exhaustive crop and extracts higher amounts of mineral nutrients from soil than rice or wheat. Currently, it is being preferred by the farmers of Indo-gangetic plains having yield potential even up to 10 t/ha. The water table in this region is receding and efforts are being made to promote maize cultivation by shifting rice area using improved agronomic interventions which may enable to bring profit margin in the favorable range at par with rice. This can be accrued with the adoption of improved soil fertility and crop management techniques. It is well perceived that for achieving high maize yield, an adequate and balanced supply of essential nutrients is required. Fertilizer requirements, particularly nitrogen fertilizer, depends on many factors including yield target, variety, inorganic soil nitrogen, potential nitrogen mineralization, soil type and numerous environmental factors (Schlegel and Havlin 1995) and because of its high grain potential, maize requires liberal application of nutrients.

Nitrogen is typically required in larger quantities than any other nutrients by the crop for its growth and development, therefore, its proper management is essential to reap high yield and ultimately the profit. It is one of the most important nutrients limiting maize yield and quality in various parts of the world (Miao et al 2007) as well as under Indian condition where per cent yield loss due to low nitrogen fertility is estimated up to 50 per cent. Low nitrogen fertility is the second most important constraint for maize production and productivity after drought in tropics, including Asia (Singh et al 2005). The doubling of agricultural food production worldwide over past few decades has been associated with a seven fold increase in use of nitrogen fertilizers (London 2005). Since nitrogen is the major structural constitute of cells, as nitrogen level increases, the rate of vegetative and reproductive growth also increases in plants due to increase in assimilatory surface of plant as well as photosynthesis (Shrikanth et al 2009). Nitrogen uptake, biomass production and grain yields are strongly correlated; the nitrogen requirement of a maize crop is strongly related to grain yield. Uptake of nutrients by crop plants in adequate amount and proportion is very important for producing higher yields. Similarly, distribution of absorbed or accumulated nutrients in shoot and grain is associated with yield improvement. About 50% of the total leaf nitrogen is directly involved in photosynthesis either as enzymes or as chlorophyll. Application of farmyard manures in cropping systems can increase organic matter content of soil, which may enhance nitrogen use efficiency of crop plants as well as improve quality of the produce. The complementary use of organic manures and chemical fertilizers has proved to be the best soil fertility management strategies (Mahapatra et al 1985) aimed at realizing higher yield and maintaining quality of the produce (Sarkar et al 1997). Use of inorganic fertilizer the world over to replenish nitrogen has no doubt resulted in substantial productivity enhancement of field crops in the recent past, but use of high analysis fertilizer containing mainly primary nutrients has had deleterious effect on nutritional quality of foods needed to meet dietary requirements of the mankind. Maize has high yield potential and responds greatly to nitrogen fertilizers. Keeping these things in view, an experiment was conducted to evaluate the effect of organic and inorganic sources of nitrogen on various growth parameters, nutrient content and uptake and productivity and to determine their interrelationships.

Materials and methods

Location

The experimental site was located on a sandy loam soil at Punjab Agricultural University (30^{0}56' N 75^{0}52' E and 247 m.a.s.l.), Ludhiana, India. On site of experiment previously maize (2011-12) and barley (2012-13) were grown. Analysis of soil in the 2nd week of June 2013, showed a pH of 7.9 (1:2 soil-water suspension), EC 0.12 dS/m at 25^{0}C, organic carbon 0.38% and available N 181.3 kg/ha, P 33.5 kg/ha and K 147.5 kg/ha.

Experimental design

The experiment was laid out in split plot design with 4 replications. Three farmyard manure levels *viz*., control (0), 15 t/ha and 20 t/ha in main plot treatments and five inorganic nitrogen levels on the basis of percentage of recommended nitrogen (125 kg/ha) *viz.*, control (0), 75, 100, 125 and 150% of recommended in sub plots were constructed. Each main-plot measured 16.2 m × 7.2 m and sub-plot 7.2 m × 3 m in gross.

Agronomic details

Maize hybrid PMH-1 was sown manually on 21st June 2013 by dibbling method at a spacing of 60 cm × 20 cm. Initially two seeds were sown per hill and these were thinned to one plant two weeks later. Well decomposed farmyard manure (1.01% N, 0.57% P and 1.5% K) was applied as per treatments to the respective plots at the time of field preparation by properly mixing with soil with the help of power tiller. Phosphorus and potassic fertilizers were applied at the rate of 60 kg P_2O_5/ha as single super phosphate and 30 kg K_2O/ha as muriate of potash. For N fertilized plots, calculated dose of nitrogen as per treatments was applied in the form of urea (46% N). Entire quantity of phosphorus and potassium with one third of nitrogen was drilled at the time of sowing and remaining nitrogen was side dressed in two equal splits i.e. at knee high and pre-tasseling stage. Crop was grown following recommended packages and practices for the state.

Measurements

Total chlorophyll contents at different intervals were determined by using dimethyl sulphoxide (DMSO) as an extractant (Hiscox and Israelstam 1979) and the equation given by Anderson and Boardman (1964). After the harvesting of crop from net plot of 4.8m × 2m on 4th October 2013, the crop was sun dried for two weeks. The cobs were dehusked manually and shelled by maize sheller after proper sun drying of cobs. Various yield attributes were recorded from the sample cobs. Samples for N analysis were ground to pass through 1 mm screen and N concentration in each sample was determined by modified Micro-Kjeldahl method (Subbiah and Asija 1956). Nitrogen uptake in grain and stover (kg/ha) was calculated as the product of the grain and stover dry matter with corresponding nitrogen concentration (%N). The phosphorus in grain and stover was determined by using Vanado-Molybdo-Phosphoric yellow colour method in nitric acid (Jackson 1967). The digested samples of grain and stover used for phosphorus determination were used for the determination of potassium content using flame photometer.

Statistical analysis

Statistical analysis was done by CPCS-1 software developed by Department of Mathematics, Statistics and Physics, Punjab Agricultural University, Ludhiana (Cheema and Singh 1990). Data were analyzed using ANOVA with mean separation using Fisher's protected least significant difference (α = 0.05). A matrix plot was prepared from different variables using Minitab 16 software to show their pair wise inter-relationships. The correlation matrix contains a matrix of scatterplots, in which rows and columns are present, each of which representing separate variable. An internal x- and y-axis is also there for each scatterplot. The Pearson's correlation coefficients were determined from SPSS 16.0 software showing bi-variate relationships of the variables.

Results and Discussion

Number of leaves

Average number of leaves per plant increased from 6.1 at 25 DAS to 11.8 at 50 DAS and further to 14.4 at 75 DAS (Table 1). A significant response in terms of number of leaves per plant to FYM application was observed at all the stages of observation. Both the FYM levels (15 and 20 t/ha) resulted in significantly higher number of leaves per plant over no FYM at 25, 50 and 75 DAS. Each nitrogen level produced significantly more number of leaves over the lower level at 25 DAS. At 50 and 75 DAS, the increase in leaf production was significant up to 125% of recommended N beyond which increase in nitrogen caused non-significant increase in the number of leaves. Increase in dose of nitrogen from 0 to 150% of recommended dose increased the number of leaves from 4.9 to 7.2 at 25 DAS, 9.5 to 13.5 at 50 DAS and 11.7 to 16.1 at 75 DAS. The interaction effect of FYM and nitrogen was not significant in terms of number of leaves per plant. This shows that higher nitrogen rates enhanced the vegetative growth and increased the source capacity of the plants as indicated by increase in number of leaves produced per plant. This agrees with Aluko and Fischer (1987), who reported increased source capacity with increase in nitrogen levels.

Leaf area index

Leaf area index (LAI) is a measure of leafiness per unit ground area and denotes the extent of photosynthetic machinery. It is the most important indicator of size of the assimilatory system in maize to maximize harvest of the incident solar radiation (Mahmood and Saeed 1998). There was considerable increase in leaf area index between 25 and 50 DAS, which further increased at 75 DAS (Table 1) to a lesser extent which might be due to the onset of senescence of a few lower leaves. FYM and nitrogen levels affected the ratio of leaf area to ground area to a large extent. Application of FYM (15 and 20 t/ha) produced significantly higher leaf area index than no FYM at all the dates of observations. However, increase in LAI with 20 t/ha of FYM over 15 t/ha was non-significant.

Table 1: Number of leaves and leaf area index as influenced by levels of organic and inorganic nitrogen in *kharif* maize

Treatment	**Number of leaves**			**Leaf area index**		
	25 DAS	**50 DAS**	**75 DAS**	**25 DAS**	**50 DAS**	**75 DAS**
Farmyard manure (t/ha)						
0	5.5	10.9	12.8	0.8	2.6	3.6
15	6.3	12.0	15.0	1.0	3.4	4.1
20	6.7	12.5	15.3	1.1	3.5	4.3
LSD (p=0.05)	0.6	0.8	0.4	0.1	0.2	0.2
Nitrogen (% of recommended 125 kg/ha)						
0	4.9	9.5	11.7	0.5	2.1	2.6
75	5.6	11.1	13.9	0.9	2.9	3.5
100	6.2	11.9	15.0	1.0	3.3	4.1
125	6.8	13.0	15.7	1.2	3.6	4.4
150	7.2	13.5	16.1	1.3	3.8	4.6
LSD (p=0.05)	0.3	0.7	0.5	0.12	0.2	0.2

Table 2: Periodic total chlorophyll content and leaf nitrogen content as influenced by levels of organic and inorganic nitrogen in *kharif* maize

Treatment	**Total chlorophyll content (mg/g)**			**Leaf nitrogen content (g/kg)**		
	25 DAS	**50 DAS**	**75 DAS**	**25 DAS**	**50 DAS**	**75 DAS**
Farmyard manure (t/ha)						
0	1.1	2.8	2.4	24.5	25.7	18.7
15	1.3	3.1	2.8	25.8	27.7	24.1
20	1.3	3.2	2.9	26.1	28.0	24.3
LSD (p=0.05)	0.1	0.3	0.2	0.9	1.2	1.6
Nitrogen (% of recommended 125 kg/ha)						
0	0.9	2.3	2.0	22.6	21.1	16.9
75	1.2	2.9	2.5	24.3	26.3	21.4
100	1.3	3.1	2.8	25.6	28.2	23.1
125	1.4	3.3	3.0	26.8	29.3	24.7
150	1.4	3.5	3.0	28.6	30.8	25.7
LSD (p=0.05)	0.06	0.1	0.2	1.0	1.6	1.5

Increasing nitrogen levels resulted in significantly higher LAI up to 125% of recommended N at 25 and 75 DAS with non-significant increase with 150% of recommended N over 125% recommended N. However, at 50 DAS, increase in LAI up to 150% recommended N over lower level levels was significant. The increased LAI with increasing nitrogen supply might be due to the effect of nitrogen on the rate of growth of meristem and the appearance and development of leaves (Ahmad *et al.,* 1993). These results are in agreement with those of Oscar and Tollenaar (2006).

Total chlorophyll content

A close glance of data (Table 2) shows that the total chlorophyll content (mg/g) increased up to 50 DAS and decreased thereafter at 75 DAS in comparison to 50 DAS. The lesser extent of decrease in chlorophyll might be due to the stay green nature of the hybrid taken for experiment. This illustrates prolonged photosynthetic ability of the crop even after silking up to maturity. The crop was in the reproductive stage at the time of determination of chlorophyll at 75 DAS. Root hairs primarily responsible for absorption of nutrients start decaying after the plant enters into reproductive stage. Consequently, absorption of the essential plant nutrients from the soil declines. Moreover, onset of the remobilization of nitrogen from leaves to sink might have also resulted in lowering the chlorophyll content of the 75 days old crop. Highest chlorophyll content was recorded with FYM 20 t/ha at all the dates of observation. Significantly higher chlorophyll content was observed with the application of FYM (15 or 20 t/ha) than no FYM at 25, 50 and 75 DAS.

Total chlorophyll content increased significantly with the increase in nitrogen level from control to 150% of recommended N at 25 DAS. However, at 50 and 75 DAS, $N_{150\%}$ and $N_{125\%}$ treatments were statistically similar with one another and significantly better than $N_{100\%}$, $N_{75\%}$ and control. Similar results have been reported by Kaur (2012) while studying the physiological basis of nitrogen use efficiency in maize at various rates of applied nitrogen. These results are in contrast with the result reported by Parija (2011) having higher chlorophyll content at 90 DAS than previous growth stages. As nitrogen is an integral part of chlorophyll, which converts light into chemical energy needed for photosynthesis, an adequate supply of nitrogen might result in high photosynthetic activity, vigorous vegetative growth and a dark green colour. Interaction effect due to FYM and levels of nitrogen was non-significant.

Periodic leaf nitrogen content

Periodic leaf nitrogen content was influenced by the different levels of farmyard manure and nitrogen (Table 2). Application of 15 and 20 t/ha FYM gave significantly higher leaf nitrogen content in comparison to control at all the dates of observation. However, these two FYM levels were statistically similar. Increasing nitrogen levels had shown profound effect on leaf nitrogen concentration. At 25 DAS, increasing nitrogen from control to 150% of recommended gave significantly higher leaf nitrogen content at every increase in nitrogen levels. At 50 and 75 DAS, the highest leaf nitrogen content was observed at 150% of recommended which was significantly higher than 100%, 75% and control and statistically similar to 125% of recommended. Statistically similar leaf nitrogen content was also observed between 100% and 125% of recommended at 50 DAS. Kaur (2012) reported the increase in leaf nitrogen up to anthesis and decreased during grain filling. The interaction effect of FYM and nitrogen levels was non-significant for periodic leaf nitrogen content.

The reviews regarding nitrogen content at different period of plant growth showed that there could be sharp reduction in nitrogen content in plants with the progression of crop age. The less extent of reduction in leaf nitrogen content in the present study might be attributed to stay green nature of the variety. Ironically, the extent of reduction could be more intense if it was compared on whole plant basis. The leaf-stem ratio during initial stage of crop growth (25 DAS) would be higher than that of during later stage of crop growth. Stalk part of maize contains less percentage of nitrogen than leaf. So, higher the dry matter partitioned to the stem part at later stage of crop growth provides the basis for higher extent of reduction in nitrogen content at later growth period on whole plant basis.

Nutrient uptake at harvest

Grain, stover and total nitrogen, phosphorus and potassium uptake were found significantly higher under 15 and 20 t/ha FYM as compared to control (Table 3). Significantly higher stover and total nitrogen was observed with the application of farmyard manure 20 t/ha but was statistically at par with 15 t/ha with respect to grain N uptake; grain, stover and total P and K uptake. Greater availability of NPK due to addition of organic manures as FYM might have contributed for higher uptake of major nutrients. Application of 20 t/ha FYM resulted in 11.4%, 8.0%, 13.1% and 13.6% higher Zn, Cu, Fe and Mn uptake by grain, respectively over 15 t/ha. However, extent of increase in micronutrient uptake by grain with the application of 15 t FYM/ha was also much higher over the control. Increase in availability of micronutrients coupled with higher dry matter accumulation with the addition of FYM might be the reason for higher micronutrient uptake by grain.

Table 3: Nutrient uptake as influenced by levels of organic and inorganic nitrogen in *kharif* maize

Treatment	NPK uptake at harvest (kg/ha)								
	Nitrogen			Phosphorus			Potassium		
	Grain	Stover	Total	Grain	Stover	Total	Grain	Stover	Total
Farmyard manure (t/ha)									
0	78.0	41.3	119.3	12.4	7.0	19.5	18.0	64.9	82.9
15	97.8	58.7	155.5	16.1	10.9	27.1	24.1	81.6	105.6
20	102.4	64.4	166.8	17.2	12.4	29.7	26.5	84.7	111.2
LSD (p=0.05)	3.7	3.9	7.9	2.1	1.9	3.2	2.6	4.6	6.3
Nitrogen (% of recommended 125 kg/ha)									
0	60.2	30.4	90.6	8.5	5.4	15.2	11.5	55.1	66.6
75	86.4	47.5	133.9	15.2	8.3	23.5	20.9	75.6	96.5
100	98.9	57.8	156.8	17.0	11.1	28.1	23.9	83.5	107.4
125	106.7	67.5	174.2	19.4	12.7	32.1	27.3	88.7	116.0
150	111.5	73.2	184.7	20.1	14.2	34.3	29.7	90.8	120.5
LSD (p=0.05)	6.7	3.4	10.6	2.3	2.1	4.0	2.9	4.8	7.9

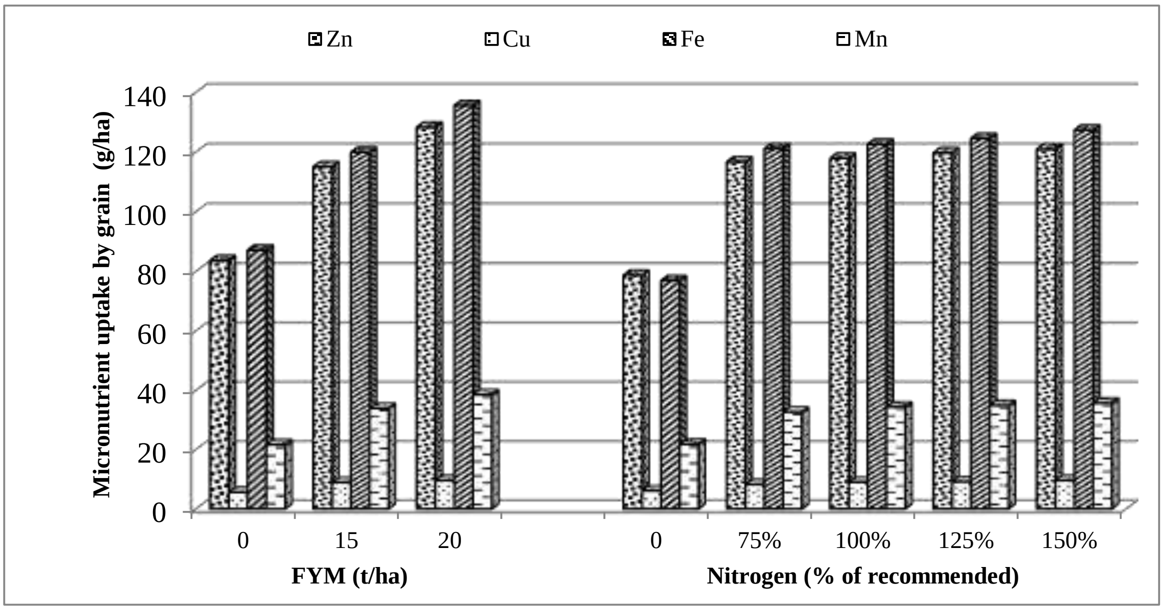

Fig. 1: Micronutrient uptake by grain as influenced by levels of organic and inorganic nitrogen in *kharif* maize

The highest nitrogen rate applied (150% of recommended) was responsible for the highest nitrogen, phosphorus and potassium uptake in grain and stover and consequently in total uptake. However, this was at par with 125% of recommended in all the cases except stover nitrogen uptake. The increase in nitrogen uptake in grain and stover is ascribed to the fact that nitrogen application increases the availability of nitrogen in soil that can be absorbed by the roots proliferated due to the adequacy of nitrogen. The increase in P and K uptake was due to the fact that nitrogen promotes phosphorus and potassium uptake by increasing top and root growth, altering plant metabolism and increasing P and K solubility and availability. Application of nitrogen 75% resulted in much higher micronutrient uptake by grain (35-57%) over control. Further increase in nitrogen level resulted in nominal increase in micronutrient uptake (Fig. 1). With the increase in inorganic nitrogen levels crop growth was enhanced resulting in higher dry matter without addition of micronutrients in the soil. The higher dry matter accumulation caused higher micronutrient uptake by maize grain. The interactive effects of farmyard manure and nitrogen levels were non-significant in terms of NPK uptake by grain and stover and were also evident in total uptake. A Purdue University study revealed that high-yielding, modern maize hybrids take up not only more nitrogen from soil but also more micronutrients such as Zinc, Iron, Manganese and Copper. Nitrogen fertilizer rates influenced the amount of these nutrients stored in the grain at harvest (Ciampitti and Vyn 2013).

Table 4: Correlations of different variables in *kharif* maize under the application of organic and inorganic sources of nitrogen

	Chlorophyll content	Leaf N content	Number of leaves	LAI	Zn content	Cu content	Fe content	Mn content	Yield
Chlorophyll content	1	0.96**	0.97**	0.96**	-0.59*	-0.50	-0.47	-0.25	0.97**
Leaf N content	0.96**	1	0.95**	0.94**	-0.71**	-0.62*	-0.58*	-0.38	0.98**
Number of leaves	0.97**	0.95**	1	0.97**	-0.58*	-0.50	-0.45	-0.22	0.94**
LAI	0.96**	0.94**	0.97**	1	-0.47	-0.38	-0.33	-0.09	0.95**
Zn content	-0.59*	-0.71**	-0.58*	-0.47	1	0.94**	0.96**	0.90**	-0.61*
Cu content	-0.50	-0.62*	-0.50	-0.38	0.94**	1	0.97**	0.92**	-0.50
Fe content	-0.47	-0.58*	-0.45	-0.33	0.96**	0.97**	1	0.94**	-0.46
Mn content	-0.25	-0.39	-0.22	-0.09	0.90**	0.92**	0.94**	1	-0.27
Yield	0.97**	0.98**	0.94**	0.95**	-0.61*	-0.50	-0.46	-0.27	1

** Correlation is significant at the 0.01 level (2- tailed); *Correlation is significant at the 0.05 level (2-tailed)

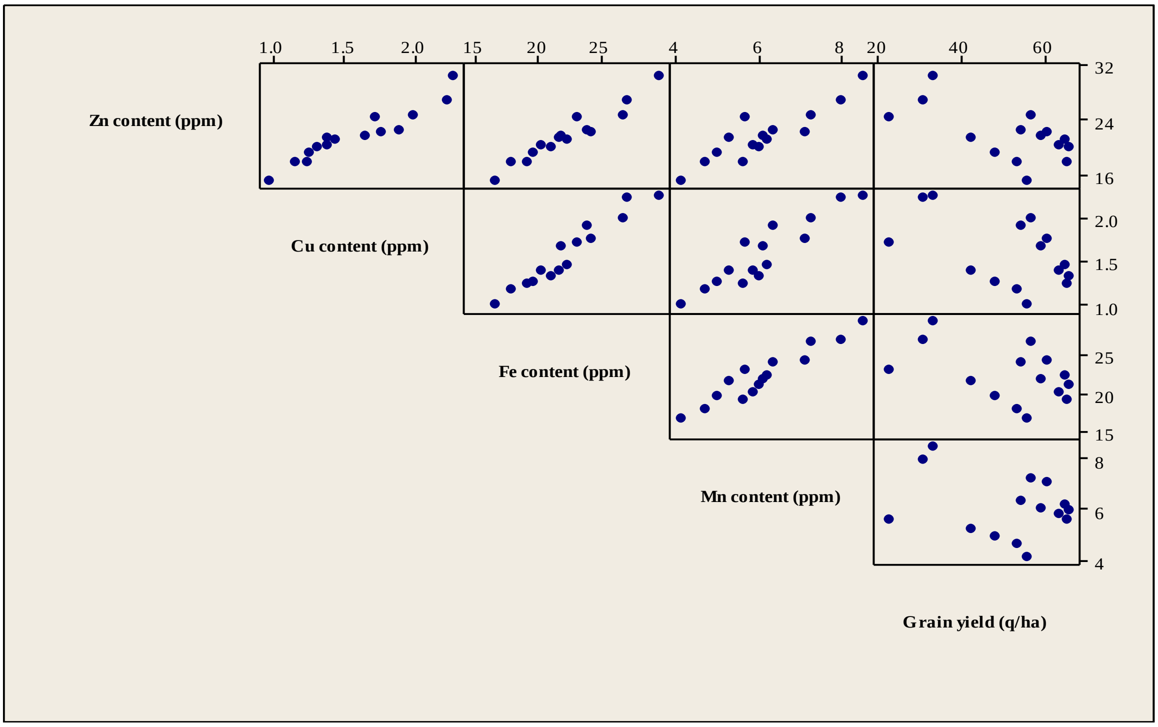

Fig. 2: Correlation matrix scatterplots of micronutrient content and grain yield of *kharif* maize

Correlation studies

Chlorophyll content, leaf N content, Number of leaves and leaf area index were correlated positively with each other and were significant at 1% level of significance (Table 4). However, their relation with micronutrient content was variegated, though being common for negative sign. Zinc content was significantly correlated with chlorophyll content (p=0.05), leaf N content (p=0.01) and number of leaves (p=0.05). Copper and Fe content were also significantly correlated with leaf N content (p=0.05). Highly significant positive correlation was obtained for the variables chlorophyll content, leaf N content, number of leaves and LAI with grain yield (p=0.01). But, among micronutrient contents, the Zn content was correlated significantly (r=-0.61) with grain yield (p=0.05). Strong positive correlation between the micronutrient contents of maize grain (p=0.01) was notable.

Correlation matrix of different variables showed that there was strong positive relationship between content of micronutrients (Zn, Mn, Cu and Fe content) each other but their relation with grain yield is fairly negatively correlated (Fig. 2).

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