PJN
ISSN 1680-5194

PAKISTAN JOURNAL OF NUTRITION

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
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Pakistan Journal of Nutrition 11 (1): 27-33, 2012
ISSN 1680-5194

Impact of Integrated Nutrient Management on Yield and Nutrient Uptake by Maize under Rain-Fed Conditions

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Abstract: A field study was conducted to determine the effect of Zinc (Zn) application as well as interactive effect of organic and mineral fertilizer sources of nitrogen (N) on maize productivity and nutrient uptake during 2008 at NARC, Islamabad. Four combinations of N sources, viz. control; 100 % recommended dose of N from Chemical Fertilizer (CF); 75% N from CF + 25% N from Farm Yard Manure (FYM) and 50% N from CF + 50% N from FYM and three levels of Zn fertilizer, viz. 0, 4, 8 kg Zn/ha were applied. Maximum maize grain yield, viz., 5.18 t/ha was obtained with 75% + 25% (CF + FYM) and 4 kg Zn/ha. It was statistically at par with treatment having 50% + 50% (CF + FYM) and 4 kg Zn/ha as well as 75% + 25% and 8 kg Zn/ha. Zinc application also enhanced maize grain yield by 12% over treatment where no Zn was applied i.e. 4.08 t/ha. Highest N uptake, viz., 98.7 kg/ha was observed with 50% + 50% (CF + FYM) and 8 kg Zn/ha application. Similarly, maximum Zn uptake, viz., 250.7 g/ha was observed with 75% + 25 % (CF + FYM) and 4 kg Zn/ha application. The study revealed that substitution of 25 or 50% N with FYM + 4 kg Zn/ha performed better than 100% N fertilizer alone, with respect to leaf area index, grain and straw yield, soil organic matter content and nutrient uptake.

Key words: Farm yard manure, nitrogen, zinc, *Zea mays* L., calcareous soil

INTRODUCTION

Soils across much of the cultivated areas in Pakistan are calcareous that developed from loess and alluvium containing low organic matter and low plant required nutrients (Rashid and Ahmad, 1994). Multiple factors, like free carbonates, low organic matter, high pH and continuous nutrient depletion due to intensive cultivation coupled with injudicious fertilizer use are conducive to nutrient deficiencies in crops. Pothwar plateau is an important part of rain-fed zone, covering an area of 1.8 million hectares and lies under semi-arid to sub-humid climate. Rainfall is erratic and 60 to 70% of the total rain is received during monsoon; however, the winter rains are gentle showers of longer duration and are useful for crop production. Maize and wheat are the major crops grown in Pothwar region. Maize grain yield in rain-fed region is much lower (3.04 t/ha) than in the irrigated areas (GOP, 2009). The key constraints to sustainable maize production are low moisture content, emergence of multiple nutrient deficiencies, low fertilizer use efficiency, less use of organic manure and unbalanced use of fertilizers (Shaheen *et al.*, 2010). Under such situations, the sustainability is getting adversely affected and there is need to develop proper soil-crop management.

Minerals fertilizers have a significant importance in crop production and are indispensable component of today's agriculture, but recovery of N to soil plant system is seldom exceeds 50%, whereas remaining is lost through different means like leaching, volatilization, denitrification etc. (Abbasi *et al.*, 2003). Declining soil fertility has also raised concerns about the sustainability of agricultural production at current levels. Thus, strategies for increasing and sustaining agricultural productivity will have to focus on using available nutrient resources more efficiently, effectively and sustainably than in the past. In this scenario, Integrated Nutrient Management (INM) - using organic manures with mineral fertilizers is advocated as viable approach not only in maintaining and sustaining proper plant growth and productivity, but also in providing stability to crop production (Hussain *et al.*, 1995; Ahmad *et al.*, 2008). Thus, neither the organic manure alone nor the chemical fertilizers can achieve the yield sustainability under any cropping system where the nutrient depletion and turnover in soil plant systems is remarkable. This paper presents the results of a study on integrated use of Zn with organic and inorganic sources of N on maize productivity in calcareous soil under rain-fed conditions of Pothwar plateau.

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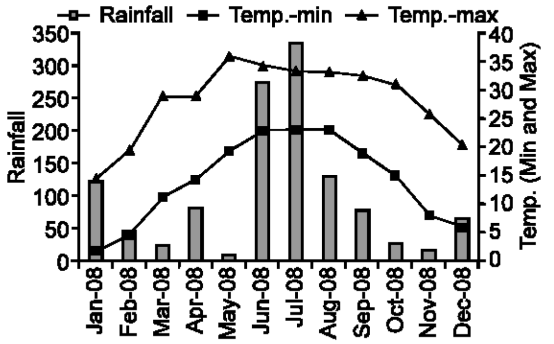

Fig. 1: Monthly rainfall (mm) and temperature (°C) during the experimental year i.e. 2008 at experimental field

MATERIALS AND METHODS

Site description: A field experiment was conducted at National Agricultural Research Centre, Islamabad, Pakistan (lat. 33° 43´ N long. 73° 5´ E) on a loamy Nabipur soil series (coarse loamy, mixed, hyperthermic Udic Ustochrept). The soil was deep, well drained and calcareous developed on level to nearly level deposition of the flood plain. It lies under sub humid to humid and medium to high rainfall zone with annual rainfall ranging from 517 mm to 1550 mm with a mean value of 1080 mm. More than half rain is received in the form of high-intensity down-pours during July and August. The crop was sown in the last week of February, 2008. Monthly rainfall and temperature for year, 2008. is given in Fig. 1, which indicates that about 150 mm rainfall was received in January and February, sufficient for sowing and germination. In March, a little-bit dry spell was observed, only 25 mm rain was recorded. However, in the month of April, good down pour of 100 mm was received, which had a positive effect on plant growth at critical growing stage. The soil of the experimental site was alkaline (pH, 8.5) and calcareous ($CaCO_3$ equiv., 3.0%) in nature and low in organic matter (0.46%), deficient in AB-DTPA extractable nutrients (Soltanpour and Workman, 1979), i.e., NO_3-N, 4.5 mg/kg; P, 2.2 mg/kg; K, 80 mg/kg and Zn, 0.59 mg/kg.

Fertilizer treatments and experimental design: The experiment was designed in a randomized complete block in split-plot arrangement with three replications. Nitrogen sources were in the main plots and Zn levels were in the sub-plots. Zinc was applied @ 0, 4 and 8 kg Zn/ha as zinc sulphate. Nitrogen was applied @ 120 kg/ha using different combinations of organic (farm yard manure) and mineral (urea) sources. The nutrient concentration in FYM was: N, 1.65%; P, 0.30%; K, 0.86% and Zn, 0.30 mg/kg. Basal fertilization included 50 kg P ha^{-1} as single super phosphate and 18 kg K/ha as sulphate of potash. Nitrogen was applied in two equal splits, i.e., during final land preparation and booting stage. Farm yard manure (on air dry weight basis) was applied prior to planting. Full dosage of P and Zn was applied at seed bed preparation. Following manure and fertilizer application, the field was disked to ~10 cm depth to mix well in the soil. The experiment consisted of 36 experimental plots each measuring 3 m x 5 m. The detail of treatments was:

Main plots-N combinations:
N 1 Control
N 2 100 % N from urea
N 3 75 % N from urea + 25 % N from FYM
N 4 50 % N from urea + 50 % N from FYM

Sub plots-Zn levels:
Z1 Control
Z2 4 kg Zn/ha
Z3 8 kg Zn/ha

Experimental crop: Maize variety Sawan-3 was sown in last week of February 2008 with row to row distance of 75 cm and plant to plant spacing 25 cm using dibbler. All other agronomic practices were kept normal and uniform for all the treatments. Composite diagnostic plant tissues, i.e., whole shoots (~30 cm tall) were collected from each plot (Jones *et al.*, 1991). Leaf area index was recorded by the plant canopy analyzer during sunshine at booting stage. At maturity crop was harvested manually. Grain and straw yields were recorded. Maize grain, straw and diagnostic whole shoots were analyzed for N by Anderson and Ingram, (1993) and Zn by atomic absorption spectrophotometery (Wright and Stuczynski, 1996). Nitrogen and Zn uptakes were computed by multiplying the N and Zn concentrations with respective grain and straw dry matter yields. After harvesting, surface soil (0-15 cm) was sampled from all experimental plots for organic matter (Nelson and Sommers, 1996) determination. Analysis of Variance (ANOVA) for the measured parameters was performed using MSTAT-C and Zn rates and N sources were compared using Duncan Multiple Range Test (DMRT) at 5% probability level.

RESULTS AND DISCUSSION

Leaf area index: Leaf Area Index (LAI) is an indication of efficient and balanced use of nutrients. Both N sources and Zn levels had significant effect on LAI of maize leaves at booting stage (Table 1). Nitrogen treatments 75 + 25 and 50 + 50 (urea + FYM) were statistically better than treatment having 100% mineral N treatment and were at par with each other. Zinc application showed a significant effect on LAI. Leaf area index recorded in both Zn rates were significantly higher than control. Interaction of N and Zn treatments was also significant for LAI. The highest LAI (2.81) was recorded with N4Z3 and it was statistically at par with N4Z2 and N3Z2

Table 1: Effect of N sources and Zn levels on maize leaf area index, grain and straw yield

Treatment	Nitrogen source input (%) Mineral	Organic	Zn levels (kg ha^{-1}) Zn1 0	Zn2 4	Zn3 8	Means (N)
			Leaf area index			
N1	00	00	1.07	1.44	1.52	1.34c
N2	100	00	2.32	2.52	2.65	2.50b
N3	75	25	2.57	2.75	2.79	2.70a
N4	50	50	2.54	2.79	2.81	2.71a
Means (Zn)			2.12c	2.38b	2.44a	
LSD (p<0.05): N sources, 0.06; Zn levels, 0.047; N sources x Zn levels, 0.094						
			Grain yield (t ha^{-1})			
N1	00	00	2.51	3.07	3.28	2.95d
N2	100	00	4.27	4.88	4.89	4.68c
N3	75	25	4.88	5.18	5.05	5.04a
N4	50	50	4.66	5.01	5.00	4.89b
Means (Zn)			4.08b	4.54a	4.55a	
LSD (p<0.05): N sources, 0.13; Zn levels, 0.08; N sources x Zn levels, 0.16						
			Straw yield (t ha^{-1})			
N1	00	00	4.58	4.94	5.07	4.86c
N2	100	00	7.28	7.69	7.84	7.60b
N3	75	25	7.93	8.27	8.20	8.13a
N4	50	50	7.89	8.15	8.16	8.07a
Means (Zn)			6.92c	7.26b	7.32a	
LSD (p<0.05): N sources, 0.07; Zn levels, 0.05; N sources x Zn levels, 0.11						

Mean within a column/row followed by different letters differ from each other significantly

treatments. Minimum LAI (1.07) was recorded in control. It is construed that in combined application of N sources, nutrient supply was sustained with minimum losses, which enhanced the LAI. While, in case of 100% Chemical Fertilizer (CF), the nutrients losses especially N leaching, volatilization, denitrification affected the nutrient availability to plants at booting stage. Beneficial effect is presumably due to stabilization of applied nutrient (N and Zn) with organic source and subsequent release to fulfill the requirements of growing crop. These results are in line with the findings of Bakyt and Sade (2002), who reported that integrated use of nutrients increased LAI. Contrarily, Ahmad *et al.* (2002) reported that mineral N fertilizer along with organic manure did not affect the leaf area of wheat.

Grain and straw yield: Analysis of variance showed significant effect of Zn levels, N sources and interaction of Zn levels with N sources on grain yield ($p<0.05$; Table 1). The highest grain yield, viz., 5.18 t/ha was obtained with treatment (N3Z2), where 25% of N was added through FYM with 4 kg Zn/ha and it was 21% more than 100% N application from c mineral source without Zn. The lowest grain yield i.e. 2.51 t/ha was obtained with treatment N1Z1 having no N and Zn application. It clearly showed that integration of organic and inorganic sources improved nutrient use efficiency by plants; as a result the maize grain yield was increased. Mugwe *et al.* (2009) reported that application of green manure or cattle manure contributing 30 kg N ha^{-1} in combination with inorganic fertilizer (30 kg N ha^{-1}) produced significantly higher maize grain yields than with only inorganic fertilizer (60 kg N ha^{-1}). Dilshad *et al.* (2010); Osman *et al.* (2010) and Ahmad *et al.* (2002) also obtained more maize grain and straw yield with combined use of organic and inorganic fertilizers. Combined use of organic and mineral fertilizer produced significantly higher straw yield than sole mineral N application (Table 1). Maximum straw yield (8.27 t/ha) was recorded in N3Z2 combination and it was statistically at par with N3Z3, N4Z2 and N4Z3. Results indicate that synergistic use of mineral and organic N sources is superior to sole application of mineral N fertilizer. This is most likely because manures application not only improve soil physical properties (Bhattacharyya *et al.*, 2004) but also enhances microbial activities and provides stable supply of both macro- and micro-nutrients (Tiwari *et al.*, 1998; Jilani *et al.*, 2007). Kanchikerimath and Singh (2001) also reported that maize crop yield was improved when organic manure is applied along with inorganic fertilizers.

Nitrogen concentration in maize whole shoot: Nitrogen concentration in maize whole shoot (30 cm tall) is given in Table 2. Nitrogen application significantly increased N concentration. Nitrogen treatments containing FYM, viz. N3 and N4 showed higher N contents in whole shoot than sole N application (N2). The highest N concentration in whole shoot, viz., 2.15% was recorded in N3Z2 and N4Z2 treatments, which was 49% and 4%

Table 2: Effect of N sources and Zn levels on N and Zn concentrations in maize whole shoot

	Nitrogen source input (%)		Zn levels (kg ha^{-1})			
			Zn1	Zn2	Zn3	
Treatment	Mineral	Organic	0	4	8	Means (N)
			N concentration in whole shoots (%)			
N1	00	00	1.44	1.50	1.50	1.48c
N2	100	00	2.05	2.07	2.10	2.07b
N3	75	25	2.12	2.15	2.07	2.11ab
N4	50	50	2.17	2.15	2.12	2.14a
Means (Zn)			1.94	1.97	1.95	
LSD ($p<0.05$): N sources, 0.05; N sources x Zn levels, 0.08						
			Zn concentration in whole shoots (mg kg^{-1})			
N1	00	00	17	25	25	22c
N2	100	00	23	35	34	31b
N3	75	25	29	29	34	31b
N4	50	50	30	37	38	35a
Means (Zn)			25c	31b	33a	
LSD ($p<0.05$): N sources, 2.01; Zn levels, 1.43; N sources x Zn levels, 2.87						

Mean within a column/row followed by different letters differ from each other significantly

higher than control and 100% mineral N treatments, respectively. It reflects that more N was available to plants from organically substituted treatments as compared to sole mineral N. It was the result of synergistic effect of organic and inorganic sources on mineralization, moisture conservation and reduction of N losses due to sustained supply of essential nutrients, as organic manures improve nitrifying activities of microorganisms and increases N use efficiency by improving CEC of the soil (Gasser, 1964). Integration of N sources viz. organic and inorganic origin increased NPK concentration in alfalfa, maize and sugarcane (Lioveras *et al.*, 2004; Sial *et al.*, 2007; Bokhtiar and Sakurai, 2005) as decomposition process is enhanced by microbial activity and energy is readily available from carbon for release of nutrients (Kaye and Hart, 1997). However, Zn fertilization did not show any significant effect on N concentration in whole shoot.

Zinc concentration in maize whole shoot: Influence of N and Zn application on Zn content in whole shoot is given Table 2. Zinc contents were significantly increased with N and Zn application. Organically substituted N treatment of 50% combination (N4) gave significantly higher Zn content, viz., 35 mg/kg in whole shoot compared with 100% mineral N application, viz., 31 mg/kg. Regarding Zn application, Z3 showed significantly higher Zn content (33 mg/kg) in whole shoot compared with Zn level 2 and 1. Math and Trivedi (2001) also reported increased Zn content and uptake in wheat and maize with Zn application. Interaction of N and Zn was also significant. The highest Zn concentration (38 mg/kg) was observed in N4Z3 followed by N4Z2. It proves that micronutrient availability and uptake is also increased with integration of plant nutrient. Akinrinde *et al.* (2006) also reported that application of cow manure + $ZnSO_4$ produced the highest plant shoot biomass and gave the highest Zn uptake by maize. Dry biomass and N and Zn content of maize plant enhanced with increasing rates of N and Zn application (Shaheen *et al.*, 2010).

Nitrogen uptake by maize: Nitrogen uptake pattern by maize is presented in Table 3. It is evident from the data that organically supplemented N treatments, viz. N3 and N4 were superior regarding N uptake as compared to sole mineral N application. In case of Zn application, N uptake was significantly affected. However, Zn levels 2 and 3 were similar. Interactive effect of N and Zn treatments was also significant. Treatments viz. N4Z3 and N4Z2 caused the highest N uptake of 98.7 and 97.9 kg/ha, respectively followed by N3Z3 and N3Z2. It was due to the sustained availability of N from organic source for longer period during crop growth as synergistic use of organic and inorganic nutrient sources exhibits multiple effects and synchronizes nutrient release and uptake by crops (Palm *et al.*, 1997). Sial *et al.* (2007) and Akhter *et al.* (2005) also reported that NPK contents increased significantly in wheat and maize by integration of organic and inorganic sources of N.

Zinc uptake by maize: Application of N and Zn significantly affected the Zn uptake by maize (Table 3). Amongst the N treatments, the highest Zn uptake (227.6 g/ha) was recorded in N3 (combination of 75% + 25%) followed by N4 and N2. In case of Zn application, the highest uptake (205.6 g/ha) was recorded with Z2 (4 kg/ha) followed by Z3 (8 kg/ha) and both levels were statistically alike. It might be due to enhanced Zn supply causing more uptakes by plants. Regarding interaction, organic manure improved the availability of nutrients by increasing soil microbial activity and improving soil

Table 3: Effect of N sources and Zn levels on total N and Zn uptake by maize

	Nitrogen source input (%)		Zn levels (kg ha^{-1})			
			Zn1	Zn2	Zn3	
Treatment	Mineral	Organic	0	4	8	Means (N)
			Total N uptake (grain + straw) (kg ha^{-1})			
N1	00	00	44.1	54.3	58.6	52.4c
N2	100	00	78.0	88.6	90.7	85.8b
N3	75	25	92.1	97.3	96.3	95.2a
N4	50	50	88.8	97.9	98.7	95.1a
Means (Zn)			75.7b	84.5a	86.1a	
LSD ($p<0.05$): N sources, 2.5; Zn levels, 2.1; N sources x Zn levels, 0.11						
			Total Zn uptake (grain + straw) (g ha^{-1})			
N1	00	00	80.8	125.3	122.9	109.7c
N2	100	00	151.6	219.2	218.8	196.5b
N3	75	25	184.8	250.7	247.2	227.6a
N4	50	50	163.6	227.1	232.6	207.8ab
Means (Zn)			145.2b	205.6a	205.4a	
LSD ($p<0.05$): N sources, 27.6; Zn levels, 17.2; N sources x Zn levels, 34.4						

Mean within a column/row followed by different letters differ from each other significantly

Table 4: Effect of N sources and Zn levels on soil organic matter content (g per 100 g)

	Nitrogen source input (%)		Zn Levels (kg ha^{-1})			
			Zn1	Zn2	Zn3	
Treatment	Mineral	Organic	0	4	8	Means (N)
N1	00	00	0.52	0.55	0.54	0.54
N2	100	00	0.54	0.55	0.56	0.55
N3	75	25	0.55	0.56	0.57	0.56
N4	50	50	0.56	0.58	0.60	0.58
Means (Zn)			0.54	0.56	0.57	

NS = Non significant difference among means within a column / row and interactions

physical properties. So, the highest amount of Zn uptake, viz., 250.7 g/ha was recorded in manure containing treatments along with Zn application, viz., N3Z2 followed by N3Z3 and N4Z3. Nitrogen and Zn content of maize plant increased with elevated N and Zn application (Shaheen *et al*., 2010). Omotoso and Flade (2007) reported that application of 30 mg Zn/kg soil and organo-mineral combination (cow dung + $ZnSO_4$) gave the highest plant shoot biomass and Zn uptake.

Organic matter content in soil: Soil organic matter is known to play an important role in maintaining soil health. Soil Organic Matter (SOM) content after harvesting of maize crops are given in Table 4. Nitrogen application irrespective of the source did not significantly enhance the SOM contents as compared to control. The highest increase (7.4%) was recorded in N4 treatment (combination of equal ratio). Interaction of N and Zn for N uptake was also non significant. Treatments containing 50% N substituted with FYM under Z3 showed the highest increase (15%) in SOM. It might be due to positive response of Zn to plant growth in Zn deficient soil and positive interaction with cation and anion for enhancing root growth and microbial biomass. In our study, slight increase in SOM with conjunctive use of organic and mineral fertilizers could be the consequences of better plant root and shoot growth, leading to some quantity of plant stubbles and leaf fall going back into the soil. Positive impact of conjunctive use of mineral and organic fertilizers could be attributed to the addition of organic matter as FYM and consequence beneficial influence on physiochemical characteristics of the soil, triggering better growth and more plant residue after crop harvest. Our observations are contrary to the findings of Rasool *et al*. (2007) who reported that addition of FYM and inorganic N fertilizer enhanced the soil organic carbon content by 44 and 37%, respectively in rice crop. Chaudhry *et al*. (2009) observed increase in soil organic matter, when composted poultry litter was applied to wheat.

Conclusion: This study compared different combinations of organic and mineral N fertilizers with and without Zn application for maize LAI, yield and nutrient uptake. Farmyard manure (25% N-basis) + 4 kg Zn/ha performed better than N fertilizer alone (100%) for maize production. The study led to the conclusion that the synergistic use of nitrogen sources (FYM and chemical fertilizer at 25:75 N ratio) is advantageous over the sole application of mineral fertilizer. Farm yard manure and Zn fertilization further enhanced the crop growth and yield. Twenty percent increase in maize yield with the above mentioned IPNM strategy makes the system economically incentive based.

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