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Direct and residual effect of nutrient management in maize (*Zea mays*) – wheat (*Triticum aestivum*) cropping system

ASHOK KUMAR*

Division of Agronomy, Indian Agricultural Research Institute, New Delhi 110 012

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ABSTRACT

A field experiment was conducted at New Delhi to investigate the response of maize (*Zea mays* L.) – wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] cropping system to different nutrient-management practices during 2003-04 and 2004-05. The highest leaf-area index (LAI), yield attributes and yield of maize were recorded with the application of 120 kg N + 26.2 kg P + 41.5 kg K/ha, closely followed by 120 kg N + 5 kg Zn + 10 t FYM/ha. The LAI, yield attributes and yield of wheat were found maximum at the residual fertility of 5 kg Zn + 20 t FYM/ha. Wheat gave 22.7% more yield at residual fertility of 5 kg Zn + 20 t FYM/ha. The data on maize-wheat system indicated that when 120 kg N + 5 kg Zn/ha was applied with 10 t FYM/ha, production efficiency (46.0 kg/ha-day), total productivity (10.8 t/ha), net returns (Rs 46,784/ha) and benefit : cost ratio (2.17) were the maximum. The Zn uptake by maize and wheat was the highest at 120 kg N + 5 kg Zn + 10 t FYM/ha and 5 kg Zn + 20 t FYM/ha, respectively. Except available P at 60 kg N + 10 t FYM/ha, 5 kg Zn + 10 t FYM/ha and 5 kg Zn + 20 t of FYM/ha, all the nutrients increased in the soil at different fertility levels. Higher residual organic C and available N, P, K and Zn in the soil were obtained with 5 kg Zn + 20 t FYM/ha. It was concluded that combined application of 120 kg N + 5 kg Zn +10 t FYM/ha was essential for higher productivity and profitability of maize – wheat cropping system.

Key words: Economics, Nutrient management, Nutrient uptake, Residual nutrients, *Triticum aestivum*, Yield, *Zea mays*

Maize (*Zea mays* L.) - wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] is the most prominent and popular double cropping system under irrigated conditions in north-western parts of India. The contribution of this cropping system to total cereal production is considerably large, being 31% of wheat (72.06 million t) and 6% of maize (14.1 million t) (FAI, 2006). Moreover, 60% area of rainy-season (*kharif*) maize is followed by wheat in winter season (Yadav *et al.,* 2000). Among the factors responsible for poor productivity, inadequate fertilizer use and emergence of multiple-nutrient deficiency due to poor recycling of organic sources and unbalanced use of fertilizers are important. Besides N, P and K, Zn is the important micronutrient for cereals as it plays major role in synthesis of tryptophan, which is precursor of indole acetic acid (Tsui, 1988). The long-term trials indicated that application of nutrients through chemical fertilizers have a deleterious effect on soil health, leading to unsustainable productivity (Swarup, 2002). Therefore, there is need to improve the nutrient-supply system in terms of integrated nutrient management, involving the use of chemical fertilizers in conjunction with organic manures. Application of different organic-inorganic sources was found very effective in realizing high yield, better economy (Kumar *et al.,* 2005) and improved residual fertility of the soil (Pathak *et al.,* 2005). Adequate information is available on the response of maize and wheat to either inorganic or organic fertilizers on single crop. However, meager information is available on the effect of different combinations of nutrient sources on maize and wheat grown in a system. The present experiment comprising different levels of inorganic and organic fertilizers was undertaken to study their direct and residual effects in maize - wheat cropping system.

***Corresponding author** (Email: ashok_agro@iari.res.in)

MATERIALS AND METHODS

A field experiment was carried out on sandy loam soil of Indian Agricultural Research Institute New Delhi during the crop years 2003-04 and 2004-05. The soil was low in organic C (0.38%), available N (149.3 kg/ha) and K (153.1 kg/ha), and medium in available P (11.6 kg/ha) C with Zn content 1.09 ppm and pH 7.6. Nine fertilizer treatments to maize, viz. control: 120 kg N + 26.2 kg P + 41.5 kg K/ha (recommended dose of NPK, RDF) ($N_{120}P_{26.2}K_{41.5}$), 60 kg N + 13.1 kg P + 20.8 kg K/ha

($N_{60}P1_{13.1}K_{20.8}$), 60 kg N + 10 t FYM/ha ($N_{60}FYM_{10}$), 120 kg N + 10 t FYM/ha ($N_{120}FYM_{10}$), 60 kg N + 5 kg Zn + 10 t FYM/ha ($N_{60}Zn_5FYM_{10}$), 120 kg N + 5 kg Zn + 10 t FYM/ha ($N_{120}Zn_5FYM_{10}$), 5 kg Zn + 10 t FYM/ha (Zn_5FYM_{10}), and 5 kg Zn + 20 t FYM/ha (Zn_5FYM_{20}) were evaluated in randomized block design with three replications. Wheat was grown on residual fertility in the undisturbed plots of different fertility levels applied to maize.

'PEMH 3' maize was sown on 5 and 7 July and harvested on 6 and 9 October during 2003 and 2004, respectively. After harvesting of maize, 'HD 2824' wheat was sown on 18 and 24 November, and harvested on 12 and 17 April during 2004 and 2005, respectively. The required amount of FYM containing 0.46% N, 0.23% P and 0.48% K as per treatment was incorporated into the soil a week before planting maize. Half the dose of N and full amount of P, K and Zn as per treatment were applied at the time of last ploughing for maize and the remaining amount of N was top-dressed at knee-high and silking stages in equal amounts. Based on prevailing market prices of inputs common cost of cultivation for maize and wheat was calculated as Rs 5,441 and Rs 12,000/ha, respectively. For working out the maize grain-equivalent yield and economics, the market price of grains of maize (Rs 5050/t) and wheat (Rs 6300/t) and maize stover (Rs 500/t), and wheat straw (Rs 2000/t) were considered. The grains and stover or straw of maize and wheat were analysed for N, P and K concentration following standard procedures and the total uptake was calculated. Soil samples up to the depth of 30 cm were collected at harvest of the second crop cycle and analysed for the organic C and available N, P and K contents.

RESULTS AND DISCUSSION

Direct effect on maize

Significantly higher leaf-area index (LAI) was recorded with the application of 120 kg N + 26.2 kg P + 41.5 kg K/ha (RDF) compared with that of the remaining fertility levels except 120 kg N + 5 kg Zn + 10 t FYM/ha (Table 1). The fertility levels of 120 kg N + 10 t FYM/ha with and without 5 kg Zn/ha, being at par, also recorded higher LAI than other treatments. Adequate and continuous availability of nutrients with recommended dose of NPK or combined application of FYM with N might have improved the LAI of maize. These results are in close conformity with Pathak *et al.* (2005). The grain yield of maize was also significantly influenced by different fertility levels. Application of 120 kg N + 26.2 kg P + 41.5 kg K/ha recorded the highest grain yield which was 134.6, 35.1, 29.7, 7.1, 23.7, 4.4, 53.0 and 42.6% more than the control, 60 kg N + 13.1 kg P + 20.8 kg K/ha, 60 kg N + 10 t FYM/ha, 120 kg N + 10 t FYM/ha, 60 kg N + 5 kg Zn + 10 t FYM/ha, 120 kg N + 5 kg Zn + 10 t FYM/ha, 5 kg Zn + 10 t FYM /ha and 5 kg Zn + 20 t FYM/ha, respectively. When 120 kg N/ha and 10 t FYM/ha were applied with or without 5 kg Zn/ha, the yield was on par with that of RDF, and these treatments proved superior to the remaining fertility levels. Higher values of cobs/plant and test weight were also noticed with the application of RDF or 120 kg N + 5 kg Zn + 10 t FYM/ha over other treatments due to improved growth in terms of LAI with these treatments, which consequently improved the yield. Kumar *et al.* (2005) also observed similar findings.

Residual effect on wheat

The highest value LAI of wheat was recorded at the residual fertility of 5 kg Zn + 20 t FYM/ha, which was significantly more than that of all other fertility levels (Table 1). Similarly, fertility levels of 5 kg Zn + 10 t FYM/ha and 120 kg N + 5 kg Zn + 10 t FYM/ha, being at par, proved superior to the remaining treatments. The findings of Kumar *et al.* (2005) confirm these results. In comparison with the control, 93.2, 40.4, 61.4, 27.3, 13.9, 22.8, 10.0 and 6.4% higher grain yield of wheat was recoded at the residual fertility of 5 kg Zn + 20 t of FYM/ha, RDF, 50% RDF, 60 kg N + 10 t FYM/ha, 120 kg N + 10 t FYM/ha, 60 kg N + 5 kg Zn + 10 t FYM/ha, 120 kg N + 5 kg Zn + 10 t FYM/ha, respectively. Similarly, the application of 5 kg Zn + 10 t FYM/ha with or without 120 kg N/ha resulted in marked improvement in grain yield of wheat than of 120 kg N + 26.2 kg P + 41.5 kg K/ha. The higher number of effective tillers, grains/spike and test weight were noticed with the fertilizers incorporating FYM, which improved the yield of wheat. After maize, the treatments having FYM might have left more nutrients in the soil than inorganic fertilizers, which was available for wheat crop. Jamwal (2005) also obtained similar positive residual effect of FYM on wheat in maize - wheat cropping system.

Production efficiency and system productivity

The highest production efficiency (46.0 kg/ha/day) and total productivity (10.8 t/ha) in terms of maize-grain equivalents (MGE) was obtained with the application of 120 kg N + 5 kg Zn + 10 t FYM/ha, followed by 120 kg N + 10 t FYM/ha, indicating yield stability with the use of FYM along with inorganic fertilizers (Table 2). It is also important to note that application of 5 kg Zn + 20 t FYM /ha and 60 kg N + 5 kg Zn + 10 t FYM /ha gave the production efficiency and total productivity equal to that of RDF fertilizers. The findings are in close conformity with those of Jamwal (2005).

Zn uptake

Zinc uptake by both maize and wheat significantly varied due to different fertility levels (Table 4). The highest

Zn uptake by maize was noted with the application of 120 kg N + 5 kg Zn + 10 t FYM/ha compared with the remaining fertility levels. It was followed by RDF, which also remained superior to the rest of the treatments. However, in wheat the fertility level of 5 kg Zn + 20 t FYM/ha, being on par with that of 5 kg Zn + 10 t FYM/ha, recorded higher Zn uptake than the remaining fertility levels (Table 4). The nutrient uptake by the crop is determined by its nutrient content and yield. It was evident that yield was a greater deciding factor for the uptake of nutrients by the crop. These results confirm the findings of Latha *et al.* (2001).

Nutrient balance sheet

Nitrogen addition to the soil through fertilizers and FYM was the highest with 120 kg N and 10 t FYM/ha, whereas P and K addition was the maximum with 5 kg Zn + 20 t FYM/ha (Table 3). The N and K harvest was the highest when 120 kg N was applied with 5 kg Zn + 10 t FYM/ha, whereas P harvest remained maximum with RDF. Based on the initial N, P and K of the soil and addition and depletion of these nutrients, the expected N, P and K balance was positive in all the treatments except K with the application of 120 kg N + 5 kg Zn + 10 t FYM/ha. In general, the expected balance of N was more favourable with the application of 120 kg N + 10 t FYM/ha, and of P and K with that of 5 kg Zn + 20 t FYM/ha. The data on gain or loss of nutrients in soil indicated that N, P and K contents showed the positive trend in all the treatments except 60 kg N + 10 t FYM/ha, 5 kg Zn + 10 t FYM/ha and 5 kg Zn + 20 t FYM/ha for P content, which ranged from - 0.3 to - 21.7 kg/ha. The maximum gain in N and K was noticed with 5 kg Zn + 10 t FYM /ha and 120 kg N + 5 kg Zn + 10 t FYM/ha, respectively. This could be ascribed to the application of FYM and N and variations in the addition and uptake of nutrients by the crops. These

Table 1. Growth, yield attributes and yield of maize and wheat as influenced by different nutrient-management practices (mean data of 2 years)

Treatment	Maize					Wheat					
	Leaf-area index	Cob/ plant	Test weight (g)	Grain yield (t/ha)		Leaf-area index	Panicles/ m row length	Grains/ spike	Test weight (g)	Grain yield (t/ha)	
				2003	2004					2003	2004
Control	2.30	0.7	202.3	1.87	3.15	2.65	70.3	26.0	40.0	2.77	1.90
$N_{120}P_{26.2}K_{41.5}$	3.01	1.4	238.1	4.94	6.84	2.86	77.2	32.0	41.7	3.43	3.00
$N_{60}P1_{13.1}K_{20.8}$	2.68	0.9	223.6	3.88	4.84	2.79	75.0	30.7	40.4	3.17	2.43
$N_{60}FYM_{10}$	2.70	1.0	225.3	3.52	5.55	3.09	78.6	35.1	42.4	3.60	3.50
$N_{120}FYM_{10}$	2.88	1.2	229.0	4.47	6.52	3.30	81.2	37.4	42.8	4.07	3.87
$N_{60}Zn_5FYM_{10}$	2.72	1.1	227.0	3.84	5.68	3.27	79.4	36.0	42.5	3.66	3.70
$N_{120}Zn_5FYM_{10}$	2.95	1.3	234.6	4.67	6.62	3.63	83.6	39.6	43.6	4.10	4.18
Zn_5FYM_{10}	2.62	0.8	219.3	3.04	4.66	3.71	86.2	40.6	44.0	4.40	4.10
Zn_5FYM_{20}	2.66	1.0	222.0	3.47	4.79	3.89	94.1	42.3	44.3	4.43	4.60
SEm±	0.03	0.1	1.8	0.20	0.17	0.04	1.3	1.3	0.9	0.21	0.19
CD(P=0.05)	0.11	0.2	5.4	0.61	0.51	0.13	4.2	3.9	2.8	0.62	0.56

Table 2. Production efficiency, total productivity and economic return of maize - wheat cropping sequence as influenced by different nutrient-management practices (mean data of 2 years)

Treatment	Production efficiency (MGEY* kg/ha/day)	Total productivity (MGEY* t/ha)	Net returns (x10^3 Rs/ha)			Benefit : cost ratio		
			Maize	Wheat	Maize-wheat	Maize	Wheat	Maize-wheat
Control	23.2	5.44	9.2	10.2	19.4	1.70	0.85	1.11
$N_{120}P_{26.2}K_{41.5}$	42.2	9.92	25.4	16.9	42.4	3.11	1.41	2.09
$N_{60}P1_{13.1}K_{20.8}$	33.5	7.86	18.3	14.4	32.7	2.66	1.20	1.74
$N_{60}FYM_{10}$	38.2	8.98	17.5	19.3	36.9	2.11	1.61	1.81
$N_{120}FYM_{10}$	44.5	10.46	22.4	22.8	45.2	2.51	1.90	2.16
$N_{60}Zn_5FYM_{10}$	39.8	9.36	18.2	20.4	38.6	2.04	1.70	1.84
$N_{120}Zn_5FYM_{10}$	46.0	10.82	22.5	24.3	46.8	2.36	2.03	2.17
Zn_5FYM_{10}	38.9	9.16	13.8	25.3	39.1	1.66	2.11	1.92
Zn_5FYM_{20}	41.6	9.78	13.3	27.3	40.5	1.27	2.27	1.80
SEm±	1.0	0.23						
CD (P=0.05)	3.0	0.71						

findings support those of Mundra *et al.* (2002).

Economics

Application of RDF resulted in the highest net returns and benefit : cost ratio from maize. But in wheat, the maximum net returns and B : C ratio were obtained when it was grown on residual fertility of 5 kg Zn + 20 t FYM/ha (Table 2). The data on overall economics of maize-wheat cropping system indicated that 120 kg N + 5 kg Zn + 10 t FYM/ha was the most profitable by recording net return of Rs 46,784/ha and B : C ratio of 2.17, closely followed by 120 kg N + 10 t FYM/ha (net returns Rs 45,196/ha and B : C ratio, 2.16). In general, the maize treatments having FYM had lower values of net return and benefit: cost ratio than those having inorganic fertilizers due to higher cost of application of FYM. On the contrary, wheat showed the reverse trend due to better response on residual fertility after FYM-containing treatments. These findings confirm those of Jamwal (2005) and Kumar *et al.* (2005).

Residual soil fertility

When FYM was applied with inorganic fertilizers to maize, there was improvement in soil- organic C and available N, P, K and Zn status (Table 4). The highest residual contents of organic and available N, P, K and Zn were analysed in the soil at the fertility level of 5 kg Zn + 20 t FYM/ha. The residual available N of 120 kg N + 5 kg Zn + 10 t FYM/ha remained similar to that of 5 kg Zn + 20 t FYM /ha. The improvement in organic C could be attributed to addition of organic matter through FYM, and higher amounts of residual available N, P and K analysed might be attributed to the increased activity of micro-organisms, leading to greater mineralization of applied and inherent nutrients. The reason for higher Zn content in the soil with FYM was that FYM improved the availability of both native and added Zn through transformation of solid phase to soluble metal complex (Latha *et al.*, 2001). Jamwal (2005) and Pathak *et al.* (2005) also reported similar effect of FYM and N in maize-wheat.

Table 3. Balance sheet of N, P and K as influenced by different nutrient-management practices (based on data of 2 years)

Treatment	Total available nutrients (initial + added through fertilizers) (kg/ha)			Nutrient harvest (kg/ha)			Expected nutrient balance after last harvest (kg/ha)			Net loss or gain in nutrient content in soil (kg/ha)		
	N	P	K	N	P	K	N	P	K	N	P	K
Control	149.3	11.6	153.1	109.0	10.7	116.6	40.3	0.9	36.5	80.0	10.2	103.7
$N_{120}P_{26.2}K_{41.5}$	269.3	37.8	194.6	231.8	30.4	198.5	37.5	7.4	3.9	102.9	5.6	148.3
$N_{60}P1_{13.1}K_{20.8}$	209.3	24.7	173.9	173.6	20.1	161.3	35.7	4.6	12.6	101.3	8.1	135.8
$N_{60}FYM_{10}$	255.3	34.6	201.1	195.5	21.8	170.5	59.8	12.8	30.6	85.8	-0.3	132.7
$N_{120}FYM_{10}$	315.3	34.6	201.1	237.5	26.9	198.0	77.8	7.7	3.1	83.6	3.5	154.9
$N_{60}Zn_5FYM_{10}$	255.3	34.6	201.1	206.9	22.8	179.4	48.4	11.8	21.7	95.8	0.4	139.3
$N_{120}Zn_5FYM_{10}$	315.3	34.6	201.1	249.4	29.4	207.6	65.9	5.2	- 6.5	96.8	6.1	165.6
Zn_5FYM_{10}	195.3	34.6	201.1	194.3	19.6	178.8	1.0	15.0	22.3	143.4	- 2.1	143.7
Zn_5FYM_{20}	241.3	57.6	249.1	211.6	21.8	187.6	29.7	35.8	61.5	135.3	-21.7	111.1

Table 4. Zinc uptake and residual contents of organic C and available nutrients in soil after maize-wheat cropping sequence as influenced by different nutrient-management practices (after completion of 2 years)

Treatment	Zn uptake (g/ha)		Organic C	Available nutrients (kg/ha)			Available
	Maize	Wheat	(%)	N	P	K	Zn (ppm)
Control	131.0	121.0	0.34	120.3	10.2	140.2	1.03
$N_{120}P_{26.2}K_{41.5}$	486.7	249.6	0.36	140.4	13.0	152.2	1.04
$N_{60}P1_{13.1}K_{20.8}$	358.6	172.0	0.35	137.0	12.7	148.4	1.08
$N_{60}FYM_{10}$	355.9	231.6	0.41	145.6	12.5	163.3	1.10
$N_{120}FYM_{10}$	430.6	306.1	0.40	161.4	11.2	158.0	1.09
$N_{60}Zn_5FYM_{10}$	438.4	285.2	0.39	144.2	12.2	161.0	1.18
$N_{120}Zn_5FYM_{10}$	565.6	370.0	0.41	162.7	11.3	159.1	1.15
Zn_5FYM_{10}	367.6	380.0	0.43	144.4	12.9	166.0	1.18
Zn_5FYM_{20}	393.6	390.1	0.45	165.0	14.1	172.6	1.20
SEm±	5.0	3.6	0.003	1.6	0.3	1.7	0.02
CD (P=0.05)	15.2	10.8	0.01	4.8	0.8	5.1	0.06

It was concluded that the combined application of 120 kg N + 5 kg Zn + 10 t FYM/ha was essential for higher productivity and profitability of maize – wheat cropping system.

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