

Influence of integrated nutrient management on the productivity, quality and soil health of maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system

N.K. JAT¹, ASHOK KUMAR², S.R. MEENA³, D.S. RANA⁴, B.P. MEENA⁵ AND K.S. RANA⁶

Indian Agricultural Research Institute, New Delhi 110 012

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ABSTRACT

A field experiment was conducted at New Delhi during the *kharif* and *rabi* season of 2006-07 and 2007-08 with maize (*Zea mays* L.)-wheat [*Triticum aestivum* (L.) emend. Fiori & Paol] cropping sequence to evaluate influence of four organic sources *viz.*, control, *Sesbania* green manure, wheat straw and their combination and three levels of fertilizer N *viz.* 0, 60 and 120 kg/ha in maize and four levels of N *viz.* 0, 40, 80 and 120 kg/ha in succeeding wheat. Direct and residual effect of organic sources significantly affected the system productivity, quality, nutrient uptake, and soil quality of maize-wheat cropping sequence. *Sesbania* green manure in combination with wheat straw followed by *Sesbania* green manure alone recorded significant improvement in system productivity (12.5 tonne/ha), protein content of maize (8.51%) and wheat (10.24%) and N, P and K uptake of both the crops and the system. Addition of *Sesbania* green manure along with wheat straw improved the available N, P, K and organic carbon in soil to the tune of 25.3, 49.3, 5.9 and 11.9 % over control, respectively. A significant response of fertilizer N up to 120 kg/ha was recorded on the system productivity, quality and nutrient uptake of maize and the residual effect of that also influenced significantly the NPK uptake by wheat and system as a whole. Wheat also responded significantly to direct application of fertilizer N for N and protein content in grain up to 80 kg/ha and up to 120 kg/ha in terms of nutrient uptake. It was concluded that integrated use of organic and inorganic sources of N is essential to achieve high productivity and quality of maize-wheat cropping system and to maintain soil fertility.

Key words : Maize-wheat cropping sequence, N levels, Productivity, *Sesbania* green manure, Soil health, Wheat straw

Cropping system has attained great significance in intensified agriculture of India. With the release of high yielding fertilizer responsive varieties the cropping pattern in India made a distinct shift in favours of cereal-cereal multiple cropping system, particularly in areas well endowed with assured irrigation facilities. Maize-wheat is one among the predominant cereal-cereal cropping systems being followed in India and occupies 1.8 m ha area. It is highly productive cropping system and may yield as high as 14 tonnes/ha/ year. Since both the crops of maize-wheat system are fertility exhaustive, the declining yield trends under long term fertilizer experiments have indicated that the productivity of the system suffers due to emerging deficiencies of plant nutrient. Intensive input use, continuous over mining of nutrients from soil and imbalanced use of fertilizers lead to deterioration of soil

health and stagnation in productivity of maize-wheat system.

Nitrogen (N) is one of the key inputs in enhancing and maintaining the productivity of intensified agricultural systems, which is being mainly supplied through chemical fertilizers. Lessons learnt from the long-term manurial and fertilizer experiment across the globe; clearly indicate that excessive rate of fertilizer N application results in its poor utilization by the crops. Several studies indicated that application of FYM, green manure, crop residues, biofertilizers and other wastes either alone or along with inorganic fertilizers enhanced the organic carbon and other plant nutrients in soil (Kumar *et al.*, 2005). Thus, the integrated use of fertilizer with organic sources like crop residue and green manure hold a great promise not only in securing high levels of crop productivity but also against emergence of micronutrient deficiencies in soil and plant and to protect soil health. Organic sources cannot meet the total nutrient need of modern agriculture; integrated use of nutrients from fertilizers and organic sources seems to be a need of time. N can be supplied to maize-wheat system

²Corresponding author Email: akagronomy@gmail.com

¹Scientist, DFSR, Modipuram; ²Principal Scientist, DMR, New Delhi; ^{3&5}Ph.D. Scholar IARI; ⁴Principal Scientist and ⁶Professor, Division of Agronomy, IARI, New Delhi

through organic sources such as *Sesbania* green manure grown *in-situ* and crop residues of previous crop. A study was, therefore, undertaken to determine the effect of green manure (*Sesbania*) and crop residues (wheat straw) separately or in combination on system productivity, quality, nutrient uptake and soil health of maize-wheat cropping system.

MATERIALS AND METHODS

A field experiment was conducted during rainy and winter season of 2006-07 and 2007-08 at the Research Farm of Indian Agricultural Research Institute, New Delhi (28.4° N latitude, 77.1° E longitude and 228.6 m above mean sea level). The rainfall during cropping seasons from July to April was 531.1 mm and 413.2 mm during 2006-07 and 2007-08, respectively. The soil at site was sandy loam with organic carbon 0.44 and 0.42, available N 124.6 and 127.8 kg/ha, available P 10.9 and 10.2 kg/ha and available K 175.4 and 181.2 kg/ha, pH 7.4 and 7.1 and EC 0.33 and 0.36 dS/m during 2006 and 2007, respectively. The experiment was carried out in split-split plot design with three replications. The treatments include four organic sources viz, control, *Sesbania* green manure (SGM), wheat straw (WS) and SGM+WS in main plots with three levels of N fertilizer (0, 60 and 120 kg/ha) applied in sub plots to maize. The succeeding wheat received four levels of fertilizer N (0, 40, 80 and 120 kg/ha) in sub-sub plots. The *in situ* raised SGM (5.24 and 5.62 tonnes/ha biomass during each year) and WS (5 tonnes/ha) were incorporated in soil 15 days before sowing. The total N content of organic sources was estimated before incorporation as 2.21 and 2.16% in SGM and 0.33 and 0.30 % in WS.

Maize 'Ganga safed-2' was sown on 1 and 4 July and harvested on 12 and 10 October during 2006 and 2007, respectively. After harvesting of maize wheat (HD-2824) was sown on 30 and 23 November, 2006 and 2007 and harvested on 2 April and 28 March during 2007 and 2008, respectively. Half dose of N was applied at the time of sowing of maize and wheat and the remaining amount of N was top dressed at knee-high and silking stages of maize and at first and second irrigation in wheat. The plant samples collected during the course of investigation were analyzed for NPK uptake. Soil samples up to the depth of 30 cm were collected at the end of cropping cycle and analyzed for organic carbon, available NPK content, bulk density, infiltration rate and water holding capacity by following standard laboratory procedures. Various N use efficiencies viz., agronomic N use efficiency, ANUE (kg grain/kg N applied), physiological N use efficiency, PNUE (kg grain/kg N uptake), apparent N recovery, ANR (%) were worked out on the basis of system productivity (maize equivalent yield) using standard formulas as;

$$\text{ANUE} = \frac{\text{Grain yield in N fertilized plot (kg/ha)} - \text{Grain yield in unfertilized plot (kg/ha)}}{\text{Quantity of N applied (kg/ha)}}$$

$$\text{PNUE} = \frac{\text{Grain yield in N fertilized plot (kg/ha)} - \text{Grain yield in unfertilized plot (kg/ha)}}{\text{N uptake in N fertilized plot (kg/ha)} - \text{N uptake in unfertilized plot (kg/ha)}}$$

$$\text{ANR} = \frac{\text{N uptake in treatment plot (kg/ha)} - \text{N uptake in control plot (kg/ha)} \times 100}{\text{Quantity of N applied for treatment plot (kg/ha)}}$$

RESULTS AND DISCUSSION

System productivity

System productivity in terms of maize equivalent yield (MEY) was influenced significantly due to the application of organic sources and fertilizer N to maize and wheat (Table 1). Among organic sources, application of SGM+WS recorded the significantly highest system productivity, statistically similar to SGM, but productivity under both the treatment was significantly higher than that of control and WS. Application of SGM+WS produced 18.7 and 8.6 % more productivity over control and WS. This behaviour of system productivity is traced to the effect of organic sources on economic yield of component crops of the system. Direct effect of SGM either alone or in combination with WS become more pronounced on the system productivity by improving the growth and yield attributing parameters due to more nutrient availability for a prolonged period in maize. Whereas in wheat, due to residual effect of organic manures more root penetration by improvement in physical condition and by improving levels of soil organic carbon, availability of nutrients and soil microbial activities (Malero *et al.*, 2007 and Bodake and Rana, 2009). Application of 120 kg N/ha to maize recorded significantly highest MEY, which was 17.5 and 5.5 % higher than 0 and 60 kg N /ha, respectively. Direct N application to wheat also caused significant improvement in system productivity up to 80 kg N/ha and it recorded 20.7 % higher MEY over control. The higher values of MEY with increased N application rate to maize and wheat were attributed to increased dry matter production and grain productivity of maize and wheat at high N level.

Interaction effect between residual effect of organic sources and direct N fertilization to wheat were found significant on MEY during both the years (Table 2). Application of SGM+WS, being at par with SGM alone recorded significantly highest system productivity over control and WS during each year. Maximum system productivity was observed under SGM+WS at all the levels of fertilizer N.

Similarly, MEY was increased significantly across all organic sources with increase in levels of fertilizer N. Maximum system productivity was recorded under 120 kg N/ha, however it was found at par with 80 kg N/ha across all organic sources during both the years. This differential response of various organic sources to graded levels of N application may be attributed to variation in nutrient composition of each organic source and differences in their decomposition behaviour which changed the quantity and duration of nutrient release in soil.

Grain quality

In general, direct application of SGM, WS and N fertilizers recorded higher and statistically significant N and protein content in maize and wheat (Table 1). In maize, the significant increase in N and protein content was recorded under SGM alone and SGM+WS, though both were found at par to each other. The highest protein content of maize grain (8.51 %) was recorded under SGM+WS which recorded 5.5 and 3.5% higher protein content over control and WS. This might have been due to continuous and consistent supply of N, especially in plots supplied with SGM. However, with WS incorporation there was no any significant increase in N content in maize grain. This might be due to slow mineralization of WS with high C: N ratio and subsequent slow solubilization of native P and K with increasing N levels. Among the N levels significantly highest increase in N and protein content in maize was re-

corded at 120 kg N/ha which was 6.9 and 1.3% higher over control, respectively. This might be due to increased supply and uptake of N by crop plant under direct effect of organic sources and fertilizer N at higher dose which ultimately was converted into higher amounts of amino acids consequently higher protein content in maize grain.

Under the residual effect of organic sources and fertilizer N applied to maize, N and protein content in wheat grain did not affected significantly. The highest protein content (10.24%) of wheat grain was noticed with

Table 2. Interaction effect of residual organic sources and direct N fertilization to wheat on system productivity (MEY, t/ha)

Treatment	Control	WS	SGM	SGM+WS
2007				
N ₀	8.3	9.2	9.8	10.1
N ₄₀	9.5	10.4	11.0	11.3
N ₈₀	10.2	11.1	11.7	12.0
N ₁₂₀	10.6	11.5	12.1	12.4
SEm±		0.22		
CD (P=0.05)		0.6		
2008				
N ₀	10.0	10.8	11.6	12.1
N ₄₀	11.5	12.3	13.1	13.6
N ₈₀	12.2	13.0	13.8	14.3
N ₁₂₀	12.5	13.3	14.1	14.6
SEm±		0.32		
CD (P=0.05)		0.8		

WS-Wheat straw; SGM-*Sesbania* green manure

Table 1. System productivity, N content, protein content and total nutrient uptake (grain+stover/straw) of maize -wheat system as influenced by direct and residual effect of organic sources and fertilizer N levels (Pooled data of two years)

Treatment	MEY (t/ha)	N content (%)		Protein content (%)		Total nutrient uptake (kg/ha)								
		Maize	Wheat	Maize	Wheat	Maize			Wheat			System		
						N	P	K	N	P	K	N	P	K
<i>Organic manure</i>														
Control	10.6	1.28	1.61	8.03	10.05	73.7	18.8	55.4	78.9	9.9	107.1	152.4	28.7	162.4
WS	11.4	1.29	1.61	8.16	10.10	77.5	20.5	58.2	83.4	10.3	114.0	163.4	31.4	171.7
SGM	12.1	1.33	1.62	8.44	10.19	85.4	22.5	61.6	85.9	10.9	116.0	169.3	32.8	177.6
SGM+WS	12.5	1.37	1.63	8.51	10.24	92.1	24	65.9	89.0	11.5	119.0	181.1	35.5	185.4
SEm±	0.22	0.006	0.005	0.101	0.06	1.12	1.02	0.62	1.48	0.15	0.92	2.83	1.23	1.09
CD (P=0.05)	0.5	0.02	NS	0.35	NS	3.1	3.4	2.1	4.9	0.4	2.8	8.4	3.9	3.2
<i>N (kg/ha) Maize</i>														
0	10.7	1.28	1.61	7.98	10.06	64.2	17.2	49.5	82.2	9.9	110.7	146.4	27.1	159.5
60	11.7	1.32	1.61	8.4	10.14	84.4	22	61.9	84.2	10.7	114.2	168.5	32.6	175.9
120	12.4	1.36	1.62	8.51	10.21	98	25.1	69.5	87	11.2	116.3	185.1	36.3	186.1
SEm±	0.21	0.006	0.007	0.142	0.055	0.99	0.88	0.67	1.16	0.18	1.53	2.32	0.95	1.23
CD (P=0.05)	0.5	0.02	NS	0.41	NS	2.9	2.4	1.7	3.2	0.6	4.4	6.7	2.7	3.9
<i>N (kg/ha)Wheat</i>														
0	10.2		1.51		9.4				63.7	8.1	96.5	145.8	18.5	208.2
40	11.5		1.59		9.93				79	10.1	111.4	161.1	21.3	223.8
80	12.3		1.65		10.39				94.6	11.7	121.7	176.7	22.7	232.4
120	12.6		1.71		10.62				100.1	12.5	125.2	182.4	23.5	236.4
SEm±	0.25		0.007		0.132				1.26	0.13	1.15	2.95	0.85	1.31
CD (P=0.05)	0.7		0.05		0.34				3.3	0.4	2.9	9.3	2.2	4.2

WS-Wheat straw; SGM-*Sesbania* green manure

SGM+WS treatment. This may be ascribed to short supply of nutrients, especially N at low soil temperature in winter season, which reduce the microbial activity and thus decreased the mineralization of nutrients from organic sources. However, the N and protein content in wheat grain was increased significantly with the direct application of fertilizer N. The highest N and protein content (1.71 and 10.62%) was noticed at 120 kg N/ha which was found at par to 80 kg N/ha.

Nutrient uptake

A significant difference in N, P and K uptake was recorded under different organic and inorganic sources of N in maize, wheat and system (Table 3). Among the organic sources, the application of SGM+WS recorded significantly higher N, P and K uptake over other organic sources which was closely followed by the treatment receiving SGM alone. The combined application of SGM+WS resulted in 25.0, 28.2 and 18.9 % higher N, P and K uptake by maize, 12.9, 16.1 and 11.1 % higher N, P and K uptake by wheat; and 18.8, 23.6 and 23.0 % higher N, P and K uptake by system, respectively over control. This might be due to easy decomposition and synchronize release of plant nutrients from SGM throughout the crop growth period. This has in particular as regard P

and K uptake of plant. Though, WS contained high concentration of K but mineralized slowly and leads to higher P and K uptake in subsequent wheat. Maize being a cereal crop removed more N, P and K from soil and mineralization of organic source as supplies nutrients to soil and also solublize the native labile pool. Besides, higher biomass production may be the most pertinent reason for higher uptake of nutrients. These findings are in close agreement with the results reported by Patro *et al.* (2005).

Increasing N levels from 0 to 120 kg N/ ha enhanced significantly N, P and K uptake in maize, wheat and system. Application of N even up to 120 kg N/ ha to maize resulted significantly higher N, P and K uptake of maize and subsequent wheat. Increasing N levels increased the vegetative growth and root biomass and increased the availability of nutrients in soil resulting in higher uptake of nutrients. This enhanced the vegetative growth which ultimately increased N, P and K concentration in total biomass of plants.

Soil health

Addition of organic sources significantly increased the organic carbon and available N, P and K content of soil after the harvest of wheat (Table 3). The significantly highest organic carbon was recorded under SGM+WS

Table 3. Soil fertility at the end of cropping cycle and nutrient use efficiency of maize-wheat system as influenced by direct and residual effect of organic sources and fertilizer N levels (pooled data of two years)

Treatment	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	ANUE	PNUE	ANR
<i>Organic sources</i>							
Control	0.42	138.7	7.9	168.2			
WS	0.49	171.8	11.3	175.3	50	72.7	68.8
SGM	0.47	173.2	11.0	173.5	12.7	88.8	14.3
SGM+W.S.	0.52	173.8	11.9	178.2	14.1	66.2	21.3
SEm±	0.007	2.38	0.5	1.62			
CD (P=0.05)	0.02	5.9	1.5	4.6			
<i>N (kg/ha) Maize</i>							
0	0.47	144.8	10.3	174.9			
60	0.48	172.5	10.7	173.2	18.3	49.8	36.8
120	0.49	173.7	10.5	173.3	13.3	41.3	32.3
SEm±	0.008	1.89	0.3	1.15			
CD (P=0.05)	NS	5.5	NS	NS			
<i>N (kg/ha) Wheat</i>							
0	0.46	164.8	10.9	177.3			
40	0.48	169.5	10.8	175.7	32.5	85	38.3
80	0.48	175.5	10.4	173.1	26.3	68	38.6
120	0.49	177.3	9.9	169.3	20	65.6	30.5
SEm±	0.006	2.7	0.54	2.88			
CD (P=0.05)	0.02	7.7	NS	NS			

WS-Wheat straw; SGM-*Sesbania* green manure

ANUE, Agronomic N Use Efficiency (additional yield, kg/kg of N applied); PNUE, Physiological N Use Efficiency (kg grain/ kg N uptake); ANR, Apparent N Recovery (%)

treatment (0.52) which was 21.4% higher over control and 10.4 %; and 8.5 % higher over their separate application as WS and SGM, respectively. This improvement in soil organic carbon could be result of direct addition of organic matter through SGM and WS and its beneficial effect on crop roots as well as on total microbial biomass of soil. Addition of SGM+WS also increased available N, P and K content of soil by 25.1, 50.1, and 5.2 % over control. The build up of soil available N and K could be attributed to greater multiplication of microbes due to addition of organic manures which helped in mineralization of soil organic matter leading to higher available N and K. Improved P availability could be due to greater mobilization of soil P owing to reduced P sorption and release of native P by solubilizing effect of organic manures. The results are in conformity of findings of Yadav *et al.* (2009).

Residual effect of N levels applied to maize could not contribute significant increase in organic carbon, available P and K contents of soil. However, N fertilizer applied to maize could maintain a significantly higher level of available N after wheat harvest. The fertilizer N applied wheat plots getting N directly could maintained a significantly higher level of organic carbon and available N and K. However, available N content in soil found significant only at higher doses i.e. 80 and 120 kg N/ha. This might be due to longer and persistent supply of nutrients at heavier fertility level and increased root biomass under the influenced of higher organic matter in soil.

Nutrient use efficiency

The various organic and inorganic sources of N had noticeable influence on ANUE, PNUE and ANR (Table 3). ANUE followed the contrast trend to grain yield of system. The highest ANUE was recorded with WS (50.0) while lowest ANUE was recorded under SGM+ WS (14.1). Reduced losses of N and higher availability of nutrients due to increased microbial activity with WS application probably led to improvement in biomass and grain yield, which consequently led to higher ANUE. Maximum PNUE was recorded with SGM alone (88.8), followed by WS (72.7) and SGM+WS (66.2). ANR was also highest (68.8) under WS treatments. Due to easy decomposition and quick release of nutrients and exhaustive cereal-cereal system the ANR under SGM (14.3) and SGM+WS (21.3) was much lower than WS. Higher ANR with WS application might be due to release of organic compounds and synthesis of growth promoting substances during decomposition. Lower losses and increased availability of nutrients has led to higher nutrient use efficiency (Chaudhary and Gautam, 2007). Over the successive N levels, application of 60 and 40 kg N/ha in maize and wheat, respectively recorded higher ANUE, PNUE and ANR compared

to their higher doses (Table 6). In maize, increase in N dose from 60 to 120 kg N/ha reduced the AE by 27. Similarly, AE was also decrease with successive increase in N doses in wheat. The ANUE was improved by 6.2 and 12.5 kg equivalent yield/ kg N with 40 kg N/ha over 80 and 120 kg N/ha, respectively. Application of 60 kg N/ha to maize and 40 kg N/ha to wheat recorded highest PNUE. The PNUE reduced by 8.5 and 19.4 MEY /kg of N at 120 kg N/ha applied to maize and wheat than at 60 and 40 kg N/ha, respectively.

The declining rate of yield increase with successive higher level of applied N was responsible for lower ANUE. Similarly, decline in PNUE at successive levels might be ascribed to greater increase in N uptake of applied N at 60 and 40 kg N/ha in maize and wheat, respectively than at 120 kg N/ha that was responsible for higher value of ANR at lower doses. Despite high N uptake values recorded at higher doses of N, utilization of applied N was poor at higher level. Thus, low PNUE values were observed with higher dose suggesting poor utilization of applied N. Since, AE is a product of recovery and physiological efficiencies. Usually, efficiency values decline with an increase in fertilizer rate because yield follows low of diminishing returns. But a better utilization of N in lower doses resulted in higher ANUE when compared with higher doses.

Thus, it is imperative from above study that fertilizer N coupled with SGM either alone or in combination with WS recorded significantly higher system productivity, grain quality and NPK uptake of maize- wheat system and also brings desirable changes in residual fertility of soil. However, application of fertilizer N failed to bring any desirable change in available P and K content of soil but significantly increase the organic carbon and available N in soil.

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