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Influence of *Sesbania* green manure with or without wheat residues and N fertilization on maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system

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ABSTRACT

Meager information is available on the use of *Sesbania* in conjunction with-crop residue and N-dose in maize–wheat cropping system. Therefore, an attempt was made to substitute the fertilizer N through organic sources in maize–wheat cropping sequence. Hence a field experiment was conducted for 2 year from 2006–2008, on maize (*Zea mays* L.)–wheat (*Triticum aestivum* L. emend. Fiori & Paol) system to evaluate the influence of four organic sources (control, *Sesbania* green manure (SGM), wheat straw; and the combination of SGM and wheat straw), and three fertilizer N levels (0, 60 and 120 kg/ha) on maize. The residual effect of above treatments and response of wheat to direct N application (0, 40, 80 and 120 kg/ha) were also assessed. The highest plant height, dry matter accumulation, leaf area index, yield attributes, yield (4.48 and 4.86 t/ha during each year) and N uptake by maize were recorded with the application of SGM in combination with wheat straw closely followed by SGM alone. Maize responded significantly to fertilizer N up to 120 kg/ha (4.63 and 4.96 t/ha grain yield during each year) and the residual effect of that also affected significantly the growth and yields of succeeding wheat. Statistically higher plant height, dry matter accumulation, leaf area index, effective tillers, test weight, yields and N uptake by wheat were recorded under residual fertility of organic sources. Under the influence of residual fertility of N, wheat growth and yield parameters responded significantly up to 120 kg N/ha. Wheat also responded significantly to direct N application with respect to all growth and yield parameters and N uptake by wheat. SGM and SGM + wheat straw treatments resulted in gain of N content. Regarding the effect of N levels, N gain was found with all N levels. It was concluded that conjoin use of organic and inorganic sources of N was essential for higher productivity of maize-wheat cropping sequence.

Key words: Economics, Maize, Nitrogen, Productivity, *Sesbania* green manuring, Wheat

Maize (*Zea mays* L.) and wheat (*Triticum aestivum* L. emend Fiori & Paol), two major cereal crops hold prominent position in the Indian agriculture covering 8.0 and 27.7 m ha area under cultivation with annual production of 18.5 and 77.6 m tonne, respectively (Economic Survey of India, 2008). In Northern part of country maize- wheat is prominent cropping system and it covers 60% of area of rainy season maize (Yadav *et al*., 2000). The contribution of this cropping system to total cereal production is considerably large, being 31% of wheat and 6% of maize. In India the productivity of both maize (2.3 tonne/ha) and wheat (2.8 tonne/ha) is substantially lower than the world average (Economic Survey of India, 2008). There are indications of stagnation or even decline in the productivity of this cropping system due to decreased soil organic matter, over mining of nutrient reserve, loss of nutrients and non-availability of cost effective fertilizer. Further, the application of inorganic fertilizers even in balanced form may not sustain soil fertility and productivity under continuous cropping. However, integrated use of inorganic and organics including green manure and crop residues may improve the soil productivity (Sharma and Prasad, 2001 and Mankotia, 2007).

Among the various factors for improving productivity, nitrogen plays vital role by participating in different metabolic activities in plant system. The improved genotypes of cereals require large quantities of nitrogen for the expression of their production potential especially under low soil nitrogen fertility. Fertilizer N and bio-sources are the major sources of nitrogen supply for crop. Inorganic fertilizer is not a complete substitute for organic matter and *vice-versa* and their role is complementary to each other. Application of organo-inorganic combination is very effective in realization of high yield and high responses to added nutrients (Dhaliwal *et al.,* 2007), while imbalance use of nutrients has detrimental effect on soil health (Swarup, 2002). Incorporation of farm waste as biological as well as practice of green manuring in cereals is viable

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options, which improves the productivity and partially substitutes the fertilizer nitrogen requirement of the subsequent crop. 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 use of *Sesbania* in conjunction with crop residue and N doses in maize-wheat cropping system. Therefore, an attempt has been made to substitute the fertilizer N through organic sources in maize-wheat cropping sequence.

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^o N latitude, 77.1^o 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 bulk density of 1.49 and 1.51 Mg/ m^3, organic carbon 0.44 and 0.42 %, available N 124.6 and 127.8 kg/ha, available P 10.9 and 11.2 kg/ha, 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 experiments were laid out in split–split plot design. In maize crop four organic sources, viz., control, S*esbania* green manure (SGM), wheat straw (WS) and SGM + WS were applied in main plots with 3 levels of N fertilizer (0, 60 and 120 kg /ha) in sub-plots. The succeeding wheat crop was raised on residual fertility of previous crop by applying 4 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 tonne/ha biomass during each year) and WS (5 t/ha) were incorporated in soil 15 days before sowing. The N content of organic sources in total N content was estimated before incorporation as 2.21 and 2.16 in SGM and 0.33 and 0.31 in wheat straw.

‘Ganga safed-2’ maize was sown on 1 and 4 July and harvested on 12 and 10 October of 2006 and 2007, respectively. After harvesting of maize ‘HD-2824’ wheat was sown on 30 and 23 November, 2006 and 2007 and harvested on 2 April and 28 March of 2007 and 2008, respectively. Half dose of N was applied at the sowing of maize (wheat) and the remaining amount of N was top dressed at knee-high (first irrigation) and silking stages (second irrigation). Leaf area index of maize and wheat were computed at 75 and 95 days stage, respectively. The grain and stover/straw of maize and wheat were analyzed for N concentration following standard procedures and the total uptake of N was calculated. The economics were worked out on the basis of prevailing market price of inputs and produces in each year.

RESULTS AND DISCUSSION

Effect of organic sources on maize

Plant height and dry matter accumulation (DMA) at harvest and leaf area index (LAI) at 75 days after sowing were influenced significantly due to different organic sources (Table 1). Among organic sources application of SGM+wheat straw, being at par with SGM recorded significantly taller plants, more DMA and LAI compared to control and wheat straw. The SGM and wheat straw incorporation alone recorded taller plants with higher DMA and LAI than control except the effect of wheat straw incorporation on DMA over control, where both of these treatments were statistically equal. These observations are in agreement with of Hemlata *et al*. (2000) and can be explained as the larger response of maize under green manure application was possible due to rapid mineralization of nutrients as it reduces soil compactness and enhance aggregation of soil particles.

The number of grain/cob of maize increased significantly under the organic manures in general and SGM in particular. However, organic sources did not make any significant improvement in number of cobs/ha and test weight (Table 1). Among organic sources the application of SGM + wheat straw recorded significantly higher number of grains/cob than all other treatments except SGM. SGM and wheat straw application differed significantly with each other and SGM recorded more values of number of grains/cob than control. This can be assign to the greater nutrient supply from organic manure incorporation and soil organic matter. Hemlata *et al. (*2000) also reported the similar findings.

The application of SGM + wheat straw being at par with SGM recorded the highest grain and biological yield of maize, which was 34.5 and 29.9% and 29.9% and 28.5% higher over control during 2006 and 2007, respectively (Table 2). The growth parameter and yield component had cumulative effect so far as the yield of maize was concerned. The more vegetative growth (plant height, LAI and DMA) with higher values of yield attributing characters resulted in improved yields with these treatments. The SGM was the second best organic source which resulted in higher grain and biological yield when compared with control during both the years. Compared to wheat straw, higher grain yield in each year and biological yield in 2007 were found with SGM treatments. However, the organic sources could not influence harvest index significantly during both the years (Table 2). It was because the biological yield of a crop is mainly determined by its growth and development attained but the final build up of yield is cumulative function of yield components. The findings of Sharma and Prasad (2001) are in close agreement of these results.

Table 1. Growth and yield attributes of maize and wheat as influenced by direct and residual effect of organic sources and N levels (mean of 2 years)

Treatment	Maize						Wheat					
	Plant height (cm)	DMA (g/plant)	Leaf area index	Cobs/ha (,000)	Grains/ cob	Test weight (g)	Plant height (cm)	DMA (g/m^2)	Leaf area index	Effective tillers/m^2	Grains/ spike	Test weight (g)
Organic manure												
Control	170.7	143.1	3.05	64.7	300.0	226.7	85.0	1,023	2.23	278.7	48.0	38.5
*SGM**	187.4	169.2	3.70	67.7	398.5	228.0	88.0	1,064	2.46	285.6	49.5	40.4
WS	178.3	150.4	3.15	66.8	344.0	227.1	87.2	1,044	2.26	282.4	50.2	38.9
SGM + WS	190.0	173.7	3.95	68.7	435.0	229.3	89.2	1,090	2.53	291.4	51.4	40.8
SEm±	1.0	2.6	0.03	1.3	14.8	0.9	0.4	7	0.02	1.6	1.3	0.3
CD (P=0.05)	3.1	8.8	0.10	NS	50.9	NS	1.5	22	0.09	5.7	NS	0.9
N (kg/ha) to maize												
0	167.7	138.8	2.85	64.9	259.5	225.2	86.8	1,044	2.23	279.7	49.2	39.4
60	183.3	162.1	3.65	67.1	394.0	227.9	87.3	1,055	2.44	285.4	50.0	39.7
120	193.8	176.3	3.85	68.9	467.0	230.3	88.0	1,062	2.72	288.1	50.6	39.9
SEm±	1.4	1.4	0.03	1.4	23.1	0.7	0.4	5	0.02	1.6	0.95	0.22
CD (P=0.05)	4.2	4.5	0.12	NS	69.2	2.1	1.4	15	0.07	4.8	NS	NS
N (kg/ha) to wheat												
0							80.9	895	1.74	246.7	45.9	35.4
40							86.4	1,051	2.34	279.8	49.5	40.0
80							90.3	1,115	2.61	302.7	51.8	40.9
120							91.8	1,159	2.78	308.8	53.0	42.5
SEm±							1.3	7	0.03	1.9	0.7	0.6
CD (P=0.05)							3.7	19	0.09	5.8	2.1	1.6

*SGM; *Sesbania* green manure, WS; Wheat straw; DMA; Dry matter accumulation

Table 2. Grain and biological yield (tonne/ha), and harvest index (%) of maize and wheat as influenced by organic sources and N levels

Treatment	Maize						Wheat					
	Grain yield		Biological yield		Harvest index		Grain yield		Biological yield		Harvest index	
	2006	2007	2006	2007	2006	2007	2007	2008	2007	2008	2007	2008
Organic manure												
Control	3.33	3.66	8.17	8.91	41.5	41.4	3.99	4.25	9.02	9.61	44.2	44.3
SGM	4.22	4.48	9.95	10.55	42.0	41.7	4.34	4.64	9.77	10.61	44.3	43.6
WS	3.84	4.14	9.26	9.95	41.5	41.6	4.23	4.41	9.59	10.13	44.1	43.7
SGM + WS	4.48	4.86	10.62	11.45	42.1	42.3	4.42	4.72	10.07	10.83	43.8	43.4
SEm±	0.08	0.07	0.16	0.12	0.5	0.2	0.07	0.07	0.13	0.17	0.3	0.4
CD (P=0.05)	0.26	0.20	0.44	0.34	NS	NS	0.21	0.23	0.36	0.44	NS	NS
N (kg/ha) to maize												
0	3.14	3.49	7.81	8.51	40.6	40.6	4.17	4.45	9.43	10.19	44.1	43.6
60	4.13	4.41	9.79	10.47	41.8	41.9	4.24	4.51	9.61	10.31	44.1	43.7
120	4.63	4.96	10.91	11.67	42.4	42.6	4.32	4.55	9.77	10.38	44.2	43.8
SEm±	0.05	0.06	0.12	0.14	0.5	0.5	0.06	0.03	0.09	0.06	0.1	0.1
CD (P=0.05)	0.16	0.18	0.35	0.41	1.3	1.5	NS	0.08	0.27	0.18	NS	NS
N (kg/ha) to wheat												
0							3.36	3.68	8.04	8.7	42.1	42.7
40							4.12	4.48	9.45	10.16	43.6	44.1
80							4.62	4.85	10.24	10.88	45.2	44.4
120							4.87	5.01	10.69	11.34	45.6	43.7
SEm±							0.08	0.05	0.14	0.11	0.5	0.5
CD (P=0.05)							0.25	0.14	0.42	0.32	1.4	1.5

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

Effect of fertilizer N on maize

Growth parameters increased significantly with each successive increase in N application rate up to 120 kg/ha (Table 1). Since maize crop is heavy feeder of all essential nutrients in general and that of N in particular, so application of N resulted in significantly taller plants with increased values of DMA and LAI. The overall improvement in growth of maize with the addition of N can be ascribed to its pivotal role in several physiological and biochemical processes. These results are in close conformity with the result obtained by Singh *et al.* (2003). The superiority of yield attributes of maize *viz.* number of grains/ cob and test weight with the increasing levels of N was found from 0 to 120 kg N/ha, however, the magnitude of response was more pronounced at higher level *i.e.* 120 kg/ ha. However, number of cobs/ha did not differ significantly due to N application rates (Table 1). This might be due to benefit derived by the maize crop during vegetative growth period from a heavier dose of top dressing of fertilizer N along with basal application. Each successive increase in N level significantly increased the grain and biological yield of maize. However, during both the years, significantly higher harvest index was observed at 120 kg N/ha than control only (Table 2). This increase in the yield of maize was due to the enhanced vegetative growth characters like plant height, dry matter accumulation and yield attributes. These results are in conformity with those of Singh *et al.* (2003).

Residual effect of organic sources on wheat

The residual effect of organic sources applied to previous crop had significant effect on plant height, DMA at harvest and LAI at 95 days after sowing of wheat during both the years of experimentation (Table 1). On the residual fertility of SGM and wheat straw, significantly taller plants with higher DMA and LAI were found than remaining treatments except SGM in respect of plant height and LAI, where the differences between SGM +wheat straw and SGM were not of significant order. The residual effect of organic sources on the effective tillers/m^2 and test weight of wheat was also found significant while number of grains/ spike did not differ significantly due to organic sources (Table 2). The beneficial residual effect of these organic sources on growth and yield attributes might be due to their favorable role in increasing supply of plant nutrients with better soil health. On account of above mentioned growth and yield parameter, the grain and biological yield of wheat increased significantly under residual effect of organic sources (Table 2). The application of SGM and wheat straw, being at par with SGM alone, recorded significantly highest grain and biological yield, which were 10.7% and 11.6%; and 11.1% and 12.6% higher over control in first year and second year, respectively. However, wheat straw remained similar to SGM during both the years but proved superior over control in respect of both grain and biological yield. No variation in harvest index was noticed because of residual fertility of organic sources. These finding are in close conformity with Gangwar *et al.* (2004).

Residual effect of fertilizer N on wheat

The data on residual effect of N application on wheat revealed that plant height, DMA and LAI attained their highest values on 120kg N/ha application in each year (Table 1). Similarly, the N level of 120 kg/ha and 60 kg/ha, being at par recorded significantly higher effective tillers than control but number of grains/spike and test weight did not differ due to N application to maize (Table 2). Application of 120 kg/ha to maize recorded significantly more yield of wheat grain in 2007-08 and biological during both the years over no N (Table 2). The residual effect of fertility at 120 kg N/ha on wheat appeared to influence favorably the plant height and effective tillers and DMA due to longer and persistent supply of N at heavier level which resulted into greater translocation of photosynthates for longer duration and hence in turn increased the grain yield. On the residual fertility of N levels there were no significant variations in harvest index of wheat (Table 2). Significant carry over effect due to combined application of organic sources and fertilizer N to previous crop on the succeeding crop was also reported by Jamwal (2005).

Effect of direct N application on wheat

Significantly higher response of various growth and yield parameters of wheat was found with direct N application to wheat. N directly applied to wheat had significant effect on plant height, DMA and LAI (Table 1). Wheat recorded significantly taller plants with each successive increase in N doses up to 80 kg/ha while DMA and LAI showed the increasing trend up to 120 kg/ha. N application to wheat increased effective tillers and test weight significantly up to 120 kg/ha, while, grains/spike increased significantly only up to 80 kg N/ha (Table 1). Successive increase in N level from 0 to 120 kg N/ha significantly improved grain and biological yield of wheat and highest yield was recorded with 120 kg/ha. N application also improved the harvest index significantly but only up to 80 kg/ha (Table 2). Further increase in N level to 120 kg/ha also recorded more harvest index over 80 kg N/ ha but the differences were not of significant. This was due to the fact that N is the fertilizer nutrient required in the greatest amount for maximizing the productivity of crops, especially cereals. This was because N is the nutrient which most often limits crop production because the crops removes large amount of N and secondly N is easily lost from the soil.

N uptake and N balance

The differences in N uptake by maize were found to be significant due to organic sources and N levels during both the years (Table 3). The application of SGM + wheat straw recorded significantly higher N uptake over all other organic sources during both the years. Similarly, increasing N levels with each successive level from 0 to 120 kg/ha also improved the N uptake by maize (Table 3). In wheat N uptake was also differed significantly with residual effect of organic sources and fertilizer N and direct N fertilization during both the years (Table 3). The significantly higher N uptake was found with SGM + wheat straw application over other organic sources except SGM during both the years. However, wheat straw alone could not enhance N uptake significantly. Regarding the effect of residual fertility of nitrogen on N uptake by wheat pronounced increase was noticed up to the highest level. The N uptake by wheat also enhanced with its direct application in wheat and maximum value was noticed at 120 kg N/ha level (Table 3). The uptake of any nutrient is the function of its content and DMA by the crop. Higher N content in produce and higher biomass production of maize and wheat might be the pertinent reasoning for higher uptake of N with these treatments. These findings are in close agreement with the results reported by Patro *et al.* (2005) in respect of maize and Jamwal (2005) in respect of wheat. N addition to the soil through organic sources and its uptake by the crops were the maximum with SGM + wheat straw followed by SGM alone. The data on gain or loss of N in soil indicated that N contents showed the positive trend all the treatments and maximum value was found with wheat straw. Regarding the effect of N levels, the quantity of added N and N uptake by the crops were increased with increasing N levels. The data on addition and depletion data and available N content in soil indicated that the maximum gain was found with control due to lower uptake on N at this level. This could be ascribed to the application of organic sources and N levels and variations in the addition and uptake of N by the crop.

Economics

Application of SGM resulted in highest net returns and B: C ratio from maize. But in wheat the maximum net returns and B: C ratio were found when it was grown on residual fertility of SGM + wheat straw (Table 4). The data on overall economics of maize-wheat cropping system indicated that residual effect of SGM alone was the most profitable by recording net returns of Rs. 49,311/ha and B: C ratio of 1.98, closely followed by SGM + wheat straw (net returns Rs. 47,297 and B:C ratio 1.58). In general, the

Table 3. Nitrogen uptake (kg/ha) by maize and wheat and nitrogen balance nitrogen after completion of cropping system as influenced by organic manure and N levels

Treatment	N uptake				Total available N (Initial + added through fertilizers) (kg/ha)		Total N uptake (kg/ha)		Available N in soil after harvest (kg/ha)		Net loss/gain in N content in soil (kg/ha)	
	Maize		Wheat									
	2006	2007	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Organic manure												
Control	71.1	76.3	76.2	81.2	124.6	127.8	147.3	157.5	137.6	139.7	160.3	169.4
SGM	82.7	88.1	84.2	87.6	239.6	243.8	166.9	175.7	172.2	174.2	99.5	101.1
WS	75.1	79.9	81.3	86.4	141.1	143.8	156.4	166.3	170.3	173.3	185.6	195.8
SGM + WS	89.3	94.9	87.7	90.1	256.1	264.8	177.0	185.0	172.2	175.3	93.1	95.5
SEm±	0.8	0.7	1.5	1.3								
CD (P=0.05)	2.7	2.3	5.3	4.5								
N (kg/ha) to maize												
0	61.8	66.6	80.7	83.6	124.6	127.8	142.5	150.2	142.9	146.7	160.8	169.1
60	81.4	87.3	81.5	86.8	184.6	187.8	162.9	174.1	171.4	173.6	149.7	159.9
120	95.5	100.5	85.0	88.9	244.6	247.8	180.5	189.4	173.2	174.2	109.1	115.8
SEm±	0.8	0.5	1.0	1.2								
CD (P=0.05)	2.4	1.5	2.9	3.5								
N (kg/ha) to wheat												
0			60.8	66.5	124.6	127.8	140.3	151.3	134.3	135.2	150.0	158.7
40			77.1	80.8	164.6	167.8	156.6	165.6	168.4	170.5	160.5	158.3
80			92.6	96.5	204.6	207.8	172.1	181.3	173.5	177.4	141.1	150.9
120			98.9	101.6	244.6	247.8	178.4	186.4	175.2	179.4	109.1	118.0
SEm±			1.0	1.4								
CD (P=0.05)			2.8	3.8								

SGM, *Sesbania* green manure; WS, wheat straw

Table 4. Economics (Rs/ha) of organic and inorganic integration under maize-wheat cropping system (mean of 2 years)

Treatment	Cost of cultivation			Net returns			B:C ratio		
	Maize	Wheat	System	Maize	Wheat	System	Maize	Wheat	System
Organic manure									
Control	8,615	14,621	23,236	13,409	28,934	42,343	1.55	1.97	1.82
SGM	10,243	14,621	24,864	16,704	32,607	49,311	1.63	2.23	1.98
WS	13,615	14,621	28,236	11,210	30,398	41,608	0.82	2.07	1.47
SGM + WS	15,243	14,621	29,864	13,518	33,730	47,297	0.89	2.30	1.58
N (kg/ha) to maize									
0	11,304	14,621	25,925	9,433	30,655	40,088	0.83	2.09	1.54
60	11,933	14,621	26,554	14,568	31,792	46,360	1.22	2.17	1.73
120	12,549	14,621	27,170	17,167	32,916	50,083	1.36	2.25	1.84
N (kg/ha) to wheat									
0		14,621			22,659			1.54	
40		15,041			30,459			2.02	
80		15,461			34,983			2.26	
120		15,881			37,050			2.33	

*SGM; *Sesbania* green manure, WS; Wheat straw; Prices (Rs/t), maize 5,400 in 2006; 6,200 2007; wheat 8,000 in 2007; 10,000 in 2008

maize treatments having wheat straw had lower values of net returns and B: C ratio than other treatments due to its higher cost of cultivation. On the contrary, wheat showed the reverse trend due to the better response on residual fertility after wheat straw when combined with SGM. These results confirm the findings of Patro *et al.* (2005). The each successive increase in N doses increased the net returns and B: C ratio of maize up to 120 kg/ha. In wheat, among residual N doses, 120 kg/ha recorded highest of net returns and B: C ratio. With direct N fertilization highest net returns (Rs.37,050) and B: C ratio (2.33) was recorded with 120 kg/ha. The net returns and B: C ratio of maize-wheat system was also increased consistently with successive increase in N levels and highest values of aforesaid parameters were recorded with 120 kg/ha. The results are confirmed with the findings of Jamwal (2005)

It is concluded that the *Sesbania* green manure either alone or in combination with wheat straw had significant effect on growth, yield attributes, yield N uptake and net return of maize. *Sesbania* green manure and wheat straw supplied with adequate fertilizer N had significant residual effect on succeeding wheat. In a highly exhaustive cereal-cereal cropping sequence in sustaining the productivity and economy higher response of applied fertilizer was obtained with organic sources.

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