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Effect of Integrated Nutrient Management on Wheat Under Long-Term Rice-Wheat Cropping Systems in Mollisol

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Field experiment was conducted at Norman E. Borlaug Crop Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar during 2008-09 to study the effect of integrated nutrient management on wheat under rice-wheat cropping system in a Mollisol. Twelve treatments were replicated twice in split plot design with 12 main and 2 sub plots. Plant height, number of tillers, wheat grain and straw yield were noted. Nutrient content (N, P, K & S) in wheat and nutrient uptake (N, P, K & S) by wheat were determined. Partial replacement of N through FYM and wheat and *moong* straw resulted in significant improvement in nutrient concentration as well as their uptake and wheat yield. The treatments with 100% N or NPK and 50% N applied through *moong* straw were better than all other treatments and *moong* straw proved the best among organic sources of N studied in respect of its effect on wheat yield & nutrient status in plant.

Key words: INM, rice-wheat cropping system, FYM, *moong* straw, wheat straw.

Agriculture is facing several critical issues like low fertilizer use efficiencies, decreasing factor productivity, low soil organic carbon (SOC) stock, mismatch between nutrient removal and addition to the soil. The whole scenario of agriculture is at a junction where one has to rethink and improve the agricultural packages and practices to fulfill the needs of the country. Fertilizers are very important sources of plant nutrients and have played a prominent role in increasing food grain production of the country. Continuous and imbalanced use of fertilizers is adversely affecting the sustainability of agricultural production besides causing environmental pollution. Indiscriminate exploitation of natural resources and non-judicious use of agricultural inputs to fetch higher production had generated a serious problem on sustaining agricultural productivity.

To sustain the productivity of different crops and cropping systems, efficient nutrient management is vital. The major issue for the sustainable agricultural production will be management of soil organic carbon and rational use of organic inputs such as animal manure, crop residue, green manure, sewage sludge and wastes known as integrated plant nutrient resources management. In most long-term experiments, a combination of mineral fertilizers and farmyard manure has generally given the best crop yield and soil quality (Wang *et al* ., 2004; Chalk *et al*., 2003). Thus keeping in view the above consideration present study was undertaken to study the effect of integrated nutrient management on wheat under rice-wheat cropping system in a Mollisol.

Materials and Methods

The experiment was conducted at Norman. E. Borlaug Crop Research Centre of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar. Twelve treatments (i.e. Rice *(Kharif)*: T_1 Control (no fertilizer or O.M.), T_2 50% recommended N dose through urea, T_3 50% recommended N dose through urea, T_4 50% recommended N dose through urea, T_5 100% recommended N dose through urea, T_6 50% recommended N dose through urea + 50% N dose through FYM, T_7 75% recommended N dose through urea + 25% N dose through FYM, T_8 50% recommended N dose through urea + 50% N dose through wheat straw, T_9 75% recommended N dose through urea + 25% N dose through wheat straw, T_{10} 50% recommended N dose through urea + 50% N dose through green gram straw, T_{11} 75% recommended N dose through urea + 25% N dose through green gram straw, T_{12} 100% Recommended N, P and K dose through fertilizers. Wheat *(Rabi)*: Treatments T_1 , T_2 , T_4 , T_5 & T_{12} were same as for rice crop while other treatments are as follows: T_3 100% recommended N dose through urea, T_6 100% recommended N dose through urea, T_7 75% recommended N dose through urea, T_8 100% recommended N dose through urea, T_9 75% recommended N dose through urea, T_{10} 100%

recommended N dose through urea, T_{11} 75% recommended N dose through urea) replicated

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twice in split plot design were compared in a permanent plot experiment on integrated nutrient supply system in rice-wheat cropping system with 12 main and 2 sub plots. The recommended dose of nitrogen was 120 kg ha^{-1} for rice as well as wheat. Phosphorus treatment was included since *kharif* 2000. Each plot was divided in two plots, and in one part of each plot phosphorus was applied @ 40 kg ha^{-1}. Observations on grain and straw yield, plant height and number of tillers were recorded. Plant Analysis for different nutrient content i.e. nitrogen content by Micro-kjeldahl procedure (Jackson, 1967), phosphorus content by vanadomolybdate phosphoric acid yellow colour method (Piper, 1996), potassium content by flame photometer (Perur *et al.,* 1973), sulphur content by turbidimetric method (Chesnin and Yien, 1950) was done. Plant uptake for nutrients (N, P, K & S) was worked out by multiplying the nutrient content with yield. Data obtained were analyzed statistically using Analysis of Variance (ANOVA) technique for a split plot design experiment.

Results and Discussion

Grain and straw yield in the year 2008-09 and 2009-10

Grain and straw yield of wheat in the year 2008-9 varied from 1225 to 3325 kg ha^{-1} and 1825 to 4800 kg ha^{-1}, respectively (Table 1). In the year 2008-9 among N treatments grain as well as straw yield was the lowest (1225 and 1825 kg ha^{-1}, respectively) in control (T_1) whereas, the highest grain yield 3325 kg ha^{-1} was found in T_5 and highest straw yield 4800 kg ha^{-1} was observed in T_{10} where 50% N dose in *kharif* season was applied through *moong* straw. Among N treatments significant increase in grain and straw yield was observed in all the treatments than the control (T_1). Higher yield is function of favourable effect of fertilizers and manures on nutrients availability as well as physical condition of the soil (Maurya and Ghosh, 1972). This finding is in conformity with that reported by Banwasi and Bajpai (2001), Yadav (2004). Lowest yield was observed under control plot due to no fertilizer and organic manure application. Singh (1999) also obtained the similar results.

In the year 2009-10 grain as well as straw yield of wheat varied from 1600 to 3400 kg ha^{-1} and 2400 to 6450 kg ha^{-1} respectively (Table 1). Lowest grain yield (1600 kg ha^{-1}) and straw yield (2400 kg ha^{-1}) was observed under T_1 (control). Among N treatments significant increase in grain and straw yield was observed in all the treatments than control (T_1). Highest grain yield (3400 kg ha^{-1}) was observed under T_5 and T_{10} treatments followed by T_7 while highest straw yield (6450 kg ha^{-1}) was recorded under T_{10} followed by T_5. This increase in yield may be understood in the light of observations that N added through the organic residue and FYM resulted significant increase in available amounts of nutrients in the soil. Similar results were also reported by Dhillon and Dhillon (1991). In both the years, the trend in the increase of grain and straw yield was seen due to the application of N with P and without P, however, the magnitude and variation among treatment was little different. In the subsequent year the yield trend was more normalized with respect to the treatments. This might be due to environmental conditions and several other factors affecting plant growth and yield.

Table 1. Effect of various long-term treatments on grain and straw yield (kg ha^{-1}) and number of tillers/m^2 of wheat.

Treatment	Grain yield (2008-09)		Mean	Straw yield (2008-09)		Mean	Grain yield (2008-09)		Mean	Straw yield (2008-09)		Mean	No. of tillers		Mean
	P_0	P_{40}		P_0	P_{40}		P_0	P_{40}		P_0	P_{40}		P_0	P_{40}	
T_1	1150	1300	1225	1950	1700	1825	1600	1600	1600	2150	2650	2400	147	163	155
T_2	2150	2600	2375	3850	3900	3875	2600	2950	2775	4900	5550	5225	184	217	200
T_3	1950	2800	2375	2550	3950	3250	3050	3350	3200	5700	4900	5300	223	215	219
T_4	2150	2700	2425	5100	4300	4700	3100	3300	3200	5400	5700	5550	195	215	205
T_5	3050	3600	3325	4950	4400	4675	3250	3550	3400	6250	5950	6100	216	267	246
T_6	2750	3050	2900	4000	3700	3850	3200	3600	3250	5550	6150	5850	242	195	219
T_7	2550	2800	2675	5450	3950	4700	3400	3350	3375	6350	5400	5875	204	178	191
T_8	1750	1950	1850	2750	2800	2775	2800	2900	2850	5450	5350	5400	168	211	189
T_9	2200	2600	2400	3800	4400	4100	2550	3100	2825	5950	5900	5925	212	215	213
T_{10}	1950	2700	2325	4550	5050	4800	3350	3150	3400	5650	6100	6450	279	276	278
T_{11}	2800	3200	3000	3700	4300	4000	3450	3200	3325	5800	5550	5675	225	243	234
T_{12}	2250	2800	2525	4000	4450	4225	3250	3350	3300	6000	6900	5875	227	237	232
S.Em. ±	291.52	174.43	264.11	1482	361	403	262	200	220	395	558	265	4	3	3
CD at 5%	905.46	537.31	821.90	477	1114	1256	813	616	687	1223	1276	825	14	12.1	12.1

Number of Tillers and Plant Height

Number of tillers varied from 155 to 278 m^{-2} and plant height varied from 44.7 to 66.3 cm (Table 2). In N treatments with P and without P more number of tillers were found under T_{10} where 50 percent nitrogen was applied through *moong* straw and 50 percent through urea in *kharif* and 100 percent nitrogen was applied through urea in *rabi* season. Maximum plant height was also noted under T_{10}. The combined effect of the two (N and P) treatments on number of tillers and plant height was highest under T_{10} treatment followed by T_5 treatment and it was lowest under control. This could be due to better availability of nutrients (N, P, and S) in the organic manure treated plot than the control. Similar results were also reported by Awan *et al*. (2000).

Table 2. Effect of various long-term treatments on plant height (cm), nitrogen, phosphorus concentration (%) & uptake (kg ha^{-1}) in wheat grain.

Treatment	Plant height		Mean	N conc.(Grain)		Mean	N uptake (Grain)		Mean	P conc. (Grain)		Mean	P uptake (Grain)		Mean
	P_0	P_{40}		P_0	P_{40}		P_0	P_{40}		P_0	P_{40}		P_0	P_{40}	
T_1	42.90	46.60	44.7	1.30	1.32	1.31	14.89	17.11	16.00	0.27	0.29	0.28	3.1	3.7	3.4
T_2	61.30	53.50	57.4	1.43	1.44	1.43	30.66	37.38	34.02	0.30	0.33	0.32	6.5	8.6	7.5
T_3	57.20	48.20	52.7	1.64	1.69	1.66	31.88	47.30	39.59	0.34	0.38	0.36	6.6	10.5	8.5
T_4	53.50	54.00	53.8	1.60	1.61	1.61	34.46	43.48	38.97	0.32	0.35	0.33	6.8	9.4	8.1
T_5	62.00	58.00	63.2	1.81	1.84	1.83	55.18	66.21	60.70	0.35	0.36	0.36	10.8	13.0	11.9
T_6	56.60	53.10	54.8	1.85	1.88	1.86	50.76	57.27	54.02	0.39	0.42	0.41	10.7	12.9	11.8
T_7	64.30	49.45	56.8	1.75	1.77	1.76	44.53	49.66	47.10	0.36	0.38	0.37	9.1	10.5	9.8
T_8	43.60	62.20	52.9	1.92	1.84	1.88	33.64	35.81	34.73	0.36	0.38	0.37	6.3	7.3	6.8
T_9	51.70	54.80	53.2	1.83	1.86	1.84	40.22	48.26	44.24	0.35	0.37	0.36	7.6	9.6	8.6
T_{10}	68.10	64.40	66.3	1.69	1.76	1.72	32.99	47.49	40.24	0.42	0.43	0.42	6.8	10.0	8.4
I_{11}	60.10	59.10	59.6	1.90	1.93	1.92	53.26	61.70	57.48	0.36	0.36	0.36	10.0	11.5	10.8
T_{12}	54.95	51.40	53.1	1.71	1.75	1.73	38.37	48.97	43.67	0.35	0.37	0.36	9.7	12.0	10.9
S.Em. ±	3.49	3.55	2.4	0.01	0.01	0.01	5.04	2.92	4.60	0.01	0.01	0.01	1.1	0.6	1.0
CD at 5%	10.82	10.95	7.6	0.03	0.01	0.03	15.67	9.0	14.32	0.03	0.02	0.03	3.5	2.0	3.1

Nitrogen Concentration and Uptake in Wheat Grain & Straw

Nitrogen concentration in grain ranged from 1.31 to 1.92 percent (Table 2) and in straw it varied from 0.31 to 0.48 percent (Table 4). Among nitrogen treatments without P nitrogen concentration in grain was found highest under T_8 where 50% nitrogen was applied through urea and 50% through wheat straw in *kharif* season and 100% N through urea in *rabi* season. While in nitrogen treatments with P highest nitrogen concentration in grain was recorded under T_{11} (where 75% nitrogen was applied through urea and 25% through *moong* in *kharif* season and 100% N through urea in *rabi* season), and in straw it was highest under T_6 (50 percent N was applied through urea and 50 per cent through FYM in *kharif* and 100 percent N through urea in *rabi* season) . This might be due to easy decomposition of *moong* and FYM and more release of nutrient. The combined effect of N treatments with P and without P on N concentration in grain was highest in T_{11} (75% N was applied through urea and 25% through *moong* straw in *kharif* season, 75% N was applied through urea in *rabi* season) followed by T_8, and in straw it was highest in T_6 followed by T_3 and T_5 where half to full N dose was applied through urea in both *kharif* and *rabi* seasons. Higher N content in wheat plant was observed in treatments having FYM, green manure and crop residue. This might be due to slow and continuous supply of N in the soil under these treatments throughout the crop growth period as a result of reduced losses. Paikaray *et al*. (2001) also reported similar results. The inorganic source of nutrient alone also increased N content in wheat (treatments T_3 and T_5) while its content was less as compared to INM treatments because inorganic sources are subjected to various losses due to which its available amount decreases at later stages when crop requirement is high. Similar observations have been made by Tiwari (1988). Significant increase in N concentration in grain and straw of wheat due to N application through urea and organic manure was recorded. This effect of N application may be attributed to increased absorption of N by the crop. Similar results were observed by Kansal *et al*. (1974). Nitrogen uptake in grain and straw varied from 16.0 to 60.70 kg ha^{-1} (Table 2) and 5.7 to 22.2 kg ha^{-1} (Table 4), respectively. In N treatments with P N uptake in straw was highest under T_{10} and without P it was highest under T_7. The combined effect of N treatments with P and without P resulted in highest N uptake in grain and straw under T_5 treatment. This is largely due to highest grain yield under T_5

Table 3. Effect of various long-term treatments on potassium, sulphur concentration (%) & uptake (kg ha^{-1}) in wheat grain.

Treatment	K conc. (Grain)		Mean	K uptake (Grain)		Mean	S conc. (Grain)		Mean	S uptake (Grain)		Mean
	P_0	P_{40}		P_0	P_{40}		P_0	P_{40}		P_0	P_{40}	
T_1	0.38	0.45	0.42	5.1	5.8	5.5	0.11	0.11	0.11	1.2	1.4	1.3
T_2	0.51	0.56	0.54	11.0	14.5	12.8	0.12	0.12	0.12	2.4	3.0	2.7
T_3	0.63	0.65	0.64	12.3	18.2	15.3	0.12	0.12	0.12	2.3	3.4	2.9
I_4	0.60	0.59	0.59	12.8	15.8	14.3	0.12	0.12	0.12	2.5	3.2	2.8
T_5	0.55	0.55	0.55	16.8	19.8	18.3	0.13	0.13	0.13	4.0	4.7	4.4
I_6	0.55	0.53	0.54	15.0	16.0	15.5	0.14	0.14	0.14	3.7	4.2	4.0
T_7	0.56	0.57	0.56	14.2	15.8	15.0	0.12	0.12	0.12	3.0	3.3	3.2
I_8	0.46	0.46	0.46	8.1	8.5	8.3	0.15	0.15	0.15	2.6	3.0	2.8
T_9	0.50	0.49	0.49	11.0	12.8	11.9	0.14	0.14	0.13	3.0	3.5	3.2
I_{10}	0.44	0.46	0.45	7.6	10.3	9.0	0.17	0.18	0.17	3.3	4.8	4.0
I_{11}	0.45	0.45	0.45	12.6	13.9	13.3	0.14	0.15	0.14	3.9	4.6	4.3
I_{12}	0.83	0.85	0.84	18.8	23.8	21.3	0.12	0.13	0.12	2.8	3.5	3.2
S.Em. ±	0.01	0.01	0.01	1.9	0.9	1.8	0.001	0.001	0.0007	0.8	0.4	0.3
CD at 5%	0.03	0.02	0.03	6.0	2.9	5.6	0.003	0.003	0.002	0.5	0.3	1.1

treatment.The highest straw yield was found in treatment T_{11} which resulted highest N uptake in this treatment. The lowest N concentration and uptake was recorded in control plot. The lowest N concentration in control plot might be due to no addition of fertilizers and manures which caused least N uptake. Addition of N significantly enhanced its uptake over control. These results corroborate the findings of Gupta *et al.* (1989).

Phosphorus Concentration and Uptake in wheat grain and straw

The P concentration of wheat grain and straw ranged from 0.28 to 0.42 (Table 2) and 0.09 to 0.19 percent (Table 4), respectively. The P concentration in grain was highest in T_{10} treatment while in straw it was highest in T_9 treatment where 75% N dose was applied through urea and 25% through wheat straw

Table 4. Effect of various long-term treatments on nitrogen, phosphorus concentration (%) & uptake (kg ha^{-1}) in wheat straw.

Treatment	N conc. (Straw)		Mean	N uptake (Straw)		Mean	P conc. (Straw)		Mean	P uptake (Straw)		Mean
	P_0	P_{40}		P_0	P_{40}		P_0	P_{40}		P_0	P_{40}	
T_1	0.31	0.32	0.31	6.0	5.5	5.7	0.08	0.10	0.09	1.6	1.7	1.6
T_2	0.39	0.39	0.39	14.9	15.2	15.1	0.16	0.17	0.16	6.2	6.6	6.4
T_3	0.47	0.47	0.47	12.1	19.5	15.8	0.18	0.18	0.18	4.6	7.1	5.9
T_4	0.38	0.38	0.38	19.4	16.3	17.8	0.13	0.14	0.14	6.6	6.0	6.3
T_5	0.47	0.48	0.47	23.4	20.9	22.2	0.15	0.15	0.15	7.4	6.6	7.0
T_6	0.48	0.49	0.48	19.2	18.0	18.6	0.18	0.19	0.17	7.2	8.4	7.8
T_7	0.46	0.46	0.46	25.2	18.2	21.7	0.13	0.15	0.14	7.1	5.9	6.5
T_8	0.41	0.42	0.42	11.4	11.7	11.5	0.14	0.13	0.14	3.9	3.6	3.7
T_9	0.43	0.43	0.43	16.3	19.0	17.6	0.16	0.17	0.19	6.4	6.3	6.3
T_{10}	0.44	0.44	0.44	20.0	22.5	21.2	0.14	0.14	0.14	6.4	7.1	6.7
T_{11}	0.42	0.41	0.42	15.5	17.8	16.7	0.13	0.13	0.13	4.8	5.6	5.2
T_{12}	0.41	0.43	0.42	16.5	19.2	17.9	0.17	0.19	0.18	6.8	8.5	7.6
S.Em. ±	0.01	0.01	0.01	2.2	1.8	1.8	0.01	0.01	0.01	0.7	0.6	0.6
CD at 5%	0.02	0.02	0.02	6.8	5.5	5.6	0.02	0.01	0.02	2.3	1.9	1.9

followed by T_3 and T_{12} treatment.. Relatively higher P concentration in treatments receiving organic sources might be due to increase in microbial population by the addition of organic manures which solublize P and it is readily utilized by the plants. Among N treatments highest value of P concentration (0.19 percent) and uptake (7.8 kg ha^{-1}) was observed under T_9 followed by T_6 treatment. Among N treatments without P phosphorus concentration was highest in T_3 and T_6 and uptake was highest in T_5. Effect of N with P on P concentration was found highest under T_6 and T_{12} than all other treatments. In N with P the P uptake was highest (8.5 kg ha^{-1}) under T_{12} treatment. Phosphorus uptake in wheat grain and straw ranged from 3.4 to 11.9 (Table 2) and 1.6 to 7.8 kg ha^{-1} (Table 4), respectively. The variation in uptake of phosphorus by wheat grain and straw was significant and lowest P uptake was in control plot. This indicated that continuous cropping without fertilization led to depletion of soil P status. Application of P along with N had enhanced P uptake. Similar results were also reported by Dhillon and Dev (1988). In grain P uptake was highest in T_5 significantly followed by T_6 treatment. This might be due to highest grain yield in T_5 treatment and better P concentration in T_6 treatment. In N treatments with P highest P uptake by wheat straw was recorded in T_{12} while in N treatments without P it was highest under T_5. This could be due to difference in straw yield in these two treatments. Combined application of N with P and without P gave highest P uptake under T_6 treatment where 50% N was applied

Table 5. Effect of various long-term treatments on potassium, sulphur concentration (%) & uptake (kg ha^{-1}) in wheat straw.

Treatment	K conc. (Straw)		Mean	K uptake (Straw)		Mean	S conc. (Straw)		Mean	S uptake (Straw)		Mean
	P_0	P_{40}		P_0	P_{40}		P_0	P_{40}		P_0	P_{40}	
T_1	0.38	0.38	0.38	7.7	6.8	7.2	0.08	0.10	0.09	1.6	1.7	1.7
T_2	0.44	0.43	0.43	16.9	16.8	16.8	0.10	0.10	0.10	4.0	3.8	3.9
T_3	0.56	0.55	0.55	14.1	21.5	17.8	0.10	0.11	0.10	3.1	4.8	3.9
T_4	0.50	0.50	0.49	25.4	21.4	23.4	0.10	0.11	0.10	4.9	4.6	4.7
T_5	0.52	0.53	0.52	25.5	23.1	24.3	0.12	0.12	0.12	4.7	4.4	4.6
T_6	0.52	0.54	0.53	20.8	19.9	20.4	0.11	0.11	0.11	4.2	4.0	4.1
T_7	0.51	0.51	0.51	28.1	20.0	24.1	0.11	0.11	0.11	6.2	4.5	5.3
T_8	0.40	0.37	0.39	10.6	10.4	10.5	0.11	0.11	0.11	2.9	3.0	3.0
T_9	0.39	0.40	0.40	15.1	17.5	16.3	0.10	0.10	0.10	3.9	4.6	4.2
T_{10}	0.41	0.36	0.39	17.7	18.1	17.9	0.11	0.10	0.10	4.8	5.3	5.0
T_{11}	0.41	0.40	0.41	15.3	17.1	16.2	0.11	0.10	0.10	3.9	4.4	4.1
T_{12}	0.69	0.70	0.69	27.4	31.0	29.2	0.11	0.11	0.11	4.3	4.9	4.6
S.Em. ±	0.01	0.01	0.01	2.2	1.8	1.8	0.01	0.01	0.01	0.5	0.4	0.44
CD at 5%	0.04	0.02	0.04	6.9	5.6	5.6	0.01	0.01	0.01	1.6	1.2	1.4

through urea and 50 % through FYM in *kharif* and 100% N through urea in *rabi* season followed by T_{12}. The increased uptake of P in FYM treated plots may be due to the better availability and conservation of nutrients and better physical condition which increased the yield and ultimately lead to high P absorption. Similar findings were reported by Lal and Mathur (1989).

Potassium Concentration and Uptake in Wheat Grain & Straw

Potassium concentration of wheat grain and straw ranged from 0.42 to 0.84 (Table 3) and 0.39 to 0. 69 percent (Table 5), respectively. The K concentration in grain and straw was highest in T_{12} where 100 percent NPK through fertilizers was applied in *kharif* as well as *rabi* season followed by the T_3 treatment. This might be due to the addition of potassium through fertilizer in to the soil. This could be due to significantly higher K availability in the T_{12} receiving K fertilization which might have resulted in its better absorption by wheat plant. Bajwa and Paul (1978) also reported similar results. K concentration was the lowest in control plot. This could be due to continuous cropping without fertilization and manuring. In the absence of potash fertilization, the concentration of potassium in plants declined (Chakravorty *et al.* 1987). Potassium uptake in wheat grain and straw ranged from 5.5 to 21.3 (Table 3) and 7.2 to 29.2 kg ha^{-1} (Table 5), respectively and the lowest K uptake was in control plot. This might be due to no use of fertilizers and manure which results low yield in control plot. In N treatments with P highest K uptake by wheat straw was recorded in T_{12} while in N treatments without P it was highest under T_7 . This could be due to the difference in straw yield in these two treatments. The combined application of N with P and without P in grain as well as in wheat straw gave highest K uptake in T_{12} treatment (where 100% NPK was applied) followed by T_5. This is due to relatively high K concentration in wheat plant in these treatments. Chakravorty *et al*. (1987) reported that K application resulted in higher K uptake by wheat as compared with no K treatment. The results were also similar with the findings of Singh and Singh (1998).

Sulphur concentration and uptake in wheat grain and straw

The sulphur concentration of wheat grain and straw ranged from 0.11 to 0.17 (Table 3) and 0.09 to 0.12 percent (Table 5), respectively. Relatively higher concentration of S was recorded in wheat grain than in wheat straw. It was because S plays a significant role in protein synthesis in grain as it is constituent of three essential amino acids namely, cystine, cysteine, and methionine. It also provides disulphide bonds (-S-S-) linking polypeptide helping in protein formation (Allaway and Thompson, 1966). In grain highest concentration of S was found under T_{10} followed by T_8 while in straw it was highest under T_5 followed by T_6, T_7, T_8 and T_{12}. Application of P had significant effect on S concentration in grain as well as in straw. This might be due to addition of sulphur

Table 6. Relationship between soil properties and plant parameters

Soil properties / Plant parameters	pH	EC	Organic carbon	Cation exchange capacity	Alkaline $KMnO_4$-N	Olsen's P	Amm. acetate-K	$CaCl_2$ extractable-S
No. of tillers	0.139 ns	0.628**	0.485*	0.114 ns	0.616**	0.451*	0.608**	0.543**
Plant height	0.348 ns	0.537**	0.466*	0.139 ns	0.618**	0.228 ns	0.296ns	0.487*
N conc. in Grain	0.282 ns	0.659**	0.628**	0.657**	0.678**	0.494*	0.409*	0.578*
N conc. in Straw	0.409*	0.435*	0.525**	0.623**	0.510*	0.327 ns	0.425*	0.480*
P conc. in Grain	0.321 ns	0.764**	0.758**	0.703**	0.716**	0.672**	0.648**	0.854**
P conc. in Straw	0.426*	0.079 ns	0.246 ns	0.388 ns	0.015 ns	0.214 ns	0.530**	0.185 ns
K conc. in Grain	0.474*	-0.138 ns	0.106 ns	-0.034 ns	-0.370 ns	0.025 ns	0.612**	-0.083 ns
K conc. in Straw	0.446*	-0.195 ns	0.155 ns	0.073 ns	-0.317 ns	-0.068 ns	0.580**	-0.075 ns
S conc. in Grain	-0.075 ns	0.814**	0.619**	0.408*	0.806**	0.545**	0.428*	0.770**
S conc. in Straw	0.367 ns	0.231 ns	0.369 ns	0.366 ns	0.352 ns	0.198 ns	0.387 ns	0.256 ns
Grain yield 2008-09	0.325 ns	0.422*	0.463*	0.311 ns	0.424*	0.487*	0.380 ns	0.359 ns
Straw yield 2008-09	0.424*	0.508*	0.490*	0.195 ns	0.426*	0.326 ns	0.435*	0.405*
Grain yield 2009-10	0.526**	0.484*	0.605**	0.459*	0.572**	0.461*	0.578**	0.487*
Straw yield 2009-10	0.600**	0.549**	0.623**	0.434*	0.472*	0.437*	0.623**	0.498*

*Significant at 5% level; **Significant at 1% level

in soil through organic manures and S bearing phosphate fertilizers. This result is in conformity with that reported by Yogendra Pal (1991). Sulphur uptake by wheat grain and straw ranged from 1.3 to 4.4 and 1.7 to 5.3 kg ha^{-1} (Table 3 & 6), respectively. In N treatments without P highest sulphur uptake by wheat grain and wheat straw was recorded under T_5 and T_7, respectively while in N treatments with P it was highest under T_{10}. This could be due to difference in yield and concentration in these treatments. The combined application of N with P and without P in grain as well as in wheat straw gave highest S uptake in T_5 and T_7 treatments (where 50% and 25% of nitrogen was replaced by the addition of FYM, respectively). Addition of FYM and crop residue resulted significant increase in uptake of sulphur in wheat grain and straw. This may be attributed to higher yield due to addition of nitrogen

through urea and organic manure. Phosphorus application also enhanced sulphur uptake in wheat grain and straw. Similar result was observed by Setia *et al*. (2004). The lowest S uptake was recorded in control plots. The reduction in sulphur uptake under control was associated with the decline in available sulphur of the soil as a result of continuous cropping without fertilizer and manure application. This result was in agreement with the sulphur uptake by wheat noticed at Jabalpur (Nambiar and Abrol, 1989) and Pantnagar (Tiwari et al. 1995) under long term experiments.

Correlation studies between Soil Properties and Plant Parameters

The correlation among various soil parameters and plant parameters studied in the experiment are shown in Table 6. Nitrogen concentration in straw, K concentration in grain as well as in straw and straw yield of year 2008-09 were positively and significantly correlated with the soil pH at 5% level and the correlation of grain and straw yields of year 2009-10 was positive and highly significant with pH (at 1% level). Electrical conductivity of soil had positive correlation with number of tillers, plant height, N concentration in grain, P concentration in grain, S concentration in grain and straw yield of year 2009-10 at 1% level. The N concentration in straw, grain yield of year 2008-09 and 2009-10 and straw yield of year 2008-09 recorded 5% level of positive and significant correlations with soil EC. Soil organic carbon had positive correlation with N, P and S concentration in grain, N concentration in straw, grain and straw yield of year 2009-10 significant at 1% level while at 5% level of significant correlation of tiller number, plant height and grain and straw yield of year 2008-09 with soil organic carbon was observed. Correlation of cation exchange capacity with N concentration in grain and in straw, P concentration in grain was positive and highly significant (at 1% level). The S concentration in grain and grain and straw yield of year 2009-10 were positively and significantly correlated with cation exchange capacity at 5% level. Correlation of available nutrients in soil with number of tillers, plant height, and concentration of nutrients in plant and the grain and straw yield was partially significant. Crop yield of year 2009-10 was found better correlated with the availability of nutrients in the soil. This may probably be due to the yield trend of the year was found more consistent with the treatment applied as mentioned earlier. Biswas *et al.* (1971), Gattani *et al.* (1976) reported similar results.

Conclusion

Continuous use of FYM and crop residues in partial replacement of fertilizer nitrogen significantly improved plant growth and yield and also increment of N dose through urea (particularly in the T_3 and T_5-treatments) also had significant effect on, plant growth and yield. *Moong* straw proved to be the best among organic sources of N studied in respect of its effect on yield. K concentration and uptake in wheat was highest under T_{12} treatment where 100% NPK was applied through fertilizers in both *kharif* and *rabi* season.

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