



P-ISSN: 2349-8528

E-ISSN: 2321-4902

IJCS 2019; 7(6): 437-443

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Received: 28-09-2019

Accepted: 30-10-2019

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Effect of organic and inorganic fertilizers on plant uptake, protein synthesis and productivity of pearl millet-wheat sequence under semi-arid inceptisols

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Abstract

Field experiments were conducted to test the effect of 12 fertilizer treatments comprising of organic and inorganic fertilizer doses on productivity of pearl millet – wheat sequence under semi-arid Inceptisols at Agra during 2008 and 2009. The treatments tested were T1: Control; T2: 100% recommended dose of fertilizer (RDF) N; T3: 100% RDF NP; T4: 100% RDF NPK; T5: 100% RDF N + ZnSO₄ @ 25 kg/ha; T6: 100% RDF N + FYM @ 10 t/ha; T7: 100% RDF N + vermicompost @ 2.5 t/ha; T8: 100% RDF N + Sulphur @ 25 kg/ha; T9: FYM 10 t/ha; T10: Vermicompost @ 2.5 t/ha; T11: 100% RDF NPK + FYM @ 10 t + S @ 25 kg + ZnSO₄ @ 25 kg/ha; and T12: 150% RDF NPK. The treatments were assessed for different yield attributes, plant uptake of nutrients, grain yield and protein parameters. The analysis of variance indicated that the treatments had a significant effect on different parameters studied in both pearl millet and wheat crops. The treatments had a significant effect on the yield of crops in both years. The quality of crops in respect of protein, N, P and K uptake increased significantly with the conjoint use of organic manures and inorganic fertilizers. Maximum plant uptake of nutrients, grain yield and protein of crops could be attained with the application of balanced use of organic and inorganic fertilizers. Ranks were assigned to treatments for their performance for different parameters over years. The cumulative rank sum of treatments for different parameters indicated that T11: 100% RDF NPK + FYM @ 10 t/ha + ZnSO₄ @ 25 kg/ha + S @ 25 kg/ha was superior with lowest rank sum, followed by T12: 150% RDF NPK for attaining maximum yield, plant uptake, protein and yield attributes under semi-arid Inceptisols.

Keywords: Pearl millet-wheat system, vermicompost, plant uptake, protein, productivity, nutrient management

Introduction

Under dryland conditions, apart from rainfall and its distribution, the crop yields could be significantly influenced by application of optimum fertilizer doses based on organic and inorganic sources of fertilizers. Pearl millet - wheat sequence is an important cropping system adopted by farmers under rainfed conditions in many states of north India. Pearl millet is predominantly grown in Uttar Pradesh, Haryana, Punjab, Gujarat and other states. During 2010-11, pearl millet was grown in an area of 8.9 million hectares with production of 6.51 million tons and productivity of 731 kg/ha, while wheat was grown in an area of 28.46 million hectares, with production of 80.8 million tons and productivity of 2839 kg/ha (IASRI, 2012). The system being exhaustive for soil nutrients, replenishment of nutrients on regular basis becomes an important aspect for sustaining the crop yields in the long-term period. Research in India has indicated integrated use of organic and inorganic manures for sustaining the productivity of soils and crops in an intensive cropping system. Application of farm yard manure (FYM) would help in increasing the native fertility of the soil as well as the physical condition including its water holding capacity. If the soil fertility of nutrients is increased, the availability of nutrients to a crop is increased. The organic manures, which were perhaps the major sources of plant nutrients in traditional agriculture received lower importance with the advent of chemical fertilizers. Without detracting from the fact that chemical fertilizers will continue to be the main source for increasing the crop productivity and over-all production in the country, there is a need for use of organic fertilizers for yield stability and improvement in the soil health.

The recent research work on different rainfed crops indicated that a judicious Combination of organic manures and fertilizers would better maintain the soil fertility and soil health for a longer period apart from sustaining maximum levels of productivity (Sharma *et al.*, 2010, 2011 and 2013)^[10]. It is necessary that use of both organic and inorganic fertilizers in appropriate proportion assumes special importance as complementary and supplementary to each other in crop production. Nema *et al.*, (2008) assessed the effect of tillage and fertilizer treatments for attaining maximum yield and profitability from pearl millet in semi-arid Inceptisols. In a paper by Maruthi Sankar *et al.*, (2012)^[9], the authors have described about assessing the organic and inorganic fertilizer treatments for attaining sustainable productivity of pearl millet under different soil and agro-climatic conditions. The present study was conducted to assess and identify a suitable integrated nutrient management practice for pearl millet-wheat sequence system for attaining maximum yield, plant uptake and protein under semi-arid Inceptisols.

Materials and Methods

Experimental details

Two field experiments were conducted on pearl millet-wheat sequence system during 2008 and 2009 at Agra in Uttar Pradesh under semi-arid Inceptisols. The study was conducted with 12 treatments of organic (FYM and vermicompost) and inorganic fertilizers (N, P, K, Sulphur and Zinc) with the objective of identifying an efficient treatment for attaining maximum yield and protein of crops. The soil is a sandy loam which is low in available nitrogen, phosphorus and potassium. The experiments were conducted in a Randomized Block Design with three replications by taking pearl millet (86-M-52) in *kharif* and wheat (HD-2338) in *rabi* season. Twelve treatments were tested in the study viz., T1: Control; T2: 100% recommended dose of fertilizer N; T3: 100% recommended dose of fertilizer NP; T4: 100% recommended dose of fertilizer NPK; T5: 100% recommended dose of fertilizer N + ZnSO₄ @ 25 kg/ha; T6: 100% recommended dose of fertilizer N + FYM @ 10 t/ha; T7: 100% recommended dose of fertilizer N + vermicompost @ 2.5 t/ha; T8: 100% recommended dose of fertilizer N + Sulphur @ 25 kg/ha; T9: FYM 10 t/ha; T10: Vermicompost @ 2.5 t/ha; T11: 100% recommended dose of fertilizer NPK + FYM @ 10 t + S @ 25 kg + ZnSO₄ @ 25 kg/ha; and T12: 150% recommended dose of fertilizer NPK.

Nitrogen was applied in the form of urea as per the doses in each treatment. Single super phosphate and muriate of potash were the sources for P₂O₅ and K₂O fertilizer respectively. The recommended dose of fertilizer 120-60-60 kg/ha of NPK was applied for pearl millet, 120-80-60 kg/ha of NPK for wheat in each year. Full quantities of phosphorus and potassium fertilizers were applied as basal at the time of sowing. In case of nitrogen, 50% of N was applied as basal dose, while the remaining 50% N was applied in two splits at first and second irrigation. Sulphur and zinc were applied at the time of sowing through elemental sulphur and zinc sulphate (ZnSO₄) respectively. Well decomposed FYM (0.6 % N, 2.5% P and 0.55% K) and vermicompost (1.15% N, 0.86% P and 0.60% K) were applied to the plots as per treatments at 10 days prior to the sowing of crops. Seeds of pearl millet variety 86-M-52 were sown in lines at 30 cm apart using an uniform seed rate of 5 kg/ha in July in both years. The seeds of wheat variety HD 2338 were sown in lines at 20 cm apart, using uniform seed rate @125 kg/ha in November in both years. The lines

were opened through pointed spade by human labor. After sowing, planking was done to cover the seed. In pearl millet, observations were recorded on (i) number of shoots/meter row length; (ii) plant height (cm); (iii) dry matter/plant (g); (iv) grain weight/ear head (g); (v) ear length (cm); (vi) 1000 grain weight (g); (vii) grain yield (kg/ha); and (viii) straw yield (kg/ha). In wheat, observations were recorded on (i) number of shoots/meter row length; (ii) plant height (cm); (iii) dry matter/plant (g); (iv) grain weight/ear head (g); (v) ear length (cm); (vi) 1000 grain weight (g); (vii) grain yield (kg/ha); and (viii) straw yield (kg/ha). Apart from the above parameters, observations were also recorded on protein synthesis (kg/ha), plant uptake of N, P and K nutrients (kg/ha) in grain and straw in pearl millet and wheat crops.

Statistical analysis

The observations recorded on different parameters were analyzed as per standard analysis of variance (Gomez and Gomez, 1984)^[5]. The treatments were compared based on Least Significant Difference (LSD) criteria at $p < 0.05$ level of significance and superior treatments were identified. Ranks were assigned to different treatments for their mean performance for yield, protein, plant uptake and other traits recorded in pearl millet and wheat crops during two years. Based on the rank sum of treatments, a superior treatment with lowest rank sum was identified for each crop for attaining maximum yield, plant uptake of nutrients, protein and yield attributes over years.

Results and Discussion

Effect of fertilizer treatments on growth characteristics of pearl millet

Based on the observations recorded in two years, the mean number of shoots/m row length ranged from 15.5 to 26.9, while plant height ranged from 195.7 to 218.6 cm. The mean dry matter/plant ranged from 42.7 to 56.0 g, while grain weight/ear head range from 8.1 to 15.4 g. The mean ear length ranged from 16.6 to 26.4 cm, while 1000-grain weight ranged from 7.4 to 12.6 g. The mean grain yield ranged from 18.5 to 29.4 q/ha, while straw yield ranged from 206.0 to 239.8 q/ha over two years as given in Table 1. Based on the analysis of variance, the treatments had a significant effect on the number of plants/meter, plant height and dry matter accumulation. Application of FYM @ 10 t/ha together with 100% NPK + Zn @ 25 kg + S @ 25 kg/ha gave significantly higher plant height, dry matter, grain weight and ear length in pearl millet. Application of 150% RDF NPK gave significantly higher number of shoots, 1000 grain weight, grain and straw yield. Similarly, the treatment vermicompost @ 2.5 t/ha along with 100% NPK fertilizer gave significantly higher number of shoots compared to control treatment. The increase in number of shoots may be attributed to the mineralization of FYM or through solubilization of nutrients from the native source during the process of decomposition which was in agreement with the findings of Gaur (1991)^[4]. The addition of FYM @ 10 t/ha or vermicompost @ 2.5 t/ha along with 100% NPK enhanced the plant height in pearl millet over 100% NPK treatment in both years. Three inorganic fertilizer treatments viz., 100% N, 100% NP and 100% NPK increased the dry matter significantly compared to control in both years. This improvement in the dry matter accumulation was due to higher availability of N, P and K nutrients in the soil. The dry matter accumulation was further enhanced when 100% NPK was applied in combination with FYM @ 10 t/ha or vermicompost @ 2.5 t/ha. This has increased the efficiency of

applied chemical fertilizers along with organic manures. An increase in the effective shoots with N, P and K fertilizers and FYM application was earlier reported by Sharma (1983)^[10]; Takchand and Tomar (1992)^[12] and Mandai *et al.*, (1994)^[7]. Our findings have converged with the results reported by these authors.

Effect of fertilizer treatments on yield attributes and yield of pearl millet

The mean effect of fertilizer treatments on the yield attributing characters viz. ear length, number of ear heads/running meter, weight of grains/ear head and 1000 grain weight are given in Table 1. The treatment differences in these yield attributing characters were found to be significant at $p < 0.05$ level. The control treatment gave lowest values of these characters in both years. Application of 100% N, 100% NP and 100% NPK significantly improved these characters compared to control. There was a significant difference between the NPK treatments in attaining these yield attributes. The yield attributes were significantly improved when 100% NPK was applied in combination with FYM @ 10 t/ha and 100% NPK + vermicompost @ 2.5 t/ha. Significantly higher values of these yield attributes were attained by T11: 100% NPK + FYM @ 10 t + S @ 25 kg +

ZnSO₄ @ 25 kg/ha in both seasons.

The grain and stover yield of pearl millet have significantly increased with application of 100% N, 100% NP and 100% NPK over control in both the crop seasons. Among treatments, 100% NPK was superior for grain and stover yield. The yield of pearl millet significantly increased with FYM @ 10 t/ha or vermicompost @ 2.5 t/ha application over control which was due to higher soil fertility of nutrients. The yield of pearl millet improved significantly when 100% NPK was applied together with vermicompost @ 2.5 t/ha compared to 100% NPK alone. The beneficial effect of FYM and vermicompost was due to the contribution in supplying additional plant nutrients, improvement of physical and biological processes in the soil. Similar results were also reported by Gangwar and Singh (1992)^[3] based on a study of nutrient management for fodder sorghum-chickpea sequence. The treatment T11: 100% NPK + FYM @ 10 t + S @ 25 kg + ZnSO₄ @ 25 kg/ha was superior with significantly higher yield compared to all treatments in both seasons. The highest yield of pearl millet was attained under this treatment due to the beneficial effect of FYM on soil properties and fertility status.

Table 1: Mean effect of fertilizer treatments on growth, yield attributing characters and yield of pearl millet (mean of 2 years).

Treatments	No. of shoot/m row length	Plant height (cm)	Dry matter/plant (g)	Grain weight/ ear head (g)	Ear length (cm)	1000-grain weight (g)	Grain yield (q/ha)	Straw yield (q/ha)
T1: Control	15.5	195.7	42.7	8.1	16.6	7.4	18.5	206.0
T2: 100% RDF N	19.5	198.4	45.5	9.1	17.8	10.3	21.0	220.5
T3: 100% RDF NP	20.7	200.2	47.3	10.6	19.1	11.0	22.1	224.6
T4: 100% RDF NPK	21.8	202.8	49.1	11.1	21.0	11.6	23.1	227.6
T5: 100% RDF NPK + ZnSO ₄ @ 25 kg/ha	23.2	207.1	50.5	12.9	21.5	11.9	23.8	228.2
T6: 100% RDF NPK + FYM @ 10 t/ha	23.4	208.3	53.6	14.0	23.0	12.3	25.3	231.7
T7: 100% RDF NPK+ VC@ 2.5 t/ha	23.7	206.9	52.9	14.1	24.0	12.5	27.2	234.2
T8: 100% RDF NPK + S @ 25 kg/ha	22.6	205.0	50.2	12.2	22.2	11.5	25.5	232.3
T9: FYM @ 10 t/ha	20.3	201.7	44.4	14.5	24.4	11.3	23.3	231.1
T10: Vermicompost @ 2.5 t/ha	20.5	201.4	44.9	14.0	24.0	11.8	24.7	232.9
T11: 100% RDF NPK + FYM @ 10 t/ha + ZnSO ₄ @ 25 kg/ha + S @ 25 kg/ha	26.3	218.6	56.0	15.4	26.4	12.2	28.9	238.5
T12: 150% RDF NPK	26.9	217.9	55.4	13.4	24.8	12.6	29.4	239.8
SEm (±)	1.3	1.9	1.5	0.3	0.8	0.9	0.6	2.0
LSD ($p < 0.05$)	2.6	3.9	3.2	0.6	1.8	1.6	1.3	4.1

VC: Vermicompost FYM: Farm yard manure LSD: Least significant difference SEM: Standard error of mean RDF: Recommended dose of fertilizer

Effect of fertilizer treatments on growth parameters of wheat

In wheat, the mean number of shoots/meter row length ranged from 74.0 to 131.5, while plant height ranged from 71.1 to 86.6 cm. The mean dry matter/plant ranged from 47.6 to 59.9 g, while grain weight/ear head ranged from 2.7 to 3.4 g. The mean ear length ranged from 41.9 to 66.7 cm, while 1000-grain weight ranged from 30 to 38.1 g. The mean grain yield ranged from 28.7 to 52.1 q/ha, while straw yield ranged from 39.9 to 72.2 q/ha over two years as given in Table 2. Application of NPK levels showed a positive effect on the number of tillers, plant height and dry matter production at all the stages of growth as given in Table 2. Application of FYM and vermicompost along with inorganic fertilizers increased the plant growth at each stage over the control. The increase in number of tillers was due to an increase in the availability of nutrients in the soil due to addition of FYM. Similar results were reported by Gaur (1991)^[4] and Singh *et al.*, (1994)^[13].

Application 100% NPK in conjunction with ZnSO₄ and sulphur produced more number of tillers and dry matter over control. Application of 100% NPK + FYM @ 10 t/ha gave maximum plant height at all the growth stages in both the cropping seasons. The increase in plant height was due to higher availability of nutrients in soil with combined application of chemical fertilizer and FYM. These results are in close conformity with the findings made by Sharma (1983)^[10].

Application of 100% NPK along with vermicompost @ 2.5 t/ha gave taller plants over 100% NPK alone but the magnitude of increase in this parameter was more or less similar to FYM application. It may be seen from the data that the accumulation of dry matter took place at a slower rate up to maximum tillering stages in wheat. The dry matter got accumulated continuously and almost linearly up to maturity of the crops irrespective of the treatment effect. During the early growth period, roots were not well established and the

leaves were not able to produce enough food material. Thus the initial rate of dry matter accumulation was slow. The differences in the dry matter accumulation in wheat due to different treatments were quite visible after maximum tillering stages. Application of inorganic fertilizers (100% N, 100% NP and 100% NPK) increased the dry matter in both years of study. This improvement in dry matter accumulation was due to higher availability of N, P and K nutrients in the soil. The dry matter accumulation was further enhanced when 100% NPK was applied in combination with FYM @ 10 t/ha in both crop seasons. This could have increased the efficiency of applied chemical fertilizers through FYM application. The increase in dry matter production with the application of fertilizers and FYM was also indicated earlier by Takchand and Tomar (1992) [12]. Application of vermicompost @ 2.5 t/ha along with 100% NPK has also enhanced the dry matter production of wheat over 100% NPK which was due to an increased availability of sulphur to the plants. Application of FYM @ 10 t/ha or vermicompost @ 2.5 t/ha alone increased the dry matter favorably from an early stage. These differences were further enlarged at the successive stages. The increase in dry matter accumulation in wheat as a result of organic manure application was due to higher availability of essential plant nutrients and improvement in the physico-chemical properties of the soil. Similar results of increase in the dry matter accumulation with FYM application was earlier reported by Negi *et al.*, (1988) [8] and Singh *et al.*, (1994) [13].

Effect of fertilizer treatments on yield attributes and yield of wheat

Application of different levels of NPK fertilizers enhanced the percentage of yield attributes but the effect of higher level of NPK was more pronounced. Application of ZnSO₄ and sulphur along with 100% NPK improved the yield attributes compared to control. The integrated use of fertilizers with FYM and vermicompost was proved to be more beneficial in respect of yield attributing characters. Maximum effect on yield attributes was observed in the plots which received 150% NPK fertilizer. Application of NPK fertilizers improved the grain and straw yields significantly over control. Application of FYM @ 10 t/ha and vermicompost @ 2.5 t/ha significantly improved the grain and straw yield of wheat compared to control. The combined use of inorganic fertilizers, FYM and vermicompost produced significantly higher grain and straw yields of wheat. The mean increase in grain yield due to FYM @ 10 t/ha or vermicompost @ 2.5 t/ha over control were 28.0 and 26.2% respectively. The combined application of NPK fertilizers, ZnSO₄ and sulphur was found to significantly increase the wheat yield. Similar influence of integrated use of FYM and chemical fertilizers on yield of crops like rice, wheat and maize were reported by Gaur (1991) [4]. Mandai *et al.*, (1994) [7] observed that the presence of easily decomposable organic residues helped in the re-mineralization of immobilized inorganic nitrogen, which was subsequently made available to the plants for a longer period. Similar synergetic influences of manures and inorganic fertilizers on the crop yield were also reported by Verma (1996) [15] and Singh *et al.*, (1996) [11].

Table 2: Mean effect of fertilizer treatments on growth, yield attributing characters and yield of wheat (mean of 2 years).

Treatments	No. of effective tillers/ m	Plant height (cm)	Dry matter /plant (g)	Grain weight/ ear head (g)	No. of grains/ ear head	1000-grain weight (g)	Grain yield (q/ha)	Straw yield (q/ha)
T1:Control	74.0	71.1	47.6	3.1	41.9	30.0	28.7	39.9
T2:100% RDF N	93.4	78.0	52.2	3.2	47.8	32.0	36.3	49.9
T3:100% RDF NP	97.9	78.8	55.1	3.2	50.1	32.7	37.7	51.9
T4:100% RDF NPK	105.9	81.1	56.2	3.3	54.3	34.0	40.5	55.8
T5:100% RDF NPK + ZnSO ₄ @ 25 kg/ha	107.6	81.6	57.2	3.3	55.1	33.6	43.4	59.4
T6:100% RDF NPK + FYM @ 10 t/ha	118.7	82.8	59.9	3.3	59.6	34.8	47.6	66.5
T7:100% RDF NPK+ VC @ 2.5 t/ha	123.4	84.3	50.4	3.3	60.2	37.3	47.5	66.4
T8:100% RDF NPK+S@25 kg/ha	117.1	82.9	57.0	3.2	55.8	37.1	44.4	59.8
T9:FYM@10 t/ha	119.4	83.6	50.7	2.7	54.2	32.7	36.8	49.1
T10:Vermicom-post @ 2.5 t/ha	118.9	82.4	49.6	3.2	54.8	32.7	36.3	48.4
T11:100% RDF NPK + FYM @ 10 t/ha + ZnSO ₄ @ 25 kg/ha + S@ 25 kg/ha	130.7	86.6	56.4	3.4	66.5	38.1	52.1	72.2
T12:150% RDF NPK	131.5	86.0	59.7	3.4	66.7	37.9	50.5	70.2
SEm (±)	1.5	1.6	1.5	0.1	0.2	0.2	0.6	1.6
LSD (p<0.05)	3.1	3.2	3.1	0.1	0.7	0.4	1.2	3.2

Effect of fertilizer treatments on the qualitative parameters

In pearl millet, the mean protein synthesis ranged from 144.9 to 305.3 kg/ha. The mean N uptake by grain ranged from 23.2 to 48.9 kg/ha, while P uptake by grain ranged from 3.6 to 9.2 kg/ha and K uptake by grain ranged from 12.5 to 26.3 kg/ha. Similarly, the mean N uptake by straw ranged from 110.2 to 176.7 kg/ha, while the P uptake by straw ranged from 23.7 to 45.4 kg/ha, and K uptake by straw ranged from 346.1 to 495.5 kg/ha over years. In wheat, the mean protein synthesis ranged from 313.3 to 763.5 kg/ha. The mean N uptake by grain ranged from 42.4 to 90.9 kg/ha, while P uptake by grain ranged from 5.9 to 13.8 kg/ha and K uptake by grain ranged from 14.1 to 30.1 kg/ha. The N uptake by straw ranged from

24.5 to 56.4 kg/ha, while P uptake by straw ranged from 4.6 to 11.9 kg/ha and K uptake by straw ranged from 82.5 to 158.2 kg/ha over years.

From the quality point of view, T11:100% RDF NPK + FYM @ 10 t/ha + ZnSO₄ @ 25 kg/ha + S@ 25 kg/ha was found to be superior. Application of N, NP and NPK alone or in combination with FYM and vermicompost have significantly improved the protein yield (Table 3 and 4) in both pearl millet and wheat crops. The integrated use of nutrients (100% NPK + ZnSO₄ or sulphur) has significantly increased the protein yield synergistically. The maximum protein yield of wheat crop was attained with application of T11:100% RDF NPK + FYM @ 10 t/ha + ZnSO₄ @ 25 kg/ha + S@ 25 kg/ha treatment in both the seasons.

Table 3: Mean effect of fertilizer treatments on protein synthesis, N, P and K uptake by pearl millet (mean 2 years)

Treatments	Protein synthesis (kg/ha)	Grain uptake (kg/ha)			Straw uptake (kg/ha)		
		N	P	K	N	P	K
T1: Control	144.9	23.2	3.6	12.5	110.2	23.7	346.1
T2: 100% RDF N	193.8	31.0	4.4	15.9	134.8	28.7	379.0
T3: 100% RDF NP	206.2	33.0	5.2	16.0	146.0	32.6	390.9
T4: 100% RDF NPK	226.2	36.2	5.9	18.1	152.5	35.3	407.5
T5: 100% RDF NPK + ZnSO ₄ @ 25 kg/ha	231.6	37.1	5.8	17.4	156.9	35.3	398.0
T6: 100% RDF NPK + FYM @ 10 t/ha	278.6	44.6	8.2	23.3	166.8	42.3	467.5
T7: 100% RDF NPK+ VC@ 2.5 t/ha	281.9	45.1	8.5	23.7	168.9	39.9	471.4
T8: 100% RDF NPK + S @ 25 kg/ha	235.8	37.7	6.1	17.7	152.8	37.9	407.9
T9: FYM @ 10 t/ha	215.3	34.5	5.6	16.5	141.4	32.8	397.2
T10: Vermicompost @ 2.5 t/ha	220.1	35.2	5.9	17.0	144.1	35.2	399.4
T11: 100% RDF NPK + FYM @ 10 t/ha + ZnSO ₄ @ 25 kg/ha + S@ 25 kg/ha	305.3	48.9	8.8	26.3	174.9	44.3	487.5
T12: 150% RDF NPK	303.6	48.6	9.2	26.3	176.7	45.4	495.5
<i>SEm</i> (\pm)	8.0	1.5	0.3	0.8	3.8	0.6	2.7
LSD ($p < 0.05$)	16.7	3.1	0.7	1.8	8.4	1.2	5.7

The protein yield increased significantly with addition of NPK fertilizers. Application of 150% NPK showed significantly higher protein yield over 100% NPK application in both seasons. The yield of protein was maximum at 100% NPK and FYM @ 10 t/ha + ZnSO₄ @ 25 kg + Sulphur @ 25 kg/ha. This increase in protein yield could be attributed to higher productivity of crop and improvement in the protein percentage. Gangwar and Singh (1992) [3] observed that inorganic fertilizer NPK significantly influenced the crude protein in their study.

Application of 100% N, 100% NP and 100% NPK has improved the utilization of N and P over control. Application of FYM and vermicompost alone or in combination with 100% NPK have also enhanced the uptake of N and P significantly over control. Similarly, 100% NPK + 25 kg S/ha improved the utilization of these nutrients by the crop. This increase in nitrogen uptake may be attributed to higher grain production with organic matter addition. Similar results were reported by Dahiya *et al.*, (1998) and Singh *et al.*, (1994) [11]. The uptake of N increased significantly over control with increasing levels of NPK fertilizers in both the years. Addition of FYM @ 10 t/ha increased the uptake of phosphorus which increased the productivity and improvement in P content of the crop. Similar results were also reported by Singh *et al.*, (1994) [13]. Combined application of 100% NPK (50 and 75%) fertilizers increased the uptake of P by the pearl millet crop. These results are in close conformity with the findings of Tekchand and Tomar (1992) [12], Jana and Ghosh (1996) [6], Singh *et al.*, (1996) [11] and Santhy *et al.*, (1998) [9]. Significantly higher uptake values were attained by 150% NPK treatment. The uptake K was improved significantly by all the fertilizer treatments compared to control. Combined application of 100% NPK with FYM @ 10 t/ha or vermicompost @ 2.5 t/ha or ZnSO₄ @ 25 kg/ha or S @ 25 kg/ha increased the uptake of K by the crops significantly over 100% NPK alone. The higher uptake was due to higher yields of crop attained in the treated plots. The organic manures besides being a source of major

nutrients supplied the micronutrients as well. Similar results were also reported by Singh and Tomar (1991) [12] in their study on effect of K and FYM levels on yield and uptake of nutrients in wheat. The maximum values of K were observed under T11: 100% RDF NPK + FYM @ 10 t/ha + ZnSO₄ @ 25 kg/ha + S@ 25 kg/ha treatment compared to other treatments. The grain portion of wheat consumed more N and P than straw. Application of 100% N, 100% NP and 100% NPK significantly enhanced the N and P uptake over control but the magnitude of increase was higher with 100% NPK as given in Table 4. The combined application of NPK + Zn and NPK + Sulphur has also improved the utilization of N and P but the effect was statistically non-significant. Application of FYM and vermicompost alone or in combination with 100% NPK enhanced the N and P uptake by the wheat crop significantly compared to NPK alone. Higher values of N uptake with addition of FYM and vermicompost were due to favorable effect of FYM on absorption. Higher uptake of N under these treatments with FYM indicated that mineralized N from FYM and vermicompost could sufficiently meet the nutritional requirement of the crop. Similar results were also reported by Dahiya *et al.*, (1980) for pearl millet and Singh *et al.*, (1994) [13] for Egyptian clover based on the nutrient management studies. Maximum N and P uptake were attained with application of 150% NPK in both seasons. Application of NPK along with FYM and vermicompost have also significantly increased the uptake of P in wheat in both seasons. Similar results were also reported for wheat by Tekchand and Tomar (1992) [12] and rice-wheat system by Singh *et al.*, (1996) [11]. This increase in P uptake with addition of FYM @ 10 t/ha was significantly higher over control. This was due to more availability of P from applied FYM and to the solubility action of organic acids produced during the degradation of organic material. This resulted in a higher release of the native and applied P in the soil. Dahiya *et al.*, (1980) reported that the addition of organic manures have increased the P uptake in grain of pearl millet based on an integrated nutrient management study.

Table 4: Mean effect of fertilizer treatments on protein synthesis, N, P and K uptake by wheat (mean of 2 years).

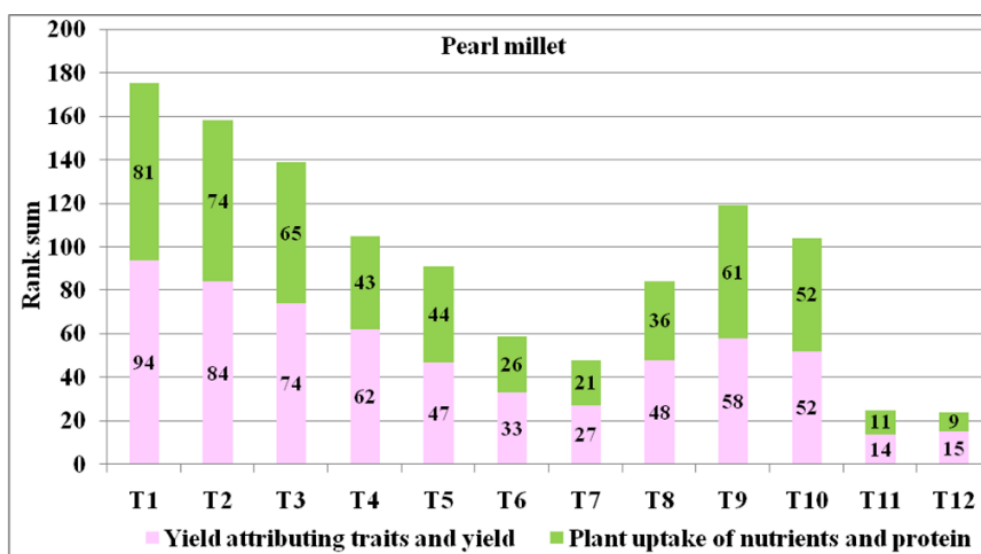
Treatments	Protein synthesis (kg/ha)	Grain uptake (kg/ha)			Straw uptake (kg/ha)		
		N	P	K	N	P	K
T1: Control	313.3	42.4	5.9	14.1	24.5	4.6	82.5
T2: 100% RDF N	500.2	58.5	7.8	18.1	34.4	6.2	104.0
T3: 100% RDF NP	525.0	62.5	9.1	18.9	36.9	7.5	109.1
T4: 100% RDF NPK	566.1	67.0	9.7	21.5	40.2	8.1	119.3
T5: 100% RDF NPK + ZnSO ₄ @ 25 kg/ha	621.3	73.1	9.1	21.3	44.0	7.4	122.9
T6: 100% RDF NPK + FYM @ 10 t/ha	690.9	82.8	12.6	26.4	51.3	10.7	144.1
T7: 100% RDF NPK+ VC @ 2.5 t/ha	697.7	83.7	12.6	26.6	51.8	11.0	144.5
T8: 100% RDF NPK + S @ 25 kg/ha	627.7	74.9	10.5	22.7	44.8	8.1	124.9
T9: FYM @ 10 t/ha	507.8	58.8	7.7	27.6	33.9	6.6	103.1
T10: Vermicompost @ 2.5 t/ha	505.3	58.3	8.0	18.3	33.4	7.0	101.2
T11: 100% RDF NPK + FYM @ 10 t/ha + ZnSO ₄ @ 25 kg/ha + S@ 25 kg/ha	763.5	90.9	13.8	30.0	56.4	11.9	158.2
T12: 150% RDF NPK	739.8	88.1	13.6	30.1	55.5	11.6	155.1
<i>SEM</i> (\pm)	9.0	2.7	0.8	1.6	2.8	0.7	4.4
<i>LSD</i> ($p < 0.05$)	19.0	5.7	1.7	3.4	5.8	1.5	9.3

Addition of chemical fertilizers was proved beneficial for improving the K uptake by wheat crop. The higher yields of grain and straw under 100% NPK coupled with FYM @ 10 t/ha or vermicompost @ 2.5 t/ha absorbed large quantities of K from the soil. This depleted the soil K consequently showing a higher uptake in plants. These results are in close conformity with the findings of Singh *et al.*, (1991)^[12].

Based on the ranks provided to the mean values of yield attributes, plant uptake of nutrients, yield and protein parameters in pearl millet and wheat in two years, rank sums were determined for each treatment in each crop. The rank sums of treatments are depicted in Fig. 1 for pearl millet and Fig. 2 for wheat crops. Among different treatments, T12: 150% RDF NPK attained minimum rank sum of 24, followed by T11: 100% RDF NPK + FYM @ 10 t/ha + ZnSO₄ @ 25 kg/ha + S@ 25 kg/ha with rank sum of 25, while T1: Control attained maximum rank sum of 175 in pearl millet. T11: 100% RDF NPK + FYM @ 10 t/ha + ZnSO₄ @ 25 kg/ha + S@ 25 kg/ha attained minimum rank sum of 22, followed by T12: 150% RDF NPK with rank sum of 26, while T1: Control attained maximum rank sum of 166 in wheat based on the study. Thus T11: 100% RDF NPK + FYM @ 10 t/ha +

ZnSO₄ @ 25 kg/ha + S@ 25 kg/ha was superior with the lowest rank sum of 47, while T12: 150% RDF NPK attained the next best rank sum of 50 for both pearl millet and wheat crops. T7: 100% RDF NPK+ VC @ 2.5 t/ha was the 3rd best treatment with rank sum of 102 comprising of 48 in pearl millet and 54 in wheat; while T6: 100% RDF NPK + FYM @ 10 t/ha was the 4th best treatment with rank sum of 117 comprising of 59 in pearl millet and 58 in wheat based on the study.

Based on the above results, we conclude that the combined application of organic manures and fertilizers had a significant effect in improving the productivity of crops. The productivity of wheat and pearl millet crops could be sustained by supplying balanced fertilizers based on the integrated use of organic manures and chemical fertilizers. The quality of both crops in respect of protein, N, P and K utilization have significantly increased with the conjoint use of organic manures and inorganic fertilizers. Since cereal-cereal cropping sequence has a high nutrient requirement, the integrated nutrient management approach will efficiently restore and sustain productivity and soil health besides meeting the nutritional deficiency under semi-arid Inceptisols.

**Fig 1:** Rank sum of treatments for yield attributing traits, plant uptake of nutrients, yield and protein in pearl millet

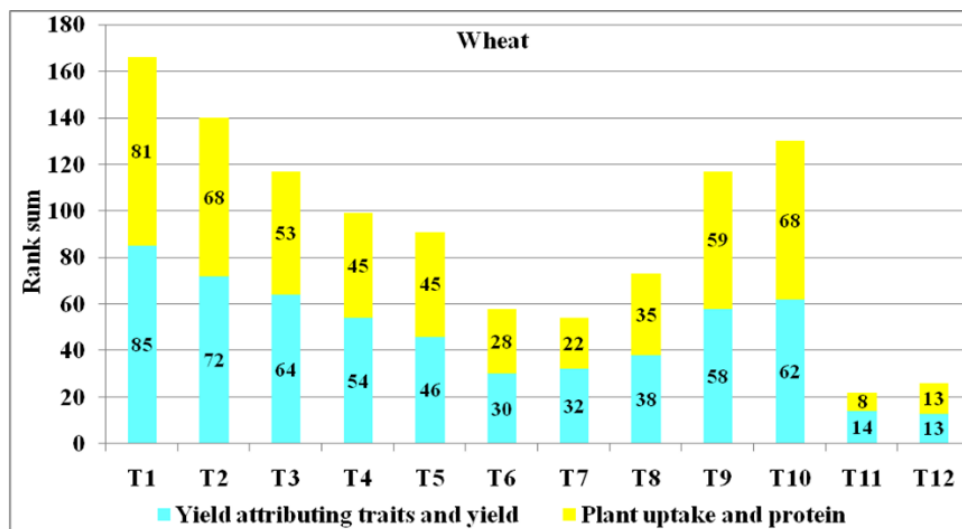


Fig 2: Rank sum of treatments for yield attributing traits, plant uptake of nutrients, yield and protein in wheat

Conclusions

Based on field experiments conducted with 12 fertilizer treatments to study their effect on productivity of pearl millet and wheat crops in a sequence during 2008 and 2009, superior treatments have been identified. The treatments were assessed for different yield attributes, plant uptake of nutrients, grain yield and protein in each year. The effects of fertilizer treatments on different parameters were tested based on analysis of variance. The treatments had a significant effect on the different parameters studied in pearl millet and wheat crops. The combined application of organic manures and fertilizers had a significant effect in improving the productivity of crops. The pearl millet and wheat yields could be sustained by supplying balanced fertilizers based on the integrated use of fertilizer through organic and inorganic sources. The quality of crops in respect of protein, and plant uptake of N, P and K have significantly increased with the conjoint use of organic and inorganic fertilizers. Based on the rank sum of treatments, T11: 100% RDF NPK + FYM @ 10 t/ha + ZnSO₄ @ 25 kg/ha + S@ 25 kg/ha was superior with minimum rank sum, while T12: 150% RDF NPK was the 2nd best treatment for attaining maximum yield, plant uptake, protein and yield attributes under semi-arid Inceptisols. Since cereal-cereal cropping sequence has a high nutrient requirement, the integrated nutrient management approach will efficiently restore and sustain productivity and soil health besides meeting the nutritional deficiency under semi-arid Inceptisols.

Acknowledgement

The authors are grateful to the Principal, Raja Balwant Singh College, Bichpuri, Agra, Uttar Pradesh for providing all facilities for conducting the study.

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