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Compensating nutrient requirement in pearl millet (*Pennisetum glaucum*)–wheat (*Triticum aestivum*) cropping system through manures and biofertilizers in semi-arid regions of Haryana

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ABSTRACT

A field experiment was conducted for 4 years, ie from rainy (*kharif*) season 2004 to winter season 2007–08 at Hisar to study compensating requirement in pearl millet [*Pennisetum glaucum* (L.) R. Br. Emend. Stuntz]–wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] using manures and biofertilizer. The recommended dose of 40 kg N + 20 kg P_2O_5/ha to pearl millet and 60 kg N + 30 kg P_2O_5/ha to wheat + 20 kg K_2O/ha (T_1) and 50% of the recommended dose of nitrogen in both the crops + 5.0 tonnes farmyard manure before pearl millet sowing + seed inoculation with *Azospirillum* in pearl millet and *Azotobacter* in wheat + phosphate-solubilizing bacteria (PSB) (T_4) resulted 54.1 and 46.6% higher grain yield yield than the control (no application of any fertilizer). In wheat, the grain yield under treatment T_1 being at par with 100% of the recommended dose of N and P in both the crops (T_2), recommended N in both the crops (T_3), T_4 (3 047 kg/ha) and T_5, 50% of the RDN in both the crops + 2.5 tonnes farmyard manure before pearl millet sowing + seed inoculation with *Azospirillum* in pearl millet/*Azotobacter* in wheat + PSB (3 102 kg/ha) was statistically better than T_6, 15.0 tonnes farmyard manure before pearl millet sowing + seed inoculation with *Azospirillum* in pearl millet and *Azotobacter* in wheat + PSB (2 664 kg/ha), T_7, 7.5 tonnes vermicompost before pearl millet sowing + seed inoculation with *Azospirillum* in pearl millet and/*Azotobacter* in wheat + PSB (2 735 kg/ha) and control (2 154 kg/ha) treatments. Maximum pearl millet equivalent yield was in the T_1 (11 991 kg/ha) which was followed by T_2 (1 1684 kg/ha), T_5 (11 096 kg/ha) and T_4 (10 973 kg/ha) treatments. On mean basis, protein content was highest in T_4 (11.14%), followed by T_3 (11.09%) and T_5 (11.06%). In wheat crop maximum content was in T_7 treatment (11.13%), followed by T_6 (11.00%) and T_5 (10.99%) and minimum value of 9.99% was recorded in control. The values of *p*H and electrical conductivity were almost similar in T_1, T_2 and T_3 treatments compared with the control and these values decreased in T_4 to T_7 treatments. In general, organic carbon content was static where only chemical fertilizers were used but substantial increase was observed where pure organic and biofertilizers were used. Nitrogen and phosphorus balance was higher in organic manure and biofertilizer treatments as compared to inorganic fertilizer treatments. However, potash content decreased compared to initial status in the soil after 4 years of crop sequence of pearl millet–wheat. Treatment T_1 gave 54.1 and 110.6% higher gross and net returns over the control (T_8). B:C ratio (2.29), System productivity (32.9 kg/ha/day) and profitability(Rs 155.3 ha/day) were quite higher in T_1 treatment than the control (1.70, 21.3 and 73.7, respectively).

Key words: B:C ratio, EC, Net returns, Organic carbon, Pearl millet, *p*H, Protein content, Wheat

Pearl millet [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz]–wheat (*Triticum aestivum* L. emend. Fiori & Paol) is one of the most important cropping systems in south-west Haryana as well as in arid and semi-arid tracts of India. This cropping system is followed in estimated area of 2 262.4 thousand ha in India and 208.7 thousand in Haryana (Yadav and Suba Rao 2002). The continuous use of chemical fertilizers after green revolution in 1965–66 increased productivity but had adverse effect on soil health and environment (Diwedi and Diwedi 2007). Chemical fertilizers are also costly and does not support optimal microbial activities. The microbes play a significant role in the life-cycle of plants through number of processes such as decomposition, solubilization, fixation and

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supply of plant nutrients. The incorporation of farmyard manure and vermicompost along with recommended fertilizer dose had beneficial effect on the crop yield. Biofertilizers improves carbon and nitrogen mineralization by promoting soil microbial activities and narrowed down C:N ratio. It also decline bulk density and increase in water-holding capacity (Nisha *et al*. 2007). Therefore, the present investigation was undertaken to compensate the high cost input (chemical fertilizer) with low-cost input, like biofertilizers and organic manures in the exhaustive crop rotation of pearl millet–wheat (*desi*).

MATERIALS AND METHODS

A field experiment was conducted in the research farm area of Pearl millet Section of Department of Plant Breeding of the University Hisar during rainy (*kharif*) season 2004 to winter (*rabi*) season, 2007–08, located at 74°27′28″ East longitude, 27°30′ east latitude, 215.2 m altitude and the area is characterized as semi-arid and the soil has been classified as sandy loam in texture. The soil was having *p*H value of 8.1, poor in organic carbon content (0.28%), EC value of 0.34 dS/m), poor in available nitrogen (112 kg/ha), medium in phosphorus (18.0 kg/ha) and rich in potash (340 kg/ha) at the starting of the experiment, ie before *kharif* 2004. Pearl millet and wheat were grown during first fortnight of July and November each year as per recommended sowing time. The experiment was established in randomized block design with 8 treatment combinations in 3 replications at a permanent site. The treatments were; T_1, recommended dose of NP [pearl millet (40 kg N + 20 kg P_2O_5/ha) and wheat (60 kg N + 30 kg P_2O_5/ha)] + 20 kg K_2O/ha in both the crops; T_2, 100% of the recommended dose of fertilizer in both the crops; T_3, recommended N in both the crops; T_4, 50% of the N in both the crops + 5.0 tonnes farmyard manure before pearl millet sowing + seed inoculation with biofertilizers in both the crops with *Azospirillum* in pearl millet/*Azotobacter* in wheat + phosphate-solubilizing bacteria (PSB); T_5, 50% of the N in both the crops + 2.5 tonnes farmyard manure before pearl millet sowing + seed inoculation with biofertilizers in both the crops with *Azospirillum* in pearl millet/*Azotobacter* in wheat + phosphate solubilizing bacteria; T_6, 15.0 tonnes farmyard manure before pearl millet sowing + seed inoculation with biofertilizers in both the crops with *Azospirillum* in pearl millet/*Azotobacter* in wheat + phosphate-solubilizing bacteria; T_7, 7.5 tonnes vermicompost before pearl millet sowing + seed inoculation with biofertilizers in both the crops with *Azospirillum* in pearl millet/*Azotobacter* in wheat + phosphate-solubilizing bacteria and T_8, control (no application of any fertilizer) The dosage of farmyard manure and vermicompost according to different treatments were applied 3–4 weeks before the sowing of pearl millet crop. Half dose of the nitrogen and full dose of phosphorus and potash as per treatment were applied at sowing time. Remaining half dose was top-dressed at 3 weeks after sowing in pearl millet and after 5 weeks in wheat crop. Pearl millet crop was planted at 45 cm× 10–12 cm, whereas wheat was sown in 22.5 cm row spacing. 'HHB 94' hybrid pearl millet and 'C 306' *desi* wheat was used in the experiment. The total rainfall received during July 2004–June 2005, July 2005–June 2006, July 2006–June 2007 and July 2007–June 2008 was 399.2 mm, 560.3 mm, 353.6 mm and 508.1 mm respectively. Pearl millet crop was planted with pre-sowing irrigation during *kharif* 2004 as there was no rainfall during the entire July. One irrigation during August 2005 and 2006 was also applied in the pearl millet crop as there was severe drought stress as only 6.0 mm and 9.4 mm rainfall received during these months. To wheat crop 2–3 irrigations were given during the *rabi* season among all the years of experimentation. About 80–85% of the rainfall occurs by the south-western monsoon (July–September). The economic efficiency of the system was calculated by dividing the net returns/ha of a crop sequence by 365 days. The comparison among different treatments were made by converting the yield of 2 crops into pearl millet equivalent on current price basis. The available NPK in the soil were analyzed by alkaline permagnate method, Olsen's method and Flame photometer method. Organic carbon, Electric Conductivity and *p*H were calculated by Walky and Black's method, Conductivity Bridge method and Glass Electric *p*H meter method. System productivity (kg/ha/day) was calculated by dividing the pearl millet equivalent yield of the system by 365. System profitability (Rs/ha/day) of the system was calculated by dividing the net returns by 365. Protein content (%) was analyzed by multiplying per cent nitrogen in grain with conversion factor of 6.25.

RESULTS AND DISCUSSION

Pearl millet and wheat yield

Perusal of data in Tables 1 and 2 on pooled as well as on individual year basis revealed that pearl millet grain and stover yield were realized maximum in pure inorganic T_1 treatment (recommended dose of NP + 20 kg K_2O treatment). All other treatments from T_2 to T_7 also gave statistically more grain and stover yield than the control (T_8). Treatments T_1 and T_2 gave 54.1 and 46.6% higher grain yield yield over the control. Stover yield of 11.52 tonnes/ha was highest in the T_1 which was statistically at par with T_2 and T_3 but none of the inorganic and organic treatment as sole and in combination could produce the yield to the tune of T_1 treatment. In wheat crop, from the mean of 4 years of study (Table 2), it is clear that significantly higher grain yield was obtained in T_1 (3 396 kg/ha) being at par with T_2 (3 350 kg/ha), T_3 (3 072 kg/ha), T_4 (3 047 kg/ha and T_5 (3 102 kg/ha) but statistically better than T_6, T_7 and T_8 treatments. The results indicated that nutrient requirement in wheat through purely organic source could not be met out in terms of grain and stover yield (T_6 and T_7). Corroborative findings have also been reported by Kumar (2004) and Pathak *et al.* (2005).

Table 1 Pearl millet grain and stover yield (kg/ha) as affected by different nutrient management practices in pearl millet–wheat crop rotation

Treatment	Pearl millet grain yield (kg/ha)					Pearl millet stover yield (kg/ha)				
	2004	2005	2006	2007	Mean	2004	2005	2006	2007	Mean
T_1	4 047	3 465	3 590	3 687	3 697	10 210	11 704	11 922	12 233	11 517
T_2	4 005	3 026	3 537	3 597	3 541	10 080	11 174	11 497	11 980	11 183
T_3	3 827	3 015	3 392	3 100	3 334	9 770	11 038	10 846	11 060	10 679
T_4	4 058	3 171	3 477	3 363	3 517	9 630	9 631	11 473	11 207	10 485
T_5	3 905	3 182	3 518	3 390	3 499	8 830	9 398	10 954	11 255	10 109
T_6	3 487	2 887	3 567	3 440	3 345	9 450	8 697	11 112	11 173	10 108
T_7	3 667	2 900	3 516	3 323	3 352	10 050	8 865	11 251	11 310	10 369
T_8	2 197	2 208	2 565	2 627	2 399	7 430	7 365	9 079	8 907	8 195
CD(*P*=0.05)	467	627	549	223		NS	1 625	NS	360	

Details of treatments are given in text

Table 2 Wheat grain and straw yield (kg/ha) as affected by different nutrient management practices in pearl millet–wheat crop rotation

Treatment	Wheat grain yield (kg/ha)					Wheat straw yield (kg/ha)				
	2004–05	2005–06	2006–07	2007–08	Mean	2004–05	2005–06	2006–07	2007–08	Mean
T_1	3 540	2 626	3 530	3 889	3 396	6 523	4 243	5 870	5 583	5 555
T_2	3 390	2 481	3 730	3 800	3 350	6 520	4 213	5 650	4 811	5 299
T_3	3 070	2 375	3 270	3 574	3 072	6 308	4 175	5 260	4 772	5 129
T_4	2 703	2 366	3 460	3 660	3 047	5 775	3 924	5 490	4 690	4 970
T_5	2 652	2 527	3 550	3 680	3 102	5 406	3 978	5 550	4 399	4 833
T_6	2 347	1 934	3 200	3 174	2 664	5 296	3 333	5 430	3 900	4 490
T_7	2 294	2 105	3 440	3 101	2 785	5 196	3 194	5 590	3 983	4 489
T_8	1 888	1 411	2 900	2 417	2 154	4 585	2 768	4 850	2 913	3 779
CD (*P*=0.05)	317	459	633	357		529	678	459	471	

More grain and stover/straw yield in both the crops might be due to easy availability of plant nutrients and higher photosynthetic activities as compared to under doses fertilized treatments. After thorough understanding of pooled grain yield data of 4 years, it was found that there was no significant difference in grain yield of pearl millet and wheat recorded at 100% recommended dose of NP + 20 kg K_2O/ha (T_1) and 50% N + 5.0 tonnes farmyard manure/2.5 tonnes vermicompost + *Azotobacter* and *Azospirillum* (T_4 and T_5) treatment. Similar results of 25 to 50% NPK substitution is possible through farmyard manure and vermicompost had been reported by Singh *et al.* (2009). This might be attributed to availability of nitrogen for entire growing season due to slow mineralization of organic nitrogen from farmyard manure in pearl millet–wheat cropping sequence. Sonawane *et al*. (2007) also corroborated the findings.

Pearl millet equivalent yield and system productivity

Different treatments had different yield potential and economic values and therefore for better comparison, the yield of wheat was converted into pearl millet equivalent on price basis. In Table 4, it was noted that mean pearl millet equivalent yield over a period of 4 years varied from 7 781 kg/ha (T_8) to 11 991 kg/ha (T_1). Maximum equivalent yield was in the T_1 treatment which was followed by T_2 (11 684 kg/ha), T_5 (11 096 kg/ha) and T_4 (10 973 kg/ha) treatments. Bagla *et al.* (2008) reported that grain yield of pearl millet was significantly higher where 50% dose of the recommended nutrients was supplied through chemical fertilizers and 50% through farmyard manure. System productivity between T_1 (32.9 kg/ha/day) and T_2 (32.0 kg/ha/day) was comparable but better than T_3 (29.8 kg/ha/day), T_4 (30.0 kg/ha/day) and T_5 (30.2 kg/ha/day) and all these were quite superior than control (21.3 kg/ha/day) and T_6 (27.3 kg/ha/day) and T_7 (27.8 kg/ha/day) treatments.

Protein content

Protein content in treatment T_8 was observed minimum where nutrients were not applied (Table 3). In pearl millet crop, the protein content was maximum in inorganic fertilizer treatments in 2005 compared to 2004 and 2008. The values of protein content in T_6 and T_7 treatments were minimum in 2004 and these values continue to increase up to *kharif* 2008 season. On mean basis, protein content was highest in T_4 (11.14%), followed by T_3 (11.09%) and T_5 (11.06%) treatments. The values were quite high among all the

Table 3 Protein content in pearl millet and wheat grain as affected by different nutrient management practices in pearl millet–wheat crop rotation.

Treatment	Protein content (%) in pearl millet grain				Protein content (%) in wheat grain			
	2004–05	2005–06	2007–08	Mean	2004–05	2005–06	2007–08	Mean
T_1	10.69	11.33	10.83	10.95	10.24	10.93	10.96	10.71
T_2	10.58	11.37	10.75	10.90	10.20	10.85	10.83	10.63
T_3	10.88	11.58	10.83	11.09	10.52	11.01	10.94	10.82
T_4	10.67	11.33	11.43	11.14	10.38	11.09	11.23	10.90
T_5	10.97	11.07	11.16	11.06	10.59	11.14	11.24	10.99
T_6	9.88	10.61	10.92	10.47	10.80	11.09	11.13	11.00
T_7	10.28	10.73	10.96	10.65	10.92	11.21	11.25	11.13
T_8	9.21	9.04	8.92	9.05	10.08	10.03	9.88	9.99
CD(*P*=0.05)	0.07	0.11	0.08		0.09	0.04	0.08	

Table 4 Effect of different integrated nutrient practices on grain yield, stover/straw yield, pearl millet equivalent yield and economics of both crops in pearl millet—wheat cropping system (mean of 2004—05 to 2007—08).

Treatment	Pearl millet crop		Wheat crop		Pearl millet equivalent yield (kg/ha)	System productivity (kg/ha/day)	Gross returns (Rs/ha)	Cost of cultivation (Rs/ha)	Net returns (Rs/ha)	System profitability (Rs ha/day)	B:C ratio ratio
	Grain yield (kg/ha)	Stover yield (kg/ha)	Grain yield (kg/ha)	Straw yield (kg/ha)							
T_1	3 697	11 517	3 396	5 555	11 991	32.9	100 728	44 037	56 691	155.3	2.29
T_2	3 541	11 183	3 350	5 299	11 684	32.0	98 148	43 637	54 511	149.3	2.25
T_3	3 334	10 679	3 072	5 129	10 877	29.8	91 364	41 099	50 265	137.7	2.23
T_4	3 517	10 485	3 047	4 970	10 973	30.0	92 177	42 406	49 771	136.4	2.17
T_5	3 499	10 109	3 102	4 833	11 006	30.2	92 450	46 406	46 044	126.1	1.99
T_6	3 345	10 108	2 664	4 490	9 977	27.3	83 804	41 735	42 069	115.3	2.00
T_7	3 352	10 369	2 735	4 489	10 145	27.8	85 220	53 715	31 505	86.3	1.59
T_8	2 399	8 195	2 154	3 779	7 781	21.3	65 361	38 445	26 916	73.7	1.70
CD(*P*=0.05)	467	993	534	442							

Rates (Rs/100 kg) – Pearl millet grain - Rs 840, Fodder - Rs 85, Wheat (*desi*) - Rs 1 600, Straw - Rs 100

treatments compared to control. In wheat crop maximum content was in T_7 treatment (11.13%) which was followed by T_6 (11.00%) and T_5 (10.99%) and minimum value of 9.99% was recorded in control treatment.

Economic returns

Highest mean values of gross returns, net returns and B:C ratio were recorded in T_1 (100% recommended dose of NP + 20 kg K_2O/ha) (Table 4). This treatment gave 54.1 and 110.6% higher gross and net returns over the control (T_8). B:C ratio was almost comparable in T_1 (2.29), T_2 (2.25), T_3 (2.23) and T_4 (2.17) and quite better than T_8 (1.70) and T_7 (1.59). The lower net returns(Rs/ha) and B:C ratio were lower as cost of 7.5 tonnes of vermicompost was very high (Rs 15 000/ha) and yield realization were not to the extent.

Physico-chemical properties

The continuous use of chemical fertilizers deteriorate the physico-chemical properties of the soil and therefore the productivity decline. But integrated nutrient supply system plays an important role in sustaining the soil condition. In general, organic carbon content was static where only chemical fertilizers were used but substantial increase was observed where pure organic and biofertilizers were used (Table 5). Due to incorporation of organic material in the soil, microorganisms increase in number and activity. These microorganisms play a major regulatory for organic carbon dynamics. The results of similar nature were reported by Gangwar *et al*. (2006) and Kumar *et al.* (2007). Organic carbon, available nitrogen and available phosphorus were significantly increased by combined use of inorganic and organic fertilizers (Thind *et al.* 2007). The values of *p*H and

Table 5 Changes in the soil properties, EC, *p*H, organic carbon (%), available N, P and K_2O from *kharif* 2004 to *rabi* 2007–08 as affected by different integrated nutrient practices in pearl millet–wheat crop rotation

Treatment	Organic carbon	*p*H	EC (ds/m)	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potash (kg/ha)
T_1	0.29	8.11	0.30	123	18	308
T_2	0.29	8.12	0.32	124	17	280
T_3	0.28	8.10	0.32	119	15	275
T_4	0.31	7.96	0.28	120	19	305
T_5	0.32	7.95	0.29	125	19	303
T_6	0.34	7.88	0.27	130	19	290
T_7	0.33	7.89	0.27	134	18	290
T_8	0.28	8.13	0.33	105	15	278
CD (*P*=0.05)	NS	0.06	0.05	6.0	NS	7.0

Native nutrient status in the soil during *kharif* 2004:N, 112 kg/ha; P, 18 kg/ha; K, 340 kg/ha; organic carbon, 0.28%; *p*H 8.1; EC, 0.34 dS/m

EC were almost similar in T_1, T_2 and T_3 treatments compared with control and these values decreased in T_4 to T_7 treatments. Masto *et al.* (2007) observed decrease in soil *p*H and EC values due to continuous application of P, K and organic manures. Nitrogen and phosphorus balance in general was higher in organic manure and biofertilizer treatments as compared to inorganic fertilizer treatments after 4 years of crop sequence of pearl millet–wheat (Table 5). The highest nitrogen balance was in T_7 (134 kg/ha) which was statistically superior than all other treatments except T_6 (130 kg/ha). Phosphorus availability was higher in integrated nutrient T_4, T_5 and T_6 treatments. Antil *et al.* (2007) reported that phosphorus availability in soil increased due to incorporation of farmyard manure. Availability of potash was significantly reduced among all the treatments compared to initial status of potash in the soil but the decrease was low where organic and biofertilizers were used (Kharub and Chander 2008). The values were in the range of 278–308 kg/ha among different treatments. The potash balance was higher in combination of inorganic, organic manures and biofertilizers treatment, whereas these values decreased when organic and biofertilizers were not used. Similar results were reported by Kumar *et al.* (2007).

The 4 years study clearly revealed that although none of the pure organic manure or biofertilizer treatment could match the yield of pure inorganic treatment but almost similar values was found in both the crop when 50% of recommended dose of nitrogen was applied in combination with 5.0 tonnes of farmyard manure/2.5 tonnes of vermicompost + seed inoculation with biofertilizers in both the crops with *Azospirillum* in pearl millet/*Azotobacter* in wheat + phosphate-solubilizing bacteria (PSB) treatments. Moreover the added advantage in terms of improvement in protein content and soil properties were also realized by these treatments.

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