Indian Journal of Agricultural Sciences **86** (2): 220—6, February 2016/Article
https://doi.org/10.56093/ijas.v86i2.55963

Effect of farmyard manure, organic manure and balanced fertilizers application on the productivity and soil fertility in pearl millet (*Pennisetum glaucum*)- mustard (*Brassica juncea*) cropping sequence in sandy loam soil of semi-arid regions

ANIL KUMAR[1], L K CHUGH[2], DEV VART YADAV[3], R S MALIK[4] and L C MANOJ KUMAR[5]

Chaudhary Charan Singh Haryana Agricultural University,Hisar, Haryana 125 004

Received: 28 November 2014; Accepted: 6 August 2015

ABSTRACT

The experiment was conducted at the research farm of Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar from 2007-08 to 2009-10 to study the effect of farmyard manure and balanced fertilizers on production potential, economic viability and soil properties in the pearl millet [*Pennisetum glaucum* (L) R. Br.]-mustard [*Brassica juncea* (L.) Czernj. and Coss.] cropping sequence. The study consisted of 12 treatment combinations of farmyard manure and inorganic fertilizers with micronutrients were laid out in Factorial Randomized Block Design with three replications. The mean data revealed that use of balanced fertilizers (Potash, gypsum, $ZnSO_4$ and $FeSO_4$) along with application of 5.0 tonnes FYM/ha in pearl millet-mustard crop sequence produced 7.5 per cent higher pearl millet grain yield (3.59 tonnes/ha) and 8.2 per cent more mustard seed yield (1.96 tonnes/ha) than no FYM application (3.34 tonnes/ha by pearl millet and 1.81 tonnes/ha by mustard). Among different balanced nutrient treatments; recommended dose of nitrogen and phosphorous for both the crops, i.e. 120 kg N + 60 kg P/ha for pearl millet and 80 kg N + 30 kg P/ha for mustard along with 5.0 tonnes FYM/ha + 20 kg K_2O/ha + 200 kg gypsum +10 kg $ZnSO_4$ /ha + 10 kg $FeSO_4$/ha (F_5) produced maximum pearl millet grain yield (3.91 tonnes/ha) and mustard seed yield (2.31 t/ha), pearl millet equivalent yield (11.91 t/ha) and gross returns (₹ 93 051/ha) whereas, maximum net returns (₹ 44 529 /ha) and B:C ratio (1:93) were observed in the treatment 5.0 t FYM /ha + RD of N and P +20 kg K_2O/ha + 200 kg gypsum/ha + 10 kg $ZnS0_4$ kg/ha (F_4). The F_5 treatment decreased pH (7.8) and EC (0.33 ds/m), improved the organic carbon (0.37%), available N (205 kg/ha), P_2O_5 (17.7 kg/ha), K_2O (331 kg/ha), Fe (3.48 ppm), Zn (2.30 ppm) and S (4.30 ppm) status in comparison to values of 8.0 and 0.36. ds/m 0.34%, 196 kg/ha, 17.3 kg/ha, 323.7 kg/ha, 3.36 ppm, 2.15 ppm and 4.45 ppm, respectively in RD of N and P + 20 kg K_2O/ha + 200 kg gypsum/ha + 10 kg $ZnSO_4$/ha + 10 kg $FeSO_4$/ha treatment when no FYM was used. The quality traits; protein content in pearl millet, oil content and oil yield were also found superior in the F_5 treament than all other combinations of balanced fertilizers with and without 5.0 tonnes FYM/ha.

Key words: B:C ratio, *Brassica juncea*, Farmyard manure (FYM), Mustard, Pearl millet, *Pennisetum glaucum,* Pearl millet equivalent yield (PMEY)

Pearl millet [*Pennisetum glaucum* (L) R. Br.] is cultivated on about 30 million ha in more than 30 countries of five continents, viz. Asia, Africa, North America, South America and Australia. Though the majority of the crop area is in Asia (>10 m ha) and Africa (about 18 m ha), pearl millet cultivation is expanded in some of the non-traditional areas also such as Brazil (about 2 m ha). It is being experimented as grain and forage crop in USA, Canada, Mexico, the West Asia and North Africa (WANA), and Central Asia. In India, pearl millet is the third most important food crop in terms of area and production after paddy and wheat. It is a dual purpose crop of arid and semiarid areas as it provides cheap food, comparatively rich in various nutrients, protein, fat, carbohydrates, minerals for poor masses, feed for poultry birds and also dry as well as green fodder for cattle. In India 9.20 million tonnes of pearl millet was produced from an area of 7.90 million hectares with a productivity of 1161 kg/ha during 2013-14 (Anonymous 2013-14).

This cropping system is reported to cover an area of 9.37 lakh ha and oilseed crops also play an important role in Indian agriculture, industry and trade since edible oils constitute an indispensable component of Indian diet. Out of nine important oilseed crops in the country, rapeseed-

[1]Professor (Agronomy) (e mail : anilbajra2009@gmail.com), [2]Associate Professor (Biochemistry) (e mail: chughlk@yahoo.co.in), [3]Assistant Professor (Genetics & Plant Breeding) (email: devart.yadav@gmail.com), Bajra Section, Department of Genetics and Plant Breeding, [4]Professor(Soil Science), Department of Soil Science (email: ranbirsinghmalik@gmail.com): [5]Associate Professor (Soil Science), Department of Agronomy (email: drmanojsharma2013 @gmail.com)

mustard occupy a prestigious position and rank second after groundnut. Rapeseed-mustard crops are grown in an area of 6.63 million ha with a total production of 8.25 million tonnes and average productivity of 1 244 kg/ha in India (Sandhu 2014). In Northern plains of India, pearl millet-mustard [*Brassica juncea* (L.) Czernj & Coss] is efficient, potential and sustainable cropping system contributes about 3.5% of national food basket (Yadav 1996). If the nutrient requirement of this cropping sequence is not managed properly, then we may face the problem of declining in productivity and soil fertility status. The long term application of chemical fertilizers alone under intensive cropping may deplete the reserve pool of non applied nutrients and carbon, which if not properly managed leads to deterioration of soil productivity and fertility.

However, combined application of both manures and chemical fertilizers depending on the nature and properties of the soil would not only maximize the crop production and improve the quality of the produce but would also help in maintaining the soil fertility (Kaushik and Gautam 1991, Parihar *et al.* 2010), optimum productivity and overall health and quality of soil (Singh *et al.* 1981) and also to sustain the system productivity (Singh and Yadav 1992). Integrated application of nutrients through manures and inorganic fertilizers is the need of the hour to check the decrease in factor productivity. The use of organic manures improves soil organic matter, long term soil fertility and crop productivity on sustainable basis have been emphasized (Esse *et al*. 2001, Katkar *et al*. 2002). Residual effect of organic manures, namely farmyard manure (FYM) may be more pronounced, as only a part of its nutrients is available to the first crop and remaining portion of nutrients will be available to the succeeding crop in sequence (Hegde 1998). Keeping this background in mind, an attempt was made to study the effect of integrated nutrient management practices on production potential, economic viability and soil properties in the pearl millet-mustard cropping sequence.

MATERIALS AND METHODS

The experiment was conducted at the research farm of Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar from 2007-08 to 2009-10. The experimental site is located at 28° 4' latitude and 76° 35' E longitude at an altitude of about 266 m above mean sea level. The average maximum temperature and minimum temperature during pearl millet growing season (July-September) was 35.4°C and 25.1°C, respectively and during mustard growing season (October to March) it was 33.1°C and 9.7°C, respectively. The average rainfall received during pearl millet and mustard growing seasons was 286.4 mm and 19.8 mm, respectively.

The climate of the area is semiarid and subtropical. Summers are very hot and winters are very cool. Temperature is as high as 46-47°C (May - June) and as low as 0°C are occasionally experienced. The average rainfall is 400 mm. The soil of the field is derived from Indo-Gangetic alluvium and is sandy loam in texture having 63.3% sand, 17.6% silt and 19.1% clay contents.

The experiment consisted of twelve treatment combinations of organic manure: With 5.0 tonnes FYM/ha and without FYM in pearl millet crop and six balanced fertiliser combinations - F_1 : Recommended dose of nitrogen and phosphorus for both the crops, i.e. 120 kg N /ha + 60 kg P/ha for pearl millet and 80 kg N /ha + 30 kg P/ha for mustard, F_2 : F_1 + 30 K_2O/ha to both the crops; F_3 : F_2 +200 kg gypsum/ha to mustard crop; F_4 : F_3 + 10 kg $ZnSO_4$ /ha in mustard crop and F_5 : F_4 + 10 kg $FeSO_4$/ha in mustard crop, F_0 : no nutrient (Control). The experiment was laid out in Factorial Randomized Block Design with three replications. Full dose of farmyard manure (FYM) was applied 15 days before the start of the experiment. Half dose of nitrogen through urea as a basal and remaining was top dressed at 30-35 days after sowing of both the crops. Full dose of phosphorus and potash was applied as single super phosphate and muriate of potash at the time of sowing. Pearl millet hybrid HHB 223 was sown with seed rate of 5.0 kg/ha during the middle of July and harvested in last week of September and mustard variety RH 30 was sown (seed rate 5 kg/ha) during the middle of October and harvested in the second or third week of March in each year.

The soil samples were collected from 0-15 cm depth of soil profile with the help of the auger in *kharif* 2007 before sowing of the pearl millet and after three crop sequence, i.e. after 2009-10 mustard crop harvesting to study the impact of various fertility treatments on soil properties of the profile. The experimental soil was sandy loam in texture, alkaline in reaction with pH value of 7.9, low in organic carbon (0.35), EC (0.32), Fe (2.56 ppm), S (3.75 ppm) and available N (196 kg/ha), whereas medium in available P (18 kg/ha), high in available K (335 kg/ha) and Zn (1.32 ppm). Chemical analysis of nutrients for the experimental soil were conducted by using Jackson (1973) procedure for pH and organic carbon, Electrical Conductivity and available K by Richards (1954), available N by Subbiah and Asija (1956), available phosphorus by Oslen *et al*. 1954, available S by Chesnin and Yien (1951) and available Zn and Fe (DTPA) extractable by Lindsay and Norvell (1978).

RESULTS AND DISCUSSION

Grain/seed yield

The mean grain/seed yields of pearl millet and mustard have (Table 1 and 2) showed significantly higher increased yield values due to by farmyard manure (FYM) and balanced nutrient fertilizer application treatments over the control. Application of 5.0 tonnes FYM/ha increased the grain yield (35.93 q/ha) to the tune of 7.5 per cent over no FYM (33.43 q/ha) in pearl millet, whereas the seed yield in mustard was values due to farmyard manure (FYM) and balanced fertilizer treatments over the control. Application of 5.0 tonnes FYM/ha increased the grain yield (359 tonnes/ha) to the tune of 7.5 per cent over no FYM (3.34 tonnes/ha) in pearl millet, whereas the seed

yield in mustard was improved by 8.2 per cent with 5.0 tonnes FYM/ha (1.96 tonnes/ha) than no FYM application treatment. Application of all needed nutrients through chemical fertilizer has deleterious effect on the soil fertility leading to unsustainable yields in long term experiments (Nambiar *et al.* 1992), whereas organic manure has been traditionally important input for maintaining soil fertility and ensuring yield stability (Hegde and Dwivedi 1993). The application of recommended dose of N and P +20 kg K_2O /ha + 200 kg gypsum/ha +10 kg $ZnSO_4$ /ha + 10 kg $FeSO_4$ along with 5.0 tonnes/FYM (F_5) and recommended dose of N and P +20 kg K_2O /ha, 200 kg gypsum/ha +10 kg $ZnSO_4$ /ha (F_4) produced 0.24 tonne/ha and 0.23 tonne/ha more grain yield in pearl millet and 0.14 tonne/ha and 0.15 tonne/ha higher seed yield in mustard than the balanced fertilizer treatments (F_5 and F_4) without FYM treatments, respectively. The mean increase in the best treatment (F_5) with 5.0 tonnes FYM/ha was 51.3 and 6.3 percent over alone 5.0 tonnes FYM/ha and recommended dose of N and P +5.0 tonnes/FYM, whereas this increase was 62.3 and 8.6% in the without FYM and recommended dose of N and P treatments. The seed yield in mustard was 94.1 and 24.9 per cent higher over 5.0 tonnes FYM/ha and 5.0 tonnes FYM/ha + RD of N and P combination, however, this increase was 110.7 and 26.9 per cent in without FYM and recommend dose of N and P fertilizer treatments. Such enhancement effect might be attributed to the favourable influence of these nutrients (Gypsum, K, Zn and Fe) on metabolism and biological activity and its stimulatory effect on photosynthetic pigments and enzyme activity which in turn improve vegetarian growth of plants and finally the yields (Michail *et al.* 2004).

The stover/straw yields of pearl millet and mustard was also influenced by gypsum, K_2O, $ZnSO_4$ and $FeSO_4$ (Table 1 and 2). The significantly highest stover yield of pearl millet (11.55 tonnes/ha) and straw yield in mustard (479 tonnes/ha) were recorded with the combined application of balanced fertilizers with 5.0 tonnes FYM/ha than the balanced fertilizers without FYM control (10.73 tonnes/ha in pearl millet; 4.49 t/ha in mustard). The increase was 7.7 per cent and 6.8 per cent in pearl millet and mustard, respectively. The stover/straw yield in both the crops among F_2, F_3, F_4 and F_5 balanced nutrient treatments along with 5.0 tonnes FYM/ha or without FYM were found significantly superior than inorganic treatments of recommend dose of N and P with 5.0 tonnes/FYM/ha or without FYM except pearl millet stover yield in F_2 treatment with 5.0 tonnes/FYM/ha. The stover yield in the best treatment (F_5) with 5.0 tonnes/FYM was found 33.6% and 4.3% higher than alone 5.0 tonnes/FYM/ha and recommended dose of N and P +5.0 tonnes/FYM whereas this increase was 42.9 and 6.3%, in the without FYM and RD of N and P treatments. The straw yield in mustard was 93.3 and 15.3 percent higher over 5.0 tonnes/FYM/ha and 5.0 tonnes/FYM/ha + RD of N and P combination, however, this increase was 93.7 and 26.7 percent in without FYM and RD of N and P fertilizer treatments. Thus balanced use of fertilizers in combinations with FYM and micronutrients is necessary for sustaining soil fertility and productivity of crops (Tiwari *et al.* 2002, Thakur *et al.* 2011). This could be due to efficient utilization of both major and micronutrients when applied in combination is helpful for better growth and development and which ultimately resulted in better vegetative growth and straw yield (Hooda *et al.* 1996, Bhagchand and Gautam 2000).

Table 1 Effect of farmyard manure and balance nutrition on the grain and stover yield of pearl millet (Mean data of 2007-2009)

Treatment	Pearl millet grain yield (tonnes/ha)				Pearl millet stover yield (tonnes/ha)			
	2007	2008	2009	Mean	2007	2008	2009	Mean
With 5.0 t FYM /ha								
F_1	3.42	4.19	3.43	3.68	11.88	12.45	10.81	11.72
F_2	3.43	4.27	3.55	3.75	11.86	12.58	11.28	11.91
F_3	3.45	4.26	3.57	3.76	12.13	12.71	11.44	12.09
F_4	3.51	4.35	3.77	3.88	12.17	12.71	11.78	12.22
F_5	3.53	4.33	3.86	3.91	11.90	12.73	12.04	12.22
F_0	2.68	3.03	2.02	2.58	9.84	10.72	6.89	9.15
Mean	3.34	4.07	3.37	3.59	11.63	12.32	10.71	11.55
Without FYM								
F_1	3.15	3.73	3.25	3.38	10.72	11.79	10.12	10.87
F_2	3.23	4.02	3.36	3.54	10.93	11.85	10.70	11.16
F_3	3.16	4.05	3.44	3.55	11.01	11.95	10.71	11.23
F_4	3.22	4.13	3.59	3.65	11.23	12.03	11.12	11.46
F_5	3.18	4.15	3.69	3.67	11.30	12.10	11.27	11.56
F_0	2.52	2.62	1.65	2.26	8.96	9.46	5.84	8.09
Mean	3.08	3.78	3.16	3.34	10.69	11.53	9.96	10.73
Balanced nutrition								
F_1	3.29	3.96	3.34	3.53	11.30	12.12	10.46	11.30
F_2	3.34	4.14	3.45	3.64	11.40	12.21	10.99	11.53
F_3	3.34	4.15	3.51	3.67	11.58	12.33	11.08	11.66
F_4	3.37	4.24	3.68	3.76	11.70	12.37	11.45	11.84
F_5	3.36	4.24	3.77	3.79	11.60	12.47	11.65	11.89
F_0	2.60	2.82	1.83	2.42	9.40	10.09	6.37	8.62
CD (P=0.05)	0.10	0.21	0.18	0.10	0.19	0.26	0.26	0.17
FYM	0.18	0.37	0.31	0.18	0.33	0.46	0.45	0.29
Balance nutrition								
FYM× Bal. Nut. Stover/ Straw yield	NS	NS	NS	NS	NS	NS	NS	NS

Quality studies

The application of FYM @ 5.0 tonnes/ha significantly improved the protein content (8.98 %) in pearl millet grain (Table 3) than no FYM (8.68 %) treatment. The oil content and its yield in mustard crop were significantly higher in 5.0 tonnes FYM/ha treatment (40.1% and 783 kg/ha) than no FYM (39.5% and 747 kg/ha). The additional application of K_2O + Gypsum + $ZnSO_4$ + $FeSO_4$ along with RD of N

Table 2 Effect of farmyard manure and balance nutrition on the seed and straw of mustard (Mean data of 2007-08 to 2009-10)

Treat-ment	Raya seed yield (t/ha)				Raya straw yield (t/ha)			
	2007-08	2008-09	2009-10	Mean	2007-08	2008-09	2009-10	Mean
With 5.0 t FYM/ha								
F_1	1.62	2.02	1.92	1.85	4.45	5.15	4.75	4.78
F_2	1.73	2.24	2.08	2.02	4.83	5.45	4.85	5.04
F_3	1.82	2.36	2.21	2.13	4.94	5.63	4.94	5.17
F_4	1.90	2.53	2.37	2.26	5.20	5.92	5.14	5.42
F_5	1.98	2.56	2.41	2.31	5.27	6.01	5.25	5.51
F_0	1.00	1.31	1.27	1.19	2.55	3.30	2.72	2.85
Mean	1.68	2.17	2.04	1.96	4.54	5.24	4.61	4.80
Without FYM								
F_1	1.54	1.85	1.74	1.71	3.92	4.53	4.25	4.23
F_2	1.65	2.03	1.98	1.89	4.62	4.93	4.74	4.76
F_3	1.71	2.22	2.00	1.98	4.82	5.18	4.93	4.98
F_4	1.80	2.35	2.18	2.11	4.92	5.36	5.06	5.11
F_5	1.86	2.37	2.29	2.17	5.09	5.44	5.02	5.19
F_0	0.92	1.12	1.04	1.03	2.50	3.08	2.45	2.68
Mean	1.58	1.99	1.87	1.81	4.31	4.75	4.41	4.49
Balanced nutrition								
F_1	1.58	1.93	1.83	1.78	4.19	4.84	4.50	4.51
F_2	1.69	2.14	2.03	1.95	4.72	5.19	4.80	4.90
F_3	1.76	2.29	2.11	2.05	4.88	5.41	4.94	5.07
F_4	1.85	2.44	2.28	2.19	5.06	5.64	5.10	5.27
F_5	1.92	2.46	2.35	2.24	5.18	5.73	5.13	5.35
F_0	0.96	1.21	1.16	1.11	2.53	3.19	2.58	2.77
CD (P=0.05)								
FYM	0.08	0.12	0.11	0.06	0.12	0.15	NS	0.10
Balanced nutrition	0.14	0.22	0.19	0.10	0.21	0.26	0.42	0.17
FYM× Bal. Nut.	NS	NS	NS	NS	NS	NS	NS	NS

Table 3 Protein content of pearl millet grain and oil content and oil yield of mustard as affected by farmyard manure and balanced fertilizer treatments

Treatment	Protein content in grain (%)	Oil content (%)	Oil yield (kg/ha)
With 5.0 t FYM /ha			
F_1	8.79	39.2	753
F_2	8.91	39.6	824
F_3	9.12	40.5	895
F_4	9.24	41.6	986
F_5	9.28	41.8	1007
F_0	8.52	38.1	484
Mean	8.98	40.1	824
Without FYM			
F_1	8.52	38.6	672
F_2	8.71	39.3	778
F_3	8.84	40.1	802
F_4	8.89	41.1	896
F_5	9.00	41.4	948
F_0	8.10	36.5	380
Mean	8.68	39.5	747
Balanced nutrition			
F_1	8.65	38.9	712
F_2	8.81	39.4	800
F_3	8.98	40.3	848
F_4	9.07	41.4	942
F_5	9.14	41.6	977
F_0	8.31	37.3	433
CD (P=0.05)	FYM	0.20	0.443
Balanced nutrition	0.35	0.8	74
FYM × Bal. Nut.	NS	NS	NS

and P (F_5) and 5.0 tonnes FYM/ha exhibited maximum protein content (9.28 %), oil content (41.8 %) and oil yield (956 kg/ha). The values of these parameters were 9.00 per cent, 41.4 per cent and 904 kg/ha in the F_5 treatment when no FYM was used. The application of gypsum along with recommend dose of N, P and K, with and without FYM had also significantly improved the oil content than the recommend dose of N and P only.

System productivity and economic returns of the system

As regards the system productivity in terms of pearl millet equivalent yield (PMEY), application of 5.0 tonnes/FYM/ha recorded significantly higher value (10.57 tonnes/ha) than without FYM (9.80 tonnes/ha). The gross and net returns were higher by 6001 ₹/ha and ₹ 1380/ha in the 5.0 tonnes FYM/ha application than without FYM treatment. The mean data of three years clearly indicated that PMEY was 1.51 tonnes/ha, 1.35 tonnes/ha, 0.87 tonne/ha and 0.53 tonne/ha higher in F_5, F_4 and F_3 and F_2 treatments than the F_1 treatment (Recommended dose of N and P) when all these treatments were in combination with 5.0 tonnes/FYM/ha. Gross returns were statistically at par in F_5 and F_4 treatment (with 5.0 tonnes/FYM/ha) and showed their significant superiority than all other treatments. Net returns and B:C ratio were observed maximum in F_4 treatment(with 5.0 tonnes/FYM/ha) and followed by F_5 treatment (with 5.0 tonnes/FYM/ha).

Soil fertility status

The addition of 5.0 tonnes/FYM/ha for three years resulted in significant increase in organic carbon(OC) content over no FYM (Table 5). The organic carbon content of the soil showed wide variations and ranged from 0.32% in control (no use of FYM and balanced fertilizers) to 0.36% (F_5: Recommended dose of N and P + 20 kg K_2O/ha + 200 kg gypsum/ha + 10 kg $ZnSO_4$/ha + 10 kg $FeSO_4$ /ha along with 5.0 tonnes FYM/ha). The increase in OC content due to use of FYM and chemical fertilizers can be attributed to higher contribution of biomass to the soil in the form of better root growth, crop stubbles biomass and residues (Katyal *et al*. 2003 and Gathala *et al.* 2007). The pH showed significant declined trend in 5.0 tonnes FYM/ha treatment (7.87) than no FYM application (8.08). Decline in pH may be attributed to the use of FYM which released organic

Table 4 Pearl millet equivalent yield (PMEY) and economics of various treatments

Treatment	Pearl millet equivalent yield (t/ha)	Gross returns (₹/ha)	Cost of cultivation (₹/ha)	Net returns (₹/ha)	B:C ratio
With 5.0 t FYM /ha					
F_1	10.40	81122	46472	34650	1.74
F_2	10.93	85335	46997	38337	1.81
F_3	11.27	87946	47097	40848	1.86
F_4	11.75	91806	47277	44529	1.93
F_5	11.91	93053	49166	43887	1.88
F_0	7.14	55513	43106	12407	1.28
Mean	10.57	82462		35776	1.75
Without FYM					
F_1	9.59	74699	45072	29626	1.65
F_2	10.26	80101	45597	34503	1.75
F_3	10.53	82262	45731	36531	1.79
F_4	10.99	85935	45911	40024	1.86
F_5	11.20	87549	47817	39731	1.82
F_0	6.23	48221	41706	6515	1.16
Mean	9.87	76461		31155	1.67
Balanced nutrition					
F_1	10.00	77910	38955	32138	1.70
F_2	10.60	82718	41359	36420	1.78
F_3	10.90	85104	42552	38690	1.83
F_4	11.17	88870	44435	42277	1.90
F_5	11.55	90301	45151	41809	1.85
F_0	6.69	51867	25934	9461	1.22
CD (P=0.05)					
FYM	0.19	1526		1523	0.03
Balanced nutrition	0.33	2641		2637	0.05
FYM × Bal. Nut.	NS	NS		NS	NS

acids during its decomposition resulting in decrease of pH. The pH in the control and other combination of treatments with 5.0 tonnes FYM/ha was significantly lower than balanced fertilizers without FYM. Electrical conductivity (EC) also followed the trend of pH and this decrease in EC is obviously due to decomposition of organic matter. These results corroborate the findings of Babu *et al*. (2007), Khambalkar *et al*. (2012).

CD: Critical Difference

The data presented in Table 5 clearly showed an increase in available nitrogen value in FYM treatment (202 kg/ha) than without FYM (194 kg/ha) and initial status value (196 kg/ha) during the year 2007. The increase in available N is due to mineralization of FYM. The continuous use of recommended dose of N and P along with 30 kg K_2O/ha, 200 kg/ha gypsum, 10 kg/ha $ZnSO_4$ and 10 kg/ha $FeSO_4$ alone or their combinations showed significant increase in available nitrogen status than the control or the treatment receiving the chemical fertilizer alone. Singh *et al.* (2009) also observed the increased value of available nitrogen with the use of recommended dose of fertilizer in combination with manure. The available phosphorus status was significantly improved with the application of 5.0 tonnes FYM/ha (16.9 kg/ha) than without FYM (15.9 kg/ha). The combined effect of both major and micronutrients in different fertility treatments along with 5.0 tonnes FYM/ha also improved the phosphorus status of the soil substantially than the control (without FYM and inorganic fertilizers). The decomposition of FYM is accompanied by release of organic and inorganic acids, resulted in acidification of the medium, thereby, enhancing the availability of phosphorus to the plant (Mahdi *et al*. 2010). The availability of potassium was maintained higher in the 5.0 tonnes FYM/ha treatment (325 kg/ha) than no FYM (316 kg/ha) but lower to the initial K availability of the soil (335 kg/ha) before start of the experiment. Applications of organic manure may have caused reduction in the potassium fixation and therefore, maintained higher values due to interaction of organic matter with clay (Prasad and Mathur 1997). The data also further revealed maximum decline in available K under unfertilized control and it was followed by treatment receiving 100% NP only. The continuous omission of potassium for crop nutrition caused mining of its native pools that caused reduction in potassium availability to the crop (Dwivedi *et al.* 2007).

Zn, Fe and S status

The DTPA—Zn content of the soil was increased with farmyard manure application (1.70 ppm) over control (1.60 ppm) and initial Zn status of the soil (1.32 ppm) prior to the experiment. The Zn status was significantly improved in the treatments of F_4 and F_5 either with 5.0 tonnes FYM/ha or without FYM than all other combination of treatments. The Table 5 also revealed that farmyard manure also affected the DTPA-extractable Fe in soil. The study also revealed that the treatments, which received additional doses of $ZnSO_4$ and $FeSO_4$ showed more accumulation of DTPA-Fe and DTPA-Zn in soil than the treatments receiving no application of these nutrients. Now a days, sulphur assumes the status of a strategic element in a balanced fertilization programme. The pearl millet — mustard cropping system removes about 28.7 kg S/ha to produce one tonne biomass of each (Gupta 2001). The sulphur status of soil was not statistically improved with the application of farmyard manure but it was significantly improved in the F_3, F_4 and F_5 treatments added with sulphur in the form of gypsum ($CaSO_4$. $7H_2O$), $ZnSO_4$, and $FeSO_4$ compared to F_0, F_1 and F_2 treatments.

It can be concluded from three years study in pearl millet mustard cropping sequence that the application of farmyard manure improves the system productivity, economic returns and improves soil health. The treatment receiving the balance nutrition, i.e. recommend dose of N and P with K_2O, gypsum, $ZnSO_4$ and $FeSO_4$ provide higher productivity of both the crops, maintained/improved the soil properties along with better returns, compared to the

Table 5 Effect of farmyard manure and balanced nutrition on the chemical properties and fertility status of the soil after three years of pearl millet-mustard cropping sequence

Treatment	Organic carbon (%)	pH	EC (dS/m)	Av. N (kg/ha)	Av. P_2O_5 (kg/ha)	Av. K_2O (kg/ha)	Av. Fe (ppm)	Av. Zn (ppm)	Av. S (ppm)
With 5.0 t FYM /ha									
F_1	0.35	7.9	0.32	199	17.0	317.0	2.51	1.38	3.72
F_2	0.37	7.8	0.33	205	17.3	329.3	2.56	1.37	3.65
F_3	0.36	7.9	0.33	204	16.7	331.0	2.51	1.38	3.83
F_4	0.36	7.8	0.34	205	18.0	332.0	2.54	2.31	4.56
F_5	0.37	7.8	0.33	205	17.7	331.0	3.48	2.30	4.50
F_0	0.33	8.0	0.30	196	15.0	307.7	2.41	1.29	3.70
Mean	0.36	7.9	0.33	202	16.9	324.7	2.67	1.67	3.99
Without FYM									
F_1	0.32	8.1	0.34	194	15.3	308.0	2.41	1.31	3.62
F_2	0.33	8.1	0.35	194	16.3	325.3	2.48	1.30	3.57
F_3	0.32	8.1	0.35	194	16.7	319.7	2.54	1.32	3.87
F_4	0.33	8.0	0.35	195	16.3	322.7	2.48	2.12	4.43
F_5	0.34	8.0	0.36	196	17.3	323.7	3.36	2.15	4.45
F_0	0.31	8.1	0.32	193	13.7	297.3	2.34	1.28	3.59
Mean	0.33	8.1	0.35	194	15.9	316.1	2.60	1.58	3.92
Balanced nutrition									
F_1	0.34	8.0	0.33	196	16.2	312.5	2.5	1.4	3.7
F_2	0.35	8.0	0.34	200	16.8	327.3	2.5	1.3	3.6
F_3	0.34	8.0	0.34	199	16.7	325.3	2.5	1.4	3.9
F_4	0.35	7.9	0.34	200	17.2	327.3	2.5	2.2	4.5
F_5	0.36	7.9	0.35	200	17.5	327.3	3.4	2.2	4.5
F_0	0.32	8.1	0.31	195	14.3	302.5	2.4	1.3	3.6
CD (P=0.05)									
FYM	0.01	0.2	0.11	2.0	0.9	4.0	NS	0.1	NS
Balanced nutrition	0.02	NS	NS	4.0	1.6	7.0	0.3	0.1	0.2
FYM × Bal. Nut.	NS	NS	NS	NS	NS	NS	NS	NS	NS

unfertilized plots and applications of recommended dose of N and P only.

ACKNOWLEDGEMENTS

The authors are thankful to the Professor and Head, Department of Genetics and Plant Breeding, CCS HAU, Hisar for providing research facilities. We are also grateful to Indian Council of Agricultural Research for providing financial assistance.

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