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Research Paper

Influence of nutrient management with organic manures on productivity, profitability and quality of pearl millet (*Pennisetum glaucum*)–chickpea (*Cicer arietinum*) sequence

H.M. BHUVA[1] AND A.C. DETROJA[2]

Pearlmillet Research Station, Junagadh Agricultural University, Jamnagar, Gujarat 361 006

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ABSTRACT

A field experiment was conducted at Jamnagar, Gujarat during 2010–11 to 2013–14 on clayey soil, to improve the productivity and sustainability of pearl millet [*Pennisetum glaucum* (L.) R. Br.]–chickpea (*Cicer arietinum* L.) cropping sequence with organic source of nutrient supply. Nine treatments comprising application of farmyard manure (2.5, 5.0 and 7.5 t/ha), vermicompost (1.0, 2.0 and 3.0 t/ha), farmyard manure (FYM) + vermicompost (2.5 + 1.0 t/ha) only in pearl millet crop and absolute control were compared with recommended dose of fertilizer [(RDF) 80-17-0 kg for pearl millet and 20–17–0 kg N-P-K/ha for chickpea). Among the organic sources, an application of 7.5 t FYM/ha to pearl millet recorded the highest values of yield attributes and yield in pearl millet (1.59 t grain and 3.92 t stover/ha) and beneficial residual effect on yield attributes and productivity of succeeding chickpea (2.37 t seed and 2.60 t stalk/ha) and remained at par with RDF. Pearl millet grain-equivalent yield (8.48 t/ha) and production (19.42 kg/ha/day) and economic efficiency (399.6 ₹/ha/day) were also comparable under 7.5 t FYM/ha with RDF. The maximum net returns were obtained under RDF (₹81,521/ha), while the maximum benefit: cost ratio (BCR) was observed with FYM 7.5 t/ha (2.84). Protein content in pearl millet and chickpea increased with the increase in the dose of FYM and vermicompost and the highest protein content (10.73% for pearl millet and 23.25% for chickpea) was recorded with 7.5 t FYM/ha. Significantly the lowest bulk density (1.36 Mg/m^3) and highest porosity (46.3%) were noted with 7.5 t FYM/ha compared to absolute control and RDF. Lower *p*H (7.60), higher organic carbon (6.0 g/kg) and significantly higher post-harvest soil-nutrients status (223.4, 11.3 and 329.8; N, P and K/ha) were observed with 7.5 t FYM/ha compared to initial status of soil.

Key words: Chickpea, Farmyard manure, Pearl millet, Productivity, Profitability, Quality, Soil fertility

India is the largest producer of pearl millet in the world, occupying about 7.32 million ha area with annual production of 9.18 million tonnes with average productivity of 1,255 kg/ha. Pearl millet is the predominant rainy season (*kharif*) crop in some parts of Gujarat. In Gujarat, it is cultivated over an area of 0.46 million ha with a production and productivity of 0.77 million tonnes and 1,677 kg/ha respectively (DES, 2016). Chickpea is the most important pulse crop grown in winter (*rabi*) season. India produced 7.33 million tonnes chickpea seed from 8.25 million ha area, with an average yield of 889 kg/ha, while the contribution of Gujarat in production was 0.20 million tonnes from 0.16 million ha area, with an average yield of 1,236 kg/ha. The actual yield is much less than potential yield of pearl millet (2,950 kg/ha) and chickpea (2,675 kg/ha), whereas demand of pulses is increasing at a very high rate. The wide yield gap between actual and potential of pearl millet and chickpea is due to intensive tillage, monocropping, imbalanced use of nutrients coupled with limited use of organic manures, less recycling and burning of crop residues in soil, soil erosion, undulated topography, indiscriminate irrigation systems etc. Likewise, biotic factors are also obstacle in yield potential of both the crops. Pearl millet–chickpea sequence has gained popularity in arid region of Rajasthan, Maharashtra, Gujarat and Uttar Pradesh. As chickpea is remunerative crop with lower water requirement as compared to wheat, farmers of this region are attracted towards cultivation of chickpea. Pearl millet–chickpea is the prevalent cropping sequence in Gujarat. This sequence covers more than 10,000 ha area in Gujarat state.

Under intensive cropping sequence, continuous use of chemical fertilizers adversely affects the soil health. Hence it is highly essential to apply organic sources which are

[1]**Corresponding author's Email**: hasmukhbhuva@gmail.com
[1]Associate Research Scientist, [2]Assistant Research Scientist

easily available and feasible. The practices of organic cultivation vary with the availability of local manurial resources and their nutrient content and as such it is necessary to identify both the source and its quantity to meet the nutrient requirement of pearl millet as well as residual chickpea. Farmyard manure (FYM) and vermicompost are the traditional sources of nutrients. Kumar *et al.* (2014) and Kumara *et al.* (2018) reported beneficial effect of FYM in economizing use of nitrogen in pearl millet. Vermicompost and FYM bring about gradual improvement in soil structure, soil health, productivity and soil-microbial diversity which results in higher crop yields owing to enhanced plant nutrients (Hargreaves *et al.*, 2008). Thus, increasing the productivity and sustainability of pearl millet-chickpea cropping system through required organic sources and doses of organic manure is important to economic fertilizer use, besides maintaining productivity and soil health in a long run. Hence present study was conducted to evaluate the potentiality of organic farming for pearl millet (*kharif*)–chickpea (*rabi)* cropping sequence in comparison to chemical fertilizers.

MATERIALS AND METHODS

A field experiment was conducted at Pearl millet Research Station, Jamnagar (22º47' N, 70º07' E, 18.00 m above the mean sea-level), Gujarat from *kharif* 2010 to *rabi* 2013–14. The site is situated in the North Saurashtra agro-climatic region of Gujarat under Gujarat plains and hills zone of India. The climate of the region is semi-arid and sub-tropical with fairly dry and hot summer. The rainy season commences in the second fortnight of June and ends in September, with an average annual rainfall of 500 mm. Winter season sets in November and continues till the middle of February. December and January are the coldest months of winter, with the mean minimum temperature ranging from 15ºC to 17ºC. Summer season commences in the second fortnight of February and ends in the middle of June. The mean maximum and minimum temperature recorded were 30.3ºC and 21.2ºC respectively. The experimental soil was clayey (14.81% sand, 17.74% silt and 67.45% clay) in texture and slightly alkaline in reaction, with *p*H 7.9 and electrical conductivity EC 0.42 dS/m. It was moderately fertile being low in organic carbon (4.2 g/kg), medium in available nitrogen (202.3 kg/ha) and phosphorus (10.6 kg/ha) and high in available potassium (282.5 kg/ha). The initial DTPA-extractable Fe and Zn were 7.0 and 0.68 mg/kg respectively. The soil-moisture content at field capacity and permanent wilting point in the upper 30 cm soil depth were 28.50 and 16.70% respectively. Besides, initial bulk density and porosity of the 30 cm soil depth were 1.42 Mg/m^3 and 44.9% respectively. Rainfall received during crop period of 2010–11, 2011–12, 2012–13 and 2013–14 were 1,516.2, 638.5, 348.0 and 1,209.0 mm with 43, 28, 13 and 40 rainy days respectively.

Nine treatments comprising FYM (2.5, 5.0 and 7.5 t/ha), vermicompost (1.0, 2.0 and 3.0 t/ha), FYM + vermicompost (2.5 + 1.0) only in pearl millet crop and absolute control were compared with recommended dose of fertilizer RDF (80-17-0 kg for pearl millet and 20-17-0 kg N-P-K/ha for chickpea) which was sown outside the organic plot, and was laid out in randomized block design with 4 replications. The pearl millet variety 'GHB 744' and chickpea 'GG-3' were used. The gross and net plot size were 6.0 m × 5.4 m and 5.0 m × 3.6 m respectively. The pearl millet was sown keeping 45 cm row spacing during the *kharif* season with onset of monsoon (9 July, 13 July, 11 September and 20 June during the year 2010, 2011, 2012 and 2013 respectively) and chickpea was sown with same row spacing during the *rabi* season (1 December, 29 November, 21 December and 21 November during the year 2010–11, 2011–12, 2012–13 and 2013–14 respectively). The excess plants were thinned out at 20 days after sowing (DAS) keeping within row distance at 10 cm to maintain uniform plant stand in pearl millet. Seed rate of 4 kg/ha for pearl millet and 60 kg/ha for chickpea was used. The N, P and K nutrients applied through chemical fertilizers were in the form of urea, single superphosphate and muriate of potash. In RDF, half dose of N and full dose of P was applied basal and remaining N was top-dressed at 30 DAS to the pearl millet crop, while in chickpea full dose of N and P was applied basal. In case of organic nutrient management, FYM and vermicompost were applied before final land preparation and thoroughly incorporated in the soil. The mean N, P and K contents of FYM and vermicompost on air-dry weight basis were 0.53, 0.23, 0.59% and 1.41, 1.23, 1.18% respectively. Pearl millet was sown under rainfed condition, but due to late commencement and early withdrawal of rainfall in 2012–13, 1 irrigation was given to pearlmillet crop. Chickpea was sown under irrigated condition and 4 irrigations were given at 50 mm depth. The required cultural practices and plant-protection measures were followed as per the recommended package, and weeds were managed by 2 weedings and 2 intercultural operations at 20 and 40 DAS in both the crop.

Due to yearly variation in price of crops, the cost of cultivation and gross return were calculated by taking mean price of 4 years of respective crops. Benefit: cost ratio was calculated. The pearl millet grain-equivalent yield (PMGEY) was calculated as per Yadav *et al.* (2017). System-production efficiency (kg/ha/day) was calculated by the dividing total system productivity by cropping period and system economic efficiency (₹/ha/day) was worked out by dividing the average net return over the

year by 365. The quality analysis, i.e. nitrogen content, was determined by Kjeldhal's method and this was multiplied by factor 6.25 to calculate the protein content in grain of pearl millet and chickpea seed. Soil samples were drawn at initial and at the end of 4th cropping cycle from a depth of 0–30 cm from each treatment and were analyzed for physico-chemical properties of soil using the standard procedure.

Data collected from the experiment at different growth stages were subjected to statistical analysis. The level of significance used in 'F' and't' test was P=0.05. Critical difference values were calculated wherever 'F'test was significant.

RESULTS AND DISCUSSION

Yield attributes and yield

Yield attributes of pearlmillet, viz. ears/m^2, ear length and 1,000-grain weight, were significantly higher under RDF, followed by FYM 7.5 t/ha applied to pearlmillet crop only (Table 1). The magnitude of increase in ears/m^2, ear length and 1,000-grain weight in pearlmillet was to the extent of 19.0, 15.6 and 13.6% with the application of 7.5 t FYM/ha over the absolute control. Similar findings were also reported by Husain *et al.* (2017). Application of 7.5 t FYM/ha (1.59 t/ha) resulted in at par grain yield with RDF (1.71 t/ha), recording nearly 93% of latter's yield showing its supremacy to the other organic sources and rate of application. The grain and stover yield of pearlmillet with 7.5 t FYM/ha increased 112.1 and 73.9%, respectively, over the absolute control. Ghanshyam *et al.* (2010) reported that, application of FYM and vermicompost to greengram increased grain yield of greengram and residual wheat grain yield in greengram–wheat cropping system. Yogananda *et al.* (2017) also reported similar increase in maize yield parameters with the application of FYM and vermicompost. The better performance of the crop under 7.5 t FYM/ha could be attributed to the higher dry-matter production and harvest index, which may be ascribed to the other beneficial effects including availability of micronutrients. This might be owing to greater availability of nutrient in soil which improved the soil environment and higher root development leading to better absorption of moisture and nutrient (Patra *et al.*, 2016).

Yield attributes of chickpea (pods/plant, seeds/pod and 1,000-seed weight) were also influenced significantly with residual effects of FYM or vermicompost applied to pearl millet. Significantly higher values of these traits were recorded with RDF applied to pearl millet and chickpea, but it was found statistically at par with 7.5 t FYM/ha applied to pearlmillet (Table 2). The magnitude of increase in pods/plant, seeds/pod and 1,000-seed weight in chickpea was to the extent of 44.3, 15.9 and 12.5% with the residual effect of 7.5 t FYM/ha over the absolute control. Gawai and Pawar (2006) reported similar results in sorghum–chickpea sequence. Significantly highest chickpea seed yield was recorded during 2010–11 and 2011–12 with FYM @ 7.5 t/ha and remained statistically at par with RDF, while during 2012–13 and 2013–14 the RDF resulted in significantly highest seed yield. In pooled results, application of RDF showed the highest chickpea seed yield (2.40 t/ha) and comparable with 7.5 t FYM/ha (2.37 t/ha), which was only 1.2% higher than that of 7.5 t FYM/ha. The extent of increase in seed yield over the absolute control was 63.4, 90.2, 100.6, 70.6 and 74.8% under 7.5 t FYM/ha in 2010–11, 2011–12, 2012–13, 2013–14 and pooled results respectively. Ghanshyam *et al.* (2010) reported that, application of FYM and vermicompost to greengram increased the grain yield of greengram and residual wheat grain yield in greengram–wheat cropping system. Similar results were reported by Nemade *et al.* (2017) in sorghum–chickpea cropping sequence. Similar trend was observed for stalk yield of chickpea under 7.5 t FYM/ha. Significantly highest stalk yield was recorded with RDF and 7.5 t FYM/ha applied to pearlmillet (2.60 t/ha). A relative build-up of soil organic carbon noticed under application of FYM might have created favourable environment for higher growth of microorganisms and in turn better productivity.

Pearl millet grain-equivalent yield

The highest pearl millet grain-equivalent yield (PMGEY) was recorded owing to RDF (8.71 t/ha) applied to pearl millet and chickpea crop during respective season and remained at par with FYM @ 7.5 t/ha (8.48 t/ha) to pearl millet crop in *kharif* season. An increase in PMGEY to the tune of 86.1 and 80.1% was recorded with the application of RDF applied to both the crop and 7.5 t FYM/ha to pearl millet crop over the absolute control respectively. The decrease in pearl millet grain-equivalent yield under application of 7.5 t FYM/ha was only 2.7% compared to RDF. Kumar *et al.* (2017) reported that, maize + blackgram-chickpea cropping sequence under different organic manures recorded the highest maize–equivalent yield and benefit: cost ratio. Increase in potato-equivalent yield through FYM under potato–frenchbean cropping sequence was reported by Yadav *et al.* (2017), soybean–equivalent yield under soybean–wheat was reported by Machhar *et al.* (2015) and pearl millet-equivalent yield under pearl millet–chickpea was reported by Husain *et al*. (2017).

System production and economic efficiency

System-production efficiency and system economic efficiency were significantly influenced by the application

Table 1. Effect of nutrient management with organic manures on yield attributes and yield of pearl millet

Treatment	Yield attributes*			Grain yield (t/ha)					Stover yield (t/ha)				
	Ears/ m^2	Ear length (cm)	1,000-grain weight (g)	2010	2011	2012	2013	Pooled	2010	2011	2012	2013	Pooled
RDF (Both crops)	34.5	25.2	9.12	0.86	0.16	2.15	2.23	1.71	3.06	6.56	3.78	3.75	4.29
Absolute control	28.4	21.1	8.02	0.29	0.68	1.03	0.98	0.75	1.39	3.08	2.18	2.36	2.25
FYM 2.5 t/ha	29.7	23.1	8.76	0.40	0.95	1.36	1.30	1.00	1.88	5.39	2.51	2.64	3.10
FYM 5.0 t/ha	32.1	23.8	8.93	0.52	1.21	1.66	1.67	1.27	2.11	5.76	2.93	3.01	3.46
FYM 7.5 t/ha	33.8	24.4	9.11	0.79	1.52	2.00	2.05	1.59	2.72	6.01	3.33	3.61	3.92
VC 1.0 t/ha	29.1	22.1	8.57	0.30	0.84	1.15	1.05	0.83	1.71	4.35	2.47	2.47	2.75
VC 2.0 t/ha	31.3	22.5	8.79	0.39	1.15	1.35	1.26	1.04	1.94	4.61	2.96	2.72	3.06
VC 3.0 t/ha	32.0	23.3	8.95	0.49	1.23	1.63	1.53	1.22	2.25	5.00	3.18	2.92	3.34
FYM 2.5 t/ha + VC 1.0 t/ha	32.4	23.7	8.99	0.60	1.03	1.69	1.71	1.26	2.30	5.61	2.81	2.75	3.37
SEm±	1.2	0.9	0.21	0.04	0.08	0.08	0.08	0.06	0.09	0.24	0.09	0.14	0.17
CD (P=0.05)	3.5	2.6	0.62	0.13	0.24	0.25	0.22	0.17	0.28	0.69	0.27	0.40	0.51

RDF, Recommended dose of fertilizer; FYM, farmyard manure; VC, vermicompost; *pooled data of 4 years

Table 2. Effect of nutrient management with organic manures on yield attributes and yield of chickpea

Treatment	Yield attributes*			Seed yield (t/ha)					Stalk yield (t/ha)				
	Pods/ plant	Seeds/ pod	1,000-seed weight (g)	2010–11	2011–12	2012–13	2013–14	Pooled	2010–11	2011–12	2012–13	2013–14	Pooled
RDF (Both crops)	92.4	1.84	201.3	2.82	3.04	1.17	2.57	2.40	2.90	2.88	1.64	2.98	2.60
Absolute control	63.2	1.57	178.2	1.97	1.64	0.51	1.25	1.36	1.99	1.71	0.92	2.20	1.70
FYM 2.5 t/ha	83.9	1.69	189.7	2.59	2.43	0.61	1.55	1.80	2.61	2.46	1.22	2.68	2.24
FYM 5.0 t/ha	87.4	1.75	195.6	2.86	2.64	0.76	1.73	2.00	2.95	2.64	1.31	2.69	2.40
FYM 7.5 t/ha	91.2	1.82	200.5	3.22	3.11	1.02	2.13	2.37	3.24	3.00	1.43	2.73	2.60
VC 1.0 t/ha	75.4	1.63	184.3	2.31	2.07	0.53	1.36	1.57	2.46	2.11	1.14	2.50	2.05
VC 2.0 t/ha	79.2	1.69	189.6	2.37	2.30	0.66	1.55	1.72	2.49	2.31	1.17	2.59	2.14
VC 3.0 t/ha	84.3	1.73	192.4	2.51	2.33	0.71	1.68	1.81	2.53	2.41	1.21	2.67	2.21
FYM 2.5 t/ha + VC 1.0 t/ha	85.2	1.79	198.7	2.64	2.60	0.78	1.73	1.94	2.68	2.65	1.24	2.69	2.31
SEm±	2.9	0.04	4.1	0.17	0.14	0.04	0.10	0.08	0.11	0.19	0.05	0.13	0.07
CD (P=0.05)	8.5	0.12	12.1	0.51	0.41	0.11	0.28	0.22	0.33	0.54	0.16	0.38	0.20

RDF, Recommended dose of fertilizer; FYM, farmyard manure; VC, vermicompost; *pooled data of 4 years

of different organic manures (Table 3). The highest production (20.17 kg/ha/day) and economic (409.5₹/ha/day) efficiency were recorded under RDF, which were statistically at par with FYM @ 7.5 t/ha (19.42 kg/ha/day and 399.6₹/ha/day) applied to pearl millet crop. The extent of increase in production and economic efficiency under RDF was 95.4 and 128.5% and under 7.5 t FYM/ha was 88.2 and 123.0%, respectively over the absolute control. Significantly lowest production and economic efficiency was noticed under the absolute control. Yadav *et al.* (2017) reported that, higher economic efficiency was recorded with 30 t FYM/ha in potato–frenchbean cropping sequence over RDF.

Economics

Pearl millet, chickpea and system economics were significantly affected by different organic manure treatments (Table 3). In pearl millet, the highest gross returns, net returns and benefit: cost ratio (BCR) were recorded with RDF and only gross returns were comparable with 7.5 t FYM/ha. The negative net returns and BCR were recorded with application of vermicompost @ 3 t/ha due to higher cost of vermicompost compared to FYM. In chickpea, the highest gross returns (86.60 × 10^3₹/ha) was noted with RDF, whereas the highest net returns (71.03 × 10^3₹/ha) and BCR (4.88) were recorded with application of FYM @ 7.5 t/ha and among them BCR was found significantly higher than RDF (4.20). The application of 7.5 t FYM/ha, resulted in 1.6% higher net income of chickpea seed yield over RDF. The highest system economics in terms of gross returns (113.17 × 10^3₹/ha) and net returns (83.53 × 10^3₹/ha) were recorded with RDF applied to both the crops and it remained at par with 7.5 t FYM/ha applied to only pearl millet (110.19 × 10^3₹/ha and 81.52 × 10^3₹/ha), whereas the highest BCR was calculated with FYM @ 7.5 t/ha (2.84) which was comparable with RDF (2.82). Husain *et al.* (2017) reported highest gross returns, net returns and BCR under 7.5 t FYM/ha over rest of treatments.

Table 3. Effect of nutrient management with organic manures on pearl millet grain-equivalent yield, system-production efficiency, system-economic efficiency and economics of pearl millet–chickpea cropping sequence (pooled data of 4 years)

Treatment	PMGEY (t/ha)	System production efficiency (kg/ha/day)	System economic efficiency (₹/ha/day)	Pearl millet			Chickpea			System		
				Gross returns (× 10^3 ₹/ha)	Net returns (× 10^3₹/ha)	Benefit: cost ratio	Gross returns (× 10^3 ₹/ha)	Net returns (× 10^3₹/ha)	Benefit: cost ratio	Gross returns (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio
RDF (Both crops)	8.71	20.17	409.5	26.57	13.59	1.05	86.60	69.94	4.20	113.17	83.53	2.82
Absolute control	4.70	10.32	179.2	12.00	1.94	0.19	49.17	34.61	2.38	61.17	36.55	1.48
FYM 2.5 t/ha	6.25	13.71	269.9	16.12	4.50	0.39	65.10	50.55	3.47	81.22	55.05	2.10
FYM 5.0 t/ha	7.10	16.00	317.8	19.93	7.06	0.55	72.33	57.78	3.97	92.26	64.84	2.36
FYM 7.5 t/ha	8.48	19.42	399.6	24.60	10.49	0.74	85.59	71.03	4.88	110.19	81.52	2.84
VC 1.0 t/ha	5.42	11.77	208.6	13.61	0.24	0.02	56.86	42.31	2.91	70.47	42.55	1.52
VC 2.0 t/ha	6.07	13.52	235.3	16.54	0.17	0.01	62.37	47.83	3.29	78.91	48.00	1.55
VC 3.0 t/ha	6.52	14.86	249.0	19.23	-0.13	-0.01	65.49	50.93	3.50	84.72	50.80	1.50
FYM 2.5 t/ha + VC 1.0 t/ha	6.91	15.67	298.8	19.74	5.37	0.37	70.14	55.59	3.82	89.88	60.96	2.11
SEm±	0.34	1.12	14.1	1.21	1.14	0.05	3.22	3.05	0.21	4.32	3.24	0.14
CD (P=0.05)	0.99	3.27	41.2	3.53	3.32	0.14	9.40	8.91	0.61	12.61	9.48	0.40

RDF, Recommended dose of fertilizer; FYM, farmyard manure; VC, vermicompost; PMGYE, pearl millet grain-equivalent yield; Selling price (₹/kg): pearl millet grain, ₹13; pearl millet stover, ₹1; chickpea seed, ₹35; chickpea stalk, ₹1

Quality

The protein content in pearl millet grain and chickpea seed were significantly affected by different organic manures (Table 4). Significantly highest protein content in pearl millet grain (10.73%) and chickpea seed (23.25%) was recorded with7.5 t FYM/ha applied to pearl millet and it remained statistically at par with RDF applied to both the crops (10.40% in pearl millet grain and 23.22% in chickpea seed). Application of FYM @ 7.5 t/ha and RDF increased the protein content by 23.3 and 19.5% in pearl millet grain, respectively, over the absolute control. The magnitude of increase in protein content in pearl millet grain and chickpea seed was 3.2 and 0.1% with the incor-

poration of 7.5 t FYM/ha to pearlmillet crop over RDF to both the crops. Khurab and Chander (2008) also reported that, protein content in residual wheat increased with the increase in the dose of FYM under rice–wheat cropping sequence.

Soil physical properties

The bulk density (BD) of soil after harvesting of pearl millet and succeeding chickpea crops under different organic manure-treated plots decreased as compared to the absolute control, resulting in significant increase in porosity of the soil (Table 4). The lowest BD (1.36 Mg/m^3) was recorded with application of 7.5 t FYM/ha over all the remaining treatments as well as the initial level. The decrease in BD under FYM @ 7.5 t/ha compared to RDF, absolute control and initial level was 3.7, 5.5 and 4.4% respectively. Rathore *et al.* (2011) reported that, the addition of organics reduced the bulk density of the soil. Significantly the maximum porosity was recorded with FYM @ 7.5 t/ha (46.3%) over the absolute control (44.7%) and initial level (44.9%). The increase in porosity with 7.5 t FYM/ha over RDF, absolute control and initial level was 3.6, 5.0 and 3.2% respectively. The improvement in the soil physical properties might be owing to increased organic matter and improved soil structure. Rathore *et al.* (2011) also reported significantly higher total porosity in treatments receiving FYM.

Soil chemical properties

Application of organic manure significantly improved the soil fertility in terms of *p*H, organic carbon (OC) and soil-available nutrients (N, P and K) at post-harvest stage (Table 4). The decrease in soil *p*H with 7.5 t FYM/ha was 3.9% from the initial value. The reduction in soil *p*H might be due to production of weak organic acids due to decomposition of organic manure. The results are in accordance with the findings of Nagar *et al.* (2016), who reported that *p*H and EC reduced slightly with application of FYM and crop residues. Significantly the highest organic carbon was recorded with 7.5 t FYM/ha (6.0 g/kg) over RDF, absolute control and initial status, which remained comparable with all the organic manure treatments. Increasing levels of FYM and vermicompost increased the soil-available NPK status. The application of 7.5 t FYM/ha increased soil-available nutrients N, P and K to the tune of 12.6, 31.4 and 24.0%, 1.9, 8.7 and 14.6%, 10.4, 6.6 and 16.7% over RDF, absolute control and initial soil status respectively. These results confirm the findings of Yogananda *et al.* (2017). The increase in N status was solely attributed to the decomposition of N-bearing organic compounds in applied FYM, while the enhanced P availability was the combined effect of released organic acids and organic anions on decomposition of FYM. Yadav *et al.* (2009) reported that, the higher availability of potassium owing to FYM may be ascribed to the reduction of K fixation and release of K due to the interaction of organic matter with clay. Soil fertility build up through application of organic manure also reported by Kumara *et al.* (2018).

From the results of the 4 year experimentation, it can be concluded that to obtain higher net income and maintaining soil fertility in pearl millet–chickpea sequence, application of 7.5 t FYM/ha every year to pearl millet in pearl millet–chickpea sequence may be recommended.

Table 4. Effect of nutrient management with organic manures on protein content and soil physico-chemical properties in pearl millet-chickpea cropping sequence after four crop cycle

Treatment	Protein (%)		Soil physical properties		Soil chemical properties					
	Pearl millet grain	Chickpea seed	BD (Mg/m^3)	Porosity (%)	*p*H	EC (dS/m)	OC (g/kg)	Soil-available nutrients (kg/ha)		
								N	P	K
RDF (Both crops)	10.40	23.22	1.41	44.7	7.94	0.61	4.6	219.3	10.4	287.7
Absolute control	8.70	21.42	1.43	44.1	7.91	0.56	3.9	198.4	8.6	266.0
FYM 2.5 t/ha	9.22	22.04	1.41	44.8	7.83	0.59	5.3	204.5	9.8	307.5
FYM 5.0 t/ha	9.57	22.32	1.40	45.2	7.71	0.57	5.6	213.3	10.5	318.1
FYM 7.5 t/ha	10.73	23.25	1.36	46.3	7.60	0.51	6.0	223.4	11.3	329.8
VC 1.0 t/ha	8.71	21.88	1.41	44.8	7.91	0.61	5.3	205.6	9.2	313.5
VC 2.0 t/ha	9.26	22.10	1.40	45.0	7.88	0.59	5.3	210.0	10.2	316.7
VC 3.0 t/ha	9.65	22.19	1.39	45.4	7.93	0.55	5.4	216.5	10.7	323.9
FYM 2.5 t/ha + VC 1.0 t/ha	9.60	22.32	1.37	45.8	7.81	0.60	5.2	212.8	10.6	282.7
SEm±	0.19	0.24	0.01	0.4	0.08	0.03	0.4	5.2	0.2	8.9
CD (P=0.05)	0.56	0.71	0.03	1.1	0.23	NS	1.2	15.3	0.6	26.0
Initial soil status	-	-	1.42	44.9	7.90	0.59	4.2	202.3	10.6	282.5

RDF, Recommended dose of fertilizer; FYM, farmyard manure; VC, vermicompost; EC, electrical conductivity; OC, organic carbon

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