



Yield trends and changes in soil fertility in a long term pearl millet (*Pennisetum glaucum*)-wheat (*Triticum aestivum*) cropping system managed with organic, inorganic and integrated sources of nutrients

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ABSTRACT

The present study was carried out to evaluate the yield trends and soil fertility under long term field experiment at soil research farm of CCS Haryana Agricultural University, Hisar, India. Results showed that average grain yield of wheat (*Triticum aestivum* L.) and pearl millet (*Pennisetum glaucum* (L.) R. Br) across the experimentation period was higher under integrated application of organic manures along with 150 kg N+30 kg P₂O₅/ha through chemical fertilizers as compared to application of recommended dose of nutrients through chemical fertilizers alone (150 kg N+60 kg P₂O₅/ha). Lowest grain yield of both crops was observed when organic manures applied alone. Positive yield trend of both the crops was observed under all the nutrient management practices. The highest soil organic carbon (SOC) (1.14%) was recorded with the application of farmyard manure (FYM) followed by pressmud and poultry manure. Build-up of organic carbon ranged from 0.016 to 0.037%/year with application of FYM, poultry manure, pressmud as a component of integrated nutrient management. Highest amount of humic acid-C (HA-C) and fulvic acid-C (FA-C) (0.40 and 0.21%, respectively) was observed with application of 7.5 Mg pressmud along with 150 kg N+30 kg P₂O₅ /ha. Integrated nutrient management (INM) showed superiority on better grain yield of pearl millet and wheat in these alluvial soils of Haryana.

Key words: Available nutrients, Fulvic acid, Grain yield, Humic acid, Soil organic C

In India, soils of arid and semi-arid eco-regions are light to medium textured having low fertility. So, in these areas addition of organic manures is a general practice which enhances soil organic matter (SOM) content and available nutrient status of soil (Yadav *et al.* 2000, Manna *et al.* 2005, Antil *et al.* 2011, Kharche *et al.* 2013). Nutrients contained in soil organic matter undergo mineralization as well as humification.

On one hand, mineralization releases the nutrients in the form which can be utilized by plants and hence directly improves the soil fertility. On another hand, under humification process organic compounds are converted to humic substances. Soil organic matter is constituted by both non-humified and humified groups of substances. Humic substances have greater chemical stability and lower bioavailability than non-humic substances (Piccolo 2001) and thus known as passive, highly stable soil organic matter

pool having key role in organic carbon dynamics in soil (Andreux 1996). The humified organic matter plays a crucial role in maintaining soil quality by influencing physical, chemical and biological properties of soil. Different organic inputs to soil can affect the quantity and quality of SOM and their continuous addition modifies the activity of microbial communities and consequently the organic carbon turn over. Hence monitoring the qualitative and quantitative changes of SOC is very essential for evaluating the soil quality and maintaining the soil productivity on long term basis.

The complex problems of soil fertility can be monitored by conducting long term field experiments as they provide an ideal base to study the nutrients and SOM transformation in soil under continuous application of manures and fertilizers. In many cereal based cropping systems, yields have started declining because of decrease in factor productivity (Yadav *et al.* 2000, Manna *et al.* 2005). The information on long term effect of manures and fertilizers on soil productivity and yield trends under pearl millet-wheat cropping in semiarid conditions of Haryana are limited. Keeping in view the above facts, we analyzed the data of a long term field experiment involving applications of FYM, poultry manure, pressmud and chemical fertilizers alone and in combination on pearl millet-wheat cropping system to understand yield

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trends and also measure the changes in soil organic carbon (SOC), HA-C, FA-C, available nitrogen (N), phosphorus (P) and potassium (K) content in soil.

MATERIALS AND METHODS

A long-term experiment was initiated in 1995 at Research Farm of Department of Soil Science, CCS Haryana Agricultural University, Hisar (India) to study the individual and integrated effects of manures and fertilizers on soil fertility under pearl millet (*Pennisetum glaucum* LR. Br.)-wheat (*Triticum aestivum* L.) cropping sequence. The experimental site is located at 29°16'N latitude and 75°7'E longitude in north-west part of India. The climate of the area is semi-arid with a mean annual rainfall of 443 mm that is mainly received in the month of July to October. Maximum temperature (48°C) is observed in the month of May/June while minimum temperature (below zero) is sometimes observed in the month of December/January. Mean annual temperature is 24.8°C. The soil is coarse loamy, *Typic Ustochrept* and alkaline in nature. At the start of the experiment, the field soil (0-15 cm) had a pH (1:2 soil: water suspension) of 8.1, electrical conductivity (E.C., 1:2 soil: water supernatant) of 0.36 dS/m, soil organic carbon (SOC) of 0.39% available N, P and K as 196, 25.2 and 434 kg/ha, respectively.

The locally available organic manures, viz. FYM, poultry manure (Pt), pressmud were selected for long term use in the present study. Since 1995, the following 10 treatments with three replications were maintained on the permanent plots in randomized block design: T₁: 75 kg N + 30 kg P₂O₅/ha, T₂: 150 kg N + 60 kg P₂O₅/ha (recommended dose of fertilizer), T₃: 15 Mg FYM/ha, T₄: 15 Mg FYM + 150 kg N/ha, T₅: 15 Mg FYM + 150 kg N + 30 kg P₂O₅/ha, T₆: 5 Mg poultry manure/ha, T₇: 5 Mg poultry manure + 150 kg N + 30 kg P₂O₅/ha, T₈: 7.5 Mg pressmud/ha, T₉: 7.5 Mg pressmud + 75 kg N + 30 kg P₂O₅/ha, T₁₀: 7.5 Mg pressmud + 150 kg N + 30 kg P₂O₅/ha. The plot size was 24 m × 5 m. The FYM and poultry manure were collected from University dairy and poultry farm, while pressmud was collected from sugar factory, Meham, district Rohtak. This pressmud was generated as a byproduct from sugar industry during the purification of juice by sulphitation process. The moisture content of FYM, poultry manure and pressmud was 20, 8, and 10%, respectively. The average nutrient composition of FYM, poultry manure and pressmud applied in the experiment during past 19 years was as follows: OC 38.1, 25.2, and 49.6%, total N 1.2, 2.51, and 3.23%, total P 0.97, 1.82 and 1.10% and total K 1.87, 1.72, and 0.86% respectively. The organic manures were applied once in a year at the time of field preparation for wheat sowing, in the month of November. In both the pearl millet and wheat crops, N and P were applied through urea and diammonium phosphate, respectively. In pearl millet full dose of fertilizer P and half dose of urea were applied at the time of sowing, and remaining urea was applied in two splits, viz. half dose at thinning and half at heading stage. Pearl millet variety (HHB 65) was sown in the first fortnight of July

and harvested in third week of October each year. In wheat whole of P and half of recommended N were applied at the time of sowing. Remaining N was applied one week after first irrigation. Wheat variety (WH 711 or WH 1105) was sown in the fourth week of November and harvested in third week of April each year pearl millet and wheat crops were irrigated with canal water and an irrigation of about 7.5 cm was applied when required depending on the visual inspection of the field.

Pearl millet and wheat crop were harvested at about 4-6 cm above the ground level in the month of September and April, respectively and biological yield of sun-dried bundles of each plot was recorded. The bundles were threshed, winnowed and grains so obtained were weighed. The straw yield was obtained by subtracting the grain yield from the biological yield. Straw of both the crops were removed from the field and used as fodder for dairy animals. The grain yield of wheat was averaged across the 19 years, however, in case of pearl millet; the grain yield was averaged of 16 years because of crop failure due to heavy rain in the year 2008 and 2011. Least squares linear regression of yield against time (years) was computed for each treatments (as given in Fig 1, 2) to determine a time trend variable.

$$Y = a + b t$$

where Y is the grain yield (Mg/ha), *a* is the constant, *b* is the slope or magnitude of yield trend (yield changes per year), *t* is the time (experimentation period in years).

Soil samples (0-15 cm depth) were collected after 19 cycles of pearl millet-wheat cropping system after harvest of wheat crop. Soil samples were air-dried, ground and sieved (2 mm) for further analysis. Soil samples were analyzed for pH (1:2 soil: water), electrical conductivity (E C, 1:2 soil: water supernatant). The organic C was determined by wet oxidation method (Walkey and Black 1934), available nitrogen by Kjeldahl-distillation method (Subbiah and Asija 1956), available phosphorus by NaHCO₃ extraction and colorimetry method (Olsen *et al.* 1954) and available potassium by N NH₄OAc extraction and flame photometry (Jackson 1973). Humic and fulvic acids in soil samples were extracted with 0.1 N NaOH by using method of Schlichting and Blume (1966). Humic acid and fulvic acids were separated by precipitation of HA with the addition of 5 N H₂SO₄ in extract followed by separation from FA by centrifuging at 8000 revolution per min (rpm) The humic acid and fulvic acid carbon contents were determined using potassium dichromate oxidation method and expressed on carbon basis. The humification index which determines the degree of humification of organic matter was calculated by using (humic acid/total organic carbon) × 100 expressions (Bernal *et al.* 1998).

Statistical analysis was accomplished using the program STATISTCA 6.0 Stat Soft, Inc. (2001). Within the STATISTCA 6.0 after calculating ANOVA, we have applied DUNCAN multiple range test to compare significant differences within the treatments.

RESULTS AND DISCUSSION

Grain yield and yield trend

The average grain yield of wheat and pearl millet over 19 years varied from 1.89 to 4.84 Mg/ha (Table 1) and highest yield was observed under $FYM_{15}N_{150}P_{30}$ treatment which was about 12% higher than recommended dose of fertilizers (RDF). With the application of integrated use of pressmud @7.5 Mg/ha along with 150 kg/ha N and 30 kg/ha P_2O_5 , the grain yield also increased about 6% over RDF. However, under integrated use of poultry manure @ 5 t/ha along with 150 kg/ha N and 30 kg/ha P_2O_5 , the grain yield decreased about 7% over RDF. But yield under this treatment increased after 2007 over that of RDF. The lower grain yield of wheat was observed under the application of FYM or poultry manure or pressmud alone @ 15, 5 and 7.5 t/ha, respectively and yield decreased about 55, 48 and 44% when compared to that of RDF. Similar trend in grain yield of pearl millet was observed but the magnitude of increase or decrease in yield over that of RDF was less (Table 1). The average grain yield pearl millet of over 16 years varied from 1.30 to 2.13 Mg/ha. About 5 and 6% higher grain yield of pearl millet was observed under $FYM_{15}N_{150}P_{30}$ and $PM_{7.5}N_{150}P_{30}$ treatments, respectively as compared to RDF. The grain yield of pearl millet decreased about 37, 36 and 28% over the RDF value with the sole application of FYM, poultry manure and pressmud. The grain yield of both the crops with the application of organic manures alone was even lower than that of 50% RDF. The grain yield of both the crops with the application of 15 Mg/ha FYM along with 150 kg/ha N was comparable with RDF.

The lower grain yield of both crops recorded with the application of organic manure alone was due to slow release of nutrients (particularly N) from these manures which were not able to synchronize the crop nutrient demand. However, integrated application of organic manures and NP fertilizers increases the mineralization of nutrients and their continuous release during the growth period coupled with better soil physico-chemical characteristics resulted in better plant canopy and consequently the higher rate of photosynthesis increased the crop productivity. Superiority of INM treatment in increasing the productivity of wheat based cropping systems compared to application of chemical fertilizers alone has also reported by Narwal and Antil (2005), Singh *et al.* (2014). The difference in grain yield of both the crops under RDF and INM treatments increased continuously over passage of time due to increase in SOC content and nutrient availability under improved soil conditions.

The yield trend of wheat (49 to 146.0 kg/ha/year) and pearl millet (46 to 98 kg/ha/year) was positive for all the treatments. Wheat grain yield increased maximum @146.0 kg/ha/year under $Pt_5N_{150}P_{30}$ treatments followed by $FYM_{15}N_{150}P_{30}$ treatment (120 kg/ha/year). Similarly, pearl millet yield increased maximum @ 98 kg/ha/year under $FYM_{15}N_{150}P_{30}$ treatment followed by $Pt_5N_{150}P_{30}$ treatment (97 kg/ha/year). The grain yield of wheat and pearl millet

Table 1 Effect of long term application of organic manures and fertilizers on average grain yield of wheat and pearl millet

Manure type	Dose (Mg/ha)	Fertilizer (kg/ha)		Yield (Mg/ha)	
		N	P_2O_5	Wheat	Pearl millet
No manure	0	75	30	‡3.10±0.50 [¶]	#1.62±0.45
	0	150	60	4.38±0.58	2.01±0.53
FYM	15	0	0	1.89±0.66	1.30±0.45
	15	150	0	4.52±0.69	2.03±0.60
	15	150	30	4.84±0.79	2.11±0.62
Poultry manure	5	0	0	2.19±0.66	1.33±0.42
	5	150	30	4.04±0.88	1.86±0.59
Pressmud	7.5	0	0	2.27±0.29	1.49±0.42
	7.5	75	30	3.88±0.58	1.94±0.64
	7.5	150	30	4.62±0.67	2.13±0.55

Represents standard deviation (SD), ‡ Average grain yield of 19 years, # Average grain yield of 16 years.

crop under RDF increased @ 81 and 72 kg/ha/year which were lower than that observed under integrated application of organic manures and NP fertilizers. With the application of FYM and poultry manure alone @ 15 and 5 Mg/ha/year, respectively, the increment in wheat grain yield/year was found higher as compared to RDF. The grain yield of wheat increased @ 49 kg/ha/year with the application of pressmud alone @ 7.5 Mg/ha.

The pearl millet yield increased with slow rate under application of organic manure alone (60, 59 and 46 kg/ha/year for FYM, poultry manure and pressmud, respectively) as compared to that of RDF (72 kg/ha/year). During the initial years of experimentation, the yield gap between RDF and INM treatment of FYM and pressmud ($FYM_{15}N_{150}P_{30}$ and poultry manure $_5N_{150}P_{30}$) was less and this yield gap increased with passage of time (Fig 1 and 2). After 2005, the grain yield of wheat increased with higher rate as compared to RDF. Similarly, in case of pearl millet, the grain yield increased with higher rate after 2004. At the end of 19th year of experimentation about 112 and 115% higher grain yield of wheat was observed under $FYM_{15}N_{150}P_{30}$ and $PM_{7.5}N_{150}P_{30}$ treatment compared to RDF treatment. Under $Pt_5N_{150}P_{30}$ treatment, the grain yield of wheat and pearl millet was lower than RDF till 2007, 2008, respectively. After that grain yield of both crops increased with higher rate and it surpassed to RDF and reached to 6 and 12% higher in the 2014.

There are contradictory reports on yield trends of various crops grown with RDF and INM under long term fertility experiments of Indian conditions. Yadav *et al.* (2000) reported the negative yield trend of rice-wheat cropping system at Ludhiana and Pantnagar, however, a positive yield trend under NPK treatment was observed at Kanpur, Sabour and Jabalpur, and under INM (50% RDF+50% FYM) treatment at Kanpur, Sabour, Jabalpur,

Kalyani and Faizabad. Manna *et al.* (2005) reported a negative yield trend of soybean and wheat crop at Ranchi, sorghum and wheat crop at Akola under NP (100% recommended N and P) treatment. However, they observed a positive yield trend of these crops under NPK (100% recommended N, P and K) and NPK+FYM (100% recommended N, P and K+10 Mg/ha) treatments at both

the locations. The yields of different cropping systems depend on several factors such as soil type, climate, crop variety and management practices. In the present study the positive yield trend under different treatments could be due to increasing SOC content, growing high yielding, use of disease resistance varieties and better crop management practices adopted during experimentation.

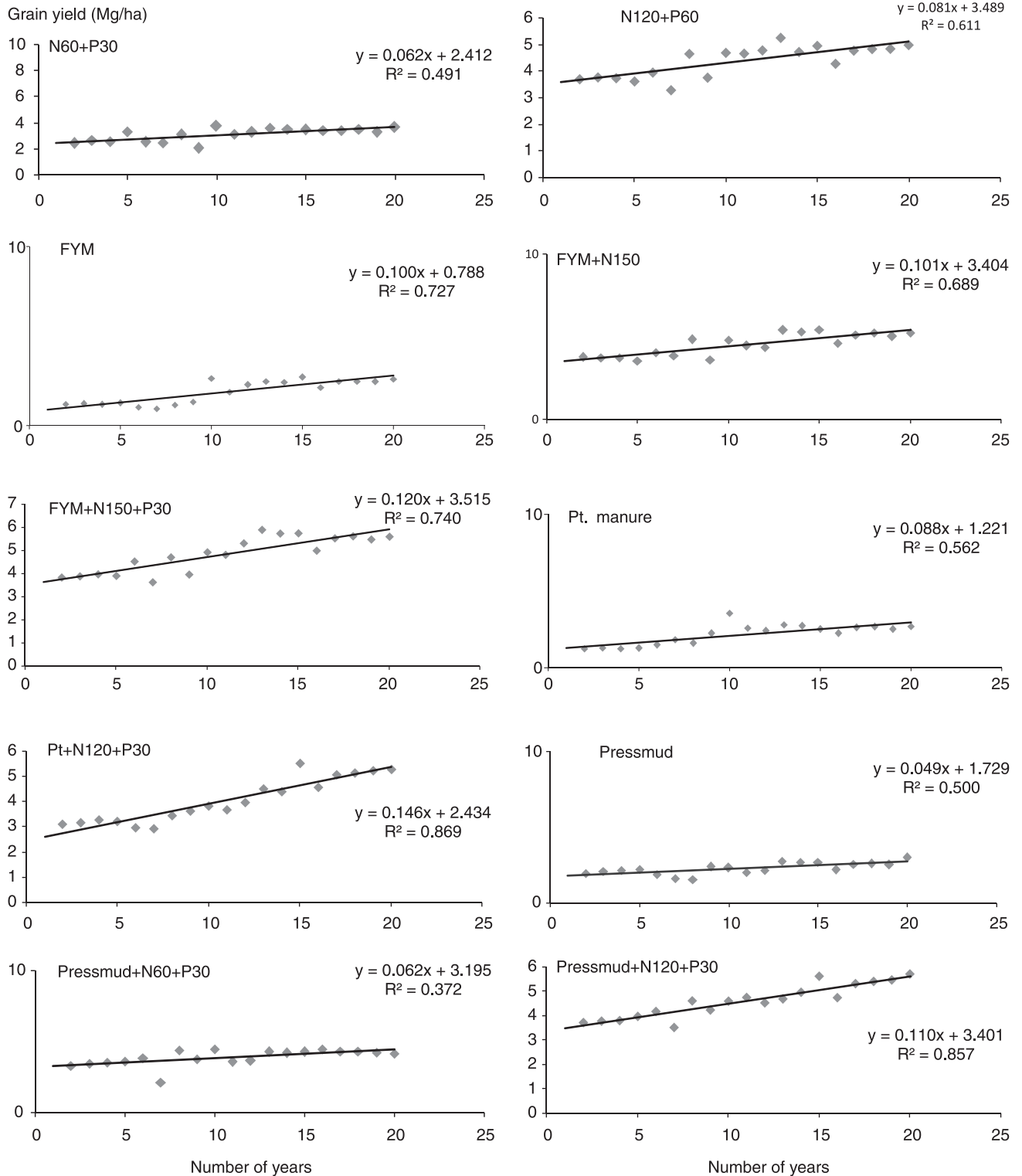


Fig 1 Trends in grain yield of wheat under different treatment of manures and fertilizers.

Grain yield (Mg/ha)

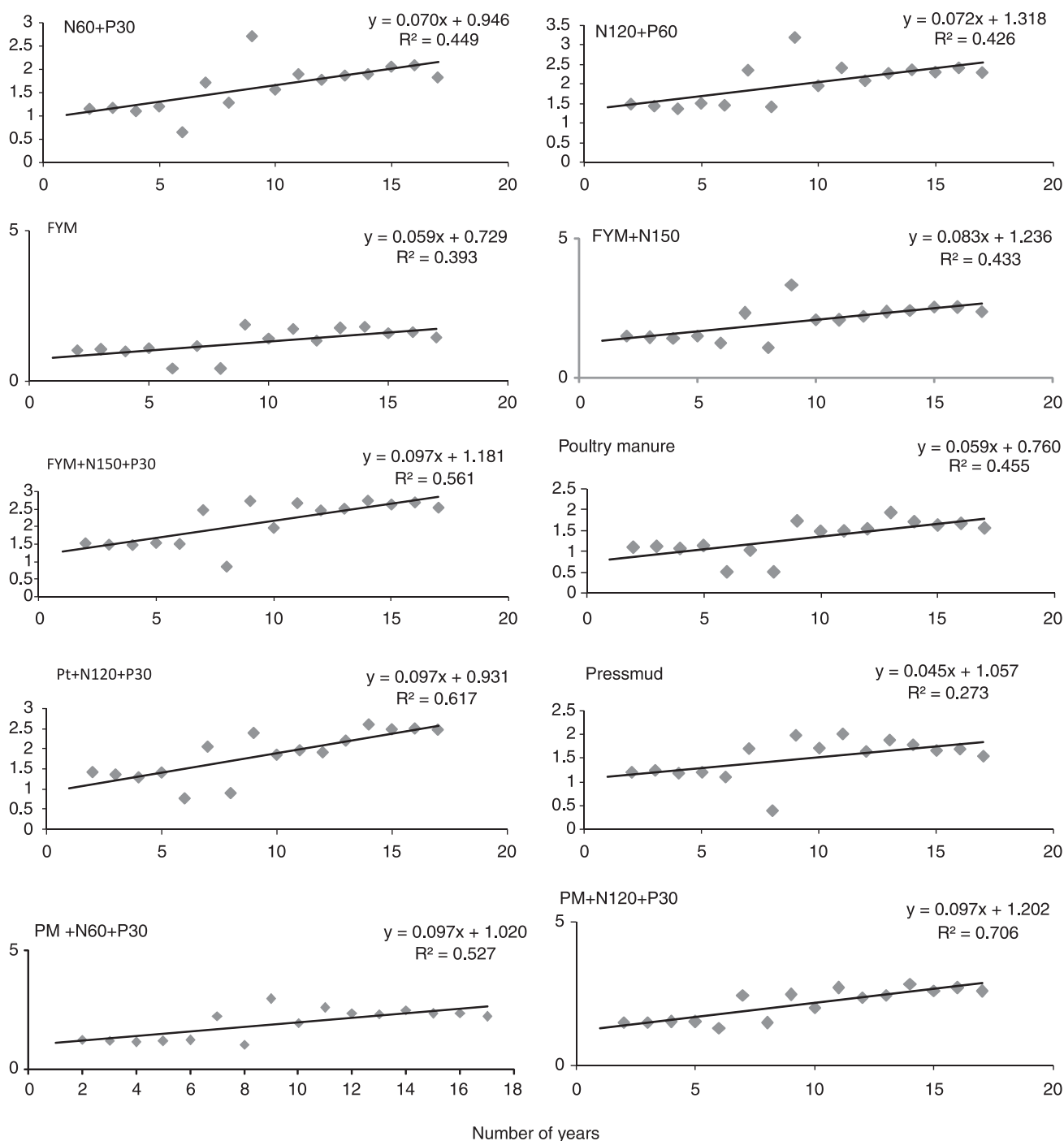


Fig 2 Trends in grain yield of pearl millet under different treatment of manures and fertilizers.

Soil reaction (pH) and EC

Soil pH in the treatments receiving continuous organic manure application for 19 years, either alone or in combination with NP fertilizers was significantly lower than that in the treatments receiving chemical fertilizers alone (Table 2). The soil pH decreased over the initial value with the application of manures and fertilizers either alone and in combination. Maximum decrease (7.50) was observed with the application of 15 Mg/ha FYM+150 kg/ha N+30 kg/

ha P₂O₅. This must be due to organic matter oxidation and release of CO₂ (Walker *et al.* 2004) resulting into formation of organic acids during decomposition of organic matter. The decrease in soil pH was more pronounced with addition of FYM as compared to poultry manure and pressmud. This type of results may be due to release of more quantity of organic acids as a result of higher amount of FYM addition. A strong negative correlation between pH and SOC indicated that the increasing SOC decreases the pH of soil. A slight

decrease in soil pH with continuous addition of FYM has also been reported by Mishra *et al.* (2008) and Santillan *et al.* (2014). A further decrease in soil pH with addition of fertilizers along with manures may be due to residual acidity developed by nitrogenous fertilizers in soil. Bhoi and Mishra (2012) reported the increase in soil pH with addition of poultry manure due to release of ammonia during its decomposition.

However, reverse trend was observed in case of EC and it varied from 0.28 to 0.65 dS/m under different treatment combinations (Table 2). The continuous application of organic manures increased EC of soil and it further increased when NP fertilizers were applied in combination with FYM and pressmud as compared to chemical fertilizers applied alone. On comparing with initial value (0.36 dS/m) the proportionate increase in EC was more with the addition of FYM, while there was not much difference with the application of poultry manure and pressmud. A positive correlation between SOC and EC also revealed this type of behaviour in soil. Significant increase in EC with the application of FYM in comparison to initial value was due to the higher salt content in FYM (Na=0.68%, Ca=1.25%, Mg=7.0, and SO₄=0.36%). Feeding of mineral mixture to dairy cattle is a common practice that increases the salt content in FYM and thus their continuous addition increases the EC of soil. As good quality irrigation water was applied in both the crops thus the salts leached out from the surface soil and not deposited to the level of threshold value.

Increase in EC with the application of poultry manure over control was also observed by Dikinya *et al.* (2010) and Bhoi *et al.* (2012). Kumara *et al.* (2014) observed that increase in EC was more with the application of FYM as compared to poultry manure and pressmud under pearl millet-wheat cropping system of semiarid ecoregions. Further, Meena *et al.* (2013) reported that soil EC was increased significantly with increasing rate of FYM under pearl millet-mustard cropping system on sandy loam soil.

Addition of NP fertilizers along with FYM and pressmud further increased the EC of soil which might be due to soluble salts present in NP fertilizers. Contrary to this, Bahadur *et al.* (2013) found FYM and pressmud more effective in reducing the EC of soil.

Soil organic carbon (SOC)

The soil organic carbon content measured after 19 cycles of pearl millet-wheat cropping system varied from 0.36 to 1.14% (Table 3) under different treatment combinations of manures and fertilizers. The highest organic carbon content (1.14%) was recorded with FYM₁₅N₁₅₀P₃₀ that was statistically at par with FYM₁₅N₁₅₀ (1.09%). Gupta *et al.* (2003) also reported the accrual of soil organic carbon (0.97 to 1.38%) in a long term field experiment with the application of 15 Mg/FYM along with 120 kg/ha N under pearl millet-wheat cropping system at Hisar. The higher build-up of SOC with the application of FYM as compared to poultry manure and pressmud was due to variation in their applied amount. Soil organic carbon content increased by 131.8, 59.1, and 84.1%, respectively, with the application of 15 Mg FYM, 5 Mg poultry manure and 7.5 Mg pressmud/ha over RDF. Similarly, SOC content was increased by 159.1, 68.2, and 109.1% with the application of organic manures along with N₁₅₀P₃₀ over the application of RDF, respectively. As compared to initial status, the SOC content increased by 1.8 to 2.9 times with continuous application of organic manures alone or in combination with NP fertilizers. However, with the application of RDF alone, the SOC content increased about 13% over the initial value. The increment of SOC content with the application of NP fertilizers was due to more plant residue returned into soil under increased plant growth and root biomass condition. The further increase in SOC content under INM treatments was due to addition of organic matter directly by organic manures along with high plant biomass returned into the soil. Among different organic manures, the build-up of SOC

Table 2 Long term effects of manures and fertilizers application on soil pH, EC and available nutrients in soil

Manure (Mg/ha)	Fertilizer (kg/ha)		pH	EC (dS/m)	Available nutrients (kg/ha)		
	N	P ₂ O ₅			N	P	K
No manure	75	30	8.05g	0.28 a	125.5 a	19.7 a	337.0 a
	150	60	8.00g	0.29a	132.2a	21.5 a	332.0 a
FYM	0	0	7.68cd	0.60 d	161.5 bc	58.5 de	751.5g
	150	0	7.60 b	0.62de	163.4 c	56.1 cd	683.7f
	150	30	7.50a	0.65 e	166.5 c	61.4 e	656.8e
Poultry manure	0	0	7.81f	0.36 bc	154.2 b	67.9f	446.5d
	150	30	7.65 bcd	0.34 b	160.2 bc	69.7 f	413.0bc
Pressmud	0	0	7.77 ef	0.35 b	185.2 d	51.6 b	441.5d
	75	30	7.71de	0.35 b	188.5 de	53.5bc	422.7c
	150	30	7.62 bc	0.39 c	193.5 e	54.0 bc	410.0b
CD (P=0.05)			0.06	0.03	7.5	3.3	10.11
Initial			8.1	0.36	196.0	25.2	434

Different lower case letters within columns indicate significance at $P < 0.05$.

followed the order: FYM > pressmud > poultry manure. The higher build up in SOC (about 1.1 to 1.5 times) with the continuous application of organic manures and chemical fertilizers in different long term fertilizer experiments was also reported by several workers (Yadav *et al.* 2000, Manna *et al.* 2005, Kharche *et al.* 2013, Brar *et al.* 2013), but the increment in SOC over the initial value in these above said studies was less as compared to the present study (about 1.71 to 2.92 times). Higher amount of SOC build up in the present study was due to variation in season of organic manures application. In the present study, all the manures were applied in winter season, while in other studies, manures were applied in summer season which resulted in more oxidation of SOC under high temperature of summer and thus less SOC retained in the soil. Gupta *et al.* (1992) in a long term study at same location established that build up of SOC was more when FYM was applied in winter season compared to their application in summer season. Reports on impact of long term application of fertilizers on maintenance of SOC are contradictory. While some workers observed the significant increase in SOC over the initial value with the application of fertilizers (Raun *et al.* 1998, Hynes and Naidu 1998, Walia *et al.* 2010, Thakur *et al.* 2011), a decrease in SOC with continuous application of fertilizers was also reported by others (Halvorson *et al.* 2002, Bodruzzaman *et al.* 2010).

Taking into consideration the amount of FYM, poultry manure and pressmud added during the period of 19 years and assuming no loss of C, the organic carbon of soil should have been approximately 86868, 19152, and 56544 kg/ha, respectively, but the overall corresponding increase was only 0.63, 0.31 and 0.43% C over the initial value and only about 14.5, 21.9, and 15.2% of added organic carbon was retained in soil.

Humic acid and fulvic acid carbon (HA-C and FA-C)

The HA-C and FA-C content in soil varied from 0.15 to 0.40 and 0.08 to 0.21%, respectively under different treatments (Table 3). The lowest and highest HA-C and FA-C in soil was produced with $N_{75}P_{30}$ and $pressmud_{7.5}N_{150}P_{30}$ treatments, respectively. Production of HA was higher than the FA irrespective of different treatments of manures and fertilizers. The higher amount of HA-C than FA-C in alkaline soils was also observed by others researchers (Gathala *et al.* 2007, Preethi *et al.* 2013, Song *et al.* 2014). However, contrary to above, the production of FA-C was found higher than HA-C in acidic soils (Kumari *et al.* 2011, Wapa 2014, Meena and Sharma 2016). Application of 15 Mg/ha FYM, 5 Mg/ha poultry manure, and 7.5 Mg/ha pressmud increased HA-C content by 82.4, 58.8, and 94.1% over RDF, respectively. Application of above organic manures along with 150 kg/ha N and 30 kg/ha P_2O_5 increased HA-C content by 117.7, 76.5, and 135.3%, respectively, over the application of RDF and by 19.4, 11.1, and 21.2%, respectively, over application of organic manures alone. Similarly, application of 15 Mg Mg/ha FYM 5 Mg Mg/ha poultry manure and 7.5 Mg Mg/ha pressmud increased FA-C content by 88.9, 66.7,

and 77.8%, respectively, over RDF. The FA-C content further increased by 122.2, 88.9, and 133.3% with the application of fertilizers along with organic manures when compared to RDF alone, respectively. Humic substances production under different organic manure amended plots followed the order: $pressmud > FYM > poultry\ manure$. The increase in humic substances with the application of organic manures alone or in combination with NP fertilizers was due to increased organic matter content in soil and favourable environment for the formation of humic substances (Santhy *et al.* 2001). The amounts of HA-C and FA-C produced in soil were significantly affected by types of organic manures, their rates and nitrogen levels (Wapa 2014). In present study, higher amount of humic substances was produced under $pressmud$ application than other manures. This may be attributed due to the higher degree of humification because of higher microbial activity. $Pressmud$ is a byproduct of sugar industry which contains residual sugar compounds and it might be responsible for higher microbial activity and humification of organic matter as also indicated by higher value of HA/FA ratio and humification index (HI).

The HA-C/FA-C ratio and HI quantify the degree of humification to determine the stability stage of different kinds of organic matter during their decomposition. In present study, the ratio of HA-C/FA-C varied from 1.76 to 2.06 under different treatments (Table 3). The HA-C/FA-C ratio and HI was highest under $pressmud$ application as compared to FYM and poultry manure application. The HA-C/FA-C ratio decreased with the combined application of organic manures and fertilizers as compared to application of organic manures alone while HI followed the reverse trend. The HA-C/FA-C ratio was lower in case of FYM and poultry manure as compared to the application of fertilizers; however, this ratio was higher in case of $pressmud$ application. Decomposing organic matter which has HA-C/FA-C ratio > 1.9 is considered to be stable enough and does not have any adverse effect on seed germination and plant growth (Iglesias *et al.* 1992).

Available nitrogen

The available N content in soil after 19 years of continuous cultivation of pearl millet and wheat decreased over the initial value under all the treatments and found in the range of 125.5 ($N_{75}P_{30}$) to 193.5 kg/ha ($pressmud_{7.5}N_{150}P_{30}$) under various treatments (Table 2). Available N in plots treated with 15 Mg FYM, 5.0 Mg poultry manure and 7.5 Mg $pressmud/ha$ was found to be significantly greater than RDF treatment by a magnitude of 22.2, 16.6, and 40.1% respectively. With the integrated application of above manures and NP fertilizers ($N_{150}P_{30}$), available N content was found 26.0, 21.2, and 46.4% greater over RDF alone while 3.1, 3.9, and 4.5% greater over sole application of organic manures, respectively. None of treatment of present study is able to maintain the initial level of available N which decreased about 1.3 to 33.0% over the initial value under different treatment combinations. The initial level of available N was not maintained due to the losses of N from

Table 3 Long term effects of manures and fertilizers application on SOC, HA-C and FA-C content in soil

Organic manure	Fertilizer (kg/ha)		SOC (%)	HA-C (%)	FA-C (%)	HA/FA	HI
	N	P ₂ O ₅					
No manure	75	30	0.36 a	0.15 a	0.08 a	1.87	41.67
	150	60	0.44 b	0.17 a	0.09 a	1.89	38.64
FYM	0	0	1.02 g	0.31 cd	0.17 cd	1.82	30.39
	150	0	1.09 gh	0.34 ef	0.19 ef	1.79	31.19
	150	30	1.14 h	0.37 g	0.20 fg	1.85	32.46
Poultry manure	0	0	0.70 c	0.27 b	0.15 b	1.80	38.57
	150	30	0.74 cd	0.30 c	0.17 cd	1.76	40.54
Pressmud	0	0	0.81 de	0.33 de	0.16 bc	2.06	40.74
	75	30	0.86 ef	0.36 fg	0.18 de	2.00	41.86
	150	30	0.92 f	0.40 h	0.21 g	1.90	43.48
CD (P=0.05)			0.07	0.02	0.01		

Initial SOC is 0.39 percent. Different lower case letters within columns indicate significance at $P < 0.05$.

the soil in addition to the utilization by crops. The results of present study are on the line of several long term manurial experiment of the country where decrease in available N was also observed over the initial value by Gupta *et al.* (1992), at Hisar (15 to 42%), Yadav *et al.* (2000) at Jabalpur (53 to 56%), Eresha *et al.* (2016) at Bengaluru (4 to 23%). However, several other long term experiments revealed that build-up of available N over the initial value with the application of different organic manures and chemical fertilizers [Manna *et al.* 2005 at Barrackpore (3 to 28%), at Akola (97 to 166%), Behera *et al.* 2007 at Indore (11.5 to 69%), Walia *et al.* 2010 at Ludhiana (23 to 53%)]. Results showed that the depletion of available N from the soil was less with addition of organic manures and the efficiency to reduce this depletion was in order: Pressmud > FYM > Poultry manure. Organic manures reduced the N losses and released the organic bound N into the inorganic form after mineralization and thus increased the available N in soil compared to chemical fertilizers. A significant positive correlation of available N with SOC and HA-C and FA-C also supports the above fact. The higher amount of available N content in soil observed with the application of pressmud was because of higher N content in it which in turn releases more N in soil. The FYM treated plots have low available N as compared to pressmud treated plots. Possible reason could be of higher EC under FYM treated plots which inhibit the nitrification process and favors the volatilization losses of N from the soil. Considering the amount of total N added through FYM, poultry manure and pressmud during the period of 19 years of experimentation (approximately 2740, 1907, and 3682 kgN/ha, respectively), no residual effect was observed.

Available phosphorus

The available P content of soil varied between 19.7 to 69.7 kg/ha under different treatments of manures and fertilizers applied alone or in combination (Table 2). Application of organic manures significantly ($P=0.05$)

increased available P content of soil and their efficiency to improve the available P content in soil was found in the order: poultry manure > FYM > pressmud, which might be due to variation in their P content and amount of manure applied. Behera *et al.* (2007) also reported higher amount of P build up under poultry manure treated plots compared to that of FYM. Application of 15 Mg FYM, 5.0 Mg poultry manure and 7.5 Mg pressmud/ha alone significantly increased the available P content by 172.1, 215.8, and 140.0%, respectively over RDF. Similarly, with integrated application of manures and NP fertilizers (N₁₅₀P₃₀), the available P content increased by 185.6, 224.2, and 151.2%, respectively, over RDF. However, when compared to organic manures alone, the available P content increased only by 4.9, 2.6, and 4.6%, respectively. The available P content in soil after 19 years of experimentation decreased from initial value of 25.2 to 21.5 kg/ha with the application of RDF. This available P content in soil decreased due to fixation of applied P besides its removal by crops. Contrary to this, with the application of organic manures alone or in combination of NP fertilizers, the available P content in soil increased in the range of 104.7 to 176.6% over the initial value. This increase in available P with the application of organic manures alone or in combination with NP fertilizers was due to the mineralization of organic P, release of organic acids which solubilize native soil P and also reduced the fixation of P in soil (Gupta *et al.* 1992, Dhram Prakash *et al.* 2017). A significant positive relationship of available P with SOC and humic substances was observed in correlation study.

The depletion of available P over the initial value even after continuous application of recommended dose of P under rice-wheat system in long term experiments at Pantnagar (47-56%), Kalyani (3-2%), and Jabalpur (17-37%) was also reported by Yadav *et al.* (2000), however they reported the buildup of available P at Kanpur (21 to 94%), Ludhiana (49 to 96%), Faizabad (48 to 90%), and Sabour (13 to 58%) over initial value under same cropping system. In most of long term studies at different locations of country under

different cropping systems, the buildup of available P over the initial value with the application of fertilizers alone or in combination with organic manures was reported by different workers [Manna *et al.* 2005 (21 to 102%), Walia *et al.* 2010 (83 to 287%), Thakur *et al.* 2011 (153 to 335%), Kharche *et al.* 2013 (16 to 73%)]. It is very clear from this study that the initial level of available P can be maintained with the application of FYM, poultry manure and pressmud alone annually @ 15, 5, and 7.5 Mg/ha, respectively. Likewise, Gupta *et al.* (1992) also reported this fact under long term experiment of FYM and fertilizer-N at the same location. The critical evaluation of data indicated that considering the amount of total P added through FYM, poultry manure and pressmud during the tenure of experiment (2211, 1383, and 1254 kg P/ha, respectively). But the overall corresponding increase in available P was only 17.1, 21.4 and 13.2 mg/kg (over the initial level) and about 1.5, 3.1 and 2.1% available P was retained in the soil.

Available potassium

The available K content in soil after 19 years of experimentation without K application varied from 332 to 751.5 kg/ha (Table 2) and lowest value was observed with RDF while highest value was recorded with FYM₁₅N₁₅₀P₃₀ treatment. Application of FYM, poultry manure and pressmud alone increased available K content in soil by 126.4, 34.5, and 33.0%, respectively, over RDF. However, integrated application of organic manures and fertilizers (N₁₅₀P₃₀) increased the respective available K content by 97.8, 24.4, and 23.5% over that of RDF. Available K content in soil with application of full and half RDF for 19 years decreased by 30.7 and 28.8%, respectively, compared to initial value. This fact was due to removal of K from soil without K addition in any form. Application of 15 Mg FYM, 5.0 Mg poultry manure and 7.5 Mg pressmud/ha are able to maintain the initial level of available K and they increased the available K content by 73.2, 2.9, and 1.7%, respectively over the initial value. However, integrated application of poultry manure and pressmud along with NP fertilizers could not maintain the initial level of available K and it decreased by 4.8, 2.6, and 5.5% under poultry manure₅N₁₅₀P₃₀, pressmud_{7.5}N₇₅P₃₀ and pressmud_{7.5} N₁₅₀P₃₀ treatments, respectively. Contrary to this, integrated application of 15 Mg FYM along with N₁₅₀ and N₁₅₀P₃₀ are able to maintain the initial value of available K and their value increased by 57.5 and 51.3%, respectively. The decrease in available K (12.5 to 14.0%) over the initial value under integrated application of chemical fertilizers and poultry manure (Behera *et al.* 2007) and chemical fertilizers and pressmud (11.0%), (Bokhtiar *et al.* 2010) was also observed under long term study of wheat-soybean and sugarcane-sugarcane cropping system in Indian subcontinent. They also observed the higher amount of K build up in FYM treated plots as compared to that of poultry manure and pressmud. So, the results of present study are in conformity of the above findings. Significant build up of available K over

the initial value observed with the application of FYM alone or in combination with NP fertilizers was due to the higher amount of K addition through 15 Mg FYM as compared to other manures. Improvement in available K content in soil due to application of organic manures alone was found in the order of FYM > poultry manure > pressmud. The organic manures increased the availability of K in soil due to release of K from organic material and thereby reducing the fixation and leaching losses. In some long term experiments, the initial level of available K was not maintained even after application of RDF alone or in combination with organic manures (Yadav *et al.* 2000, Thakur *et al.* 2011, Kharche *et al.* 2013). It is very clear from this study that the initial level of available K can be maintained by application of 15 Mg FYM, 5 Mg poultry manure and 7.5 Mg pressmud/ha alone in alluvial soil of semiarid condition. The results are in conformity with the findings of Gupta *et al.* (1992), who reported that initial K level can be sustained with the application of FYM 15 Mg/ha in soil which was under long term fertility experiment from the last 20 years at the same location. Considering the amount of total K added through FYM, poultry manure and pressmud during the 19 years of experimentation, total K content of soil should have been approximately 4332, 859, and 901 kg K/ha, respectively but the overall corresponding increase in available K was only 159, 7, and 4 mg/kg (over the initial level). About 7.3, 1.6, and 0.9% of available K was retained in soil.

The influence of organic manures on the build-up of soil organic carbon and available nutrients content per year as a component of integrated nutrient management were calculated as the difference between the content in soil due to addition of organic manures plus NP fertilizers minus NP fertilizers divided by number of years of the experimentation (19 years). It has been observed that the organic carbon content, HA-C, FA-C, available N, P and K of soil increased and ranged from 0.016 to 0.037%/ha/year, 0.007 to 0.012/ha/year, 0.004 to 0.006%/ha/year, 1.81 to 3.23 kg/ha/year, 1.71 to 2.54 kg/ha/year, 4.11 to 17.09 kg/ha/year with application of FYM, poultry manure, pressmud as component of integrated nutrient management.

The higher grain yield of pearl millet and wheat was obtained under integrated application of organic manures (15 Mg FYM or 5 Mg poultry manure or 7.5 Mg pressmud/ha) along with full dose of recommended N and half of recommended P fertilizers as compared to RDF. The yield of both the crops increased continuously over passage of time under all nutrient management practices, but the yield gap between RDF and INM treatments increased continuously. The conjunctive use of organic manures and fertilizers accrued the SOC, HA-C and FA-C content and availability of nutrients in soil which leads to higher soil productivity. The soil fertility with respect to P and K could be maintained with the application of 15 Mg FYM, 5 Mg poultry manure and 7.5 Mg pressmud/ha annually but not for N. Therefore, integrated nutrient management practice

is important to enhance the grain yield of pearl millet and wheat under these semi-arid conditions of Haryana.

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