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Long-term effects of organic manures and inorganic fertilizers on organic carbon and nutrient contents in soil under pearl millet-wheat cropping sequence

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Abstract
An ongoing long-term experiment initiated in 1995 under pearl millet-wheat cropping sequence was selected to investigate the effect of organic manures (FYM, poultry manure and pressmud) and inorganic fertilizers on changes of pH, electrical conductivity (EC), organic C and nutrient (N, P, K, Zn, Mn, Fe and Cu) contents of soil. Continuous application of organic manures alone or in conjunction with NP fertilizer for 16 years decreased the soil pH. However, an increase in case EC was observed. Organic C content of soil deceased from its initial value, when only NP fertilizers were applied and increased significantly with the application of organic manures applied alone or with NP fertilizers. The highest organic C content of soil has approached to 1.12 % in plot receiving 15 Mg FYM+150 kg N + 30 Kg P_2O_5 ha^{-1}. Soil fertility with respect to P, K and micronutrients (except N) can be maintained with the application of organic manures with or without NP fertilizers. Hence, the application of P, K and micronutrients fertilizers can be avoided. The build-up of organic C and nutrient contents was higher in surface (0-15 cm) soil as compare to sub-surface (15-30 and 30-45 cm) soil.

Keywords: Organic manures, inorganic fertilizer, organic C, NPK

Introduction
The role of soil organic matter is well established in governing the improvement in soil physical [8], nutrient fluxes, microbial biomass and chemical [5] properties. The use of inorganic fertilizers in combination with organic manures has been found more advantageous than either of them on their own for sustainable agriculture for long-term basis [14, 9]. Application of FYM increased the organic C, macro and micronutrient content of soil [6]. Long-term experiments are valuable tools for determining yield trend, understanding changes in yield, estimating nutrient dynamics, and assessing system sustainability. The results of ongoing long-term field experiment on integrated nutrient management under pearl millet-wheat cropping sequence initiated in 1967 indicated that application of 15 t FYM ha^{-1} $year^{-1}$ is sufficient to maintain the nutrients (except N) status of P, K and micronutrients of soil to its initial level [7, 2]. Application of FYM increased the organic C, macro and micronutrient content of the soil [14, 6, 2]. An ongoing long-term field experiment with rice-wheat cropping system which was established in 1995 at CCS HAU, Hisar, Haryana, India was selected for the present study test the above technology by using different kinds of organic manures in combination with fertilizers. Therefore, this study aimed at to monitor changes in nutrient contents of soil and organic carbon after long-term organic manures and inorganic fertilizers application to pearl millet-wheat cropping sequence.

Materials and methods
An ongoing long-term field experiment with pearl millet-wheat cropping sequence which was established in 1995 on a coarse loamy, Typic Ustochrept soil at CCS Haryana Agricultural University, Hisar, India was selected for the present study. The site is located between 29.16º N latitude and 75.75 º E longitude in the northwest part of India. The climate of the experimental area is semi arid with a mean annual precipitation of 443 mm and mean annual temperature of 24 º C. the pH (1:2) of soil (0-15 cm depth) was 8.1, electrical conductivity (EC) (1:2) 0.36 dSm^{-1}, organic C 0.39 %. Available N, P and were respectively, 98, 12.6 and 217 mg kg^{-1}. The average nutrient composition of FYM, poultry manure and pressmud applied in the experiment during this period are given in the Table I. All the organic manure contained about 20 % moisture. The experiment was laid out with the following treatments in a randomized block design with three replications; 75 kg N + 30 Kg P_2O_5 ha^{-1}, 150 kg N + 60 Kg P_2O_5 ha^{-1}, 15,000 kg FYM ha^{-1}, 15,000 kg FYM + 150 kg N ha^{-1}, 15,000 kg FYM + 150

kg N ha^{-1}+30 Kg P_2O_5 ha^{-1}, 5000 kg poultry manure ha^{-1}, 5000 kg poultry manure +150 kg N ha^{-1}+30 Kg P_2O_5 ha^{-1}, 7500 kg press mud ha^{-1}, 7500 kg press mud +75 kg N + 30 Kg P_2O_5 ha^{-1}, 7500 kg press mud +150 kg N + 30 Kg P_2O_5 ha^{-1}. FYM, poultry manure and pressmud were applied once a year in winter at time of wheat planting. The plots are of 24X 5 m in size. Soil samples were collected from 0-15, 15-30 and 30-45 cm depths after harvesting of wheat. Five cores samples collected from each treatment plot were mixed thoroughly and a composite sample was taken. Soil samples were air-dried, ground, and sieved (2 mm) for analysis. The pH of soil was estimated in 1:2 soils: water suspension by using systronic digital pH meter. The electrical conductivity was estimated in supernatant solution of 1:2 soils: water suspension using Conductivity Bridge. Organic C was determined by the wet digestion method. Available (mineralizable) N was estimated by distilling soil with alkaline 0.5 % $KMnO_4$ in a mico-kjeldhal apparatus [16]. Available P was extracted with 0.5 M $NaHCO_3$ (pH 8.5) and estimated spectro-photometrically. Available K was extracted with neutral 1N NH_4OAC and estimated by flame emission spectroscopy. Available micronutrients (Zn, Mn, Fe and Cu) were extracting with DTPA [13] and estimated by atomic absorption spectrophotometer (Varian spectra AA 20 plus). Analysis of variance (ANOVA) was carried out using the randomized block design method and Least Significance Difference (LSD) was calculated on soil data for treatment means at 5% probability.

Results

The pH of the soil decreased slightly with the addition of organic manures (FYM, poultry manure, pressmud) alone or in combination with N or NP fertilizer for 16 years over the initial value (see Table II), that might be attributed to the formation of organic acids during decomposition of organic matter. A slight decrease in soil pH with addition of FYM has also been reported by [12]. The reduction in pH was more pronounced with the addition of FYM compared to poultry manure and pressmud. An increase in the EC of the soil was observed with the continuous application of organic manures for 16 years (Table II). However, an increase in soil EC with the continuous application of NP fertilizers over the initial value was marginal.

The application of organic manure alone or with NP fertilizers for 16 years resulted in an increases organic C content due to addition of organic matter through organic manures (see Table II). The highest organic C (1.12 %) was noted when FYM + 150 kg N ha^{-1}+30 Kg P_2O_5 $ha^{-1}$for 16 year were applied. Increase or decrease in soil organic C was marginal from its initial value with the continuous application of NP fertilizers. However, recommended dose of NP fertilizers were tended to have more organic C in soil compared to half recommended dose of NP fertilizers. Among the organic manures applied plots, the highest build-up in soil organic C was recorded with the application of FYM followed by pressmud and poultry, which might be due to variation in their amounts applied, nutrient composition and their release patter into soil.

The available (mineralizable) N content decreased from 98 to 64.5 mg kg^{-1} due to cropping with 75 kg N + 30 Kg P_2O_5 $ha^{-1}$for 16 years (see Table III) whereas it was 82.6 mg kg^{-1} was with 15,000kg FYM ha^{-1}. These results showed that the depletion of the soil in available N was less after FYM application. A significant increase in available N was observed when organic manures were applied in conjunction with N or NP fertilizers over NP fertilizers applied alone. The critical evaluation of the data indicated that considering the amount of total P added through FYM, poultry manure and pressmud during the tenure of experiment (700, 716 and 522 kg P ha^{-1}, respectively) but the overall corresponding increase in available P was only 12.9, 14.2 and 11.8 mg kg ha^{-1} (over the initial level) and about 1.8, 2.0 and 2.2 % available P was retained in the soil. The available K content decreased from 217 to 173.4 mg kg^{-1} to 16 years cropping where 75 kg N + 30 Kg P_2O_5 ha^{-1} fertilizers were applied, whereas it increased to 294.4 mg kg^{-1} with15,000kg FYM ha^{-1} yr^{-1} (Table III). Application of organic manures resulted in significant higher build up in available K over NP fertilizers applied alone. When organic manures were applied in conjunction with N or NP fertilizers, it resulted in significant improvement in available K over the organic manures were applied alone. The proportionate increase in available K was apparently more with FYM application followed by pressmud and poultry manure. It may be due to the variation in K content and the amounts of organic manures applied.

The relationship between organic C and available nutrients (N, P and K) were polynominal (Figure 1). The influence of organic manures on the build-up of soil organic carbon and available nutrient contents per year as a component of integrated nutrient management were calculated as the difference between organic carbon build-up due to the addition of organic manure plus NP fertilizers minus NP fertilizers alone divided by numbers of years of experimentation (16). the organic carbon, available N, P and K contents of soils increased and ranged from 0.04-0.07 yr^{-1}, 5.1-6.1, 1.7-1.8 and 15.8-18.9 mg kg yr^{-1}, respectively, with the application of FYM, poultry manure and pressmud as a component of integrated nutrient management.

Discussion

Highest soil pH (7.87) was recorded with the application of NP fertilizers. Soil pH was lower in sub-surface soil than in surface soil, regardless of treatments. It may be due to the leaching of soluble salts from surface and their concentration in sub-surface soil. The effect of different treatments on pH of sub-surface soils was significant lowest was recorded in FYM treated plots. There was a significant increase in EC of the soil with the combined application of organic manures plus NP fertilizers over application of NP fertilizers alone, similar to finding of [4]. Continuous application of organic manures alone or in conjunction with NP fertilizers for 10 years decreased the soil pH and reverse trend was observed in case of EC [3]. The proportionate increase in EC was apparently more with the addition of FYM than poultry manure and pressmud, which might be due to the supply of higher quantity of salts through FYM compared to pressmud and poultry manure. Soil EC was higher in surface soil than in sub-surface soil.

Taking into consideration the amount of FYM, poultry manure and pressmud added during the period of 16 years and assuming no loss of carbon, the organic carbon content of soil should have been approximately 4620, 900 and 2244 kg ha^{-1}, respectively, but the overall corresponding increases only 0.57, 0.12 and 0.32 % C (over the initial level) and only about 12.5, 13.2 and 14.0 % of added organic C was retained in the soil. Similarly, [10] observed a higher C sequestration in a 33 year old rice–wheat system due to application of FYM and the cropping system has greater capacity to sequester C because of high C input through enhanced productivity. A 20-40 % increase in organic C with continuous use of FYM was also reported by [15].

Increase in available N content with the addition of organic manures might be due to the release of N through the decomposition of organic manures [14, 3]. Moreover, it could also be attributed to the greater multiplication of soil microbes, which could convert organically bound N into inorganic form. Among the different organic manures, pressmud registered more increase in available N content of soil compared to FYM and poultry manure. Available N decreased with soil depth in all the treatments. Considering the amount total N added through FYM, poultry manure and pressmud during the period of 16 years of experimentation (approximately 139, 100 and 181 kg N ha^{-1}, respectively), no residual effect was observed. 16 years of continuous cultivation of pearl millet-wheat cropping system could not sustain the initial level of N by crops. Besides, a part of the N might have been converted to such forms, which were not extracted in alkaline KMnO4. Twenty years of continuous application of pearl millet-wheat rotation in sequence with different amounts of FYM fertilizer N could not sustain the initial concentration of N in surface (0-15 cm) soil [7]. The increase in available P of the soil resulting from the application of organic manures may be due to the mineralization of organic P, the production of organic acids which have a solubilizing effect on soil P and the organic aminos which retard the fixation phosphorus in soil [14, 3]. The available K content in sub-surface layer was less as compared to the surface layer. There is increasing evidence that organic amendments at high rates of application can cause dramatic increases in soil nutrients, particularly N, P and K [1, 11]. Considering the amount total N added through FYM, poultry manure and pressmud during the period of 16 years of experimentation, total K content of soil should have been approximately 2280, 452 and 474 kg N ha^{-1}, respectively, but the overall corresponding increase in available K was only 63, 14 and 16 mg kg^{-1} (over the initial level) and only about 2.7, 3.0 and 3.3 % of available K was retained in the soil.

Table I: Average nutrient composition of various organic manures used

Organic manure	Organic C	N	P	K	C:N
	…..……%.....				
FYM	38.1	1.18	0.60	1.92	32.3
Poultry manure	22.8	2.55	1.80	1.15	8.9
Pressmud	38.0	3.10	0.90	0.80	12.3

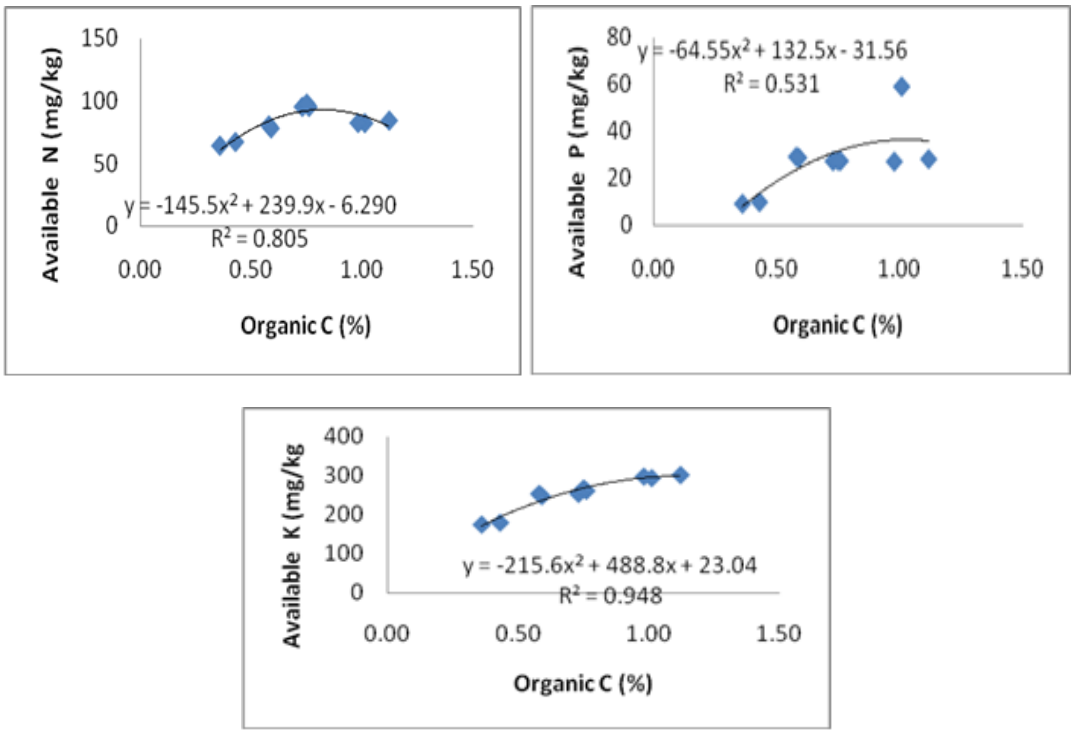
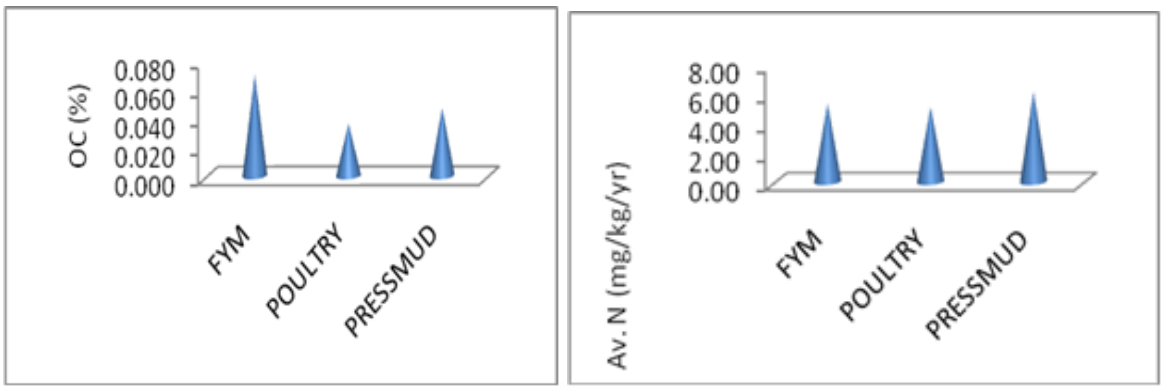


Fig 1: Relationship between organic carbon and available nutrients statutes in soil



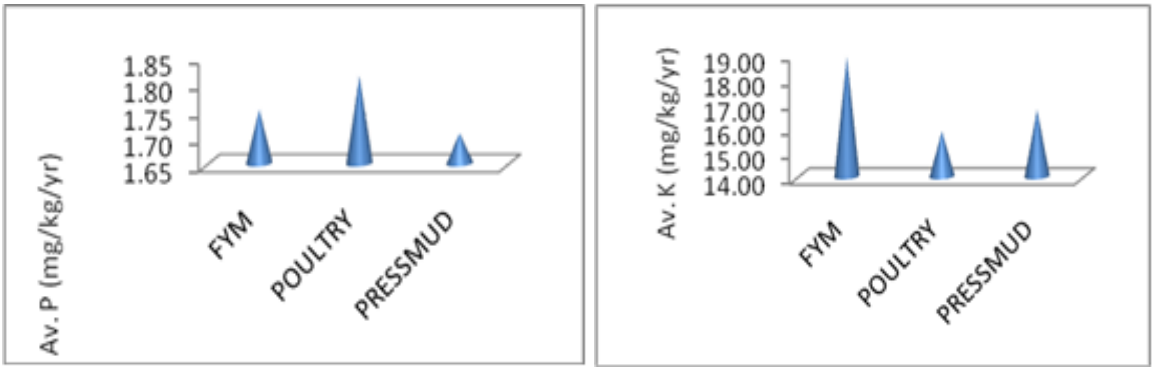


Fig 2: Influence of organic manures on build up (per year) of org. C, avail. NPK as a component of integrated nutrient management

Table II: Effect of long-term application of organic manures and fertilizers on pH, EC and organic C status at different depths of soil

Types of manure	Dose (Mg ha^{-1})	Fertilizer (kg ha^{-1})		pH			EC (dSm^{-1})			Organic C (%)		
		N	P_2O_5	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
No manures	0	75	30	8.10	7.87	7.52	0.39	0.28	0.15	0.36	0.29	0.26
	0	150	60	8.02	7.87	7.51	0.41	0.29	0.18	0.43	0.36	0.31
FYM	15	0	0	7.65	7.53	7.19	0.51	0.38	0.26	1.01	0.43	0.35
	15	150	0	7.67	7.55	7.20	0.51	0.39	0.28	0.98	0.64	0.43
	15	150	30	7.78	7.65	7.30	0.51	0.38	0.26	1.12	0.65	0.50
Poultry Manure	5	0	0	7.86	7.72	7.37	0.46	0.34	0.22	0.59	0.46	0.53
	5	75	0	7.85	7.72	7.37	0.44	0.32	0.21	0.58	0.65	0.38
Pressmud	7.5	0	0	7.78	7.67	7.31	0.48	0.36	0.24	0.73	0.64	0.51
	7.5	75	30	7.78	7.67	7.31	0.45	0.33	0.21	0.76	0.65	0.53
	7.5	150	30	7.77	7.65	7.30	0.48	0.36	0.24	0.75	0.53	0.57
Initial in 1995				8.1			0.36			0.39		
LSD (0.05)				0.073	0.013	0.015	0.008	0.009	0.008	0.05	0.04	0.013

Table III: Effect of long-term application of organic manures and fertilizers on available N, P and K status at different depths of soil

Types of manure	Dose (Mg ha^{-1})	Fertilizer (kg ha^{-1})		N			P			K		
		N	P_2O_5	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
No manures	0	75	30	64.5	41.5	18.5	8.9	8.3	4.5	173.4	156.2	120.4
	0	150	60	67.5	44.5	21.5	9.6	8.6	4.8	178.4	163.2	127.4
FYM	15	0	0	82.6	74.1	51.1	59.0	17.3	13.6	294.4	237.2	201.4
	15	150	0	82.7	74.2	51.2	26.9	17.4	13.7	298.4	241.2	205.4
	15	150	30	84.6	76.1	53.1	28.0	17.3	13.6	302.4	238.2	202.4
Poultry Manure	5	0	0	78.4	72.9	49.9	28.6	17.7	14.0	247.4	212.2	176.4
	5	75	0	80.9	75.4	52.4	29.0	18.0	14.2	253.4	224.2	188.4
Pressmud	7.5	0	0	95.7	89.6	66.6	27.1	16.9	13.1	253.4	213.2	177.4
	7.5	75	30	95.7	89.6	66.6	27.2	16.9	13.2	261.4	225.2	189.4
	7.5	150	30	98.3	92.2	69.2	27.3	17.0	13.3	267.4	232.2	196.4
Initial in 1995				98			12.6			217		
LSD (0.05)				2.2	1.9	1.9	0.2	0.12	0.13	2.6	1.3	2.5

Conclusion

Organic carbon content of the soil decreased from its initial value, when only NP fertilizers were applied and increased significantly with the application of organic manures (FYM, poultry manure, pressmud) applied alone or with NP fertilizers. The build-up of organic carbon, macro and micronutrients contents was higher in surface soil as compare to sub-surface soil. soil fertility with respect to P, K and micronutrients can be maintained with the application of FYM, pressmud and poultry manure but not for N. hence the application of P and K can be avoided with the application of 15,000 kg FYM ha^{-1} or 7500 kg pressmud ha^{-1} or 5000 kg poultry manure ha^{-1} in a pearl millet-wheat cropping sequence. These results indicate that the use of organic manures in conjunction with mineral fertilizers is very important for ensuring better soil health and in sustaining crop productivity on a long-term basis.

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