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Effect of organic manures on productivity, nutrient uptake and soil fertility in pearl millet-wheat cropping sequence in Agra region

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Abstract
A study was conducted in Agra region soil for two years (2021-22 and 2022-23) in a randomized block design replicated thrice with nine locally available sources of organic manures along with one absolute control to study the residual effect of treatments of preceding wheat crop. Grain and straw yield as well as nutrient (NPK) uptake in both wheat and pearl millet were significantly higher in plots receiving 75% RDF + 5 t FYM ha^{-1} + 5 Kg Zn ha^{-1}, followed by T6 (50% RDF + 5 t FYM + 5 Kg Zn ha^{-1}), T8 (75% RDF + 5 t FYM ha^{-1}) respectively during both the years due to higher residual fertility of respective organics. Productivity and NPK uptake both in wheat and pearl millet also increased significantly with uses of RDF, FYM and Zn levels. The study revealed that integrated use of organic manures fertilizers can play a key role in improving crop productivity, nutrient uptake and soil fertility in wheat-pearl millet sequence in Agra region.

Keywords: Organic manures, productivity, pearl millet, soil fertility, wheat

Introduction
Pearl millet- wheat cropping system is most important cropping pattern in Agra region of Uttar Pradesh. Pearl millet is a major warm season coarse grain cereal grown on 26 million ha in some of the harshest semi-arid tropical environments of Asia and Africa. Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is grown under both arid and semi-arid conditions in India. It is the fourth most widely cultivated food crop after rice, wheat, and maize. It occupies an area of 6.93 million ha with an average production of 8.61 million tons and productivity of 1,243 kg/ha (Directorate of Millets Development, 2020). It is cultivated in the most sandy, infertile soils and droughty environments (*e.g.*, arid Rajasthan) where no other cereal crop can survive. Even under these conditions, pearl millet yields 300-400 kg/ha of grain. Pearl millet is a principal source of energy, protein, vitamins and minerals for millions of poorest people in the regions where it is cultivated. It generally has 9 to 13% protein, but large variation among genotypes ranging from 6 to 21% has been observed. Pearl millet contains more calories than wheat, probably because of its higher oil content of 5%, of which 50% are polyunsaturated fatty acids. It is rich in calcium, potassium, magnesium, iron, zinc, manganese, riboflavin, thiamine, niacin, lysine and tryptophan. Pearl millet grain is gluten free and thus is the only grain that retains its alkaline properties after being cooked which is ideal for people with gluten allergies.
Wheat is the main cereal crop in India. The total area under the crop is about 29.8 million hectares in the country. The production of wheat in the country has increased significantly from 75.81 million MT in 2006-07 to an all time record high of 112.74 million MT in 202-23. The national wheat production accounts for approximately 13% of global wheat production. Wheat is an important source of carbohydrates. Globally, it is the leading source of vegetable proteins in human food, having a protein content of about 13%, which is relatively high compared to other major cereals but relatively low in protein quality (supplying essential amino acids). When eaten as the whole grain, wheat is a source of multiple nutrients and dietary fiber. Wheat and its various products play an increasingly important role in managing India's food security and India became the wheat surplus nation as against the wheat deficient nation during 1960's. The

tremendous progress in area, production and productivity of wheat to the tune of 2.9, 12.2 and 4.2 times respectively as compared to 1950 has made India the member of elite group of wheat exporting countries. About 91.5% of the wheat produced in six states viz. Uttar Pradesh, Punjab, Haryana. Madhya Pradesh, Rajasthan and Bihar.

The soil quality has been defined the capacity of soil to perform with land boundaries to sustain the productivity, environment quality and promote human and animal health. Therefore, the soil quality is imperative for the environmental quality and agricultural sustainability. The soil quality is considered physical, chemical and biological properties and the properties which influence the productivity. Among the properties soil organic carbon status and its different pools are considered as main contributor of the soil quality. The labile pools of the carbon are vital for the reducing the climate change impact on the different land uses. The enhancement of the organic carbon status provides the resilient to soil and standing crops against the variable climate. The other dynamic properties of soil might also be influence to management practices and land use.

The soil fertility of Agra region is low, therefore the main challenge is to restore and sustain soil fertility while improve the productivity of crop. The organic manure has potential to improve nutrient supplying capacity of soil. A proper and cost-effective recycling of crop residues in the form of Farm Yard Manure (FYM), compost, vermicompost, green manures etc. and the use of bio fertilizers may provide a substantial supply of nutrients to the soil plant system (Dixit and Gupta 2000) [2]. Present scenario of agriculture where limited availability of FYM, vermicompost may be a another potential source of organic matter in cultivated soils, which not only supply macronutrients and plant growth promoting hormones but also take of micronutrients which are otherwise limiting the growth and yields of the crop of many intensively cultivated areas. The sustainability of agricultural production system also depends on maintaining the reserves of soil organic matter at the minimum level necessary to protect the soil, soil biomass and maintain productivity. Soil organic matter plays a key role in influencing the nutrient dynamics in soils. It acts as a sink by boarding the nutrients temporarily through array of biochemical processes ranging from adsorption reactions to organically held plant nutrients play a vital role in sustaining plant nutrient availability. In nature, it is widely recognized that maintenance of an adequate level of soil organic matter should be a guiding principle in developing appropriate soil management practices. If the quantity of soil organic matter is declining, then it is usual to find that soil productivity will also deteriorate.

Literature review

Mathur *et al.* (1998) [5] reported in their study that phosphorus availability in soils after wheat and pearl millet crop increased significantly with increasing rates of applied P. Application of P also enhanced the available K content in soil after the harvest of wheat crop. They further reported non-significant variation in available N and K of soil by the application of zinc in pearl millet-wheat cropping system. Hegde and Katyal (1999) [3] have found in their investigation that the response of N was closely related to available nitrogen status in pearl millet-wheat cropping system. Chaudhary and Narwal (2005) [1] revealed that dose and mode of application of FYM in the pearl millet–wheat cropping sequence significantly affect the DTPA extractable fraction and total availability of Zn, Fe, Mn and Cu. They also revealed that the application of 45 Mg ha^{-1} FYM give the highest content of the micronutrients. The winter application of FYM was relatively better than the summer application. Kumar *et al.* (2014) [4] showed that the combined application of organic manures and fertilizers had significant and positive effects on productivity of the system in pearl millet- wheat cropping sequence under semi arid condition and the productivity of the wheat and pearl millet crop can be sustained by the application of balanced use of nutrients to the crops through integration of organic manures and fertilizers. The quality of both the crops in respect of protein, nitrogen and phosphorus and potash utilization increased significantly with conjoint use of organic manures and inorganic fertilizers. Singh (2002) [8] revealed that the increasing levels of NPK from 50 to 100% NPK significantly increased the yields of both the crops. The application of 100% NPK resulted in 55.0 and 63.9 per cent increase over FFP in pearl millet and wheat yields, respectively. The mean reductions in the grain yield of pearl millet due to N, P and K omission were 44.0, 3.3 and 12.0%, respectively and in wheat grain, they were 49.0, 7.8 and 9.7% respectively. The quality of produce of both the crops, in terms of protein content, improved significantly with increasing levels of NPK and maximum values were recorded under 100% NPK. The uptake of N, P and K by the crops was significantly reduced in the respective nutrient omission treatments. The uptake of these nutrients by pearl millet and wheat was more drastically reduced in the N omission treatment. Rani *et al.* (2020) [6] have conducted a field experiment for two years to determine the suitable combinations of organic manure (farmyard manure @ 10 t/ha, vermicompost @ 2.5 t/ha and biogas slurry @ 2.5 t/ha), chemical fertilizers (75%, 100% and 125% recommended dose of fertilizer (RDF)) and microbial inoculants (*Azotobacter chroococcum* and Biomix) for enhancing productivity of the pearl millet–wheat cropping system irrigated with saline water. A significant improvement in the yield of pearl millet and wheat crops was obtained by integrated application of nutrients compared with untreated control and RDF treatments. They also observed a decrease in soil EC and pH, and an increase in organic carbon. The T10 combination (RDF + VC + Biomix) was found to be the most suitable for profitable production of pearl millet and wheat crops under saline conditions of northwestern India.

Materials and Methods

The experiment was carried out at R. B. S. College Research Farm Bichpuri, Agra (U.P.) during 2021-22 and 2022-23. The farm is situated at 27^0 2' N latitude, 77^0 9' E longitudes and in on altitude of 163.4 meter above mean sea level in Uttar Pradesh state of India in a silty-clay loam soil under randomized block design replicated thrice with nine treatment combinations (50% RDF, 75% RDF, 50% RDF + 5 Kg Zn ha^{-1}, 50% RDF + 5 t FYM ha^{-1}, 100% RDF ($N_{120}P_{60}K_{40}$ ha^{-1}), 50% RDF + 5 t FYM + 5 Kg Zn ha^{-1}, 75% RDF + 5 Kg Zn ha^{-1}, 75% RDF + 5 t FYM ha^{-1}, 75% RDF + 5 t FYM ha^{-1} + 5 Kg Zn ha^{-1}) along with one absolute control. Gross plot size both in wheat and pearl millet was kept 16.00 m^2. Soil chemical properties, viz. soil pH, organic carbon, total nitrogen, available N, P and K were determined initially, after first year of experimentation and at the end of the experimentation by standard methods. NPK content in grain and straw were determined by the standard procedures suggested by Jackson (1967) in order to estimate total NPK uptake. On the basis of chemical analysis, soil was categorized as medium in organic carbon, available nitrogen (173.1 kg ha^{-1}) and available phosphorus (9.7 kg ha^{-1}), and high in available potassium (225.3 kg ha^{-1}) before experimentation. The pH was recorded as 8.2 while EC was 0.19. Statistical analysis was done

by the standard procedures suggested by Gomez and Gomez. Before application and incorporation into the soil, different organic sources of plant nutrients were analyzed for their chemical composition with reference to NPK on dry weight basis during both the years of experimentation.

Results and Discussion

Crop productivity

Application of organic manures significantly influenced the wheat productivity with significantly highest grain (50.02 q ha^{-1}) and straw yield (74.73 q ha^{-1}) in T9 (75% RDF + 5 t FYM ha^{-1} + 5 Kg Zn ha^{-1}), followed by T6 (50% RDF + 5 t FYM + 5 Kg Zn ha^{-1}), T8 (75% RDF + 5 t FYM ha^{-1}) and T7 (75% RDF + 5 Kg Zn ha^{-1}) respectively (Table 1 and 2). Grain and straw yield of both wheat and pearl millet were significantly higher in plots receiving 75% RDF + 5 t FYM ha^{-1} + 5 Kg Zn ha^{-1} followed by 50% RDF + 5 t FYM + 5 Kg Zn ha^{-1} and 75% RDF + 5 t FYM ha^{-1} respectively.

Table 1: Effect of various treatments on yield (q/ha) of wheat crop growth during year 2021-22 and 2022-23

Treatment	Grain			Straw		
	21-22	22-23	Pooled	21-22	22-23	Pooled
T1	38.37	37.67	38.02	50.17	48.30	49.23
T2	38.60	37.03	37.82	49.20	46.77	47.98
T3	38.73	36.63	37.68	45.03	45.43	45.23
T4	41.03	41.17	41.10	55.30	54.03	54.67
T5	41.73	42.03	41.88	58.13	56.53	57.33
T6	48.87	47.37	48.12	71.20	69.93	70.57
T7	42.90	42.23	42.57	61.27	60.70	60.98
T8	46.80	46.60	46.70	64.63	63.77	64.20
T9	50.57	49.47	50.02	75.43	74.03	74.73
T10	32.30	31.40	31.85	44.77	43.57	44.17
CD	3.81	2.04	2.70	4.38	3.03	3.17
S.Em	1.28	0.69	0.91	1.47	1.02	1.07
S.Ed	1.81	0.97	1.29	2.08	1.44	1.51
CV(%)	6.1	3.34	4.37	5.12	3.62	3.75

Table 2: Effect of various treatments on grain and straw yield (q/ha) of pearl millet during year 2021-22 and 2022-23

Treatment	Grain			Straw		
	21-22	22-23	Pooled	21-22	22-23	Pooled
T1	12.44	12.00	12.22	24.31	21.33	22.82
T2	12.89	12.51	12.70	26.98	21.64	24.31
T3	13.78	13.33	13.56	28.17	24.58	26.38
T4	14.22	14.67	14.45	29.87	26.36	28.12
T5	15.51	15.11	15.31	31.42	27.11	29.27
T6	17.33	16.79	17.06	36.44	30.93	33.69
T7	15.58	15.06	15.32	31.78	27.89	29.84
T8	16.89	16.21	16.55	35.47	30.53	33.00
T9	17.78	17.05	17.42	36.98	33.21	35.10
T10	11.47	10.30	10.89	22.80	20.44	21.62
CD	0.97	0.93	0.83	1.98	1.74	1.61
S.Em	0.32	0.31	0.28	0.66	0.58	0.54
S.Ed	0.46	0.44	0.39	0.94	0.82	0.77
CV(%)	3.83	3.82	3.83	3.81	3.84	3.83

Nutrient uptake

Application of various organic manures in wheat and their respective residual effect on succeeding pearl millet exhibited significant variation in nutrient uptake by these crops (Table 3 and 4). Nutrient uptake in both the crops was significantly higher with the application of T9 (75% RDF + 5 t FYM ha^{-1} + 5 Kg Zn ha^{-1}), followed T6 (50% RDF + 5 t FYM + 5 Kg Zn ha^{-1}), T8 (75% RDF + 5 t FYM ha^{-1}). On an average, varied nutrient status of organic manures (Table 3) and their respective addition in soil might have resulted in significant variation in nutrient uptake in wheat. As the release of nutrients is slow and incomplete in a season of wheat, its residual effect on the succeeding pearl millet was significant as evident by its nutrient uptake.

Total NPK uptake by wheat and rice (grain + straw) during both the years increased significantly and consistently with increase in NPK levels (Table 5). Uptake of nutrients by crop plants is obviously determined by the available nutrient content in the soil. Increasing levels of NPK are expected to increase the available NPK pool of the soil, which might have resulted in higher content of these nutrients in grain and straw as well as better crop yield of wheat and pearl millet. As nutrient uptake is a function of nutrient content and biomass production of the crops, the increase in fertilizer levels resulted in significant increase in nutrient uptake by these crops as seen in the present study.

Table 3: Effect of various treatments on N, P, K uptakes of wheat crop during both years

Treatment	2021-2022			2022-23		
	N	P	K	N	P	K
T1	92.67	10.77	19.90	87.10	9.13	19.14
T2	86.35	9.72	18.98	80.72	8.41	17.91
T3	81.72	8.17	18.94	77.49	7.49	17.45
T4	108.57	12.23	23.35	103.29	11.29	22.36
T5	115.62	13.45	25.56	110.87	13.47	24.06
T6	120.74	14.12	30.83	115.13	13.12	29.18
T7	102.74	11.38	22.93	96.53	10.84	21.69
T8	113.63	13.94	27.94	108.32	13.17	25.44
T9	124.89	14.52	31.91	117.35	13.69	30.29
T10	31.64	6.22	14.85	64.50	5.60	13.64
CD	6.62	0.77	1.62	6.52	0.72	1.53
S.Em	2.23	0.26	0.55	2.19	0.24	0.51
S.Ed	3.15	0.37	0.77	3.10	0.34	0.73
CV(%)	4.56	4.55	4.64	4.57	4.54	4.66

Table 4: Effect of various treatments on N, P, K uptakes of Pearl millet crop during both years

Treatment	2021-2022			2022-23		
	N	P	K	N	P	K
T1	25.73	1.64	7.21	23.65	1.61	7.05
T2	28.07	1.79	9.91	26.51	1.72	9.72
T3	30.52	2.03	11.67	29.54	1.98	11.35
T4	35.38	2.28	11.71	32.89	2.21	11.42
T5	35.85	2.43	11.51	33.12	2.26	11.28
T6	40.18	2.71	13.24	37.25	2.52	13.01
T7	39.42	2.94	13.61	35.33	2.71	13.25
T8	40.47	3.02	12.8	41.26	2.85	12.32
T9	44.33	3.24	14.36	42.52	3.12	13.98
T10	20.36	0.62	6.98	18.92	0.58	6.72
CD	2.21	0.148	0.73	2.08	0.141	0.71
S.Em	0.74	0.05	0.24	0.70	0.04	0.24
S.Ed	1.05	0.07	0.34	0.99	0.06	0.33
CV(%)	3.79	3.81	3.78	3.78	3.83	3.78

Soil chemical properties

Soil chemical properties determined at the end of first and second year of experimentation revealed that all the soil chemical properties under study improved with the application of different organic manures (Table 5 and 6) over initial status and absolute control. The maximum organic carbon, available N, available P, available K, Sulpher and Zinc in soil after harvesting was found in T9 (75% RDF + 5 t FYM ha^{-1} + 5 Kg

Zn ha^{-1}) followed by T6 (50% RDF + 5 t FYM + 5 Kg Zn ha^{-1}), T8 (75% RDF + 5 t FYM ha^{-1}), T5 (100% RDF) and T7(75% RDF + 5 Kg Zn ha^{-1}). From the results it was observed that the combining use of RDF, FYM and Zn improved the status in the soil over the RDF alone.

Table 5: Effect of various treatments on OC, N, P, K, S and Zn in soil after harvest of wheat (Mean of Two Years)

Treatment	OC	N	P	K	S	Zn
	g h^{-1}	Kg h^{-1}	Kg h^{-1}	Kg h^{-1}	Kg h^{-1}	Kg h^{-1}
T1	4.11	170.5	9.6	215.3	8.3	0.56
T2	4.11	170.6	10.3	215.7	8.3	0.57
T3	4.16	170.8	10.7	216.3	8.4	0.59
T4	4.26	174.3	12.2	230.5	9.5	0.65
T5	4.52	176.1	12.6	234.2	9.6	0.67
T6	4.66	183.2	13.5	244.0	10.6	0.71
T7	4.22	171.6	11.5	222.9	9.2	0.63
T8	4.55	180.5	12.7	236.5	10.4	0.71
T9	4.76	185.5	13.6	244.6	10.9	0.73
T10	4.10	163.5	9.1	213.1	8.2	0.54
CD	0.29	11.88	0.76	15.39	0.62	0.04
S.Em	0.09	4.00	0.25	5.18	0.20	0.01
S.Ed	0.14	5.65	0.36	7.32	0.29	0.02
CV (%)	3.94	3.96	3.83	3.94	3.89	3.87

It was observed that T9 (75% RDF + 5 t FYM ha^{-1} + 5 Kg Zn ha^{-1}) resulted in significantly higher build up of organic carbon, available N and available P content in soil after harvest of pearl millet followed T6 (50% RDF + 5 t FYM + 5 Kg Zn ha^{-1}) and T8 (75% RDF + 5 t FYM ha^{-1}) during both the years, whereas T9 (75% RDF + 5 t FYM ha^{-1} + 5 Kg Zn ha^{-1}) resulted in significantly higher build up of available K, Sulpher and Zinc content followed T8 (75% RDF + 5 t FYM ha^{-1}) and T6 (50% RDF + 5 t FYM + 5 Kg Zn ha^{-1}) in soil during both the years. From the results it was observed that the combining use of RDF, FYM and Zn improved the status in the soil over the RDF alone.

Table 6: Effect of various treatments on OC, N, P, K, S and Zn in soil after harvest of pearl millet (Mean of Two Years)

Treatment	OC	N	P	K	S	Zn
	g h^{-1}	Kg h^{-1}	Kg h^{-1}	Kg h^{-1}	Kg h^{-1}	Kg h^{-1}
T1	4.08	172.3	10.2	216.2	8.7	0.59
T2	4.11	173.8	10.8	217.6	8.9	0.64
T3	4.15	174.6	10.6	217.8	9.3	0.69
T4	4.3	174.6	12.7	222.4	9.8	0.72
T5	4.42	176.2	12.9	229.3	9.8	0.73
T6	4.57	181.3	13.9	235.1	10.5	0.75
T7	4.31	177.4	12.6	228.3	10.2	0.7
T8	4.52	180.5	13.2	237.1	10.6	0.78
T9	4.71	184.3	14.2	242.9	11.1	0.8
T10	4.08	169.1	9.9	214.4	8.5	0.57
CD	0.29	12.04	0.80	15.36	0.65	0.04
S.Em	0.09	4.05	0.26	5.17	0.21	0.01
S.Ed	0.13	5.73	0.38	7.31	0.31	0.02
CV(%)	3.95	3.98	3.85	3.96	3.90	3.86

Conclusion

The study revealed that integrated use of RDF, FYM and Zn in combination in wheat and pearl millet resulted in significantly higher crop yield, nutrient uptake and improvement in soil fertility status in wheat-pearl millet sequence in Agra region.

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