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Conjunctive Application of Organic and Inorganic Fertilizers to Improve Soil Fertility and Wheat (*Triticum aestivum* L.) Productivity in Semi-arid Region

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Abstract: Intensive cultivation and use of high-yielding cultivars with the elevated and alone application of inorganic fertilizers cause a severe decline in soil fertility. However, application of organic manure, especially the farmyard manure (FYM), vermicompost (VC), and fly ash (waste of coal-based thermal power plants) along with inorganic fertilizer can be an effective integrated nutrient management technique to sustain the crop productivity. In the view of above facts, a pot experiment was carried out in a completely randomized block design to analyze the influence of the FYM (10, 15, 20 t ha⁻¹), VC (2.5, 5, 7.5 t ha⁻¹), and fly ash (10, 20, 30 t ha⁻¹) along with the recommended dose of fertilizer control (RDF) on the performance of wheat crop and soil physico-chemical properties. The results reveal that the application of RDF + 7.5 t ha⁻¹ VC recorded the maximum plant height (60 days after sowing) (65.3 cm), grain (17.5 g plot⁻¹) and straw yield (19 g plot⁻¹), available N (154.7 kg ha⁻¹) and available S (7.56 mg kg⁻¹) in soil. Whereas, the maximum K (1.623%) and S (0.363%) content in wheat and available K (377.1 kg ha⁻¹) in soil, were recorded with treatment RDF + 20 t ha⁻¹ FYM. The application of the RDF + 5 t ha⁻¹ VC enhanced the available P in the soil. However, conjunctive application of fertilizer did not significantly affect the plant height at 30 days after sowing, effective tiller plot⁻¹, harvest index, P content in wheat straw, bulk density, pH, electric conductivity and organic carbon.

Key words: Fly ash, FYM, soil fertility, wheat, vermicompost.

Rice-wheat cropping system (RWCS), the 'food basket' of the country, is one of the most popular cropping systems in India, occupying about 10.0 million ha extended over the entire Indo-Gangetic plains (IGP) (Chauhan *et al.*, 2012). During the green revolution, RWCS has also played an immense role to achieve the self-sufficiency in food grain production (Sekar and Pal, 2012) and provide food security to more than 20% of the world population (Memon *et al.*, 2018). In RWCS, wheat (*Triticum aestivum* L.) is the primary staple crop, and IGP fulfils about 75% of the nation's wheat requirement. Although, with the progress in the agricultural sector and intensive cultivation, over the years, the productivity of the wheat crop rise only in absolute terms; decreased over the four decades and becomes negative at the end of the century (Sekar and Pal, 2012), especially in the semi-arid region. This fatigue in the productivity of

the wheat occurs due to the depletion in the soil fertility (Shukla *et al.*, 2005), especially in the context of the organic matter, which also raised the question of its sustainability.

Indeed, chemical fertilizer has an indispensable role in increasing crop productivity, but over-reliance on chemical fertilizers causes a decline in soil fertility and crop yield over time (Hepperly *et al.*, 2009). Moreover, excess mining of the nutrients (Chauhan *et al.*, 2012), mostly the organic matter of which IGP soils are deficient (Sapkota *et al.*, 2017), imbalanced or excessive use of the inorganic fertilizers (Singh *et al.*, 2008), multi-nutrient deficiency (Ladha *et al.*, 2003) worsens the situation and cause the unfavourable alterations in the physical and chemical properties of soil. Also, the continuous degradation of soil fertility by chemical fertilizers adversely affects the crop yield level (Das *et al.*, 2020), thus increasing

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the cost necessitates researchers to seek viable alternatives. Therefore, there is an urgent need for integrated nutrient management practices, as organic manures or inorganic fertilizers alone cannot sustain productivity (Prasad, 1996). The combined application of the organic manures (OM) and inorganic fertilizer (IF) has the potential to enhance the judicious usage of the nutrient that augments the efficiency of the inorganic fertilizers while reducing nutrient losses (Schoebitz and Vidal, 2016). Moreover, simultaneously substantially increase/improve the soil structure, nutrient cycling, soil nutrient status, soil organic matter, water holding capacity, soil's biological activity and cation exchange capacity (Saha *et al.*, 2008). Among the various OM, farmyard manure (FYM) and vermicompost (VC) are widely used mainly due to their easy availability and economic feasibility.

FYM is one of the oldest organic manure containing dung and crop residues, not only improve the soil's physico-chemical and biological attributes through the addition of organic carbon (Liu *et al.*, 2013) but simultaneously also enhances the supply of N, P, K, Fe, Mn and Cu to crops (Davari *et al.*, 2012). A larger number of studies already stated that the application of FYM improved wheat productivity (Sheoran *et al.*, 2017; Mazhar *et al.*, 2018; Ali *et al.*, 2019). Whereas, VC is well-decomposed organic material produced by the use of earthworms and offers a route by which organic waste can be stabilized to a significant extent, converting it into a finished fertilizer. VC has a significant role to enhance the oxygen availability, soil porosity, water infiltration and improves/maintains soil microbial activity, soil temperature, and nutrient content, thus augmenting the growth, productivity, and quality of the crop (Arora *et al.*, 2011). Thus, VC alone or in combination with the IF can be used to get improved qualitative and quantitative crop yield (Jack *et al.*, 2011). However, there are still controversies whether VC had a detrimental effect or at least no positive effect on the crop (Karthikeyan *et al.*, 2014).

Moreover, fly ash, the byproduct of the coal-based thermal power plants which are the primary source of electricity in India and generally considered as a waste product. Annually, India alone produced more than 175

million tons of fly ash (Lal *et al.*, 2012), although utilizes only 38% and projected to exceed 1000 million tons by 2031-32 (Kumar and Jha, 2014). Thus in the coming years, the disposal of fly ash can create a big problem. However, fly ash has enormous potential to ameliorate the soil because of its low to medium bulk density, the high surface area along with very light texture and pH ranged 4.5-12 depending on the coal S content (Lal *et al.*, 2012) and simultaneously provide a secondary source of fertilizers such as P, K, Ca, Mg, S, Fe, Cu, Zn, Mn, Mo (Totawat *et al.*, 2002). Although, still, despite the potential, it is significantly less frequently used as organic fertilizer to ameliorate the soil. Additionally, though previously extensive studies conducted to assess the impact of OM and IF alone on the wheat crop and soil physico-chemical properties, so there is a need to unite the information on the combined use of OM and IF. In the view of above facts, the present study undertakes to investigate the effect of the IF alone or in combination with FYM, VC, and fly ash on crop growth and soil physico-chemical properties of the wheat crop in pot culture at the IGP region.

Materials and Methods

Experiment site and soil information

The plot experiment was conducted at the Rajiv Gandhi South Campus, Banaras Hindu University, (25° 02' N, 82° 35'E, 167 m above msl), Barkachha, Mirzapur during the *rabi* season of 2017-18. The bulk of soil collected (0-30 cm) from the agriculture farm was grounded, sieved through 2 mm sieve, and filled in each pot (about 10 kg). The initial soil has sandy loam texture (Order *Inceptisol*; Typic *Ustochrept*) having sand 50.1%, silt 37.2% and clay 12.7% with - slightly acidic pH 1:2.5 soil water suspension (6.89), electric conductivity (EC) mentioned 1:2.5 or 1:2 ratio) (0.01 dS m⁻¹), low in organic carbon (0.37%), nitrogen (225.63 kg ha⁻¹) and phosphorus (20.97 kg ha⁻¹), while medium in available K (243.38 kg ha⁻¹). Moreover, the soil had a bulk and particle density (Mg m⁻³) of 1.45 and 2.65, respectively, along with field and water holding capacity of 19.13 and 30%.

Experimental details

The pot experiment with a test crop, i.e., wheat (*Triticum aestivum* L.) laid down at

the end of December 2017 in completely randomized block design having ten treatments each replicated thrice. The treatment includes recommended dose of fertilizer (RDF); RDF + 10 t ha⁻¹ Fly ash; RDF + 20 t ha⁻¹ Fly ash; RDF + 30 t ha⁻¹ Fly ash; RDF + 10 t ha⁻¹ farmyard manure (FYM); RDF + 15 t ha⁻¹ FYM; RDF+ 20 t ha⁻¹ FYM; RDF + 2.5 t ha⁻¹ vermicompost (VC); RDF + 5 t ha⁻¹ VC; RDF + 7.5 t ha⁻¹ VC. The HUW-234 (Malviya-234) cultivar of the wheat was sown manually in each plot, having a seed rate of 125 kg ha⁻¹. The recommended dose of fertilizer includes the application of the nitrogen (120 kg ha⁻¹) phosphorus (80 kg ha⁻¹) and potassium (80 kg ha⁻¹) in the form of urea, diammonium phosphate (DAP) and muriate of potash, respectively. Although a full dose of phosphorus and potassium and half dose of nitrogen applied as basic dose during the sowing time, whereas the remaining nitrogen dose was applied in two equal splits at tillering and flower initiation stages. The fly ash, FYM, and VC were applied as basal dose as per the treatment. The crop was harvested on 5th March 2018.

Observations

Plant height and the number of effective tillers were measured from the five randomly selected plants, however plants height recorded at 30 and 60 days after sowing (DAS) while the number of effective tillers at the crop harvest. At the physiological maturity, the crop harvested has threshed, winnowed, and grain, as well as straw yield, recorded and articulated as kg ha⁻¹. Also, the harvest index obtained using the procedure described by Donald and Hamblin (1976) and expressed as a percentage. The plant samples were washed (using a detergent solution followed by 0.1 N HCL and deionized water in sequence), dried (at 70°C), ground and sieved (30 mesh sieve) for P, K and S content determination by using the vanadomolybdate yellow colour method (Jackson, 1958), flame-photometer method (Jackson, 1973) and turbidity method (Cottenie *et al.*, 1979), respectively. After the harvest, the soil samples were also collected and analyzed for the bulk and particle density by Keen-Peczowski box method (Sankaran, 1966), soil pH by glass electrode method (Jackson 1973), electric conductivity (1:2.5 soil-water suspension) by Systronics EC meter

(Jackson 1973), organic carbon by chromic acid rapid titration method (Walkley and Black, 1934), available N by Alkaline potassium permanganate method (Subbiah and Asija, 1956), available P by 0.5 M NaHCO₃ extractable (Olsen *et al.*, 1954), available K by 1N neutral ammonium acetate method (Jackson, 1973) and available S by turbidimetric method (Chesnin and Yien, 1951).

Statistical analysis

The data collected on the wheat growth, yield, and quality parameters along with the soil physico-chemical properties were statistically analyzed by the method of analysis of variance (Fisher and Yates, 1963) to draw a valid conclusion. The significance of the treatment effect was judged with the F test and critical difference (CD) at the 5% level of the probability used to evaluate the significance between the two treatment means.

Results and Discussion

Growth, yield and nutrient content

The result of the study reveals that the combined application of the OM and IF compared to RDF alone, significantly improves the growth, and yield of the wheat crop. Plant height is an important characteristic, which indicates the nutrient absorption capacity and health of the plants. Combined application of OM and IF significantly affect the plant height at 60 days after sowing (DAS) (Table 1) and ranged between 52.9 to 65.3 cm. The maximum height was recorded with the application of RDF + 7.5 t ha⁻¹ VC, however statistically at par with the RDF + 5 t ha⁻¹ VC, RDF + 20 t ha⁻¹ FYM and RDF + 2.5 t ha⁻¹ VC. Whereas, the minimum height recorded in application of RDF alone (control), was statistically similar to all the left treatments. The plant height increased due to the VC, FYM and fly ash by up to 23, 19 and 3%, respectively compared to the control. The increase in plant height is probably due to enhanced availability of nutrients, especially the N, which helps in cell division and expansion and ultimately influences the vegetative growth and simultaneously the plant height. Also, the VC generally have a higher amount of available N compared to the FYM and fly ash (Ravimycin, 2016). Although, for the height at the early stage of crop growth (30 DAS) and the number of productive tillers per

Table 1. Effect of fly ash, FYM and vermicompost on growth, yield and nutrient content of wheat

Treatments	Plant height (cm)		Effective tillers pot ⁻¹	Yield (g pot ⁻¹)		Harvest index (%)	Nutrient content in wheat (%)		
	30 DAS	60 DAS		Grain	Straw		Phosphorus	Potassium	Sulphur
Control (RDF)	22.6	52.9	10.7	13.8	16.5	45.4	0.230	1.227	0.243
RDF + 10 t ha ⁻¹ Fly ash	22.2	53.7	11.3	14.6	17.3	45.8	0.200	1.133	0.183
RDF + 20 t ha ⁻¹ Fly ash	24.2	54.5	11.3	14.8	16.5	47.4	0.197	1.260	0.263
RDF + 30 t ha ⁻¹ Fly ash	22.5	54.6	12.7	15.0	17.2	46.4	0.243	1.457	0.333
RDF + 10 t ha ⁻¹ FYM	21.7	54.9	12.0	14.2	16.2	46.8	0.267	1.290	0.257
RDF + 15 t ha ⁻¹ FYM	24.9	58.9	12.3	16.2	17.6	47.8	0.273	1.330	0.257
RDF + 20 t ha ⁻¹ FYM	22.5	63.0	14.7	17.0	17.8	48.9	0.297	1.623	0.363
RDF + 2.5 t ha ⁻¹ VC	21.3	61.2	13.7	15.5	18.8	45.3	0.203	1.327	0.240
RDF + 5 t ha ⁻¹ VC	22.9	63.8	14.7	15.1	18.8	44.6	0.277	1.377	0.287
RDF + 7.5 t ha ⁻¹ VC	25.8	65.3	14.7	17.5	19.0	47.8	0.340	1.520	0.357
CD (P=0.05)	NS	6.03	NS	2.09	1.79	NS	NS	0.264	0.095

DAS = Day after sowing; FYM = Farm yard manure; RDF = Recommended dose of fertilizer; VC = Vermicompost; NS = Non-significant.

plant, the effect of the combined application of OM and IF was non-significant.

Moreover, the combination of the OM and IF also improve the grain and straw yield of the wheat crop. The maximum grain and straw yield (17.5 g pot⁻¹) was recorded in RDF + 7.5 t ha⁻¹ VC, statistically similar to the RDF + FYM treatments (except the 10 t ha⁻¹) and the minimum in control (RDF) and fly ash combined treatment. The application of the VC and FYM along with RDF increases the grain yield by up to 27 and 23% over the control respectively while straw yield by 15 and 8% over the control, respectively. The synergistic effect may be due to the multi-nutrient supply, that on slow release in the OM, whereas specifically high yield in VC, as the slowly released nutrients, are in readily available form especially nitrates, P, K, Ca and Mg (Ali *et al.*, 2020). Similarly, Makinde and Ayoola (2010), also reported the effectiveness of the conjunctive application of OM and IF on the growth of maize and improving the yields. Whereas, wheat grain and straw yield reacted statistically similar to the application of fly ash along with RDF (only increases the grain and straw yield by up to 8 and 4%, respectively) and control. Contrary to our study, Matte and Kene (1995) suggested the soil application of fly ash augmented wheat grain yield by 20% whereas, Grewal *et al.* (2001) found increased grain and straw yield in pearl millet (direct) and subsequent yield of wheat (residual) significantly at all levels of fly ash. Also, the

harvest index of wheat varied non-significantly with the combined application of fly ash, FYM, and VC with RDF. Our study coincides with the findings of Nagaraj *et al.* (2004), who also reported a non-significant effect of poultry manure and FYM on the harvest index of maize.

Conjunctive application of the OM and IF significantly increased the K and S content in the wheat straw (Table 1). The maximum K (1.62%) and S (0.363%) content was recorded in RDF + 20 t ha⁻¹ FYM which was statistically similar to the 30 t ha⁻¹ FYM, 5 and 7.5 t ha⁻¹ VC along with the RDF. The application of the FYM, VC and fly ash increased the K content in straw by up to 32, 24 and 18%, respectively while S content by up to 49, 46 and 37%, respectively over the control. The increase may be attributed to the ability of the FYM, VC and fly ash to release the K and S in the soil in readily available form. Treatments amended with fly ash, and lower doses of FYM and VC showed statistically at par K and S content in wheat straw compared to control. In these treatments, the K and S content was increased, but the effect was not significant. The above results are in corroboration with those of Aziz *et al.* (2010) and Samarah *et al.* (2010). However, surprisingly, the P content in straw did not vary significantly with the combined application of OM and IF mainly due to the depressing effect of the Ca and Fe present in the fly ash (Sikka and Kansal, 1995), VC and FYM on the P accumulation in plant.

Table 2. Effect of fly ash, FYM and vermicompost on physico-chemical properties of soil

Treatments	BD (Mg m ⁻³)	PD (Mg m ⁻³)	pH	EC (dS m ⁻¹)	OC (%)	Available N (kg ha ⁻¹)	Available P (kg ha ⁻¹)	Available K (kg ha ⁻¹)	Available S (mg kg ⁻¹)
RDF	1.42	2.67	6.98	0.083	0.38	112.9	11.8	235.2	3.28
RDF + 10 t ha ⁻¹ Fly ash	1.39	2.78	6.45	0.097	0.40	117.1	13.5	251.7	2.33
RDF + 20 t ha ⁻¹ Fly ash	1.36	2.73	6.31	0.080	0.44	121.3	14.1	287.1	2.90
RDF + 30 t ha ⁻¹ Fly ash	1.33	2.68	6.68	0.180	0.44	125.4	16.4	362.1	4.21
RDF + 10 t ha ⁻¹ FYM	1.40	2.74	6.45	0.140	0.45	125.4	12.6	358.4	3.45
RDF + 15 t ha ⁻¹ FYM	1.38	2.72	6.41	0.130	0.45	133.8	14.3	358.4	6.53
RDF + 20 t ha ⁻¹ FYM	1.33	2.70	6.18	0.197	0.53	142.1	17.2	377.1	6.90
RDF + 2.5 t ha ⁻¹ VC	1.37	2.72	6.58	0.083	0.46	117.1	17.4	321.1	5.37
RDF + 5 t ha ⁻¹ VC	1.35	2.70	6.55	0.273	0.47	146.3	20.2	362.1	7.03
RDF + 7.5 t ha ⁻¹ VC	1.35	2.67	6.48	0.327	0.53	154.7	20.0	369.6	7.56
CD (P=0.05)	NS	0.053	NS	NS	NS	25.7	5.58	71.3	0.49

FYM = Farm yard manure; RDF = Recommended dose of fertilizer; VC = Vermicompost; BD = Bulk density; PD = Particle density; EC = Electric conductivity; N = Nitrogen; P = Phosphorus; K = Potassium; S = Sulphur; NS = Non-significant

Soil physico-chemical properties

The combined application of the OM and IF significantly affects most of the soil physico-chemical properties of the soils (Table 2). Although, bulk density, pH, electric conductivity and organic carbon of the soil did not vary due to the shorter period of study. A small deviation recorded in particle density, decreased slightly with the graded application of fly ash, FYM, as well as VC, but increased in comparison to control. The maximum particle density (2.78 Mg m⁻³) was recorded in RDF + 10 t ha⁻¹ fly ash, while the minimum was in control (RDF).

The application of the fly ash, FYM, and VC, along with the RDF appreciably increased the available N content in the soil. The maximum available N was recorded in RDF+ 7.5 t ha⁻¹ VC (154.7 kg ha⁻¹) statistically similar to the 5 t ha⁻¹ VC, 15 and 25 t ha⁻¹ FYM, whereas, the minimum in control (112.9 kg ha⁻¹). The increase in the available N in the soil has directly related to the ability of the VC and FYM to release the nitrates in the soil. Additionally, the precise application of manure and fertilizer could be as useful as commercial N fertilizer for yield response (Zhang *et al.*, 1998). Although, treatments amended with fly ash had a non-significant increase in available N content, and it was statistically at par with control. Also, the maximum available P content (20.2 kg ha⁻¹) was recorded in RDF + 5 t ha⁻¹ VC which is statistically at par with RDF + 7.5

t ha⁻¹ VC while the minimum in control (11.8 kg ha⁻¹). The increase in available P content of soil due to the application of FYM/VC may be attributed to the direct addition of P as well as solubilization of native P through the release of organic acids. Similar improvement in available P status due to the integrated use of manures and fertilizers (Sharma and Saxena, 1985). Also, the increase in the organic manure increases the soil moisture content (Boateng *et al.*, 2006), thereby improving the P availability in soil. As, P is a relatively immobile nutrient that moves in soil by diffusion and is regulated by soil moisture (Marschner, 1995). Furthermore, despite the depressing effect of the Ca and Fe present in the fly ash, the treatment RDF + 30 t ha⁻¹ fly ash recorded significantly higher available P in the soil.

Likewise, the available K content of post-harvest soil was also found to increase significantly with the application of fly ash, FYM, and VC and the maximum recorded in RDF + 20 t ha⁻¹ FYM (377.1 kg ha⁻¹) while the minimum in control (235.2 kg ha⁻¹). Surprisingly, except for the 10 and 20 t ha⁻¹ fly ash + RDF and control; all the treatments recorded the statistically similar and maximum available K content in the soil. The higher buildup of available K in the soil treated with FYM/VC compared to sole IF treated soil might be due to the addition of supplement K to the available pool of the soil. Besides, the organic acids released during the decomposition of manures

mobilize the native or non-exchangeable forms of K and charge the soil solution with K ions, so that it can be readily available (Anuradha, 2003). Furthermore, the available S content in soil recorded a gradual increase from control to higher rates; minimum in the fly ash while maximum in the VC. Specifically, the maximum available S content in soil was recorded in the RDF+ 7.5 t ha⁻¹ VC (7.56 mg kg⁻¹) while the minimum in the RDF + 10 t ha⁻¹ fly ash (2.33 mg kg⁻¹). The treatment RDF + 30 t ha⁻¹ Fly ash and RDF + 15 t ha⁻¹ FYM significantly increased the available S content by 28 and 99% over the control (RDF).

Conclusions

Our study concludes that it is high time to change the perception about the use of the inorganic fertilizers, which usually leads to soil fertility loss, especially in the wheat, an exhaustive nutrient crop. The application of the inorganic fertilizer and organic manures like fly ash, FYM, and VC can appreciably improve the growth and yield of wheat, nutrient accumulation in plant and soil physico-chemical properties in the Indo-Gangetic plains. The extent of improvement effect was found to be more for the VC followed by FYM and fly ash. Specifically, the higher doses of the fly ash, FYM, and VC, along with the RDF recorded the maximum growth, nutrient accumulation, and soil physico-chemical properties, whereas treatment RDF + 7.5 t ha⁻¹ VC recorded the overall best result. Hence for sustainable wheat production, the application of fly ash, FYM and VC may be followed. Future long-term research is needed to confirm the benefit of the combined use of the inorganic fertilizers and organic manures on yield, crop, and soil quality.

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