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Effect of FYM and vermicompost under prescription based fertilizer application on physical properties of soil and yield in maize-wheat system in an Acid Alfisol

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Abstract
This study was carried out at experimental farm of Department of Soil Science, College of Agriculture, CSK HPKV, Palampur. There were nine treatments which were replicated thrice in a randomized block design. The experiment was conducted on maize and wheat for two years i.e. *kharif* 2011 to *rabi* 2012-13. The soil of experimental farm was silty clay loam in texture, acidic in reaction (pH 5.1), medium in organic carbon (7.8 g kg^{-1}) with 208, 26.8 and 214 kg ha^{-1} of available N, P and K, respectively. Surface (0-0.15 m) and sub-surface (0.15-0.30 m) soil samples were analysed for Bulk density, particle density, water holding capacity, water stable aggregates before the sowing and after harvest of last crop. Yield of maize and wheat was recorded. The study revealed that the bulk density and particle density reduced whereas water holding capacity and water stable aggregates increased in targeted yield treatments with integrated plant nutrient supply (IPNS) as compared to their non-IPNS counterparts. Highest yield of both the crops was recorded in treatment where 5t vermicompost ha^{-1} was applied with targeted yield concept.

Keywords: prescription based fertilizer application, mean weight diameter, soil test crop response

Introduction
Fertilizers are the essential among different factors contributing towards agricultural production. The benefits of increased use of fertilizers in achieving targets of food grain production are well established. However, practicing farming with high yielding crop varieties under present fertilizers constraints due to the ever increasing prices, a viable proposition would be the adoption of economic and judicious use of fertilizers and management practices so that the higher investment on fertilizers is reaped adequately. Further, chemical fertilizers alone are unable to maintain the long-term soil health and sustain crop productivity as they are unable to supply all the essential nutrients, particularly the trace elements (Subba Rao and Srivastava 1998) [1]. In conventional soil testing soil is being categorized into low, medium and high fertility classes (Verma *et al.* 2007) [2]. These are generalized recommendations and do not taken into account, the actual content of particular nutrient. The lacuna leads to the development of prescription based fertilizer recommendations for a given soil- crop- fertilizer situation (Ramamoorthy *et al.* 1967) [3]. Prescription based fertilizer application leads to improve physical condition of soil soil health and ultimately yield. Therefore, to overcome the imbalance use of nutrients and enhancing the productivity of the system the present research was carried out.

Material and Methods
In order to achieve the objectives of the investigation a field study was conducted on the maize and wheat for two years i.e. *kharif* 2011 to *rabi* 2011-12 and *kharif* 2012 and *rabi* 2012-13 at the Experimental Farm of Department of Soil Science, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalya, Palampur which was a long term experiment initiated during 2008. There were nine treatments which were replicated thrice in a randomized block design. The treatments were control, soil test based, farmers' practice, 100% NPK, target yield (non-IPNS), target yield with 2.5t and 5t FYM ha^{-1} target yield with 2.5t and 5t vermicompost ha^{-1}. The target yield for maize and wheat was 40 q and 35 q ha^{-1}, respectively. The soil of experimental farm was silty clay loam in texture, acidic in reaction (pH 5.1), medium in organic carbon (7.8 g kg^{-1}) with 208, 26.8 and 214 kg ha^{-1} of available N, P and K, respectively. The micronutrient cations *viz.* Fe, Mn, Zn and Cu were 21.2, 0.83, 0.99 and 16.9 mg kg^{-1}. During the field experimentation, representative soil samples (0-15 and 15-30 cm depth) were collected from each plot before and after harvest of crop.

The soil physical properties like bulk density, particle density, water holding capacity and water stable aggregates were analysed with standard procedures like core sampler methods (Singh 1980) [4], Pycnometer method (Gupta and Dhakshinamoorthy 1980) [5], Keen box method (Piper 1950)[6] and Wet sieving method (Yoder 1936) [7], respectively. The data generated from field and laboratory analysis were subjected to statistical analysis and interpretation of results as described by Gomez and Gomez (1984) [8].

Results and Discussions

The soil samples (0-0.15 m and 0.15-0.30 m) before the start of the experiment and at the harvest of last crop were analyzed for the physical properties.

Bulk density: Before the sowing of maize (*kharif* 2011) with application of graded doses of fertilizers alone or with FYM and vermicompost decreased the values of bulk density. However, the differences among the treatments were not significant. The higher values of bulk density might be due to the reason that only inorganic sources of nutrients were applied. Use of organic and integration organic and inorganic together improved the organic matter content of the soil, which caused a decrease in bulk density and results are corroborated with findings of Pathak *et al.* (2005) [9]. Continuous application of chemical fertilizers along with organics caused a decrease in the bulk density of soil may be due to the addition of higher organic carbon that resulted in more pore space and good soil aggregation Gupta *et al.* 2006 [10]; Chaudhary and Thakur 2007 [11]; Sharma *et al.* 2007 [12]; Verma *et al.* 2010 [13].

Table 1: Effect of FYM and vermicompost on bulk density (Mg m^{-3}) under prescription based fertilizer application

Treatment	Before the sowing of maize 2010-11		After the harvest of wheat 2012-13	
	Bulk density		Bulk density	
	Depth			
	(0-0.15m)	(0.15-0.30m)	(0-0.15m)	(0.15-0.30m)
T_1: Control	1.23	1.26	1.22	1.26
T_2: Soil Test Base	1.20	1.22	1.21	1.23
T_3: FP - 25% N + 5t FYM ha^{-1}	1.14	1.17	1.14	1.16
T_4: 100% NPK	1.18	1.19	1.17	1.19
T_5: Target yield (non-IPNS)	1.17	1.18	1.17	1.19
T_6: Target yield - 2.5 t FYM ha^{-1}	1.15	1.17	1.14	1.15
T_7: Target yield - 2.5 t VC ha^{-1}	1.15	1.17	1.15	1.16
T_8: Target yield - 5 t FYM ha^{-1}	1.14	1.16	1.14	1.17
T_9: Target yield - 5 t VC ha^{-1}	1.13	1.16	1.12	1.15
CD (P=0.05)	NS	NS	NS	NS
Initial	1.23			

Target yield: maize - 40 q ha^{-1} and wheat - 35 q ha^{-1}

Particle density: The differences among the treatments were not significant. Similar trend was observed after the harvest of wheat 2012-13. The higher values of particle density in soil test base, general recommended dose (GRD) and targeted yield treatment with non-IPNS was recorded which might be due to the reason that only inorganic sources of nutrients were applied. Like bulk density more decrease in particle density was also recorded in treatments where organics were applied along with inorganic fertilizers. This may be due to higher organic carbon addition in soil which is an important component of soil (Sepehya 2011) [14].

Table 2: Effect of FYM and vermicompost on particle density (Mg cm^{-3}) under prescription based fertilizer application

Treatment	Before the sowing of maize 2010-11		After the harvest of wheat 2012-13	
	Particle Density (Mg m^{-3})		Particle Density (Mg m^{-3})	
	Depth			
	(0-0.15m)	(0.15-0.30m)	(0-0.15m)	(0.15-0.30m)
T_1: Control	2.56	2.59	2.55	2.58
T_2: Soil Test Base	2.53	2.55	2.52	2.55
T_3: FP - 25% N + 5t FYM ha^{-1}	2.48	2.50	2.46	2.49
T_4: 100% NPK	2.51	2.52	2.5	2.52
T_5: Target yield (non-IPNS)	2.50	2.51	2.51	2.50
T_6: Target yield - 2.5 t FYM ha^{-1}	2.48	2.49	2.47	2.48
T_7: Target yield - 2.5 t VC ha^{-1}	2.47	2.5	2.46	2.49
T_8: Target yield - 5 t FYM ha^{-1}	2.48	2.51	2.47	2.51
T_9: Target yield - 5 t VC ha^{-1}	2.46	2.49	2.45	2.48
CD (P=0.05)	NS	NS	NS	NS

Target yield: maize - 40 q ha^{-1} and wheat - 35 q ha^{-1}

Water holding capacity: The treatment comprising soil test base, farmers' practice and general recommended dose (GRD) improved water holding capacity over control. These treatments recorded 1.9, 4.8 and 0.9 per cent increase over control. When graded doses of chemical fertilizers were applied alongwith FYM (i.e. 2.5t and 5t FYM) and vermicompost (i.e. 2.5t and 5t vermicompost), there was enhancement in it over non-IPNS and recorded 1.2, 1.5, 2.4 and 2.9 per cent increase over non-IPNS treatment. The surface soils (0-0.15 m) exhibited low water holding capacity in comparison to the sub-surface (0.15-0.30 m) soils. Similar trend was recorded in sub-surface soil samples as surface soil samples before the sowing of maize 2011. The highest increase (4.8%) over control was recorded in farmers' practice followed by soil test base (1.9%) and general recommended dose (GRD) (0.9%) over control. All the IPNS treatments were better than non-IPNS treatments and recorded 1.2, 1.9, 2.8 and 3.3 per cent increase over non-IPNS. Among IPNS, all the treatments were found statistically at par with one another. The surface soils (0-0.15 m) exhibited low water holding capacity in comparison to the sub-surface (0.15-0.30 m) soil. Similar trend was recorded in sub-surface soil samples as surface soil samples after the harvest of wheat 2012-13. All the targeted treatments with IPNS were found superior to the non-IPNS treatments.

Table 3: Effect of FYM and vermicompost on water holding capacity (%) under prescription based fertilizer application

Treatment	**Before the sowing of maize 2010-11**		**After the harvest of wheat 2012-13**	
	Water holding capacity (%)		**Water holding capacity (%)**	
	Depth			
	(0-0.15m)	(0.15-0.30m)	(0-0.15m)	(0.15-0.30m)
T_1: Control	53.15	53.21	53.02	53.08
T_2: Soil Test Base	54.18	54.53	54.05	54.40
T_3: FP - 25% N + 5t FYM ha^{-1}	55.74	56.10	55.85	56.19
T_4: 100% NPK	53.64	53.92	53.51	53.79
T_5: Target yield (non-IPNS)	54.51	54.92	54.38	54.79
T_6: Target yield - 2.5 t FYM ha^{-1}	55.17	55.64	55.20	55.67
T_7: Target yield - 2.5 t VC ha^{-1}	55.37	55.98	55.45	56.06
T_8: Target yield - 5 t FYM ha^{-1}	55.86	56.21	55.94	56.29
T_9: Target yield - 5 t VC ha^{-1}	56.12	56.75	56.20	56.83
CD (P=0.05)	1.38	1.36	1.34	1.31

Target yield: maize - 40 q ha^{-1} and wheat - 35 q ha^{-1}

The lower values of water holding capacity in soil test base, general recommended dose (GRD) and target yield treatment with non-IPNS was recorded might be due to the reason that only inorganic sources of nutrients were applied and in farmers' practice inadequate supply of P and K nutrients (Bedi 2009) [15]. Continuous addition of organic manures influenced the water holding capacity positively which could be ascribed to the improvement in structural condition of soil. These results are in confirmation with the findings of Mishra and Sharma (1997) [16], Babhulkar *et al.* (2000) [17] and Selvi *et al*. (2005) [18]. Water holding capacity was increased in lower depth might be due to the reason that due to better structural conditions more infiltration of water into macro and micropores of lower depth.

Water stable aggregates: All the treatments enhanced water stable aggregates over control. The highest increase (92.0%) over control was found in farmers' practice followed by soil test base (25.3%) and general recommended dose (GRD) (17.4%). Application of different levels of FYM and vermicompost with targeted yield treatment improved water stable aggregates over target yield non-IPNS treatment. The increase in water stable aggregates in those plots which were receiving 5t vermicompost, 5t FYM, 2.5t vermicompost and 2.5t FYM ha^{-1} alongwith targeted yield was 10.3, 29.0, 44.2 and 50.9 per cent over target yield non-IPNS treatment. The treatments comprising, soil test base, farmer' practice and general recommended dose (GRD) were numerically superior over control and recorded 25.8, 92.0 and 17.4 per cent increase over control. All the IPNS target yield treatments, (i.e. 2.5 t and 5t FYM; 2.5t and 5t vermicompost) recorded 12.2, 31.2, 46.6 and 53.3 per cent increase over non-IPNS target yield treatment. The water stable aggregates decreased in sub-surface soil samples as compared to surface soil samples with increase in soil depth. Similar trend was recorded in sub-surface soil samples as surface soil samples after the harvest of wheat 2012-13. All the targeted treatments with IPNS were found superior to the non-IPNS treatments. The lower values of water stable aggregates in soil test base, general recommended dose (GRD) and targeted yield treatment with non-IPNS was recorded might be due to the reason that only inorganic sources of nutrients were applied and in farmers' practice inadequate supply of P and K nutrients (Dutta 2009) [19]. Continuous addition of organics not only influenced bulk density and particle density of soil but also brought a favorable change in the aggregate size that influenced the other physical properties like water holding capacity of the soil (Mahimairaja *et al.* 1986) [20].

Table 4: Effect of FYM and vermicompost on water stable aggregates (mm) under prescription based fertilizer application

Treatment	**Before the sowing of maize 2010-11**		**After the harvest of wheat 2012-13**	
	Water stable aggregates (mm)		**Water stable aggregates (mm)**	
	Depth			
	(0-0.15m)	(0.15-0.30m)	(0-0.15m)	(0.15-0.30m)
T_1: Control	1.26	0.97	1.24	0.92
T_2: Soil Test Base	1.58	1.13	1.56	1.11
T_3: FP - 25% N + 5t FYM ha^{-1}	2.42	2.28	2.43	2.30
T_4: 100% NPK	1.48	1.23	1.46	1.21
T_5: Target yield (non-IPNS)	1.65	1.19	1.63	1.17
T_6: Target yield - 2.5 t FYM ha^{-1}	1.82	1.73	1.83	1.74
T_7: Target yield - 2.5 t VC ha^{-1}	2.13	2.06	2.14	2.07
T_8: Target yield - 5 t FYM ha^{-1}	2.38	2.23	2.39	2.24
T_9: Target yield - 5 t VC ha^{-1}	2.49	2.38	2.50	2.39
CD (P=0.05)	0.334	0.294	0.323	0.306

Target yield: maize - 40 q ha^{-1} and wheat - 35 q ha^{-1}

The microbial action on soil organic matter might have resulted in considerable increase in polysaccharide and microbial gum synthesis in the soil. These microbial decomposition products might have acted as binding agents for the soil particles and thereby helped in soil aggregation.

Crop Yield

Maize grain yield: During both the years of experimentation, i.e *kharif* 2011 and *kharif* 2012, different treatments exhibited significant effect on maize grain and straw yield data over the control. During the year 2011, the grain yield varied between 21.8 to 40.5 q ha^{-1} The treatment comprising of soil test base significantly enhanced the grain yield of crop as compared to farmers' practice and it was found statistically at par with general recommended dose (GRD) and recorded 22.3 and 3.2 per cent increase, respectively over soil test base. The target yield 40 q ha^{-1} with non-IPNS was found significantly superior as compared to soil test base and general recommended dose in terms of grain yield. The target yield 40 q ha^{-1} with IPNS i.e. 2.5 t and 5 t FYM ha^{-1} as well as vermicompost were significantly superior as compared to non-IPNS target yield treatment except 2.5t ha^{-1} FYM was applied and recorded per cent increase over non-IPNS targeted yield treatments 2.4, 7.1, 4.9 and 11.5, respectively over targeted yield with IPNS treatments.

Table 5: Effect of FYM and vermicompost on maize grain and straw yields (q ha^{-1}) under prescription based fertilizer application

Treatment	Grain yield		Straw yield	
	2011	2012	2011	2012
T_1: Control	21.8	18.2	35.0	29.4
T_2: Soil Test Base	31.8	26.4	53.5	42.4
T_3: FP - 25% N + 5t FYM ha^{-1}	26.0	24.4	41.5	39.4
T_4: 100% NPK	30.8	25.2	52.3	40.8
T_5: T_{40} (non-IPNS)	36.3	37.8	57.2	61.1
T_6: T_{40} - 2.5 t FYM ha^{-1}	37.2	40.5	62.3	65.3
T_7: T_{40} - 2.5 t vermicompost ha^{-1}	38.9	40.0	63.4	64.5
T_8: T_{40} - 5 t FYM ha^{-1}	38.1	41.4	63.5	66.4
T_9: T_{40} - 5 t vermicompost ha^{-1}	40.5	43.3	65.2	70.1
CD(P=0.05)	1.93	1.82	3.12	3.55

Similar trend was observed during the year 2012, where grain yield varied between 18.

2- 43.3 q ha^{-1} in different respective treatments. The target yield 40 q ha^{-1} with IPNS *i.e.* 2.5 t and 5 t FYM ha^{-1} as well as vermicompost was significantly superior as compared to non-IPNS targeted yield treatment.

Maize straw yield: During 2011, straw yield varied between 35.0 to 65.2 q ha^{-1}. The treatment consisting of soil test base significantly enhanced the straw yield of crop as compared to farmers' practice and it was statistically at par with general recommended dose. The target yield 40 q ha^{-1} with non-IPNS was found significantly superior as compare to soil test base and general recommended dose in terms of straw yield. The target yield 40 q ha^{-1} with IPNS i.e. 2.5 t and 5 t FYM ha^{-1} as well as vermicompost was significantly superior as compared to non-IPNS targeted yield treatment and recorded 8.9, 10.8, 11.0 and 13.9 per cent increase, respectively. Similar trend was recorded during 2012, where straw yield varied between 29.4 to 70.1 q ha^{-1} in different respective treatments. The target yield 40 q ha^{-1} with IPNS i.e. 2.5 t and 5 t FYM ha^{-1} as well as vermicompost was significantly superior as compared to non-IPNS targeted yield treatment.

Wheat grain yield: Among the treatments *viz.* soil test base, farmers' practice, general recommended dose (GRD) and soil test base significantly enhanced the grain yield of crop as compared to farmers' practice and it was found to be statistically at par with general recommended dose (GRD) and recorded 26.9 and 2.6 per cent increase, respectively. The target yield 35 q ha^{-1} with non-IPNS was found significantly superior as compare to general recommended dose and farmers' practice in terms of grain yield but it was found statistically at par with soil test base. Application of different levels of FYM and vermicompost i.e. 2.5 t and 5 t FYM ha^{-1} and vermicompost 2.5 t and 5 t FYM ha^{-1} were found statistically at par with non-IPNS targeted yield treatment and recorded 4.3, 5.6, 7.1 and 10.5 per cent increase, respectively. All the targeted yield IPNS treatments were found statistically at par with one another.

Table 6: Effect of FYM and vermicompost on wheat grain and straw yields (q ha^{-1}) under prescription based fertilizer application

Treatment	Grain yield		Straw yield	
	2011-12	2012-13	2011-12	2012-13
T_1: Control	16.8	16.5	28.6	28.8
T_2: Soil Test Base	27.3	26.1	46.4	45.2
T_3: FP - 25% N + 5t FYM ha^{-1}	21.5	19.7	36.3	34.0
T_4: 100% NPK	26.6	25.5	45.5	44.2
T_5: T_{35} (non-IPNS)	32.1	33.8	54.9	58.4
T_6: T_{35} - 2.5 t FYM ha^{-1}	33.5	34.4	57.9	59.7
T_7: T_{35} - 2.5 t vermicompost ha^{-1}	33.9	35.1	59.0	61.0
T_8: T_{35} - 5 t FYM ha^{-1}	34.4	35.3	59.8	61.4
T_9: T_{35} - 5 t vermicompost ha^{-1}	35.5	36.2	61.0	63.4
CD(P=0.05)	5.5	1.5	9.34	3.2

Similar trend was observed during the year 2012, where grain yield varied between 16.5 to 36.2 q ha^{-1} in different respective treatments. The target yield 35 q ha^{-1} with IPNS i.e. 2.5 t and 5t FYM ha^{-1} and 5t vermicompost ha^{-1} were found significantly superior as compared to non-IPNS targeted yield treatment.

Wheat straw yield: The treatment comprising of soil test base significantly enhanced the straw yield of crop as compared to farmers' practice and it was statistically at par with general recommended dose. The target yield 35 q ha^{-1} with non-IPNS was found significantly superior to general recommended dose and farmers' practice. All the IPNS targeted yield treatments were found statistically at par with one another. Similar trend was recorded during the year 2012, where grain yield varied between 28.8 to 63.4 q ha^{-1} in different treatments. The targeted yield 35 q ha^{-1} with IPNS i.e. 5t vermicompost ha^{-1} was found significantly superior as compared to non-IPNS target yield treatment. The integrated use of chemical fertilizers with organic manures *viz.* FYM and vermicompost might have added organic matter in soil that increased grain and straw yield. This might be due to improvement of physical, chemical and microbiological properties of soil that resulted in increased productivity by increasing availability of plant nutrients (Chaudhary and Thakur 2007) [21]. Further, the organic matter might have supplied macro and micro nutrients and resulted as chelating agents for enhancing the availability of nutrients in soil. These results are in conformity with the findings of Sharma *et al.* (2005) [22], Urkurkar *et al.* (2010) [23] and Thakur *et al.* (2011) [24]. The reasons for increased response to FYM and vermicompost are generally ascribed to the beneficial effects of FYM and vermicompost on soil productivity. The organic manures supply nutrients and chelating agents to soil which maintain balanced supply of nutrients to plants (Brady and Weil 2002) [25]. Insoluble nutrients present in soil are solubilised due to fulvic acid and humic acid liberated from the organic materials and become available to plants for their growth. The increased availability of nutrients in addition to good physical conditions is favourable for higher biological activity and could have resulted in better crop growth and higher yields.

Conclusion

- Bulk density and particle density decreased with the application targeted yield treatments with organics compared to targeted yield without organics treatments whereas water holding capacity and water stable aggregates improved.
- Yield was increased with the application of different levels of FYM and vermicompost i.e. 2.5 t and 5t ha^{-1} with targeted yield based use of fertilizers as compared to non-IPNS counterparts, soil test base, farmers' practice and general recommended dose.

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