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Effect of FYM and vermicompost under STCR approach on microbiological properties of soil and yield in maize-wheat system

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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 soil microbial biomass carbon, urease and phosphtase activity before the sowing and after harvest of last crop. Yield of maize and wheat was recorded. The study revealed that the Microbial biomass carbon, urease activity and phosphatase activity was recorded highest in the treatment comprising of fertilizer application based on targeted yield with 5t vermicompost ha^{-1}. Highest yield of both the crops was recorded in treatment where 5t vermicompost ha^{-1} was applied with targeted yield concept. Highest yield of both the crops was recorded in treatment where 5t vermicompost ha^{-1} was applied with targeted yield concept.

Keywords: soil test crop response (STCR), soil testing

Introduction
The dawn of 21st century poses very tough challenges to the agriculture with slogan to produce more food to nourish the increasing human population from shrinking land for sustainable agriculture. It will be challenging task for agricultural scientists in already shrunken arable land and only alternative is the vertical growth in agriculture production through increased production per unit area per unit time (Bedi 2009) [1]. Furthermore, increasing the production, quality and productivity on sustainable basis is yet another challenge to the agricultural scientist and planners. 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) [2]. In conventional soil testing soil is being categorized into low, medium and high fertility classes (Verma *et al.* 2007) [3]. 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) [4]. Prescription based fertilizer application leads to improve physical condition of 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
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 Vishvavidyalaya, 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 microbiological properties like soil microbiological biomass carbon, urease and phosphates activities were analyzed with standard procedures like Chloroform fumigation extraction method Vance *et al.* (1987) [5], Colorimetric method Tabatabai and Bremner (1972) [6] and Colorimetric method Tabatabai and Bremner (1969) [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

Microbiological properties

Soil microbial biomass carbon (SMBC): During *kharif* 2011, all the treatments significantly enhanced soil microbial biomass carbon (SMBC) content over control. The treatments comprising soil test base, general recommended dose (GRD) and farmers' practice significantly differ from each other and were significantly superior over control. The highest increase (175.9 per cent) over control was found in farmers' practice followed by general recommended dose (GRD) (30.7 per cent) and soil test base (93.8 per cent). The increase in soil microbial biomass carbon content in the plots receiving target yield with 5t vermicompost, 5t FYM, 2.5t vermicompost and 2.5t FYM ha^{-1} was 7.2, 16.0, 24.4 and 29.5 per cent over target yield (non-IPNS). In the sub-surface soil samples (table 4.18) the highest (106.4 µg g^{-1} soil) soil microbial biomass carbon (SMBC) was recorded in the treatment where 5t vermicompost ha^{-1} with targeted yield was applied and lowest (32.4 µg g^{-1} soil) in control. All the treatments were found significantly superior over control. The treatments with targeted yield (IPNS) were found significantly superior over non-IPNS counterpart. The treatment comprising, soil test base, farmers' practice and general recommended dose (GRD) were significantly superior over control and farmers' practice was also found significantly superior over soil test base and general recommended dose (GRD) before the sowing of maize 2011 in sub-surface soil samples.

Table 1: Effect of FYM and vermicompost on microbial biomass carbon (µg g^{-1} soil) under prescription based fertilizer application

Treatment	Before the sowing of maize 2010-11		After the harvest of wheat 2012-13	
	SMBC		SMBC	
	Depth			
	(0-0.15m)	(0.15-0.30m)	(0-0.15m)	(0.15-0.30m)
T_1: Control	35.8	32.4	33.5	30.8
T_2: Soil Test Base	69.4	65.2	66.0	61.8
T_3: FP - 25% N + 5t FYM ha^{-1}	98.8	95.4	104.5	97.6
T_4: 100% NPK	46.8	42.6	43.4	39.2
T_5: Target yield (non-IPNS)	88.2	84.3	84.8	80.9
T_6: Target yield - 2.5 t FYM ha^{-1}	94.6	92.3	98.8	96.5
T_7: Target yield - 2.5 t VC ha^{-1}	102.4	99.3	106.6	103.5
T_8: Target yield - 5 t FYM ha^{-1}	109.8	102.4	114.0	106.6
T_9: Target yield - 5 t VC ha^{-1}	114.3	106.4	118.5	110.6
CD(P=0.05)	9.17	7.79	20.9	17.9

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

It is indicated from the table that maximum (118.5 µg g^{-1} soil) soil microbial biomass carbon content was revealed under treatment targeted yield with 5t vermicompost ha^{-1} and minimum (33.5 µg g^{-1} soil) under control. All the treatments were significantly superior over control. The treatment comprising, soil test base, farmers' practice and general recommended dose (GRD) were significantly superior over control and recorded 9.7.0, 211.9 and 29.5 per cent increase over control. Among the IPNS targeted yield treatments, all the treatments were found significantly superior over non-IPNS except 2.5t FYM ha^{-1}. The target yield treatments with 2.5t, 5t FYM, 2.5t, and 5t vermicompost ha^{-1} recorded 17.0, 26.3, 35.0 and 40.4 per cent increase over non-IPNS treatment in soil microbial biomass carbon, respectively. After the harvest of wheat 2012-13, the soil microbial biomass carbon decreased in all respective treatments with depth. The treatments with targeted yield IPNS were found significantly superior on non-IPNS treatment except 2.5t FYM ha^{-1} with targeted yield. The treatment comprising, soil test base, farmers' practice and general recommended dose (GRD) were significantly superior over control and farmers' practice was found significantly superior over soil test base and general recommended dose (GRD). Combined use of chemical fertilizers and FYM and vermicompost as per target yield approach might have improved the microbial biomass carbon as compare to the FYM and inorganic fertilizer alone. The readily available carbon fraction of FYM supported the development of microbial biomass that increased soil microbial biomass carbon. These results are in accordance with the findings of (Kukreja *et al.* 1991 [9], Ghoshal and Singh 1995 [10] and Selvi *et al.* 2004) [11]. The supply and availability of additional mineralizable and readily hydrolysable carbon due to manure application might be responsible for higher microbial activity and microbial biomass carbon in organic manure treated plots. These results are in accordance with the findings of, Gogoi *et al.* (2010) [12] and Nath *et al.* (2012) [13]. The decrease in soil microbial biomass carbon (SMBC) into lower depth might be due to the presence of low organic matter which is the substrate of microorganisms that enhanced the soil microbial biomass carbon.

Urease activity

All the treatments enhanced urease activity over control. The treatments comprising soil test base, general recommended dose (GRD) and farmers' practice increased urease activity over control. The highest increase (17.0%) over control was found in soil test base followed by general recommended dose (GRD) (9.5%) and farmers' practice (7.2%). Application of different levels of FYM and vermicompost improved urease activity over target yield (non-IPNS). The increase in urease activity in the plots receiving 5t vermicompost, 5t FYM, 2.5t vermicompost and 2.5t FYM ha^{-1} with target yield treatment was 6.5, 17.3, 21.5 and 37.7 per cent over targeted yield (non-IPNS). Before the sowing of maize 2011, urease activity decreased under sub-surface soil as compared to surface soil samples. The treatments with targeted yield with IPNS were found significantly superior over non-IPNS targeted yield treatment except 2.5t FYM ha^{-1} with targeted yield.

At the harvest of *rabi* 2012-13 maximum (8.56 µg g^{-1} min^{-1}) urease activity was observed under treatment targeted yield with 5t vermicompost ha^{-1} and minimum (5.09 µg g^{-1} min^{-1}) under control. All the treatments were superior over.

Table 2: Effect of FYM and vermicompost on urease activity (µg g^{-1} min^{-1}) under prescription based fertilizer application.

Treatment	Before the sowing of maize 2010-11		After the harvest of wheat 2012-13	
	Urease activity		Urease activity	
	Depth			
	(0-0.15m)	(0.15-0.30m)	(0-0.15m)	(0.15-0.30m)
T_1: Control	5.11	4.75	5.09	4.61
T_2: Soil Test Base	5.98	5.69	5.53	5.24
T_3: FP - 25% N + 5t FYM ha^{-1}	5.48	5.40	5.12	4.95
T_4: 100% NPK	5.60	5.53	5.21	5.08
T_5: Target yield (non-IPNS)	6.12	5.92	5.67	5.47
T_6: Target yield - 2.5 t FYM ha^{-1}	6.25	6.12	6.46	6.34
T_7: Target yield - 2.5 t VC ha^{-1}	7.18	7.02	7.31	7.15
T_8: Target yield - 5 t FYM ha^{-1}	7.44	7.38	7.57	7.51
T_9: Target yield - 5 t VC ha^{-1}	8.43	8.29	8.56	8.42
CD(P=0.05)	1.13	1.21	1.23	1.79

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

Control. The treatment comprising, soil test base, farmers' practice and general recommended dose (GRD) were numerically superior over control and recorded 8.64, 0.58 and 2.3 per cent increase over control. Moreover, soil test base and farmers' practice were found statistically at par with each other. Among the IPNS treatments, all the treatments were found significantly superior over non-IPNS except 2.5t FYM ha^{-1}. The treatment comprising of 2.5t FYM, 2.5t vermicompost, 5t FYM and 5t vermicompost recorded 7.05, 28.5, 33.5 and 50.9 per cent increase over non-IPNS target yield treatment. After the harvest of wheat 2012-13, urease activity decreased under sub-surface soil as compared to surface soil samples.

Higher urease activity in all the treatments over control might be due to addition of amide form of nitrogen applied through urea (Rai and Yadav 2011) [14]. The higher urease activity recorded in the combined application of organics and inorganics than application of inorganics alone. Application of organic sources might have maintained the continuity of conversion of nutrients from organic to inorganic form because it acts on C-N bonds other than peptide bonds in linear amides. The results are corroborated with the findings of Jaun *et al.* (2008) [15]. The decrease in urease activity into lower depth might be due to the presence of low organic matter which is the substrate of microorganisms that enhances urease activity.

Phosphatase activity

It indicated that maximum (7.35 µg g^{-1} hr^{-1}) phosphatase activity was observed under the treatment targeted yield with 5t vermicompost ha^{-1} and minimum (3.92 µg g^{-1} min^{-1}) under control. The treatments comprising soil test base, farmers' practice and general recommended dose (GRD) improved phosphatase activity over control. The highest increase (21.6%) over control was found in soil test base followed by general recommended dose (GRD) (11.9%) and farmers' practice (9.1%). While comparing IPNS targeted yield treatments with non-IPNS treatments, all the IPNS treatments were significantly better than non-IPNS treatments except target yield 2.5t FYM ha^{-1} and recorded 10.3, 24.0, 29.4 and 52.4 per cent increase over non-IPNS. The surface soils (0-0.15 m) exhibited high phosphatase activity in comparison to the sub-surface (0.15-0.30 m) soils. In the sub-surface soil samples. All the IPNS treatments with targeted yield were found better than the non-IPNS targeted yield treatment.

Table 3: Effect of FYM and vermicompost on phosphatase activity (µg g^{-1} hr^{-1}) under prescription based fertilizer application

Treatment	**Before the sowing of maize 2010-11**		**After the harvest of wheat 2012-13**	
	Phosphatase activity		**Phosphatase activity**	
	Depth			
	(0-0.15m)	**(0.15-0.30m)**	**(0-0.15m)**	**(0.15-0.30m)**
T_1: Control	3.92	3.52	3.80	3.40
T_2: Soil Test Base	4.65	4.34	4.77	4.46
T_3: FP - 25% N + 5t FYM ha^{-1}	4.28	4.17	4.16	4.05
T_4: 100% NPK	4.27	4.19	4.39	4.31
T_5: Target yield (non-IPNS)	4.70	4.57	4.82	4.69
T_6: Target yield - 2.5 t FYM ha^{-1}	5.20	5.11	5.36	5.23
T_7: Target yield - 2.5 t VC ha^{-1}	5.98	5.79	6.04	5.85
T_8: Target yield - 5 t FYM ha^{-1}	6.24	6.16	6.3	6.22
T_9: Target yield - 5 t VC ha^{-1}	7.35	7.24	7.41	7.30
CD(P=0.05)	1.19	1.25	1.23	1.36

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

The treatments comprising soil test base, farmers' practice and general recommended dose (GRD) improved phosphatase activity over control and recorded 22.3, 12.3 and 9.4 per cent increase, respectively. Among IPNS treatments, all the treatments significantly enhanced the phosphatase activity as compared to non-IPNS except 2.5t FYM ha^{-1}. Different levels of FYM and vermicompost recorded 10.6, 28.5, 34.0 and 57.6 per cent increase over non-IPNS targeted yield treatment. Among IPNS, target yield 5t vermicompost, 2.5t vermicompost ha^{-1} and 5t FYM ha^{-1} were found statistically at par with one another. The surface soil (0-0.15 m) exhibited high phosphatase activity in comparison to the sub-surface (0.15-0.30 m) soil. In the sub-surface soil samples, the highest (7.30 µg g^{-1} min^{-1}) phosphatase activity was recorded under the treatment where 5t vermicompost was applied and lowest (3.40 µg g^{-1} min^{-1}) in control.

The treatments which received the combined application of organic and inorganics together might be due to fact that the addition of organic sources maintained the continuity of addition of nutrients from organic to inorganic form so the substrate of phosphorus *i.e.* monoesters and di-esters are continuously available and cause the phosphatase activity. Similar results were obtained by Bedi *et al.* (2009) [1]. The decrease in phosphatase activity into lower depth might be due to the presence of low organic matter which is the substrate of microorganisms that enhances phosphatase activity.

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 4: 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 5: 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) [16]. 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) [17], Urkurkar *et al.* (2010) [18] and Thakur *et al.* (2011) [19]. 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) [20]. 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

- Soil microbial biomass carbon was also increased with the application of different levels of FYM and vermicompost i.e. 2.5t and 5t ha^{-1} with target yield treatment and farmers' practice as compared to non-IPNS counterpart, soil test base and general recommended dose.
- Enzymatic activity (phosphatase and urease) increased when inorganics were applied following targeted yield concept (IPNS) to their non- IPNS counterpart, soil test base and general recommended dose.
- 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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