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Soil Science

Effect of Fertilizer Levels, FYM and Bioinoculants on Soil Properties in Inceptisol of Varanasi, Uttar Pradesh, India

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Abstract

A field experiment was conducted during *Rabi* seasons of 2009-10 and 2010-11 at the Agricultural Research Farm, Banaras Hindu University, Varanasi (U.P.) to study the effect of fertilizer levels, FYM and bioinoculants and their interaction effect on soil properties. The treatments consisted four levels of recommended dose of fertilizer (0, 50, 75 and 100% NPK), two levels of farmyard manure (0, 10 t ha^{-1}) and four inoculation [no inoculation, PGPR (*Azotobacter chroococum* W5 + *Azospirillum brasilence* Cd+ *Pseudomonas fluorescens* BHU PSB06 + *Bacillus megaterium* BHU PSB14), VAM (vesicular arbuscular mycorrhiza) and PGPR+VAM]. The experiment was replicated thrice in a split plot design. The results revealed that application of different treatments did not affect the pH, EC and bulk density decreased, water holding capacity, organic carbon and CEC significantly improved after harvest of wheat. The dehydrogenase, phosphatase enzyme activity and soil microbial biomass carbon (SMBC) and available N, P and K and microbial population of soil after the harvest of wheat were improved significantly due to the integration of inorganic fertilizers with FYM and bioinoculants. Positive impact of biological and organic manure application have been recorded with an additional advantage of reduction of chemical fertilizer use.

Highlights

- Physical, chemical and microbial properties of soil were improved by combined application of fertilizer levels, FYM and bioinoculants over control.
- Combined application of 75% NPK fertilizer, FYM @ 10 t ha^{-1} and bioinoculants emerged as an viable alternative for sustainable maintenance of soil fertility, plant nutrient and wheat productivity

Keywords: *PGPR, FYM, enzyme activity, SMBC*

The integrated nutrient management advocates balanced and conjoint use of inorganic fertilizer, organic manure, (Rakshit *et al.,* 2008) green manure and biofertilizer in order to maintenance or adjustment of soil fertility and plant nutrient supply to an optimum level for sustaining desired crop productivity. Fertilizers are very important sources of plant nutrients for increasing agricultural production. The inorganic fertilizer could supply only one, two or three nutrients but integrated use of inorganic fertilizers, FYM and bioinoculants would provide N, P, K, S, Zn, Fe and B to plant, soil and resist occurrence of multiple nutrient deficiencies. If sufficient quantity of organic manures is added along with inorganic fertilizers then perhaps there would be no need of adding micronutrients (Parsad, 1999).

Excessive use of chemical fertilizers harms the biological power of soil which must be prevented as transformations of all the nutrients are negotiated by soil microflora. An optimum soil microorganism population must be maintained in the soil for higher nutrient use efficiency. No single source of plant nutrients can meet the entire nutrient need of crops in modern agriculture, rather they need to be used in an integrated manner following a management technology that is appropriate, economically viable,socially acceptable and ecologically sound (Finck, 1998).

An organic source like FYM is the source of energy to the soil microflora and organic carbon content is considered to be an index of the soil health (Chand, 2006). There is a great need for more research on biological nitrogen fixation and phosphorus solubilization for energy conservation. Most soils of Uttar Pradesh are low in organic matter content and poor in nitrogen and phosphorus. Hence introduction of efficient strains of bioinoculants in soils may help in boosting up production through increased microbial population and consequently fixation of more atmospheric nitrogen and more solubilization of insoluble phosphorus from the soil. Hence present study was undertaken to know the effect of inorganic fertilizers, FYM and bioinoculants and their interaction effect on the soil properties in the rhizosphere soil of wheat crop.

Materials and Methods

A field experiment was conducted during Rabi season of 2009-10 and 2010-2011 at Agricultural Research Farm, Banaras Hindu University,Varanasi (U.P.). The soil of experimental field was sandy loam in texture having low soil organic carbon (0.38%), low available N (207.87 kg ha^{-1}), medium available P (17.9 kg ha^{-1}) and K (227.0 kg ha^{-1}), bulk density (1.41 Mg M^{-3}), particle density (2.62 Mg M^{-3}), water holding capacity (45.7%), cation exchange capacity [18.70 Cmol (P^{+}) kg^{-1} soil] contents with neutral pH 7.3 (1:2.5 soil: water ratio). The biological properties of the initial soil sample viz. dehydrogenase activity ranging from 143.2 to 144.8 µg TPF g^{-1} soil 24 h^{-1}, phosphatase 33.6 to 34.2 µg PNP g^{-1} soil h^{-1}, soil microbial biomass carbon (SMBC) 170-172 mg kg^{-1} soil, bacterial and fungal population 20 to 22 cfu x 10^{5} g^{-1} soil and 9 to 11 cfu x 10^{4} g^{-1} soil, respectively, during the 1st and 2nd year of experiments. A total of 32 treatments combinations comprising of four levels of fertilizer (0, 50, 75 and 100% NPK ha^{-1}), two levels of FYM (0 and 10 t ha^{-1}) and four bioinoculants [No inoculation, PGPR (*Azotobacter chroococum* W5 + *Azospirillum brasilence* Cd+ *Pseudomonas fluorescens* BHU PSB06 + *Bacillus megaterium* BHU PSB14), Vesicular Arbuscular Mycorrhiza (VAM) and PGPR+ VAM] were replicated thrice under spilt-split plot design and assigned in main plots, sub plot and sub-sub plots, respectively.

Wheat seeds were inoculated with Azotobacter chroococum W5 + Azospirillum brasilence Cd+ Pseudomonas fluorescens BHU PSB06 + Bacillus megaterium BHU PSB14 in 1:1:1:1: ratio. Inoculum of VAM, Glomus fasciculatum was drilled below seeds in soil. Wheat var. HUW-234 was taken as a test crop to observe direct effect of the treatments. The 100% NPK recommended dose of fertilizer for wheat was 120 kg N, 60 kg P2O5 and 60 kg K2O ha^{-1}, respectively. The FYM @ 10 t ha^{-1} was incorporated one month before sowing as per treatments. Total N, P and K contents of the FYM were 0.47, 0.24, and 0.46%, respectively. Half dose of N and full dose of P and K were applied as basal in the form of urea, di-ammonium phosphate and muriate of potash manually by placement method into open furrows, respectively. The remaining N was applied in two equal splits at tillering and flower initiation stages, respectively during both the years. Soil samples were collected after harvesting of the crop and analysed by the standard procedure.

Results and Discusssion

Soil physical properties

The data presented in Table 1 indicate that increasing levels of fertilizer application and inoculation of seeds with bioinoculants did not show any significant effect on bulk density, yet it decreased bulk density during both the years from the initial value. The bulk density of soil decreased significantly with incorporation of

Table 1: Effect of fertilizer levels, FYM and bioinoculants on some soil properties of soil

Treatment	Physical properties						Chemical properties					
	Bulk density		WHC (%)		pH		EC		Organic carbon (%)		CEC	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Fertility levels (kg N, P_2O_5, and K_2O ha^{-1})												
control	1.40	1.40	45.23	45.61	7.30	7.29	0.166	0.167	0.39	0.40	20.20	20.27
NPK50%	1.39	1.39	47.73	48.92	7.29	7.28	0.170	0.168	0.42	0.43	20.82	21.16
NPK75%	1.38	1.38	48.64	49.80	7.27	7.28	0.170	0.172	0.43	0.45	21.57	21.71
NPK100%	1.38	1.38	50.05	50.74	7.27	7.26	0.173	0.175	0.46	0.48	21.86	21.95
SE m±	0.007	0.006	0.091	0.118	0.015	0.011	0.003	0.003	0.005	0.007	0.114	0.120
CD 5%	NS	NS	0.314	0.408	NS	NS	NS	NS	0.016	0.023	0.395	0.413
FYM levels (t ha^{-1})												
FYM0	1.41	1.42	45.22	46.00	7.30	7.29	0.168	0.168	0.35	0.36	20.08	20.11
FYM10	1.36	1.35	50.60	51.54	7.27	7.25	0.171	0.173	0.50	0.52	22.14	22.43
SE m±	0.007	0.005	0.101	0.109	0.011	0.013	0.001	0.003	0.005	0.007	0.124	0.129
CD 5%	0.022	0.016	0.328	0.356	NS	NS	NS	NS	0.018	0.022	0.404	0.419
Bioinoculants												
No inoculation	1.39	1.39	47.62	48.43	7.30	7.28	0.168	0.167	0.42	0.43	20.98	21.12
PGPR	1.38	1.39	47.88	48.71	7.28	7.28	0.169	0.171	0.43	0.44	21.08	21.22
VAM	1.38	1.38	47.95	48.87	7.27	7.27	0.170	0.171	0.43	0.45	21.13	21.33
PGPR+VAM	1.38	1.38	48.19	49.06	7.27	7.27	0.172	0.172	0.44	0.45	21.25	21.41
SE m±	0.005	0.005	0.117	0.121	0.013	0.012	0.002	0.002	0.007	0.008	0.136	0.136
CD 5%	NS	NS	0.332	0.343	NS	NS	NS	NS	NS	NS	NS	NS
Initial value	1.41		45.7		7.3		0.168		0.38		18.7	

FYM @ 10t ha^{-1} was might be due to increase in organic carbon content in the soil. The results are corroborated with the findings of Prakash *et al.,* (2002) and Dadhich *et al.,* (2011).

It is discernable from the Table 1 that water holding capacity of soil significantly increased in all the treatments from its initial value (45.7%) except in control. Addition of fertilizer levels significantly increased water holding capacity after harvesting of the wheat crop. The increased water holding capacity with increasing levels of fertilizer application in soil was might be due to enhanced root growth leading to accumulation of more root residues in the soil which ultimately enhanced WHC in soil

Application of FYM @10 t ha^{-1} significantly increased WHC from 45.22 to 50.60% and 46.0 to 51.54% during both the years. The improvement in WHC in response to the addition of FYM causes better environment for root development, improved soil structure and water stable aggregates, as well as moisture retention capacity by increasing the total number of storage pores (Bhattacharyya *et al.,* 2004). The results are in accordance with the findings of Datt *et al.,* (2013). Integrated treatment of 100% NPK fertilizer levels and FYM gave numerically more water holding values as compared to control and 100% NPK fertilizers applied treatments. Furthermore, use of bioinoculants also increased significantly water holding capacity of soil. Biofertilizer improve soil texture, structure, supply of nutrients, WHC and proliferate useful microorganism which enhances the root biomass and ultimately organic carbon in soil (Sharma, 2011).

Soil Chemical Properties

A perusal of data on pH and EC as affected by various treatments under study indicated that application of fertilizer levels, FYM and bioinoculants have no significant effect on EC and pH during both the years. However soil pH maintained or slight decreased to the initial value (Table 1) might be due to the formation of organic acids during the decomposition of organic manure and crop residues (Sharma *et al.,* 2013).

Organic carbon and cation exchange capacity (CEC) differed significantly under various treatments over control in soil after harvest of the wheat. The significant higher values of organic carbon and CEC under 100% NPK level compared to control (Table 1) clearly indicate the effect of fertilizer in an improvement of soil condition. The use of fertilizer helps in increasing organic carbon content and CEC of soil due to higher biomass which might be due to the differential rate of oxidation of organic matter by microbes (Trehan, 1997). The highest values of organic carbon (0.50 and 0.52%) and CEC [22.14 and 22.43 C mol (P+) kg^{-1} soil] due to incorporation of FYM @ 10 t ha^{-1} were recorded during both the years. These values higher due to direct addition of FYM and release of cations with the decomposition of organic matter. The result of the present investigation is harmony with the findings of Bhardwaj *et al.,* (2010) and Datt, *et al.,* (2013). Use of bioinoculants did not show any significant variation in organic carbon content in soil after harvest of the wheat during both the years.

Available N, P and K content in control treatment decreased from its initial value (207.87, 17.9 and 227.0 kg ha^{-1} respectively) whereas the availability of these nutrients in rest of the treatments increased from its initial levels. Higher values of available N (227.48 and 228.76 kg ha^{-1}), P (18.25 and 18.31 kg ha^{-1}) and K (233.40 and 235.78 kg ha^{-1}) were obtained due to combined application of 100% NPK fertilizer, FYM @ 10 t ha^{-1} and bioinoculants during both the years ascribed due to direct application of fertilizer in the soil. The lower values of these nutrients in control during both the years might be due to more absorption of nutrients by component wheat crop. It is clear from the Table 2 that available N, P and K content in soil increased significantly with increasing levels of fertilizer application but these nutrients following application of 75% and 100% NPK were at par during both the years. These observations are in close conformity to those obtained by Abraham and Lal (2004) and Thakur *et al.,* (2011).

Addition of FYM @ 10 t ha^{-1} significantly increased the available N, P and K in soil as compared to no FYM application during both the years. The increase was might be due to the direct addition of nutrients through decomposition of the FYM added to the soil and could convert organically bound N to inorganic form and retardation of soil P fixation by organic anions formed during FYM decomposition, moreover minimizing the losses due to fixation as well as solubilization of K through the action of organic acids librated during decomposition. These results were in the same line with those obtained by Patidar and Mali (2004) and Singh *et al.,* (2012).

Bioinoculants did not show any significant variation in available N and K status estimated under soil. Moreover, combined inoculation of PGPR+VAM increased the available P content of soil after the harvest of crop during both the years. The increase availability of P might be due to greater multiplication of soil microbes causing greater mineralization and production of organic acids, which reduce the fixation of phosphate by providing protective cover on sesquioxides and thus reduce the phosphate fixing capacity and increase the available P in soil (Bharadwaj and Omanwar, 1994).

Biological properties

The activity of dehydrogenase and phosphatase enzyme differed significantly amongst all the treatments (Table 4). The minimum activities of these enzymes were recorded in control and maximum was found at each highest levels of the treatment during both the years. The increased activity by increasing levels of fertilizer application might be attributed to the fact that inorganic source of nutrient stimulated the activity of microorganisms to utilize the native pool of organic carbon as a source of carbon, which acts as substrate for these enzyme. Masto *et al.,* (2006) reported that dehydrogenase activity was dependent on addition of number and amount of nutrient.

Addition of FYM @ 10 t ha^{-1} significantly increased the enzyme activity in the soil. This increased might be due to manure promote biological and microbial activities

Table 2. Effect of fertilizer levels, FYM and bioinoculants on available nutrients in the rhizosphere soil after harvest of wheat

Treatment	Available nutrients (kg ha^{-1})					
	N		P_2O_5		K_2O	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Fertility levels (kg N, P_2O_5, and K_2O ha^{-1})						
control	197.53	198.09	14.52	14.57	185.92	186.15
NPK50%	209.07	212.87	16.14	16.17	217.86	218.13
NPK75%	221.69	223.93	17.67	17.70	230.44	231.38
NPK100%	227.48	228.76	18.25	18.31	233.40	235.78
SE m±	1.890	1.915	0.047	0.082	1.162	1.196
CD 5%	6.524	6.609	0.162	0.285	4.010	4.127
FYM levels (t ha^{-1})						
FYM0	205.01	207.43	16.08	16.14	209.55	210.44
FYM10	222.87	224.40	17.21	17.24	224.27	225.28
SE m±	1.431	1.501	0.040	0.054	0.971	0.980
CD 5%	4.660	4.890	0.132	0.175	3.164	3.191
Bioinoculants						
No inoculation	211.17	213.59	16.45	16.53	215.63	216.36
PGPR	214.39	216.11	16.55	16.63	216.80	218.15
VAM	213.99	215.29	16.72	16.71	216.63	217.49
PGPR+VAM	216.21	218.67	16.85	16.89	218.56	219.44
SE m±	1.861	1.895	0.070	0.064	1.140	1.205
CD 5%	NS	NS	0.198	0.183	NS	NS
Initial value	207.87		17.9		227.0	

Table 3. Interaction effect of fertilizer levels and FYM on available phosphorus of soil after harvest of wheat during 2009-10 and 2010-11

Treatment	Available phosphorus (kg ha^{-1})							
	2009-10				2010-11			
	Control	$NPK_{50\%}$	$NPK_{75\%}$	$NPK_{100\%}$	Control	$NPK_{50\%}$	$NPK_{75\%}$	$NPK_{100\%}$
FYM0	14.08	15.91	17.07	17.26	14.15	15.96	17.08	17.36
FYM10	14.95	16.36	18.27	19.24	14.99	16.39	18.32	19.26
	SEm± = 0.081, CD (5%) = 0.264				SEm± = 0.107, CD (5%) = 0.350			

Table 4. Effect of fertilizer levels, FYM and bioinoculants on biological properties of soil

Treatment	Biological properties									
	Dehydrogenase (µg TPF g^{-1} soil 24 h^{-1})		Phosphatase (µg PNP g^{-1} soil h^{-1})		SMBC (mg kg^{-1} soil)		Bacterial population (10^5 cfu g^{-1} soil)		Fungal population (10^4 cfu g^{-1} soil)	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Fertility levels (kg N, P_2O_5, and K_2O ha^{-1})										
control	147.39	147.73	35.43	35.76	161.08	161.92	22.79	22.75	13.88	14.25
NPK50%	167.98	169.50	38.78	40.02	179.58	180.88	30.17	30.50	20.17	20.96
NPK75%	182.48	183.63	44.59	45.24	188.00	189.79	35.21	35.71	23.08	24.38
NPK100%	195.29	196.21	48.61	49.41	194.17	195.83	36.17	36.54	23.83	25.17
SE m±	0.949	1.028	0.498	0.521	0.899	0.962	0.283	0.288	0.241	0.265
CD 5%	3.276	3.549	1.717	1.798	3.104	3.319	0.978	0.995	0.831	0.914
FYM levels (t ha^{-1})										
FYM0	166.99	168.17	40.31	40.77	176.89	177.42	24.96	25.00	17.02	17.88
FYM10	179.58	180.37	43.39	44.44	184.52	186.79	37.21	37.75	23.46	24.50
SE m±	0.905	0.958	0.463	0.471	0.899	0.937	0.278	0.157	0.227	0.251
CD 5%	2.948	3.119	1.509	1.533	2.894	3.051	0.905	0.510	0.739	0.819
Bioinoculants										
No inoculation	168.60	169.27	39.92	40.53	177.63	178.83	29.71	29.42	18.58	18.88
PGPR	172.06	173.13	41.98	42.90	179.83	181.58	31.21	31.67	19.50	20.29
VAM	175.28	176.47	41.55	42.24	181.54	183.00	30.75	31.21	20.96	22.25
PGPR+VAM	177.20	178.20	43.96	44.76	183.83	185.00	32.67	33.21	21.92	23.33
SE m±	0.910	0.927	0.505	0.638	0.948	0.968	0.224	0.241	0.292	0.304
CD 5%	2.587	2.636	1.436	1.815	2.696	2.754	0.637	0.685	0.830	0.865
Initial value	144.0		33.9		171		21 x 105 cfu g^{-1} soil		10 x 104 cfu g^{-1} soil	

Table 5. Interaction effect of fertilizer levels and FYM on microbial population in rhizosphere soil after harvest of wheat

Treatment	**2009-10**							
	Bacterial population (10^5 cfu g^{-1} soil)				**Fungal population (10^4 cfu g^{-1} soil)**			
	Control	**$NPK_{50\%}$**	**$NPK_{75\%}$**	**$NPK_{100\%}$**	**Control**	**$NPK_{50\%}$**	**$NPK_{75\%}$**	**$NPK_{100\%}$**
FYM0	17.92	23.58	28.42	29.92	10.25	16.00	20.42	21.42
FYM10	27.67	36.75	42.00	42.42	17.50	24.33	25.75	26.25
	SEm± = 0.556, CD (5%) = 1.811				SEm± = 0.454, CD (5%) = 1.477			
2010-11								
FYM0	17.5	23.25	29.25	30.00	10.33	16.67	21.58	22.92
FYM10	28.00	37.75	42.17	43.08	18.17	25.25	27.17	27.42
	SEm± = 0.313, CD (5%) = 1.020				SEm± = 0.503, CD (5%) = 1.637			

and accelerated the breakdown of organic substances in the added manure, which is known to stimulate the dehydrogenase activity (Pedrazzini and Mckee, 1984). The significant increased of enzyme activity were also found by the use of bioinoculants (PGPR+VAM) as compared to no inoculation control (Table 4). Increased the enzyme activity of soil significantly over no inoculation, may possibly be due to the improvement in the porosity and more availability of nutrients (especially P) to the plant (Shinde and Bangar, 2003).

It is evident from data presented in Table 4, that the contents of soil microbial biomass carbon (SMBC) varied significantly under different treatment. The contents of biomass carbon have decreased from its initial status (171 mg kg^{-1} soil) in control. The contents of SMBC were the highest under application of 100% NPK (194.17 and 195.83 mg kg^{-1} soil) during both the years. Microbial biomass carbon increased with increase in doses of inorganic fertilizers may be due firstly to increase in microbial population (Hasebe *et al.,* 1985) and secondly to the formation of root exudates, mucigel soughed off cells and underground roots of previous cut crops, which also play an important role in increasing biomass carbon (Goyal *et al.,* 1992). The SMBC increased with fertilizer level were also reported by Gogoi *et al.,* (2010).

Application of FYM @ 10 t ha^{-1} significantly increased the SMBC in soil during both the years. The SMBC at 10 t FYM ha^{-1} being 184.52 and 186.79 mg kg^{-1} soil during 2009-10 and 2010-11, respectively. The extent increase over no FYM (176.89 and 177.42 mg kg^{-1} soil) was 4.31 and 5.28% during both the years. The higher microbial biomass in FYM might be due to higher below ground plant residues as well as added FYM (Grego *et al.,* 1998). Moreover the use of bioinoculants in an integrated manner enhanced the microbial biomass carbon during both the years. The increase might be due to integrated use of fertilizer, FYM and bioinoculants add more organic matter, which provide carbon and energy to the soil microbes resulting into multiplication of microbial population and increase in soil microbial biomass carbon during both the years. The results of the present investigation are in accordance with the finding of Datt *et al.,* (2013).

Microbial population (Table 4) showed higher bacterial population as compared to fungi in wheat rhizosphere after harvest of the wheat in both the years of the experimentation. The results of experiment revealed that increasing fertilizer levels from 0 to 100% NPK, farmyard manure @ 10 t ha^{-1} and co-inoculation with PGPR+VAM significantly increased the bacterial and fungal population in the rhizosphere soil. Application of increasing levels of fertilizer increased the bacteria and fungi population in rhizosphere soil significantly upto 75% NPK levels and further increase to 100% NPK although resulted in slightly increase in population but was at par to 75% NPK levels. The increase in microbial population might be due to increasing levels of N, P and K which increases the biomass, root exudates and ultimately provides carbon and energy to the soil microbes resulting into multiplication of microbial population (Geethakumari and Shivashankar, 1991). The results are harmony with the finding of Chand *et al.,* (2010).

Similarly, application of FYM @ 10 t ha^{-1} enhanced significantly higher values of soil bacteria and fungi population over no FYM application at the harvest of the wheat crop during both the years (Table 4). The increased microbial population might be due to application of organic manures in turn provides adequate biomass as a feed for the microbes and helps in increasing microbial population in soil (Singh *et al.,* 2012).

The bioinoculants PGPR, VAM and PGPR+VAM either singly or in combination significantly increased the population of microbes viz., bacteria and fungi in rhizosphere soil after harvest of wheat over no inoculation during both the years. The bioinoculants trigger the microbial population might be possibly due to the improvement in the porosity and more availability of nutrients (especially P) to the plant by the bioinoculants (Shinde and Bangar, 2003). Sushila and Giri (2000) also reported increase in microbial population in rhizosphere of wheat with Azospirillum and Azotobacter inoculations.

Interaction effect of fertilizers and farm yard manures

Data presented in Table 3 show that there was significant interactive effect of fertilizer levels and FYM application on available P content of soil after harvest of wheat during both the years. The available P content of soil recorded with combined use of 10 t FYM ha^{-1} + 75% NPK application (18.27 and 18.32 kg P2O5 ha^{-1}) was significantly higher than recorded with application of 100% NPK without FYM (17.26 and 17.36 kg P2O5 ha^{-1}). The increased availability of available P with organics could be ascribed to their solubilizing effect on the native soil P and consequent contribution of the P as solubilized to labile pool. Incorporation of FYM along with inorganic fertilizer increased the availability of P to crop and mineralization of organic P due to microbial action and enhanced mobility of P (Prasad *et al.,* 2010).

Interaction effect of fertilizers and FYM revealed that microbial population was increased by increasing application of fertilizer (0, 50, 75 and 100% NPK) with FYM 10 t ha^{-1} or without FYM (Tables 5). The maximum microbial population viz, bacteria (42.42 and 43.08 x105 cfu g^{-1} soil) and fungi (26.25 and 27.42 x 104 cfu g^{-1} soil) was recorded in the treatment receiving 100% NPK+FYM @ 10 t ha^{-1}, but it was at par with 75% RDF+FYM 10 t ha^{-1} during both the years. Hence the result indicated that higher dose of the fertilizer adversely affect the microbial activity in the soil and it indicates that native soil has sub-optimum population of these bacteria and responds to single as well as combined application with positive interaction (Chand *et al.,* 2010). Addition of FYM with inorganic fertilizer levels showed a profound increase in the microbial population in comparison to chemical fertilizer used alone. FYM acts as a source of the nutrients and also as a substrate for decomposition and mineralization of nutrients, thereby creating a favourable condition for the proliferation of microbes in the soil. Selvi *et al.,* (2004) recorded highest bacterial counts at the end of the crop with the addition of FYM along with 100% NPK followed by 150% NPK.

Conclusion

The overall results demonstrated that bulk density, water holding capacity, organic carbon, available N, P and K; and enzyme activity, soil microbial biomass carbon and microbial properties of soil were improved by combined application of fertilizer levels, FYM and bioinoculants over control. Hence, it can be concluded that integration of all the treatment in balance form improve the physico-chemical and biological properties of the soil. Finally the goal is to integrate the use of all natural and man-made sources of plant nutrients, so that crop productivity increases in an efficient and environmentally benign manner, without sacrificing soil productivity of future generations.

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