SHORT COMMUNICATION

Long-term effect of mineral fertilizers and amendments on microbial dynamics in an alfisol of Western Himalayas

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Abstract The microbial dynamics expressed in terms of culturable microbial populations i.e. bacteria, fungi, actinomycetes and *Azotobacter* were measured after 33 years of continuous application of mineral fertilizers and amendments to an acid alfisol. The bacterial, fungal and *Azotobacter* populations were maximum in plots treated with mineral fertilizers and FYM (100%NPK+FYM) while actinomycetes population was maximum in mineral fertilizers and lime treated plots (100%NPK+Lime). The bacterial population decreased and fungal population increased with increasing levels of NPK i.e. from 50% to 150%NPK. *Bacillus* species of bacteria and *Gliocladium*, *Aspergillus* and *Rhizopus* species of fungi were the main dominating culturable microorganisms in all the treatments. The FYM and lime amended plots sustained crop productivity and microbial populations at higher levels than rest of the mineral fertilizer treatments. The nitrogenous fertilizers alone had the most deleterious effect on crop productivity and the biological soil environment.

Keywords: Mineral fertilizers · amendments · alfisol · microbial dynamics

The chemical fertilizers are one of the key factors contributing to increase in agricultural production of our farming system, but these are known to exhibit deleterious effect on soil environment, if used injudiciously¹. The continued low and imbalanced use of nutrients is one of the prime areas of concern for agricultural sustainability in the state of Himachal Pradesh². Besides keeping the production level low, the low and imbalanced use of nutrients led to the soil quality deterioration². A long-term fertilizer field experiment under All India Coordinated Research Project was initiated in 1972–73 (*rabi* season) at Agricultural University, Palampur. The soil quality for the last 33 years was assessed in terms of chemical and physical soil environments only.² However, the biological environment of soils was never looked into in this particular experiment. The microorganisms present in the soil carry out a wide range of activities like organic matter decomposition, nitrogen fixation and translocation of immobile elements.³ The microbial community structure can provide a sensitive reflection of soil quality under different land use and management practices as shown by Drijber et al.⁴ The experimental site lies in the Palam Valley of Kangra district in the mid hill sub-humid zone of Himachal Pradesh.

The experimental farm is at 31°6' N latitude and 76°3' E longitude at an altitude of about 1290 m above mean sea level. The area received 2178.54 ± 573 mm mean annual rainfall (averaged for 1972 to 2004), with June to September being the wettest months. The surface soils (0–0.15 m) had a pH of 5.8 (1:2.5 soil: water ratio). The soil characteristics, details on cultural practices, irrigation and fertilizer application schedule at the beginning and followed during the entire period of experimentation have been discussed elsewhere².

The long term fertilizer experiment comprising 11 treatments replicated four times in randomized block design was

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Table 1 Treatment details of long term fertilizer experiment.

Treatment No.	Treatment	Remarks
T ₁	Control	No external inputs of nutrients
T ₂	100% N	N through urea
T ₃	100% NP	N through urea P through single super phosphate
T ₄	100% NPK	N through urea @ 120 kg ha ⁻¹ P through single super phosphate @ 26 kg ha ⁻¹ K through muriate of potash @ 25 kg ha ⁻¹
T ₅	100% NPK+FYM	FYM* @ 10 t ha ⁻¹ yr ⁻¹ to maize crop only
T ₆	100% NPK+lime	Lime as CaCO ₃ @ 900 kg ha ⁻¹ to maize crop till pH is attained at neutrality (pH 6.5)
T ₇	100% NPK+Zn	Zn as ZnSO ₄ @ 25 kg ha ⁻¹
T ₈	100% NPK+HW	Hand weeding**
T ₉	100% NPK (-S)	P through di-ammonium phosphate (DAP)***
T ₁₀	50% NPK	Sub-optimal level
T ₁₁	150% NPK	Super-optimal level

*FYM applied had 60% moisture and 1.01, 0.26 and 0.40% of N, P, K, respectively.

**Chemical weedicide (iso-protruron @ 1.25 kg ai ha⁻¹) was used in all the treatments except in T₈ where weeds were removed manually.

***P applied through DAP to assess the effect of 'S' free high analysis P fertilizers in crop production.

established in 1972-73 at the experimental farm of the CSK Himachal Pradesh Agricultural University, Palampur, following a maize (*Zea mays*) -wheat (*Triticum aestivum* L.) crop sequence (Table 1). Wheat crop grown in 2004-05 was tested as the test crop in the present study.

For biological soil environment, samples were collected from a depth of 0–0.15 m. Each sample was compounded by pooling five sub-samples collected in 5 x 3 m² area and a total of 44 soil samples were collected, representing the four replications. These samples were sieved (<2mm) and were then stored in polythene bags and kept in refrigerator at 4–8°C. The serial dilution technique was used for all soil sample counts⁵. The data on grain yield of wheat, soil reaction and microbial populations were subjected to standard analysis of variance and the means of the treatments were tested for significant differences at 5% using the IRRISTAT data analysis package.

As evident from the results given in Table 2, a significant reduction in bacterial population was noticed with increasing doses of NPK from sub-optimal level (50% NPK) to super-optimal levels (150% NPK). This reduction may be attributed to the changes in chemical properties of soil brought out by long term application of mineral fertilizers². The application of FYM in addition to 100% NPK (T₅), showed maximum counts, which might be due to the stimulatory effect of organic matter⁶ on the growth and multiplication of bacteria. Genus *Bacillus* (*Bacillus* species; *B. cereus* and *B. megaterium*) was the predominant among culturable bacteria in all the treatments. The lowest

bacterial activity was noticed in plots receiving only nitrogen through urea (T₂) which might be due to more acidification of soil vis-à-vis accumulation of various toxic elements and mining of some important macronutrient⁷.

With changes in mineral fertilizer levels from 50% NPK (T₁₀) to 150% NPK (T₁₁), fungal population showed an increasing trend. This is probably due to the acid producing nature of nitrogenous fertilizers⁸, which has affected the soil pH (Table 2), and thereby led to the elevation in the fungal population. The lowest fungal counts (0.45 X 10⁴ / g soil) were observed in case of lime treated plots (T₆) which is in accordance with the studies of Patil & Varade⁹. Lime addition along with NPK brought the soil to about neutrality by raising the pH to 6.4 from the initial value of 5.8, thereby affecting the fungal population. In case of fungi, *Gliocladium*, *Aspergillus* and *Rhizopus* were main culturable fungi observed in all the treatments. *Mucor* and *Penicillium* were also observed in some of the treatments. The presence of *Gliocladium*, a bio-control agent against many soil borne pathogens¹⁰ is an interesting observation which probably reflects the acquisition of natural control mechanism against certain pathogens observed in the present experimental set up.

The highest population of actinomycetes (87.86 x 10³/g soil) was observed in lime treated plots followed by 100% NPK + FYM (T₅). High count of actinomycetes in the FYM treated plots is in accordance with the findings of Shah et al¹¹ who have observed more proliferation of these organisms in soils containing high organic matter content.

Table 2 Effect of continuous application of chemical fertilizers and amendments on soil reaction, crop productivity (t ha⁻¹) and microbial population (cfu x 10ⁿ/g soil).

Treatment	pH	Wheat grain yield (t ha ⁻¹)		Microbial population			
		1972–73	2004–05	Bacteria (cfu x 10 ⁵)	Fungi (cfu x 10 ⁴)	Actinomycetes (cfu x 10 ³)	<i>Azotobacter</i> (cfu x 10 ³)
T ₁	5.6	1.01	0.35	9.53	4.43	19.76	127.83
T ₂	4.6	2.27	0.00	4.55	6.98	46.63	11.86
T ₃	5.3	3.81	1.09	7.96	5.13	24.33	45.50
T ₄	5.3	3.93	1.84	11.49	7.83	20.30	17.50
T ₅	5.4	4.30	2.38	28.08	2.78	73.20	226.16
T ₆	6.4	4.19	2.20	18.88	0.45	87.86	92.66
T ₇	5.2	4.10	1.60	18.23	2.61	8.86	15.93
T ₈	5.3	5.12	2.05	9.21	5.75	12.10	68.53
T ₉	5.2	-	1.22	13.76	5.04	34.63	14.60
T ₁₀	5.6	2.66	1.04	24.56	4.39	52.40	55.16
T ₁₁	5.1	4.70	1.76	6.94	8.06	5.75	14.61
CD (0.05)		0.61	0.21	0.787	2.993	5.259	7.964

Table 3 Correlation between microbial populations with grain yield and pH.

Characters	Bacteria	Fungi	Actinomycetes	<i>Azotobacter</i>
Grain yield	*0.470	*-0.285	0.190	*0.311
pH	*0.491	*-0.716	*0.532	*0.420

*Values showing significant correlation at 5% level of significance.

Except T₇ and T₁₁, a significantly higher population of actinomycetes was seen on application of mineral fertilizers as compared to the plots receiving no fertilizer. This might be due to the depletion of available nutrients as a result of continuous cropping⁵ which has probably affected the microbial activity.

Maximum counts of *Azotobacter* were observed in treatment where FYM was applied in addition to mineral fertilizers. It may be due to large amount of C source provided by FYM¹² which is required for proliferation of *Azotobacter*. The *Azotobacter* count was lowest in 100% N treated plots, which is in accordance with the findings of Fauci & Dick¹³ who reported that long term inorganic N application decreases organic matter, biological activity and limits N fixation. Interestingly, higher counts of *Azotobacter* in T₈ than T₄ are probably due to the sensitivity of *Azotobacter* to weedicide as reported by Milosenvic & Govedarica¹⁴. The increased *Azotobacter* population in this experiment is also probably responsible for augmenting crop productivity though the chemical environment of both the plots was identical².

Correlation studies revealed that bacterial population is significantly correlated with grain yield of wheat (Table 3)

which is in confirmation with studies of Hofflich *et al*¹⁵. The relationship of actinomycetes with crop yield was positive but a non significant one. *Azotobacter* was significantly and positively related to grain yield but fungi had a negative relationship. These results are in agreement with the studies of Patil & Varade⁹ who also reported that fungi are more related to pH of the soil and show a negative correlation with productivity.

The continued low and imbalanced use of nutrients degraded the soil quality and produced a deleterious effect on biological soil environment. The integrated use of organic amendment (FYM) or lime with recommended levels of inorganic fertilizers increased the soil organic matter content, resulting in more microbial proliferation and thereby sustained soil health. The results of the present study thereby support the concept of balanced fertilization and integrated nutrient management practices for improving the soil quality and sustained crop productivity.

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