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Impact of Nutrient Management Practices on Soil Physical and Biological Properties in an Acid Alfisol of Himachal Pradesh, India

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Abstract: The present investigation was carried out to assess the effect of nutrient management practices on soil physical and biological properties under maize crop in an acid Alfisol. The experiment consisted of eleven treatments comprising recommended NPK levels, NPK + FYM, NPK + lime, organic farming packages, NFS-*Desi* Cow, NFS-Crossbred Cow, NFS-Buffalo, and their supplementation with 25 per cent of recommended NPK. The highest water holding capacity, and mean weight diameter, while lowest bulk density were under organic farming+ 25 per cent NPK treatment. Among soil microbial properties, organic farming + 25 per cent NPK treatment showed the highest microbial biomass nitrogen, urease activity, viable bacterial, fungal, and actinomycetes count, however, all these parameters were found lowest under 100 per cent NPK treatment.

Keywords: Bulk density, Mean weight diameter, Microbial biomass nitrogen, Urease activity, Bacterial count

Productive soil is the fundamental base for harnessing the potential of intensified cropping system. In the last fifty years, globally, the size of the per capita arable landholding has significantly reduced from 0.44 ha to 0.18 ha per capita, and by 2050, it is likely to drop even lower to 0.1 ha (Mehra et al 2018). Furthermore, diminishing agricultural output, soil fertility, and mounting environmental issues add to the difficulties of agricultural sustainability and consequently, production is inadequate to meet the demands of growing population. Adoption of chemical fertilizers for increasing food grain production has largely replaced traditional practices, *viz.,* recycling of crop residues and application of organic manures. Intensive cultivation and declining soil organic carbon content results in deterioration of soil physical and microbial properties. Soil physical properties *viz.,* bulk density, porosity, and aggregate stability are the key components of soil quality, and their variation with time can reflect the agricultural sustainability. Maintenance of optimum soil physical properties is an essential component of soil fertility management. Sole application of inorganic fertilizers decreases the stability of macro-aggregates and capacity of moisture retention, however, increases the bulk density of soil. A number of management practices viz., integrated farming, organic farming and natural farming have been developed that are supposed to be more sustainable substitutes to traditional farming systems. Organic amendments in combination with inorganic fertilizers can improve aggregate stability as well as moisture retention capacity of soil. Another essential component of soil fertility management is soil microbes. Microorganisms regulate various important processes such as soil aggregate formation, humus formation, regulation of nutrient cycling, decomposition of various compounds etc. The alterations in soil organic carbon contents are directly linked with microbial biomass nitrogen (MBN), and biological activity in the soil. Microbial adaptation to environmental variabilities allows microbial analysis to be quite fruitful in soil health assessment, and therefore, microbial population dynamics may serve as an excellent indicator of change in soil health. The sole application of inorganic fertilizers significantly declined the total microbial activity, porosity, particle and bulk density of soil (Manivannan et al 2009). However, another study showed that the combined use of organic and inorganic fertilizers maintained the highest soil quality index followed by the application of 100% organic fertilizer (Schulz and Glaser 2012). Xu (2006 reported that natural farming practices can improve soil physical properties, biodiversity, and enzyme activities. As natural farming system generally involves use of formulations prepared using products of indigenous cow, therefore, little is known about the composition and characteristics of the microbial communities present in formulations prepared using products of crossbred cows and buffaloes. It is important to know the efficacy of formulations prepared from the dung and urine of these cattle (crossbred cows and buffaloes), as most of the farmers in our country are rearing these cattle as compared to indigenous one.

Therefore, this study was carried out to examine the comparative effects of different sources of nutrients on some soil physical and biological properties under maize based cropping system. We hypothesized that organic farming practices in conjunction with inorganic fertilizers might have a great beneficial impact on soil physical and microbial properties in comparison to other treatments.

MATERIAL AND METHODS

Study site: The present study was conducted in 2020 at CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The experimental site is located at an altitude of nearly 1290 meters above mean sea level ($32^0$6´N latitude and $76^0$3´ E longitude). The study site falls in the North-Western Himalayas of district Kangra and lies under mid hills sub humid agro-climatic zone of Himachal Pradesh which receives average annual rainfall of about 2750 mm. These soils belong to the order Alfisol and subgroup Typic Hapludalf and owe their origin to different kind of rocks such as slates, phyllites, quartzites, schists and gneisses. The weekly maximum and minimum temperature ranged between 26.0 to 30.5 and 13.0 to 20.1°C, respectively during crop growth period. The maize crop received a total rainfall of about 1449.0 mm and the weekly relative humidity varied from 57.95 to 92.05 per cent.

Experimental details: The experiment comprised of a randomized block design with three replications consisting eleven treatments (Table 1). Recommended dose of fertilizers for maize is 120:60:40 kg ha^{-1} of N:P_2O_5:K_2O. Urea, single super phosphate, and muriate of potash were applied as source of nitrogen, phosphorus and potassium, respectively. At the time of sowing, half dose of N and full doses of P and K were applied in treatments comprising inorganic fertilizers. The remaining half dose of N was given as top dressing in two equal splits at knee high and pre-tasseling stage of maize. Before sowing, whole quantity of FYM was given as per the treatments of the experiment. NPK content of FYM was 0.98, 0.47 and 0.85 %, respectively. Lime ($CaCO_3$) was thoroughly incorporated in the specified plots (@ 3.2 t ha^{-1}) about four weeks prior to sowing of the maize. In organic farming plots, 60 kg N ha^{-1} (50 per cent of RDF) was provided through FYM and another 60 kg N ha^{-1} was supplemented through vermicompost. In NFS plots, before sowing, the seeds were treated with *beejamrit* for 30 minutes. *Ghan-jeevamrit* was applied along with sieved FYM, followed by application of jeevamrit at sowing, and sprays of *jeevamrit* were given 5 times at 21days interval during crop growth. *Ghan-jeevamrit* was applied @ 250 kg ha^{-1} along with sieved FYM @ 250 kg ha^{-1}, jeevamrit @ 500 l ha^{-1} at sowing, and sprays of 10% *jeevamrit* were given 5 times at 21days interval during crop growth. Soybean was intercropped in the ratio of 2:1 in between the rows of maize plants. Mulching with locally available organic residues was also done. In addition to this, fermented butter milk was sprayed at 60 days after sowing (DAS) and at grain filling stage of maize (@ 12.5 l ha^{-1}). Microbial count present in *beejamrit, jeevamrit, and ghanjeevamrit* formulations prepared using products of different cattle (Table 2).

Sample analysis: After the harvest of maize, soil samples

Table 1. Effect of conventional, organic and natural farming treatments on bulk density, water holding capacity and mean weight diameter

Treatments details	BD (g cm^{-3})	WHC (%)	MWD (mm)
T_1- 100% NPK	1.36	45.14	2.15
T_2- 100% NPK+FYM	1.34	46.34	2.18
T_3-100% NPK+Lime	1.35	46.15	2.17
T_4- Organic farming	1.26	48.92	2.24
T_5-NFS-*Desi* cow	1.27	48.89	2.22
T_6-NFS-Crossbred cow	1.27	48.78	2.21
T_7-NFS-Buffalo	1.32	48.65	2.19
T_8-T_4+25% NPK	1.24	49.07	2.26
T_9-T_5+25% NPK	1.26	48.92	2.24
T_{10}-T_6+25% NPK	1.26	48.90	2.23
T_{11}-T_7+25% NPK	1.31	48.69	2.20
LSD (P=0.05)	0.02	0.91	0.03
Initial	1.36	44.42	2.12

BD: Bulk density, WHC: Water holding capacity, MWD: Mean weight diameter

Table 2. Microbial count in natural farming formulations prepared from products of different cattle

Excreta used	Bacteria (10^6cfu ml^{-1})	Fungi (10^4 cfu ml^{-1})	Actinomycetes (10^2cfu ml^{-1})
Beejamrit			
Desi Cow	25.1	10.3	22.6
Crossbred Cow	23.3	7.4	21.3
Buffalo	19.8	4.8	18.2
Jeevamrit			
Desi Cow	19.6	15.4	21.3
Crossbred Cow	16.4	12.3	18.6
Buffalo	14.5	10.5	16.2
Ghanjeevamrit			
Desi Cow	28.6	12.5	21.3
Crossbred Cow	26.6	11.4	19.6
Buffalo	22.4	9.8	17.4

Table 3. Method used for analysis of soil samples

Soil property	Method employed	Reference
Bulk density	Core sampler	Singh (1980)
Water holding capacity	Keen's moisture box	Richard (1954)
Mean weight diameter	Wet sieving	Yoder (1936)
Microbial biomass N	Incubation	Brookes et al (1985)
Urease activity	Colorimetry	Tabatabai and Bremner (1972)
Viable microbial count	Serial dilution pour plate	Alef and Nannipieri (1995)

were collected from 0-0.15 m depth from each plot. For determining the bulk density, soil samples from each replication were taken by using a core sampler having cores of 5 cm height and 5 cm diameter. For aggregate analysis, surface soil samples were collected in cores at field capacity moisture content. After drying, they were broken by giving gentle strokes in a wooden hammer and only aggregates of 4-8 mm size were used for analysis. The aggregate size distribution of soil was determined by wet sieving method using Yoder's apparatus. For microbiological properties, about 500 g of fresh soil samples from each plot were immediately preserved under refrigerated conditions for further analysis. Physical (bulk density, water holding capacity and aggregate stability) and biological properties (MBN, soil urease activity, viable bacterial, fungal and actinomycetes count) of soil samples were estimated (Table 3).

Data analysis: The data recorded was analyzed using MS-Excel, OPSTAT and SPSS 16.0 package as per design of the experiment.

RESULTS AND DISCUSSION

Physical Properties

Bulk density: The lowest bulk density (1.24 g cm^{-3}) was in organic farming + 25% NPK which was statistically at par with NFS-*Desi* cow + 25% NPK , NFS-Crossbred cow + 25% NPK and organic farming treatments (Table 1). Moreover, no change in bulk density was observed where 100% NPK was applied which might be due to low soil organic matter content and soil structure degradation. Bulk density reduced under organic farming + 25 per cent NPK treatment that might be due to higher soil organic carbon content, better aggregation, increased root growth, and biopores in the combined fertilizer and manure treated plots Sharma et al (2016).

Water holding capacity: Highest water holding capacity (49.07%) of soil was observed under organic farming + 25% NPK with non-significant differences with T_5, T_6, T_7, T_4, T_9, T_{10} and T_{11}, while the lowest (45.14%) was in T_1 (Table 1). Application of small dose of chemical fertilizers in combination with organic manures significantly increased the water holding capacity of soil over sole application of chemical fertilizers which could be attributed to enhanced soil structure and stable aggregates, as well as an increased number of storage pores which in turn, increased the moisture retention capacity. This clearly showed that the amount of organic matter in soil greatly affects ability to retain moisture, and organic matter not only increased the soil's water holding capacity but also increased the amount of water accessible for plant growth. Similar findings were reported by Amipara and Jadhav (2017). Water holding capacity was also improved under integrated nutrient management treatments *viz.,* 100% NPK + FYM and,100 % NPK + lime from the initial value which might be attributed to improved soil structure as well as aggregation with the application of FYM and lime). Water holding capacity was also recorded high in all the NFS treatments which could be due to increased build-up of soil carbon as a result of increased microbial activities.

Aggregate stability: MWD of soil ranged from 2.15 mm under 100% NPK treatment to 2.26 mm under organic farming + 25% NPK treatment. Initially mean weight diameter recorded was 2.12 mm which increased to 2.26 mm after the application of organic manures in combination with fertilizers (organic farming + 25 per cent NPK) which was statistically at par with NFS-*Desi* cow + 25% NPK, NFS-Crossbred cow + 25% NPK and organic farming treatments (Table 1). The highest mean weight diameter in organic farming + 25 per cent NPK might be due to release of various organic acids after decomposition of organic residues which led to greater binding of soil particles, increased soil organic matter content and greater earthworms activity thereby, resulting in significant increase in MWD (Shepherd et al 2006). In manure amended soil, the formation of macro-aggregates was favoured if soil organic matter content increased which resisted slaking, and earthworms present might also improve aggregate stability.

Biological Properties

Microbial biomass nitrogen (MBN): The maximum MBN (26.4 μg g^{-1}) was in T_8 which was statistically at par with T_9 and T_4. Lowest MBN (19.9 μg g^{-1}) was in conventional treatment i.e., 100% NPK (Fig. 1). Farm yard manure and lime amended treatments exhibited an increase of 11.1 and 5.5% in MBN over 100% NPK treatment, respectively. The significantly highest soil MBN found under organic farming practices combined with inorganic fertilizers which might be attributed to the balanced fertilization resulted in improved plant growth, root biomass and rhizosphere activity. Moreover, increased inputs to the soil from above and below ground residues as well as rhizo-deposition might be another reason for significant increase in MBN as these materials are the main carbon sources for soil microorganisms (Chahal et al 2019). .

Soil urease activity: The significantly highest soil urease activity (42.12 µg NH_4^+-N g^{-1} soil hr^{-1}) was in organic farming + 25% NPK , while the lowest (37.21 µg NH_4^+-N g^{-1} soil hr^{-1}) was in NFS-Buffalo treatment. Organic farming + 25% NPK treatment produced non-significant differences with NFS-*Desi* cow + 25% NPK, ,NFS-Crossbred cow + 25% NPK and NFS-Buffalo+25% NPK treatments (Fig. 1). Among organic treatments, organic farming treatment recorded higher soil urease activity (39.09 µg NH_4^+-N g^{-1} soil hr^{-1}) which was found statistically at par with , NFS-*Desi* cow treatments (38.32 µg NH_4^+-N g^{-1} soil hr^{-1}). The highest urease activity recorded under organic farming practices supplemented with small amount of chemical fertilizers might be due to increasing population of microorganisms like bacteria and increased availability of substrate through organic manures (Sireesha et al 2017). It was also likely that ureolytic heterotrophic microbes were encouraged by the addition of organic materials, consequently resulted in an increased urease activity.

Viable bacterial count: The highest viable bacterial count (24.5 x 10^6 cfu g^{-1} soil) was in T_8 which produced non-significant differences with NFS-*Desi* cow + 25% NPK treatment. The lowest viable bacterial count (13.5 x 10^6cfu g^{-1} soil) was in T_1 followed by T_3 (Fig. 2). Among organic treatments, T_4 recorded higher viable bacterial count (19.5x 10^6 cfu g^{-1} soil) which was statistically at par with T_5. The superiority of organic farming combined inorganic fertilizers practices in microbial population (bacteria and fungi) could be due to the fact that addition of FYM and vermicompost might have served as a source of carbon and energy for microorganisms. Application of organic matter provided proper aeration, moisture content and nutrients which might resulted in proliferation of microorganisms (Sharma and Banik, 2016). NFS-*Desi* cow treated plots also recorded higher viable bacterial count than other NFS treatments which might be due to high microbial count present in the NF products prepared from dung and urine of *Desi* cow.

Viable fungal count: The highest viable fungal count (14.3 x 10^4 cfu g^{-1} soil) was in T_8 which was statistically at par with T_9. The lowest viable fungal count (3.5 x 10^4 cfu g^{-1} soil) was in 100% NPK treatment (Fig. 2). Organic farming treatment recorded higher viable fungal count (10.0 x 10^4 cfu g^{-1} soil) with NFS-*Desi* cow treatment. Organic farming supplemented with 25 per cent of chemical fertilizers showed the highest viable fungal count which might be attributed to increased organic carbon and mineral nitrogen content providing energy and conducive environment for microbial proliferation thereby leading to increase in total fungal count. Low microbial population count in inorganic treatment might be due to poor availability of substrate to sustain microbial biomass (Sudhanshu et al 2015).

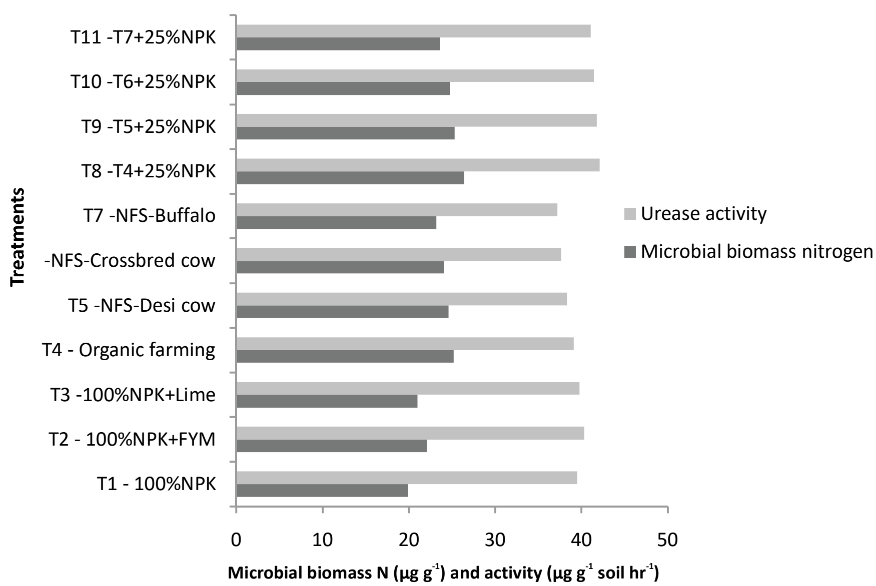

Fig. 1. Soil microbial biomass nitrogen and urease activity under different treatments

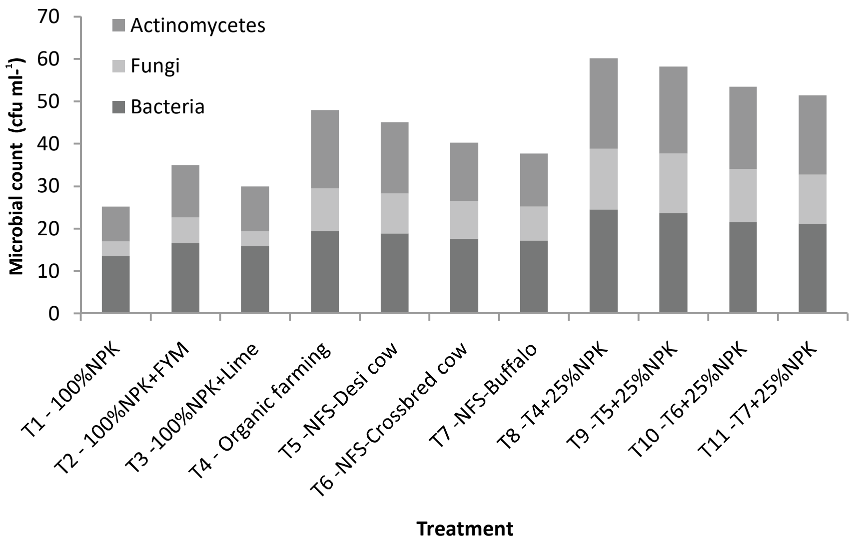

Fig. 2. Soil microbial count under different treatments

Viable actinomycetes count: The highest viable actinomycetes count (21.4 x 10^2 cfu g^{-1} soil) was in organic farming + 25% NPK treatment and was found statistically at par (20.5 x 10^2 cfu g^{-1} soil) with NFS-*Desi* cow + 25% NPK treatment (Fig. 2). Among organic treatments, higher viable actinomycetes count (18.5 x 10^2 cfu g^{-1} soil) was in organic farming, followed by T_5. The lowest viable actinomycetes count (8.2 x 10^2 cfu g^{-1} soil) was recorded under 100% NPK treatment. The highest viable actinomycetes count recorded under organic farming + 25 per cent NPK treatment could be due to the fact that majority of soil microorganisms are chemoheterotrophs, which require an organic source of carbon as food and obtain energy through the oxidation of organic substances. The result corroborates the findings of Watts et al (2010). Moreover, organic manures provided with mineral fertilizer increased crop residue and root exudates, which provide organic matter for microorganisms resulting in higher culturable microbial counts in organic manure treatments.

CONCLUSIONS

The integration of organic farming packages with inorganic fertilizers exerted a beneficial impact on soil physical properties as well as on microbial properties over sole application of organic manures or chemical fertilizers. Natural farming system had also significant positive impact on studied soil properties over conventional farming.

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