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Effect of farming practices on chemical properties of soil under maize in an acid Alfisol of Himachal Pradesh

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Abstract

The present investigation was carried out to assess the effect of farming practices on soil chemical properties under maize crop in an acid hill soil. The experiment consisted of three replications in a randomized block design having eleven treatments comprising recommended NPK dose, NPK + farmyard manure (FYM), NPK + lime, organic farming packages, NFS-*Desi* Cow, NFS-Crossbred Cow, NFS-Buffalo, and their supplementation with 25% of recommended NPK. The results revealed that the optimum pH was found in the lime amended treatment. Highest soil organic carbon content was found under organic farming practices + 25% NPK, while lowest was found under 100% NPK. Available N, P and K were found highest under 100% NPK+ FYM, while, lowest of these parameters were found under NFS-Buffalo treatment. These results could provide a better understanding of the significance of integration of mineral fertilizers with organic manures in maintaining soil fertility and crop growth.

Keywords: Nitrogen, organic carbon, phosphorus, potassium, soil pH

Maize (*Zea mays*) is the third leading cereal crop after rice and wheat across the world (Ramzani *et al*. 2017). It is a staple food for a huge section of the world's population. Maize contributes approximately 10% to India's food basket (Kumar *et al*. 2013). In India, it covers an area of 9.3 M ha with production of 29 MT with an average productivity of 3.1 t ha^{-1} (Anonymous 2018). Maize is a high nutrient intensive crop and productive soils are the fundamental base for harnessing the potential of intensified cropping system. Deteriorating soil fertility due to intensive cultivation is a serious concern around the world nowadays. For maintaining yield and soil fertility, a balance between crop nutrient requirement and soil nutrient reserve is critical. Fertilizers play an important role in production and productivity of crops but imbalanced and constant use of high analysis chemical fertilizers adversely influences the soil health (Parmar *et al*. 2007). Therefore, returning to non-chemical or less chemical based agriculture has become extremely important in terms of maintaining soil fertility and achieving long-term production sustainability (Sharma and Sharma 2004).

Addition of organic manure is necessary for maintaining soil fertility and sustained productivity (Sharma and Sharma 2016) but they cannot supply all nutrient requirements on their own. As a result, combining nutrients from fertilizers and organic sources is critical for providing plant nutrients and sustaining soil health (Sharma and Sharma 2016). To maintain soil fertility and crop growth, integrated nutrient management has been demonstrated to be a very good alternative to solitary use of chemical fertilizers (Sharma *et al*. 2003). However, to supplement chemical fertilizers, a large volume of organic manures such as farmyard manure (FYM), vermicompost, and other organic manures are required. Therefore, we must look for alternate low-cost sources of nutrients which are easily manageable, locally available, socially acceptable and environmentally sustainable.

Recently, Natural Farming System (NFS) has become quite popular among farmers of our country as it is more farmer friendly in terms of cost of production

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besides having beneficial impact on soil fertility and health (Vinay *et al*. 2021). However, NF system emphasizes the use of products of *'Desi'* cows only. Therefore, its applicability would be quite limited, as in our country, many farmers are either rearing crossbred cows or buffaloes. Therefore, there is a need to evaluate the efficacy of formulations prepared using the products from these cattle (Noori *et al*. 2023), and their integrated use with little quantity of chemical fertilizers. Keeping this in view, this study was carried out to standardize the best nutrient management practices in terms of soil chemical properties and maize growth. This hypothesis suggests that conjunctive use of inorganic fertilizers and organic manures would perform better among all the nutrient management practices.

Materials and Methods

The present study was carried out on maize during the year 2020 at the experimental farm of the Department of Agronomy, CSK Himachal Pradesh Agricultural University, Palampur, Himachal Pradesh, India. The study site is located at 32°6´N latitude and 76°3´E longitude and 1290 m above the mean sea level. The research site falls under the mid-hills sub-humid agro-climatic zone and its climate is characterized as wet temperate. The soil of the research site has been classified as Typic Hapludalf and the texture is silty loam. Mean weekly meteorological data recorded at the meteorological observatory of Himachal Pradesh Krishi Vishvavidyalaya, Palampur during the crop growth period revealed that the weekly maximum and minimum temperature ranged between 26.0 to 30.5°C and 13.0 to 20.1°C, respectively. The crop received a total rainfall of 1449.0 mm, and the weekly mean relative humidity varied from 57.95 to 92.05 per cent.

Experimental details

The experiment comprised of eleven treatments viz., 100% NPK-(T_1), T_1 + farmyard manure-(T_2), T_1 + lime (T_3), Organic farming practices-(T_4), Natural farming system using excreta of '*desi*' cow (NFS-*Desi* Cow)- (T_5), Natural farming system using excreta of crossbred cow (NFS-Crossbred Cow)- (T_6), Natural farming System using excreta of buffalo (NFS-Buffalo)-(T_7), T_4+25%NPK-(T_8), T_5+25%NPK- (T_9), T_6+25%NPK-(T_{10}) and T_7+25%NPK- (T_{11}) which were replicated thrice in a randomized block design 100% NPK corresponding to 120 kg nitrogen (N), 60 kg phosphorus (P), and 40 kg potassium (K) ha^{-1} for maize. Urea, single super phosphate, and muriate of potash were used to supply N, P, and K, respectively. The whole quantity of FYM (0.98%, 0.47% and 0.85 % N, P and K, respectively on a dry weight basis) was incorporated at the time of sowing in 100% NPK + FYM @ 10 ha^{-1} treatment. Nearly four weeks prior to sowing of the maize, lime was applied @ 3.2 t ha^{-1} in specified plots comprising 100% NPK + lime treatment. The full doses of P and K and half dose of N were applied at the time of sowing and the remaining half N was top-dressed in two equal splits at knee high and pre-tasseling stages. In organic farming plots, 60 kg N ha^{-1} was supplied through FYM and another 60 kg N ha^{-1} was supplemented through vermicompost (29.4% moisture content with average nutrient composition of 1.83%, 0.97% and 0.73% of N, P and K, respectively on dry weight basis).

In NFS plots, before sowing, the seeds were treated with *Beejamrit* for a period of 30 minutes. At sowing, *Ghan-jeevamrit* (@ 250 kg ha^{-1}) was applied along with sieved FYM (@ 250 kg ha^{-1}), followed by application of *Jeevamrit* @ 500 l ha^{-1}. During crop growth, sprays of *Jeevamrit* @10% were given five times at an interval of 21 days. Soybean was intercropped in between the rows of maize plants (2:1). Mulching with locally available organic residues was also done. The nutrient composition of *Beejamrit, Jeevamrit* and *Ghan-jeevamrit* prepared using products of different animals have been presented in Table 1.

Table 1. Composition of *Beejamrit, Jeevamrit* and *Ghan-jeevamrit* prepared using excreta of different cattle with respect to pH and NPK content (%)

Excreta used	*Beejamrit*				*Jeevamrit*				*Ghan-Jeevamrit*			
	pH	N	P	K	pH	N	P	K	pH	N	P	K
Desi Cow	8.1	0.46	0.115	0.27	4.07	0.20	0.048	0.08	5.24	1.19	0.46	0.87
Cross-bred Cow	7.7	0.49	0.119	0.30	3.95	0.22	0.049	0.09	5.13	1.37	0.47	0.99
Buffalo	7.9	0.48	0.118	0.27	3.90	0.22	0.046	0.07	5.09	1.32	0.43	0.75

Sampling and analysis

After the harvest of maize, surface soil samples (0-0.15 m) were collected from each plot. The samples were then air-dried, crushed in a wooden pestle mortar and passed through 2-mm sieve and then used for analysis of soil pH, available nitrogen (N), phosphorus (P) and potassium (K). The soil pH was estimated as described by Jackson (1973). Soil samples were passed through 0.5 mm sieve and then used for the determination of organic C using rapid titration method (Walkley and Black 1934). Available N was estimated using standard procedure given by Subbiah and Asija (1956). Available P was extracted by sodium bicarbonate having pH 8.5 and further determined by method given by Olsen *et al*. (1954). Available K was extracted with the help of method given by Merwin and Peech (1951) and K content in the filtrate was further determined on the flame photometer.

Statistical analysis

The data generated from laboratory and field studies were subjected to statistical analysis. The technique of analysis of variance (ANOVA) for randomized block design was used for the interpretation of results. Statistical analysis was done as per the standard procedure described by Gomez and Gomez (1984).

Results and Discussion

Before the start of experiment, initial soil pH was recorded 5.56. After the harvest of maize, soil pH ranged from 5.55 under 100% NPK treatment (T_1) to 6.15 under 100% NPK + lime treatment (T_3) (Table 2). Treatment T_2 *i.e.* 100% NPK+ FYM also increased the soil pH (5.59) over 100 per cent NPK alone. Among organic and integrated organic treatments, all treatments recorded ameliorating effect on soil pH. Optimum soil pH under lime amended plots might be due to the precipitation of exchangeable Al and Fe as their respective insoluble hydroxides, consequently decreasing the concentrations of Al and Fe in soil solution and thereby soil acidity. In addition, lime application has positive effects on soil pH due to its flocculating and cementing actions (Chimdi *et al*. 2012). The application of organic manures also had a moderating influence on soil pH which could be attributed to the chelation of Al^{3+} ions in the soil solution by organic compounds released by manure thereby resulting in decrease in their activity (Sharma *et al*. 2018).

The significant differences in soil organic carbon content under different nutrient management practices was observed. The highest soil organic carbon content (8.87 g kg^{-1}) was recorded under organic farming + 25% NPK treatment (T_8), while, the lowest (8.33 g kg^{-1}) was found under T_1 *i.e.*, 100% NPK treatment (Table 2). Higher organic C content under organic farming practices in combination with small quantity of inorganic fertilizers might be due to balanced fertilization (organic + inorganic) that increased the accumulation of root biomass in soil over time, which

Table 2. Effect of different treatments on soil pH, OC (g kg^{-1}) and available NPK content (kg ha^{-1})

Treatments	pH	OC	Available N	Available P	Available K
T_1	5.55	8.33	275.5	36.33	213.4
T_2	5.59	8.62	281.3	38.79	216.8
T_3	6.15	8.54	278.4	38.62	215.2
T_4	5.63	8.84	264.2	32.43	210.1
T_5	5.65	8.82	261.7	31.97	208.5
T_6	5.64	8.80	259.2	31.35	207.2
T_7	5.64	8.73	256.7	31.07	205.4
T_8	5.62	8.87	272.4	35.19	214.9
T_9	5.63	8.84	271.7	34.66	213.2
T_{10}	5.63	8.83	269.9	33.89	211.8
T_{11}	5.62	8.77	267.0	33.48	209.7
LSD (P=0.05)	0.05	0.15	3.2	0.79	2.6
Initial	5.56	8.31	257.4	33.17	211.3

ultimately enhanced the soil organic carbon content (Anjali *et al*. 2022). Moreover, addition of FYM might have created the environment conducive for formation of humic acid which stimulates the soil microbial activity resulting in an increase in the organic carbon content of the soil (Thakur *et al*. 2019). Soil organic carbon was also recorded high in all NFS treatments over control which might be attributed to high microbial activity leading to mineralization of organic matter and hence resulted in build-up of soil organic carbon content (Sharma *et al*. 2016).

Different nutrient sources influence the available N content significantly. The highest available nitrogen content (281.3 kg ha^{-1}) was found under 100% NPK + FYM treatment (T_2) which produced non-significant differences (278.4 kg ha^{-1}) with 100 % NPK + lime treatment (T_3), whereas, NFS-Buffalo treatment (T_7) recorded the lowest available N content (256.7 kg ha^{-1}) in the soil (Table 2).

Among organic treatments, organic farming treatment (T_4) recorded higher available nitrogen content (264.2 kg ha^{-1}) which was found statistically at par with T_5 *i.e*., NFS-*Desi* cow treatment (261.7 kg ha^{-1}). Among integrated organic treatments, organic farming + 25% NPK (T_8) recorded higher available nitrogen content (272.4 kg ha^{-1}) which was found statistically at par with T_9 i.e., NFS-*Desi* cow + 25% NPK (271.7 kg ha^{-1}) and T_{10} i.e., NFS-Crossbred cow + 25% NPK (269.9 kg ha^{-1}) treatments. FYM amended plot recorded higher available N content which might be resulted from the decomposition of FYM and mineralization of nitrogen. Furthermore, FYM promoted greater multiplication of soil microbes which in turn, converts organically bound nitrogen into inorganic form (Kumara *et al*. 2018). Lime amended plots also recorded higher available N over control which could be due to ameliorating effect of lime on soil pH that increased the nitrogen availability. The lower availability of nitrogen in NFS-Buffalo treated plots could be attributed to the lower nutrient composition of formulations prepared from buffalo excreta as compared to *desi* cow and crossbred cow excreta products.

Available P content was significantly influenced by different nutrient management practices. The 100% NPK + FYM (T_2) recorded the highest available phosphorus content (38.79 kg ha^{-1}) which was found statistically at par (38.62 kg ha^{-1}) with 100% NPK + lime treatment (T_3), whereas, T_7 i.e., NFS-Buffalo recorded the lowest (31.07 kg ha^{-1}) available phosphorus content (Table 2). Among organic treatments, organic farming (T_4) recorded higher available phosphorus content (32.43 kg ha^{-1}) which produced non-significant differences (31.97 kg ha^{-1}) with T_5 i.e., NFS-*Desi* cow treatment. Among integrated organic treatments, organic farming + 25% NPK (T_8) recorded higher available phosphorus (35.19 kg ha^{-1}) which was found statistically at par (34.66 kg ha^{-1}) with NFS-*Desi* cow + 25% NPK treatment (T_9).

Higher P availability due to combined application of organic and inorganic manures might be attributed to the fact that FYM helped in the build-up of available phosphorus due to the formation of fulvic acid and other chelating agents which formed soluble complexes with native phosphorus present in the soil (Mohammad and David 2016). Higher P availability in lime amended plots over control could be due to increased pH from 5.5 in non-amended plots to 6.15 in lime amended plots which could have enhanced the availability of P and reduced its fixation and precipitation at lower soil pH.

Highest available K content (216.8 kg ha^{-1}) was found under 100% NPK + FYM treatment (T_2) which was found statistically at par with T_3 i.e., 100% NPK + lime (215.2 kg ha^{-1}). NFS-Buffalo treatment (T_7) recorded the lowest available K content (205.4 kg ha^{-1}) among all the treatments (Table 2). Among organic treatments, organic farming (T_4) recorded higher available potassium content (210.1 kg ha^{-1}) which was found statistically at par (208.5 kg ha^{-1}) with T_5 i.e., NFS-*Desi* cow treatment Among integrated organic treatments, T_8 i.e., organic farming + 25% NPK recorded higher available potassium content (214.9 kg ha^{-1}) which was found statistically at par (213.2 kg ha^{-1}) with T_9 *i.e*., NFS-*Desi* cow + 25% NPK treatment.

Higher availability of potassium with integrated use of mineral fertilizers and organic manures might be due to improved soil physical properties with the application of FYM. Organic manures also supply macro and micronutrients and maintains healthy positive nutrient balance besides being a source of organic matter (Phom *et al*. 2018). The build-up of soil available potassium due to FYM application might be due to addition of potassium through the solubilizing action of certain organic acids produced during FYM decomposition and its greater capacity to hold potassium in the available form (Sharma *et al*. 2021).

Conclusion

From the present investigation, it was concluded that integration of inorganic fertilizers with organic fertilizers, exerted a more beneficial impact on soil chemical properties (NPK) as well as growth of maize over sole application of organic manures or chemical fertilizers. NFS formulations had significant positive impact on soil organic carbon content over conventional farming.

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