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Assessment of soil nutrients status under 49th cropping cycle of maize-wheat in an acid *Alfisol* of Himachal Pradesh

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Abstract

The study to assess status of secondary and micronutrients in soil was carried out after harvest of 49th maize crop (maize-wheat cropping cycle) during *kharif* 2021 at Palampur. The addition of fertilizers and amendments significantly influenced S, Ca and Mg as well as DTPA extractable micro nutrients (Fe, Mn, Cu and Zn). The highest build-up of available S was recorded with 150% of recommended NPK alone at 0-15 and 15-30 cm soil depth. The highest exchangeable Ca and Mg was observed with recommended NPK + lime, and 100% NPK + FYM, respectively. All treatments recorded higher contents of DTPA extractable nutrients as compared to their level at beginning of experiment in 1973 and these contents were numerically higher in surface layer compared to sub-surface. The continuous use of integrated NPK + FYM and lime had led to higher build-up of secondary and micro nutrients levels compared to NPK alone and control plots.

Keywords: *Alfisols*, Himachal Pradesh, maize, soil nutrients, wheat

Fertilizers have historically played a pivotal role in bolstering the food grain production. However, inadequate nutrient supply particularly in cereal-based cropping systems has resulted in significant depletion of soil nutrient reserves (Parmar and Sharma 2002).The reliance on a single-nutrient approach has further diminished fertilizer use efficiency, resulting in multiple nutrient deficiencies in intensive cropping systems (Sharma *et al*. 2016). Recognizing the adverse impacts associated with the continuous sole application of mineral fertilizers, there is a growing interest for the adoption of integrated use of fertilizers, amendments (FYM) and lime in acid soil regions of Himachal Pradesh (Sharma and Sharma 2016). The application of organic amendments plays a crucial role in maintaining soil quality by supplying almost all the essential nutrients (Sharma *et al*. 2018).However,due to their slow nutrient release, they offer long-term benefits by improving soil structure and fertility (Kumar *et al*. 2023). Additionally, the incorporation of lime in acid soils not only mitigates the adverse effects of H^+ and Al^{+3} ions but also enhances the biological health of the soil and boost crop productivity (Bossolani *et al*. 2020). Therefore, strategic approach through integrating soil amendments along with inorganic nutrient sources, will not only maintain crop productivity but also enhance soil fertility, thereby effectively mitigating the risk of nutrient imbalances (Sharma *et al*. 2003; Suri *et al*. 2022).

Maize (*Zea mays* L.) is the third most crucial cereal crop in India, following rice and wheat. Due to its high genetic potential among all cereal crops, it is known as a "miracle crop" or "Queen of cereals". Despite being primarily rain-fed, contributes around 10 percent to the national food basket. In India, it covers an area of 10.04 million hectares with a production of 33.62 million tonnes and productivity of 3.34 metric tonnes per hectare (Anonymous 2022). In Himachal Pradesh, maize serves as a staple diet and is grown over an area of 0.255 million hectares with a production of 0.708 million tons and productivity of 2.77 metric tonnes per hectare (Anonymous 2023). Maize being an exhaustive crop, requires judicious fertilization combining organic and inorganic sources to meet its nutrient demands. To understand the sustained effects of the integration of nutrient sources on soil health, crop productivity, and environmental sustainability over extended periods, it is imperative to conduct long-term fertilizer experiments rather than short-term experiments (Johnston and Poulton 2018).

Keeping these facts in view, thepresent investigation was carried out to assessthe long-term effect of fertilizers and amendments on soil secondary and micronutrient statusof maize under mid-hill conditions in an acid *Alfisol* of Himachal Pradesh.

Materials and Methods

The study was conducted in anongoing long-term fertilizer experiment in maize-wheat system at the Research Farm of the Department of Soil Science, College of Agriculture, CSKHPKV Palampur. Maize was selected as a test crop to assess the status of secondary and micronutrients after its harvest during *kharif* 2021. The experimental site is located at 32°6′N latitude and 76°3′ E longitude, at an altitude of approximately 1290 meters above mean sea level. The study site falls within the mid-hills sub-humid zone of Himachal Pradesh, characterized by mild summers (March to June) and cool winters (December to February). Generally, the average annual rainfall of the area ranges from 2500 to 3000 mm of which more than 75 percent is received during the monsoon period (June to September). During the crop growth period in *kharif* 2021, a total rainfall of 1989 mm was recorded, with precipitation ranging from 6.2 mm to 559 mm across the standard weeks. The relative humidity varied between 51.1% and 97.6%, while the minimum and maximum temperatures observed were 14.9°C and 31.1°C, respectively. The soil of the experimental site is taxonomically classified as *Typic Hapludalfs*, with a silty loam texture. At the start of the experiment (1972-73), the soil exhibited a pH of 5.8, organic carbon content of 7.9 g kg^{-1}, 736 kg ha^{-1} N, 12 kg ha^{-1} P, and 194 kg ha^{-1} K. The exchangeable Ca and Mg were 5.30 and 1.30 c mol (p^+) kg^{-1}, respectively. The contents of DTPA extractable Fe, Mn, Zn and Cu were 26.0, 24.3, 1.9 and 0.4 mg kg^{-1}, respectively.

The experiment consisted of 11 treatments, replicated thrice in a randomized block design (RBD) with 5.0 m×3.0 m plot dimension. The tested treatments were: T_1 -50% NPK, T_2 -100% NPK, T_3 - 150% NPK, T_4 -100% NPK + hand weeding (HW), T_5 - 100% NPK + Zn @ 25 kg ha^{-1} through $ZnSO_4$, T_6 - 100% NP, T_7-100% N, T_8 -100% NPK + FYM @ 10 t ha^{-1} (to maize crop only), T_9 -100% NPK (-S), T_{10} - 100% NPK + lime @ 900 kg ha^{-1}, T_{11}- Control. The 100% NPK corresponds to the state-level recommendations *i.e.*, 120 kg N, 33 kg P, and 33 kg K ha^{-1} for maize. The Kanchan Gold hybrid of maize was sown on 12th June 2021. Urea, single super phosphate, and muriate of potash was used as a source of N, P and K, respectively, except in 100% NPK(-S) where P was applied through di-ammonium phosphate. Half dose of N and full dose of P and K were applied at the time of sowing and the remaining half of N was top dressed in two equal splits at knee high and silking stages. A standard package of practices was followed from sowing to harvesting of the crop. The crop was grown up to physiological maturity and harvested on 6th October 2021.

The surface (0-15 cm) and sub-surface (15-30 cm)soil samples were collected after the harvest of the maize during 2021. Air-dried soil samples were processed and then analyzed to assess nutrient status by employing standard methods. Todetermine available S, soil samples were extracted with 0.15 percent $CaCl_2$ and the soluble sulphate was estimated turbidimetrically on a colorimeter. Exchangeable Ca and Mg was determined using1N NH_4OAc extractant while DTPA-extractable micronutrients as per the methods of Lindsay and Norvell (1978). For statistical analysis of data, Analysis of variance (ANOVA) for RBD on Microsoft Excel were prepared as described by Gomez and Gomez (1984). The difference of treatment means was tested by 'F' test of significance on the bases of null hypothesis at 5% level of significance.

Results and Discussion

Effect of fertilizer and amendments on secondary nutrients

Available Sulphur (S)

The data in Figure 1 revealed that all the fertilizer treatments with or without amendments observed a significant variation in available S after 49 years of maize cultivation. The highest content of available S at the 0-15 cm depth was recorded with the 150% NPK treatment (40.3 kg ha^{-1}) possibly due to the continuous application of higher doses of S through single superphosphate (SSP). The use of FYM and lime with 100% NPK for a longer period also resulted in significantly higher available S compared to the control. However, optimal dose of fertilizer in maize without S application *i.e.*, 100% NPK (-S) led to

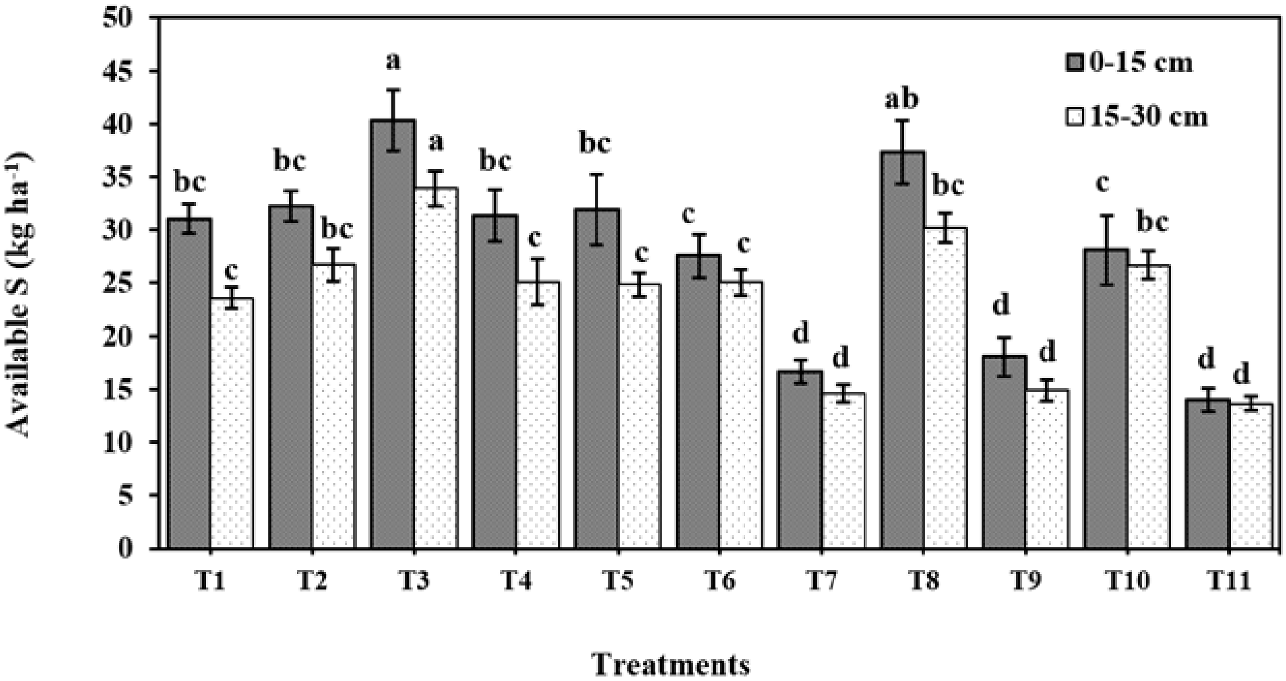

Fig. 1 Effect of continuous application of fertilizers and amendments on soil available S (kg ha^{-1}).Error bars denote ± SE. Bars with similar lowercase letters are not significantly different concerning least significant difference (LSD) values atp=0.05

decline in soil available S. The build-up of available S with the continuous application of FYM alongside inorganic fertilizers (100% NPK + FYM) may be attributed to the mineralization of FYM that converts organic forms of S to readily available inorganic forms over the years. Contrary, the lowest content for available S was recorded in the control treatment (13.9 kg ha^{-1}) at 0-15 cm depth, which was statistically comparable to the values observed in the 100% N (16.60 kg ha^{-1}) and 100% NPK without S (18.0 kg ha^{-1}) treated plots. Similar trend for available S in sub-surface was also observed. Lavanya *et al*. (2019) recorded similar results in a 30-year long-term fertilizer experiment under a finger millet-maize cropping sequence in *Alfisols* of Karnataka and that of the findings of Gourav *et al*. (2024) in acid soil profiles of Himachal Pradesh.

Exchangeable Calcium (Ca)

Continuous fertilization and cropping significantly caused variation in exchangeable Ca among all the treatments and the values varied from 1.51 to 4.97 cmol (p+) kg^{-1}and1.40 to 3.93 c mol (p+) kg^{-1} in 0-15 cm and 15-30 cm depth, respectively being highest under100% NPK + lime application and lowest under control (Figure 2). The high content of exchangeable Ca in lime-amended plots might be due to the release of Ca^{2+} ions from lime through dissociation (Li *et al*. 2018).Also,the increase in exchangeable Ca content with conjoint application of inorganic fertilizers and organic amendment(FYM) might be due to increased root biomass, crop residues and organic matter content which on decomposition releases basic cations. The additional supply of Ca content with the addition of FYM can be attributed to its higher adsorptive capacity which might allow the adsorption of Ca^{2+} ions that otherwise would have leached down. The application of compost along with fertilizers increased exchangeable Ca content in clayey soils of Ethiopia (Ejigu *et al*. 2021)

Exchangeable Magnesium (Mg)

The highest exchangeable Mg in surface soil was recorded under 100 % NPK + FYM treatment (0.81 cmol (p+) kg^{-1}) followed by 100% NPK + lime (0.69 cmol (p+) kg^{-1}). The lowest content was noted in 100% N treatment (0.15 cmol (p+) kg^{-1}) which was statistically similar to unfertilized plots (control). A similar trend was observed for Mg in the sub-surface depth across treatments, though there was a decline in exchangeable Mg content with increasing soil depth (Figure 3).

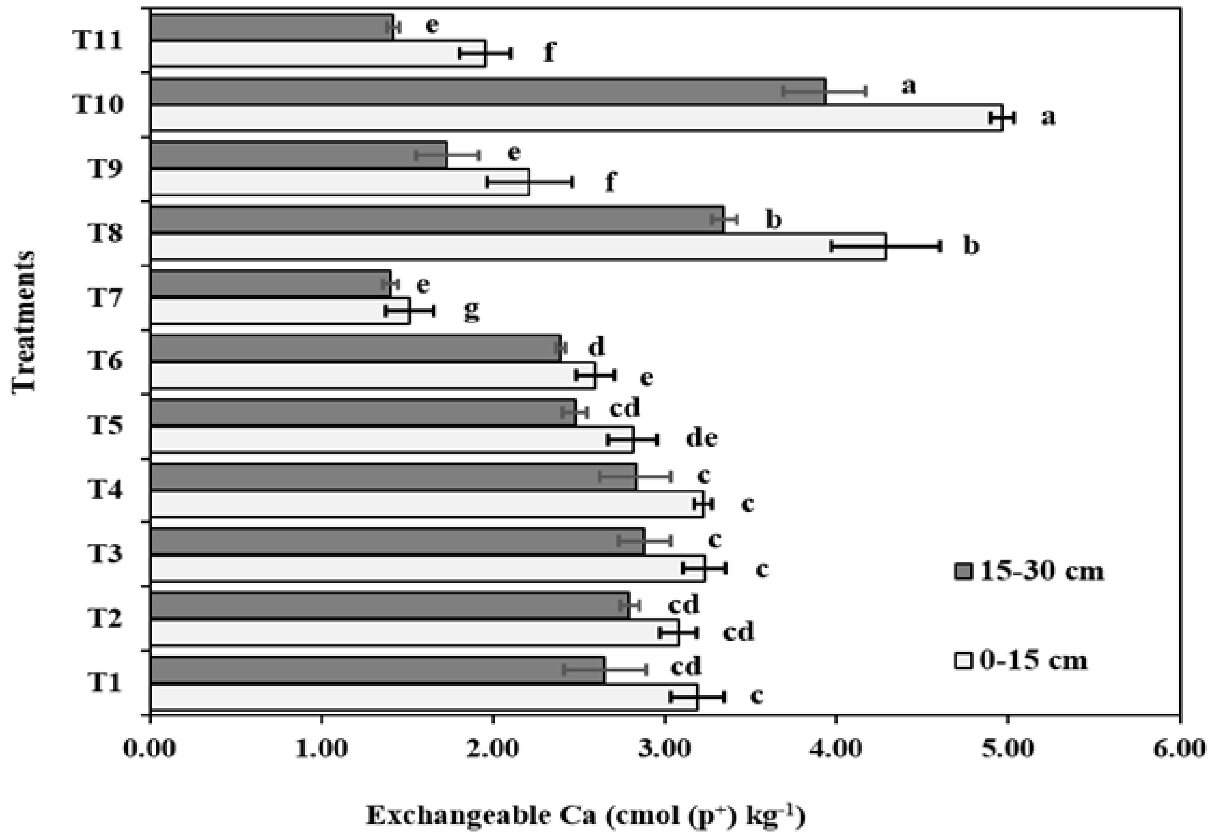

Fig.2 Effect of continuous application of fertilizers and amendments on soil exchangeable Ca (cmol (p^+) kg^{-1}).Error bars denote ± SE. Bars with similar lowercase letters are not significantly different concerning least significant difference (LSD) values at p=0.05

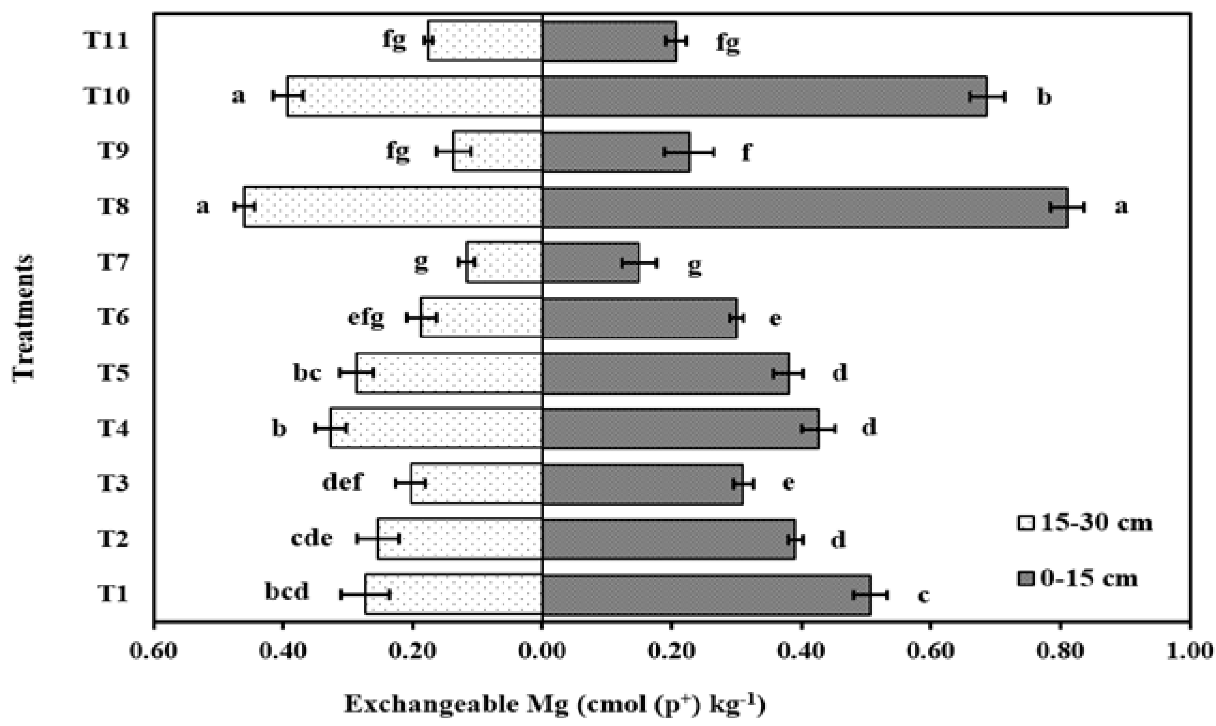

Fig.3 Effect of continuous application of fertilizers and amendments on soil exchangeable Mg (cmol (p^+) kg^{-1}).Error bars denote ± SE. Bars with similar lowercase letters are not significantly different concerning least significant difference (LSD) values at p=0.05

The higher Mg content with application of 100% NPK along with FYM and lime may bedue to the release of nutrients through manure decomposition and improved soil pH. Similareffects of manure and lime application on exchangeable Mg were also observed by Shambhavi *et al*. (2018).

Effect of fertilizer and amendment on micronutrients

DTPA-extractable iron (Fe)

Significant changes were recorded in DTPA extractable Fe content of soil among tested treatments. The results showed that its content in surface depth varied from a lowest value of 18.5 mg kg^{-1}in control to a highest of 38.1 mg kg^{-1} in 100% NPK + FYM (Table 1). The identical trend for DTPA extractable Fe was also observed in sub-surface layer. The higher concentration of DTPA extractable Fe with integrated use of manures and fertilizer might be due to the solubilization of native Fe by organic acids produced from the decomposition of organic sources or production of a chelating agent which prevents their fixation and precipitation, thereby, improving its availability in soil. Among all the treatments, a significant reduction in DTPA extractable Fe content compared to its initial value of 26.0 mg kg^{-1}, was recorded in control (18.5 mg kg^{-1}) followed by application of 100% NPK + lime (23.6 mg kg^{-1}). The reduction in Fe with application of recommended fertilizers along with limemight be attributed to its conversion to insoluble form with the increase in soil pH.The results were in accordance with Chauhan *et al.* (2018) in acid *Alfisols* of Himachal Pradesh.

DTPA extractable manganese (Mn)

The DTPA extractable Mn content in soil varied significantly among all the treatments at 0-15 cm depth and its contentsranged from 17.2 to 40.9 mg kg^{-1} in control and FYM amended plots, respectively (Table 1). The graded doses of NPK @ 50, 100 and 150% of its recommended level, increased the soil Mn over control, however, these treatments were statistically similar to each other. A reduction in DTPA extractable Mn content was observed with increasing soil depth and the treatment-wise effect was similar to surface layer. Application of 100% NPK along with FYM resulted in a maximum DTPA extractable Mn which might be due to there lease of Mn during the mineralization of well decomposed FYM. Besides this, well-decomposed FYM might have been involved in the formation of chelates with organic ligands, which potentially reduced the susceptibility of Mn to adsorption, fixation and precipitation and facilitated its movement from the solid phase to the soil solution phase. These results are in conformity with Puniya *et al*. (2019), who observed similar results after 25th cycle of continuous rice–wheat cropping at Pantnagar.

DTPA extractable copper (Cu)

Significantly higher DTPA extractable Cu content of 2.29 and 1.91mg kg^{-1} was recorded in 0-15 and 15-30 cm depth, respectively with the application of

Table1. Effect of continuous application of fertilizers and amendments on DTPA extractable micronutrientcations in soil (mg kg^{-1})

Treatment	DTPA extractable micronutrient cations (mg kg^{-1})							
	Fe		Mn		Cu		Zn	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1 : 50% NPK	29.3	23.1	24.4	17.8	1.76	1.18	1.35	1.22
T_2 : 100% NPK	31.4	24.4	23.3	17.4	1.73	1.14	1.29	1.16
T_3 : 150% NPK	32.6	26.3	25.9	19.2	1.70	1.11	1.32	1.28
T_4 : 100% NPK + HW	33.1	24.5	24.5	18.6	1.84	1.26	1.38	1.25
T_5 : 100% NPK + Zn	26.8	23.8	21.3	16.8	1.69	1.13	4.20	2.30
T_6 : 100 % NP	27.3	24.0	21.8	17.3	1.62	1.03	1.31	1.18
T_7 : 100% N	31.5	27.4	22.6	16.9	1.45	1.01	1.28	0.94
T_8 : 100% NPK + FYM	38.1	30.6	40.9	29.5	2.29	1.91	2.55	1.88
T_9 : 100% NPK (-S)	24.2	18.5	21.1	16.2	1.64	1.09	1.44	1.14
T_{10} : 100% NPK + Lime	23.6	23.3	25.4	13.8	1.79	1.20	1.40	1.26
T_{11} : Control	18.5	15.9	17.2	10.9	1.35	0.98	1.08	0.91
CD (p=0.05)	3.2	2.5	2.7	1.9	0.08	0.06	0.15	0.13

100% NPK in combination with FYM over 100 % NPK alone (Table 1). The lowest concentration of Cu in 0-15 and 15-30 cm depth to the extent of 1.35 and 0.98 mg kg^{-1}, respectively was however, observed under unfertilized plots (control). The different treatment combinations increased the Cu content over control due to the continuous addition of Cu as a contaminant through fertilizers for over 49 years.

The increased availability of Cu in plots amended with FYM along with fertilizers can also be attributed to the accumulation of organic matter, fostering the proliferation of microorganisms and their activity which aids in the liberation of micro nutrients through mineralization. Additionally, the chelation process may contribute to the rise in Cu availability. Overall, variations in the content of available soil micro nutrients seem to be predominantly influenced by changes in soil pH (Bangre *et al*. 2023).

DTPA extractable zinc (Zn)

DTPA extractable Zn content in the surface soil layer varied from 1.08 and 4.20mg kg^{-1} under control and 100 % NPK + Zn treatment, respectively (Table 1). The maximum improvement in the Zn content (2.55 mg kg^{-1}) was observed with the integrated application of organic manure and inorganic fertilizer *i.e*., 100% NPK + FYM whereas the rest of the treatments showed a decline in DTPA extractable Zn from its initial status (1.9 mg kg^{-1}).The impact of different treatments on Zn content was observed to be significant and exhibited a similar trend as observed in the surface layer. There was a consistent decline in DTPA extractable Zn in the subsurface soils compared to the surface layer.

A significant improvement in the status of DTPA-extractable Zn under NPK+Zn treated plots was understandable due to its continuous supply over a long period. A significant improvement in DTPA-extractable Zn content with the incorporation of FYM alongside 100% NPK may be attributed to the positive impact of FYM in providing an ample amount of Zn, not only meeting the crops requirements but also contributing to its accumulation in the soil. Moreover, the decomposition of organic manures generates various organic chelating agents that form soluble organic complexes with Zn, thereby increasing its availability. The reduced availability of Zn in plots treated with 100% NPK + lime is attributed to elevated pH levels induced by lime, leading to the conversion of available zinc into insoluble forms (Casagrande *et al*. 2004).

Conclusion

The study concluded that the long-term balanced application of fertilizers and organic manure (100% NPK + FYM) significantly enhanced secondary and micro nutrient status of the soil. In contrast, imbalanced fertilization adversely affected the availability of these nutrients. A reduction in soil available S content was observed in treatments where S application was omitted compared to those receiving it. The use of amendments such as FYM or lime, combined with the optimal dose of fertilizers, maintained soil's Ca and Mg levels better than other treatments. Although the content of micro nutrient cations surpassed critical limits across all treatments, a significant improvement was observed with the combined application of NPK and FYM, demonstrating its positive effect in providing ample essential nutrients during the crop growth period.

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References

Anonymous 2022. Cooperation and Farmers Welfare Directorate of Economics and Statistics. Ministry of Agricultural & Farmers Welfare, Department of Agriculture, New Delhi, India.

Anonymous 2023. Economic Survey 2022-2023. Economic and Statistics Department, Himachal Pradesh.

Bangre J, Mandloi S and Vishwakarma M 2023. Sustaining Soil Fertility: Exploring the long-term effects of chemical fertilizers and farmyard manure application. International Journal of Plant & Soil Science **35 (21):** 534-541.

Bossolani JW, Crusciol CAC, Merloti LF, Moretti LG, Costa NR, Tsai SM and Kuramae EE 2020. Long-term lime and gypsum amendment increase nitrogen fixation and decrease nitrification and denitrification gene abundances in the rhizosphere and soil in a tropical no-till intercropping system. Geoderma **375:** 114476.

Casagrande JC, Alleoni LRF, de Camargo OA and Arnone AD 2004. Effects of pH and ionic strength on zinc sorption by a variable charge soil. Communications in Soil Science and Plant Analysis **35:** 2087–2095.

Chauhan N, Sankhyan NK, Sharma RP and Singh J 2018. Effect of long-term application of fertilizers and amendments on wheat productivity and DTPA extractable micronutrients in an acid Alfisol. Himachal Journal of Agricultural Research **44 (1&2):** 36-42.

Ejigu W, Selassie YG, Elias E and Damte M 2021. Integrated fertilizer application improves soil properties and maize (*Zea mays* L.) yield on Nitisols in North-Western Ethiopia. Heliyon e06074.https://doi.org/10.1016/j.heliyon.2021.e06074

Gomez KA and Gomez AA 1984. Statistical procedures for agricultural research. New York, Wiley Interscience.

Gourav, Sankhyan NK, Kumar P and Sharma GD 2024. Sulphur distribution in acidic soil profiles of Himachal Pradesh. Himachal Journal of Agricultural Research 50 **(1):** 45-55.

Johnston AE and Poulton PR 2018. The importance of long-term experiments in agriculture: their management to ensure continued crop production and soil fertility; the Rothamsted experience. European Journal of Soil Science **9:** 113 – 125.

Kumar D, Purakayastha TJ, Das R, Yadav RK, Shivay YS, Jha PK, Singh S, Aditi K and Prasad PVV 2023. Long-term effects of organic amendments on carbon stability in clay–organic complex and its role in soil aggregation. Agronomy **13 (1):** 39.

Lavanya KR, Kadalli GG, Jayanthi T, Patil S, Jayanthi T, Naveen DV and Channabasavegowda R 2019. Sulphur fractionation studies in soils of long-term fertilizer experiment under finger millet – maize cropping sequence. International Journal of Current Microbiology and Applied Sciences **8 (9):** 1334-1345.

Li Y, Cui S, Chang SX and Zhang Q 2018. Liming effects on soil pH and crop yield depend on lime material type, application method and rate, and crop species: a global meta-analysis. Journal of Soils and Sediments doi:10.1007/s11368-018-2120-2

Lindsay WL and Norvell WA 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Science Society of American Journal **42:** 421-428.

Parmar DK and Sharma V 2002. Studies on long-term application of fertilizers and manures on yield of maize-wheat rotation and soil properties under rainfed conditions in Western-Himalayas. Journal of the Indian Society of Soil Science **50 (3):** 311-312.

Puniya R, Pandey PC, Bisht PS, Singh DK and Singh AP 2019. Effect of long-term nutrient management practices on soil micronutrient concentrations and uptake under a rice–wheat cropping system. The Journal of Agricultural Science 1–9 doi:10.1017/s0021859619000509

Shambhavi S, Kumar R, Sharma SP, Sharma SK and Sharma RP 2018. Effect of 36 years of continuous cropping and fertilization on productivity, micro and secondary nutrient status and uptake by maize-wheat cropping system in western Himalayas. International Journal of Bio-resource and Stress Management **9 (2):** 197-202.

Sharma A and Sharma RP 2016. Effect of boron and lime on productivity of garden pea under acidic soils in northwestern Himalayas. Communications in Soil Science and Plant Analysis **47 (3):** 291-297.

Sharma A, Sharma RP and Singh S 2016. Influence of Rhizobium inoculation, split nitrogen applications and plant geometry on productivity of garden pea (*Pisum sativum* L.) in an acid alfisol. Legume Research 39 (6): 955-961.

Sharma A, Sharma RP, Katoch V and Sharma GD 2018. Influence of vermicompost and split applied nitrogen on growth, yield, nutrient uptake and soil fertility in pole type French bean (*Phaseolus vulgaris* L.) in an acid alfisol. Legume Research **41 (1):** 126-131.

Sharma A, Sharma RP, Sood S and Sharma JJ 2003. Influence of integrated use of nitrogen, phosphorus, potassium and farmyard manure on yield - attributing traits and marketable yield of carrot (*Daucus carota* L.) under high hill dry temperate conditions of NW Himalayas. Indian Journal of Agricultural Sciences 7**3** **(9):** 500-502.

Suri D, Sharma RP, Sankhyan NK and Manuja S 2022. Effect of five decades of application of inorganic fertilizers, farmyard manure and lime on maize and wheat productivity in an acid Alfisol. Himachal Journal of Agricultural Research **48 (2):** 285-290.