Himachal Journal of Agricultural Research 50(2): 236-243 (2024)

Impact of fertilizers and amendments on soil chemical properties and status of primary macro nutrients at different depths after maize harvest in acid *Alfisol*

Isha Thakur[1*], Raj Paul Sharma[1], Narender Kumar Sankhyan[1], Rushali Katoch[1], and Rameshwar Kumar[2]
Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya,
Palampur-176062, India.

*Corresponding Author: e-mail: ishathakur775@gmail.com
Manuscript received: 12.6.2024; Accepted: 9.7.2024

Abstract

A field experiment was conducted in an on-going long-term fertilizer experiment (initiated during 1972) at Palampur using randomized block design comprising eleven treatments, replicated thrice to study the effects of various fertilizer treatments, along with application of farmyard manure and lime on soil chemical properties. The long-term application of optimal doses of inorganic fertilizers in conjunction with FYM or lime in acid *Alfisol* improved key soil chemical properties significantly. A notable influence of FYM or lime when applied in integration with chemical fertilizers was observed on soil pH, organic carbon content, CEC and status of available NPK in surface and sub-surface layers. Conversely, imbalanced nutrient use resulted in soil acidification, reduced OC, CEC and nutrients depletion, thereby, deteriorating soil health. Therefore, balanced nutrition and use of amendments like FYM and lime in acid soils is essential to ensure sustainable soil health and crop productivity in long-term agricultural systems.

Keywords: *Alfisol,* fertilizers, FYM, lime, maize, nutrients

Maize (*Zea mays* L.) is one of the most important cereal crops worldwide after wheat and rice. As a nutrient-intensive crop, maize demands a substantial availability of essential nutrients. Nitrogen contributes to the protein synthesis and vegetative growth of the plant; phosphorus promotes root development and energy transfer; potassium aids in water regulation and enzyme activation (Hasanuzzaman *et al*. 2018). Achieving high maize yields necessitates a balanced and adequate supply of these nutrients, given that declining soil fertility is a significant constraint to maize production (Sharma and Arora 2010).

Fertilizers have been pivotal in transforming Indian agriculture from subsistence farming to surplus production. However, continuous cultivation over centuries, the adoption of modern agricultural practices and the inefficient and imbalanced use of fertilizers have depleted soils of their finite nutrient reserves (Bhatt *et al*. 2019). The insufficient fertilization negatively impacts the soil health resulting in reduced soil fertility and lower crop yields, whereas, the excessive use of chemical fertilizers causes soil and water pollution due to nutrient losses and accumulation in the environment. Also, the benefits of organic manures in enhancing plant nutrition and improving soil properties are well-documented but they alone cannot meet the nutrient demands of intensive agriculture (Xin *et al*. 2016; Sharma *et al*. 2018). The balanced fertilization through integrating organic and inorganic fertilizers has proven to improve maize yields and soil fertility, thus ensuring that soil remains a productive resource while minimizing negative effects on environment (Suri *et al*. 2022).Besides, declined soil fertility, soil acidity has been identified as a significant limitation to crop production on a global scale (Bharti *et al*. 2021). The persistent application of ammonium- based fertilizers also contributes toward soil acidity with pronounced effect in acidic soil environments. Lime is applied to ameliorate acid soils due to its high neutralizing value (Hume *et al.* 2023). Studies also highlight that incorporation of lime along with judicious use of various nutrient sources is advocated for ameliorating

[1]Department of Soil Science; [2]Department of Organic Agriculture and Natural Farming

acidity-induced soil health constraints and increasing the availability of essential nutrients to the plant (Sharma and Sharma 2016; Thakur *et al*. 2022).

In addition to soil nutrient levels, the properties of soil pH, cation exchange capacity (CEC) and organic carbon (OC) also determines soil health and productivity. Understanding the impact of fertilizers and amendments on soil organic carbon and pH could help in managing soil conditions to optimize plant growth as increase in soil organic matter improves soil physical and microbial properties, whereas, pH influences the availability of nutrients in the soil (Page *et al*. 2020). The CEC serves as a crucial indicator of soil quality and reflects the ability of soil to retain and exchange essential nutrients (Mishra *et al*. 2022). Considering the above facts, this study was conducted with the aim to assess the impact of fertilizers and amendments on soil chemical properties and available N, P and K status in acid Alfisols of Himachal Pradesh.

Materials and Methods

Experimental site

A long-term fertilizer experiment was established in 1972 at research farm of Department of Soil Science, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur, India. The site belongs to mid hills sub-humid zone of Himachal Pradesh and is located at 32°6´N latitude and 76°3´ E longitude at an altitude of 1290 m above mean sea level. Generally, the area receives an average rainfall of 2600 mm, annually. The soil at experimental fields is silt loam in texture, belongs to the order *Alfisol* and is classified as *Typic Hapludalfs*. At the initiation of experiment (1972), the soil samples were found to be acidic with pH value of 5.8, high in available N (736 kg ha^{-1}) and medium in organic carbon (7.9 g kg^{-1}), available P (12.0 kg ha^{-1}) and available K (194.2 kg ha^{-1}).

Experiment details

The experiment was carried out in a randomized complete block design comprising one control and ten treatments of fertilizers alone or in combination with amendments such as lime and FYM. The treatments were replicated thrice in the maize-wheat cropping system. The treatments were randomly allocated in each block and each treatment plot was 5 m long and 3 m wide. The fertilizer 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+Zinc (Zn); T_6 = 100% NP; T_7 = 100% N; T_8 = 100% NPK+FYM @ 10t ha^{-1}; T_9 = 100% NPK (-S); T_{10} = 100% NPK+lime @900kg ha^{-1} and T_{11} = control, comprising no fertilizer application.

The original treatment structure was slightly modified from *kharif* 2011 due to the marked build-up of available phosphorous in soil. The optimal and super optimal dose of P was reduced by 50% and in case of T_1 *i.e*. 50% NPK, the addition of FYM @ 5 t ha^{-1} on dry weight basis to maize crop only was also included. The chemical weed control measures were taken in all treatments except T_4 (100% NPK + Hand Weeding). Nitrogen, phosphorus and potassium were supplied through urea, single super phosphate and muriate of potash respectively, except T_9 *i.e*. 100% NPK (-S) where source of phosphorous was diammonium phosphate.

Soil analysis

The soil samples were collected from two depths of 0–0.15m and 0.15–0.30m from each plot with core sampler following the maize harvest in *kharif* 2021. The samples were processed and analyzed for chemical properties and status of primary macro nutrients. Standard analytical procedures were employed to determine soil pH, organic carbon content, cation exchange capacity (CEC) and the available nitrogen, phosphorus and potassium.

Statistical Analysis

The data recorded was analysed on the basis of standard procedures described by Gomez and Gomez (1984). The analysis of variance (ANOVA) for the randomized complete block design was performed using an F-test to draw inferences. The least significant difference (LSD) test at the 0.05 significance level was used to compare treatment means for various parameters. For the statistical analysis of the data, Microsoft Excel (Microsoft 365) software was used.

Results and Discussion

Soil pH

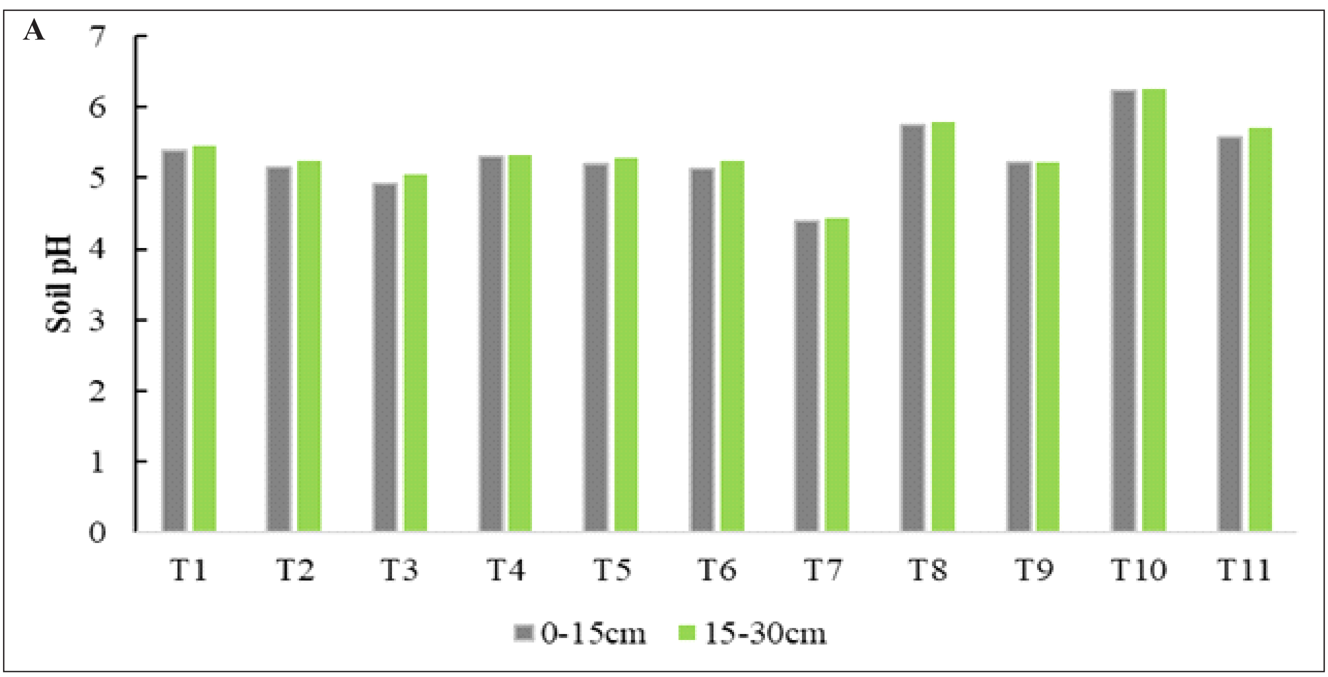
The soil pH exhibited a decreasing trend from the initial value of 5.8 across all treatments, except for T_{10} (100% NPK + lime) which resulted in highest pH value *i.e*. 6.24 in surface and 6.26 in subsurface layer (Figure 1a). The application of lime in combination with NPK improved the soil pH to neutrality as lime dissociates into Ca^{2+} and OH^- ions and hydroxyl ions react with hydrogen and Al^{3+} ions, forming Al³z hydroxide and water, thereby increasing the soil pH in the soil solution. The lowest pH value was recorded in the treatment involving the continuous application of urea (T_7) and the pH declined to 4.39 and 4.43 at surface and sub-surface depths, respectively. Compared to sub-optimal, optimal and super-optimal fertilizer treatments, the regular addition of FYM along with NPK (T_8) resulted in higher pH values. The application of ammonium fertilizers results in soil acidification due to release of H^+ ions during hydrolysis of urea and ammonium nitrification process (Dal Molin *et al.* 2020). Furthermore, the incorporation of organic matter helps to stabilize the pH and resist any major change in soil pH (Sharma *et al.* 2014). Overall, the pH increased with increasing soil depth.

Soil organic carbon

A buildup in soil organic carbon (SOC) content was recorded with balanced fertilization, exceeding the initial content of 7.9 g kg^{-1} (Figure 1b). In contrast, the use of chemical fertilizers in imbalanced forms (100% N, 100% NP) or no fertilization resulted in a significant decline in SOC. The integrated use of NPK fertilizers and farmyard manure (T_8) recorded the highest SOC content (13.97 g kg^{-1}) followed by the treatments of 100% NPK + hand weeding (T_4) and 100% NPK + lime (T_{10}). FYM serves as a substantial source of carbon, enhancing belowground biomass production. The increased return of plant residues to the soil, driven by enhanced crop growth due to addition of FYM and lime along with 100% NPK also increased SOC. Conversely, low root biomass resulting from imbalanced fertilization contributed to reduced SOC content. A similar trend was observed in the subsurface soil depth, with a decrease in content compared to the upper depth.

Cation exchange capacity

The application of manure or lime in conjunction with 100% NPK significantly enhanced the cation exchange capacity (CEC) at both surface and subsurface soil layers, as shown in Figure 1 (c). Specifically, the treatments T_8 and T_{10} exhibited increase in CEC of 19.3% and 18%, respectively over the 100% NPK treatment (T_2) at 0-0.15 m soil depth. The CEC values ranged from 6.22 cmol (p^+) kg^{-1} *i.e.* lowest under 100% N fertilization (T_7) to12.39 cmol (p^+) kg^{-1} (highest) in treatment T_8. Treatments with imbalanced fertilizers and control showed a decrease in CEC compared to the initial value of 12.1 cmol (p^+) kg^{-1}. The increase in CEC observed in FYM-fertilized plots could be attributed to the colloidal nature of organic matter (Vishwanath *et al.* 2020). In lime-amended plots the CEC increased due to increased soil pH and dissociated calcium ions. Regardless of the treatments, CEC decreased with soil depth due to the



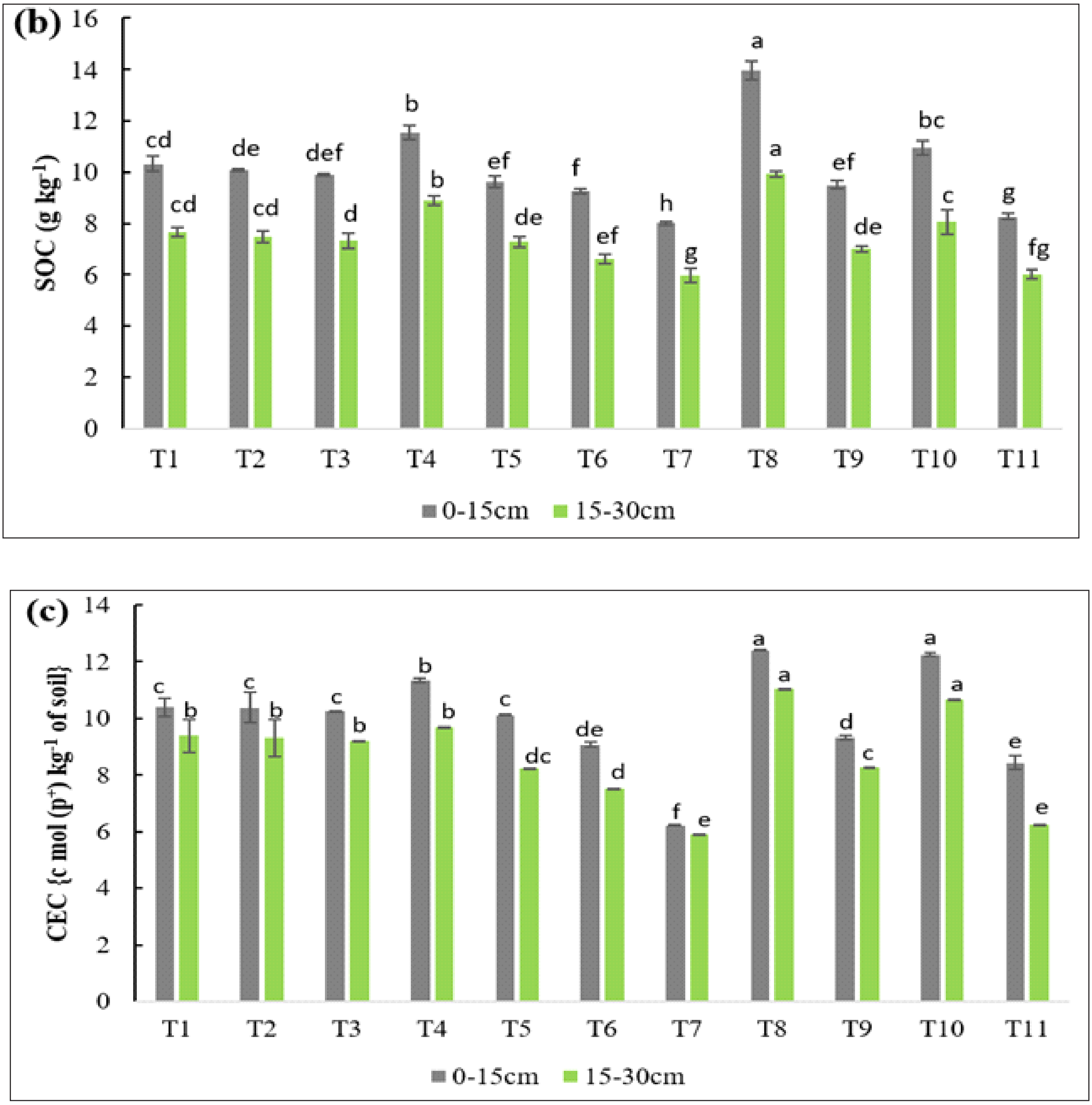


Fig. 1 Effect of fertilizers and amendments on (a) Soil pH, (b) SOC and (c) CEC. Error bars denote ± SE. Bars with similar lowercase letters are not significantly different concerning least significant difference (LSD) values at p=0.05

lower organic carbon content in the subsurface layer. The reduction in CEC under imbalanced and no fertilizer treatments, especially in the 100% N treated plots, could be ascribed to the acidifying effect of fertilizers, which lowered the pH and consequently reduced the pH-dependent negative charges (Gourav *et al.* 2019).

Available Nitrogen

The results illustrated in Figure 2 (d) indicated that the continuous application of 100% NPK combined with FYM (T_8) resulted in the highest value of available nitrogen (390 kg ha^{-1}), followed by the super-optimal dose of fertilizers at 150% NPK (T_3). The higher nitrogen content under T_8 could be attributed to the additional supply of nitrogen through FYM over the years and the addition of organic components. The increase in nitrogen content with increase in fertilizer doses indicates the impact of fertilizer application on enriching nitrogen pools (Sharma *et al*. 2003; Mukhi *et al*. 2022). In contrast, a significantly lower value of 272 kg ha^{-1} was recorded in the control treatment (T_{11}). The available nitrogen status in the control plot clearly revealed that cultivation without any addition of fertilizers or manure drastically reduced soil nitrogen availability and this might be due to nitrogen mining caused by continuous cropping without fertilization (Shambhavi *et al*. 2017). The values of available nitrogen decreased with increasing soil depth, although the treatment-wise trend remained consistent throughout the soil profile.

Available Phosphorus

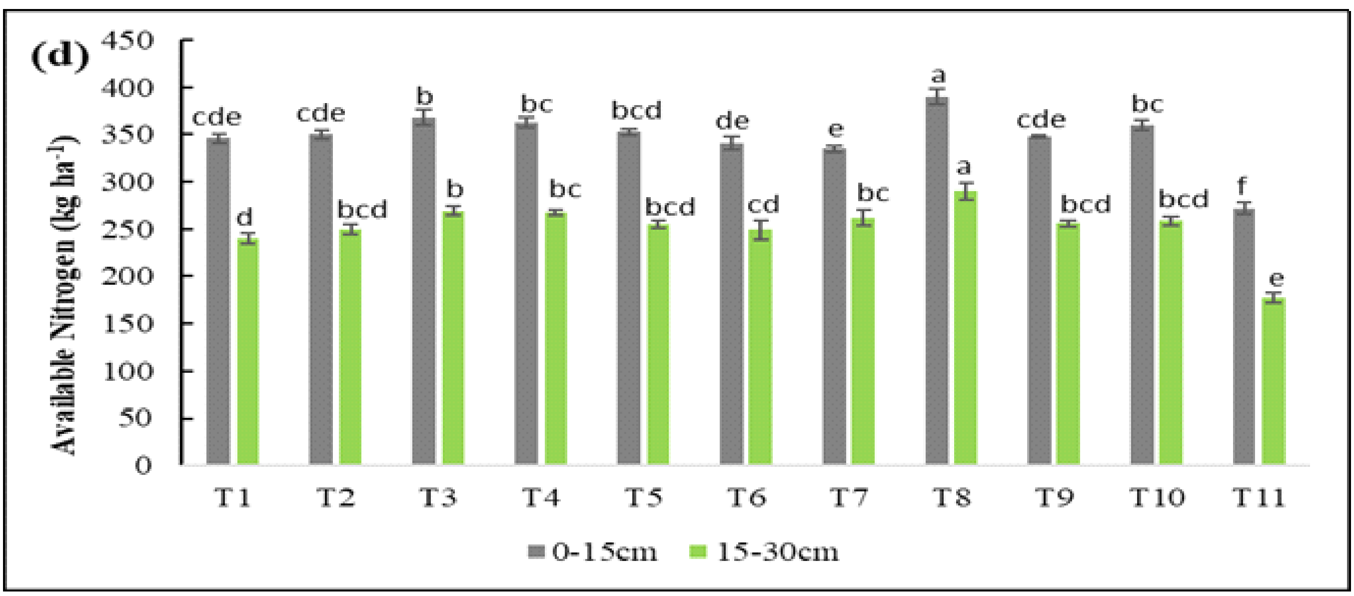
A significant increase in available phosphorus content (164.8 kg ha^{-1}) was recorded with the application of 150% NPK (T_3) across both soil depths, compared to other treatments (Figure 2 e). The application of 100% NPK (T_2), whether alone or when combined with FYM (T_8) or lime (T_{10}), also resulted in higher available phosphorus content than the control (T_{11}) and 100% N (T_7) treatments. The substantial buildup of available phosphorus in plots receiving fertilizer P could be attributed to the increase in the available pool of soil phosphorus. The improvement in soil available phosphorus with the addition of FYM was due to addition of organic phosphorus through FYM and reduction in P-fixation by organic anions formed during FYM decomposition. Likewise, a decrease in exchangeable acidity due to addition of lime resulted in higher available P (Verma *et al*. 2012). In contrast, the low pH in plots with 100% N alone led to high phosphorus-fixing capacity and the absence of phosphorus application resulted in very low available phosphorus content in T_7 and T_{11} both.

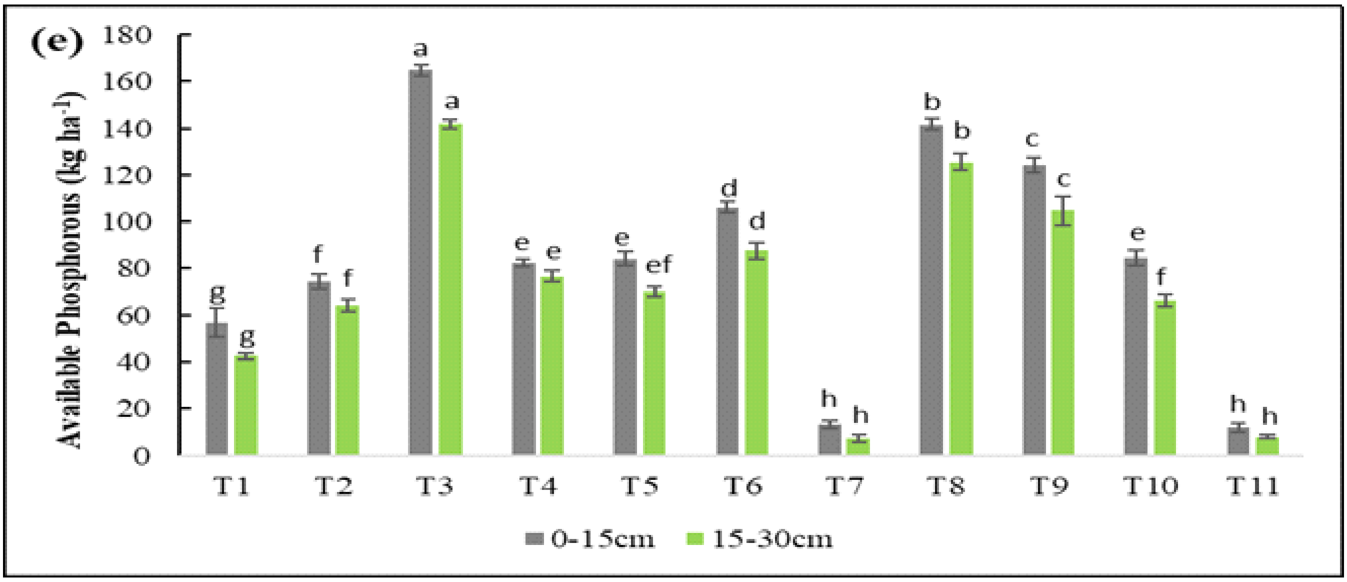
Available Potassium

The available potassium content ranged from 115 kg ha^{-1} to 213 kg ha^{-1} in the surface layer and from 92 kg ha^{-1} to 173 kg ha^{-1} in the subsurface layer, with the lowestvalue in T_{11} and the highest in T_8 (Figure 2 f). The addition of FYM along with100% NPK reduced potassium fixation and its decomposition resulted in continuous release of potassium (Urkurkar *et al*. 2010). The omission of potassium in T_6 (100% NP) and T_7 resulted in significantly lower values compared to balanced fertilizer treatments due to nutrient imbalance in the soil. Also, the depletion of native potassium pools in T_2 (100% NPK) may be attributed to its increased removal by crops compared to the addition in soil.

Conclusion

The continuous application of optimum doses of fertilizers with organic manure in acid *Alfisol* positively influenced the soil organic carbon content, cation exchange capacity and primary macro nutrients' contents. The periodical addition of lime along with





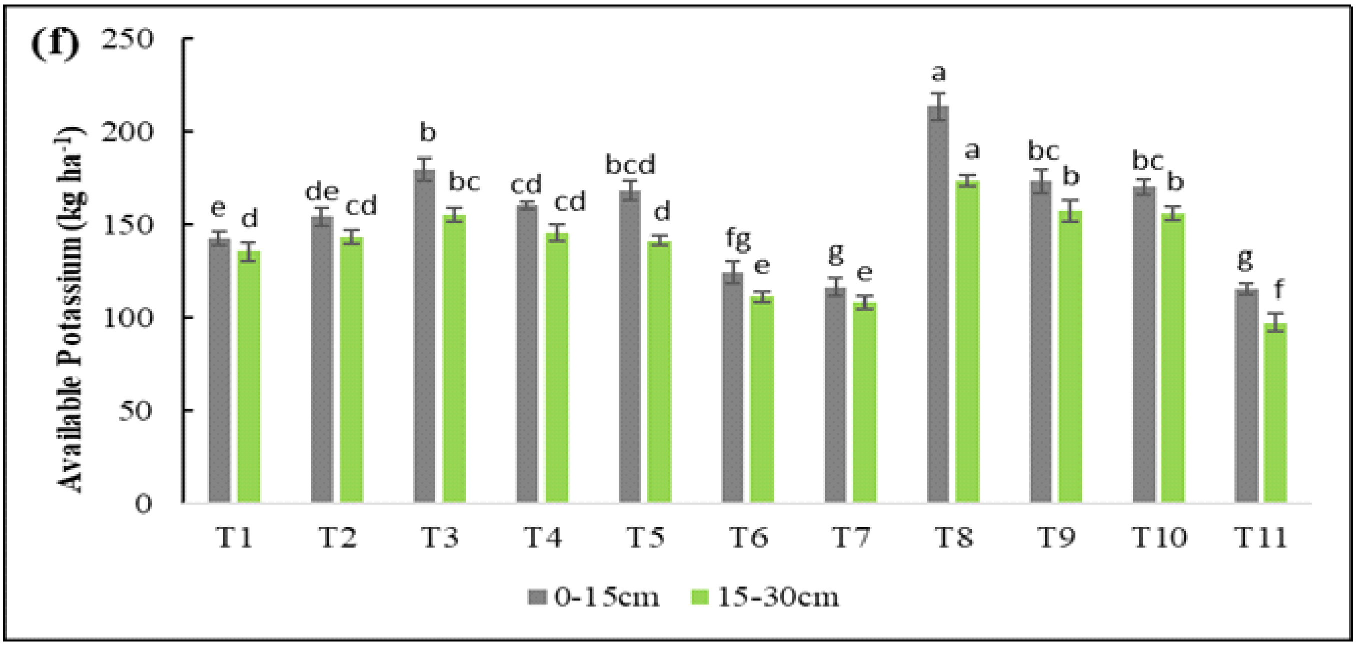


Fig.2 Effect of fertilizers and amendments on (d) Available nitrogen, (e) Available phosphorus and (f) Available potassium. Error bars denote ± SE. Bars with similar lowercase letters are not significantly different concerning least significant difference (LSD) values at p=0.05

balanced fertilization raised the soil pH to neutrality. The study demonstrated that an integrated approach of combining balanced fertilization with FYM or lime is crucial for sustaining the chemical components of the soil health, whereas, prolonged application of only urea increased soil acidity, thereby, degraded the soil health.

Acknowledgments: The authors express sincere gratitude to ICAR, New Delhi for their financial support and technical guidance during the research conducted at CSKHPKV, Palampur, Himachal Pradesh, as part of the "All India Coordinated Research Project on Long Term Fertilizer Experiment".

Conflict of interest: Authors declare no competing interest.

References

Bharti A, Sharma RP, Sankhyan NK and Kumar R 2021. Productivity and NPK uptake by maize as influenced by conjunctive use of FYM, lime and fertilizers in an acid Alfisol. Journal of Soil and Water Conservation **20 (1):** 100-106.

Bhatt MK, Labanya R and Joshi HC 2019. Influence of long-term chemical fertilizers and organic manures on soil fertility-A review. Universal Journal of Agricultural Research **7(5):** 177-188.

Dal Molin SJ, Ernani PR and Gerber JM 2020. Soil acidification and nitrogen release following application of nitrogen fertilizers. Communications in Soil Science and Plant Analysis 1–8. doi:10.1080/00103624.2020.1845347

Gomez KA and Gomez AA 1984. Statistical procedure for agricultural research. New York, NY: Wiley.

Gourav, Sankhyan NK, Sharma RP and Sharma GD 2019. Long term effect of fertilizers and amendments on the properties of an acid Alfisol and uptake of primary nutrients and sulfur in maize- wheat rotation in North Western Himalayas. Journal of Plant Nutrition **42 (15):** 1770–1788.

Hasanuzzaman M, Bhuyan MB, Nahar K, Hossain MS, Mahmud JA, Hossen MS, Masud AA, Moumita and Fujita M 2018. Potassium: a vital regulator of plant responses and tolerance to abiotic stresses. Agronomy **8 (3):** 31.

Hume R, Marschner P, Mason S, Schilling RK, Hughes B and Mosley LM 2023. Measurement of lime movement and dissolution in acidic soils using mid-infrared spectroscopy. Soil and Tillage Research **233:** 105807.

Mishra G, Sulieman MM, Kaya F, Francaviglia R, Keshavarzi A, Bakhshandeh E, Loum M, Jangir A, Ahmed I, Elmobarak A, Basher A and Rawat D 2022. Machine learning for cation exchange capacity prediction in different land uses. Catena 216.

Mukhi SK, Rout KK, Samant PK, Patra RK, Dash A, Parida AK, Shivhare S and Pradhan S 2022. Sub-soil nitrogen content as influenced by long-term manuring and its relationship with nitrogen availability and productivity of a rice-rice cropping system in eastern India. International Journal of Environment and Climate Change **12 (11):** 1304-1317.

Page KL, Dang YP and Dalal RC 2020. The ability of conservation agriculture to conserve soil organic carbon and the subsequent impact on soil physical, chemical, and biological properties and yield. Frontiers in Sustainable Food Systems **4:** 31.

Shambhavi S, Kumar R, Sharma SP, Verma G, Sharma RP and Sharma SK 2017. Long-term effect of inorganic fertilizers and amendments on productivity and root dynamics under maize-wheat intensive cropping in an acid Alfisol. Journal of Applied and Natural Science **9(4):** 2004-2012.

Sharma A and Arora S 2010. Soil quality indices and relative production efficiency for maize and wheat crops in different agro-climates of North-West India. Soil Science **175 (1):** 44-49.

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

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 **73 (9):** 500-502.

Sharma U, Paliyal SS, Sharma SP and Sharma GD 2014. Effects of continuous use of chemical fertilizers and manure on soil fertility and productivity of maize– wheat under rainfed conditions of the western Himalayas. Communications in Soil Science and Plant Analysis **45 (20):** 2647–2659.

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

Thakur A, Sharma RP, Sankhyan NK and Sepehya S 2022. Effect of 46 years' application of fertilizers, FYM and lime on physical, chemical and biological properties of soil under maize– wheat system in an acid Alfisol of northwest Himalayas. Soil Use and Management 1–11.

Urkurkar JS, Tiwari A, Chitale S and Bajpai RK 2010. Influence of long-term use of inorganic and organic manures on soil fertility and sustainable productivity of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) in Inceptisols. Indian Journal of Agricultural Sciences **80 (3):**208–12.

Verma G, Mathur AK and Verma A 2012. Effect of continuous use of organics and in-organics on nutrient status of soil and yield under maize-wheat intensive cropping system in an Inceptisol. Journal of Soils and Crops 22: 280–6.

Vishwanath, Kumar S, Purakayastha TJ, Datta SP, KG R, Mahapatra P, Sinha SK and Yadav SP 2020. Impact of forty-seven years of long-term fertilization and liming on soil health, yield of soybean and wheat in an acidic Alfisol. Archives of Agronomy and Soil Science **68 (4):** 531-46.

Xin X, Zhang J, Zhu A and Zhang C 2016. Effects of long-term (23 years) mineral fertilizer and compost application on physical properties of fluvo- aquic soil in the North China plain. Soil and Tillage Research **56:** 166–172. https://doi.org/10.1016/j. still. 2015.10.012