Review Article

Assessing the Various Soil Properties Affecting Soil Fertility in North Western Himalayas of India

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Abstract
Soil fertility refers to the inherent capacity of a soil to supply essential nutrients to plant in adequate amount, in correct proportion and at the right time for their optimum growth. Soil fertility of an area is controlled by pedogenic (climate, parent material, topography, microorganisms and time) as well as artificial (land use and management practices) factors. The interactions between soil properties like soil texture, soil reaction, organic carbon, cation exchange capacity with available nutrient concentration are used as a clue to indicate soil fertility status. Therefore, the present study was undertaken to study the factors affecting soil fertility of Saproon valley of Himachal Pradesh. The pH ranged from 6.16 to 7.94 and EC of the surface and sub-surface soils ranged from 0.09 to 1.02 and 0.11 to 0.49 dS m^{-1}, respectively. The organic carbon content varied from 5.70 to 32.60 and 0.30 to 20.50 g kg^{-1} in the surface and sub-surface soils, respectively. DTPA extractable Fe and Mn content of the soils ranged from 7.03 to 24.16 mg kg^{-1} and 0.25 to 29.04 mg kg^{-1}, respectively. The results showed that average DTPA extractable Cu content of surface and sub-surface soils was 5.33 and 4.18 mg kg^{-1}, respectively and DTPA extractable Zn content of surface soils ranged from 0.01 to 4.23 mg kg^{-1}, with a mean value of 2.12 mg kg^{-1}. Addition of zinc along with FYM and N, P and K fertilizers will help in achieving higher and sustainable production.

Keywords: Soil fertility, pH, EC, Saproon Valley, Himachal Pradesh and sustainability

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Introduction

Sustainable agriculture aims at meeting the needs of the present without endangering the resource base for the future generations. According to FAO (1989) [1], it is necessary to manage agricultural resources judiously for changing human needs while maintaining or enhancing the quality of environment and conserving the natural resources. In India, sustainability of agro-ecosystems has also become a major concern in order to feed the burgeoning population and maintaining the environmental quality. More than 57 per cent of total geographical area of India is suffering from different kinds of soil degradation problems [2]. Further, India needs 350 million tons (mt) of food grains to feed the projected population of 1.48 billion by 2030 [3].

Sustainable agricultural productivity is affected by a number of factors *viz.* climate, soil, agricultural input availability, size of land holding, technical know-how, irrigation facilities, population pressure on land, land tenure system etc. Amongst all, soil is the critical component, functioning not only for the production of food, fodder and fiber but also for the maintenance of local, regional and global environmental quality [4]. The soil characteristics and properties always define sustainable land use practices to harness the potential of different agro- ecoregions for commercial agriculture. Warren and Agnew (1998) [5] described that of all the threats to sustainability, the threat due to soil fertility depletion is most serious. As long as agriculture remains a soil based industry major increase in productivity is unlikely to be attained without ensuring an adequate and balanced supply of nutrients. The estimates by Biswas *et al.* (1996) [6] showed that there is a depletion of about 25 MT of nutrients through various crops in India. The addition of nutrients through various fertilizers and manures is hardly returning 14 MT of nutrients, thus leaving a negative balance of 11 MT.

Soil fertility refers to the inherent capacity of a soil to supply essential nutrients to plant in adequate amount, in correct proportion and at the right time for their optimum growth. Soil fertility of an area is controlled by pedogenic (climate, parent material, topography, microorganisms and time) as well as artificial (land use and management practices) factors. The interactions between soil properties like soil texture, soil reaction, organic carbon, cation exchange capacity with available nutrient concentration are used as a clue to indicate soil fertility status [7]. A proper evaluation of fertility of the soil before planting a crop helps in adopting appropriate measures to make up for the shortcomings and ensuring a good crop production [8].

For soil fertility to be sustained, extracted soil nutrients must equal replenished soil nutrients, but in large areas of country, more soil nutrients are extracted than replenished, thus, soil fertility and its management play an important role in farm productivity. Farmers, their advisors, and any growers need to know the soil properties which have an influence on soil fertility, some of which include soil texture, structure, organic matter, anion and cation retention, cation exchange capacity, base saturation, bulk density and pH. This information will assist them in managing their soils more efficiently in terms of understanding how the soil will behave under various conditions.

This valuable knowledge on the factors affecting soil fertility are essential for an efficient nd sustainable management of soil. Therefore, the present study entitled "Soil Micronutrient Status Assessment in North Western Himalayas of India" has been reviewed under the following heads:

Properties affecting soil fertility, soil depth, soil pH, soil EC and soil organic carbon

Properties affecting soil fertility

Soil fertility has been considered, in the past as a physico-chemical phenomenon taking place in the soil system. Soil characteristics and properties are the outcome of the interplay of pedogenic processes prevailing in an area and are very much needed for the interpretation of the soil fertility status. The interrelationships of soil nutrients with these properties decide the supplying power of respective nutrients by the soil. A review on interrelationships between soil properties and soil fertility is necessary for better production of nutrient supplying power of soils.

Soil depth

Plants derive their nutrition from surface and sub-surface soils in different amounts and proportions. Shallow rooted plants such as tomato draw more nutrients from surface soils as compared to sub-surface soils. Soil nutrients follow a definite trend of distribution with depth in a given landscape. Horizons are formed due to a particular set of pedogenic processes. Basic soil forming processes *viz*., gains, losses, translocation and transformation of soil materials within a soil will ultimately affect total and available nutrient contents.

Zoon (1950) [9] made comparisons between a natural oak-hornbeam brown soil and a similar former forest soil that had been under cultivation for over 100 years. He found, in general, more even distribution of nutrient elements in the cultivated profile. Higher degree of leaching bases and a lower degree of leaching of P were also observed. Gupta *et al*. (1974) [10] studied the properties of seven typical forest profiles of Kangra district of Himachal Pradesh and reported that the soil horizons were rich in total nitrogen status.

Singh and Raman (1982) [11] studied some soil profiles of North Eastern Himalayas and reported a decreasing order of exchangeable Ca and Mg content with depth. It might be due to mild leaching of calcium and magnesium from upper to lower horizons. Singh and Datta (1988) [12] found decrease in available nitrogen with increase in profile depth. The higher amount of organic carbon in the surface layers was responsible for higher nitrogen contents.

Jalali *et al*. (1989) [13] studied the distribution of micronutrients in benchmark soils of Kashmir at different altitudes and reported that available Fe, Mn, Zn and Cu contents of soils decreased with increase in profile depth. Lahiri and Chakravarti (1989) [14] evaluated the soils of Sikkim at various altitudes and reported that high altitude soils were high in available Fe than low altitude soils due to low soil pH and high organic matter content.

Singh *et al*. (1990) [15] found higher available Fe content in surface soils. That might be due to the regular addition of Fe through plant residues on the surface followed by suitable moisture regimes that accelerate the reduction process causing more availability of Fe. Mahajan (2001) [16] found that available macro and micronutrient cations except for available Ca and Mg showed a decreasing trend with depth in orchard soils in Indora-Nurpur areas of Himachal Pradesh.

Sangwan and Singh (1993) [17] reported an irregular trend of distribution of Fe, Mn, Zn and Cu with increasing depth. Chahal and Saini (1995) [18] assessed the distribution of available Fe in arid zones of Punjab and indicated its decreasing pattern with increasing depth. The variation with depth was due to lower amount of organic matter in lower depths.

Walia and Rao (1996) [19] observed an increase in exchangeable Ca as well as Mg content with soil depth in red soils of Bundelkhand region of Uttar Pradesh. Tripathi *et al*. (2000) [20] found and irregular trend in distribution of available S in grasslands.

Trivedi *et al.* (2010) [21] observed that available P showed a decreasing trend with increasing depth in cultivated alluvial soils of Madhya Pradesh, which might be attributed to a decrease in organic matter content down the profiles. The highest P level in surface soils might be due to continuous addition of manure and fertilizer in this layer.

Soil pH

Soil pH is considered as the driver of soil fertility because of its direct impact on nutrient availability and plant growth. A pH range of 6 to 7 seems to promote the most ready availability of nutrients.

Katyal and Agarwala (1982) [22] depicted an inverse relationship of soil pH with available micronutrient cations *viz*., Fe, Mn, Zn and Cu. Mishra *et al* (1990) [23] observed a positive relationship of soil pH with available P, Cu and Mn in foot hill soils of Himalayas. Rajkumar *et al*. (1990) [24] reported that available Fe, Mn and Zn in hills and hill ridges of Bundelkhand were negatively correlated with soil pH.

According to Tiwary and Mishra (1990) [25], available Zn and Mn were negatively correlated with pH; however, available Cu as well as Fe were positively correlated with pH. The pH values were found to increase with depth, possibly due to leaching of bases [19, 26, 27].

pH values of soils ranged from 4.3 to 9.9 in different regions of the country [27-30]. Kaistha and Gupta (1993) [31] reported that soil pH varied from 6.7 to 7.7 in the Central Himalayas of Himachal Pradesh, whereas, Singh *et al* (1991) [32] reported that it ranged from 6.5 to 8.4 in the mid altitude of outer Himalayas and Walia and Rao (1996) [19] reported that it ranged from 5.1 to 9.8 in the soils of North-Western Himalayas.

Minhas *et al.* (1997) [33] observed that soil pH under forest cover ranged from 5.0 to 5.8 in the wet temperate zone of Himachal Pradesh, whereas, it varied from 5.3 to 6.5 in the cultivated soils of Palampur (Kangra district) and Ahju (Mandi district). The soils of Darang, Palampur and Ahju were less acidic because of their location at relatively lower altitude (about 1200 m) and have lower organic matter content in the surface horizon.

Gangopadhyay *et al.* (1998) [34] found that paddy growing soils of Assam were moderately acidic at the surface (pH 4.7 to 5.7) and slightly acidic to nearly neutral in the sub-surface pH (5.0 to 6.8). Brady and Weil (2002) [35] indicated that the solubility, availability and plant uptake of micronutrient cations (Cu, Fe, Mn and Zn) was more under acidic conditions (pH of 5.0 to 6.5).

Chaudhary *et al*. (2005) [36] categorized soils of Himachal Pradesh as slightly acidic (pH 6.0) to mildly alkaline (pH 8.3) and values increased with depth which might be due to the decrease in organic carbon content. Sharma and Kanwar (2010) [37] reported that in the soils of dry temperate zones of Himachal Pradesh, pH ranged from 6.2 to 10.3 with a mean value of 7.6.

The literature clearly indicates that soils of different cultivated lands are slightly acidic to moderately alkaline in reaction. pH increased with increasing soil depth.

Electrical Conductivity (EC)

EC is a measure of soluble salt concentration in the soil solution. When a soil solution containing a relatively large amount of dissolved salts is brought into contact with a plant cell it causes shrinkage of the protoplasmic lining. This action, called plasmolysis increases with the concentration of the salt solution. Higher concentration of dissolved salts in any soil affects plant growth adversely.

Arora and Takkar (1988) [38] reported that available S showed a positive and significant relationship with EC in different soils. Singh and Choudhary (1990) [39] observed a negative and non-significant relationship between available Cu and EC.

Ramana Murthy and Srivastava (1994) [40] observed a positive and significant correlation of EC with available P, K and Fe in soils of lower Shivaliks. Available Cu had a positive and non-significant relation, while available Mn showed a negative and non-significant relation with it.

Chattopadhyay *et al*. (1996) [41] revealed that micronutrients were significantly and negatively correlated with EC in the cultivated soils of hills and hill ridges of Rajasthan. Singh *et al*. (2005) [42] found that EC varied from 0.16 to 0.35 dS m^{-1} in surface and from 0.09 to 0.22 dS m^{-1} in sub surface soils of Uttaranchal and decreased with increasing depth.

Trivedi *et al*. (2010) [21] found a negative and highly significant relation of EC with available P in the soils of Madhya Pradesh. Bhanwaria *et al*. (2011) [43] reported a negative and non-significant correlation between available micronutrients and EC in soils of Rajasthan.

Soil Organic Carbon

Soil organic carbon content is recognized as a key indicator of soil fertility and sustainability of agricultural systems. It has long been recognized as a source of plant nutrients, principally N and substantially P, S and micronutrients, besides being a promoter of a range of soil physical characteristics. According to Hodgson (1963) [44], the presence of organic carbon may promote the availability of certain elements by supplying soluble complexing agents that interfere with their fixation.

Sauchelli (1969) [45] reported a negative correlation between organic carbon and Cu as organic matter fixes Cu. Since Fe is held in the chelates as soluble complex there was a positive relation between organic carbon and Fe.

Bhandari and Randhawa (1978) [46] observed a positive correlation of organic carbon with available micronutrient elements in soils of district Shimla. Ruhal and Paliwal (1980) [47] found that available S had a significant correlation with organic carbon in the soils of Rajasthan.

The studies carried out by Singh and Datta (1988) [12], Lahiri and Chakravarti (1989) [14], Gangopadhyay *et al*. (1990) [29] and Mandal *et al*. (1990) [48] indicated an increase in organic carbon content with the increase in elevation. It was further observed that organic carbon content was high in the surface horizons which sharply decreased in the sub surface horizons of the profiles.

Kaistha *et al*. (1990) [26] reported that organic carbon content varied from 0.3 to 8.3 per cent in the soils of different regions of Himachal Pradesh. Singh *et al.* (1991) [32] reported moderately high content of organic carbon (1.40 to 2.58 per cent) in the mid altitude soils of outer Himalayas and the organic carbon content in the surface horizons of forest soils increased with increase in altitude (0.9 to 3.6 per cent). Kaistha and Gupta (1994) [49] and Minhas *et al*. (1997) [33] found the organic carbon content to decrease with decreasing with soil depth.

Minhas *et al*. (1997) [33] reported lower amounts of organic carbon in cultivated soils of Palampur (Kangra) and Ahju (Mandi) regions of Himachal Pradesh.

Kaistha and Gupta (1994) [49] and Minhas *et al*. (1997) [33] reported that organic carbon content decreased with increasing soil depth. The increase in organic carbon content with increase in altitude was due to continuous addition of leaf litter and slow decomposition of organic residues under low temperature [33].

Sarkar and Sahoo (2000) [50] found that organic carbon content of the soils varied from 0.08 to 0.86 per cent which decreased gradually with depth in Indo-Gangetic plains of Bihar.

Najar *et al*. (2009) [51] found the organic carbon content in north facing pedons to vary from 0.16 to 3.5 per cent, whereas, in southern aspect it ranged from 0.1 to 2.4 per cent in the apple growing soils of Kashmir Valley. The organic carbon content in soils of dry temperate zone of Himachal Pradesh varied from 0.42 to 4.08 per cent [37]. Devi and Kumar (2010) [52] found that the organic carbon content in the surface layer of the profiles of coffee growing soils of Karnataka ranged from 1.47 to 5.29 per cent and it decreased with depth.

The literature clearly indicates a significant variation in organic carbon content and showed a decreasing trend with increase in soil depth.

Conclusion

Soil fertility is a dynamic natural property which can change under the influence of natural and human induced factors. In agriculture, depletion can be due to excessively intense cultivation and inadequate soil management. Soil fertility is affected my many soil physical, chemical and biological properties. Amongst many soil properties, soil depth, soil pH, soil EC and soil OC play an important role in defining nutrient availability to the plants. The literature clearly indicates that soils of different cultivated lands are slightly acidic to moderately alkaline in reaction and pH increased with increasing soil depth. It has also been made clear that soil EC varies from normal to saline and alkaline. Also, the Indian soils on an average are low to medium in soil organic carbon due to tropical climate of the country.

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