DOI : 10.5958/0974-0112.2019.00067.7

Indian J. Hort. 76(3), September 2019: 417-422

Soil fertility appraisal for apple orchards of Himachal Pradesh using GPS and GIS techniques

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ABSTRACT

About 420 geo-referenced soil samples (0-30 cm) were collected from apple orchards spread over 60 selected villages of Kinnaur district of Himachal Pradesh following stratified random sampling approach and GIS technique. The soil samples were analyzed for 14 physico-chemical parameters, namely pH, EC, soil organic carbon and available macro (N, P, K, Ca and Mg) and micro nutrients (Fe, Mn, Zn, Cu, B and Mo). Different thematic maps were prepared using Arc GIS software version 9.3. The maps revealed that a major area of the district was slightly acidic to neutral in soil reaction (pH 5.53-7.55), non-saline and rich in organic carbon (0.84 to 5.5 %). Available N and Ca were low in 15 % and 18% area with overall fertility rating of high. Available P, K and micronutrients were sufficient but available N is the major constraint in apple orchards of Kinnaur district which warrants for soil test based integrated nutrient approach.

Key words: Geo-reference, Soil organic carbon, macro and micronutrients, thematic maps.

INTRODUCTION

Apple *(Malus domestica* Borkh), cultivation was previously confined to Shimla, Kullu and Mandi areas, but due to high economic returns farmers has started growing apples in Kinnaur but with low yield. The slope aspect, relief and the altitude have pronounced effect on soil properties (Bangroo *et al*., 1) and also on the nutrient supplying capacity of the soils, thereby influencing growth, yield and quality of fruit (Wani *et al*., 17). To steer the achievements in the apple production in the state, there is a need to blend the traditional knowledge with frontier technologies like global positioning system and GIS (Sharma, 12) to facilitate the soil fertility mapping and provide quantitative support for decision and for balanced nutrition (Sawant *et al*., 11). The information on fertility status of different apple growing soils of Kinnaur district, Himachal Pradesh is virtually lacking and hence present study was carried out to assess the soil fertility status and prepare thematic maps using GPS and GIS techniques for apple growing areas of Kinnaur district.

MATERIALS AND METHODS

Four hundred twenty (GPS based) geo-referenced stratified soil samples (0-30 cm) from the selected orchards of sixty apple growing villages of district Kinnaur were collected during first week of November to third week of December at a grid size varying from 1.0 to 1.5 km^2 depending on the homogeneity of the area.

The collected soil samples were air-dried, processed and analyzed for pH, electrical conductivity (EC) and soil organic carbon (OC) by standard methods (Jackson, 5). Available nitrogen (N) and phosphorus (P) were determined by the procedures outlined by Subbiah and Asija (15) and Olsen *et al.* (8), respectively. Available K and exchangeable Ca and Mg were extracted using N neutral ammonium acetate solution (Jackson, 5) and were estimated using atomic absorption spectrophotometer. Available Cu, Zn, Fe and Mn were extracted as per the procedure described by Lindsay and Norvell (7) and estimated using atomic absorption spectrophotometer. Available B and Mo were extracted in hot water and acid ammonium oxalate of pH 3.3 solution and then determined by Carmine (Hatcher and Wilcox, 4) and stannous chloride (Johnson and Arkley, 6) methods, respectively. The analytical results of each soil sample was categorized as low, medium and high categories for OC and macronutrients whereas deficient, moderate and sufficient for micronutrients based on the critical limits as followed in Himachal Pradesh. Making use of the number of samples in each category, the per cent sample category and nutrient index values (NIV) were computed using the formulae furnished below.

$$\text{Per cent sample category} = \frac{\text{No. of “low (L)” or “medium (M)” or “high (H)” category}}{\text{Total no. of samples}} \times 100$$

Nutrient index value (NIV) *and fertility rating* was calculated from the proportion of soils under low,

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medium and high available nutrient categories, as represented by

$$NIV = \frac{[(PH\times3) + (PM\times2) + (PL\times1)]}{100}$$

where, NIV = nutrient index value; PL, PM and PH are the percentage of soil samples falling in the category of low, medium and high nutrient status and given weightage of one, two and three respectively (Ramamoorthy and Bajaj, 10). The index values are rated into various categories *viz*., low (<1.67), medium (1.67-2.33) and high (>2.33) for OC and available N, P and K. For available S and micronutrients, the ratings are very low (<1.33), low (1.33-1.66), marginal (1.66-2.00), adequate (2.00-2.33), high (2.33-2.66) and very high (>2.66) (Parkar *et al*., 9).

Database on soil available nutrient was generated in Microsoft Excel package at College of Horticulture and Forestry, Neri - Hamirpur and the thematic maps of soil variables were prepared at Centre for Geo-informatics Research and Training, CSK Himachal Pradesh Agriculture University Palampur, (HP) using Arc-GIS software version 9.3. The thematic maps on soil variables were categorized as low, medium and high for OC as well as for available N, P, K, Ca, Mg and deficient, moderate and sufficient for micronutrients based on the critical limits.

RESULTS AND DISCUSSION

The pH of the surface soil varied from 5.53 to 7.55 (Table 1). About 62.1 and 32.9 % of the samples were found to be neutral and acidic, respectively and apple can grow well in nearly acidic to neutral soil (Ferree and Warrington, 3). The EC of the soil (Table 1) ranged from 0.11 to 0.86 dS m^{-1} in apple orchards of the district and the values were also within the optimum range for the growth of apple.

The organic carbon content of the soil ranged from 0.84-5.55% (Table 1) with a mean value of 3.25%. About 98.8 per cent of the soil samples were under high status with an overall fertility rating of high primarily due to the application of FYM during winter months and its subsequent mineralization.

The available N contents ranged from 250 to 672 kg ha^{-1} (Table 1) with a mean value of 508.7 kg ha^{-1} and the per cent sample category under low, medium and high was 1.2, 51.2 and 47.6, respectively with an overall high fertility rating. The Olsen-P ranged from 14-188 kg ha^{-1} (Table 1) with an overall mean value of 72.04 kg ha^{-1}. About 51.2% soil samples were rated as high status with an overall fertility rating of high might be due to the continuous application of single super phosphate and reduced rate of mineralization under temperate climate. The range of available K

Table 1. Soil parameters of apple growing area of Kinnaur district.

Parameters/ Nutrients	Range	Mean	CV (%)	Per cent sample category			NIV	Fertility rating	Per cent area based on soil fertility maps		
				Acidic/ Non-saline/ Low/ Deficient	Neutral/ Slightly saline/ Medium/ Moderate	Alkaline/ Saline/ High/ Sufficient			Acidic/ Non-saline/ Low/ Deficient	Neutral/ Slightly saline/ Medium/ Moderate	Alkaline/ Saline/ High/ Sufficient
pH	5.53-7.55	6.69	6.3	32.9	62.1	5.0			18	82	0
EC (dS m^{-1})	0.11-0.86	0.26	41.9	95.1	4.9	0			100	0	0
OC (%)	0.84-5.55	3.25	32.5	0	1.2	98.8	2.99	High	0	0	100
N (kg ha^{-1})	250-672	508.7	21.7	1.2	51.2	47.6	2.46	High	15	85	0
P (kg ha^{-1})	14-188	72.04	60.2	0	8.5	91.5	2.91	High	0	1	99
K (kg ha^{-1})	168-829	439.2	37.5	0	17.1	82.9	2.65	High	0	6	94
Ca (kg ha^{-1})	570-2090	1431.6	24.8	4.9	18.3	76.8	2.71	High	18	16	66
Mg (kg ha^{-1})	395-1663	995.9	25.4	4.9	25.7	69.4	2.64	High	0	78	22
Fe (mg kg^{-1})	2.80-69.7	22.41	64.00	7.3	22.2	70.5	2.63	High	4	0	96
Mn (mg kg^{-1})	11.5-37.0	20.74	30.00	0	0	100	3.00	Very High	0	0	100
Zn (mg kg^{-1})	0.50-4.90	2.37	42.17	2.4	13.4	84.2	2.81	Very High	1	4	95
Cu (mg kg^{-1})	0.80-2.90	1.60	28.50	0	0	100	3.00	Very High	0	0	100
B (mg kg^{-1})	0.36-1.70	0.68	35.90	14.6	58.5	26.9	2.12	Adequate	4	0	96
Mo (mg kg^{-1})	0.12-0.40	0.26	24.66	0	0	100	3.00	Very High	0	0	100

Acidic, neutral and alkaline for pH; Non-saline, slightly saline and saline for EC; Low, medium and high for OC, available N, P and K; Deficient, moderate and sufficient for micronutrients was 168 to 829 kg ha^{-1} (Table 1) with a mean of 439.2 kg ha^{-1}. A major percentage of soil samples (82.9%) were under high status with an overall fertility rating of high owing to a mixture of muscovite, smectite, vermiculite and kaolinite in these soils (Bhandari and Sharma, 2).

The exchangeable Ca and Mg contents ranged from 570-2090 and 395-1663 kg ha^{-1} with a mean of 1431.6 and 995.9 kg ha^{-1}, respectively (Table 1). Sufficient status of Ca and Mg was noticed in 76.8 and 69.4% of the samples with an overall fertility rating of high as these soils are young and least leached.

The available Zn status ranged from 0.50 to 4.90 mg kg^{-1} with a mean of 2.37 mg kg^{-1} (Table 1). About 84.2% of the soil samples were sufficient in available Zn with an overall rating of very high and the results are in line with the findings of Sharma (13).

The available Fe status varied from 2.80 to 69.7 mg kg^{-1} with a mean of 22.4 mg kg^{-1} (Table 1). Deficient, moderate and sufficient Fe status was noticed in 7.3, 22.2 and 70.5% of the samples, respectively with a mean fertility rating of high based on NIV. High available Fe may be due to gypsi-ferrous shales and ferruginous limestone containing hematite and limonite (Wadia, 16) and favourable soil reaction for solubilising native Fe. With reference to available Cu and Mn status, the values ranged from 0.80 to 2.90 mg kg^{-1} and 11.5 to 37.0 mg kg^{-1} with a mean of 1.60 and 20.7 mg kg^{-1}, respectively. The per cent sufficiency of Cu and Mn was 100 with an overall rating of high in the soils of the area might be due to decomposition of organic matter and chelation.

The mean available B status ranged from 0.36-1.70 mg kg^{-1} (Table 1) (mean 0.68 mg kg^{-1}) exhibiting 85.4% sufficiency with an overall rating of high. The available Mo varied from 0.12 to 0.40 mg kg^{-1} (Table 1) with a mean of 0.26 mg kg^{-1} exhibiting 100% sufficiency with an overall rating of high.

The per cent area based on thematic maps for different parameters is depicted in fig. 1 to 11. The soils are predominantly neutral (82%) followed by acidic (18%). These soils are non-saline. Soil organic carbon was grouped in higher category (100%). The available N status was predominantly medium accounting 85% of the total sampled area followed by low (15%). Available P and K had 1 and 6% under medium category and 99% and 94% of the total area were under high rating, respectively. Exchangeable Ca was in medium and high category in 6% and 94% of the area, respectively. Similarly Mg, was in high range in 22% of the area and medium in 78% of the area. The plausible explanation for high contents of available nutrients and only 15% sampled area low in N in high altitude soils may be ascribed to reduced rate of mineralization under temperate climate of the region (Sharma *et al*., 14).

DTPA Fe and Zn status was sufficient in 96 and 95% of the area, respectively. Available Cu and Mn, were in sufficiency category. Boron was sufficient in 96% of the area while deficiency was reported in 4% area. Molybdenum was sufficient in the area so far in apple growing soils of the district.

It may concluded that based on thematic maps, the soils of major apple growing villages of district Kinnaur were neutral in reaction and non-saline having high rating for soil organic carbon. Plant available N and Ca were low in 15 % and 18% area with overall fertility rating high for the district, respectively. However available P, K and Mg were high with overall high rating. Micronutrients were sufficient in the area under study. Available N is constraints in apple orchards of Kinnaur district which warrants soil test based nutrient recommendations through INM. The study may also be useful in monitoring the change detection in soil as samples have been collected on grid basis and sites are geo-referenced.

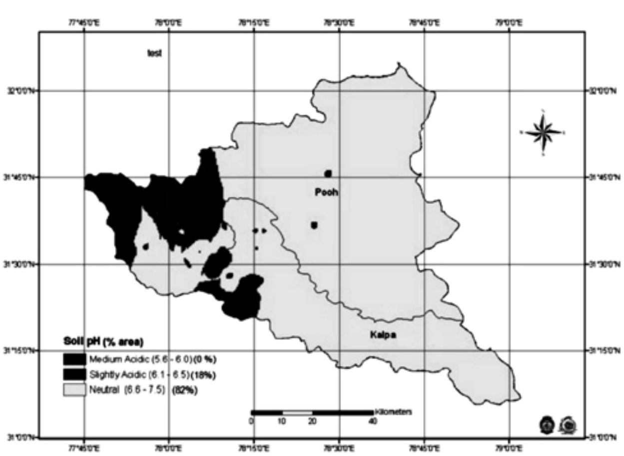

Fig. 1. pH of the soils

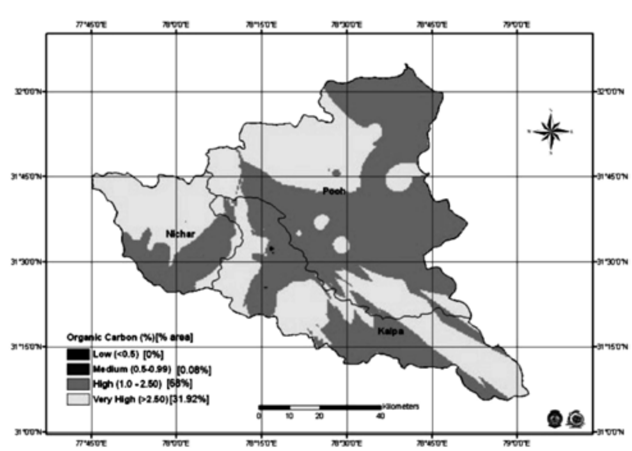

Fig. 2. Organic carbon

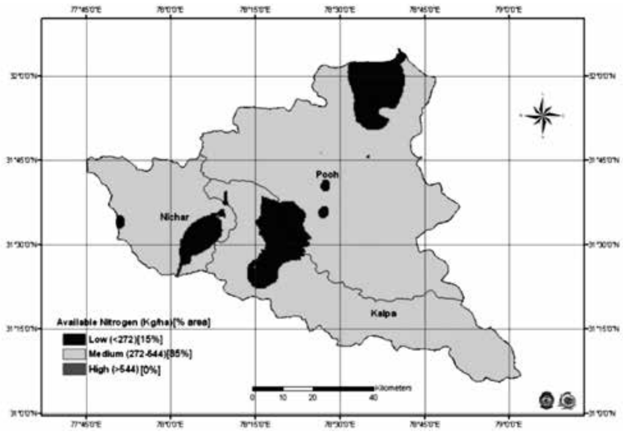

Fig. 3. Available nitrogen

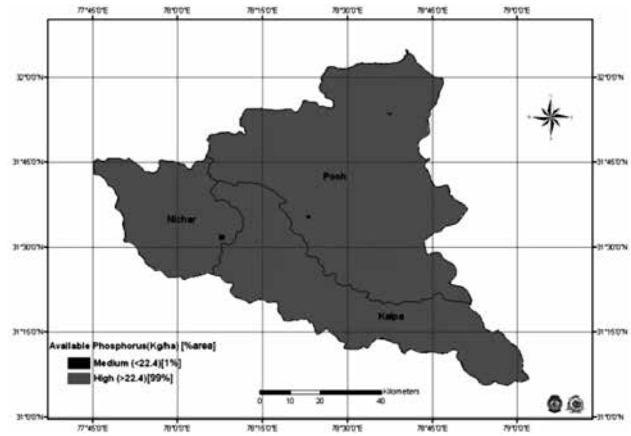

Fig. 4. Available phosphorus

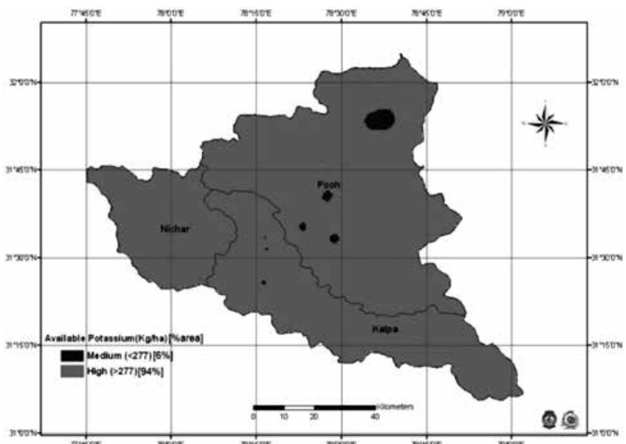

Fig. 5. Available potassium

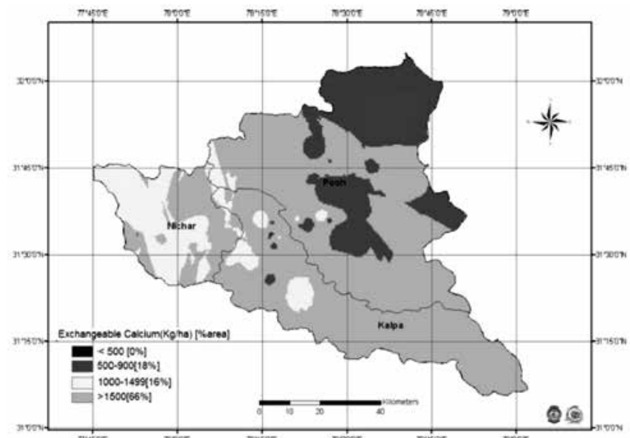

Fig. 6. Available calcium

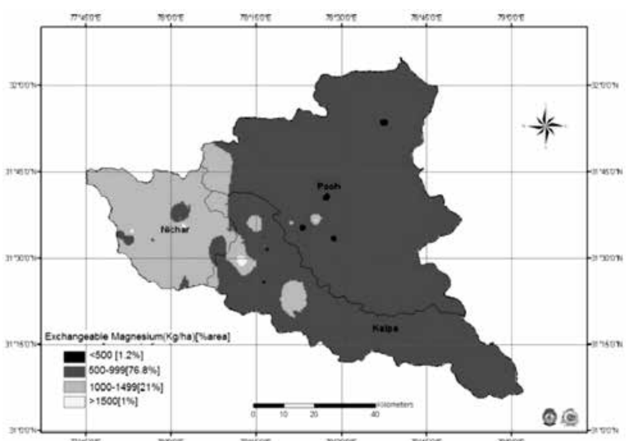

Fig. 7. Available magnesium

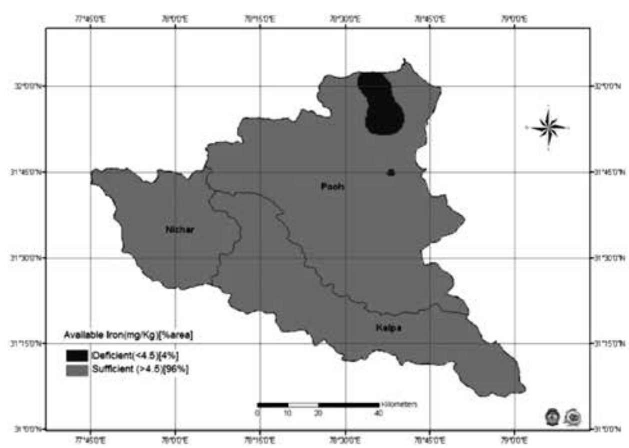

Fig. 8. Available iron

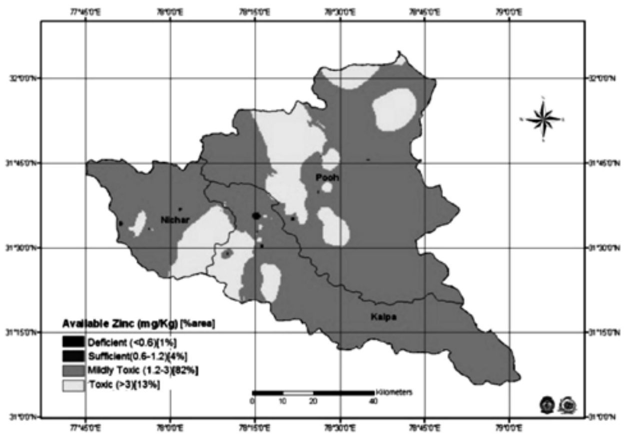

Fig. 9. Available zinc

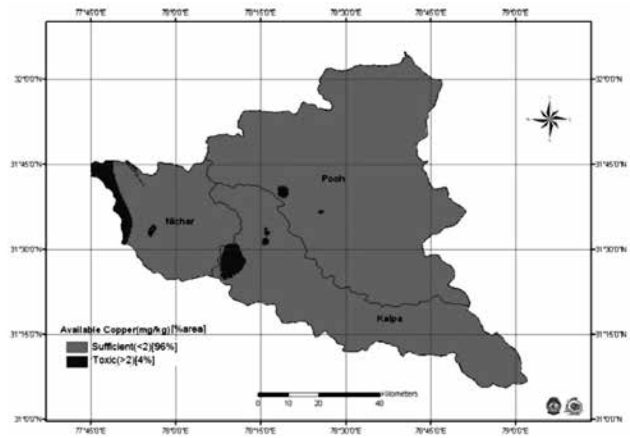

Fig. 10. Available copper

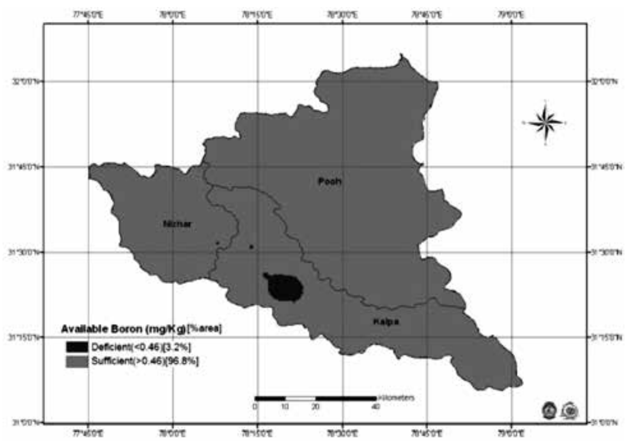

Fig. 11. Available boron

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Received : June, 2019; Revised : August, 2019; Accepted : August, 2019