Indian Journal of Ecology (2017) 44(2): 226-231

**Manuscript Number: 2503**
**NAAS Rating: 4.96**

# Assessment of Soil Fertility Status of Mid Himalayan Region, Himachal Pradesh

**Sudheer Kumar Annepu, Mahantesh Shirur and V.P. Sharma**

*ICAR-Directorate of Mushroom Research, Chambaghat – 173 213, India*
*Email: sudheerannepu@gmail.com*

***Abstract:*** A study was conducted to assess the soil fertility status of mid Himalayan region based on two hundred and fifty surface soil samples collected at a depth of 0-15 cm by using systematic sampling methodology using GPS points. The soils of this region were predominantly neutral in soil reaction with low soluble salts and high in organic carbon content. Soil fertility assessment of crop fields showed the soils of mid-Himalayan region are high in available K and P contents and relatively medium to low in available N content. Among the micronutrients tested, widespread deficiencies were recorded for available Cu (69.23ha), B(50.26ha), Zn (43.84ha) and Fe (42.01ha). The correlation studies between the soil properties and available nutrients showed that OC has significant and positive correlation with the availability of N, P, S, B and Mn indicating the compelling role of OC in the maintenance of balanced soil health.

***Keywords:*** Fertility status, Mid-Himalayan Soils, Micronutrients, Nutrient Index

The mid-hills zone of Himachal Pradesh extends from 651 to 1800 m above mean sea level with mild temperate climate and it occupies 32 per cent of the total geographical area and about 37 % of the cultivated area of the state (Parmar, 2014). With its bestowed climatic conditions, farmers in mountainous areas can produce a variety of off season vegetables and other cash crops, but cultivating the land without best management practices leads to environmental degradation through loss of soil fertility. Limited area under the fertile soils in the mountain landscapes is assuming extra significance because of the decreasing land availability for agriculture caused by the demand for alternate uses. Under these conditions, the high cropping intensity and unscrupulous use of chemical fertilizers adopted by the farmers to reach the higher productivity levels have ultimately rendered the soils in this region with depleted nutritional status (Sharma *et al.,* 2001).

A farmer must take into account the requirement of crops and the characteristics of the soil while making decisions on the timing and quantity of fertilizer application. Lack of understanding about soil health is leading to indiscriminate or imbalanced use of chemical fertilizers and exposing farm based livelihoods to soil health related risks. The assay of soil fertility status is essential for judicious use of fertilizers and assurance of better crop yields. Among the diagnostic techniques for fertility evaluation such as fertilizer trails, soil test and plant analysis; the soil test provides the most accurate information on the availability of various plant nutrients. Soil-test based fertility management is an effective tool for increasing productivity of agricultural soils that have high degree of spatial variability resulting from the combined effects of physical, chemical or biological processes. Long-term sustainability of hill agriculture system must rely, as much as possible on balanced use of fertilizers and effective management of resource inputs. The crop lands in the mountain province of Himachal Pradesh in the western Himalayas have witnessed depleting N from the soil system at an alarming rate. The situation of P and K seems to be slightly satisfactory with positive balance. However, information available on those aspects in the mid-hill conditions of Himachal Pradesh is highly sporadic and inconclusive. In such situations, assessment of site specific soil fertility status and study of their relation with other physicochemical properties would be of high significance. Hence, it was hypothesized that soil fertility related risks can be managed through soil test based balanced nutrition to bring in sustained intensification and resilience building. Therefore, the present study was envisaged to understand the current soil fertility status of mid Himalayan region. This would help the farmers to make more informed decisions to increase the productivity of their lands and to improve their livelihood.

## MATERIAL AND METHODS

The study was conducted at Solan district, which is located between 30° 50` to 31° 15` N latitude and 76° 42` and 77° 22` E longitude with an altitude ranging from 1200-1550 m above mean sea level. This area comes under the mid Himalayan region of Himachal Pradesh, which includes more than 100 villages. It shares common boundaries with Shimla district in the north; Ropar district of Punjab and Ambala district of Haryana in the south and Bilaspur and Sirmour districts of Himachal Pradesh in the east and west, respectively.

**Collection of soil samples:** A systematic survey has been conducted in the grid areas and composite surface soil samples from 0-15 cm depth were collected from randomly selected villages of Anji, Dharot, Chibar Pattar, Dadhog, Ber, etc. by using GPS. Eight to ten cores of surface soil samples were collected and mixed together to make a composite sample. The sampling points were taken from the cadastral map of each village by locating in such a way, that each 10 hectares area may represent one grid based sample. The total area covered under this study was 192.31 ha. Samples were collected during the autumn season of 2015 when there was no standing crop. Out of the total samples collected, 32 per cent samples collected from the irrigated area and rest of the samples from the fields depending on the seasonal rains. The cropping pattern is mainly marked by the cultivation of vegetables.

**Soil analysis:** Collected soil samples were air dried under shade, crushed gently with a wooden roller and passed through 2.0 mm sieve to obtain a uniform representative sample. These samples were analyzed for different physicochemical properties such as soil color, texture, pH, EC, OC and available macro and micro-nutrients. Colour of the soil was judged by visually comparing a soil sample with the chips of standard Munsell Soil Colour Charts (*hue*, *value* and *chroma* indices) to describe colours. The soil texture was judged by feel method as suggested by Thien (1979). Soil pH was measured by glass electrode pH meter using soil to water ratio of 1:2 and EC of supernatant liquid was determined by using microprocessor based EC meter. OC was estimated by Walkley and Black's rapid titration method as described by Jackson (1973). Available N was determined by alkaline $KMnO_4$ method (Subbiah and Asija, 1956), available P was determined using colorimetric method, while K by flame photometric method and S by $CaCl_2$ extraction method as out lined by Tabatabai (1996). The available Fe, Cu, Mn and Zn in soil samples were extracted with DTPA (0.005 M DTPA + 0.01 M $CaCl_2$ + 0.1 M triethanolamine, pH 7.3) as per method described by Lindsay and Norvell (1978). Concentration of Zn, Fe, Cu and Mn in the DTPA extracts was determined using Atomic Absorption Spectrophotometer (AAS). The concentration of available B was estimated by hot water procedure as laid out by Keren (1996).

The nutrient index was arrived based on the formula suggested by Parker *et al.* (1951) as given below

$$\text{Nutrient index} = \frac{(N1 \times 1) + (Nm \times 2) + (Nh \times 3)}{Nt}$$

$N_l$ = Number of samples falling in low category of nutrient status.

$N_m$ = Number of samples falling in medium category of nutrient status

$N_h$ = Number of samples falling in high category of nutrient status

$N_t$ = Total number of samples analysed for a nutrient in any given area

Separate indices were calculated for different nutrients like N, P, K and S. The soils were rated as per the nutrient index values as low (<1.5), medium (1.5 to 2.5) and high (>2.5).

## RESULTS AND DISCUSSION

**Physico chemical properties:** The soil varies from dark grey to dark greyish brown in color, loamy to sandy loamy in texture and neutral to slightly acidic in reaction. It has been assumed that the organic matter or humus content, which is mainly responsible for the color of soils, has a fertility value. The pH values ranges from 6.59 to 7.81with mean pH value of 7.36 (Table 1). Higher rainfall and lower temperatures associated with increasing altitude results in lower pH (Katherine *et al.,* 1985). EC of soil varies from 0.049 dS $m^{-1}$ to 0.793 dS $m^{-1}$ with a mean value of 0.426 dS $m^{-1}$ (Table 2). The EC values under normal range (< 1.0 dS $m^{-1}$) may be ascribed to leaching of salts to lower horizons of soil due its light texture. The soils of the study area are predominantly high in organic carbon (OC) which ranges from 0.15 to 1.98 per cent (Table 2). Among the soil samples studied, only 11.6%of soils exhibited the lower levels of OC whereas, 31.6 and 56.8 per cent of samples showed medium and high OC contents, respectively. The prevailing low temperature results in suppression of microbial and enzymatic activities, which results least soil organic matter decomposition and its accumulation in surface soils (Bhattacharyya *et al.,* 2008). Parallel to the present findings, Khera *et al.* (2001) also reported the higher levels of OC ranged between 0.80-2.30 percent in the Central Himalayan region

The higher OC in soils of this region further supported by the findings of Pathak *et al.* (2010) who reported *in situ* burning of 38.66 per cent of agro residues in the states of Punjab and Haryana, whereas it was confined to 14.38 per cent in Himachal Pradesh, which indicates the proper recycling of agro wastes in this region. Maintenance of high cattle population per unit cultivable land in mid hills zone also upkeeps much organic matter in the surface soils (Bala *et al.,* 2004).

**Status of macro-nutrients:** The available N content in soils varied from 201.21 to 603.37 kg $ha^{-1}$, with an average of 312.91 kg $ha^{-1}$ (Table 2). Considering the available nitrogen rating values as prescribed by Arora (2002), 42% of the soils (80.77 ha) appeared to be in low status and the soils in

109.61 ha and 1.92 ha were found medium and low in available N status, respectively. Since organic carbon content is an indicator of available N status, the soils of the area should also be sufficient in N content. This trend was reported earlier reported by many workers (Mondal e*t al.,* 2015; Singh and Rathore, 2013). The present study also confirms the positive correlation between N and OC (Table 3) but the lower N status in 42 per cent of soils indicates its expeditious depletion from the surface soils. The available P content of mid Himalayan soils varied from 7 to 9 kg $ha^{-1}$ in soils with low P content and 10.06 to 25kg $ha^{-1}$ in soils with medium P content and 26 to 45 kg $ha^{-1}$ in soils with high available P content (Table 2). Very less per cent of soils (2.8%) exhibited the deficiency of P (Fig. 1). Out of the total area under study, 138.46 ha showed medium in available P content and 48.08 ha and 5.77 ha of area showed high and less in available P content. The research findings of Singh and Rathore (2013) also indicate the higher levels of available P in soils located in greater topographic position of Aravali mountain ranges. Relatively higher phosphorus content in soils could be due to lesser availability of free oxides of Ca, Mg and Na at higher altitude which induce the fixation and subsequent precipitation of phosphorus. The available K in the soils of the study area ranged from 70.56 to 448 kg $ha^{-1}$, with an average of 193.83 kg $ha^{-1}$ (Table 2). In the total study area 165.38 ha was classified under medium category with respect to availability of K (Fig. 1) and only 6.8 per cent (13.08 ha) of soils were under low range. Prevalence of clay minerals like illite and kaolinite in hills soils attributed to the sufficient levels of K. These results confirms the findings of Sharma *et al.,* (2001) who reported medium to high fertility status of available P and K in the soils of Lohnakhad in sub-humid mid-hill zones of Himachal Pradesh. Available 'S' content varied from 14.0-32.0 kg $ha^{-1}$ with an average of 23.77 kg $ha^{-1}$. On the basis of the rating suggested for available S content by Hariram and Dwivedi (1994), 20 per cent of soils exhibit the deficiency symptoms (Fig. 1).

**Table 2.** Salient soil properties of study area

| Soil Characteristics | Range | Mean |
|---|---|---|
| pH | 6.59 - 7.81 | 7.36 |
| EC (dS $m^{-1}$) | 0.049-0.793 | 0.426 |
| Organic carbon (%) | 0.15-1.98 | 1.09 |
| Available N (Kg $ha^{-1}$) | 201.21-603.37 | 312.91 |
| Available P (Kg $ha^{-1}$) | 7.0-45.0 | 21.41 |
| Available K (Kg $ha^{-1}$) | 70.56-448.0 | 193.83 |
| Available S (Kg $ha^{-1}$) | 14-32 | 23.77 |
| Available Zn (ppm) | 0.29-5.07 | 1.25 |
| Available B (ppm) | 0.21-0.98 | 0.546 |
| Available Fe (ppm) | 2.14-15.69 | 7.298 |
| Available Mn (ppm) | 0.45-8.87 | 2.363 |
| Available Cu (ppm) | 0.10-5.91 | 0.9 |

The soil nutrient index in the reference area was in

**Table 1.** Limits for the test values for rating the soils

| Classification for pH values | | | | | | |
|---|---|---|---|---|---|---|
| Strongly acid | Moderately acid | Slightly acid | Neutral | Moderately alkaline | Strongly alkaline | Reference |
| < 5.5 | 5.5-6.0 | 6.0-6.5 | 6.5-7.5 | 7.5-8.5 | > 8.5 | Muhr *et al.* (1965) |
| Classification for total soluble salts (EC as dS $m^{-1}$) | | | | | | |
| No deleterious effect on crop | | Critical for germination | Critical for salt sensitive crop | | Injurious to most crops | Reference |
| < 1.0 | | 1.0-2.0 | 2.0-3.0 | | >3.0 | Muhr *et al.* (1965) |
| Macro-nutrients parameters | | Low | Medium | | High | Reference |
| Organic Carbon (%) | | < 0.50 | 0.50-1.0 | | > 1.0 | Muhr*et al.* (1965) |
| Available N (Kg $ha^{-1}$) | | < 280 | 280-560 | | > 560 | Arora (2002) |
| Available P (Kg $ha^{-1}$) | | < 10 | 10-25 | | > 25 | Arora (2002) |
| Available K (Kg $ha^{-1}$) | | < 118 | 118-280 | | >280 | Arora (2002) |
| Available S (Kg $ha^{-1}$) | | < 20 | 20-40 | | > 40 | Hariram and Dwivedi |
| Micro-nutrient | | Critical level (Deficient) | Critical level (Sufficient) | | | |
| Available Zn (ppm) | | < 0.6 | > 0.6 | | | Bansal and Takkar (1986) |
| Available B (ppm) | | < 0.5 | > 0.5 | | | Katyal and Rattan (2003) |
| Available Fe (ppm) | | < 4.5 | > 4.5 | | | Lindsay and Norvell (1978) |
| Available Mn (ppm) | | < 1.0 | > 1.0 | | | Lindsay and Norvell (1978) |
| Available Cu(ppm) | | < 0.5 | > 0.5 | | | Lindsay and Norvell (1978) |

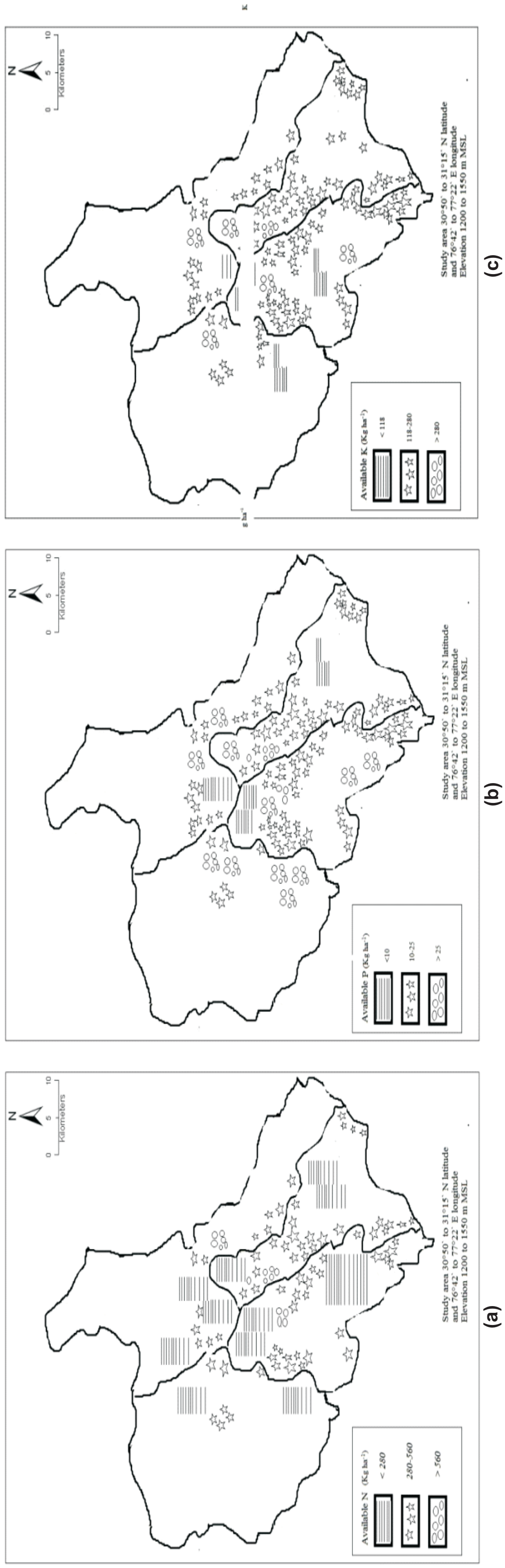


**Fig. 1.** Status of available macronutrients in the study area as per the nutrient index (a) available N (b) Available P (c) Available K

medium category for the all available macronutrients. The values for available N, P, K and S worked out from nutrient index were 1.59, 2.22, 2.00 and 1.80, respectively

**Micronutrient status:** The Zn content ranged between 0.29 – 5.07 ppm with a mean of 1.25 ppm. Available Fe content ranged between 2.14-15.69 ppm with a mean of 7.298 ppm. A mean of 2.363 ppm and 0.9 ppm was observed with respect to available Mn and Cu, respectively. The B content in soils ranged between 0.21 to 0.98 ppm with mean of 0.546 ppm. Considering the critical limits as suggested by Lindsay and Norvell (1978), the deficiency of micronutrients in the soils of the study area were in the order of Cu (36%) > B (26%) > Fe (22.8%) > Zn (22%) >Mn (9.6%) (Fig. 2). The critical observation of data indicated that soils rich in organic carbon are less prone to Mn deficiency. These results find support from the research findings of Chinchmalatpure *et al.* (2000). Such observations were further substantiated by generation of electrons during decomposition of organic matter in turn reducing the oxides of Mn and changing them to more soluble forms that are easily available to plants Availability of high concentrations of Mn in soils rich with OC content was earlier reported by Chander*et al.* (2012) in Madhya Pradesh and Jharkhand soils and Prabhavathi *et al.* (2013) in soils of South Indian regions.

**Correlation among soil parameters:** Correlation among soil parameters showed a significant and positive effect of soil OC on the availability of N, P, S, B and Mn contents and positive effect on other available nutrients. These results clearly suggest the need to manage optimum amounts of soil OC to regulate adequate supplies of essential plant nutrients. Strong and positive correlation exists between available N (r=0.351**) and OC (Table 3). There is a definite relation of organic carbon with available N as organic matter releases most of the mineralizable N in a proportionate amount present in the soil (Mondal *et al.,* 2015; Singh and Rathore,

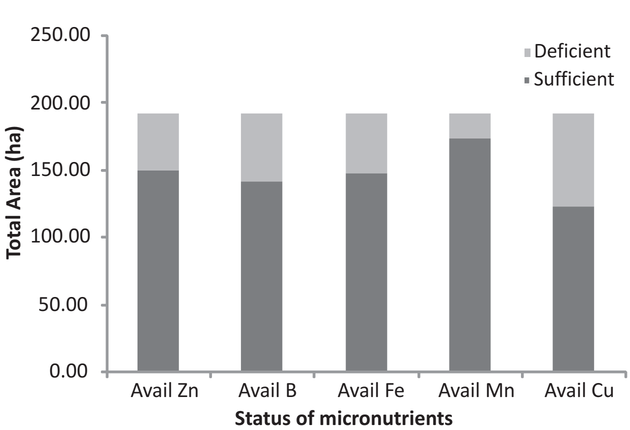


**Fig. 2.** Status of available micro-nutrients in soils of mid Himalayan region

**Table 3.** Correlation coefficient (r) between physico-chemical properties and available macro and micro nutrients

| | pH | EC | OC | N | P | K | S | Zn | B | Fe | Mn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | | | | | | | | | | | |
| EC | 0.261$^{**}$ | | | | | | | | | | |
| OC | 0.115$^{NS}$ | 0.069$^{NS}$ | | | | | | | | | |
| N | 0.180$^{**}$ | -0.113$^{NS}$ | 0.351$^{**}$ | | | | | | | | |
| P | 0.005$^{NS}$ | -0.008$^{NS}$ | 0.341$^{**}$ | 0.263$^{**}$ | | | | | | | |
| K | -0.024$^{NS}$ | -0.046$^{NS}$ | 0.009$^{NS}$ | 0.036$^{NS}$ | -0.022$^{NS}$ | | | | | | |
| S | 0.036$^{NS}$ | 0.028$^{NS}$ | 0.133$^{*}$ | 0.122$^{NS}$ | 0.520$^{**}$ | 0.066$^{NS}$ | | | | | |
| Zn | -0.484$^{**}$ | -0.135$^{*}$ | 0.009$^{NS}$ | 0.152$^{*}$ | -0.021$^{NS}$ | -0.012$^{NS}$ | -0.089$^{NS}$ | | | | |
| B | 0.074$^{NS}$ | -0.000$^{NS}$ | 0.359$^{**}$ | 0.250$^{**}$ | 0.116$^{NS}$ | -0.047$^{NS}$ | 0.060$^{NS}$ | 0.100$^{NS}$ | | | |
| Fe | -0.300$^{**}$ | -0.047$^{NS}$ | 0.074$^{NS}$ | 0.036$^{NS}$ | 0.079$^{NS}$ | 0.060$^{NS}$ | 0.005$^{NS}$ | 0.144$^{*}$ | -0.083$^{NS}$ | | |
| Mn | 0.075$^{NS}$ | -0.014$^{NS}$ | 0.184$^{**}$ | -0.051$^{NS}$ | -0.016$^{NS}$ | 0.043$^{NS}$ | -0.106$^{NS}$ | -0.158$^{*}$ | 0.008$^{NS}$ | 0.110$^{NS}$ | |
| Cu | -0.345$^{**}$ | -0.180$^{**}$ | -0.076$^{NS}$ | 0.037$^{NS}$ | -0.058$^{NS}$ | -0.118$^{NS}$ | -0.073$^{NS}$ | 0.096$^{NS}$ | -0.048$^{NS}$ | 0.036$^{NS}$ | 0.006$^{NS}$ |

* and ** indicate significance of value at P=0.01 and 0.05, respectively

2013). Available N showed a positive significant correlation with available P (r=0.263**) and positive relation with available K (Table 3). The positive relation among the major nutrients indicates the synergistic effects. Similar findings reported by Meena *et al.* (2006) in soils of Rajasthan and Kumar *et al.* (2009) in soils of Jharkhand region. Contrary to the reports many workers (Ghosh *et al.,* 2015; Singh *et al.,*2014; Jatav and Mishra, 2012) observed non-significant correlation of potassium with all other parameters studied.

The available Zn in the soil has significant and negative relationship with pH (r = -0.484**) thereby indicating that availability of Zn increases at lower pH levels. To some extent, organic matter reduces the pH of the soil locally, which helps in increasing solubility of zinc through its effect on weathering of minerals containing zinc. Products of organic matter decay may also have chelating effect on zinc and helps to increase its availability to plant

The findings of Yadav and Meena (2009) in Degana soil series of Rajasthan state also confirm the relation between Zn with pH. Similarly, Fe and Cu were negatively and significantly correlated with soil pH (r= - 300** & r=-0.345**) indicating their higher availability at acidic pH. The studies on soil properties in hilly regions of Jammu district (Mondal *et al.,* 2015), Bhimber district (Nazif *et al.,* 2006) and Assam region (Talukdar *et al.,* 2009) also illustrates the similar correlation pattern of micro nutrients with the changes in pH levels.

Results are indicating the scope to cut use of P and K fertilizers as 97 and 93 per cent of soils under study area were showed medium to high in available P and K content, respectively. Going by essentiality of the nutrients, it is apparent that the widespread deficiencies of Cu, B and Zn might be a constraint to harvest full yield potential of crops under cultivation in the study area.

## REFERENCES


Arora CL 2002.Analysis of soil, plant and fertilizers. In fundamental of soil science (GS Sekhon, Chhonkar PK, Das DK, Goswami NN, Narayanasamy G, Poonia SR, Rattan R K and Sehgal J, Eds), Indian Society of Soil Science, New Delhi.

Bala B, Sharma RK and Sharma SD 2004. Size and composition of bovine population in Himachal Pradesh- A district wise analysis. *Indian Journal of Animal Research* **38**(1): 8-13.

Bansal RL and Takkar PN 1986. Micronutrient status of soils in Amritsar district. *Indian Journal of Ecology* **13**: 158–160.

Bhattacharyya T, Pal DK, Chandran P, Ray SK, Mandal C and Telpande B 2008. Soil carbon storage capacity as a tool to prioritize areas for carbon sequestration. *Current Science* **95**:482-492.

Chander G, Wani SP, Sahrawat KL and Jangawad LS 2012. Balanced plant nutrition enhances rain fed crop yields and water productivity in Jharkhand and Madhya Pradesh states. *Indian Journal of Tropical Agriculture* **50**(1): 24-29.

Chinchmalatpure AR, BrijL, Challa O and Sehgal J 2000. Available micronutrient status of soils on different parent materials and landforms in a micro watershed of Wanna catchment near Nagpur (Maharashtra). *Agropedology* **10:** 53-58.

Ghosh R, Chander G, Rathore A, Telangre R, Rao SK, Sharma RN, Pande S and Sharma 2015. An assessment of soil fertility status of the rainfed region of Chhattisgarh and Madhya Pradesh.*Indian Journal of Soil Conservation* **43**(2)**:** 142-146.

Hariram and Dwivedi KN 1994. Delineation of sulphur deficient soil group in the central alluvial tract of Uttar Pradesh. *Journal of the Indian Society of Soil Science* **42:** 284-286.

Jackson M L 1973. Soil Chemical Analysis. *Oxford IBH Publishing House*, Bombay. pp 38.

Jatav GK and Mishra VN 2012. Evaluation of soil fertility status of available N, P and K in Inceptisol of Baloda block in Janjgir district of Chhattisgarh. *Journal of Progressive Agriculture* **3:** 28-32.

Katherine AB, Logan, Michael JS and Floate 1985. Acidity in upland and hills soils: Cation Exchange Capacity, pH and lime requirement. *Journal of the Science of Food and Agriculture* **36:** 1084-1092.

Katyal JC and Rattan RK 2003. Secondary and Micronutrients: Research gap and future needs. *Fertilizer News* **48**: 9-14

Keren R 1996. *Methods of soil analysis* Part 3: Chemical methods (Soil Science Society of America Book series No.5). Madison, Wisconsin, USA. pp 603-626.

Khera NA, Kumar JR and Tewari A 2001. Plant biodiversity assessment in relation to disturbances in midelevational forest of Central Himalaya. India. *Tropical Ecology* **42**(1): 83-95.

Kumar R, Sarkar AS, Singh KP, Agarwal BK and Karmakar S 2009. Appraisal of available nutrients status in Santhal Paraganas region of Jharkhand. *Journal of the Indian Society of Soil Science* **57**(3)**:** 366-369.

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

Meena HB, Sharma RP and Rawat US 2006. Status of macro and micronutrients in some soils of Tonk district of Rajasthan. *Journal of the Indian Society of Soil Science* **54**(4)**:** 508 -512.

Mondal AK, Rai AP, Pardeep W and Manoj K 2015. Available micronutrient status and their relationship with soil properties of vegetable growing area of Jammu district. *Progressive Horticulture* **47**: 95-98.

Muhr GR, Datta NP, Sankara, Subramoney H, Liley VK and Donahue RR 1965. Soil testing in India. *US Agency for International Development*, New Delhi. pp 120.

Nazif W, Perveen S and Saleem I 2006. Status of micronutrients in soils of district Bhimber (Azad Jammu and Kashmir). *Journal of Agriculture and Biological Science* **8**: 35-40.

Parker FW, Nelson WL, Winter E and Miller IE 1951. The broad interpretation of soil test information. *Agronomy Journal* **43**: 105-102.

Parmar DK 2014. Yield, produce quality and soil health under vegetable cropping systems as influenced by integrated nutrient management in mid-hill zone of Himachal Pradesh. *Journal of the Indian Society of Soil Science* **62**(1)**:** 45-51.

Pathak H, Bhatia A and Jain N 2010. Inventory of greenhouse gas emission from agriculture. *Report submitted to Ministry of Environment and Forests, Govt. of India*.

*Received 12 February, 2017; Accepted 28 April, 2017*

Prabhavathi M, Patil SL and Raizada A 2013. Assessment of soil fertility status for sustainable crop production in a watershed of Semi Arid Tropics in Southern India. *Indian Journal of Soil Conservation* **41**(2): 151-157.

Sharma PK, Sharma SP and Jain PK 2001. Nutrient mining in different agro- climatic zones of Himachal Pradesh. *Fertilizer News* **46**(8)**:** 69-73.

Singh DP and Rathore MS 2013. Available nutrient status and their relationship with soil properties of Aravalli mountain ranges and Malwa plateau of Pratapgarh, Rajasthan, India. *African Journal of Agricultural Research* **8**(41): 5096-5103.

Singh YP, Raghubanshi BPS, Rajbeer S, Tomar SK, Verma and Dubey SK 2014. Soil fertility status and correlation of available macro and micronutrients in Chambal region of Madhya Pradesh. *Journal of the Indian Society of Soil Science* **62**(4): 369-375.

Subbiah BV and Asija GL 1956. A rapid procedure for the determination of available nitrogen in soil. *Current Science* **25**: 259-260.

Tabatabai MA 1996. Methods of soil analysis, Part 3: (Soil Science Society of America Book series No.5). Madison, Wisconsin, USA. pp 921-960.

Talukdar MC, Basumatary A and Dutta SK 2009. Status of DTPA-extractable cationic micronutrients in soils under rice and sugarcane ecosystems of Golaghat district in Assam. *Journal of the Indian Society of Soil Science* **57**: 313-316.

Thien SJ 1979. A flow diagram for teaching texture by feel analysis. *Journal of Agronomic Education* **8**: 54-55.

Yadav RL and Meena MC 2009. Available micronutrients status and their relationship with soil properties of Degana soil series of Rajasthan. *Journal of the Indian Society of Soil Science* **57**: 90-92.