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MACRONUTRIENT STATUS AND THEIR RELATIONSHIP WITH LEAF NUTRIENT CONTENT OF CAULIFLOWER (*Brassica oleracea* var. botrytis) GROWING AREAS OF KUNAH RIVER FLOOD PLAINS IN HAMIRPUR, HIMACHAL PRADESH

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ABSTRACT

A nutritional survey was carried out in vegetable growing areas of Kunah river flood plains in Hamirpur district of Himachal Pradesh to study the nutritional status of these areas and to work out the relationship of the soil characteristics with leaf nutrient contents. For this 18 soil sampling sites from cauliflower growing areas were selected randomly and three soil samples from each location at a depth of 0-15 cm (surface) and 15-30 cm (subsurface) were collected after the harvesting of previous crop during the months of September, 2018 and analyzed for bulk density, texture, pH, EC, organic carbon and available macronutrients. Cauliflower leaf samples were collected from the vegetable growing fields from where the soil samples were collected during November-December, 2018 and analyzed for all macronutrients. The Kunah river flood plains soils of Hamirpur district were loam to sandy clay laom in texture. The overall soil pH of the study areas was slightly acidic to neutral in reaction. All the nutrients were found high in status except available S which was found low in nutrient indices and available N which was medium in nutrient status. All of the macronutrients of cauliflower leaves were sufficient except S which was found deficient. Organic carbon showed significant positive correlation with available N. Significant positive correlation of leaf N, P, K, S, Ca and Mg was found with their respective availability in soil. Available N, P and K showed highest positive significant correlation with available P, N and P, respectively. Highest positive significant correlation of available S, exchangeable Ca and Mg was observed with available K, exchangeable Mg and Ca, respectively. From this assessment it is concluded that deficiency of available S emphasizes the immediate and urgent need for adoption of judicious nutrient management system in the study area for sustaining optimum productivity level of cauliflower.

(Key words: Cauliflower, Kunah river, macro nutrient and correlation)

INTRODUCTION

Vegetables play a major role in Indian agriculture by providing food, nutrition, economic security and most importantly, they produce higher returns unit^{-1} area and time. In addition, vegetables have shorter maturity cycle and high value and provide greater income leading to improved livelihood of farmers. India ranks second in terms of vegetable production in the world after China. In India vegetables are grown in an area of 10259 thousand ha with the production of 184394 thousand metric tonnes (Anonymous, 2018). Among various states in India, West Bengal, Uttar Pradesh, Madhya Pradesh are the major vegetable growing states. Though the area under vegetable cultivation in Himachal Pradesh is low but the state is known for its rich biodiversity and varied agriculture conditions which are highly suitable for growing different types of vegetables round the year. Presently, area and production of vegetables in Himachal Pradesh is 89.31 thousand ha and 1811.7 thousand metric tonnes. Major vegetable growing district of Himachal Pradesh is Shimla, Solan, Kullu, Sirmour, Kinnaur, Hamirpur etc. In Hamirpur district of Himachal Pradesh, total area under vegetable crops is 3.40 thousand ha, while the annual production is 56.40 thousand metric tonnes (Anonymous, 2018).

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The vegetable growers of the Kunah river floodplains have also shown interest in the introduction of hybrid/high yielding varieties of vegetables. The high yielding/hybrid varieties are very responsive to the higher doses of nutrients and further the nutritional requirement of these varieties is very high. In vegetable crops, production depends mainly on soil fertility and availability of water. Application of major nutrients (nitrogen, phosphorus and potassium) became common; therefore, the crops started responding to micronutrient fertilizers when smaller quantities were applied to soil, the amount of nutrients removed in harvested crops are generally much higher than the quantity added and hence resulting in exhaustive mining of nutrients from the soil, thus increasing the nutrient related stresses and yield losses. Soil fertility deterioration is a major constraint for higher crop production in Hamirpur. Vegetable productions without adequate and balanced use of chemical fertilizers, non-ecofriendly tillage practices, and with little or no use of organic manure caused severe fertility deterioration of agricultural soils resulting in stagnating or even declining of crop productivity and soil health (Baruah *et al.,* 2013).

Therefore, in order to achieve higher productivity and profitability, every farmer of Kunah river should realize that fertility levels of the flood plains should be managed properly. Further the fragile ecosystem of the floodplains make it more imperative that only correct and needed doses of fertilizers should be added to maintain fertility of the floodplains soil without any contamination of river water by leaching losses etc. Keeping the above points into consideration present study was carried out.

MATERIALS AND METHODS

A survey was carried out during 2018 in cauliflower growing areas in the vicinity of Kunah river flood plains of Hamirpur district. Eighteen soil sampling sites/cauliflower growing areas were selected randomly and one hundred eight representative surface (0-15 cm) and subsurface (15-30 cm) soil samples were collected from each location in the vicinity of Kunah river flood plains of Hamirpur district during the months of September. Three soil samples from each location at a depth of 0-15 cm (surface) and 15-30 cm (subsurface) were collected after the harvesting of previous crop and analyzed for bulk density, texture, pH, EC, organic carbon and available macronutrient elements.

The texture of the soil was determined by Hydrometer method (Bouyoucos, 1927). The soil pH was estimated in 1:2 soil: water suspension (Piper, 1950) and the electrical conductivity of the supernatant liquid was recorded as per the method detailed by Jackson (1973) and organic carbon (Walkley and Black, 1934). Available N was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956), available P by Olsen's method (Olsen *et al*., 1954) and determined by stannous chloride reduced ammonium molybdate method (Jackson, 1973), available K by neutral normal ammonium acetate (Black, 1965). Sulphate-S was determined by Turbiditeric method (Chesnin and Yien, 1950). Exchangeable Ca and Mg were determined by using ammonium acetate extract by atomic absorption spectrophotometer (Jackson, 1973).

Cauliflower leaf samples were collected from the vegetable growing fields from where the soil samples were collected. Cauliflower leaf samples were collected from vegetable growing areas during November-December in respective fields. Most recent, fully matured leaf, at heading stage were collected as per the recommendations of Kensworthy (1964), Reuter and Robinson (1986) and Raghupati (1993) and processed for analysis as per the methodology suggested by Chapman (1964).

The descriptive statistics *viz*., ranges, mean, standard error and coefficient of variation were derived for each soil and leaf parameter. Also, the data was subjected to statistical analysis by adopting simple correlation to find out the extent of relationship of soil characteristics with leaf nutrient contents (Singh and Chaudhary, 1994).

RESULTS AND DISCUSSION

Physico-chemical properties of the soil

Physical properties of soil

The data presented in Table 1 revealed that the bulk density in surface and subsurface soil varied from 1.09 to 1.32 Mg $m^{-3}$and 1.13 to 1.37 Mg m^{-3} with overall mean values of 1.21 and 1.24 Mg m^{-3}, respectively. In surface soil the highest and lowest values of bulk density was recorded in villages of Dera Parol and Baletha Khurd ranging from 1.25 to 1.32 Mg m^{-3} and 1.09 to 1.15 Mg m^{-3} with a mean value of 1.28 and 1.12 Mg m^{-3}, respectively. The bulk density increased with the increase in soil depths which might be due to decline in organic matter content in the lower depth. Sharma and Kanwar (2010) at Spiti valley of Himachal Pradesh also reported increase in bulk density with the increase in soil depth.

In overall eighty-eight per cent of the surface soil samples were found to be loam in texture and remaining twelve per cent were sandy clay loam in texture (Figure 1) and this textural class was found in Baba Di Kutiya and Sidhpur villages. Figure 2 revealed that 72 per cent of subsurface soil samples were loam in texture, 17 per cent were sandy loam and 11 per cent were sandy clay loam in texture (Table 2). There was a decrease in the percentage of sand and increase in percentage of silt and clay with the increase in soil depth, indicating translocation of finer soil particles to lower depths. Kaur (2017) also reported the same trend of decline in the sand percentage (52.8 to 67.5 % in surface and 50.6 to 65.8 % in subsurface) and increase in the silt (17.8 to 26.0 % in surface and 18.4 to 27.4 % in subsurface) and clay (14.0 to 25.2 % in surface and 14.5 to 25.4 % in subsurface) with the increase in the soil depth.

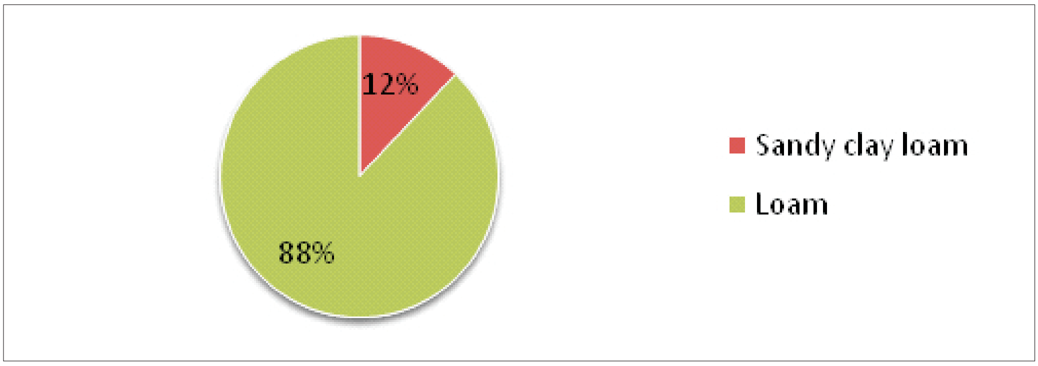

Fig. 1. Percentage distribution of textural classes in surface soils (0 to 15 cm depth)

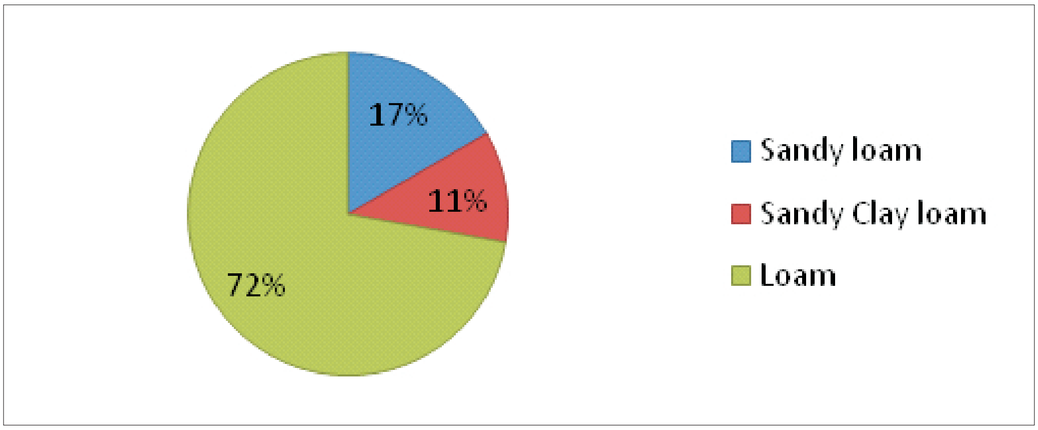

Fig. 2. Percentage distribution of textural classes in sub surface soils (15 to 30 cm depth)

Chemical properties of soil

The perusal of the data in Table 3 revealed that the surface soil pH ranged from 6.30 to 7.37 with overall mean value of 6.73. The lowest pH value was found in the Kanjian village ranging from 6.39 to 6.75 with a mean value of 6.53 and highest pH value was found in Jangloo village which varied from 6.95 to 7.37 with a mean value of 7.14.Whereas, in subsurface soils the pH value varied from 6.40 to 7.28 with overall mean value of 7.12. The lowest value of pH was found in the village Kanjian ranging from 6.40 to 6.85 with a mean value of 6.60. The highest value of pH was observed in the village Jangloo and ranged from 7.10 to 7.28 with a mean value of 7.19. The cv of 3.43 per cent for the surface soil and 6.51 per cent for subsurface indicates that it varied spatially in both surface and subsurface depths. The overall soil pH of the study areas was slightly acidic to neutral in reaction. The lower pH in few locations of the study areas might be due to low degree of base saturation in surface soil. There was increase in pH value with the increase in depth. Similar results of increase in soil pH value with increase in soil depth have also been reported by Khajuria *et al.* (2015).

The electrical conductivity (EC) in the surface and subsurface soil ranged from 0.11 to 0.46 dS m^{-1} and 0.10 to 0.38 dS m^{-1} with overall mean values of 0.26 and 0.21 dS m^{-1}, respectively (Table 3). The lowest value in both surface (0-15cm) and subsurface (15-30cm) soil was found in village Kanjian ranging from 0.11 to 0.26 dS m^{-1} and 0.12 to 0.21dS m^{-1} with a mean value of 0.18 dS m^{-1} and 0.16 dS m^{-1}, respectively. While, the highest value in both surface and subsurface soil was found in Baba Di Kutiya village which ranged from 0.39 to 0.46 and 0.27 to 0.38 dS m^{-1} with a mean value of 0.40 and 0.32 dS m^{-1}, respectively. The cv of 32.36 and 30.73 per cent for EC in both surface and subsurface depths respectively indicates that it varied spatially. The results showed that all the EC values were under normal range (<1.0). The normal EC range of the soil is attributed to the leaching of salts to lower depths due to continuous tillage practices and cropping. Soil samples of the study areas have the safe range of EC for crop growth and development. Similarly, normal range (0.14 to 4.57 dSm^{-1}) and (0.094 to 0.138 dSm^{-1}) of EC have also reported by Bali *et al.* (2010) and Loria *et al.* (2016), respectively in agriculture soils of Himachal Pradesh.

An insight of data in Table 3 revealed that the organic carbon content in the surface and subsurface soil ranged from 15.2 to 37.1 g kg^{-1} and 13.0 to 33.2 g kg^{-1} with overall mean values of 25.02 and 22.54g kg^{-1}, respectively. Kunna village recorded the highest organic carbon content in both surface and subsurface soil ranging from 22.4 to 35.5 g kg^{-1} and 23.3 to 33.0 g kg^{-1} with mean values of 29.7 and 27.8 g kg^{-1}, respectively. Whereas, Dera Parol and Mehal villages recorded the lowest content of organic carbon in surface and subsurface ranging from 15.2 to 22.0 and 14.0 to 16.0 g kg^{-1} with mean values of 18.3 and15.0 g kg^{-1}, respectively. The cv of 16.11 and 17.48 per cent for organic carbon indicates that, it varied spatially in the surface and subsurface depths. Most of the soil samples of the study areas fall under the high soil fertility class of organic carbon which might be due to the regular addition of FYM and plant residues by the vegetable growers. However, organic carbon content decreased with increase in depth. Similar vertical distribution pattern of organic carbon has been reported by Tripathi *et al.* (1994), Sharma *et al.* (1996), Kumar *et al.* (2002), Krishna *et al.* (2004), Sharma (2011) and Pal *et al.* (2013).

The available nitrogen content in surface and subsurface soils ranged from 261.54 to 395.35 kg ha^{-1} and 214.10 to 395.15 kg ha^{-1} with overall mean values of 338.62 and 316.87 kg ha^{-1}, respectively. The highest content in surface and subsurface soil was recorded in village Jangloo ranging from 385.25 to 395.35 kg ha^{-1} and 368.05 to 381.70 kg ha^{-1} with mean values of 391.25 kg ha^{-1} and 374.38 kg ha^{-1}, respectively. Whereas, the lowest content of nitrogen in surface and subsurface soil was observed in Sohri village and ranged from 261.54 to 295.64 kg ha^{-1} and 214.10 to 284.42 kg ha^{-1} with mean values of 279.97and 249.58 kg ha^{-1}, respectively (Table 4). The cv of 9.46 and 14.93 per cent for available nitrogen content indicates that, it varied spatially in the surface and subsurface depths. Available nitrogen content in the study area was recorded low to medium in surface as well as in subsurface soils. Most of the samples had medium levels of nitrogen content which is attributable to the addition of urea and FYM by the vegetable grower. The available nitrogen content of the soil was decreased with increasing in soil depth. Similar results were also reported by Khajuria *et al.* (2015), who also recorded the available nitrogen content varied from 344.9 to 419.2 and 271.3 to 386.9 kg ha^{-1} in surface and subsurface soil, respectively.

The available phosphorus in surface and subsurface soil samples ranged from 24.33 to 63.85 kg ha^{-1} and 16.19 to 59.47 kg ha^{-1} with overall mean values of 42.68 and 34.86 kg ha^{-1}, respectively (Table 4). The highest content of available P in surface and subsurface soil was found in Jangloo village ranged from 50.67 to 63.85 kg ha^{-1} and 46.35 to 59.47 kg ha^{-1} with mean values of 57.43 and 52.08 kg ha^{-1}, respectively. Whereas, the lowest content of phosphorus in surface and subsurface soil was observed in Kunna and Sohri villages and ranged from 24.33 to 37.50 kg ha^{-1} and 16.19 to 24.23 kg ha^{-1} with mean values of 29.39 and 22.86 kg ha^{-1}, respectively. Available phosphorus content varied spatially in the surface and subsurface depths as indicated by the respective cv's of 24.26 and 27.56 per cent. Higher P content in the surface soil might be due to confinement of crop roots to surface layer and the availability of P is highly pH dependent with maximum availability near neutral pH and most of soils of our study area are near neutral in reaction which explains its high contents in these soils. The results of the study areas are in agreement with findings of Chandel *et al.* (2017), who also observed the mean available phosphorus content of 55.43 kg ha^{-1}.

Available potassium concentration in surface and subsurface soil samples varied from 139.93 to 388.16 kg ha^{-1} and 132.40 to 332.75 kg ha^{-1} with overall mean values of 258.77 and 225.53 kg ha^{-1}, respectively (Table 4). The highest and lowest content of potassium in surface soil was recorded in villages of Rail and Kanjian and varied from 310.15 to 332.10 kg ha^{-1} and 140.92 to 180.55 kg ha^{-1} with mean values of 319.18 and 162.19 kg ha^{-1}, respectively. Whereas, in subsurface soil highest and lowest potassium content ranged from 286.40 to 301.10 kg ha^{-1} and 132.40 to 143.20 kg ha^{-1} with mean values of 293.93 and 138.63 kg ha^{-1} in Rail and Kanjian villages, respectively. The cv of 23.19 and 22.68 per cent for available potassium content indicates that, it varied spatially in the surface and subsurface depths, respectively.

The status of potassium content in the study area was medium to high which might be due to the presence of potassium rich minerals like illite and feldspars and also due to the release of labile potassium from organic residues and potassium fertilizers. These results are in conformity with the findings of Khajuria *et al.* (2015), who registered the available potassium content varied from 161.30 to 328.80 kg ha^{-1} in surface and 113.00 to 356.40 kg ha^{-1} in subsurface soils of Himachal Pradesh and similar results (185 to 260 kg ha^{-1}) were also reported by Nilima *et al.* (2017).

The available sulphur in surface and subsurface soil ranged from 10.54 to 23.24 kg ha^{-1} and 8.45 to 24.08 kg ha^{-1} with overall mean values of 17.58 and 15.09 kg ha^{-1}, respectively (Table 5). The highest content of sulphur in surface and subsurface soil was found in Jangloo village ranging from 20.97 to 23.24 kg ha^{-1} and 16.47 to 24.08 kg ha^{-1} with mean values of 21.81 and 18.96 kg ha^{-1}, respectively. Whereas, the lowest content of sulphur in surface and subsurface soil was found in villages of Kunna and Servari ranging from 11.39 to 12.04 kg ha^{-1} and 9.18 to 11.17 kg ha^{-1} with mean values of 11.74 and 10.42 kg ha^{-1}, respectively. The cv of 19.36 and 21.55 per cent for available sulphur content indicates that, it varied spatially in the surface and subsurface depths. All the soils of the study area were deficient in available sulphur which might be due to high removal of sulphur by the cauliflower crop which leads to considerable depletion of sulphur from the soil. Further problem is aggravated as the farmers are not applying sulphur from any external source except little addition through FYM. Similar results were also recorded by Kumar *et al.* (2017) with regard to available sulphur content ranged from 8.4 to 58.8 kg ha^{-1} in Spiti valley of Himachal Pradesh.

Exchangeable calcium content in the surface and subsurface soil varied from 1.74 to 4.49 cmol (p^{+}) kg^{-1} and 1.51 to 4.21 cmol (p^{+}) kg^{-1} with overall mean values of 2.96 and 3.40 cmol (p^{+}) kg^{-1}, respectively (Table 5). The highest content of calcium was found in Khola Plassi village in surface and subsurface soil varied from 3.50 to 4.49 cmol (p^+) kg^{-1} and 3.32 to 4.21 cmol (p^+) kg^{-1} with mean values of 3.96 and 3.83 cmol (p^+) kg^{-1}, respectively. Whereas, the lowest content of calcium in surface and subsurface was observed in village Rail ranging from 1.74 to3.47 cmol (p^+) kg^{-1} and 1.51 to 2.57 cmol (p^+) kg^{-1} with mean values of 2.36 and 1.96 cmol (p^+) kg^{-1}, respectively. The cv of 20.11 and 14.96 per cent for exchangeable calcium content indicates that it varied spatially in the surface and subsurface depths. Exchangeable Ca content of the study areas was high due to the regular addition of FYM which have higher adsorption capacity that might have adsorbed Ca which otherwise would have leached down Similar results were also reported by Gupta and Tripathi (1989), Kaistha and Gupta (1993) and Babu *et al*. (2007). They also reported positive effect of FYM addition on exchangeable Ca in soil.

Exchangeable magnesium content in surface soil varied from1.61 to 3.98 cmol (p^+) $kg^{-1}$with overall mean value of 3.01 cmol (p^+) kg^{-1}, while in subsurface it varied from 1.25 to 3.88 cmol (p^+) kg^{-1} with overall mean value of 2.75 cmol (p^+) kg^{-1} (Table 5). The highest content in surface and subsurface was recorded in village Dera Parol which varied from 3.74 to 3.98 cmol (p^+) $kg^{-1}$and 3.40 to 3.88 cmol (p^+) kg^{-1} with mean values of 3.79 and 3.62 cmol (p^+) kg^{-1}, respectively. While, lowest content of magnesium was recorded at Khagal village in surface and subsurface soil ranging from 1.61 to 2.18 cmol (p^+) kg^{-1} and 1.25 to 1.93cmol (p^+) kg^{-1} with mean values of 1.89 and 1.52 cmol (p^+) kg^{-1}, respectively. The cv of 21.48 and 25.75 per cent for exchangeable magnesium content indicates that it varied spatially in the surface and subsurface depths. The higher values of exchangeable Mg in soils are attributed to the higher organic matter content and neutral soil pH. Similar results were also reported by Kumar *et al.* (2017) in respect of exchangeable magnesium content varied from 1.16 to 3.77 cmol (p^+) kg^{-1} and 1.27 to 3.78 cmol (p^+) kg^{-1} in surface and subsurface Spiti valley soils of Himachal Pradesh.

Nutrient indices of soil

Nutrient indices of surface soil

The data presented in Table 6 revealed that the status of available nitrogen and sulphur was found low in 1.85 and 96.29 per cent of soil samples, respectively. The status of available nitrogen, phosphorus, potassium and sulphur was found medium in 98.15, 3.70, 55.55 and 3.71 per cent of soil samples, respectively and 96.30, 44.45, 100.00 and 100.00 per cent samples were found high in available phosphorus, potassium, exchangeable calcium and magnesium, respectively in surface soils. The data further indicated that most of the soils of the study area were low in sulphur (1.03), medium in available nitrogen (1.98), high in available phosphorus (2.96), potassium (2.44), exchangeable calcium (3.00) and magnesium (3.00).

Nutrient indices of subsurface soil

The data depicted in Table 7 revealed that the status of available nitrogen and sulphur was found as low in 16.66 and 96.29 per cent of soil samples, respectively. The status of available nitrogen, phosphorus, potassium and sulphur was found medium in 83.34, 16.66, 83.34 and 3.71 per cent of soil samples, respectively and 83.34, 16.66, 100.00 and 100.00 per cent samples were high in available phosphorus, potassium, exchangeable calcium and magnesium, respectively in subsurface soil. The data further indicated that most of the soils of the study area were low in available sulphur (1.03), medium in available nitrogen (1.83) and high in available phosphorus (2.83), potassium (2.61), exchangeable calcium (3.00) and magnesium (3.00).

Macronutrients content of leaves

Primary macronutrient content

Total nitrogen, phosphorus and potassium content in the cauliflower leaves varied from 1.65 to 4.03, 0.32 to 0.84 and 2.08 to 3.86 per cent with overall mean values of 3.33, 0.50 and 2.70 per cent, respectively (Table 8). The highest content of N, P and K in the cauliflower leaves was observed in villages Rail, Jangloo and Baba Di Kutiya ranging from 3.85 to 3.95, 0.66 to 0.84 and 3.02 to 3.46 per cent with mean values of 3.90, 0.75 and 3.27 per cent, respectively. Whereas, the lowest nitrogen, phosphorus and potassium contents were in Sohri, Buni and Kanjian villages and varied from 1.65 to 1.98, 0.32 to 0.36 and 2.08 to 2.26 per cent with mean values of 1.75, 0.34 and 2.18 per cent, respectively. The cv of 19.08, 26.20 and 15.70 per cent for leaf nitrogen, phosphorus and potassium indicates that these varied spatially.

The sufficient concentration of leaf nitrogen, phosphorus and potassium may be ascribed to the medium availability of nitrogen and high availability of phosphorus and potassium in these soils to the plants. The observations are in agreement with those made by Hochmuth *et al*. (2012) with respect to sufficient concentration of leaf nitrogen (2.2 to 4.0 %), phosphorus (0.3 to 0.7 %) and potassium (1.5 to 3.0%).

Secondary macronutrient content

The data presented in the Table 8 revealed that S, Ca and Mg content in the cauliflower leaves varied from 0.18 to 0.57, 1.09 to 1.88 and 0.30 to 0.83 per cent with overall mean values of 0.41, 1.45 and 0.53 per cent, respectively. The lowest content of S, Ca and Mg was noticed in the villages Kunna, Rail and Khagal ranged from 0.18 to 0.33, 1.09 to 1.18 and 0.30 to 0.45 per cent with mean values of 0.25, 1.14 and 0.37 per cent, respectively. The highest contents of sulphur, calcium and magnesium were recorded in villages Jangloo, Servari and Dera Parol ranged from 0.42 to 0.57, 1.73 to 1.78 and 0.57 to 0.83 per cent with mean values of 0.50, 1.75 and 0.67 per cent, respectively. The cv of 28.76, 15.05 and 20.45 per cent for leaf nitrogen, phosphorus and potassium indicates that these varied spatially.

The content of sulphur in the cauliflower leaves was low which might be due to lower uptake as a result of the depletion of S reserves in soil under intensive cropping in absence of addition of sulphur from any external source.

The concentration of Ca and Mg in cauliflower leaves were recorded as high which might be due to the sufficient content of Ca and Mg in soils. Similar results were given by Hochmuth *et al*. (2012), who reported the sufficient range with regards to Sulphur (0.6 to 1.0 %), Calcium (1.0 to 2.0 %) and Magnesium (0.25 to 0.60 %) content in the cauliflower leaves.

Plant nutrient status

Leaf nitrogen, phosphorus, sulphur and zinc were found in deficient category with the values of 37.00, 1.85 and 92.60 per cent, respectively (Table 9). The status of leaf nitrogen, phosphorus, potassium, sulphur, calcium and magnesium were found in intermediate category with the mean values of 59.30, 87.03, 70.40, 7.40, 100.00 and 48.00 per cent, respectively. The leaf nitrogen, phosphorus, potassium and magnesium were found in high category with the values of 3.70, 11.12, 29.60 and 52.00 per cent, respectively.

Relationship between soil properties and nutrient content of leaves

Relationship of surface soil characteristics with the leaf nutrient content revealed that leaf nitrogen had highest significant positive correlation with available nitrogen (0.71**) (Table 10). Leaf phosphorus content was highly significantly positively correlated with available phosphorus (0.73**) followed by soil pH (0.65**) and available potassium (0.61**). Highest significant positive correlation of leaf potassium was noticed with available potassium (0.79**) followed by phosphorus (0.54**) and available nitrogen (0.53**). Leaf sulphur showed significant positive correlation with available sulphur (0.77**). Leaf magnesium was highly positively correlated with exchangeable magnesium (0.64**) followed by exchangeable calcium (0.34*) and soil pH (0.33*). Likewise, for subsurface (Table 11) leaf nitrogen showed highest significant positive correlation with available phosphorus (0.74**). Leaf phosphorus was highly significantly positively correlated with available phosphorus (0.78**). Leaf potassium was highly positively significantly correlated with available potassium (0.71**). Leaf sulphur was highly significantly and positively correlated with available phosphorus (0.63**) followed by EC (0.61**), soil pH (0.55**) and available sulphur (0.49**). Highest significant positive correlation of leaf calcium was noticed with exchangeable calcium (0.39**). Leaf magnesium was highly positively correlated with exchangeable magnesium (0.67**).

From the present study, it is concluded that available sulphur was found low in nutrient indices. Available nitrogen was medium in nutrient status and the available phosphorus, available potassium, exchangeable calcium and magnesium were found high in nutrients indices. Most of the macronutrient contents of cauliflower leaves of the vegetable growing areas of the Kunah river flood plains of Hamirpur district were sufficient. Sulphur was deficient in most of the leaf samples of cauliflower. Organic carbon showed significant positive correlation with available nitrogen. Significant positive correlation of leaf nitrogen, phosphorus, potassium, sulphur, calcium and magnesium was found with their respective availability in soil. Available nitrogen, available phosphorus and available potassium showed highest positive significant correlation with available phosphorus, available nitrogen and available phosphorus, respectively. Highest positive significant correlation of available sulphur, exchangeable calcium and exchangeable magnesium was observed with potassium, exchangeable magnesium and calcium, respectively.

Table 1. Status of bulk density (BD) in soils of vegetable growing areas of Kunah river flood plains

Village	Bulk density (Mg m^{-3}) Depth (cm)	
	0-15	15-30
Kanjian	1.19(1.17-1.21)	1.24(1.21-1.27)
Sidhpur	1.21(1.15-1.25)	1.25(1.22-1.28)
Dera Parol	1.28(1.25-1.32)	1.30(1.21-1.37)
Mehal	1.21(1.13-1.27)	1.26(1.19-1.32)
Farnol	1.20(1.18-1.23)	1.23(1.19-1.27)
Khagal	1.23(1.19-1.27)	1.25(1.20-1.30)
Neri	1.17(1.14-1.20)	1.20(1.16-1.24)
Baletha Khurd	1.12(1.09-1.15)	1.15(1.13-1.17)
Sohri	1.18(1.15-1.22)	1.20(1.13-1.28)
Khola Plassi	1.15(1.12-1.18)	1.17(1.15-1.19)
Kunna	1.24(1.20-1.29)	1.26(1.18-1.35)
Buni	1.23(1.19-1.27)	1.27(1.19-1.33)
Servari	1.20(1.15-1.25)	1.23(1.19-1.28)
Rail	1.20(1.13-1.26)	1.24(1.21-1.27)
Fathepur	1.24(1.21-1.27)	1.30(1.26-1.35)
Baba Di Kutiya	1.22(1.20-1.24)	1.25(1.21-1.30)
Kutheda	1.20(1.16-1.24)	1.24(1.20-1.29)
Jangloo	1.21(1.18-1.23)	1.25(1.21-1.30)
Range	**1.09-1.32**	**1.13-1.37**
Overall mean	**1.21**	**1.24**
SE±	**0.01**	**0.01**
CV (%)	**4.05**	**4.21**

* Values in parenthesis indicates range

Table 2. Status of soil texture in surface (0-15 cm) and subsurface soils (15-30 cm) of vegetable growing areas of Kunah river flood plains

Village	% Sand	% Silt	% Clay	Textural class	% Sand	% Silt	% Clay	Textural class
	0-15 cm				15-30 cm			
Kanjian	45.8 (42.4-48.2)	38.6 (37.0-41.3)	15.6 (14.3-16.3)	Loam	50.4 (47.2-52.4)	34.0 (30.2-37.1)	15.6 (13.2-18.6)	Loam
Sidhpur	48.0 (45.4-51.4)	28.0 (24.2-34.2)	24.0 (20.2-29.2)	Sandy clay loam	51.3 (50.4-52.3)	29.7 (26.4-31.7)	19.0 (17.3-21.2)	Loam
Dera Parol	51.4 (50.3-52.5)	30.7 (28.3-33.2)	17.9 (14.2-21.1)	Loam	51.4 (49.1-53.5)	30.0 (26.3-32.4)	18.6 (16.2-20.7)	Loam
Mehal	46.8 (43.1-51.4)	38.6 (34.0-41.1)	14.6 (13.3-16.3)	Loam	47.7 (41.3-52.4)	35.3 (30.2-36.4)	17.0 (14.1-18.2)	Loam
Farnol	50.4 (43.6-53.2)	32.6 (27.3-33.3)	17.0 (13.2-19.2)	Loam	50.1 (47.4-52.6)	24.0 (21.2-29.2)	25.9 (20.2-31.3)	Sandy clay loam
Khagal	50.7 (48.2-53.4)	34.9 (32.2-40.2)	14.4 (11.2-17.2)	Loam	51.8 (51.6-52.5)	34.3 (30.1-36.3)	13.9 (12.2-17.2)	Loam
Neri	43.2 (36.4-48.5)	34.3 (25.1-45.4)	22.5 (17.1-29.4)	Loam	44.8 (43.2-46.0)	32.6 (26.2-37.5)	22.6 (19.3-25.4)	Loam
Black Khurd	32.2 (25.4-39.4)	43.2 (36.0-53.2)	24.6 (20.2-27.2)	Loam	36.4 (32.4-39.4)	39.7 (35.2-46.2)	23.9 (21.7-25.5)	Loam
Sohri	45.7 (39.4-53.3)	31.6 (21.2-38.2)	22.7 (12.8-25.5)	Loam	49.5 (41.7-54.3)	32.5 (28.3-37.3)	18.0 (15.4-21.2)	Loam
Khota Plassi	41.5 (33.2-51.6)	34.6 (31.2-41.2)	23.9 (17.8-29.3)	Loam	42.8 (31.4-49.4)	33.9 (27.2-45.4)	23.3 (21.2-25.6)	Loam
Kunna	48.9 (45.3-52.5)	32.9 (27.2-42.6)	18.2 (12.2-24.2)	Loam	52.7 (52.5-53.7)	26.6 (23.1-32.7)	20.7 (15.1-24.3)	Sandy clay loam
Buni	47.9 (41.4-51.4)	33.2 (27.4-37.2)	18.9 (14.3-21.6)	Loam	54.3 (52.4-55.4)	31.1 (30.2-32.0)	14.6 (12.3-17.2)	Sandy loam
Servari	46.5 (43.1-48.7)	32.6 (25.2-35.4)	20.9 (17.3-21.2)	Loam	47.8 (41.8-50.6)	33.2 (27.6-37.2)	19.0 (17.2-20.1)	Loam
Rail	48.1 (41.4-52.2)	32.7 (28.2-35.3)	19.2 (14.7-24.1)	Loam	51.4 (50.1-52.7)	29.2 (27.2-31.4)	19.4 (17.4-20.0)	Loam
Fathepur	51.8 (50.4-53.4)	30.3 (25.8-33.2)	17.9 (15.3-21.2)	Loam	53.1 (51.4-55.4)	29.6 (29.3-30.5)	17.3 (15.2-19.2)	Sandy loam
Baba Di Kutiya	50.8 (48.6-52.2)	27.9 (25.2-29.2)	21.3 (19.2-22.7)	Sandy clay loam	47.4 (41.0-51.7)	30.3 (23.0-37.2)	22.3 (18.3-27.5)	Loam
Kutheda	47.4 (43.5-48.7)	33.9 (31.6-35.5)	18.7 (16.1-21.3)	Loam	51.1 (50.2-51.3)	29.2 (23.2-34.7)	19.7 (15.7-25.2)	Loam
Jangloo	47.5 (44.4-52.4)	32.7 (26.2-38.2)	19.8 (17.8-21.8)	Loam	52.7 (50.2-55.4)	27.6 (25.1-29.2)	19.7 (18.2-22.4)	Sandy loam
Range	**25.4-53.4**	**21.2-53.2**	**11.2-29.3**		**31.4-55.4**	**21.2-46.2**	**12.2-31.3**	
Overall mean	**46.9**	**33.3**	**19.8**		**49.1**	**30.9**	**20.0**	
SE±	**0.79**	**0.82**	**0.62**		**0.73**	**0.70**	**0.55**	
CV (%)	**12.43**	**18.09**	**23.52**		**11.00**	**16.72**	**20.89**	

* Values in parenthesis indicates range

Table 3. Status of pH, electrical conductivity (EC) and organic carbon (OC) in the soil of vegetable growing areas of Kunah river flood plains

Village	Soil pH		Electrical conductivity (dS m^{-1})		Organic carbon (g kg^{-1})	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Kanjian	6.53(6.39-6.75)	6.60(6.40-6.85)	0.18(0.11-0.26)	0.16(0.12-0.21)	20.7(19.2-23.0)	18.5(14.5-23.0)
Sidhpur	6.62(6.45-6.89)	6.80(6.72-6.88)	0.20(0.18-0.23)	0.17(0.11-0.23)	20.0(17.9-21.4)	18.1(13.0-24.0)
Dera Parol	6.77(6.60-6.89)	6.91(6.83-7.00)	0.21(0.14-0.26)	0.18(0.12-0.24)	18.3(15.2-22.0)	16.2(14.0-18.5)
Mehal	6.83(6.75-6.90)	6.92(6.85-7.02)	0.24(0.20-0.28)	0.20(0.17-0.23)	19.3(16.0-24.0)	15.0(14.0-16.0)
Farnol	6.65(6.55-6.80)	6.68(6.58-6.884)	0.21(0.18-0.25)	0.19(0.17-0.21)	24.3(20.6-27.6)	22.0(17.0-28.0)
Khagal	6.72(6.60-6.81)	6.74(6.57-6.83)	0.25(0.19-0.31)	0.29(0.28-0.31)	26.2(23.4-28.6)	23.0(18.3-29.4)
Neri	6.63(6.46-6.89)	6.78(6.60-6.90)	0.23(0.13-0.26)	0.17(0.10-0.24)	26.5(22.3-30.4)	22.6(18.0-27.3)
Baletha Khurd	6.74(6.57-6.83)	6.76(6.60-6.88)	0.28(0.24-0.33)	0.24(0.18-0.28)	28.9(18.1-36.1)	26.8(22.3-31.0)
Sohri	6.74(6.56-6.84)	6.92(6.82-7.03)	0.29(0.24-0.34)	0.22(0.19-0.25)	29.5(19.1-37.1)	27.1(24.3-32.1)
Khola Plassi	6.61(6.45-6.86)	6.72(6.60-6.84)	0.30(0.22-.40)	0.25(0.20-0.30)	22.4(18.4-27.4)	19.1(15.3-25.0)
Kunna	6.71(6.59-6.84)	6.95(6.90-7.0)	0.27(0.22-0.35)	0.20(0.17-0.23)	29.7(22.4-35.5)	27.8(23.3-33.0)
Buni	6.63(6.30-6.90)	6.73(6.55-6.84)	0.25(0.18-0.32)	0.22(0.18-0.26)	29.6(20.4-36.3)	25.7(19.1-32.7)
Servari	6.88(6.67-7.00)	6.98(6.91-7.05)	0.28(0.21-0.33)	0.25(0.18-0.32)	24.8(21.6-28.5)	23.8(18.4-29.6)
Rail	6.78(6.60-6.90)	6.92(6.70-7.06)	0.25(0.15-0.32)	0.14(0.12-0.16)	26.7(21.5-31.7)	22.6(19.2-26.3)
Fathepur	6.83(6.75-6.89)	6.95(6.80-7.10)	0.29(0.23-0.34)	0.26(0.24-0.28)	26.7(20.6-33.7)	23.1(17.3-30.4)
Baba Di Kutiya	6.90(6.57-7.21)	6.99(6.90-7.11)	0.40(0.39-0.46)	0.32(0.27-0.38)	26.0(20.0-32.0)	25.1(18.1-32.1)
Kutheda	6.81(6.63-7.00)	7.04(6.97-7.12)	0.36(0.22-0.38)	0.28(0.21-0.32)	29.4(21.4-35.4)	27.0(22.1-32.8)
Jangloo	7.14(6.95-7.37)	7.19(7.10-7.28)	0.38(0.30-0.43)	0.31(0.26-0.37)	29.2(24.4-33.4)	25.9(16.1-33.2)
Range	**6.30-7.37**	**6.40-7.28**	**0.11-0.46**	**0.10-0.38**	**15.2-37.1**	**13.0-33.2**
Overall mean	**6.73**	**7.12**	**0.26**	**0.21**	**25.02**	**22.54**
SE±	**0.03**	**0.06**	**0.01**	**0.01**	**0.45**	**0.37**
CV (%)	**3.43**	**6.51**	**32.36**	**30.73**	**16.11**	**17.48**

* Values in parenthesis indicates range

Table 4. Status of available nitrogen, phosphorus and potassium (kg ha^{-1}) in the soils of vegetable growing areas of Kunah river flood plains

Village	N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Kanjian	328.65 (321.86-339.00)	302.79 (288.72-318.19)	40.53 (33.44-52.70)	31.75 (26.35-38.51)	162.19 (140.92-180.55)	138.63 (132.40-143.20)
Sidhpur	334.17 (326.15-342.28)	297.82 (281.36-311.92)	39.93 (36.80-42.65)	32.87 (28.34-37.40)	207.46 (198.17-217.29)	194.00 (176.06-212.43)
Dera Parol	325.43 (296.16-343.35)	263.97 (240.08-282.32)	36.90 (31.46-41.86)	35.62 (33.56-38.18)	264.08 (248.06-279.10)	243.94 (211.47-272.16)
Mehal	355.70 (338.21-365.81)	304.54 (290.81-320.79)	46.66 (36.48-52.70)	38.51 (30.40-43.58)	257.44 (244.77-266.56)	208.55 (197.21-219.15)
Farnol	326.52 (309.24-342.23)	287.54 (274.69-298.19)	44.56 (38.55-48.63)	30.06 (28.38-32.43)	301.97 (262.21-364.00)	280.38 (252.22-332.75)
Khagal	340.41 (336.45-344.12)	308.71 (295.81-323.79)	44.24 (39.40-51.00)	33.12 (30.18-37.04)	260.49 (254.00-266.32)	241.62 (234.38-246.49)
Neri	343.31 (338.40-348.45)	317.48 (283.27-350.86)	40.97 (31.42-57.04)	30.26 (23.92-41.55)	288.31 (277.52-297.45)	276.45 (270.25-283.40)
Baletha Khurd	367.87 (356.42-376.12)	359.64 (334.11-386.59)	47.61 (42.57-53.67)	43.28 (38.50-48.10)	317.82 (288.95-357.67)	288.47 (280.46-300.20)
Sohri	279.97 (261.54-295.64)	249.58 (214.10-284.42)	35.32 (30.45-41.25)	22.86 (16.19-24.23)	223.69 (176.95-275.88)	187.02 (172.88-198.43)
Khota Plassi	313.83 (305.50-318.40)	353.08 (308.51-390.63)	39.18 (34.46-46.62)	32.02 (28.05-36.00)	265.78 (220.70-290.05)	222.72 (208.67-247.37)
Kunna	323.98 (316.61-330.01)	257.39 (247.36-263.51)	29.39 (24.33-37.50)	27.36 (22.29-33.44)	292.10 (278.15-308.00)	261.88 (255.65-266.75)
Buni	334.43 (327.40-341.40)	324.35 (279.11-363.68)	30.62 (25.33-39.19)	25.77 (21.28-32.74)	167.58 (139.93-207.66)	146.17 (135.50-158.60)
Servari	336.30 (330.40-342.30)	356.66 (339.75-387.36)	44.58 (24.38-60.81)	37.16 (23.31-49.66)	286.20 (225.57-320.60)	246.54 (202.67-281.27)
Rail	344.16 (338.18-345.21)	328.53 (312.23-345.23)	41.23 (36.84-45.80)	32.93 (26.40-39.56)	319.18 (310.15-332.10)	293.93 (286.40-301.10)
Fathepur	360.27 (352.46-370.18)	331.64 (292.36-386.12)	46.59 (43.58-49.66)	40.86 (35.47-45.58)	260.06 (241.18-279.41)	239.60 (214.36-276.44)
Baba Di Kutiya	353.81 (348.45-358.62)	337.34 (298.36-395.15)	48.99 (39.51-59.78)	42.88 (35.46-48.62)	311.70 (239.90-388.16)	246.74 (219.24-262.59)
Kutheda	360.78 (336.11-387.59)	348.82 (340.18-358.21)	49.99 (44.59-58.78)	47.97 (44.59-49.68)	291.68 (284.15-295.25)	286.51 (278.45-293.76)
Jangloo	391.25 (385.25-395.35)	374.38 (368.05-381.70)	57.43 (50.67-63.85)	52.08 (46.35-59.47)	309.33 (298.45-320.18)	247.04 (238.15-256.02)
Range	**261.54-395.35**	**214.10-395.15**	**24.33-63.85**	**16.19-59.47**	**139.93-388.16**	**132.40-332.75**
Overall mean	**338.62**	**316.87**	**42.68**	**34.86**	**258.77**	**225.53**
SE±	**4.24**	**5.78**	**1.44**	**1.36**	**7.98**	**6.96**
CV (%)	**9.46**	**14.93**	**24.46**	**27.56**	**23.19**	**22.68**

* Values in parenthesis indicates range

Table 5. Status of available sulphur (kg ha^{-1}), exchangeable calcium and magnesium content [cmol (p$^+$) kg^{-1}] in the soils of vegetable growing areas of Kunah river flood plains

Village	S (kg ha^{-1})		Ca (cmol (p$^+$) kg^{-1})		Mg (cmol (p$^+$) kg^{-1}	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Kanjian	12.48(10.54-15.84)	11.38(9.10-14.20)	3.41(3.02-3.84)	2.98(2.70-3.50)	2.18(1.97-2.19)	1.97(1.87-2.07)
Sidhpur	15.00(11.08-17.05)	13.88(10.02-15.84)	2.93(2.64-3.40)	2.87(2.53-3.20)	2.22(2.01-2.63)	2.02(1.77-2.42)
Dera Parol	19.55(18.00-22.17)	17.06(14.25-20.58)	3.64(3.50-3.91)	3.61(3.17-3.90)	3.79(3.74-3.98)	3.62(3.40-3.88)
Mehal	17.79(14.78-20.54)	16.53(12.73-19.48)	3.33(3.23-3.47)	3.30(2.82-3.43)	3.37(2.71-3.96)	3.29(2.62-3.85)
Farnol	17.62(16.04-19.20)	15.51(14.00-17.08)	3.40(3.22-3.67)	3.23(2.61-3.89)	3.74(3.34-3.96)	3.52(3.41-3.83)
Khagal	18.79(15.96-20.73)	17.41(11.92-23.10)	3.29(2.83-3.61)	3.12(2.71-3.72)	1.89(1.61-2.18)	1.52(1.25-1.93)
Neri	19.26(18.06-21.47)	16.36(15.40-17.30)	2.65(2.45-2.89)	2.35(2.23-2.54)	2.02(1.87-2.18)	1.60(1.27-1.81)
Baletha Khurd	16.68(12.46-19.85)	14.97(10.50-18.06)	3.32(3.10-3.60)	2.93(2.66-3.35)	3.03(2.37-3.95)	2.93(2.16-3.62)
Sohri	19.79(17.69-21.72)	15.90(13.77-19.26)	2.63(2.54-2.73)	2.60(2.40-2.75)	2.59(2.30-2.92)	2.35(2.12-2.63)
Khola Plassi	17.96(16.99-19.54)	15.77(15.20-16.24)	3.96(3.50-4.49)	3.83(3.32-4.21)	3.36(3.20-3.53)	2.70(2.06-3.41)
Kunna	11.74(11.39-12.04)	15.43(12.10-19.10)	3.53(2.73-4.01)	2.92(2.32-3.68)	2.76(2.36-3.35)	2.50(2.10-3.02)
Buni	15.83(13.07-19.60)	13.19(12.62-13.83)	3.63(2.91-4.40)	2.99(2.01-3.71)	3.70(3.56-3.92)	3.22(3.06-3.56)
Servari	17.86(15.86-19.46)	10.42(9.18-11.17)	3.63(3.10-3.99)	3.61(3.09-3.96)	3.45(3.12-3.95)	3.35(3.00-3.73)
Rail	21.02(18.41-22.48)	16.89(14.25-19.01)	2.36(1.74-3.47)	1.96(1.51-2.57)	2.82(2.26-3.73)	2.62(1.91-3.65)
Fathepur	19.95(18.06-21.22)	18.93(18.25-19.82)	3.72(3.33-4.00)	3.47(3.35-3.61)	3.30(3.14-3.53)	3.02(2.63-3.38)
Baba Di Kutiya	17.84(16.39-18.82)	12.38(10.55-15.88)	3.21(2.70-3.62)	3.08(2.83-3.22)	3.01(2.38-3.47)	2.52(2.06-2.85)
Kutheda	18.49(14.76-20.96)	12.34(8.45-16.18)	3.16(2.45-3.77)	2.94(2.10-3.75)	2.97(2.59-3.12)	2.69(2.57-2.80)
Jangloo	21.81(20.97-23.24)	18.96(16.47-24.08)	3.42(3.14-3.87)	3.35(3.10-3.62)	3.33(3.26-3.42)	3.15(3.10-3.23)
Range	**10.54-23.24**	**8.45-24.08**	**1.74-4.49**	**1.51-4.21**	**1.61-3.98**	**1.25-3.88**
Overall mean	**17.58**	**15.09**	**2.96**	**3.40**	**3.01**	**2.75**
SE±	**0.48**	**0.47**	**0.09**	**0.07**	**0.09**	**0.10**
CV (%)	**19.36**	**21.55**	**20.11**	**14.96**	**21.48**	**25.74**

* Values in parenthesis indicates range

Table 6. Nutrient indices of surface soils of the vegetable growing areas of Kunah river flood plains

Nutrient	Percentage of samples rating			Nutrient Index	Nutrient Status
	Low	Medium	High		
Nitrogen	1.85	98.15	-	1.98	Medium
Phosphorus	-	3.70	96.30	2.96	High
Potassium	-	55.55	44.45	2.44	High
Sulphur	96.29	3.71	-	1.03	Low
Calcium	-	-	100.00	3.00	High
Magnesium	-	-	100.00	3.00	High

Table 7. Nutrient Indices of subsurface soils of the vegetable growing areas of Kunah river flood plains

Nutrient	Percentage of samples rating			Nutrient Index	Nutrient Status
	Low	Medium	High		
Nitrogen	16.66	83.34	-	1.83	Medium
Phosphorus	-	16.66	83.34	2.83	High
Potassium	-	83.34	16.66	2.61	High
Sulphur	96.29	3.71	-	1.03	Low
Calcium	-	-	100.00	3.00	High
Magnesium	-	-	100.00	3.00	High

Table 8. Content of total N, P, K, S, Ca and Mg content (per cent) in cauliflower leaves

Village	Nitrogen	Phosphorus	Potassium	Sulphur	Calcium	Magnesium
Kanjian	2.84(2.76-2.90)	0.44(0.41-0.49)	2.18(2.08-2.26)	0.31(0.24-0.37)	1.55(1.63-1.87)	0.50(0.45-0.57)
Sidhpur	2.71(2.02-2.79)	0.53(0.46-0.63)	2.34(2.26-2.41)	0.32(0.22-0.35)	1.51(1.44-1.59)	0.46(0.39-0.53)
Dera Parol	3.05(2.90-3.24)	0.62(0.52-0.74)	2.59(2.52-2.67)	0.39(0.36-0.43)	1.69(1.55-1.88)	0.67(0.57-0.83)
Mehal	2.96(2.88-3.05)	0.42(0.38-0.47)	2.50(2.20-2.83)	0.36(0.26-0.51)	1.33(1.24-1.41)	0.53(0.48-0.61)
Farnol	2.83(2.74-2.91)	0.55(0.49-0.81)	2.73(2.35-2.97)	0.32(0.26-0.43)	1.27(1.18-1.37)	0.48(0.41-0.55)
Khagal	3.13(2.35-3.58)	0.63(0.56-0.74)	2.90(2.83-2.96)	0.37(0.30-0.44)	1.23(1.17-1.28)	0.37(0.30-0.45)
Neri	2.92(2.86-2.98)	0.48(0.39-0.60)	3.17(2.36-3.86)	0.38(0.32-0.43)	1.58(1.51-1.66)	0.43(0.37-0.52)
Baletha Khurd	2.73(2.46-2.95)	0.52(0.48-0.57)	2.83(2.56-3.17)	0.34(0.26-0.40)	1.20(1.14-1.25)	0.65(0.58-0.74)
Sohri	1.75(1.65-1.98)	0.41(0.40-0.44)	2.25(2.23-2.27)	0.36(0.31-0.38)	1.43(1.13-1.82)	0.50(0.40-0.61)
Khola Plassi	2.80(2.06-2.89)	0.46(0.41-0.52)	2.32(2.26-3.12)	0.38(0.29-0.47)	1.34(1.25-1.44)	0.57(0.48-0.65)
Kunna	2.72(2.35-3.01)	0.49(0.39-0.61)	2.35(2.28-3.46)	0.25(0.18-0.33)	1.66(1.58-1.77)	0.49(0.40-0.58)
Buni	2.48(2.40-2.56)	0.34(0.32-0.36)	2.28(2.08-2.51)	0.37(0.33-0.41)	1.57(1.46-1.68)	0.57(0.44-0.69)
Servari	2.90(2.68-3.14)	0.50(0.41-0.61)	3.00(2.42-3.36)	0.41(0.35-0.46)	1.75(1.73-1.78)	0.61(0.55-0.66)
Rail	3.90(3.85-3.95)	0.47(0.39-0.58)	3.15(3.08-3.21)	0.39(0.38-0.41)	1.14(1.09-1.18)	0.52(0.40-0.60)
Fathepur	3.36(3.29-3.43)	0.49(0.42-0.57)	2.56(2.37-2.91)	0.35(0.27-0.45)	1.28(1.17-1.46)	0.48(0.40-0.57)
Baba Di Kutiya	3.63(3.30-4.03)	0.64(0.53-0.74)	3.27(3.02-3.46)	0.40(0.33-0.48)	1.51(1.42-1.61)	0.44(0.38-0.51)
Kutheda	3.81(3.74-3.84)	0.72(0.64-0.79)	2.71(2.33-3.24)	0.43(0.39-0.51)	1.56(1.48-1.65)	0.63(0.56-0.71)
Jangloo	3.75(3.68-3.84)	0.75(0.66-0.84)	2.86(2.78-2.94)	0.50(0.42-0.57)	1.36(1.28-1.44)	0.62(0.54-0.70)
Range	**1.65-4.03**	**0.32-0.84**	**2.08-3.86**	**0.18-0.57**	**1.09-1.88**	**0.30-0.83**
Overallmean	**3.33**	**0.50**	**2.70**	**0.41**	**1.45**	**0.53**
SE±	**0.38**	**0.02**	**0.06**	**0.02**	**0.03**	**0.01**
CV (%)	**19.08**	**26.20**	**15.70**	**28.76**	**15.05**	**20.25**

* Values in parenthesis indicates range

Table 9.Per cent plant samples falling in various categories of nutrient levels

Nutrient elements	Per cent samples		
	Deficient	Intermediate	High
Nitrogen	37.00	59.30	3.70
Phosphorus	1.85	87.03	11.12
Potassium	-	70.40	29.60
Sulphur	92.60	7.40	-
Calcium	-	100.00	-
Magnesium	-	48.00	52.00

Table 10. Simple relationship (r) between surface layer (0-15 cm) soil characteristics and leaf nutrient status

Soil/ Leaf	BD	% Sand	% Silt	% Clay	Soil pH	EC	O C	N	P	K	S	Ca	Mg
Leaf N	0.20	0.28*	-0.14	-0.25	0.53**	0.42**	0.00	0.71**	0.70**	0.61**	0.40**	-0.15	-0.02
Leaf P	0.22	0.23	-0.16	-0.15	0.65**	0.59**	0.01	0.60**	0.73**	0.61**	0.37**	0.06	0.05
Leaf K	-0.08	0.02	-0.10	0.09	0.44**	0.42**	0.21	0.53**	0.54**	0.79**	0.52**	-0.35**	-0.06
Leaf S	-0.01	0.04	-0.15	0.11	0.70**	0.59**	0.16	0.49**	0.64**	0.49**	0.77**	-0.05	0.26
Leaf Ca	0.35**	0.20	-0.31*	0.07	-0.04	-0.15	-0.13	-0.22	-0.37**	-0.33*	-0.39**	0.22	0.05
Leaf Mg	-0.10	-0.36**	0.27*	0.21	0.33*	0.02	0.01	0.22	0.15	0.19	0.15	0.34*	0.64**

**. Significant at the 0.01 level

*. Significant at the 0.05 level

Table 11. Simple relationship (r) between subsurface layer (15-30 cm) soil properties and leaves nutrient status

Soil/Leaf	B.D	% Sand	% Silt	% Clay	Soil pH	EC	O C	N	P	K	S	Ca	Mg
Leaf N	0.55**	0.14	-0.27*	0.12	0.39**	0.41**	0.00	0.50**	0.74**	0.60**	0.21	-0.07	0.03
Leaf P	0.34**	0.08	-0.26	0.17	0.58**	0.57**	0.08	0.32*	0.78**	0.49**	0.19	0.25	0.11
Leaf K	0.14	-0.23	-0.03	0.34*	0.20	0.40**	0.21	0.37**	0.44**	0.71**	0.29*	-0.25	-0.04
Leaf S	0.11	0.03	0.00	-0.03	0.55**	0.61**	0.12	0.40**	0.63**	0.20	0.49**	0.15	0.24
Leaf Ca	0.14	0.22	-0.15	-0.13	0.30*	-0.21	0.00	-0.02	-0.15	-0.26	-0.50**	0.39**	0.02
Leaf Mg	-0.06	-0.21	0.13	0.14	0.30*	0.08	0.05	0.10	0.42**	0.12	0.05	0.34*	0.67**

**. Significant at the 0.01 level

*. Significant at the 0.05 level

REFERENCES

Anonymous. 2018. Indian Horticulture Database.National Horticulture Board.

Babu, M. V. S., M. C. Reddy, A. Subramanyam and D. Balaguravaih, 2007.Effect of integrated use of organic and inorganic fertilizers on soil properties and yield of sugarcane. J. Indian Soc. Soil Sci.**55**: 161-166.

Bali, S. K., R. Kumar, H. S. Hundal, K. Singh and B. Singh, 2010. GIS aided mapping of DTPA extractable zinc and soil characteristics in the state of Punjab. J. Indian Soc. Soil Sci.**58**: 189-199.

Baruah, B. K., B. Das, C. Medhi and A. K. Misra, 2013. Fertility status of soil in the tea garden belts of Golaghat district, Assam, India.J. Chem. https://doi.org/10.1155/2013/983297(20th May, 2018).

Bouyoucos, G.J. 1927. The hydrometer as a new method for the mechanical analysis of soils.Soil Sci.**23**:343-352.

Black, C.A. 1965. Methods of Soil Analysis. Part II. American Society of Agronomy, Madison, Wisconsin, USA. pp. 1572.

Chandel, S., D.Tripathi and R.Kakar, 2017. Soil health assessment under protected cultivation of vegetable crops in North West Himalayas. J. Environ. Biol.**38**:97-103.

Chapman, H. D. 1964. Suggested foliar sampling and handling techniques for determining the nutrient status of some field, horticultural and plantation crops.Indian J.Hortic. **21**(2):97-116.

Chesnin, L. and C. H. Yien, 1950.Turbidimetric determination of available sulphates.Soil Sci. Soc. Am. Proc.**15**:149-151.

Gupta, R. D. and B. R. Tripathi, 1989.Morphological, physico-chemical, mineralogical properties and pedogenesis of some rice growing soil profiles occurring in Kangra district of Himachal Pradesh (India).Oryza.**26**: 263-272.

Hochmuth, G., D.Maynard, C.Vavrina, E.Hanlon and E.Simonn, 2012.Plant tissue analysis and interpretation for vegetable crops in Florida.University of Florida.Cooperative Extension Service.The Institute of Food and Agricultural Sciences.pp.48.

Jackson, M. L. 1973. Soil Chemical Analysis.Prentice Hall of India Pvt. Ltd., New Delhi.

Kaistha, B. P. and R. D. Gupta, 1993.Morphology, mineralogy, genesis and classification of soils of the sub-humid temperate high lands of the central Himalayas. J. Indian Soc. Soil Sci.**41**:120-124.

Kaur, M. 2017. Nutritional Survey of Pomegranate (*Punica Granatum* L.)Orchards in Kullu District of Himachal Pradesh. M.Sc. Thesis. Department of Soil Science and Water Management, YSP University of Horticulture & Forestry, Solan.pp.77.

Kensworthy, A. L. 1964. Fruit, Nut and Plantation Crops- A guide for collection of foliar samples for nutrient element analysis.Horticulture Department, Memordium Michigan State University East Lansing,pp.39.

Khajuria N, D.Tripathi, R.Kumar, V.Sharma and S. S. Pathania. 2015. Characteristics and soil fertility appraisal of forest nursery soils of Bilaspur circle in Himachal Pradesh. Ecol. Environ. Conserv J. **21**:379-383.

Krishna, P.K., M. Nair, L. G. K. Naidu, S. Seinivas, K. Arti, R. A. Nasre, M. Ramesh and K. S. Gajbhiya, 2004. Land, soils and land use of Lakshdeep Coral Islands. J. Indian Soc. Soil Sci.**52**: 226-231.

Kumar, R., K. P. Singh and S. Singh, 2002.Vertical distribution of sulphur fractions and their relation among carbon, nitrogen and sulphur in acidic soils of Jharkhand. J. Indian Soc. Soil Sci. **50**: 502-505.

Kumar R, S. S. Paliyal, Sharma and R. S. Rana, 2017. Status and distribution of available macronutrients in relation to physico- chemical properties under different land uses of cold arid soils of Spiti valley in Himachal Pradesh. Ecol. Environ. Conserv. J.**18**:79-86.

Loria, N. S., K. Bhardwaj and K. N. Charles, 2016.Impact of cropping systems on soil properties nutrient availability and their carbon sequestration potential in Shiwalik hills of Himachal Pradesh.J. Appl. Nat.Sci. **8**:1479-1484.

Nilima, S. S., M.S.S. Nagaraju and I. T. Sonal, 2017.Vertical distribution of available macro and micronutrients in Nagalvadi micro-watershed of Wardha district, Maharashtra.J.Soils and Crops. **27**(2): 26-29.

Olsen, S. R., C. V. Cole, F. S. Watanable and L. A. Dean, 1954.Estimation of available posphorous in soil by extraction with sodium bicarbonate.United States Department of Agriculture Circular. **939**:1-19.

Pal, S., P. Panwar and D. R. Bhardwaj, 2013. Soil quality under forest compared to other land-uses in acid soil of North Western Himalaya, India. Ann. For. Res.**56**: 187-198.

Piper, C. D. 1950.Soil and Plant Analysis. Scientific Publications, New York,pp.257.

Raghupathi, H. B. 1993. Analysis of Plant material for macro and micronutrient. In H.L.S. Tandon (ed.) Methods of Analysis of Soils, plants, water and fertilizers, FDACO, New Delhi pp. 49-82.

Reuter, D. J. and J. B. Robinson, 1986. Plant Analysis-An Interpretation Manual.Inkata Press, Melbourne, Sydney,pp.1-80.

Sharma, A. 2011.Status and Distribution of Micronutrients under Different Land Uses in Soils of Kangra District. M.Sc. Thesis. Department of Soil Science, Himachal Pradesh KrishiVishvavidalya, Palampur, India, pp. 122.

Sharma, S. S., K. L. Totawat and R. L. Shyampura, 1996. Characterization and classification of soils in a to posequence over Besaltic Terrain.J. Indian Soc. Soil Sci.**44**: 470-475.

Sharma, V. and B. B. Kanwar, 2010. Copper status and its relation with soil properties in pea growing soils of high hills dry temperate zone of Himachal Pradesh. Indian J. Agric. Res.**44**:32-37.

Singh, R.K. and B.D. Chaudhry, 1994.Biometrical methods in quantitative genetic analysis.Kalyani Publishers, New Delhi, India, pp. 54-58.

Subbiah, B. V. and G. L. Asija, 1956.Rapid method for estimation of available nitrogen in soils.Curr. Sci. **25**:259-260.

Tripathi, D.,K. Singh and G. P. Upadhyay, 1994. Distribution of micronutrients in some representative soil profiles of Himachal Pradesh. J. Indian Soc. Soil Sci.**42**: 143-145.

Walkley, A. and I. A. Black, 1934.Examination of the method for determining soil organic matter and a proposed modification of the chromic acid titration method.Soil Sci. **37**:9-38.

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