ISSN: 0973-4929, Vol. 16, No. (3) 2021, Pg. 818-835

Current World Environment

www.cwejournal.org

# Soil Nutrient Evaluation and Crop Management for Sustainable Growth of Patiya village Cluster in Almora, Uttarakhand

**PRABHAS KUMAR PANDE[1]*, RAKESH KUMAR[2], SEEMA GUPTA[3], RAJESH SACHDEV[3], MUKTA DATTA MAZUMDER[3], and LOVELEEN SATAPATHY[4]**

[1]Department of Geology, Ram Lal Anand College, University of Delhi, New Delhi-110021, India.
[2]Department of History, Ram Lal Anand College, University of Delhi, New Delhi-110021, India.
[3]Department of Statistics, Ram Lal Anand College, University of Delhi, New Delhi-110021, India.
[4]JRF [Geology & Environment (NMHS Project)], Ram Lal Anand College, University of Delhi, New Delhi-110021, India.

**Abstract**

The present study deals with the assessment of soil nutrients at four adjacent villages, 15 km NE of Almora, to understand the soil fertility and suitability of crops to help rejuvenate the agricultural activities in the region which subsequently will be used as a testing ground to mitigate prevailing Human-Wildlife Conflict in the study area. Soil samples were analyzed for textural classification, power of hydrogen (pH), Electrical Conductivity (EC), Organic Carbon percentage (OC%), available Nitrogen (N), Potassium (K), Sulphur (S), Boron (B), Manganese (Mn), 0.1M Hydrochloric Acid (HCl), and Diethylene Triamine Pentaacetic Acid (DTPA) extractable, Iron (Fe), Zinc (Zn), and Copper (Cu) to examine the soil fertility of the area. The soils of the region vary from loam to sandy loam. The soil reaction varies from slight to extremely acidic whereas the salinity was varying from non-saline to slightly saline. Low soil fertility index of N, P, K, Zn, B, and Fe; and medium soil fertility index of S, Mn, and Cu were observed, which is suggestive of additional requirement of Farm Yard Manure (FYM) and fertilizers to make them suitable for plantation. Through this study, an attempt has been made to recommend the selection and cultivation of high yield indigenous cash crops with the support of bio-fertilizers to maximize the use and production of these fallow lands and enhance the agricultural activities in the region and provide better livelihood options. The shift from the traditional method of plowing and sowing to new basic techniques has brought about encouraging results to the extent that these fields have now become favorite destinations of wild boars and monkeys. Hence, allowing us to mitigate this problem through various means.

**Article History**
Received: 03 June 2021
Accepted: 20 December 2021

**Keywords**
Crops;
Kumaon;
Macronutrients;
Micronutrients;
Nutrient Indices;
Patiya, Almora;
Soil Fertility;
Uttarakhand.

**CONTACT** Prabhas Kumar Pande prabhaspandey.geo@rla.du.ac.in Department of Geology, Ram Lal Anand College, University of Delhi, New Delhi-110021, India.


Doi: http://dx.doi.org/10.12944/CWE.16.3.14

**Introduction**

The mountainous regions have a wide range of macro and micro climate due to a great influence on soil genesis processes and vegetation[1]. The genesis and characteristics of soils derived from various metamorphic rocks in Kumaon Himalayas were studied, and the soils were classified under three soil orders viz. Entisols, Inceptisols, and Alfisols.[1,2]

The study area, falling in the Almora District, Uttarakhand (India), covering nearly 25 km$^2$ of geographical area, lying between an elevation of 1300 m to 1550 m above MSL, is located between the latitude of 29º38'N to 29º42'N and longitude of 79º38'E to 79º43'E.The temperature range was found to be between 31.3ºC and 3.43ºC. The average annual rainfall in the region is around 1013.9 mm, mainly confining to the rainy season. Agriculture was one of the major occupations of the hill people because of the presence of various agro-climate zones along the altitudinal gradient. In the past few decades, it has been greatly affected due to the harsh climatic conditions resulting in un-predictable rains and drying natural run-offs. The presence of a large number of fallow lands indicates that villagers are no more interested in this occupation; whatever little agricultural activities that have been seen are done as customary in a traditional way only, which is not enough to support livelihood. The present study relates to assessment of the macro- and micro-nutrient present in soils to understand soil fertility and recommend fertilizers for optimum growth of the indigenous crops. Fallow lands measuring approximately 10 acres have been identified in four villages, namely, Kasoon, Bhatgaon, Patiya and Kotyura (Figure 1), for solar fencing to mitigate Human Wildlife Conflict and rejuvenate agricultural operations in the region.

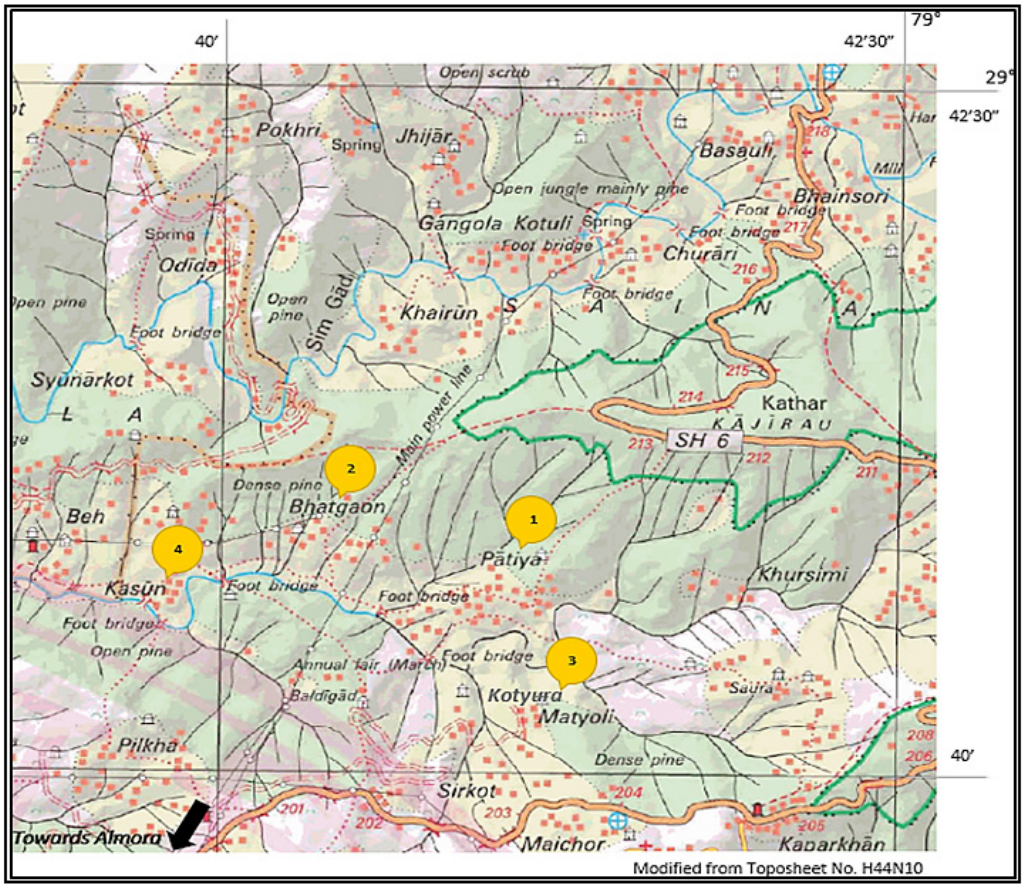


**Fig. 1: Study area map showing four villages (1- Patiya; 2- Bhatgaon; 3- Kotyura; 4- Kasoon) selected for soil analysis**

## Materials and Methods

Soil, a mixture of minerals and organic materials essential for plant life, contains 15 out of the 18 elements vital for plant growth.[3,4,5,6] The essential elements used by the plants in large quantities (primary and secondary macronutrients) and in small quantities (micronutrients) are responsible for plant growth is supplied by soil only.[6] The determining factor in the crop yield happens to be the essential nutrients in the soil and its ability to sustain agricultural growth[7]. The evaluation of soil quality is important to determine the fertilizer recommendation to increase crop health and maximize yield and in turn help farmers to effectively manage their agricultural practices.[8,9]

Besides physico-chemical and biological conditions in the rhizosphere the nutrient up take by plants is also dependent upon pH, available nutrients, organic matter content, and adsorptive surfaces.[7,10,4] Hence, the study of the available pool of nutrients and their balance in the soil along with the evaluation of fertility status of the soils is foremost to understand soil health and plant-soil nutrient relationship for sustainable agriculture production.[10]

### Collection and Preparation of Samples

A total of 26 representative soil samples, from a depth of 0-20 cm were collected using a hand-held soil auger of 1 inch core diameter and 10 inch length. Soil samples were air-dried in shade, discarding plant residues, gravels, and other materials. These were then pulverized and sieved to obtain 2 mm size fraction for chemical analysis and the samples were stored in airtight containers for further examination.

### Sample Soil Analysis

The soil samples were examined for pH, EC, Organic-C, available-N, -P, -K, -S, -B, -Mn, 0.1M HCl, and DTPA extractable-Fe, -Zn, and -Cu. The analysis was carried out using PUSA (STFR) soil Meter Kit, recommended by ICAR which analyzes soil parameters quantitatively and gives crop-specific fertilizer recommendation including field crops, horticultural crops, and spices.

Standard Nomenclature of the ranges of the soil macro-nutrients

| Nutrient | Low | Medium | High | V. High |
|---|---|---|---|---|
| Organic Carbon (%) | <0.5 | 0.5-0.75 | >0.75 | |
| Nitrogen ($kgha^{-1}$) | <280 | 280-560 | >560 | |
| Phosphorus ($kgha^{-1}$) | <10 | 10 -25 | >25-50 | >50 |
| Potassium ($kgha^{-1}$) | <120 | 120-280 | >280-600 | >600 |

Ranges of soil nutrients based on STFR Meter ($mgkg^{-1}$)

| Nutrient | Deficient | Critical limit for STFR Meter | Sufficient |
|---|---|---|---|
| Sulphur ($mgkg^{-1}$) | <10 | 10 | ≥10 |
| Zinc ($mgkg^{-1}$) | <1.3 | 1.3 | ≥1.3 |
| Iron ($mgkg^{-1}$) | <14 | 14 | ≥14 |
| Copper ($mgkg^{-1}$) | <0.72 | 0.72 | ≥0.72 |
| Manganese ($mgkg^{-1}$) | <2.5 | 2.5 | ≥2.5 |
| Boron ($mgkg^{-1}$) | <0.5 | 0.5 | ≥0.5 |

Types of soil reactions based on soil pH values

| pH Range | Soil Reaction |
|---|---|
| <4 | Extremely acid |
| 4-5 | Strongly acid |
| 5-6 | Moderately acid |
| 6-7 | Slightly acid |
| 7 | Neutral |
| 7-8 | Moderately alkaline |
| >8.5 | Strongly alkaline |

Relationship between EC and salinity effect from PUSA STFR Meter

| EC of extract ($mScm^{-1}$) | Salt (%) in soil | Salinity Effect |
|---|---|---|
| 0- 4 | 0- 0.05 | Non-Saline (Salinity effect mostly negligible) |
| 4- 8 | 0.05- 0.1 | Very slightly saline (Yield of very sensitive crops may be restricted) |
| 8- 16 | 0.1-0.2 | Moderately saline (Yield of many crops restricted. Cotton, sugarbeet, cereals, grain sorghum may be taken) |
| > 16 | > 0.2 | Strongly Saline (Only tolerant crops yield satisfactorily) |

**Fig. 2: Ranges of soil nutrients, pH and EC value categorization based on STFR standards used in present studies**

### Categorization of Soil Nutrient Status

Categorization of soil nutrients, pH, and EC has been done based on the values provided along with the instrument. Figure 2 shows the ranges of the soil nutrients, pH, and EC value categorization based on STFR standards. Based on these values, the various nutrients were classified into Low-Medium-High, Sufficient-Deficient, and subsequent fertilizers were recommended for the soils.

### Nutrient Indices (NI)

The nutrients present in the soil were calculated for their index values on the basis of formula suggested by Parker *et al*[11] where in indices were classified as low (<1.67), medium (1.67-2.33), and high (>2.33).[4]

$$NI\ (NutrientIndex) = \frac{(N_l \times 1) + (N_m \times 2) + (N_h \times 3)}{N_t}$$

Where,

$N_t$ = the Total number of samples analyzed for a nutrient in any given area.
$N_l$ = 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.

Nutrient supplying capacity of soil to plants is measured by Nutrient Index and comparative analysis of the soil fertility of an area is carried out using a single value for each nutrient.[12,13]

**Results and Discussion**

**Physico-Chemical Properties of Soil**

The soil of the study region has good natural drainage with mean thickness ranging between 0.1 to 0.5 m) and colour varying from light to moderately dark showing varying physico-chemical properties.

Textural classification of soil[14] revealed the dominance of silty to sandy loam type of soil in the study region. Bhatgaon, Kotyura, and Kasoon exhibit Loam, Sandy loam (+Organic Content), and Sandy loam texture, respectively. Patiya has been further divided into four regions, namely, Samdeo-Nigad,Tanala, Aegra, and Samdeo, based on varying altitude and terrain, the textural class of these soils varied from silty loam, loam, sandy loam (+ organic content) & sandy loam in these four regions, respectively.

**pH, EC, and OC%**

Table 1 elaborates the physico-chemical properties of each of the collected soil samples and its classification. Figure 3, 4, and 5 represent the graphical comparison of these physico-chemical properties of the collected soil samples.

Based on the values obtained from PUSA STFR Meter Kit, the pH of soil samples from Patiya displayed variance from 6.34 to 6.98 having a mean value of 6.6 (slightly acidic). The soils of Samdeo-Nigad, Tanala, Aegra, and Samdeo have 6.61, 6.475, 6.4625, and 6.735 mean pH values respectively. The pH of soil samples has a mean value of 5.4 (moderately acidic) in Bhatgaon, 5.9 (moderately acidic) in Kotyura, and 3.7 (extremely acidic) in Kasoon (Figure 3).

**Table 1: Soil Properties- Physical and Chemical**

| Village Name | Sample Code | Soil Type | pH | Soil Reaction | EC ($mScm^{-1}$) | Salinity Effect | OC (%) & Category (L)- Low, (M)-Medium (H)- High |
|---|---|---|---|---|---|---|---|
| Patiya | 111 | silty | 6.44 | slightly acidic | 7.375 | slightly saline | 0.3966 (L) |
| Samdeo | 112 | loam | 6.78 | slightly acidic | 7.37 | slightly saline | 0.3408(L) |
| -Nigad | 121 | loam | 6.61 | slightly acidic | 4.752 | slightly saline | 0.391(L) |
| | 122 | | 6.34 | slightly acidic | 5.113 | slightly saline | 0.3781(L) |
| Tanala | 131 | sandy | 6.35 | slightly acidic | 5.72 | slightly saline | 0.4841(L) |
| Aegra | 132 | loam | 6.38 | slightly acidic | 4.458 | slightly saline | 0.2964(L) |
| | 133 | (OC+) | 6.58 | slightly acidic | 0.165 | non-saline | 0.284(L) |
| | 134 | | 6.54 | slightly acidic | 0.161 | non-saline | 0.1983(L) |
| | 141 | sandy | 6.69 | slightly acidic | 0.078 | non-saline | 0.2697(L) |
| | 142 | loam | 6.96 | slightly acidic | 0.086 | non-saline | 0.1239 (L) |
| Samdeo | 143 | (OC+) | 6.75 | slightly acidic | 0.089 | non-saline | 0.3902 (L) |
| | 144 | | 6.75 | slightly acidic | 0.104 | non-saline | 0.7592 (H) |
| | 145 | | 6.52 | slightly acidic | 0.078 | non-saline | 0.4765 (L) |
| | 146 | | 6.74 | slightly acidic | 0.083 | non-saline | 0.153 (L) |
| Bhatgaon | 201 | loam | 6.99 | slightly acidic | 0.09 | non-saline | 0.1814 (L) |
| | 202 | | 6.5 | slightly acidic | 0.076 | non-saline | 0.3153 (L) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 203 | | 4.07 | strongly acidic | 1.849 | non-saline | 0.3291 (L) |
| | 204 | | 3.95 | strongly acidic | 2.038 | non-saline | 0.3662 (L) |
| Kotyura | 301 | sandy | 6.74 | slightly acidic | 1.321 | non-saline | 0.5895(M) |
| | 302 | loam | 6.78 | slightly acidic | 1.07 | non-saline | 0.4951 (L) |
| | 303 | (OC+) | 6.84 | slightly acidic | 1.181 | non-saline | 0.516 (M) |
| | 304 | | 3.38 | strongly acidic | 1.021 | non-saline | 0.4447 (L) |
| Kasoon | 401 | sandy | 3.26 | strongly acidic | 1.013 | non-saline | 0.3899 (L) |
| | 402 | loam | 4.14 | strongly acidic | 1.165 | non-saline | 0.5154(M) |
| | 403 | | 4.37 | strongly acidic | 1.215 | non-saline | 0.3458 (L) |
| | 404 | | 3.05 | strongly acidic | 1.353 | non-saline | 0.3462 (L) |

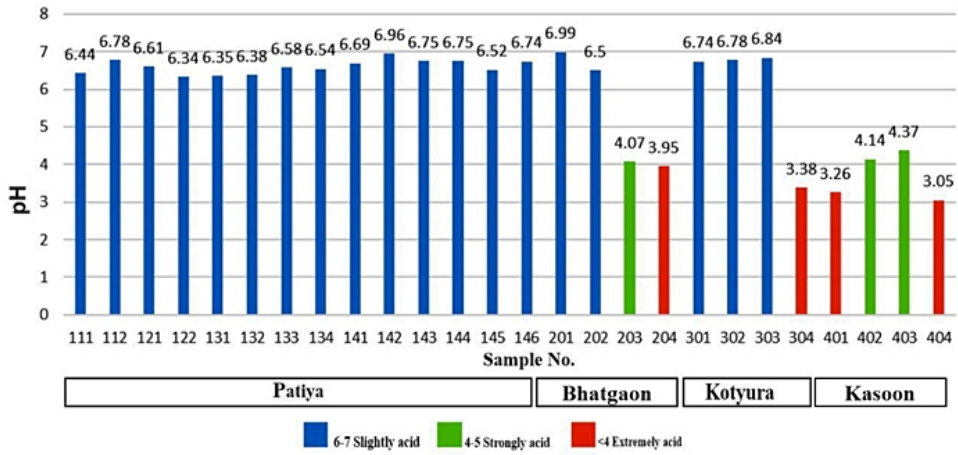


**Fig. 3: pH values of the collected 26 samples**

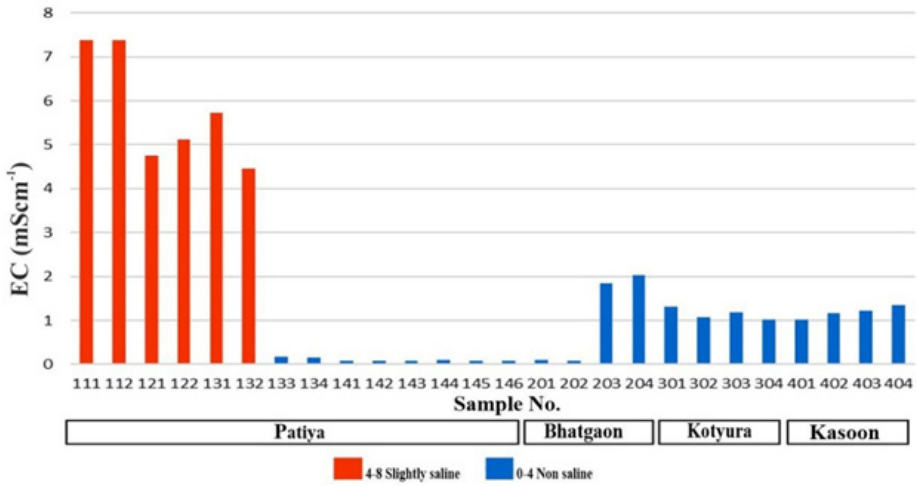


**Fig. 4: EC (mScm$^{-1}$) values of the collected 26 samples**

The EC of soil samples from Patiya shows a wide range that varies from 0.078 mScm$^{-1}$ to 7.375 mScm.$^{-1}$ The soils of Samdeo-Nigad, Tanala, Aegra and Samdeo have 7.37 mScm$^{-1}$ (slightly saline), 4.93 mScm$^{-1}$ (slightly saline), 2.63 mScm$^{-1}$ (non-saline) and 0.086 mScm$^{-1}$ (non-saline) mean EC values, respectively. The average EC values of soil samples are 1.01325 mScm$^{-1}$ (non-saline) in Bhatgaon,

1.14825 $mScm^{-1}$ (non-saline) in Kotyura, and 1.1865 $mScm^{-1}$ (non-saline) in Kasoon. Electrical Conductivity analysis shows that the study area has low salinity on average (Figure 4).

The organic-C content in the soils of Patiya ranges between 0.1239-0.7592% with an average value of 0.353%. The soils of Samdeo-Nigad, Tanala, Aegra and Samdeo have 0.3687% (low), 0.3845% (low), 0.3157% (low) and 0.3621% (low) mean OC% content respectively. This content has a mean value of 0.298% (low) in Bhatgaon, 0.5113% (medium) in Kotyura, and 0.3993% (low) in Kasoon (Figure 5).

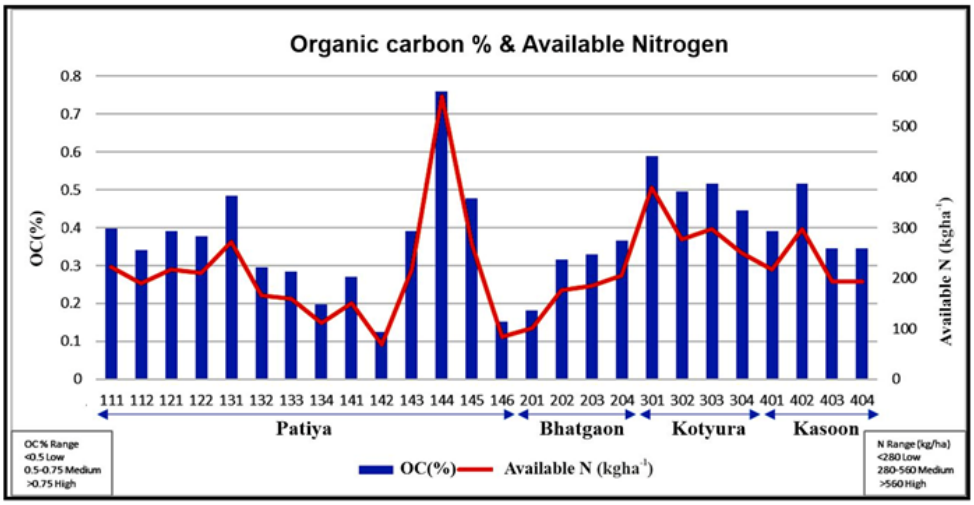


**Fig. 5: Organic Carbon % and Available Nitrogen ($kgha^{-1}$) values of the collected 26 samples**

**Available Nutrients (Primary and Secondary)**

The available primary nutrients (N, P, and K) and secondary nutrient (S) in the soil, as obtained from the PUSA STFR Meter Kit, have been tabulated in Table 2, along with their classification. Figure 6, 7, and 8 show the graphical comparison of P, K, and S content of the collected soil samples respectively. The fertilizers for these major macronutrients such as N-P-K are crop recommended. Table 2 also summarizes the crop RDF to be applied based on the obtained category of these nutrients.[15]

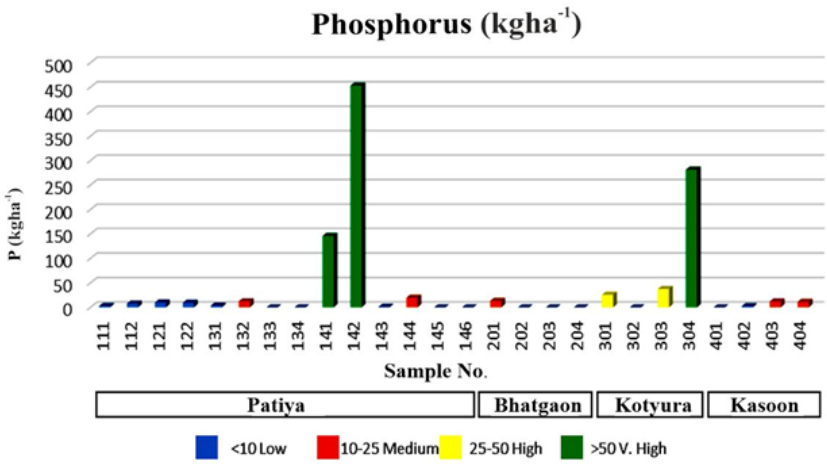


**Fig. 6: Phosphorus ($kgha^{-1}$) values of the collected 26 samples**

**Table 2: Available primary (N, P, K) and secondary (S)nutrient in the soil and Crop RDF to be applied based on Category of N-P-K**

| Village Name | Sample Code | N(kgha$^{-1}$) & Category | P (kgha$^{-1}$)& Category | K (kgha$^{-1}$) & Category | S(mgkg$^{-1}$) & Category |
|---|---|---|---|---|---|
| | | **(L)- Low, (M)- Medium, (H)- High, (VH)- Very High (D)- Deficient, (S)- Sufficient** | | | |
| Patiya | 111 | 222 (L) | 2.5 (L) | 24.5 (L) | 51.7 (S) |
| Samdeo | 112 | 190 (L) | 7.6 (L) | 35.8 (L) | 66 (S) |
| -Nigad | 121 | 218 (L) | 9.7l (L) | 41.6 (L) | 71.2 (S) |
| Tanala | 122 | 211 (L) | 9.2 (L) | 38.7 (L) | 13 (S) |
| | 131 | 271 (L) | 3.5 (L) | 27 (L) | 24.6 (S) |
| Aegra | 132 | 166 (L) | 12.1 (M) | 55.8 (L) | 86.8(S) |
| | 133 | 159 (L) | 0 (L) | 17.6 (L) | 33(S) |
| | 134 | 111(L) | 0 (L) | 15.1(L) | 19.2(S) |
| | 141 | 151 (L) | 145.9 (VH) | 115.5 (L) | 72.3(S) |
| Samdeo | 142 | 69 (L) | 453.3 (VH) | 119.1 (L) | 57.9(S) |
| | 143 | 218 (L) | 0.9 (L) | 21(L) | 53.4(S) |
| | 144 | 560 (H) | 19.6 (M) | 68.5(L) | 20.4(S) |
| | 145 | 266(L) | 0(L) | 30.2(L) | 17.6(S) |
| | 146 | 85(L) | 0(L) | 23.4(L) | 89(S) |
| Bhatgaon | 201 | 101(L) | 13.1 (M) | 54.4(L) | 82.4(S) |
| | 202 | 176(L) | 0 (L) | 26.5 (L) | 91.2 (S) |
| | 203 | 184 (L) | 0 (L) | 21.2(L) | 41 (S) |
| | 204 | 205 (L) | 0 (L) | 28.9(L) | 77 (S) |
| Kotyura | 301 | 380 (M) | 25.6 (H) | 196.3 (M) | 112.1(S) |
| | 302 | 277 (L) | 0(L) | 24.1 (L) | 96.8 (S) |
| | 303 | 297 (M) | 37.4 (H) | 267.7 (M) | 104.9(S) |
| | 304 | 249 (L) | 281.3 (VH) | 114.5 (L) | 62.3 (S) |
| Kasoon | 401 | 218 (L) | 0(L) | 19.8 (L) | 85.1 (S) |
| | 402 | 297 (M) | 2.4 (L) | 22 (L) | 29 (S) |
| | 403 | 193 (L) | 11.7 (M) | 55.7 (L) | 20.2(S) |
| | 404 | 193 (L) | 11.1 (M) | 48.1 (L) | 33.7(S) |
| | | **Crop RDF to be applied as per Category of N-P-K** | | | |

Low category- 25% more than crop RDF, Medium category- Exact crop RDF, High Category- 25% less than crop RDF, Very High category- No fertilizer of that nutrient

Available-N (Figure 5) of soil samples from Patiya has a mean value of 206.928 kgha$^{-1}$ (low). The soils of Samdeo-Nigad, Tanala, Aegra, and Samdeo have 206 kgha$^{-1}$ (low), 214.5 kgha$^{-1}$ (low), 176.75 kgha$^{-1}$ (low) and 224.833 kgha$^{-1}$ (low) mean available N values, respectively. The average available-N value of soil samples is 166.5 kgha$^{-1}$ (low) in Bhatgaon, 300.75 kgha$^{-1}$ (medium) in Kotyura and 225.25 kgha$^{-1}$ (low) in Kasoon.

Phosphorus level has an average value of 47.45 kgha$^{-1}$ (high) in Patiya; 3.275 kgha$^{-1}$ (low) in Bhatgaon; 86.075 kgha$^{-1}$ (very high) in Kotyura; and 6.3 kgha$^{-1}$ (low) in Kasoon (Figure 6).

Potassium level has an average value of 45.2714 kgha$^{-1}$ (low) in Patiya; 32.75 kgha$^{-1}$ (low) in Bhatgaon; 150.65 kgha$^{-1}$ (medium) in Kotyura; and 36.4 kgha$^{-1}$ (low) in Kasoon (Figure 7).

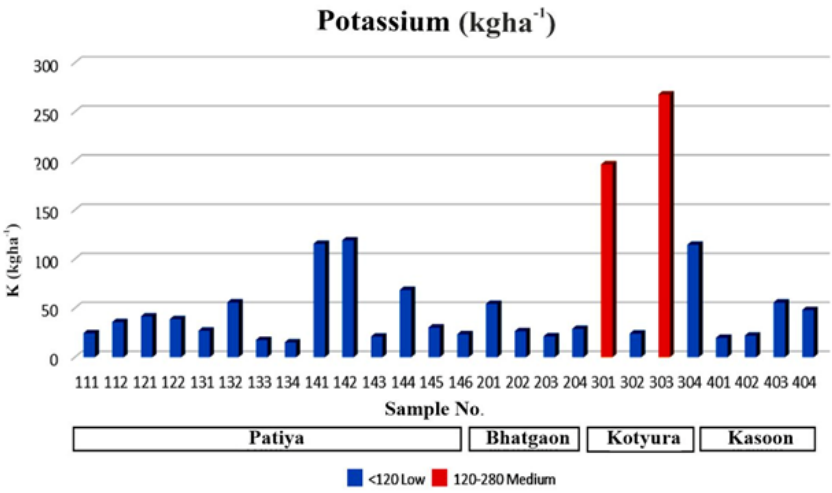


**Fig. 7: Potassium (kgha$^{-1}$) values of the collected 26 samples**

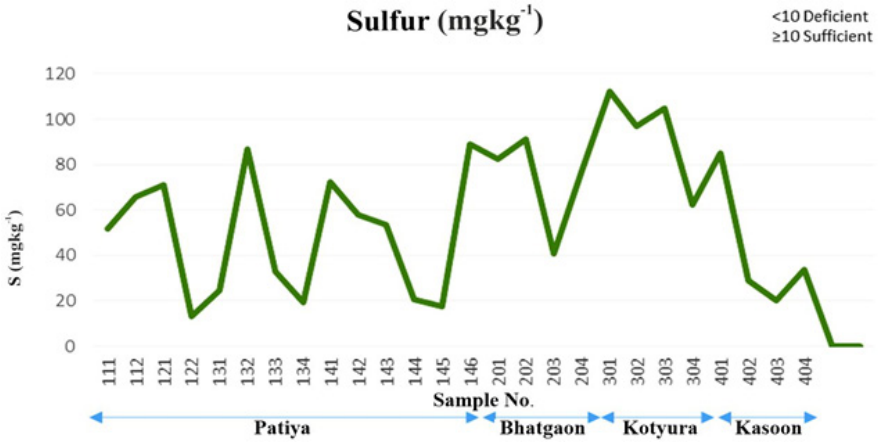


**Fig. 8: Sulfur (mgkg$^{-1}$) values of the collected 26 samples**

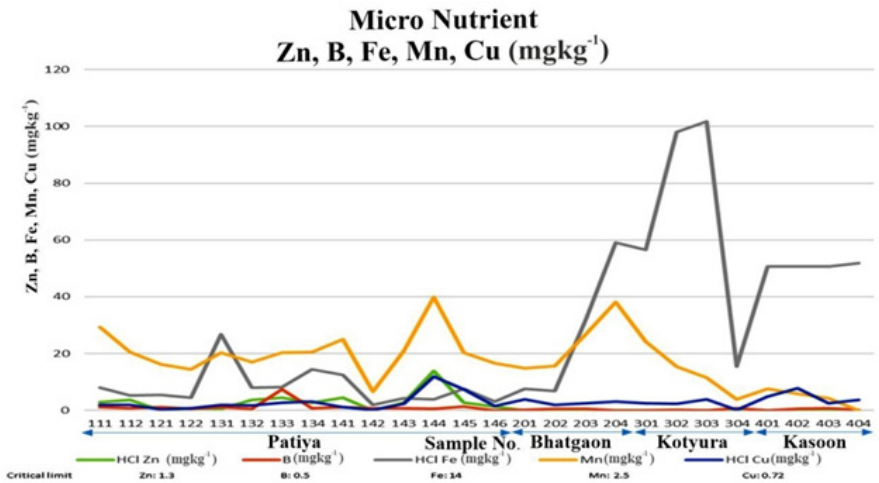


**Fig. 9: Micro Nutrient Zn, B, Fe, Mn, Cu (mg/kg) values of the collected 26 samples**

Sulfur content in the all the soil samples were found to be sufficient. It has a mean value of 48.29 $mgkg^{-1}$ (sufficient) in Patiya; 72.9 $mgkg^{-1}$ (sufficient) in Bhatgaon; 94.025 $mgkg^{-1}$ (sufficient) in Kotyura and 42 $mgkg^{-1}$ (sufficient) in Kasoon (Figure 8)

**Table 3: Micronutrient (Zn, B, Fe, Mn, and Cu) values of soil by the STFR Meter and the recommended dose of fertilizer for the deficiency**

| Village Name | Sample No. | Zn ($mgkg^{-1}$) HCl /DTPA (Category) | B($mgkg^{-1}$) (Category) | Fe ($mgkg^{-1}$) HCl/DTPA | Mn($mgkg^{-1}$) (Category) (Category) | Cu ($mgkg^{-1}$) HCl/DTPA (Category) |
|---|---|---|---|---|---|---|
| | | | (S)- Sufficient | (D)- Deficient | | |
| Patiya | 111 | 2.8/1.3 (S) | 1.035 (S) | 7.9/2.54(D) | 29.31 (S) | 1.84/0.51 (S) |
| Samdeo | 112 | 3.7/1.7 (S) | 0.648(S) | 5.26/1.69(D) | 20.56 (S) | 1.84/0.51 (S) |
| -Nigad | 121 | 0/ 0 (D) | 1.087(S) | 5.48/1.76(D) | 16.23 (S) | 0.39/ 0.1 (D) |
| Tanala | 122 | 0.7/0.3 (D) | 0.463 (D) | 4.5/1.44 (D) | 14.43 (S) | 0.73/0.25(S) |
| | 131 | 0.5/0.2 (D) | 1.06 (S) | 26.74/8.59 (S) | 20.3 (S) | 1.84/0.51(S) |
| Aegra | 132 | 3.7/1.7(S) | 0.465 (D) | 7.87/2.52 (D) | 17.04(S) | 1.7/0.47(S) |
| | 133 | 4.4/2(S) | 7.343(S) | 8.18/2.63 (D) | 20.33(S) | 2.64/0.73(S) |
| | 134 | 2.7/1.2(S) | 0.692(S) | 14.49/4.65 (S) | 20.56(S) | 3.16/0.87(S) |
| | 141 | 4.4/2(S) | 1.067(S) | 12.48/4.01(D) | 25.08(S) | 1.05/0.29(S) |
| | 142 | 0/0 (D) | 0.645(S) | 1.86/0.6(D) | 6.68(S) | 0.04/0.01(D) |
| Samdeo | 143 | 2.7/1.2(S) | 0.765(S) | 4.32/1.39(D) | 20.8(S) | 2.25/0.62 (S) |
| | 144 | 13.9/6.4(S) | 0.461 (D) | 3.81/1.22(D) | 39.83(S) | 11.9/3.31(S) |
| | 145 | 2.7/1.2(S) | 1.241 (S) | 7.6/2.44(D) | 20.35(S) | 7.4/2.05(S) |
| | 146 | 1.3/0.6(S) | 0.001(D) | 3.06/0.98(D) | 16.52(S) | 1.47/0.4(S) |
| Bhatgaon | 201 | 0/0(D) | 0.042(D) | 7.58/2.43(D) | 14.79(S) | 3.92/1.08(S) |
| | 202 | 0/0(D)) | 0.504 (S) | 6.84/2.2 (D) | 15.55(S) | 1.86/0.51(S) |
| | 203 | 0/0(D)) | 0.435(D) | 31.93/10.26(S) | 26.85(S) | 2.54/0.7(S) |
| | 204 | 0/0(D) | 0.001(D) | 59.14/19.01(S) | 38.16(S) | 2.98/0.83(S) |
| Kotyura | 301 | 0/0(D) | 0.001(D) | 56.56/18.18(S) | 24.21(S) | 2.41/0.67(S) |
| | 302 | 0/0(D) | 0.155(D) | 98.03/31.51(S) | 15.43(S) | 2.35/0.65(S) |
| | 303 | 0/0(D) | 0.001(D) | 101.81/32.7(S) | 11.42(S) | 3.89/1.08(S) |
| | 304 | 0/0 (D) | 0.69 (S) | 15.5/4.81(S) | 3.9(S) | 0.15/0.04(D) |
| Kasoon | 401 | 0/0(D) | 0.001 (D) | 50.58/16.25(S) | 7.63(S) | 4.89/1.36(S) |
| | 402 | 0/0(D) | 0.438 (D) | 50.64/16.27(S) | 5.91(S) | 7.76/2.06(S) |
| | 403 | 0/0(D) | 0.651 (S) | 50.58/16.25(S) | 4.33(S) | 2.45/0.68(S) |
| | 404 | 0/0(D) | 0.104 (D) | 51.89/16.67(S) | 0.01 D | 3.75/1.04(S) |

**Nutrient Deficiency/ Recommended Fertilizer (with Quantity in mg/Kg)**
**Zn/$ZnSO_4$(10) B/Borax(4) Fe/$FeSO_4$(40) Mn/$MnSO_4$(50) Cu/$CuSO_4$/4**

**Available Micronutrients**

Table 3 tabulates the micronutrients along with their category and the recommended dose of fertilizer for the deficiency of these micronutrients by the STFR Meter and Figure 9 shows the trend of these micronutrients in the study region. The STFR Meter Kit recommends the dose of fertilizer for these micronutrients directly based on their obtained values and category.

HCl and DTPA Zn content were found to have a mean value of 3.25 $mgkg^{-1}$ and 1.5 $mgkg^{-1}$ respectively in Samdeo-Nigad (sufficient); 0.35 $mgkg^{-1}$ and 0.15 $mgkg^{-1}$ respectively in Tanala (deficient); 2.825

$mgkg^{-1}$ and 1.275 $mgkg^{-1}$ respectively in Aegra (sufficient); and 4.1667 $mgkg^{-1}$ and 1.9 $mgkg^{-1}$ respectively in Samdeo (sufficient) in Patiya; and 0 mg/kg in Bhatgaon, Kotyura and Kasoon (deficient). The STFR Meter recommended the 10 $kgha^{-1}$ $ZnSO_4$ for the deficient soils.

Boron content was found to have a mean value of 1.2124 $mgkg^{-1}$ (sufficient) in Patiya; 0.2455 $mgkg^{-1}$ (deficient) in Bhatgaon; 0.21175 $mgkg^{-1}$ (deficient) in Kotyura; and 0.2985 $mgkg^{-1}$ (deficient) in Kasoon. Further, the STFR Meter recommended the 4 $kgac^{-1}$ Borax for deficient soils.

HCl and DTPA Fe content were found to be deficient in Patiya (mean value of 8.111 $mgkg^{-1}$and 2.6043 $mgkg^{-1}$ respectively); sufficient in Bhatgaon (mean value of 26.3725 $mgkg^{-1}$ and 8.475 $mgkg^{-1}$ respectively); sufficient in Kotyura (mean value of 67.975 $mgkg^{-1}$ and 21.805 $mgkg^{-1}$ respectively); and sufficient in Kasoon (mean value of 50.9225 $mgkg^{-1}$ and 16.36 $mgkg^{-1}$ respectively). The STFR Meter recommended the 40 $kgac^{-1}$ $FeSO_4$ for the deficient soils of Patiya.

Mn content in all the soil samples was found to be sufficient except for one sample from Kasoon. The Mn content has an average value of 20.573 $mgkg^{-1}$ (sufficient) in Patiya, 23.8375 $mgkg^{-1}$ (sufficient) in Bhatgaon; 13.749 $mgkg^{-1}$ (sufficient) in Kotyura; and 4.47 $mgkg^{-1}$ (sufficient) in Kasoon.

**Table 4: The categories of nutrients and nutrient indices (Low, Medium and High) of the soil in the study region**

| Village Name | Sample Size | Category | N | P | K | S | Zn | B | Fe | Mn | Cu |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Patiya | | Low | 13 | 10 | 14 | - | 4 | 4 | 12 | - | 2 |
| | | Medium | - | 2 | - | 14 | 10 | 10 | 2 | 14 | 12 |
| | 14 | High | 1 | 2 | - | - | - | - | - | - | - |
| | | NI | 1.1428 | 1.4286 | 1 | 2 | 1.7143 | 1.7143 | 1.1428 | 2 | 1.8571 |
| | | NI | Low | Low | Low | Medium | Medium | Medium | Low | Medium | Medium |
| Bhatgaon | | Low | 4 | 3 | 4 | - | 4 | 3 | 2 | - | - |
| | | Medium | - | 1 | - | 4 | - | 1 | 2 | 4 | 4 |
| | 4 | High | - | - | - | - | - | - | - | - | - |
| | | NI | 1 | 1.25 | 1 | 2 | 1 | 1.25 | 1.5 | 2 | 2 |
| | | NI | Low | Low | Low | Medium | Low | Low | Low | Medium | Medium |
| Kotyura | | Low | 2 | 1 | 2 | - | 4 | 3 | - | - | 1 |
| | | Medium | 2 | - | 2 | 4 | - | 1 | 4 | 4 | 3 |
| | 4 | High | - | 3 | - | - | - | - | - | - | - |
| | | NI | 1.5 | 2.5 | 1.5 | 2 | 1 | 1.25 | 2 | 2 | 1.75 |
| | | NI | Low | High | Low | Medium | Low | Low | Medium | Medium | Medium |
| Kasoon | | Low | 3 | 2 | 4 | | 4 | 3 | | 1 | - |
| | | Medium | 1 | 2 | | 4 | | 1 | 4 | 3 | 4 |
| | 4 | High | | | | | | | | | |
| | | NI | 1.25 | 1.5 | 1 | 2 | 1 | 1.25 | 2 | 1.75 | 2 |
| | | NI | Low | Low | Low | Medium | Low | Low | Medium | Medium | Medium |

**Table 5. Recommended crops and their ecological, manure and nutrient requirements. (Data used from various sources [22-33])**

| Crop & Season | Soil properties and Irrigation Climate [Temperature (°C), Rain-fall (cm)] | Manure Requirement (Ton per hectare) | Nutrient Requirement ($kgha^{-1}$) N | $P_2O_5$ | $K_2O$ | S | Suitable location in study area |
|---|---|---|---|---|---|---|---|
| Mustard & Rapeseed Rabi (Oct-Nov) | Sandy loam to clay loam soils, better yield on light loam soils. Neutral pH is ideal. Requires watering at pre-bloom and pod filling stages. [22-25°C; 25-40 cm] | 15-20 FYM | 60-90 | 60 | 40 | - | Aegra |
| Sesame Kharif (July) | Well-drained light to medium textured soils is preferred. Optimum pH range - 5.5 to 8.0. Usually grown under rain fed conditions. [25-35ºC] | 12.5 FYM | 20 | 10 | 0 | - | Patiya |
| Turmeric Kharif (May-June) | Better yield in well-drained sandy or clayey loam having pH range of 4.5-7.5. Grown as a rain fed crop so irrigation can be provided depending upon rainfall. [24-28º C; 70-230 cm] | 30-40 FYM | 60 | 50 | 120 | - | Aegra, Samdeo Kotyura |
| Ginger Kharif (May-June) | Provides best yield on well-drained soils (sandy loam, clayey loam, red loam or lateritic loam). Not desirable to grow in the same soil repeatedly as it is an exhausting crop. Ideal pH range- 6-6.5. Grown as rain fed crop so irrigation can be provided depending upon rainfall intensity and rainfall frequency. [12-35°C; 150 cm] | 30-40 FYM | 180 | 15 | 100 | - | Tanala Kotyura |
| Pear Rabi (Jan-July) | Good results can be achieved when grown in deep and well drained fertile soil without having any hard pan up to 2-meter depth. pH of soil should not be more than 8.7. A well distributed average rainfall of 75–100 cm is required throughout the year for pear cultivation. [10-25º C; 75-100 cm] | FYM per tree 5 kg for 1 yr of age and for higher ages in the multiple of 5. | 0.5 kg / tree | 1 kg / tree | 1 kg / tree | - | Aegra, Samdeo Kasoon |
| Guava Kharif | Gives good yield in all type of soil. Best results can be achieved when grown under deep, well drained, sandy loam to clayey loam soil. Young plants require water | FYM /tree 10-20 kg 1-3 yr 25-40 kg 4-6 yr | 0.4 kg / tree | 0.25 kg / tree | 0.35 kg / tree | | Samdeo-Nigad Aegra Samdeo Kasoon |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | at weekly interval in summer month and 2-3 watering cycle during winter month. [15-30º C; 100 cm] | 40-50 kg7-10yr<br>50 kg>10 yr | | | | | |
| Mango<br>Rabi<br>(February-July) | Grows on variety of soils. pH of soil should be less than 8.5. Summer irrigation- interval of 5-7 days; winter irrigation- interval 25-30 days; Rainy season- irrigation depends upon rainfall intensity. [22-27º C; 100 cm] | Kg/tree (Age) Well decomposed cow dung 5-20 (1-3yr), 25 (4-6 yr),60-90 (7-10 yr), 100 >10 yr | 65 | 20 | 75 | - | Aegra, Samdeo |
| Litchi<br>Rabi<br>(August- Sept) | Also grows on variety of soils. Deep, fertile, well drained, medium texture soils are suitable. pH- 5.5 to 7. Cannot tolerate high pH and saline soils. Irrigation required at all stages of development. [25-35º C; 120 cm] | Kg/tree (Age) Well decomposed cow dung 10-20(1-3 yr)<br>25-40(4-6 yr)<br>40-50(7-10 yr)<br>60 >10 yr | kg/ tree<br>0.36<br>0.72<br>1.08<br>1.2 | kg/ tree<br>0.15<br>0.3<br>0.45<br>0.5 | kg/ tree<br>0.18<br>0.36<br>0.54<br>0.6 | - | Samdeo |
| Barley<br>Rabi<br>(Mid Oct-Nov) | Gives yield in moderate loam to sandy soils with neutral to saline response and moderate fertility. Acidic soils are not suitable. Two or three irrigation are required during its life cycle. [12-32º C; 80-110 cm] | 30 FYM | 60 | 30 | 15 | - | Patiya<br>Kotyura |
| Barnyard millet (Madira)<br>Kharif (April-May)<br>Uttarakhand | Cultivated in soils of marginal fertility. Gives best results on sandy loam to loam soil. Grown as a rain fed crop and does not require any irrigation. | 5-10 FYM | 20 | 20 | 0 | - | Tanala, Bhatgaon<br>Kotyura |
| Fingermillet (Manduwa/ Ragi)<br>Kharif (June-Oct)<br>Uttarakhand | Grows on a variety of soils and is alkaline resistant to some extent. Suitable soil is alluvial, loamy and sandy with good drainage. Finger millet sown during Kharif ordinarily does not require much water. [20-34º C; 10 cm] | 5-10 FYM | 40 | 20 | 20 | - | Tanala, Bhatgaon<br>Kotyura |
| Horsegram (Gahat)<br>Kharif | Grows on wide range of soils which are free from alkalinity. A drought-resistant crop requiring a rainfall of about 800 mm. Performs well even under low rainfall areas. [25-30º C; 80cm] | 10-15 FYM | 20 | 30 | - | - | Bhatgaon<br>Kotyura |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Blackgram (Urad) Kharif | Appropriate soil is well-drained loam, pH of 6.5 to 7.8. Inability to grow on saline soils. If needed, irrigation is provided depending upon the climatic conditions. [15-30º C; 50-75 cm] | 10-15FYM | 20 | 40 | 20 | 20 | Bhatgaon Kotyura |
| Lentil (Masoor) Rabi (Oct-March) | Grown on all types of soil. Saline, alkaline, or water-logged soils should be avoided. Mainly grown as a rain fed crop. [18-20º C; 100 cm] | 4-5 FYM | 20 | 40 | 20 | 20 | Bhatgaon Kotyura |
| Soyabean Kharif (Mid-June) | Well drained, fertile loamy soils. Optimum pH range- 6 to 7.5. Waterlogged or saline soils are not suitable for cultivation. Overall crop requires three to four irrigations. Irrigation applied depending upon rainfall conditions. [18-38º C; 30-60 cm] | 15 FYM | 20 | 60 | 40 | 20 | Patiya Kotyura Kasoon |
| Black Soyabean (Kala Bhat) Kharif (Mid-June) | Grows in natural drainage and fertile loamy soils. Optimum pH range- 6 to 7.5. Waterlogged or saline soils are not suitable for cultivation. Overall crop requires three to four irrigations. Irrigation applied depending upon rainfall conditions. [18-38º C; 30-60 cm] | 15 FYM | 20 | 60 | 40 | 20 | Patiya Kotyura Kasoon |
| Pigeon Pea Kharif (June-July) | Fertile and well drained loamy soils. Optimum pH range - 6.5 to 7.5. Three to four weeks after sowing first irrigation must be applied. Remaining irrigation is dependent upon rainfall intensity. [35-38º C; 60-65 cm] | 5-6 FYM | 25 | 40 | 30 | 20 | Patiya, Bhatgaon |

**Table 6: Manure, nutrient, and Fertilizer requirement for the pulses to be grown in the areas studied in the project**

| Village Name | Crop | Manure Requirement | Soil Treatment | Nutrient Requirement ($kgha^{-1}$) | | | | Fertilizer Requirement ($kgha^{-1}$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | N | $P_2O_5$ | $K_2O$ | S | $ZnSO_4$ | $CuSO_4$ | $FeSO_4$ | $MnSO_4$ | Borax |
| Patiya | Soyabean | $15tha^{-1}$ FYM | _ | 20 Since low, Add 25% extra | 60 Since high, Add 25% less | 40 Since low, Add 25% extra | 20 | _ | _ | 100 | _ | _ |
| Bhatgaon | Pigeon Pea | $5\text{-}6tha^{-1}$ FYM | $2tha^{-1}$ lime - 7 days before sowing | 25 Since low, Add 25% extra | 40 Since low, Add 25% extra | 30 Since low, Add 25% extra | 20 | 25 | _ | _ | _ | 10 |
| Kotyura | Black Soyabean | $15tha^{-1}$ FYM | $2tha^{-1}$ lime - 7 days before sowing | 20 Since medium, add exact amount. | 60 Do not apply | 40 Since medium, add exact amount. | 20 | 25 | _ | _ | _ | 10 |
| Kasoon | Soyabean | $15tha^{-1}$ FYM | $2tha^{-1}$ lime - 7days before sowing. | 20 Since low, Add 25% extra | 60 Since low, Add 25% extra | 40 Since low, Add 25% extra | 20 | 25 | _ | _ | _ | 10 |

HCl and DTPA Cu content were found to have a mean value of 1.84 $mgkg^{-1}$ and 0.51 $mgkg^{-1}$ respectively in Samdeo-Nigad (sufficient); 0.56 $mgkg^{-1}$ and 0.175 $mgkg^{-1}$ respectively in Tanala (deficient); 2.335 $mgkg^{-1}$ and 0.645 $mgkg^{-1}$ respectively in Aegra (sufficient); and 4.0233 $mgkg^{-1}$ and 1.11333 $mgkg^{-1}$ respectively in Samdeo (sufficient) in Patiya; 2.825 $mgkg^{-1}$ and 0.781 $mgkg^{-1}$ respectively in Bhatgaon (sufficient); 2.2 $mgkg^{-1}$ and 0.61 $mgkg^{-1}$ respectively in Kotyura (sufficient); and of 4.7125 $mgkg^{-1}$ and 1.285 $mgkg^{-1}$ respectively in Kasoon (sufficient). The STFR Meter recommended the 4 $kgac^{-1}$ $CuSO_4$ for the deficient soils of Tanala in Patiya.

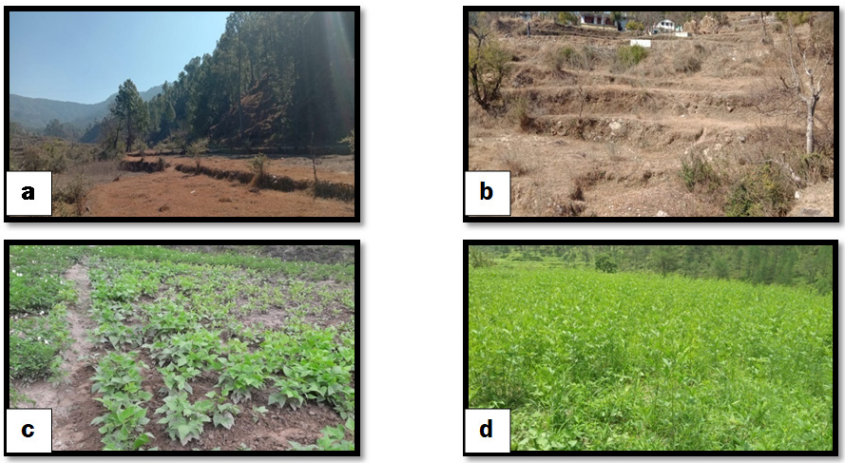


**Fig. 10: Photographs showing the enhancement in the crop productivity in two of the villages after the interventionssuggested in the present studies were employed. Fallow lands in Kasoon(a) and Bhatgaon (b)Village, respectively. High turn out of cropsin Kasoon (c) and Bhatgaon (d)Village, respectively**

**Nutrient Index**

To examine fertility of the region and nutrient supplying capacity of these soils to plants, Nutrient Index (NI) was calculated.

For calculation, in the case of primary nutrients, samples of high and very high categories have been placed in "High" class of nutrient status. Following the same methodology, in case of S and micronutrients, "Deficient" samples have been placed in "Low" and "Sufficient" samples have been placed in "Medium" class of nutrient status.

The nutrient indices and the categories are tabulated in Table 4.

The soils of Patiya show low N, P, K, and Fe fertility, and medium S, Zn, B, Mn, and Cu fertility. Bhatgaon soil has low NI and fertility of N, P, K, Zn, B, and Fe, and medium NI and fertility of S, Mn, and Cu.

The soil of Kotyura has low N, K, Zn, and B fertility, medium S, Fe, Mn, and Cu fertility, and high P fertility, whereas the soil of Kasoon has low N, P, K, Zn, B fertility, and medium S, Fe, Mn, and Cu fertility.

On average, the study area shows the medium category of NI values for S, Mn, and Cu in all the locations, indicating sufficient fertility of these nutrients for plant growth.

Fertility status as revealed by Nutrient Index is very significant in selecting the bio fertilizers as the region is applying traditional organic manure.[16] Bio fertilizers are comprised of living microbial cells and promote plant growth by increasing nutrient availability and acquisition[17] and play an important role in functioning of ecosystem by facilitating many biogeochemical cycles and organic matter degradation.[18] Sustainable agriculture which has a long-term effect on soil fertility of this region can be achieved by the application of bio fertilizers.[19,20,21]

**Conclusion**

The overall fertility status of the soil of the region is low of N, P, K, Zn, B, and Fe; and medium of S, Mn,

and Cu. These are indicative of a requirement for additional farm yard manure (FYM) and fertilizers to make them suitable for the cultivation of crops. Since the agricultural system in the region is largely organic, the use of bio-fertilizers such as Nitrogen and Phosphorus bio-fertilizer is recommended.

Further, high yield indigenous cash crops suited for the region along with their ecological and nutrient requirements were studied in detail from various digital platforms[22-33] run by the government and non-government agencies, and the outcome was categorically tabulated in Table 5. The tabulated data displays that the lands of Patiya such as Samdeo-Nigad and Samdeo are more suited for fruit trees such as Pear, Guava, Mango, Litchi, etc., and Bhatgaon and Kotyura are more suited for pulses such as Horse gram, Black gram, Lentil, etc. It also reveals that Soyabean and Black Soyabean is well suited to the type of soil and irrigation facilities available in the study region. Hence, it was recommended to sow Yellow Soyabean in Patiya and Kasoon; Black Soyabean (Kala Bhat) in Kotyura; and Pigeon Pea (Arhar) in Bhatgaon for the current season (June-July 2020). Table 6 presents the manure, nutrient, and fertilizer requirements of these Kharif crops to be used as a reference to maximize the use and production from these fallow lands and enhance the agricultural activities in the region, and provide better livelihood options. Based on the above outcome four self-help groups were created and villagers with identified lands were motivated for deep plowing of the land with handheld scooter tractor and crops of beans and peas were selected for sowing of seeds with line-makers to maintain essential distance between them. This resulted in an encouraging yield convincing farmers that crop can have a substantial impact on their income which led to an enthusiasm in all villages to adapt cooperative farming as per the suggestions utilizing (Figure 10)

**Acknowledgements**

The authors are thankful to NMHS (under Ministry of Environment, Forest and CC) for funding the project (GBPNI/NMHS-2019-20/MG59-01/07. 02e1 dated 02/07/2019) under which the present research work was carried out. We are immensely grateful to the residents of Patiya and surrounding villages for providing access to their lands for conducting the study. We would also like to show our gratitude to the field attendants and support staff for their assistance.

**Funding**

GRANT No.: GBPNI/NMHS-2019-20/MG59-01/07.02e1 dated 02/07/2019, National Mission on Himalayan Studies (NMHS) [Ministry of Environment, Forest and Climate Change.

**Conflict of Interest**

The authors do not have any conflict of interest.

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