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Soil Physico-Chemical Properties and Macronutrients Evaluation during Sowing and after Harvesting of Crop at High Altitude, Leh-Ladakh, India

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ABSTRACT

The present study was aimed to investigate the effect of physico-chemical parameters and soil macro-nutrients to know the nutrient uptake status during sowing time (ST) and after the harvesting (AH) of crops of Leh-Ladakh. In this context, total 55 no. of soil samples were collected from the eleven villages. Thereafter, soil texture, pH, electrical conductivity (EC), total dissolved solids (TDS), organic carbon (OC), nitrogen (N), phosphorus (P), and potassium (K) were analyzed as per the standard methods. The results exhibited variation in different studied parameters at ST and AH, are OC (ST- 1.70 ± 0.11; AH-2.31±0.08), N (ST- 171.54±11.40; AH- 212.03±13.18), P (ST- 75.62±8.16; AH- 96.32±11.56), pH (ST- 8.12±0.05; AH- 8.16±0.06), EC (ST- 0.48±0.04; AH- 0.58±17), TDS (ST-309±22.41; AH-189±16.42) and soil texture gradient (Sand: ST-75.16±1.27 & AH-71.75±1.26, Silt: ST- 18.55±1.09 & AH- 20.66±1.02 and clay: ST- 6.33±0.53 & AH- 7.76±0.63). The comparison of physico-chemical parameters, macronutrients, soil texture, and organic carbon at sowing time (ST) and after harvesting (AH) revealed significant difference in some macronutrients, EC, and organic carbon, whereas no changes were observed in soil texture, pH and phosphorus. Hence, this study highlights the need of physico-chemical parameters management during crops sowing for enhancing macronutrients availability to crops in trans-Himalayan high altitude region.

Keywords: Nitrogen; Organic carbon; Phosphorus; Potassium; Soil texture; High altitude; Macronutrient

1. INTRODUCTION

At latitude 34° 17′ N and longitude 77° 58′ E, Leh is located. It is the Ladakh district headquarters and also the capital of India's newly formed union territory. The beautiful city of Leh is located in the foothills of the Indus river catchment of the Ladakh ranges and has an altitude of 3500 m (11500 ft) above the sea's average level. Heterogeneous topography is one of the mountain region's main characteristics[1]. Variable environmental temperature ranges and precipitation patterns directly affect the melting of the glacier, agriculture, water source, etc. [2-3]. Variation in temperature in winter and summer from –35° to +35 °C and high UV (ultra-violet) radiation (level up to 6–7 kWh/mm) in this area, precipitation level is less than 100 mm, fluctuation of humidity between 25 per cent – 39 per cent, and sunny days with long photoperiod[4]. Due to these unusual climatic circumstances, Ladakh is a called as cold-desert of India. Some researchers also reported that the rise in global warming decreases the average seasonal precipitation and has declined in precipitation regions over the last decade[5]. In these regions, the soil is coarse-textured, permeable, deserted, and has inadequate capacity to hold water and nutrients, so nutrients are lowly available for crop growth[6-8]. The winter season has below sub-zero temperature affecting the soil texture, mineralogy, and reducing the microflora population, biological activity, and soil growth phase[9]. The soil's inherent fertility and runoff-erosion behaviour are also influenced by insufficient soil structure, texture, high sand, and clay content, indicating a more advanced weathering level[9]. As the annual rainfall in this area is less than 250 mm, the current climate conditions are cold arid in the study areas. Extreme winters, low precipitation, and other climatic conditions restrict the cultivation season of crops from June to October; therefore, widespread mono-cropping practices.

The concentration of soil organic matter is influenced by snowfall and temperature fluctuations, directly or indirectly[10]. As we know, Ladakh is a critical location for national strategic security because of the large number deployment of armed forces, leads to an increased population density of high-altitude regions in addition to civilian populations. The demand for agricultural products has increased due to the high population, which has created pressure for increased food grain production on limited agricultural land. Ultimately, this utilises the soil resources available that influence soil health and their management practises[8]. Soil health depends on many factors like minerals, microflora, soil texture, etc. Minerals like N, P, K, Ca, Mg, Fe, and S, are present in the soil, grouped into primary and secondary macronutrients. Primary macronutrients contain

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Table 1. Demography and agricultural scenario of Ladakh

Villages	Location	Total Area (In hectares)	Net Sown Area (In hectares)	Total population (Number)
Saboo	34°07'49"N 77°37'32"E	347.00	136.80	1233
Stok	34°04'31"N 77°33'20"E	584.00	393.40	1471
Chuchut Yakma	34°04'15"N 77°36'01"E	471.10	231.50	2162
Stakna	34°00'12"N 77°42'00"E	295.40	113.70	0355
Matselang	33°55'23"N 77°45'14"E	179.70	069.20	0381
Nang	34°03'02"N 77°45'08"E	125.90	056.20	0334
Taroo	34°11'44"N 77°25'22"E	102.80	062.70	0442
Nimoo	34°11'29"N 77°20'28"E	270.30	152.20	1134
Ney	34°16'35"N 77°17'56"E	310.00	105.70	0560
Umla	34°14'23"N 77°24'07"E	029.10	012.50	0099
Basgoo	34°12'46"N 77°17'09"E	340.30	145.70	0950

Source: Total area, net sown area and total population from the census of India 2011 & village location.

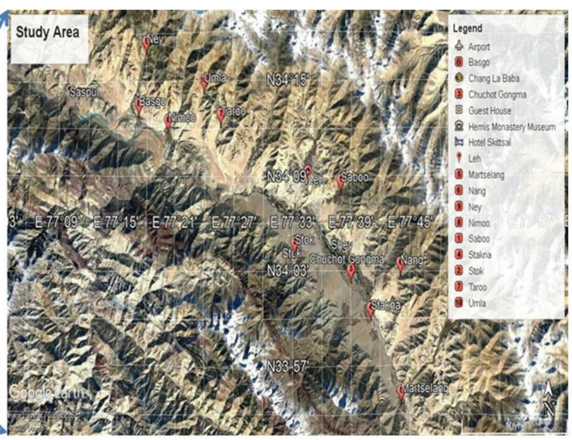

Figure 1. Study area.

Nitrogen (N), Phosphorous (P), and Potassium (K). In contrast, secondary macronutrients include calcium (Ca), Magnesium (Mg), Iron (Fe), and sulphur (S). These macronutrients play a significant role in plants' metabolism (synthesis of protein, DNA, RNA, plant photosynthetic pigment components, enzyme cofactors associated with metabolites transport) and protect them against different abiotic stressors[20]. N, P, and K play a very crucial role in the high yield of the crop. One of the essential components for plant growth is nitrogen[11]. For good rooting and fruiting of plants, phosphorus also plays a critical role[11]. For efficient water usage in plants, P is crucial as it controls the opening and closing of stomata in plant cells. Potassium allows plants to synthesise starch, withstand drought and improve crop resistance to disease[12].

The microenvironment and physico-chemical distinctiveness of soils in this area are directly affected by environmental conditions. Therefore, in high-altitude regions, there is a need to investigate physico-chemical and primary macronutrient status for improving crop nutrient status and their yield to produce quality food grain by using limited resources without affecting the soil's quality. There is limited or substantially less literature available on assessing soil physico-chemical characteristics during cultivation in this region. Therefore, this study was conducted in eleven villages to understand the status of soil physico-chemical properties of agricultural soil at the time of sowing and after harvesting in Ladakh, a high-altitude area in Trans-Himalayas. Consequently, this study would be beneficial for further agricultural management to increase crop production in this area.

2. MATERIALS AND METHODS

2.1 Study Area

The studied areas were selected based on agriculture activities, where farmers mainly depend on the cultivation of various crops and vegetables. Thereafter, eleven villages were selected viz. Saboo, Stok, Chuchut (Y), Stakna, Martaslang, Nang, Taroo, Nimoo, Ney, Umla, and Basgoo from District Leh, Ladakh UT, a high-altitude trans-Himalayan region (Table 1; Fig. 1) at sowing and after harvesting of crops i.e. crop harvested field. The latitude and longitude of collecting sites are mentioned in Table 1. The soil sampling was done during sowing in June 2018, and the second sampling was done after harvesting in October 2018.

2.2 Method of Sample Collection

The soil samples were collected from five different sites in each village, and the distance between each sample site varied from 200 meters -500 meters. Soil samples were collected from the depth of 15 cm - 25 cm i.e. plough depth using Trowel. Total 55 no. of soil samples (5 samples from each village, total 11 villages) were collected in an airtight plastic bag and dried at room temperature for further analysis.

2.3 Determination of Chemical Properties of Different Types of Soil

The soil pH, EC, TDS were evaluated by the digital pH Meter (Cole–Parmer; model number Oakton, PC2700) and Soil texture was determined after following the method of Singh, *et al.*[13]. Further, The soil organic carbon (SOC) was evaluated by the procedure given by Walkley and Black[14], where in brief, 10 g of soil sample was taken in 250 ml flask and mixed with 10 mL $K_2Cr_2O_7$.20 ml in H_2SO_4 (1N) solution and incubated for 30 minutes. After that, 100 ml distilled water was added along with 10 mL H_3PO_4, 0.2 g NaF and 1 ml indicator (0.5N AFSH). The prepared sample was titrated until the red colour appears. The following equation are used to calculate the organic carbon in the soil.

$$\text{Soil organic carbon (OC) in soil (\%)} = \frac{[10 \times (\text{Blank reading-sample reading}) \times 0.003 \times (100)]}{\text{Blank reading} \times \text{Weight of soil sample}}$$

Moreover, Soil macronutrients i.e., N, P, and K were evaluated after following the method described by Singh, *et al.*[13].

2.4 Statistical analyses

One-way ANOVA and t-test were used to analyse the soil physico-chemical properties, macronutrient, organic carbon and texture. Mean ± Standard Error Mean; indicates the significant variation at 0.05 level of significance.

3. RESULTS & DISCUSSION

Various cropping patterns and agricultural practices are known to be vulnerable at high altitudes due to inclement weather conditions, affecting nutrient availability and absorption to the growing fodder crops. Moreover, a soil's ability to hold and supply the nutrient to plant is directly linked with the cations and anions exchange capacity, which further depends on the soil texture, pH, EC, OC, etc. In this context, the present study was proposed on the hypothesis that change of crops, quality of water, manure application, and soil ageing affect the physico-chemical, primary macronutrient, organic carbon, and soil texture, affecting the nutrient availability and their absorption to the growing crops. Therefore, the soil texture, pH, EC, OC of selected sites were determined in this study for evaluating the physico-chemical status of soil at high altitude region. The soil texture result showed that the sand type of soil is dominating at the Leh-Ladakh region, followed by silt and clay in both the conditions, i.e., during sowing and after harvesting (Table 2). Moreover, Table 2 indicates no significant change in the sand, silt, clay, pH, and P from sowing time to after harvest; there is a significant change reported in EC, TDS, OC, N, and K.

The basic parameters studied in this work play a vital role in nutrition mobilisation, uptake, and availability to the crops. The climatic condition of high-altitude regions has changed in the last few decades. Therefore, it may affect soil fertility, the absorption capacity of primary macronutrients and low precipitation affect crop yield, leading to increased production costs.

The soil's pH is one factor that affects the availability of nutrients for the crop; it causes either deficiency or excess nutrient level in the soil system. Maximum utilisation of nutrients by crops occurs in a pH range of 6.5 to 7.5, which is neutral pH; therefore, if soil pH range below 6.5, it is said to be acidic soil, and greater than 7.5 is called alkaline soil[21]. Many crops required either alkaline or acidic soil conditions for their survival[21]. Some of the researchers have been reported that the soil of Ladakh is alkaline in nature[15-16]; likewise, Dar *et al.* also supported the alkaline nature of soil[27]. Our study also found that soil pH in Ladakh villages at time crop sowing 8.12±0.05 and after harvesting of crops are 8.16±0.06, i.e., alkaline (Table 2). It may be due to high sodium concentration or maybe continuous use of basic fertilisers without recommendation. The increase of soil pH after harvesting of crops from the sowing time of crops shows that it improves soil structure, reduces crusting, and reduces power need for tillage[18]. Even though pH also influences the soil's cation and anion exchange capacity by McCauley *et al.*[18]. Commonly Agropyron (Rampa) or Phragmites (Dambu), buckwheat, Chenopodium spp, etc., weeds are prevalent in the alkaline soil of Ladakh crop/fodders feilds[19].

Soil texture is another vital component, based on the proportion of sand, silt, and clay particles divided into various textural groups, directly influencing soil-water relation, aeration, and root penetration. As per the literature and report available, clay soil texture is highly conductive, but sand soil is poor conductors[25]. We found the percentage of sand, silt, and clay at the time of sowing of crops as 75.13±1.27, 18.55±1.09, and 6.33±0.53, but after harvesting of crops 71.75±1.26, 20.66±1.02, and 7.76±0.63. It shows that the texture of soil may be changed due to cropping patterns and irrigation water quality, however the difference was not so significant. Soil texture also affects the nutrient supply of the soil[23]. Gupta and Arora studied the Ladakh region's soil and reported that the sand, silt, clay, the level was 83.8 per cent, 7.2 per cent, 9.0 per cent, respectively[17]. Sandy soils are light soils with low nutrient concentration, low ability to retain moisture, low cation exchange capacity and buffer capacity, and rapidly permeable. These characteristics of sandy soil make it difficult to maintaining moisture retention capacity and overcome nutrient deficiency[24].

It has been found that the EC value varies from 0.48±0.04 to 0.58±17 from sowing to after harvesting time, the same trend observed in organic carbon, nitrogen phosphorus, and potassium, i.e., 1.70±0.11 to 2.31±0.08, 171.54±11.40 to 212.03±13.18, 75.62±8.16 to 96.32±11.56, and 658.19±86.05 to 1112.50 ±152.35 respectively in the soil after harvesting

Table 2. Physico-chemical status of soil (N=55) sowing time and after harvesting

Parameters	Sand	Silt	Clay	pH	EC	TDS	OC	N	P	K
Sowing time	75.13±1.27	18.55±1.09	6.33±0.53	8.12±0.05	0.48±0.04	309.65±22.41	1.70±0.11	171.54±11.40	75.62±8.16	658.19±86.05
After harvesting	71.75±1.26	20.66±1.02	7.76±0.63	8.16±0.06	0.58±0.17*	189.86±16.42*	2.31±0.08*	212.03±13.18*	96.32±11.56	1112.50±152.35*

Mean ± Standard Error Mean; * indicates the significant variation at 0.05; t-test; EC-Electrical conductivity; TDS-Total dissolved solids; OC-Organic carbon; N-Nitrogen; P-Phosphorus; K-Potassium.

Table 3. Reference range of all the studied soil parameters

Parameter	Unit	Reference Value	Reference
Soil texture	%	Sand (80.73%), silt (12.83%), and clay (6.44%)	16
		Sand (80.7%), silt (12.6%) and clay (7.0%) at less than15% slope	17
		Sand (55.40-69.40%), silt (19.04-35.08%) and clay (10.96-12.53%) altitude varies from1000ft->12000ft)	05
pH	-	5.65 - 10.12	15
		7.90 - 8.80	17
EC	µs/cm	0.05 - 1.56	15
TDS	ppm	160.35-131.82 altitude varies from1000ft->12000ft)	05
Available Nitrogen	(kg/ha)	185.60 - 411.40	15
Available Phosphorus	(kg/ha)	4.00 - 25.66	15
Available Potassium	(kg/ha)	12.32 - 496.15	15
Organic Carbon	(%)	0.70 - 1.41	07
		0.22 - 0.88	17

conditions have a significantly higher level than the soil during sowing conditions except phosphorus. An optimal supply of P and K are required for the high yield of any crop during periods of water stress; these nutrients should be applied before sowing in the spring or autumn season unless there is a danger of K leaching on sandy soils. Less loss of nutrition or less nutrition absorption capacity by crops in the region may be possible. Matike, *et al.* reported that the high content of available potassium on surface soil might be attributed to the application of potassium fertilisers and the addition of manures[25]. Availability of soil nitrogen is also directly correlated with soil organic carbon, i.e., high nitrogen content high will be organic carbon level in soil[26]. Dwivedi, *et al.* reported that the organic carbon concentration of soil is high in Ladakh agriculture soil[7]. Hence, high organic matter content in the study area's soil typically has higher cation exchange capacity; they may directly affect plant nutrition and soil fertility status[18]. NPK fertiliser used in these areas may affect the leaching of basic cations, such as potassium, calcium, and magnesium. The farmers in this region used locally produced manure which they applied on fields after sowing seeds. This might be the probable reason for the significantly higher organic carbon level followed by nitrogen phosphorus and potassium. In addition, Total Dissolve Solid (TDS) consists of inorganic salts (Ca, Mg, Na, K, $HCO3^-$, Cl^- and $SO4^-$) and some amount of organic matter.[28] The level TDS of soil present at altitude range has already been reported as 160.35±12.12 at 10000-11000 ft amsl; 142.05±10.72 at 11000-12000ft amsl level and 131.82±8.89 at more than 12000 ft [5]. However, In this study, TDS of soil samples during of sowing time was found to be 309.65 ± 22.41 and after harvesting was of about 189.86± 16.42 and both values were above the reference range already reported. This increase in soil TDS level at such an altitude might be due to the higher accumulation of base forming cations like Ca+2, Mg+2, or irrigation with inorganic salt containing water i.e. use saline water for irrigation.

4. CONCLUSIONS

The analysis of physico-chemical parameters, organic carbon, and primary macronutrient status during sowing and after harvesting of agriculture crops from Ladakh region indicated the sandy and alkaline nature of the soil. Moreover, significant difference in EC, TDS, OC, N, and K were observed between sowing and after harvesting time. From this result, it is concluded that external supplementation with manure and quality of irrigation water after sowing of crops may have affected the soil's physio-chemical properties, which has caused variation in nutrient availability to the crops. Further, the mineral's availability and soil texture during sowing and after the harvesting of crops are being reported for the first time. Hence, these findings will help to fill the knowledge gap on soil physico-chemical, organic carbon and primary macronutrient status of high-altitude soil.

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