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Assessment of various land use systems on soil potassium fractions and soil properties under lesser Himalayas

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Abstract
Potassium fractions serve as chemical markers of potassium stocks, furnishing capacity and their accessibility in soils. However, the allocation of various potassium fractions differs in response to fluctuations in land use and management practices. Therefore, the knowledge pertaining to potassium contribution from different pools in response to land use pattern grabs a prime importance for assessing the soil fertility status along with the provision of better interpretation in near future. The current study was performed to assess the distribution of different forms of soil potassium under different land uses of temperate lesser Himalayas during the year 2019-20. Surface samples (0 - 20 cm) were collected from different land uses of district Kupwara except for the horticultural land use from which both surface (0 - 20 cm) as well as sub-surface samples (20 - 40 cm) were taken. The results revealed that water soluble potassium ranged from 0.02 to 0.06 $cmol_c\ kg^{-1}$, available potassium from 0.09 - 0.44 $cmol_c\ kg^{-1}$ and exchangeable potassium from 0.07-0.34 $cmol_c\ kg^{-1}$. Non-exchangeable potassium was noted to vary from 1.54-4.22 $cmol_c\ kg^{-1}$, boiling nitrate extractable potassium from 1.63-4.66 $cmol_c\ kg^{-1}$ lattice potassium from 26.43-37.71 $cmol_c\ kg^{-1}$ while that of total potassium was observed to range from 28.05 - 42.36 $cmol_c\ kg^{-1}$. The magnitude of determined potassium forms was noted to be highest for agriculture irrigated soils followed by pasture soils and lowest in wasteland soils. A significant and positive correlation was observed among different potassium fractions.

Keywords: Potassium fractions, physico-chemical properties, land uses, correlation, Himalayas

Introduction
Potassium (K) is the chief component of the crust with a higher proportion in igneous rocks rather than sedimentary rocks. Potassium is rated in the earth's crust from 2.1 to 2.3 per cent and is assessed as the seventh most common element [1]. As far as nutrition is considered, potassium is regarded as a macro-element for the nutrition of plants, animals, and humans [2]. Potassium ions are influential in the functioning of all living cells and are key elements of plant growth. Potassium is contributory in nutrition and physiology of plants, paying its requirement for activation of not less than sixty different enzymes, concerned for plant growth, protein synthesis, osmo-regulation, water balance, cation-anion balance, reducing lodging, ensuring resistance to disease and enhancing quality and durability of culture. For better comprehension of productivity and sustainability of several ecosystems; it is pivotal to amplify knowledge of the potassium cycle [3].

Soil potassium might be bifurcated into four forms based on the extent to which they are of available to crops [4] manifesting a dynamic relationship with one another. The manifestation of equilibrium reactions existing between potassium forms determines the solubility and accessibility of potassium to plants. However, the allocation as well as accessibility of potassium is further altered by fluctuations in land use practices and management practices. The soluble and exchangeable forms of potassium comprise a little fraction of total soil potassium, while non-exchangeable and structural fractions constitute the considerable part. The potassium release from non-exchangeable pool is governed by soil particle size distribution and clay mineralogy, the depletion of soil potassium being accounted to the plant uptake and leaching while the improvisation to organic as well as inorganic fertilization. In soils, the meager application of potassium bringing about ample withdrawal of intrinsic potassium reserve of soil owes to the disinclination of farmers towards potassium fertilizer application, apparently on the customary view that the soils prevalent in our country are rich in potash [5]. Therefore, considerable depletion of reserve potassium in soil may occur due to continuous cropping in parallel with imbalanced fertilization which might be inconspicuous in accordance with standard soil test existing for available K [6]. The soils of Kupwara district of Kashmir valley possess illitic clay mineralogy and are observed to fall under medium status with respect to the available potassium [7-8]. In India, the suboptimal supplication rates of potassic manures and fertilizers are accounted for the attenuation of soil potassium stocks [9]. Such scenario alarms for sensible use of potassium in crops and calls for the assessment of potassium status in response to different land use practices. Keeping in view the above aspects, an attempt was made to study distribution of different potassium forms under different land uses of district Kupwara temperate lesser Himalayas.

Materials and Methodology

The present investigation was carried out during the year 2019-20 in district Kupwara falling under lesser Himalayas. The district is located at 34.3 to 35.5°N and 73.4 to 74.9°E, encircled by mountain slopes, profuse forests, and snow laden heights across three borders. The major soil types observed in Kupwara are Hapludalfs, medium to fine textured usually developed on Karewa tops. A total of 60 soil samples were collected from five land uses comprising Agri. Irrigated, Agri. Unirrigated, Horticulture (0-20 cm, 20-40 cm), pasture and wasteland. The gathered soil samples after being air dried were crushed with mortar and pestle followed by passing via 2 mm sieve. Mechanical analysis of the respective soil samples was performed by the hydrometric method as described by Bouyoucos (1962) [10]. These samples were analyzed for soil pH and water soluble K [11]. Cation exchange capacity was estimated in line with the procedure as delineated by Rhoades (1982) [12], calcium carbonate the procedure defined by Puri (1930) [13] and organic carbon with the employment of rapid titration method delineated by Walkley and Black (1934) [14]. Determination of available K and fixed potassium (Boiling HNO_3-K) was done as per method given by Pratt (1982) [15]. The difference attained between available K and water soluble K gave the estimate for exchangeable K. The difference attained between boiling nitrate extractable potassium and available K provided the estimation of non-exchangeable K [16]. Derivation of lattice potassium was attained as the difference between the total K and boiling nitrate extractable K (Sharma and Mishra, 1986) [17] and total K was determined by conventional method of aqua regia [18].

The statistical analysis were performed using analysis of variance (ANOVA) and data were analyzed using SPSS software. The data were also subjected to linear correlation and stepwise regression to establish the relationship among various soil K fractions and with physico-chemical properties. Comparison of means were made by LSD test $P< 0.01$.

Results and Discussion

Physico-chemical properties

The particulars in respect of soil physico-chemical properties are presented in Table 1. It can be inferred from the pursued data that texture shifted from heavy textural class (clay loam) in agricultural land use to relatively light class (sandy loam) in pasture and wasteland land uses. Depth wise analysis revealed loam as dominant textural class for horticultural soils (20 - 40 cm) possessing 22.84 per cent clay, 42.02 per cent silt and 35.02 per cent sand. This might be accredited to illuviation and translocation of clay to B horizons during the soil development [19].

The pH values exhibited a significant difference among different land uses and varied from 6.60 in pasture land use to 7.57 in wasteland land use. This could be attributed to more rainfall, which promotes salt leaching from upper layers, and higher organic matter content, which, when released as organic acids, lowers soil pH, as in pasture soils, and salt and calcium carbonate accumulation in wasteland soils. An increase in soil pH with increasing depth in horticultural soils might be ascribed to leaching of exchangeable bases from top layers [20]. The mean values of organic carbon differed significantly and varied under different land uses from 0.46-2.03% exhibiting a decreasing trend with depth in horticultural land use. The higher values of organic carbon might be ascribed to higher biomass incorporation in soils like pastures and less biomass additions in wasteland soils because of less vegetation. The higher values might be also attributed to low temperature and slow rate of mineralization while low values in cultivated soils owe to the rapid mineralization and loss of carbon from soils [21]. The results portrayed in Table 1 revealed that cation exchange capacity and calcium carbonate varied from 9.34 to 18.56 $cmol_c\ kg^{-1}$ and 1.05 to 2.59 per cent, respectively. The predominance of calcium carbonate in soils of wasteland land use might be accredited to available calcium and prevalence of calcification process [22-23]. A consistent increase in cation exchange capacity and calcium carbonate content was observed with increase in depth of horticultural soils which might be accredited to the leaching down of clay content and calcium carbonate from upper soils surfaces, respectively. Karwade *et al.*, (2020) [24] also observed that in surface soil the calcium carbonate ranged from 2.02 to 3.81 per cent and ranged from 2.09 to 4.21 per cent in sub-surface soil.

Table 1: Physico-chemical properties of the soils under different land use systems of Kupwara district

Land uses	pH	OC	$CaCO_3$	CEC	Sand	Silt	Clay
	1:2.5	(%)	(%)	(cmol (p^+) kg^{-1})		(%)	
Agri - Irrigated	7.31[b]	0.88[d]	1.20[d]	13.88[d]	36.79[d]	29.06[f]	34.02[a]
Agri- Unirrigated	7.03[d]	0.83[e]	1.61[c]	12.97[e]	36.59[e]	41.84[b]	21.07[d]
Hort (0-20cm)	6.75[e]	1.02[b]	1.05[f]	15.05[c]	37.20[c]	41.06[c]	21.46[c]
Hort (20-40cm)	7.11[c]	0.91[c]	1.07[e]	16.70[b]	35.02[f]	42.02[a]	22.84[b]
Pasture	6.60[f]	2.03[a]	1.92[b]	18.56[a]	42.82[a]	36.84[e]	20.43[e]
Wasteland	7.57[a]	0.46[f]	2.59[a]	9.34[f]	42.06[b]	37.47[d]	20.04[f]

Values in the same column followed by different lowercase letters are significantly different at p= 0.05

Potassium Forms

Available Potassium

The various forms of potassium under different land uses in the Kupwara district are depicted in Figure 1. In the examined soils, the available potassium varied from 0.09 - 0.44 $cmol_c$ kg^{-1}, following the trend agriculture irrigated > pasture > horticulture > agriculture un-irrigated > wasteland with mean values 0.44, 0.43, 0.39, 0.14 and 0.09 $cmol_c$ kg^-1, respectively. The higher available potassium could be ascribed to higher organic matter content of these soils. Kashmir soils being illitic in nature might have contributed to higher content of available potassium [25]. A decrease in available potassium content with increase in depth of horticultural soils was observed accounting it to the changes in organic matter content along the soil profile. These findings are additionally promoted by Singh *et al*., (2019) [26]. Depth wise analysis of horticultural soils for water soluble potassium showed a decreasing trend owing to decreased organic matter content in lower soil surfaces [27].

Boiling Nitrate Extractable Potassium

The boiling nitrate extractable potassium in the investigated soils varied from 1.63-4.66 $cmol_c$ kg^{-1} following the trend agriculture irrigated > pasture > horticulture > agriculture un-irrigated > wasteland with the mean values 4.66, 4.58, 4.54, 2.13 and 1.63 $cmol_c$ kg^-1, respectively. The higher amount of this potassium fraction might be due to preponderance of potassium bearing minerals in the respective soil. The variations in boiling HNO_3-K might be accounted to the differences in texture and degree of weatherability of the soils [16]. A decrease in the fixed potassium was observed during the depth wise analysis of horticultural soils possessing mean values of 4.54 and 4.52 $cmol_c$ kg^{-1} at 0-20 cm and 20-40 cm depth, respectively [27].

Exchangeable Potassium

The mean values for exchangeable potassium varied from 0.07-0.34 $cmol_c$ kg^{-1} and were marked to differ significantly following the order agriculture irrigated >pasture > horticulture > agriculture un-irrigated > wasteland with mean values 0.38, 0.37, 0.34, 0.11 and 0.07 $cmol_c$ kg^-1, respectively. Higher content of organic matter and nature of clay minerals might be accredited to the considerable content of this potassium fraction in the examined soils [28]. A consistent decrease in exchangeable potassium with depth of horticultural soils was observed with an average value of 0.34 $cmol_c$ kg^{-1}at 0 - 20 cm depth and 0.32 $cmol_c$ kg^{-1} at 20 - 40 cm depth of the respective soils. The higher exchangeable potassium content of surface soils might be accredited to utilization of potassium fertilizers, crop residues and high organic matter content. The observations are in agreement with the determinations outlined by Karwade *et al*. (2020) [24].

Lattice Potassium

The mean values for the lattice potassium content varied between 26.43-37.71 $cmol_c$ kg^{-1} under different land uses following the order agriculture irrigated > pasture > agriculture un- irrigated > horticulture > wasteland with mean values 37.71, 32.64, 29.77, 29.75 and 26.43 $cmol_c$ kg^-1, owing to higher amount of clay content in soils like in agriculture irrigated. The existence of substantial amounts of lattice potassium in the examined land uses might be accredited to mineralogical makeup and degree of weathering [25]. Depth wise analysis of horticultural soils revealed an increased trend in the lattice potassium content with mean values of 29.75 and 30.09 $cmol_c$ kg^{-1} at 0-20 cm and 20-40 cm respectively. These observations are further augmented by Divya *et al*., (2016) [29]. The non - exchangeable potassium showed an overall range of 1.54 - 4.22 $cmol_c$ kg^{-1} under different land uses. The order followed is agriculture irrigated > pasture > horticulture > agriculture un-irrigated > wasteland with mean values 4.22, 4.15, 1.99, 1.54 $cmol_c$ kg^{-1}, respectively.

Non-Exchangeable Potassium

The higher content of non-exchangeable potassium might be ascribed to the higher clay content which aids in easy fixation of potassium especially in soils enriched with illitic form of clay minerals [30]. Depth wise analysis of horticultural soils for non-exchangeable potassium showed a decreased trend with mean values of 4.15 and 4.14 $cmol_c$ kg^1 at 0-20 cm and 20- 40 cm depth respectively [27].

Total Potassium

The results acquired reflected the mean values for total potassium content under different land uses were statistically significant and varied from 28.05 - 42.36 $cmol_c$ kg^{-1} following the trend agriculture irrigated > pasture > horticulture > agriculture un- irrigated > wasteland with mean values 42.36, 36.79, 33.91, 31.91 and 28.05 $cmol_c$ kg^{-1}, respectively. Illite, mica and feldspars being the primary potassium bearing minerals might be accredited for elevated content of total potassium prevailing in examined soils which are capable of releasing large amount of potassium. The predominance of these minerals in soils of Kashmir has also been reported by Wani *et al*., (2009) [8]. A rise in the total potassium content was observed with depth wise analysis of horticultural soils. The edge over the top layers of soil may possibly be ascribed to the more content of clay, removal by crops and leaching losses paving to sub-surface soils. The clay mineralogy and lattice K content might be accounted for the variation in the surface and sub-surface soils with respect to total K content [29].

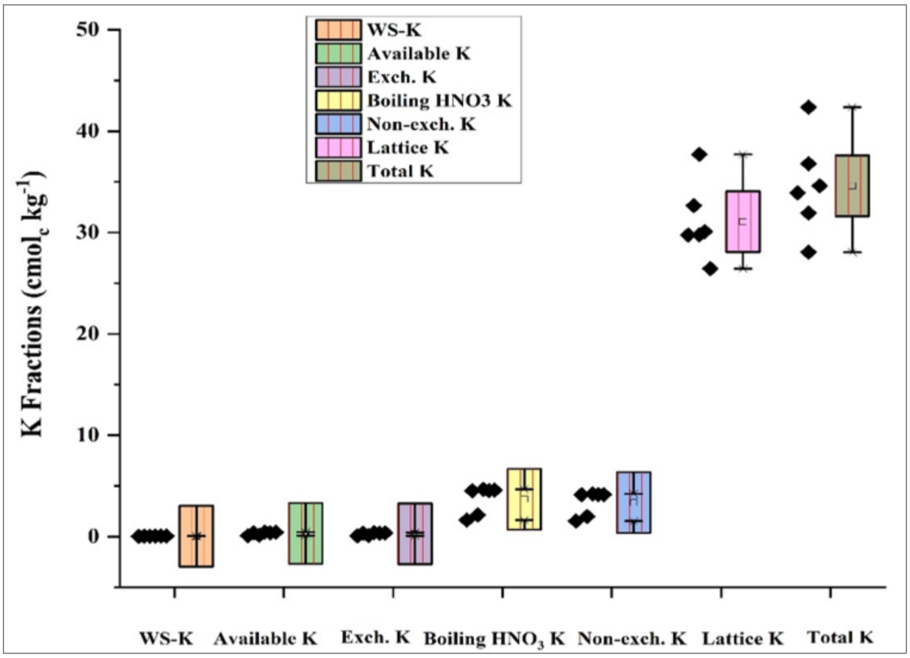
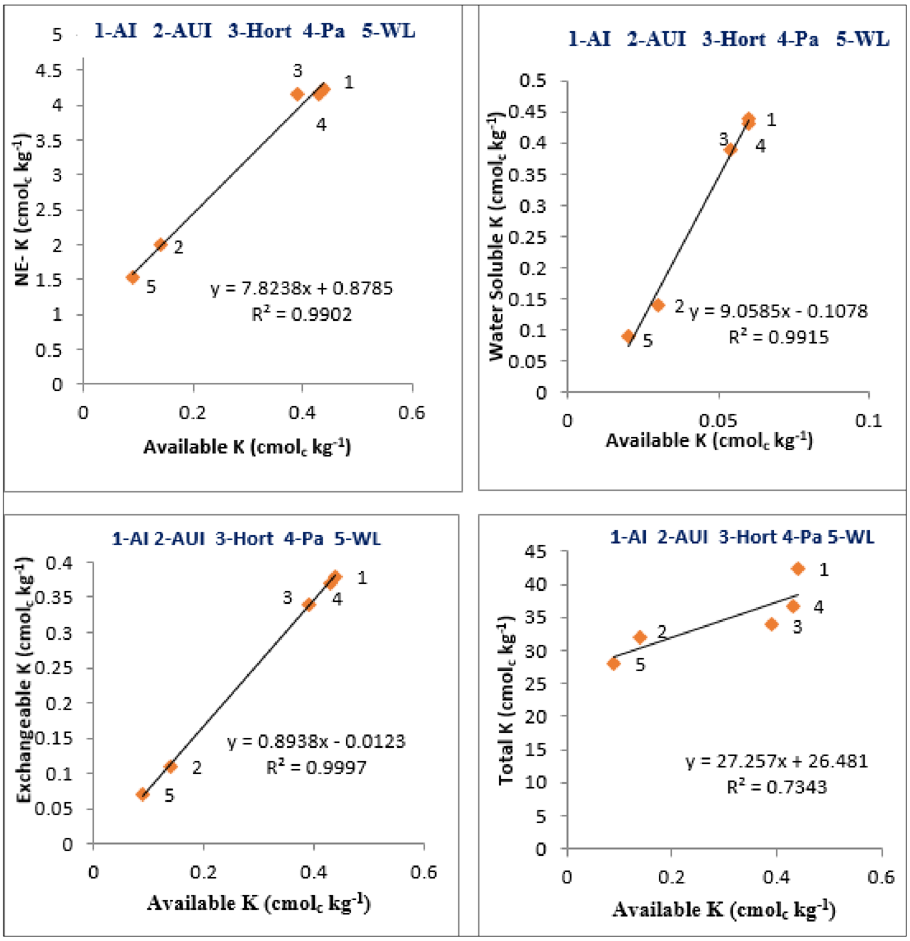


Fig 1: Distribution of various potassium fractions under different land use systems of Kupwara district

Inter-relationship between various Soil Potassium Forms

The correlation matrix inferred a significant positive relationship between various potassium forms (Figure 2). Regression analysis elucidated the relationship between soil available potassium and other potassium fractions (Figure 3).

A positive association between the available potassium and other potassium forms *viz*., exchangeable potassium (R^2= 0.99), non-exchangeable (R^2= 0.99), total potassium (R^2= 0.73), soluble potassium (R^2= 0.99) was observed.



1. AI- Agriculture Irrigated 2. AUI- Agriculture Un-irrigated 3. Hort- Horticulture
4. Pasture 5. Wasteland

Fig 2: Regression analysis of different potassium fractions and soil available potassium

Correlation coefficient between various K fractions and soil physico-chemical properties

A significant as well as a positive correlation was noticed between different forms of potassium with organic carbon content, clay and cation exchange capacity of the investigated soils. Also, various forms of potassium exhibited negative and significant correlations with calcium carbonate content and soil pH (Figure 3). These observations run parallel with the findings of Wani *et al*., (2009) [8].

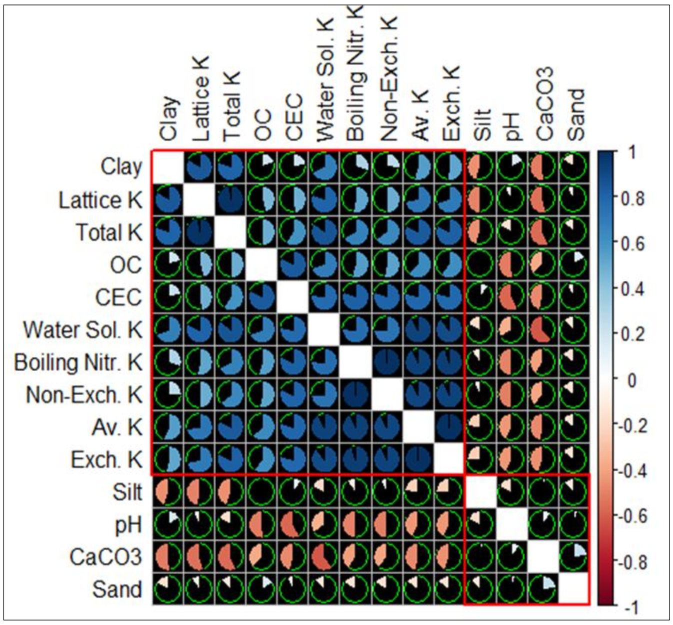


Fig 3: Relationship between various soil K fractions and soil physico-chemical properties

Conclusion

The examined land uses reflected a significant effect on chemical properties as well as potassium fractions in soil. The magnitude of determined potassium forms was noted to be highest in case of agriculture irrigated soils and lowest in wasteland soils, the differences being accounted to the content of clay and organic matter that differed significantly among different land uses and thereby inferring the significant impact of land use and management practices on potassium status of soil. Depth-wise analysis of horticultural soils showed a decreasing trend with respect to all potassium forms except for lattice and total potassium which increased with increase in depth of soil. The significant and positive correlations were observed between different potassium forms reflecting the exhibition of dynamic equilibrium among them, where exhaustion of one is instantaneously replenished by one or the other fractions of potassium in soil. Distribution of various potassium fractions was noted to be affected by different soil properties like organic carbon, clay content and cation exchange capacity of soils. Therefore, to avert the degradation of soil and nutrient depletion, it is mandatory to periodically explore the soil nutrient status of soil encircling the different fractions of potassium for better management of potassium fertilization.

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