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**Research Paper**

# Different forms of potassium in pear orchard soils of district Budgam of Kashmir region

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ABSTRACT

**An attempt was made to study various forms of potassium in pear orchard soils of district Budgam to understand the actual reserves of potassium and to determine how much more impact is needed to maintain the potassium balance in the soil. A total of fifty-four surface samples (0-30cm) representing eighteen pear orchards from six altitudes were collected and subjected to different studies, *viz.,* physicochemical characteristics, different forms of potassium, potassium saturation and leaf potassium. The results obtained revealed water-soluble potassium, available potassium, exchangeable potassium, $HNO_3$-extractable potassium, non-exchangeable potassium, lattice potassium and total potassium ranged from 0.012-0.045 $cmol_c kg^{-1}$, 0.224-0.474 $cmol_c kg^{-1}$, 0.201-0.429 $cmol_c kg^{-1}$, 1.328-2.642 $cmol_c kg^{-1}$, 1.019-2.168 $cmol_c kg^{-1}$, 27.436-43.846 $cmol_c kg^{-1}$ and 29.487-46.410 $cmol_c kg^{-1}$, respectively. All forms of potassium were positively and significantly correlated with each other indicating dynamic equilibrium among various forms. The leaf potassium content ranged from 0.35-1.84%. Among various soil properties organic carbon, clay and CEC ranged from 1.39-2.44%, 24.25-39.25% and 15.27-18.62 $cmol_c kg^{-1}$, respectively and played most important role to predict the variability of different forms of potassium.**

**Key words:** Forms of potassium, physico-chemical characteristics, pear orchards, soils.

Pear orchard soils in the Budgam district, Kashmir, exhibit variations in potassium forms and mineralogical composition. Pear cultivation, predominantly in the Kashmir region, benefits from its adaptability to various altitudes, with chilling hours ranging from 500 to 1500. Notably, superior pear cultivars, such as *Pyrus communis,* thrive in the highlands of Jammu and Kashmir, Himachal Pradesh, and Uttaranchal due to their high chilling requirements (Dar *et al.,* 2012). Potassium (K) is the third most crucial plant nutrient, vital to many plant processes owing to its requirement for activation of at least 60 distinct plant growth-related enzymes, including those involved in osmoregulation, cation-anion balance, protein synthesis, water balance, minimizing lodging, imparting disease resistance and enhancing quality and shelf life of crop produce (Ramamurthy *et al.,* 2017). Despite its paramount importance, farmers, particularly in high-intensity agricultural settings, often neglect adequate potassium fertilization, mistakenly assuming Indian soils inherently provide enough (Sanyal, 2014). This unsettling tendency is mostly due to the idea that Indian soils are naturally rich in potassium. As a result, for the country's predominant farming methods, the sole supply of potassium to rely on is frequently the potassium in the local soil (Sarkar *et al.,* 2014). The dynamic interplay between potassium forms and soil properties shapes availability, with water-soluble and exchangeable potassium directly accessible to plants, while non-exchangeable, fixed, and clay lattice forms offer a slower release (Harpreet Kaur, 2019). Few studies have been conducted on various forms of potassium in soils representing intermediate zone of Jammu region (Sharma *et al.,* 2009), but no specific information is available about the distribution of different forms of potassium and their interrelationship with various soil physicochemical properties for the Kashmir region, particularly in the soils of Budgam district. Therefore, an attempt was made to assess the status of different forms of potassium, interrelating its availability indices and important soil properties in soils of Budgam district of Kashmir region and to delineate the area of deficiency or sufficiency of potassium in the study area.

## MATERIALS AND METHODS

In 2021-22, research in Budgam district explored the region bounded by 32º.17′ to 37º.50′ N latitude and 72º.14′ to 80º.30′ E longitude, at 3700 meters above sea level. Budgam's alluvial-filled basin, reminiscent of the valley, harbors fertile Karewa formations from the Pleistocene and post-Pleistocene eras. These formations, characterized by horizontally stratified lacustrine origins, boast sand, silt, clay, buff-colored sandy clay, and partly compacted conglomerates. These fertile Karewa areas predominantly cultivate temperate fruits like pear, apple, and walnut, epitomizing nature's bounty in this picturesque landscape. A total of 54 soil samples were collected from various pear orchard soils across six different altitudes. After air-drying, the soil samples were crushed and passed through a 2 mm sieve. Mechanical analysis was conducted using the international pipette method (Piper, 1966). The composite soil samples were then analyzed for various physicochemical properties and forms of potassium. Soil pH and electrical conductivity (EC) were determined using standard procedures (Jackson, 1973). Organic carbon (OC) content was measured by dichromate oxidation (Walkley and Black, 1947), while cation exchange capacity (CEC) was assessed following Chapman's method (1965). Exchangeable calcium and magnesium were estimated *via* EDTA titration (Jackson, 1973). By agitating the soils with water in a 1:5 ratio, water-soluble potassium was extracted and measured in a saturation paste extract (Jackson, 1973). Available potassium was extracted with 1N ammonium acetate (pH 7.0) (Jackson, 1973). Exchangeable potassium was obtained by subtracting water-soluble potassium from available potassium (Dhillon *et al*., 1985). $HNO_3$-extractable potassium was obtained by boiling the samples in 1N $HNO_3$ (Pratt, 1982), while non-exchangeable potassium was calculated by subtracting available potassium from $HNO_3$-extractable potassium (Bangroo, 2010). Total potassium was extracted using conventional aqua regia digestion (Nieuwenhuize *et al*., 1991), and lattice potassium was determined by subtracting $HNO_3$-extractable potassium from total potassium (Sharma and Mishra, 1986). Potassium saturation was calculated using the formula by Chand and Swami (2000):

$$\text{Potassium saturation} = \frac{\text{Exchangeable potassium}}{\text{CEC}} \times 100$$

Potassium in soil samples and leaves was analyzed using a flame photometer (Jackson, 1973). Sixty to eighty healthy leaves with petioles were collected from the mid-portions of current season's shoots between July 15 to August 15, 2021, following Chapman's procedure (1964) from the same orchards where soil samples were collected. Correlation analysis was performed using Opistat software.

## RESULTS AND DISCUSSION

***Physicochemical properties:*** The physico-chemical characteristics of the soil are shown in Table 1. It is evident that all elevations of soils have fine textures, varying from silty clay loam to clay loam. These properties are influenced by altitude, relief, and the alluvial nature of the soil, which is consistent with the findings of Bangroo, (2010) for Kashmir soils. Overall, the soil reaction was slightly acidic to alkaline, with a pH range of 6.2 to 7.8. The pH varied with altitude, attributed to base leaching, temperature fluctuations, and organic matter content. The increasing trend of pH with decreasing altitude is in agreement with the findings of Amenla *et al.* (2010) and Sharma *et al.* (2015). Electrical conductivity ranged from 0.26 to 0.48 $dSm^{-1}$, decreasing with altitude due to leaching and runoff, as observed by Baseerat, (2021) and Irshad *et al.* (2015) for Kashmir soils. Organic carbon content ranged from 1.39 to 2.44%, with altitude significantly influencing this variation. Higher values were associated with lower temperatures, more rainfall, and a slow mineralization rate, all of which encouraged the build-up of organic materials. Conversely, cultivated soils exhibited lower values due to rapid mineralization and carbon loss (Chauhan *et al.,* 2014). The cation exchange capacity varied between 15.27 and 18.62 cmol $(p^+)$ $kg^{-1}$; greater values were associated with the presence of clay and organic matter, in line with the findings of Wani *et al.* (2009). The ranges of exchangeable calcium and magnesium contents were 7.25-11.23 ($cmol_c$ $kg^{-1}$) and 0.54-2.35 ($cmol_c$ $kg^{-1}$), respectively. These values varied greatly with altitude and were probably impacted by the parent material and flora. Mid-altitude orchard soils exhibited higher exchangeable magnesium, possibly due to mineral composition. Verma *et al.* (2012) and Gogoi *et al.* (2018) also observed parent material and regolith depth's role in calcium and magnesium pools.

***Different forms of potassium:*** The water-soluble potassium levels in the soil ranged from 0.012-0.045 $cmol_ckg^{-1}$ averaging at 0.027 $cmol_ckg^{-1}$ (Table 2), aligning with findings of Bashir *et al.* (2016) for Kashmir soils. The higher organic matter content in the soils likely contributed to this result, as it has the potential to block binding sites of clay minerals, thus reducing potassium fixation. However, this level of potassium was found to be insufficient to meet the requirements of plants. Available potassium ranged from 0.224-0.474 $cmol_ckg^{-1}$ with an overall mean of 0.331 $cmol_ckg^{-1}$, possibly influenced by the illitic nature of Kashmir soils and their higher organic matter content. The distribution pattern of exchangeable potassium was similar, ranging from 0.201 to 0.429 $cmol_ckg^{-1}$ with a mean value of 0.304 $cmol_ckg^{-1}$, attributed to organic matter and clay minerals. Potentially as a result of minerals containing potassium, the range of $HNO_3$-extractable potassium was 1.328 to 2.642 $cmolckg^{-1}$. Sharma *et al.* (2015) reported a higher content of these minerals in Kashmir soils, contributing to increased $HNO_3$-extractable potassium. In soils enriched with illitic clay minerals, non-exchangeable potassium ranged from 1.019 to 2.168 $cmol_ckg^{-1}$. This is probably because higher clay contents facilitate potassium fixation. Similar findings were reported by Waheeda and Radhwan (2019), who found that surface soil had an average of 2.038 $cmol_ckg^{-1}$ of non-exchangeable potassium, ranging from 1.150 to 3.261 $cmol_ckg^{-1}$. Lattice potassium ranged from 27.436-43.846 $cmol_ckg^{-1}$, decreasing with altitude possibly due to variations in clay minerals and organic matter (Wani and Kumar, 2008). This trend aligns with the findings of Bashir *et al.* (2016), who reported mean values of 39.09 $cmol_ckg^{-1}$ across altitude ranges. Total potassium content varied from 29.487-46.410 $cmol_ckg^{-1}$, decreasing with altitude. Despite the high total potassium content, only a small fraction is available to plants, as it exceeds plant uptake. This finding is in line with the research conducted by Bangroo (2010) in a study of Kashmir soils along a toposequence, where potassium saturation ranged from 1.24% to 2.49%, all of which exceeded 1.0%. Coupled with lower mean CEC, this suggests high potassium saturation (Sharma *et al.,* 2018). All the orchards we studied displayed adequate leaf potassium levels. The highest value (1.98%) was at high altitude, and the lowest mean (1.69%) was at low altitude. Among orchards at varying altitudes, leaf potassium varied considerably, most likely as a result of variations in soil potassium and other related factors. These outcomes are consistent with Sharma *et al.* (2017).



***Relationship among different forms of potassium, potassium saturation and leaf potassium:*** Table 3 presents a statistically significant positive association between the various types of potassium found in soil. Water-soluble and exchangeable potassium (r = 0.769**) and $HNO_3$-extractable potassium (r = 0.770**) show significant positive correlations, indicating a dynamic equilibrium among different potassium pools, as noted by Bashir *et al.* (2016). Furthermore, the significant correlation (r = 0.829**) between exchangeable potassium and total potassium suggests that exchangeable potassium is replenished from the total potassium pool, in line with El-Hedek *et al.* (2017). $HNO_3$-extractable potassium showed a highly significant positive correlation with non-exchangeable (r = 0.987**), lattice (r = 0.793**), and total potassium (r = 0.819**) fractions, implying that the non-exchangeable potassium serves as an indicator of potassium supplying capacity in soils. Panwar and Unni (2016) found significant correlations between $HNO_3$-extractable potassium, lattice potassium (r = 0.728**), and total potassium (r = 0.793**), indicating the presence of potash-bearing minerals in Nignoti village soils. Lattice potassium also showed a significant positive correlation with total potassium (r = 0.999**), aligning with Wani *et al.* (2009). These relationships suggest an equilibrium between different forms of potassium, where depletion of one form is replenished by others. Besides, all forms of potassium were positively and significantly correlated with leaf potassium, possibly attributable to potassium-bearing clay minerals present in the soils, in agreement with Sharma *et al.* (2012).

***Relationship between different forms of potassium, potassium saturation, leaf potassium and physico-chemical properties of soils:*** In order to assess the influence of soil properties on various forms of K and interrelationship of K forms with each other, coefficients of correlations were worked out. Significant positive correlations were found between different forms of potassium and organic carbon content, as well as positive correlations with clay content, in the examined soils (Table 4). Notably, there was a significant and positive correlation between exchangeable potassium and organic carbon (r = 0.694**), indicating that higher organic matter content makes clay-humus complexes more active, leading to increased exchangeable sites and access to potassium ions. Panwar and Unni (2016) also noted a positive relationship between organic carbon content and all forms of potassium in Nignoti village soils, indicating a strong dependence of potassium on organic matter. $HNO_3$-extractable potassium showed a significant and positive correlation with organic carbon (r = 0.962**) and cation exchange capacity (CEC) (r = 0.511*), along with a positive correlation with clay content suggesting higher potassium reserves in the respective soils. The positive correlation between total potassium and clay content might be attributed to the predominance of illites in the clay fraction. Overall, clay particles exhibited a positive relationship with all forms of potassium. However, the narrow range in clay content among soils at different sites might explain the lack of statistically significant relationship between potassium forms and clay content observed in this study. Leaf potassium showed a positive correlation with clay content, suggesting a dependence on the nutrient-holding capacity of clay to some extent. This finding aligns with Sharma *et al.* (2018).

**Table 1: Physico-chemical properties of pear growing soils of district Budgam**

| Site | pH (1: 2.5) | EC ($dSm^{-1}$) | Organic carbon (%) | Exchange-able Calcium ($cmol_c\ kg^{-1}$) | Exchange-able Magnesium ($cmol_c\ kg^{-1}$) | CEC ($cmol_c\ kg^{-1}$) | Sand (%) | Silt (%) | Clay (%) |
|---|---|---|---|---|---|---|---|---|---|
| $L_1$ | 6.5 | 0.46 | 1.39 | 7.25 | 0.58 | 16.43 | 23.60 | 43.00 | 33.40 |
| $L_2$ | 6.6 | 0.35 | 1.64 | 7.86 | 0.73 | 15.27 | 27.56 | 39.88 | 32.56 |
| $L_3$ | 7.8 | 0.45 | 1.42 | 8.19 | 1.14 | 16.64 | 24.40 | 42.10 | 33.50 |
| $L_4$ | 6.6 | 0.26 | 1.48 | 9.23 | 1.42 | 16.15 | 19.20 | 45.90 | 34.90 |
| $L_5$ | 7.8 | 0.48 | 1.43 | 7.36 | 0.66 | 15.68 | 17.65 | 46.37 | 35.98 |
| $L_6$ | 7.6 | 0.36 | 1.45 | 10.25 | 2.04 | 16.24 | 24.60 | 43.70 | 31.70 |
| $L_7$ | 7.5 | 0.36 | 1.92 | 8.72 | 1.42 | 17.48 | 21.50 | 45.80 | 32.70 |
| $L_8$ | 6.6 | 0.47 | 1.53 | 8.90 | 2.35 | 16.26 | 26.10 | 42.34 | 31.56 |
| $L_9$ | 7.5 | 0.33 | 1.75 | 9.34 | 1.45 | 16.81 | 30.11 | 45.46 | 24.43 |
| $L_{10}$ | 6.3 | 0.42 | 1.56 | 11.23 | 2.25 | 17.63 | 27.25 | 42.05 | 30.70 |
| $L_{11}$ | 6.5 | 0.35 | 1.68 | 10.16 | 1.96 | 17.45 | 29.08 | 38.74 | 32.18 |
| $L_{12}$ | 7.6 | 0.37 | 1.77 | 8.62 | 1.55 | 16.15 | 34.82 | 40.93 | 24.25 |
| $L_{13}$ | 6.2 | 0.35 | 2.38 | 8.53 | 1.46 | 17.74 | 20.77 | 43.32 | 35.91 |
| $L_{14}$ | 6.6 | 0.44 | 1.86 | 9.64 | 1.62 | 18.46 | 22.49 | 39.25 | 38.26 |
| $L_{15}$ | 7.6 | 0.36 | 2.44 | 7.54 | 0.54 | 17.25 | 15.32 | 46.30 | 38.38 |
| $L_{16}$ | 6.8 | 0.27 | 2.35 | 9.86 | 1.78 | 18.62 | 22.39 | 38.36 | 39.25 |
| $L_{17}$ | 6.3 | 0.37 | 2.41 | 8.43 | 1.05 | 17.36 | 18.52 | 43.96 | 37.52 |
| $L_{18}$ | 6.4 | 0.29 | 2.43 | 8.16 | 0.97 | 17.87 | 29.80 | 32.40 | 37.80 |
| **Range** | **6.2-7.8** | **0.26-0.48** | **1.39-2.44** | **7.25-11.23** | **0.54-2.35** | **15.27-18.62** | **15.32-34.82** | **32.40-46.37** | **24.25-39.25** |
| **Mean** | **6.9** | **0.37** | **1.83** | **8.85** | **1.39** | **16.97** | **24.18** | **42.21** | **33.61** |

**Table 2: Forms of soil potassium, potassium saturation and leaf potassium in pear growing soils of district Budgam**

| Site | Water-soluble potassium | Available Potassium | Exchangeable potassium | Boiling $HNO_3$ potassium | Non exchangeable potassium | Lattice potassium | Total potassium | Potassium saturation | Leaf potassium |
|---|---|---|---|---|---|---|---|---|---|
| | | | cmol$_c$ kg$^{-1}$ | | | cmol$_c$ kg$^{-1}$ | | % | |
| $L_1$ | 0.019 | 0.255 | 0.236 | 1.328 | 1.073 | 28.462 | 29.744 | 1.44 | 0.84 |
| $L_2$ | 0.024 | 0.241 | 0.217 | 1.749 | 1.508 | 33.077 | 34.872 | 1.42 | 0.56 |
| $L_3$ | 0.028 | 0.374 | 0.346 | 1.393 | 1.019 | 30.513 | 31.795 | 2.08 | 1.35 |
| $L_4$ | 0.024 | 0.283 | 0.259 | 1.626 | 1.342 | 28.718 | 30.256 | 1.60 | 0.74 |
| $L_5$ | 0.012 | 0.298 | 0.286 | 1.437 | 1.138 | 34.872 | 36.410 | 1.82 | 0.63 |
| $L_6$ | 0.023 | 0.224 | 0.201 | 1.428 | 1.204 | 33.077 | 34.516 | 1.24 | 0.31 |
| $L_7$ | 0.021 | 0.237 | 0.216 | 1.985 | 1.749 | 27.436 | 29.487 | 1.24 | 0.46 |
| $L_8$ | 0.022 | 0.234 | 0.212 | 1.676 | 1.442 | 33.333 | 35.128 | 1.30 | 0.42 |
| $L_9$ | 0.016 | 0.315 | 0.299 | 1.749 | 1.433 | 33.846 | 35.641 | 1.78 | 0.95 |
| $L_{10}$ | 0.027 | 0.351 | 0.324 | 1.524 | 1.172 | 36.410 | 37.949 | 1.84 | 1.19 |
| $L_{11}$ | 0.036 | 0.342 | 0.306 | 1.716 | 1.374 | 31.282 | 33.077 | 1.75 | 1.12 |
| $L_{12}$ | 0.030 | 0.402 | 0.372 | 1.851 | 1.449 | 36.923 | 38.718 | 2.30 | 1.52 |
| $L_{13}$ | 0.035 | 0.434 | 0.399 | 2.477 | 2.042 | 42.051 | 44.615 | 2.25 | 1.68 |
| $L_{14}$ | 0.022 | 0.226 | 0.204 | 1.847 | 1.621 | 30.256 | 32.051 | 1.11 | 0.35 |
| $L_{15}$ | 0.045 | 0.474 | 0.429 | 2.642 | 2.168 | 43.846 | 46.410 | 2.49 | 1.77 |
| $L_{16}$ | 0.025 | 0.356 | 0.331 | 2.033 | 1.677 | 39.487 | 41.538 | 1.78 | 1.23 |
| $L_{17}$ | 0.039 | 0.455 | 0.416 | 2.534 | 2.079 | 43.077 | 45.641 | 2.40 | 1.73 |
| $L_{18}$ | 0.042 | 0.461 | 0.419 | 2.583 | 2.122 | 43.333 | 45.897 | 2.34 | 1.84 |
| **Range** | **0.012-0.045** | **0.224-0.474** | **0.201-0.429** | **1.328-2.642** | **1.019-2.168** | **27.436-43.846** | **29.487-46.410** | **1.24-2.49** | **0.35-1.84** |
| **Mean** | **0.027** | **0.331** | **0.304** | **1.865** | **1.534** | **35.000** | **36.880** | **1.79** | **1.04** |

**Table 3: Correlation coefficients among different forms of soil potassium, potassium saturation and leaf potassium**

| | Water soluble potassium | Available potassium | Exchangeable potassium | Boiling $HNO_3$ Potassium | Nonexchangeable Potassium | Lattice potassium | Total potassium | Potassium saturation |
|---|---|---|---|---|---|---|---|---|
| Available potassium | 0.810** | | | | | | | |
| Exchangeable potassium | 0.769** | 0.998** | | | | | | |
| Boiling $HNO_3$ Potassium | 0.770** | 0.721** | 0.699** | | | | | |
| Nonexchangeable potassium | 0.700** | 0.598** | 0.573* | 0.987** | | | | |
| Lattice potassium | 0.692** | 0.834** | 0.831** | 0.793** | 0.721** | | | |
| Total potassium | 0.704** | 0.834** | 0.829** | 0.819** | 0.751** | 0.999** | | |
| Potassium saturation | 0.720** | 0.976** | 0.982** | 0.625** | 0.492* | 0.794** | 0.789** | |
| Leaf potassium | 0.801** | 0.983** | 0.981** | 0.680** | 0.554* | 0.783** | 0.782** | 0.957** |

**Table 4: Correlation coefficient among different forms of potassium, potassium saturation, leaf potassium and physico chemical characteristics of soils**

| | pH (1: 2.5) | EC ($dSm^{-1}$) | Organic carbon (%) | Exchangeable Calcium ($cmol_c\ kg^{-1}$) | Exchangeable Magnesium ($cmol_c\ kg^{-1}$) | CEC ($cmol_c\ kg^{-1}$) | Sand (%) | Silt (%) | Clay (%) |
|---|---|---|---|---|---|---|---|---|---|
| Water soluble potassium | -0.295 | -0.368 | 0.703** | -0.063 | -0.123 | 0.395 | -0.045 | -0.352 | 0.347 |
| Available Potassium | -0.091 | -0.304 | 0.710** | -0.193 | -0.269 | 0.355 | -0.061 | -0.190 | 0.230 |
| Exchangeable Potassium | -0.066 | -0.289 | 0.694** | -0.203 | -0.279 | 0.342 | -0.061 | -0.167 | 0.211 |
| Boiling $HNO_3$ Potassium | -0.264 | -0.464 | 0.962** | -0.214 | -0.244 | 0.511* | -0.236 | -0.207 | 0.449 |
| Nonexchangeable Potassium | -0.283 | -0.465 | 0.946** | -0.203 | -0.219 | 0.508* | -0.258 | -0.195 | 0.466 |
| Lattice potassium | -0.183 | -0.293 | 0.802** | -0.134 | -0.170 | 0.337 | -0.123 | -0.227 | 0.333 |
| Total potassium | -0.193 | -0.309 | 0.824** | -0.139 | -0.173 | 0.354 | -0.132 | -0.228 | 0.345 |
| Potassium saturation | 0.022 | -0.235 | 0.593** | -0.294 | -0.350 | 0.165 | -0.041 | -0.087 | 0.121 |
| Leaf potassium | -0.161 | -0.313 | 0.680** | -0.199 | -0.275 | 0.359 | -0.022 | -0.249 | 0.182 |

*Significant at 0.05 level; **Significant at 0.01 level

A positive correlation was found between total potassium and organic carbon (r = 0.824**), indicating that organic matter is likely the primary source of total potassium. Nevertheless, there was a negative correlation with sand content (r = - 0.132), implying that sand acts as a diluent for potassium, possibly due to the abundance of quartz in the sand fraction. Exchangeable calcium and magnesium showed negative correlations with all forms of potassium, possibly due to the dominance of calcium leading to decreased potassium availability with increasing soil pH. This finding is in line with the observations of Kassa *et al.* (2021), who also noted a negative correlation between exchangeable calcium and available potassium, exchangeable potassium, $HNO_3$-extractable potassium, and non-exchangeable potassium. Similarly, sand particles were negatively correlated with all forms of potassium, consistent with previous studies by Kaliramana *et al.* (2011) and Irshad *et al.* (2020). Moreover, pH and electrical conductivity (EC) showed a negative and non-significant relationship with all forms of potassium, as observed by Wani *et al.* (2014).

## CONCLUSION

A highly significant positive correlation among different forms of potassium indicates an equilibrium, where depletion of one form is instantly replenished by one or more other forms of potassium. Exchangeable potassium and non-exchangeable potassium contribute only 0.581% to 1.088% and 3.088% to 5.931% of total potassium, respectively, with the mineral pool being the main source, accounting for more than 90% of the total potassium. Understanding mineralogical features and properties could provide further insights. The contents of all forms of potassium were positively correlated with organic carbon and clay, but negatively correlated with sand content. Organic carbon, clay, and cation exchange capacity (CEC) played the most important role in predicting the variability of different forms of potassium. The soils studied are characterized by good potassium reserves but have a low rate of release. Therefore, periodic exploration of the soil nutrient status, especially potassium fractions, is essential to prevent soil degradation and nutrient depletion.



## REFERENCES

Amenla, T., Shrama, Y. K and Shrama, S. K. 2010. Characterization of soils of Nagaland with special references to Mokokchung district. *Environment and Ecology,* **28**: 198-201.

Bangroo, S. A. 2010. Potassium releasing and fixing capacity of rainfed maize growing soils of district Ganderbal. M. Sc. (Agri.) Thesis, Sher-e-Kashmir University of Agriculture Sciences and Technology of Kashmir, India.

Baseerat, B. N. 2021. Nutrient status of apple growing soils of Ganderbal. Ph. D. Dissertation, Sher-e-Kashmir University of Agriculture Sciences and Technology of Kashmir, India.

Bashir, U., Ali, T. and Qureshi, F. 2016. Distribution of different forms of potassium under temperature conditions of Kashmir. *International Journal of Agriculture, Environment and Biotechnology,* **9**: 213-219.

Chand, S. and Swami, B. N., 2000. Different forms of potassium in some important soil association of Bharatpur district of Rajasthan. *Journal of Potassium Research*, **16**:59-61.

Chapman, H. D. 1964. Suggested foliar sampling and handling techniques for determining the nutrient status of some field, horticultural and plantation crops. *Indian Journal of Horticulture* **21**: 97-119.

Chapman, H. D. 1965. Cation-exchange capacity. Methods of Soil Analysis: Part 2 *Chemical and Microbiological Properties* **9**: 891-901.

Chauhan, R. P., Pande, K. R. and Thakur, S. 2014. Soil properties affected by land use systems in western Chitwan, Nepal. *International Journal of Applied Sciences and Biotechnology* **2**: 265-269.

Dar, M. A., Wani, J. A., Raina, S. K., Bhat, M. Y., Malik, M. A. and Najar, G. R. 2012. Effect of altitude and depth on available nutrients in Pear orchard soils of Kashmir. *Agropedology,* **22**: 115-118.

Dhillon, S. K., Sidhu, P. S., Dhillon, K. S. and Sharma, Y. P. 1985. Distribution of various potassium forms in some benchmark soils of north west India, *Journal of potassium Research,* **1**: 154-165.

El-Hedek, K. S., Hassan, M. A. and Abdel-Aal, M. H. 2017. Distribution of different potassium forms in soil under long-term application of mineral and organic fertilizers. *Journal of Environmental Sciences,* **12**: 167-182.

Gogoi, A., Talukdar, M. C., Basumatary, A. and Baruah, U. 2018. Characterization and Classification of the Soils of Dorika Watershed of Assam using GIS and Remote Sensing Techniques. *Journal of the Indian Society of Soil Science,* **66**: 341-350.

Irshad, I., Chesti, M. H., Mir, S., Mansoor, M., Kirmani, N. A., Sofi, J. A., Sofi, K.A., and Qadri, T. N. 2020. Distribution of different forms of potassium in soils of district Ganderbal of Kashmir region. *Journal of the Indian Society of Soil Science,* **68**: 194-200.

Jackson, M. L. 1973. Soil chemical Analysis. *Prentice Hall of India Pvt. Ltd., New Delhi*. 1-485.

Kaliramana, R. S., Pannu, B. S. 2011. Vertical distribution of various forms of potassium in different agroclimate regions of Haryana. *Environment and Ecology,* **29**: 1633-1640.

Kassa, M., Kebede, F. and Haile, W. 2021. Forms and dynamics of soil potassium in acid soil in the wolaita zone of southern Ethiopia. *Applied and Environmental Soil Science*.

Kaur, H. 2019. Forms of Potassium in Soil and their Relationship with Soil Properties-A Review. *International Journal of Current Microbiology and Applied Sciences,* **8**: 1580-1586.

Nieuwenhuize, J., C. H. Poley-Vos, A. H. van den Akker and W. van Delft. 1991. Comparison of microwave and conventional extraction techniques for the determination of metals in soils, sediment and sludge samples by atomic spectrometry. *Analyst,* **116**: 347–351.

Panwar, J. K. and Unni, S. P. 2016. Status and distribution study for different forms of potassium in the soils of Nignoti village of Indore district of western Madhya Pradesh.

Piper, C. S. 1966. Soil and Plant Analysis. *Inter Science Publications. New York*.

Pratt, P. F. 1982. Potassium 225-246. In *Methods of Soil Analysis. Part II (Eds. A. L. Page, R. H. Miller and D. R. Keeney). Chemical and Microbiological Properties. America, Madison, Wisconsin, USA.*

Ramamurthy, V., Naidu, L. G. K., Chary, G. R., Mamatha, D. and Singh, S. K. 2017. Potassium status of Indian soils: need for rethinking in research, recommendation and policy. *International Journal of Current Microbiology and Applied Sciences,* **6**: 1529-1540

Saini Jagmohan and Grewal, K. S. 2014. Vertical Distribution of Different Forms of Potassium and Their Relationship with Different Soil Properties in Some Haryana Soil under Different Crop Rotation. *Advances in Plants and Agriculture Research,* **1**: 1-5.

Sanyal, S. K. 2014. Nutrient mining in soil-an issue of concern. *Newsletter Indian Society of Soil Science,* **36**: 1-3.

Sharma A., Jalali, V.K., Arya, Vivek, M. and Rai, Pradeep. 2009. Distribution of various forms of potassium in soils representing intermediate zone of Jammu region. Journal of the Indian Society of Soil Science **57**: 205- 208.

Sharma, V., Sharma, S., Arora, S. and Kumar, A. 2012. Quantity–intensity relationships of potassium in soils under some guava orchards on marginal lands. *Communications in Soil Science and Plant Analysis,* **43**: 1550-1562.

Sharma, S., Sharma, V. and Arora, S. 2017. Potassium supplying capacity of some citrus orchard soils in foothill Himalayas through quantity-intensity approach. *Journal of the Indian Society of Soil Science* **65**: 393-400.

Sharma, S., Sharma, V., Arora, S., Kumar, V., Arya, V. M. and Sharma, K. R. 2018. Forms of Potassium in Mango, Citrus and Guava Orchard Soils under Rainfed Foothill Region of Jammu. *Journal of the Indian Society of Soil Science,* **66**: 336-340.

Verma, T. P., Singh, S. P. Gopal, R., Rao, R. V. S. and Tarsem, L. 2012. Characterization and Evaluation of soils of Trans Yamuna area in Etawah district, Uttar Pradesh for Sustainable land use. *Agropedology* **22**: 26-34.

Waheeda, A. B and Radhwan, R. A. 2019. Status and distribution of different potassium forms in calcareous soils in Northern Iraq. *Mesopotamia Journal of Agriculture,* **47**: 178-191.

Walkley, A. and Black, I. A. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science,* **37**: 29-38.

Wani, M. A. and Raj, K. 2008. Distribution of potassium and clay minerals assemblage in some paddy soils of Lesser Himalayas. *Agropedology,* **18**: 98-105.

Wani, M. A., Wani, J. A. and Bhat, M. A. 2009. Potassium forms, their interrelationships and relations with soil properties in rice soils of lesser Himalayas. *SKUAST Journal of Research,* **11**: 1-7.

Wani, J. A., Malik, M. A., Dar, M. A., Akhter, F. and Raina, S. K. 2014. Impact of method of application and concentration of potassium on yield of wheat. *Journal of Environmental Biology* **35**: 623.