STUDYING OF POTASSIUM FORMS STATUS IN FOREST AND GRASS SOILS IN MATEEN MOUNTAIN, DUHOK GOVERNORATE.

VAHIL I. H. BARWARI

Soil and Water sciences department, College of Agricultural Engineering Science, University of Dohuk, Kurdistan Region – Iraq.

Vahil.ismael@uod.ac

- **Date of received 10/11/2022 and accepted 29/11/2022.**

Abstracts

Eighteen (18) surface soil samples were collected from six sites in Mateen mountain, from three different locations (ARIZ, BAMARNI, BIBADI) in Duhok governorate, North of Iraq. The research aimed to study the potassium form status and its relationship with the soil's Physico-chemical properties. The result indicated that the soils were alkaline, and electrical conductivity ranged between (0.4-0.6) $ds.m^{-1}$ is a normal range. Moreover, the highest value of organic matter and cation exchange capacity CEC was found in forest soil (4.68%,32.66 $cmol^{+}$.kg), respectively, than in Grassland (1.92%, 19.38 $cmol^{+}$.kg). Most soils ranged between clay to clay loam in soil texture; according to land use, there is a highly significant difference between all forms of potassium K (soluble K, available K, exchangeable K, total K) in forest soil than in Grassland except non-exchangeable K form. While the distribution of potassium forms depending on location, the water-soluble K was higher in Bibadi and Bamarni (0.108 and 0.085) $cmol^{+}$.kg respectively as compared to Arize. However, there was no significant difference between available K and exchangeable K, non-exchangeable potassium in forest soil more than in Grassland, and total Potassium was higher in Ariza and Bibadi locations compared to the Bamarni area. The predictability of potassium forms depended on soil properties; organic matter, cation exchange capacity CEC, and clay content.

KEYWORD; Potassium forms, Soil properties, Mateen mountain.

دراسة حالة أشكال البوتاسيوم للترب الغابات والاراضي العشبية في جبل متين بمحافظة دهوك-شمال العراق

فهيل إسماعيل حسن البرواري

قسم علوم التربة والمياه / كلية علوم الهندسة الزراعية ، جامعة دهوك-اقليم كوردستان العراق

Vahil.ismael@uod.ac

- **تاريخ استلام البحث 2022/11/10 وتاريخ قبوله 2022/11/29 .**

الخلاصة

تم جمع ثمانية عشر عينة تربة سطحية من ستة مواقع في جبل متين، من ثلاثة قرى مختلفة (ارزي، بامرني، بيبادي) في محافظة دهوك-شمال العراق، لدراسة حالة أشكال البوتاسيوم وعلاقتها بالخصائص الفيزيائية والكيميائية للتربة. أشارت النتائج إلى أن التربة كانت متعادلة الي قلوية بطبيعتها، وتراوحت الموصلية الكهربائية بين (٠,٤-٠,٦) ديسي سيمنز/م وهي غير ملحيه بطبيعتها، وأعلى قيمة للمادة العضوية وسعة التبادل الكاتيوني وجدت في تربة الغابات (٤,٦٨٪، ٣٢,٦٦ سنتمول$^{+}$/كيلوكرام) على التوالي مقارنة بالأراضي العشبية (١,٩٢٪، سنتمول$^{+}$/كيلوكرام ١٩,٣٨)، تراوحت معظم أنواع التربة حسب نسجة التربة بين الطينية الي الطينية مزيجية، هناك فروقات معنوية بين جميع أشكال البوتاسيوم (الذائب، المتبادل، الجاهز، الكلي) في تربة الغابات مقارنة بالأراضي العشبية باستثناء صور البوتاسيوم غير المتبادل. بينما توزيع أشكال البوتاسيوم حسب الموقع؛ كانت البوتاسيوم القابل للذوبان في الماء أعلى في بيبادي (٠,١٠٨) وبامرني (٠,٠٨٥٠) مقارنة مع ارزي في حين لا يوجد هنالك فروقات معنوية بين صور البوتاسيوم المتبادل والجاهز في التربة. البوتاسيوم غير القابل للتبديل اعلى قيمة في تربة الغابات مقارنة بالأراضي العشبية، وقد تمت مقارنة البوتاسيوم الكلي في موقع ارزي وبيبادي أكثر قيمة مقارنة بموقع بامرني. كانت إمكانية التنبؤ بأشكال البوتاسيوم في التربة تعتمد على خصائص التربة؛ المادة العضوية، سعة التبادل الكاتيونيCEC للتربة، محتوى الطين.

الكلمات المفتاحية؛ اشكال البوتاسيوم،الصفات التربة،جبل متين.

Introduction:

Potassium is one of the significant element constituents of the earth. It includes an average of 2.3 % of the earth's crust; it is the seventh most abundant element and the fourth most abundant mineral nutrient in the lithosphere (Jalali, 2006). Physico-chemical properties of forest soil because in location and time because of location and time because of the variation in topography, weathering processes, climate, vegetation cover, and other biotic and abiotic factors (Paudel & Sah, 2003).

Soil potassium is divided into five forms:: Water soluble H_2O-K, exchangeable, non-exchangeable, available and total K form. However, the dynamic between these forms in soil differs due to the properties of soil (Ahmed Usman & Gameh, 2008; Zhang *et al.,* 2010). The potassium forms in soil and the potential of K supply to plants is very much related to the distribution of potassium forms in the soil and the equilibrium between them (Pavlov, 2007), which is again influenced by the various physicochemical properties such as clay minerals, soil texture, cation exchange capacity (CEC), pH (Lalitha & Dhakshinamoorthy, 2014). The Soil formation, mineral weathering, and geomorphological properties have resulted in significant variations in total, non-exchangeable and exchangeable Potassium in different topographic slope positions (Samndi & Tijjani, 2014). Soil potassium distribution is influenced by slope position and clay minerals (Koné *et al.,* 2014). (Obi *et al.,* 2016) studied the effect of land use on soil K forms in Nigerian soils and reported that the amount of total K, non-exchangeable K, exchangeable K and water-soluble K, as well as pH, differed along topographic positions from up to downslope. The release of potassium ions from clay minerals is influenced soil texture and chemical composition (Huang, 2005). Previous work in forest soils has observed that the distribution and seasonal dynamics of K in plant tissues, soil organic matter, soil water, and surface waters, unlike other base cations, can be strongly influenced by biotic processes (Salmon *et al.,* 2001; Vitousek, 2004). The ed biotic availability may be impact and fire. Potassium is biotic availability may be affected additionally by disorders such as timber harvest, fire, and nitrogen extraction (Britton, 1991). Water soluble Potassium: K present in soil solution as soluble cation is termed water-soluble K, which is readily absorbed by the grasses and relatively unbound by cation exchange forces and invariably subject to leaching losses about soil properties (Ramamoorthy & Velayutham, 1976). Exchangeable Potassium is present in the soil matrix and can be replaced by cations of neutral salts in the soil solution. Exchangeable Potassium is approximately 90% of the available Potassium. Usually, the percentage of exchangeable K to total K is below 2% (Schroeder, 1974). The exchangeable K was closely correlated with clay content, pH, $CaCO_3$%, O.C%, and CEC (Baruah *et al.,* 1991). Exchangeable K was significantly and positively correlated with clay content, observed that as the amount and surface area of exchange complex increases the exchangeable K increases (Guzel *et al.*, 2001).

Non-exchangeable K plays an important role in supplying available K, specially in soils that containing K-bearing minerals (Raheb and Heidari, 2012). This form of potassium is fixed in interlayer of 2:1 clay minerals and could be released gradually (Rees *et al.,* 2013).

Total Potassium: A large portion of the total in soil occurs as a structural component of soil clay minerals and is unavailable to plants. The total potassium content in Duhok governorate soils ranged from 1700-5800 mg kg^{-1}(Ismail *et al.,* 2021). (Srinivasarao *et al.,* 2007) Observed that total K was higher in Inceptisols followed by Aridisols, Vertisols, and Vertic sub-groups, while it was low in Alfisols and Oxisols.This study aims to evaluate soil potassium forms of Mateen mountain, Duhok governorate, north of Iraq, and investigate the relations between these forms and the soil properties.

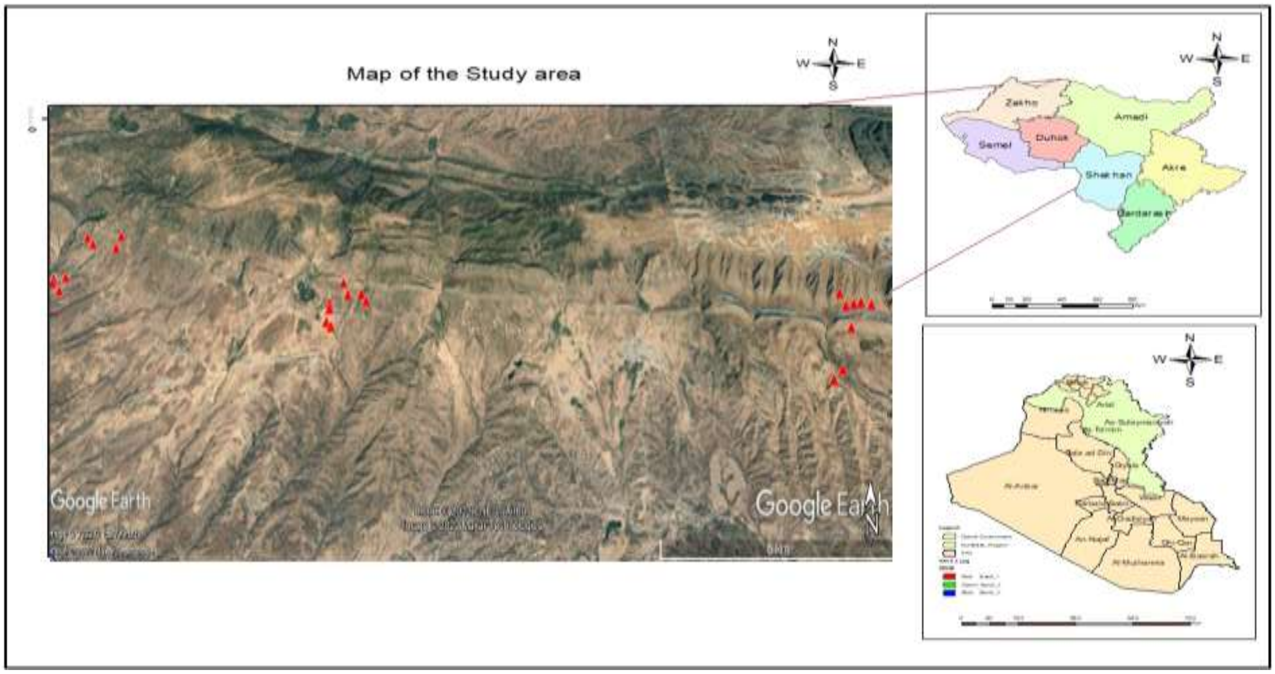
Materials and Methods:

Location and Soil sampling:

Mateen mountain is located between latitudes 37° 11' 53" North and longitude 43° 11' 24" East. (18) Eighteen surface soil samples (0-20) cm were collected from three different locations (ARIZ, BAMARNI, BIBADI), meaning that, in each location, six samples were collected (three in forest soils and three in Grassland). Then the soil samples were air-dried and sieved to pass through a 2 mm sieve; then, soil samples were stored in plastic bags for analysis. The geographic position system was used to obtain the coordinates of these three topographic positions.

Table 1: GPS soil sampling site location in forest and grass cover.

No.	Location		N (Latitude)	E (Longitude)	Land Use
1	Ariz	Forest	37° 07' 53.99''	43° 11' 6.60''	Oak Trees
2			37° 07' 40.34''	43° 11' 51.63''	Oak Trees
3			37° 07' 51.46''	43° 11' 54.74''	Oak Trees
4		Grasses	37° 07' 13.53''	43° 10' 38.80''	Grasses
5			37° 07' 4.94''	43° 10' 55.40''	Grasses
6			37° 06' 59.74''	43° 10' 54.01''	Grasses
7	Bimini	Forest	37° 06' 54.07''	43° '17' 4.79''	Oak Trees
8			37° 06' 43.66''	43° 17' 11.57''	Oak Trees
9			37° 06' 42.90''	43° 17' 28.95''	Oak Trees
10		Grasses	37° 06' 15.22''	43° 16' 53.63''	Grasses
11			37° '06' 19.39''	43° 16' 48.34''	Grasses
12			37° 06' 36.76''	43° 16' 49.07''	Grasses
13	Bibi	Forest	37° 06' 25.32''	43° 28' 0.98''	Oak Trees
14			37° 06' 25.79''	43° 27' 47.65''	Oak Trees
15			37° 06' 25.25''	43° 27' 39.02''	Oak Trees
16		Grasses	37° 05' 32.61''	43° 27' 4.76''	Grasses
17			37° 05' 24.23''	43° 26' 50.75''	Grasses
18			37° '05' 37.06''	43° 27' 27.39''	Grasses



"Fig. 1""" The **map of study area.**

Soil analysis:

The soil particle size analysis was determined of using Bouyoucous hydrometer (Klute,1986).Soil pH and EC were determined in 1:2 of soil water suspension according to (Jackson,1973). The calorimeter method estimated the total calcium carbonate (Nelson,1982). The wet oxidation method estimated soil organic matter content (Wallky & Black,1965). CEC cation exchange capacity was estimated of using the 1N ammonium acetate at pH 8.2 (page *et al.*,1982). The determination of different forms of Potassium; soluble Potassium was estimated using the soil: water ratio of 1:2 described by (Grewal & Kanwar,1966). The available K was determined by neutral solution 1 N NH_4OAc extractant in the ratio of 1:10 (soil: extractant) as described by (Pratt, 1965). Exchangeable-K was determined by shaking a 10 g sample of soil in (1M) solution of NH_4OAC (buffered at pH 7) after that filtration as outlined by (Knudsen *et al.*, 1996). Non-exchangeable-K was measured by boiling 5g of soil sample in 50 ml of (1M) HNO_3 solution. The difference between K extracted through HNO_3 and exchangeable-K equal non- exchangeable-K (Jackson, 1967; Page *et al.*, 1982). Total K was determined by digesting 1g of soil samples with a 20 mL acid mixture of $HClO_4$-HNO_3 and leaching with HCl due to (Jackson,1958). The flame photometer analyzed all K forms extraction.

Statistical calculation:

Data were analyzed using analysis of variance in the Form of two-way (ANOVA) with GLM procedure to examine the significant effect ($P < 0.05$) of location and land use on study parameters and Pearson correlation coefficient using Minitab software package 2017.

Result and Discussion:

Soil characterization:

It was observed from table (2) that there was a significant effect of location (p=0.02) on pH. Significantly higher pH values were recorded under Ariz and Bamarni (8.2 and 8.1) than Bibadi (8.012). This could be attributed to the calcareous parent material. Concerning the effect of land use, it was observed that there was no significant effect of land use on soil pH ($P < 0.05$). The interaction effect between location and land use was substantial (p=0.035). This significant effect showed that under forest soil, there is no significant difference in soil pH, while under Grassland, a significantly lower pH value was recorded in the Bibadi location compared to Armani. This is not surprising as regions have differed in their topography, weather, and vegetation cover, which affect soil properties. These pH values indicate that all profiles' reaction was slight to moderately alkaline.

It is evident from (Table:2) that there was a significant effect of location (p=0.026) on soil EC; significantly higher values of EC were recorded under Bamarni (0.6095) $ds.m^{-1}$ compared to Ariz (0.4577) $ds.m^{-1}$ and Bibadi (0.4903) $ds.m^{-1}$. The low soluble salt content in three locations is attributed to the desalinization process as affected by relatively high rainfall (precipitation). Furthermore, the effect of land use on soil EC was seen to be highly significant in forest soil compared to Grassland (P0.05). There was no significant interaction between location and land use (p=0.848). Furthermore, the data presented in (Table:2) means that the EC value differences for all locations are the same under forest and grasslands.

It is evidence from (Table:2) that there was a highly significant effect of location (p=0.00) on soil $CaCO_3$%. Significantly higher values of $CaCO_3$% were recorded under Ariz (18.98%) compared to Bibadi and Bamarni (14.14% and 12.5%), respectively (Table:2). This may be attributed to calcareous parent materials and low percentage of calcium carbonate in the surface layer due to leaching processes, and this corresponds to lower electrical conductivity values. The same finding was observed by (Ahmed *et al.*, 2010). Therefore, the results in (Table:2) indicate that the effect of

Table 2: Effect of each location and land use on soil physicochemical properties.

Locations	pH	EC dS.m^{-1}	$CaCO_3$%	O.M %	CEC cmol$^+$.kg	Clay %	Sand %	silt %	Soil texture classes
Ariz	8.20 a	0.4577 b	18.98 a	3.035 b	28.86 a	42.18 a	21.53 a	36.29 a	Clay
Bamarni	8.197 a	0.6095 a	14.14 b	2.745 b	24.45 a	36.43 a	21.94 a	41.63 a	Clay loam
Bibadi	8.012 b	0.4903 ab	12.5 b	4.578 a	28.12 a	38.48 a	21.82 a	39.70 a	Clay loam
Land use									
Forest	8.102 a	0.5884 a	9.96 b	4.116 a	30.97 a	42.79 a	17.4 b	39.81 a	Clay
Grass	8.171 a	0.4499 b	20.46 a	2.79 b	23.32 b	35.27 a	26.12 a	38.61 a	Clay loam
	Summary of ANOVA (P – values)								
Locations	0.020	0.026	0.000	0.011	0.159	0.428	0.984	0.096	
Land uses	0.218	0.006	0.000	0.011	0.001	0.054	0.001	0.529	
Locations × Land uses	0.035	0.848	0.000	0.221	0.350	0.069	0.001	0.148	
Means in each column for locations and land uses that do not share letters are significantly different at p-value < 0.05.									

Table 3: Interaction effect between locations and land use on soil properties.

	pH		**EC dS.m^{-1}**		**O.M %**		**$CaCO_3$ %**		**CEC cmol$^+$.kg**	
Locations	Forest	Grass	Forest	Grass	Forest	Grass	Forest	Grass	Forest	Grass
Ariz	8.19 ab	8.22 ab	0.527 ab	0.388 b	4.10 ab	1.97 b	16.97 b	20.99 ab	30.71 a	27 ab
Bamarni	8.06 ab	8.34 a	0.693 a	0.526 ab	3.57 ab	1.92 b	6.58 c	21.71 a	29.52 ab	19.38 b
Bibadi	8.06 ab	7.96 b	0.545 ab	0.436 b	4.68 a	4.47 ab	6.31 c	18.68 ab	32.66 a	23.59 ab

	Clay%		**Sand%**		**Silt%**	
Locations	Forest	Grass	Forest	Grass	Forest	Grass
Ariz	39.6 a	44.77 a	23.82 abc	19.23 bc	36.58 a	36 a
Armani	42.27 a	30.6 a	12.98 c	30.9 a	44.75 a	38.5 a
Bibadi	46.52 a	30.43 a	15.4 c	28.23 ab	38.08 a	41.33 a

This means sharing different letters in the duplicate rows, and columns significantly differ at P – value <0.05.

land use in T. $CaCO_3$% in Grassland is highly significant compared to forest soil ($P < 0.05$). Table (3) reveals the interaction effect between location and land use (p=0.00).The data in Table (2) indicates there is a significant difference in O.M between locations (Ariz, bamarni and Bibadi) at (p=0.011). The soil organic matter content in the Bidadi location was highly effective compared to bamarni and Ariz. Regarding the effect of land use, the forest land had significantly higher O.M content than Grassland, possibly due to a higher amount of litter falling into the forest than in Grassland. These results, also submitted by Caravaca *et al.* (1999), show that the organic carbon content varied considerably between soils even when they had similar clay and acceptable silt content. The values are generally greater in forest soils than in cultivated soils. There was no significant interaction effect between location and land use on OM (p=0.221).

Table (2) shows that within different locations, there is no significant amount in cation exchange capacity (CEC) at (p-value = 0.159). Concerning the effect of land use, it was illustrated that a highly significant value was found under forest soil, and the lowest significant value was found under Grassland at (p-value< 0.05). Additionally, in (Table 2) there was no significant interaction between location and land use on cation exchange capacity (CEC).

The textural classes of all the soil samples ranged from clay to clay loam, and concerning Table (2) No significant effect of the studied locations, land use, and their interaction was observed on the content of clay and silt (p-value 0.05).

The data presented in Table (2) revealed that there were not any significant effects ($P > 0.05$) of the studied location on sand content. On the other hand, there was a highly significant effect ($P < 0.001$) of land use on sand content and the amount of sand was significantly greater in Grassland than in forest land. A significant interaction effect ($P < 0.05$) between location and land use was on sand content, which was found to be significant in Soil (Table 2); this significant effect showed that the content of sand in both Bibadi and bamarni was significantly higher under Grassland than under forest land while the opposite effect was observed in Arize location.

Distribution of soil potassium forms in the study area:

1-Water Soluble potassium:

Potassium in soil solution as a soluble cation is termed water-soluble K, readily absorbed by the plants and relatively unbound by cation exchange forces.

Water-soluble H_2O-K was significantly affected by locations ($p< 0.05$). A higher amount of water-soluble H_2O-K was found under Bibadi and Bamarni, Table (4), while the lower value was found in Ariz. There was also a significant effect of land use on water-soluble H_2O-K ($p<0.05$). Water soluble K was significantly higher in the forest than in Grassland; this variation might be due to the nature and intensities of the Oak tree's pattern, weathering stages of K-bearing minerals (primary and secondary) and organic matter content in the soil. Similar results were reported by (Raskar and Pharande,1997), and another resons due to the annual additions falling from the leaves of trees rich in cations, especially calcium and potassium, but there is another role for organic matter in humid conditions in the release of carbon dioxide and its interaction with water and the formation of carbonic acid and its role in replacing hydrogen with bases in metal sheets and released into the soil solution.

Concerning the interaction, there was a significant interaction effect on water-soluble H_2O-K. An interaction effect indicated that the soluble K was significantly higher in the forest than in Grassland in both Ariz and Bibadi. In Bamarni the values were non-significant.

Table 4: Effect of each location and land use on different forms of potassium.

Locations	Water soluble K [cmol (K+) kg^{-1}]	Exchangeable K [cmol (K+) kg^{-1}]	Available K [cmol (K+) kg^{-1}]	NON-Exchangeable K [cmol (K+) kg^{-1}]	Total K [cmol(K+) kg^{-1}]
Ariz	0.07 b	1.378 a	1.448 a	11.4 a	18.09 a
Bamarni	0.085 ab	1.188 a	1.273 a	8.72 b	15.64 b
Bibadi	0.108 a	1.225 a	1.333 a	10.03 ab	16.64 ab
Land uses					
Forest	0.10667 a	1.62 a	1.727 a	10.66 a	18.09 a
Grass	0.06889 b	0.908 b	0.977 b	9.44 a	15.49 b
	Summary of ANOVA (P – values)				
Locations	0.016	0.111	0.202	0.024	0.035
Land uses	0.001	0.000	0.000	0.101	0.002
Locations × Land uses	0.000	0.145	0.118	2.87	0.142
Means in each column for locations and land uses that do not share letters are significantly different at p-value < 0.05.					

Table 5: Interaction effect between location and land use on different forms of potassium.

	Water soluble K [cmol (K^+) kg^{-1}]		Exchangeable K [cmol (K^+) kg^{-1}]		Available K [cmol (K^+) kg^{-1}]		NON-Exchangeable K [cmol (K^+) kg^{-1}]		Total K [cmol (K^+) kg^{-1}]	
Locations	Forest	Grass	Forest	Grass	Forest	Grass	Forest	Grass	Forest	Grass
Ariz	0.1b	0.04 c	1.64 a	1.117 b	1.74 a	1.157 b	13.17 a	9.64a b	20.24a	15.95 b
Bamarni	0.067b c	0.103a b	1.547 a	0.83 c	1.613 a	0.933 b	8.697 b	8.737 b	17.02a b	14.26 b
Bibadi	0.153a	0.063b c	1.673 a	0.777 c	1.827 a	0.84 b	10.107a b	9.953 ab	17.02a b	16.25 b
This means sharing different letters in the duplicate rows and columns is significantly different at P – value <0.05.										

2- Available Potassium:

Potassium is considered readily available for plant growth and dissolves in soil water. It is Held on clay particles' exchange sites, which are found on the surface of clay particles.

The result obtained from Table (4) showed that there was no significant effect of locations on water Available potassium ($p< 0.05$), while the effect of land use was significant. However Significantly more amounts of Available K were recorded in the forest than in Grassland use; it may be due to the organic matter and its decomposition result in dissolve some of the soil minerals which containing potassium through organic acids and leads to the release of potassium ions and increased its concentration in soil solution. These results, however, agree with (Abu-Zahra and Tahboub, 2008).The interaction effect on Available K was non-significant, meaning that the Available K was significantly higher under forest than under Grassland in all locations. These results are in agreement with (Ali,2019).

3- Exchangeable Potassium:

Exchangeable Potassium was held by the exchange sites of negative charges on soil clay and organic matter and played a vital role in the growth of plants.

There was no significant effect of locations on exchangeable K ($p< 0.05$). This may be because the exchangeable k did not change much in soil but has accumulated slightly at the surface due to bio cycling; this result was submitted by Ulery *et al.* (1995). at the same time, the effect of land use was significant. A significantly more tremendous amount of Exchangeable K was recorded under forest than in Grassland use. The interaction effect on Exchangeable K was found to be non-significant in Table (4), which means that the exchangeable K was significantly higher under forest than under Grassland in all locations. These can be referred to high organic carbon content and higher biological activities. These results agree with (Raskar and Pharande,1997) for the black soils of Maharashtra.

4- Non-exchangeable Potassium:

The non-exchangeable K form is mainly present within clay minerals and becomes available to plants with relative difficulty. However, it is in equilibrium with available forms and consequently acts as an essential reservoir of slowly available potassium.

A significantly higher amount of non-exchangeable K was recorded in Ariza, followed by Bamarni, which may be attributed to the type of clay minerals. The effect of land use on non-exchangeable K was insignificant (p=0.05). Table (4), the interaction effect between land use and location on non-exchangeable K was also found to be non-significant, meaning that under land use, the non-exchangeable K was significantly higher in Ariza than in Bamarni. While the difference between Ariza and Bamarni was not significant. In general, there was no uniformity in the distribution of non-exchangeable-K within the selected soils. It may be attributed to the nature of the trees of this forest and the decomposition of organic matter. The equilibrium reactions among K form markedly affect whether the applied Potassium that becomes available in the soil solution to plants leaches to lower soil layers or converts to unavailable forms (Ahmed Usman & Gameh, 2008).

5- Total Potassium:

Total Potassium in the soil depends on the type of parent material, primary and secondary minerals, and soil parts. There was a significant effect of locations on total K (p=0.05). Table (4) shows that a higher amount of total K was detected in Ariza than in Bamarni. At the same time, the effect of location was not significant between Ariza and Babidi: as well as between Bamarni and Bibadi,(Table:4). The higher content in higher altitude may be attributed due to the presence of illite, mica and feldspars as a primary Potassium bearing minerals which are capable of releasing a large amount of Potassium. Similar results were also reported (Wani & Kumar, 2008).

Moreover, other reasons there was a highly appositive correlation coefficient between total potassium and cation exchangeable capacity CEC in the Ariza region. There was also a significant effect of land use on total K; a higher amount of total K was observed under forest soil than in Grassland. The probability reason is due to the increase in the density of oak trees and climatological conditions, which leads to an increase in the organic matter content and the activity of the micro-organisms in that forest region compared to the Grassland. Non-significant interaction effect between land use and the location was observed in the total K Table (5). The total K was significantly higher under forest soil than in Grassland in Ariza. In contrast, the difference in total K under the two-land use was not significantly different in Bamarni and Bibadi.

Relation between potassium forms and soil properties:

The correlation between the potassium forms and soil properties is described in Table (6). The water-soluble potassium K is significantly correlated with available Potassium (r=0.53*). It was observed that the exchangeable Potassium was highly significantly correlated with available Potassium (r=1**), cation exchange capacity CEC (r=0.79**) and significantly correlated with total Potassium (r=0.57*), electrical conductivity EC (r=0.52*) and clay % (r=0.60*). However, it was shown that a highly negatively correlated with $CaCO_3$% (r=-0.71**) and sand %(r=-0.68**). Additionally, available Potassium highly significantly correlated with cation exchange capacity CEC (r=0.78**) and significantly correlated with total Potassium (r=0.56*), electrical conductivity EC (r=0.52*) and clay content % (r=0.59*), otherwise highly negatively correlated with $CaCO_3$% (r=-0.72**) and sand %(r=-0.66**), This indicates that the increase of calcium carbonate content affected the available water capacity and reduce the availability of potassium. Similar results were also described by (Ingole *et al.*, 2018).

Table 6: Pearson correlation–coefficient of different forms of Potassium with soil properties.

	Water soluble K [cmol (K^+) kg^{-1}]	Exchangeable K [cmol (K^+) kg^{-1}]	Available K [cmol (K^+) kg^{-1}]	NON-Exchangeable K [cmol (K^+) kg^{-1}]	Total K [cmol (K^+) kg^{-1}]
Exchangeable K [cmol (K^+) kg^{-1}]	0.46				
Available K [cmol (K^+) kg^{-1}]	0.53*	1.00**			
NON-Exchangeable K [cmol (K^+) kg^{-1}]	0.18	0.31	0.31		
Total K [cmol (K^+) kg^{-1}]	0.14	0.57*	0.56*	0.80**	
pH	0.07	-0.14	-0.13	-0.12	-0.26
EC dS.m	0.28	0.52*	0.52*	0.02	0.25
$CaCO_3$%	-0.44	-0.71**	-0.72**	0.01	-0.29
O.M %	0.34	0.35	0.37	0.30	0.37
CEC $cmol^+$.kg	0.30	0.79**	0.78**	0.39	0.53**
Clay %	0.17	0.60*	0.59*	0.22	0.31
Sand %	-0.08	-0.68**	-0.66**	-0.04	-0.30
silt %	-0.21	-0.08	-0.09	-0.37	-0.13

*correlation coefficient significant at value < 0.05.
** correlation coefficient significant at value < 0.01.

Also, the non-exchangeable Potassium was highly significantly correlated with total Potassium (r=0.80**), Concerning the total potassium form, it was, showed that highly significantly correlated with cation exchange capacity CEC (r=0.53**), similar results agreement with those reported by (Ali, 2019; Uzoho *et al.*, 2016).

Conclusion:

Potassium in the soil can be allocated to three pools of availability for root uptake. It is dissolved in soil water, adsorbed on particles of clay and organic matter and held within the crystal structures of feldspar and mica. This research revealed that the distribution of different forms of Potassium in the surface layer of soils is influenced by soil properties and inter-relationships among themselves. There is a positive correlation of K forms, available K, exchangeable K and total K with CEC. A higher amount of soil organic matter found in forest soil was correlated with Grassland. The results showed that soil properties and clay content are not essential in non-exchangeable K content.

Reference:

- **Abu-Zahra, T. R., & Tahboub, A. B. (2008**). Effect of organic matter sources on chemical properties of the soil and yield of strawberry under organic farming conditions. World Applied Sciences Journal, 5(3), 383-388.
- **Ahmed Usman, A. R., & Gameh, M. A. E. (2008**). Effect of sugar industry wastes on K status and nutrient availability of a newly reclaimed loamy sandy soil. *Archives of Agronomy and Soil Science*, *54*(6), 665-679.
- **Ahmed, H. M., Al-Obaidi, M. A., & Abdel-Kareem, A. W. (2010**). Particle size distribution of carbonate in some calcareous soil separates of northern iraq. *Iraqi Journal of Agricultural Science*, *41*(5).
- **ALI, R. (2019).** Status and distribution of different potassium forms in calcareous soils in northern iraq. Mesopotamia Journal of Agriculture, 47(2), 178-191.
- **Baruah, H. C., Bora, D. K., Baruah, T. C., & Nath, A. K. (1991).** Fixation of potassium in three major soil orders of Assam. Journal of Potassium Research, 7(3), 170-175.
- **Britton, D. L. (1991).** Fire and the chemistry of a South African mountain stream. *Hydrobiologia*, *218*(3), 177-192.
- **Caravaca, F., Lax, A., & Albaladejo, J. (1999).** Organic matter, nutrient contents and cation exchange capacity in fine fractions from semiarid calcareous soils. Geoderma, 93(3-4), 161-176.
- **Grewal, J. S., & Kanwar, J. S. (1966).** Forms of potassium in Punjab soils. Journal of the Indian Society of Soil Science, 14(1), 63-67.
- **Güzel, N., Büyük, G., & Ibrikci, H. (2001).** Non-exchangeable and exchangeable potassium status of soils in relation to clay mineralogy and other soil properties in Hilvan area of upper Mesopotamia in southeastern Anatolia. Communications in soil science and plant analysis, 32(17-18), 2877-2892.
- **Huang, P. M. (2005).** Chemistry of potassium in soils. Chemical processes in soils, 8, 227-292.
- **Ingole, A. J., Vaidya, P. H., Aundhakar, A. V., & Ghode, M. K. (2018).** Effect of moisture and calcium carbonate content on chemical properties of soil and yield of cotton

in Nanded District of Maharashtra. *Journal of Pharmacognosy and Phytochemistry*, *7*(5), 1971-1976.

- **Ismail, H. K., Mehmedany, L. A. M., & Mohammed, H. S. (2021).** Potassium forms for main soil orders in the north of iraq. Journal of Duhok University, 24(2), 49-59.
- **Jackson, M. L. (1967).** Prentice Hall of India. *Pvt. Ltd.*, *New Delhi*, *498*.
- **Jackson, M.L.(1973).**Soil chemical analysis prentice Hall. *Inc.,Englewood Cliffs, NJ*, *498*,183-204.
- **Jackson, M. L.(1958).** Soil Chemical Analysis. Prentice – Hall Inc. Englewood cliffs., New Jersey.
- **Jalali, M. (2006).** Kinetics of non-exchangeable potassium release and availability in some calcareous soils of western Iran. *Geoderma*, *135*, 63-71.
- **Klute, A.. (1986).** Methods of Soil Analysis, American Society of Agronomy, Inc. *Soil Science Society of America. Madison, Wisconsin. USA*, 635-686.
- **Knudsen, D; Peterson, G. A. and Pratt, P. F. (1996).** Lithium, Sodium and Potassium. In: A. L. Page (ed) Methods of Soil Analysis. Part 2, Second edition, American Society Agronomy, Madison, WI, pp: 403-429.
- **Koné, B., Bongoua-Devisme, A. J., Kouadio, K. H., Kouadio, K. F., & Traoré, M. J. (2014).** Potassium supplying capacity as indicated by soil colour in Ferralsol environment. Basic Research Journal of Soil and Environmental Science, 2(4), 46-55.
- **Lalitha, M., & Dhakshinamoorthy, M. (2014).** Forms of soil potassium-a review. *Agricultural reviews*, *35*(1).
- **Nelson, R. E. (1982).** Carbonate and gypsum. P. 181-198 In A. L. Page, R.H. Miller and D. R. Keeney. Method of soil analysis part 2, Chemical and microbiological properties 2nd edition. *Soil Sci. Soc. Am. Inc., Madison*, WI, USA.
- **Obi, J. C., Ibia, T. O., & Eshiet, P. B. (2016).** Effect of land use on potassium form of coastal plain sands of Nigeria. *Chemistry and Ecology*, *32*(3), 238-258.
- **Page, A. L., Miller, R. H., & Kenney, D. R. (1982).** Methods of soil analysis part 2 (agronomy monographs 9). *Amer. Soc. Agronomy and Soil Sci. Soc. Amer., Madison, Wisconsin*.

- **Paudel, S., & Sah, J. P. (2003).** Physiochemical characteristics of soil in tropical sal (Shorea robusta Gaertn.) forests in eastern Nepal. *Himalayan Journal of Sciences*, *1*(2), 107-110.
- **Pavlov, K. V. (2007).** The assessment of the potassium status of soil by the proportion between different forms of potassium. *Eurasian Soil Science*, *40*(7), 792-794.
- **Pratt, P. F. (1965).** Digestion with hydrofluoric and perchloric acids for total potassium and sodium. *Methods of Soil Analysis: Part 2 Chemical and Microbiological Properties*, *9*, 1019-1021.
- **Raheb, A., & Heidari, A. (2012).** Effects of clay mineralogy and physico-chemical properties on potassium availability under soil aquic conditions. *Journal of soil science and plant nutrition*, *12*(4), 747-761.
- **Ramamoorthy, B., & Velayutham, M. (1976).** Nitrogen, phosphorus and potassium in soil--chemistry, forms and availability. *Soil Fertility: Theory and Practice*.
- **Raskar, B. N., & Pharande, A. L. (1997).** Different forms of potassium and their distribution in some important soil series of vertisol and alfisol of Western Maharashtra. *Journal of Potassium Research*, *13*(1), 21-30.
- **Rees, G. L., Pettygrove, G. S., & Southard, R. J. (2013).** Estimating plant-available potassium in potassium-fixing soils. *Communications in soil science and plant analysis*, *44*(1-4), 741-748.
- **Salmon, C. D., Walter, M. T., Hedin, L. O., & Brown, M. G. (2001).** Hydrological controls on chemical export from an undisturbed old-growth Chilean forest. *Journal of Hydrology*, *253*(1-4), 69-80.
- **Samndi, M. A., & Tijjani, M. A. (2014).** Distribution of potassium forms along a hillslope positions of newer basalt on the Jos Plateau Nigeria. *International Journal of Soil Science*, *9*(3), 90.
- **Schroeder, D. (1974).** Proc. 10th cong. Int. Potash. Inst. Potassium research and Agrl production, p. 53 - 63.
- **Srinivasarao, C. H., Vittal, K. P. R., Tiwari, K. N., Gajbhiye, P. N., & Kundu, S. (2007).** Categorisation of soils based on potassium reserves and production systems: implications in K management. *Soil Research*, *45*(6), 438-447.

- **Ulery, A. L., Graham, R. C., Chadwick, O. A., & Wood, H. B. (1995).** Decade-scale changes of soil carbon, nitrogen and exchangeable cations under chaparral and pine. *Geoderma*, *65*(1-2), 121-134.
- **Uzoho, B. U., Ihem, E. E., Ogueri, E. I., Igwe, C. A., Effiong, J. A. I., & Njoku, G. U. (2016).** Potassium forms in particle size fractions of soils on a toposequence in Mbano, southeastern Nigeria. *International Journal of Environment and Pollution Research*, *4*(3), 1-11.
- **Vitousek, P. M. (2004).** Nutrient cycling and limitation: Hawai'i as a model ecosystem. Princeton Univ. Press, Princeton, NJ. *Nutrient cycling and limitation: Hawai'i as a model ecosystem. Princeton Univ. Press, Princeton, NJ.*
- **Walkley, A., & Black, C. A. (1965).** Organic carbon. *Methods of soil analysis. American Society of Agronomy, Madison*, *37*, 1372-1375.
- **Wani, M. A., & Kumar, R. A. J. (2008)**. Distribution of potassium and clay minerals assemblage in some paddy soils of Lesser Himalayas. *Agropedology*, *18*, 98-105.
- **Zhang, F., Niu, J., Zhang, W., Chen, X., Li, C., Yuan, L., & Xie, J. (2010).** Potassium nutrition of crops under varied regimes of nitrogen supply. *Plant and soil*, *335*(1), 21-34.