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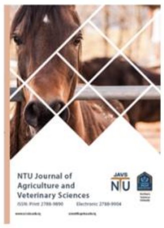

IMPACT OF K- LEVEL ON CLAY DISPERTION IN CALCAREOUS SOILS NORTHERN IRAQ

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Cation ratio of soil structural stability
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potassium
clay dispersion

ABSTRACT

Twelve soil samples were selected from the total soils prevalent in northern Iraq, predominating the illicit mineral, from three governors: Nineveh within the Aridisol order and the governors of Dohuk and Erbil within the Mollisol order. They were packed into soil columns of length (13) cm and diameter (4) cm at a bulk density of 1.33 mcg. m^{-1}, Increasing electrolyte solutions of potassium ion (20, 40, 60, 80) mmol.L^{-1} is allowed to flow quietly, mixed with sodium, calcium, and magnesium ions to give a constant level of sodium adsorption ratio (SAR) and obtain four concentrations of ratios of single to binary ions in terms of CROSS (4.26, 7.57, 10.89, 14.20) mmol$_c$. L^{-1}, up to the tenth pore size, for 16 weeks, then measuring the dispersible clay before and after adding electrolyte solutions. The results indicated an increase in the optical density of the soil suspensions with an increase in the added potassium concentration, up to 15.4 mmol$_c$.L^{-1}. The clay dispersion values as a function of the density of their optical suspensions in all soils of the study, as the optical density was highly correlated with the increase in the added level of CROSS ranged between (0.99 - 0.90). The soils varied in their degree of clay dispersion, and the distilled water treatment was less dispersed than the CROSS treatment, and the difference in optical density values between the soils is due to the role of potassium, the high clay content, and the dominance of the minerals montmoronite and illite, due to their dominance. In the study of soil samples, there is a high ability to swell and disperse clay. According to the results, it is suggested that the effect of potassium be taken into account in evaluating the structure of soils, the extent of its deterioration, and its effect on water functions in calcareous soils.

Introduction

Many studies have dealt with the sodium adsorption ratio in describing the dispersion of clay in the soil-water system, as sodium is responsible for the dispersion of clay [1]. However, in recent studies conducted by [2] The adsorbed potassium ion (PAR) can show effects similar to sodium. [3], Potassium was introduced into the SAR equation because it contributes to the dispersion process, and it was given another name, which is MCAR, meaning the adsorption ratio of monovalent cations, to modify the original SAR calculation to predict the ability of mineral colloids to adsorb monovalent ions. [4,5] indicated that high concentrations of potassium and magnesium ions in irrigation water and soil solution work to raise the level of potassium exchanged relative to the positive binary ions, which works to build the soil, as it is an ion Potassium is one of the medications that cause clays to swell and disperse. They concluded that the potassium ion is not equivalent to the sodium ion in its dispersion and causes problems in soil construction. However, most researchers have not given great importance to this ion due to its low concentration in irrigation water [6] and because most studies on soil construction and stability focused on the effect of high exchangeable sodium ions [7]. However, [8] concluded that the indicators (SAR and ESP) could lead to misleading stability of soil construction if the soil contains high amounts of potassium ions. Comparing magnesium with sodium and calcium ions, [9] showed that there is a similar ionic effect of Na K on the swelling and dispersal of clay through a new concept that affects the stability of soil population called CROSS, which shows the effects of Na, K, Ca, and Mg. According to this concept, Any increase in either Na or K in the soil will increase clay dispersion and reduce the stability of soil aggregates. Here [9] pointed out that to give a complete conception of the concept of the cross, it is necessary to refer to the dispersion charge, according to what [10]. The dispersion of mineral colloids when using different aqueous media depends on the strength of the dispersed charge, soil particles were closed from each other and their aggregation into complex structural units depends on the forces of repulsion and attraction occurring between these particles, meaning that the forces of repulsion result in the phenomenon of dispersion, and when the forces of attraction prevail, the soil particles will
approach. From each other and collecting them [11,12] pointed out that the aggregation or dispersion behavior that occurs in mineral colloids is controlled by the salt concentration, the type of exchanged cations, the clay minerals [7], the valence of the cations, and the calcium carbonate. Natural salts are characterized by their negative effects on soil construction because monovalent cations such as Na^+ and K^+ cause the dispersion and swelling of clay and then the deterioration of soil structure [13]. which affects air movement and the water balance in the soil [10]. Therefore, these indicators can be used as evidence of the quality of soil structural construction as a result of soil use and management, such as tillage, agricultural rotations, and fertilization, because soil structure controls the characteristics of water seepage and soil aeration [14]. So this behavior leads to the deterioration of the structural structure of the soil and its instability [15], and determining the degree of disintegration of soil and clay particle structure [16,17]. explained that potassium durion in agricultural soils that contain high concentrations of potassium is similar to sodium ions [18]. This was assumed on the basis that potassium ion generates repulsive forces between clay particles, causing it to disperse, and that the ability to disperse clay increases with an increase in the percentage of clay. Potassium ion to sodium ion. Although there is a clear effect of exchangeable positive ions on the net dispersion charge and the importance of the topic, [19] Results found by [20,21] with the presence of similarity in the ionic influence of K and Na, which They cause swelling of the clay and increased dispersion, which leads to negative effects on the physical properties of the soil, especially water conductivity [22]. have demonstrated a new indicator in the stability of soil aggregates called " CROSS " [23,24]. According to the CROSS concept, any increase in. Na or K in the soil increases clay dispersion [10]. Exchangeable cations and clay dispersion: The mean affection of dispersion clays is a soil aggregate stability concept that can be considered an indicator of the quality of the physical characteristics of soil [25] surface runoff, and erosion Soil productivity [26] and degradation Seedling emergence and [27] root growth (soil carbon content) [11]. Our current research sheds light on the role of added potassium in the dispersion of clay in the calcareous soils of northern Iraq, whose cultivation patterns have changed from irrigated to irrigated [28].

MATERIALS AND METHODS

Twelve e soil samples were collected from Ninavha, Dohuk, and Erbil provinces of northern Iraq, according to variation of clay, SOM, and CaCO3 contents from the soil reservoir layer (0 - 0.30) m. The research region experiences semi-arid weather with 210 to 835 mm of yearly rainfall on average. The soil sample's chemical and physical properties were analysis according to [29] as shown in table (1) Effect of CROSS Solutions on clay dispersion was carried out by using different potassium levels of 20,40,60, and 80 $mmol_c.L^{-1}$ mixed with 20 mm. l-1 of Na, Ca, and Mg to gate negative effects on the physical properties of the soil, especially water conductivity. [23] have demonstrated a new indicator in the stability of soil aggregates called " CROSS ". According to the CROSS concept, any increase in. Na or K in the soil increases clay dispersion [10]. Exchangeable cations and clay dispersion: The mean affection of dispersion clays is a soil aggregate stability concept that can be considered an indicator of the quality of the physical characteristics of soil surface [25] run off, and erosion Soil productivity [26] and degradation Seedling emergence [27] and root growth (soil carbon content) [11,28]. Our current research sheds light on the role of added potassium in the dispersion of clay in the calcareous soils of northern Iraq, whose cultivation patterns have changed from irrigated to irrigated. Materials and Methods: Twelve soil samples were collected from Ninavha, Dohuk, and Erbil provinces of northern Iraq, according to variation of clay, SOM, and $CaCO_3$ contents from the soil reservoir layer (0 - 0.30)m. The research region experiences semi-arid weather with 210 to 835 mm of yearly rainfall on average. The soil samples' chemical and physical properties were analysis according to [29] as shown in table (1) Effect of CROSS Solutions on clay dispersion was carried out by using different potassium levels of 20,40,60, and 80 $mmol_c.L^{-1}$ mixed with 20 mmol $.L^{-1}$ of Na, Ca, and Mg to gate CROSS solutions (4.26, 7.57, 10.89,14.20) according [17]. That calculated by using the following equation:

CROSS = [Na + 0.56K] / ([Ca + 0.6Mg]/2)0.5 ($mmol_c$. L^{-1}).

This experiment was carried out by using undisturbed soil columns with an inner diameter (4) cm and a length of (13) cm soil columns were wetted by adding one pore volume and left to dry for 10 days. This treatment was repeated 4 cycles (wetting and drying) finally soil columns were left to dry. The clay dispersion was done by adding (30) ml electrolytic solution to 5 g of soil samples and placed in the shaker for an hour, The suspension was then left for 15 minutes to settle, and then (2) ml of each tube process was drawn to a depth of (2) cm. The optical density (O.D) measured at (641 nm) according to the method described by [30] is compared to the refereed treatment containing distilled water.

RESULTS AND DISCUSSION

Physicochemical characteristics of the soil:
The results show that the study soils were classified as Mollisols in all samples of the Dohuk and Erbil governorates, and Nineveh soils were classified as Inceptisols [31]. Table (1) shows that the study soil environment
were characterized as calcareous with a high content of carbonate minerals (315 - 375) $g.Kg^{-1}$ with high pH (6.80 - 8.10), According to the reports of the World Food and Agriculture Organization [32] which indicate that the soils of areas with high temperatures and not guaranteed rainfall are characterized by high accumulation of $CaCO_3$ due to lack of rain,
High evaporation and limited filtration [33]. In saline soil, with electrical conduction values ranging from 0.15 to 2.13 dS.m1. Clay content (292 - 569) $g.Kg^{-1}$. The importance of this separation is that it is the main part of the solid soil phase responsible for the processes of adsorption, ion exchange and many interactions that occur in the soil environment.
This difference in clay content was reflected positively in the studied soil cross capacity values, which ranged from 24.06-48.77 soil $g.Kg^{-1}$. The results showed that there was a clear variation in cation-exchange values between the study soil, affecting the amount of adsorbed ionic species. The amount of organic matter in the soil was low and ranged from 10.3 to 29.7 $g.Kg^{-1}$ The difference in the type of vegetation cover, as well as the difference in the rate of degradation of plant residues and products in the soil areas studied, was the main factor leading to the difference in the values of organic matter in those soils [33].

Table 1. Some physical and chemical properties of the study soils.

NO	Site	EC $dS.m^{-1}$	pH	CEC $Cmole_c.Kg^{-1}$	$CaCO_3$	O.M	Sand	Silt	Clay	Texture
							$g.Kg^{-1}$			
1	Buddy	0.77	7.66	24.06	365	17.4	528	180	449	SCL
2	Bakira	0.76	7.07	33.55	345	14.8	403	230	367	CL
3	Suaruhtuka (1)	0.69	7.12	35.23	370	21.6	303	255	442	C
4	Kiflsen	0.81	7.59	24.50	375	27.1	421	283	649	CL
5	Mosul Dam	0.85	7.52	37.88	315	15.6	371	183	447	C
6	Fayda	0.15	6.80	43.90	335	29.3	246	308	723	C
7	Sheikhs	2.13	8.10	48.77	335	29.7	158	273	569	C
8	Talkif	1.42	8.10	34.87	355	28.7	258	323	663	C
9	Sulak	0.40	7.18	44.16	345	21.7	181	353	467	C
10	Hiran	0.40	7.44	30.75	375	10.3	431	203	367	CL
11	Sinja Castle	0.48	7.14	26.28	325	26.6	581	103	736	SCL
12	Ziarat	0.32	6.82	42.78	350	19	256	228	517	C

The effect of monocations on Clay–Dispersion :

The effect of adding potassium levels as a function (CROSS) on the optical density and the amount of dispersed clay particles. Diffuse clay is a measure of the stability of soil structure towards water [34]. the ratio of dispersed clay is a good indicator of the stability of soil structure, and photometric densities represent dispersed soil particles to express the CROSS effect on dispersion, where there is a correlation between the optical density and the amount of dispersed particles in suspension. The addition of electrolytic solutions increased the optical density of soil suspensions from 13 at the Bakyra soil site to the highest value (1.23) at the soil site and with a rate of increase (0.083). As we can see from Table 2, the visual density values in the comparison samples (distilled

water) at all sites decreased compared to CROSS levels, which is due to the higher clay content at these sites.

The results are given the first, the witness of the soil of the mud, the more of the soil theater, the highest the distortion of the Iron [15], leading to the conclusion that Porgotion Baloting is analyzed soil, so that the panic of the water is rather than the dominance of the sovereignty [35], the effect of the soil thermal molecules, which may affect the decline in the soil of the soil the assembly and replacement of the sodium towards liquid phase, launching the NOT potassium in the balance of solution to the increase in the balancing of the commentary for a mutant [10].

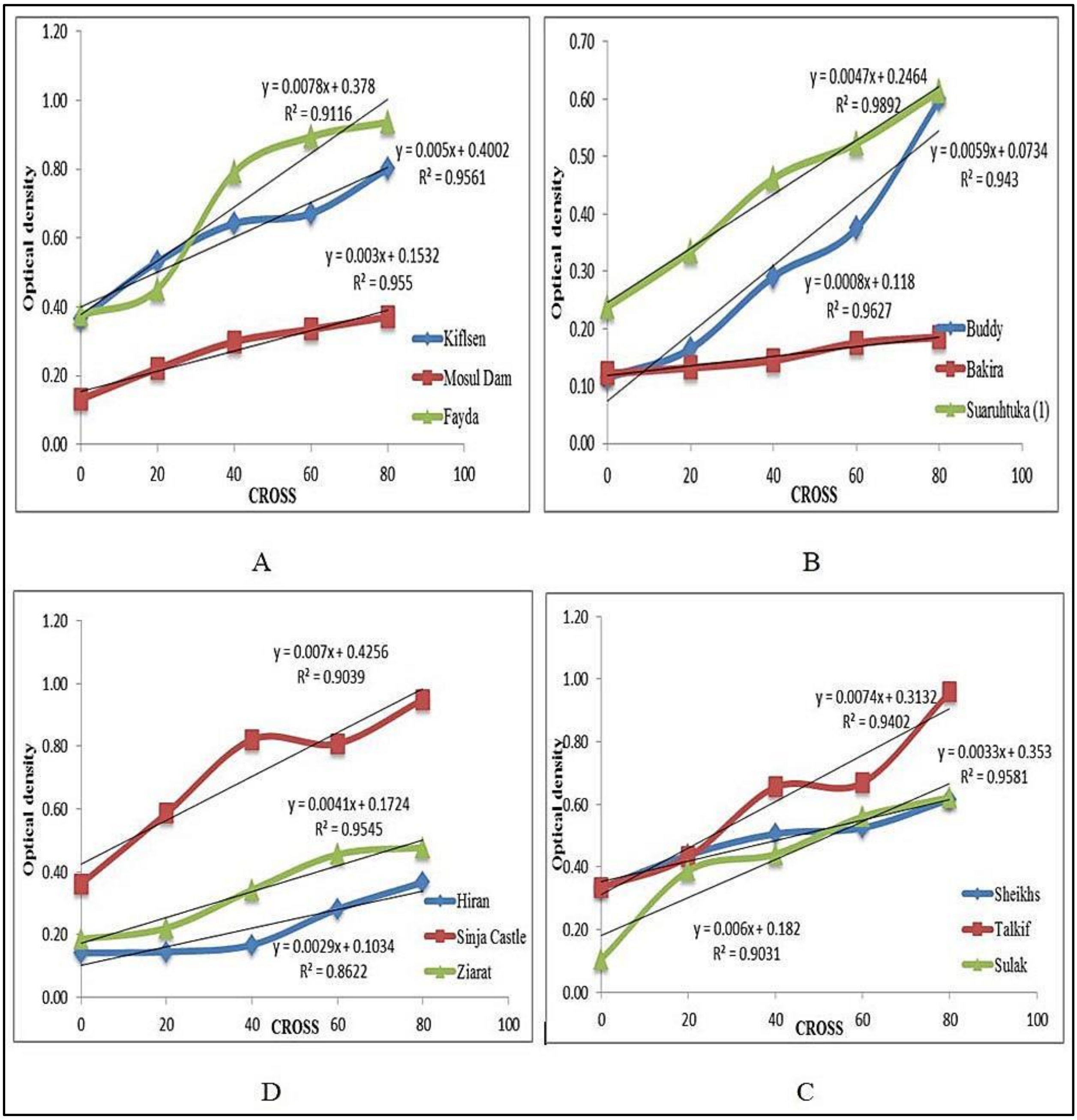

Figure 1. Effect of CROSS level on clay dispersion (C.D)

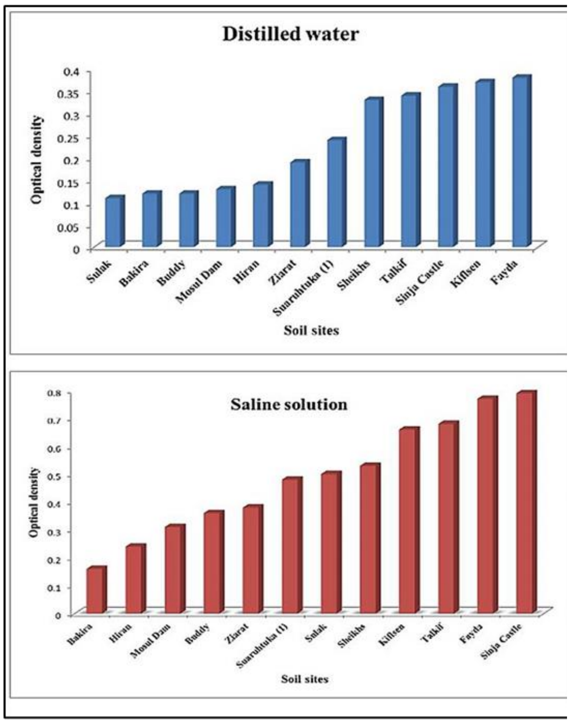

Figure 2. Soils are arranged in ascending order according to clay dispersion

The data presented confirm the very close and significant statistical correlation between optical density and the percentage of individual ions in terms of CROSS, where the determinant (R2) values ranged from 0.90 to 0.99, as shown in Figure 1, with a concentration of K in increased to 80 mole.L^{-1} optical density increased due to an increase in the amount of particles dispersed [1] due to the destruction of the structure. This results in a modification of the geometric structure of the Spaces with a change in the state of the clay minerals and the release of ions on the clay-plate tectonics, thus increasing the colloidal clay suspension and turbidity [36].

The difference in soil dispersion is due to the presence of calcium carbonate and the common role of the ion in reducing solubility, increasing precipitation of calcium, and decreasing visual density. The dispersal (O.D) values vary among soils due to the role of potassium, high clay content, and the predominance of montmorillonite, elite, and primary metals, which are prevalent in most Iraqi soils and are characterized by their high capacity to swell and disperse clay particles. In this regard, [37] stated that there is a problem when the exchange ratio of Na^+ to K^+ is greater than one, in which case K^+ is not considered a dispersal factor in the exchange ratio. Our results confirmed that this ratio was greater for potassium than for sodium, and for this reason there was dispersion in the clay colloids [18].

Table 3. Effect of CROSS-K levels on Clay dispersion.

	Mean Clay dispersion (C.D)		
Soil no	Distilled water	Saline solution	% Increasing
1	0.12	0.36	200
2	0.12	0.16	33
3	0.24	0.48	100
4	0.37	0.66	78
5	0.13	0.31	138
6	0.38	0.77	103
7	0.33	0.53	61
8	0.34	0.68	100
9	0.11	0.50	355
10	0.14	0.24	71
11	0.36	0.79	119
12	0.19	0.38	100

Figers (3,4) showed linear relationship between the clay content and organic matter in soil with optical density (R= 0.90-0.80), respectively our results agree with finding by [14]

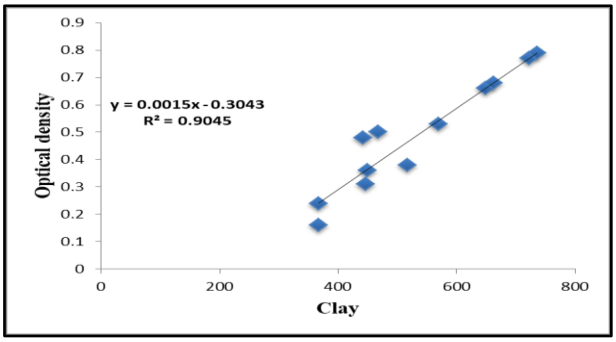

Figure 3. Linear relationship between the clay content and the OD.

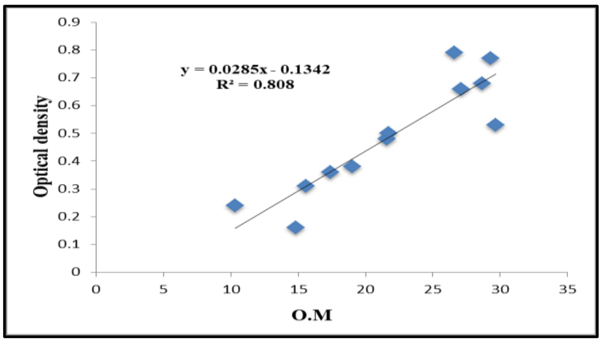

Figure 4. Relationship between organic matter in soil and O.D of dispersed clay

Conclusion

1- Effect of flow type on the physicochemical and kinetic behavior of single and multiple adsorption reactions of potassium.
2- Conducting subsequent studies on non-saline soils by adding different concentrations of sodium and potassium to determine which one is more effective in causing dispersion and breaking down soil aggregates.
3- Adopting a new classification of soil and water values instead of SAR using the CROSS concept.
4- Beware of high additions of potassium fertilizers in rain-fed

References

[1] Marchuk, S., 2016. The Dynamics of Potassium in some Australian soils. PhD Thesis, University of Adelaide, Australia. https://digital.library.adelaide.edu.au/dspace/handle/2440/100189

[2] Smiles, D. E. and Smith, C. J.: A 2004 Survey of the cation content of piggery effluents and some consequences of their use to irrigate soils, Soil Res., 42, 231–246. https://doi.org/10.3390/molecules29040916

[3] Bennett, J., Marchuk, A., Marchuk, S., 2016. An alternative index to the exchangeable sodium percentage for an explanation of dispersion occurring in soil. Soil Research54, 949 - 957. https://doi.org/10.1071/SR15281

[4] Auerswald, K., M. Kainz, S. Angermuller and H. Steindl. 1996. Influence of exchangeable potassium on soil erodibility. *Soil Use and Management* 12: 117-121. https://doi.org/10.1111/j.1475-2743.1996.tb00531.x

[5] Rengasamy, P.; M.E. Sumner (1998). Processes Involved in Sodic Behaviour., in: M. E. Sumner and R. Naidu (Eds.), Sodic Soils. Distribution, Properties, Management, and Environmental. Consequences. Press.New York. pp. 35-50. https://digital.library.adelaide.edu.au/dspace/handle/2440/30310

[6] Arienzo, M., E.W. Christen, W. Quayle and A. Kumar. 2009. A review of the fate of potassium in the soil-plant system after land application of wastewaters. Journal of Hazardous Materials 164: 415-422. https://doi.org/10.1016/j.jhazmat.2008.08.095

[7] Rengasamy, P., 2002. Clay Dispersion. In: McKenzie, B.M., Coughlan, K., Cresswell, H. (Eds.), Soil Physical Measurement and Interpretation for Land Evaluation. CSIRO Publishing, Collingwood, Australia, pp. 200-210. DOI:10.1071/9780643069879

[8] Marchuk, A. 2013. Effect of cations on structural stability of salt-affected soils. Ph.D. Thesis. The University of Adelaide. Australia. https://digital.library.adelaide.edu.au/dspace/handle/2440/92048

[9] Rengasamy, P., Marchuk, A., 2011. Cation ratio of soil structural stability (CROSS). Soil Research 49, 280-285. https://doi.org/10.1071/SR10105

[10] Rengasamy,P.;E. Tavakoli, and G.K.Mc Donald (2016). Exchangeable cations and clay dispersion: net dispersive charge, a new concept for dispersive soil. Eur. J. Soil Sci., 67, 659-665. https://doi.org/10.1111/ejss.12369

[11] Annabi, M., D.; H. Raclot, J. S. Bahri, , C.Bailly Gomez, and Y.Le Bissonnais (2017). Spatial variability of soil aggregate stability at the scale of an agricultural region in Tunisia. Catena 153:157-167. https://doi.org/10.1016/j.catena.2017.02.010

[12] Pessoal,L.; B.Maria, and L.Rento (2019). Salin water irrigation in semiarid region effects on soil chemical properties.Australin Journal of Crop Science .13(70):1169-1176. DOI:10.21475/ajcs.19.13.07.p1686

[13] Stephan, K .; K .D Annette and D.Reiner (2018). Comparison of the Critical Coagulation Concentrations of Allophane and Smectites. Colloids Interfaces. 1- 12. https://doi.org/10.3390/colloids2010012

[14] Johannes, A.; A.Matter, R.Schulin, P.Weisskopf, P.G.Baveye,and P.Boivin (2017). Optimal organic carbon values for soil structure quality of arable soils. Does clay content matter? Geoderma, 302, 14-21. https://doi.org/10.1016/j.geoderma.2017.04.021.

[15] Yotsapon, P.; A. Surachet, C .Natthapol and W.Worachart (2018). Potassium influence on soil aggregate stability, Communications in Soil Science and Plant Analysis, 49:17, 2162-2174. https://doi.org/10.1080/00103624.2018.1499752

[16] Smith, C. J, J. D.Oster and G.Sposito, (2014). Potassium and magnesium in irrigation water quality assessment. Agricultural Water Management, 157: 59-64. https://doi.org/10.1016/j.agwat.2014.09.003

[17] Al-Hadedi K E. and M A. Al-Obaidi (2021) Impact of cation ratio structure stability (CROSS) on the Hydraulic Conductivity Saturation and clay dispersion For some Calcareous soils in north Iraq J. of Kirkuk Univ.for Agri. Sci.Vol. (12) No.(1). https://www.iasj.net/iasj/download/950ccac8571c14ea

[18] Farahani, F., H. Emami, A. Fotovat and R. Khorassani. 2019. Effect of different K:Na ratios in soil on dispersive charge, cation exchange and zeta potential. European Journal of Soil Science 70 (2) : 311-320. https://doi.org/10.1111/ejss.12735.

[19] Levy, G.J. and J.R. Torrento. 1995. Clay dispersion and macroaggregate stability as affected by exchangeable potassium and sodium. Soil Science 160: 352-358. https://doi.org/10.1097/00010694-199511000-00004.

[20] Arienzo M, Christen EW, Jayawardane NS, Quayle WC.2012. The relative effects of sodiumand potassium onsoil hydraulic conductivity and implications for winery waste water management.

Geoderma 173-174:303–10. https://doi.org/10.1016/j.geoderma.2011.12.012

[21] Chorom, M., Rengasamy, P., 1995. Dispersion and zeta potential of pure clays as related to net particle charge under varying pH, electrolyte concentration and cation type. European Journal of Soil Science 46, 657-665. https://doi.org/10.1111/j.1365-2389.1995.tb01362.x

[22] Smiles, D.E.; 2006. Sodium and potassium in soils of the Murray – Darling Basin: a note. Aust. J. Soil Res., 44, 727-730. https://doi.org/10.1071/SR06057.

[23] Marchuk, A., Rengasamy, P., 2011. Clay behaviour in suspension is related to the ionicity of clay–cation bonds. Applied Clay Science 53, 754-759. https://doi.org/10.1016/j.clay.2011.05.019

[24] Marchuk, A. and P. Rengasamy. 2012. Threshold electrolyte concentration and dispersive potential in relation to CROSS in dispersive soils. Soil Research 50: 473-481. https://doi.org/10.1071/SR12135

[25] Oster, J., 2008. Potassium Impacts on Soil Physical Properties. http://esce.ucr.edu/oster/slphynote/note04

[26] Zhao, J.; Chen, S.; Hu, R.; Li, Y. Aggregate Stability and Size Distribution of Red Soils under Different Land Uses Integrally Regulated by Soil Organic Matter, and Iron and Aluminum Oxides. Soil Tillage Res. 2017, 167, 73–79. https://doi.org/10.1016/j.still.2016.11.007

[27] Wang, J.; Yang, W.; Yu, B.; Li, Z.; Cai, C.; Ma, R. Estimating the Influence of Related Soil Properties on Macro- and Micro-Aggregate Stability in Ultisols of South-Central China. CATENA 2016, 137, 545–553. https://doi.org/10.1016/j.catena.2015.11.001

[28] Awedat, A. M., Zhu, Y., Bennett, J. M., and Raine, S. R. (2021): The impact of clay dispersion and migration on soil hydraulic conductivity and pore networks, Geoderma, 404, 115297. https://doi.org/10.1016/j.geoderma.2021.115297.

[29] Sparks DL 2017 Methods of soil analysis soil science society of America 5585 Guilford Rd., Madison. https://nrcspad.sc.egov.usda.gov/DistributionCenter/pdf.aspx?productID=886

[30] Thellier, C.; and G. Sposito (1989). Influence of electrolyte concentration and exchangeable cations on the flocculation of silver Hill Illite. Soil. Sci. Soc. Am. J 53: 611-715. https://doi.org/10.2136/sssaj1989.03615995005300030011x

[31] Soil Survey Laboratory Staff 2017 Soil survey laboratory methods manual. Soil Surv. Invest. Reps. 42 USDA – SCS, Washington, DC. soils. Advances in Agronomy. 96: 197- 2.

[32] FAO. (2017). Voluntary Guidelines for Sustainable Soil Management Food and Agriculture Organization of the United Nations Rome, Italy. https://link.springer.com/chapter/10.1007/978-3-319-68885-5_3.

[33] Taalab, A.S. G.W. Ageeb, Hanan S. Siam and Safaa A. Mahmoud (2019) Some Characteristics of Calcareous soils. A review,Middle East Journal of AgricultureResearchISSN 2077- 4605 08 : 01 Pages:96-105. https://www.curresweb.com/mejar/mejar/2019/96-105.pdf

[34] Zhu, G.; Shangguan, Z.; Deng, L. Variations in Soil Aggregate Stability Due to Land Use Changes from Agricultural Land on the Loess Plateau, China. CATENA 2021, 200, 105181. https://doi.org/10.1016/j.catena.2021.105181

[35] Sipal M Y ,and K, AbduL-Karim Hassan (2022) Effect of monovalent cations in different naturaL waters on Physical and chemical properties of two soils Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition) ISSN : 1671-5497 E-Publication Online Open Access Vol: 41 Issue: 11-2022.

[36] Sposito G .2018. The Chemistry of soils Oxford University Press, New York. https://global.oup.com/academic/product/the-chemistry-of-soils-9780195313697?cc=bg&lang=en&

[37] Marchuk, S. and Marchuk, A .2018: Effect of applied potassium concentration on clay dispersion, hydraulic conductivity, pore structure and mineralogy of two contrasting Australiansoils., .SoilTillageRes., 182,3544. https://doi.org/10.1016/j.still.2018.04.016