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ORIGINAL ARTICLE

REHABILITATION OF SALINE SODIC SOIL BY WASHING IT WITH ENRICHED WATER OF COMBINATIONS OF PHOSPHOGYPSUM AND HUMIC ACIDS

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Abstract: A field study was conducted during the spring season of 2020 on saline-sodic with clay loam texture to study 16 combinations of phosphogypsum and humic acids. The experiment was carried out by Randomized complete block design according to the order of additive treatments for factorial experiments with three replications. That is included the use of humic acids (HA_1, HA_2, HA_3 and HA_4), phosphogypsum (G_1, G_2, G_3 and G_4) and four concentrations (0.5, 1.0, 1.5, 2.0 gm l^{-1}) for both. They were mixed in the washing water to become 16 combinations, in addition to washing with a commercial clean salt (CS) and with water of the Euphrates River only (W) to become 18 treatments. All the experimental units were washed with water enriched with phosphogypsum and humic acids combination, with a commercial clean salt and water only and water volumes were added equivalent to two times the size of the soil pores to a depth of 30 cm and then soil samples were taken from five depths within a depth of 1 m and planted with the corn crop. The results showed, in general, a decrease in the values of electrical conductivity and the sodium adsorption ratio at all the studied depths compared to what they were before washing. Washing with HA_1G_4 combination gave the highest significant difference in electrical conductivity, which reached 26.63 dS m^{-1} compared to HA_4G_1, CS and W washing, which were 11.42, 14.28 and 11.23, respectively. Whereas, washing with HA_4G_4 combination gave the highest significant decrease in sodium adsorption ratio, which was 0.83, compared to washing with CS and W, which reached 15.28 and 23.57, respectively. Combination HA_4G_4 gave the highest significant increase in grain yield and dry matter weight, with an increase of 67.00% and 190.62 compared to washing with water alone (W), respectively.

Keywords: Phosphogypsum, Humic acid, Saline-sodic soil, Clean salt.

Cite this article

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1. Introduction

Salinity and sodicity are one of the main problems facing agriculture [Dagar and Amit (2013)], as it affects the chemical and physical properties of the soil that lead to the breakdown of the soil structure and thus its lack of permeability to water, as well as its aeration through the high exchangeable sodium percentage on the surfaces of the exchange for clay particles. The area of soils affected by salinity differs from one country to another, as the proportion of saline land in the world is about 7% and in Iraq, it exceeds 50% of the arable land area. Conventional salinity treatment methods such as surface washing of salts, surface skimming and water-only washing are of no use. This is to expand the area of saline land, as well as the high treatment cost, as well as time, effort and use of large quantities of water, as well as the establishment of efficient drainage networks. Recently many salinity treatment compounds, including chemical and organic, have appeared with multiple brand names and competition for them has become great among manufacturers due to the positive effect they add in reducing the effect of salts in the soil, improving the chemical properties of the soil and reducing the sodium

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adsorption ratio [Golly (2017)]. Recent studies have resorted to the use of some chemical and organic materials and compounds to study their effect in reducing salts from the soil in a chemical process such as ion exchange (displacement and substitution) and among these compounds are phosphogypsum and humic acids and have been used by adding them directly to the soil and gave good results [Al-Hadethi and Al-Alwani (2020)], by reducing the sodium adsorption ratio to saline soils when washing water is mixed with humic acids [Reddy and Mundinamani (2014) and Al-Hadethi *et al.* (2019)]. Phosphogypsum is a good source of the calcium ion present in its composition ($CaSO_4.2H_2O$). When adding a mixture to the soil, the calcium displaces and replaces the monovalent sodium adsorption ratio on the exchange complex, which leads to a decrease in the sodium adsorption ratio, although it leads to an increase in the electrical conductivity of the electrolyte solution and a decrease in the pH value through the presence of sulfates in its chemical composition. It is considered a good chemical reformer [Dick (2000)]. Humic acids (humic acid and fulvic acid) are important compounds responsible for many chemical processes that occur in the soil, as they have a role in reducing the pH value of the soil, in addition to containing functional groups such as hydroxyl and carboxyl groups which have a role in facilitating the process of washing salts by forming complexes with single and double cationic salt ions [Turan *et al.* (2011)]. Humic acids are complexes that are easy to move with sodium ions and less mobile with calcium and magnesium ions [Zhang *et al.* (2013)]. Therefore, the research aims to study the effect of different combinations of phosphogypsum and humic acids on the movement and distribution of salts in saline-sodic soil, compared to commercial saline and water treatment in addition to its effect on two indicators the growth of corn crop.

2. Materials and Methods

The study was conducted during the spring season of 2020 in the fields of the College of Agriculture, University of Anbar, in a saline-sodic soil. Soil texture is clay loam whose content of clay is 299 gm kg^{-1} soil and classified according to the modern American classification within the class Typic Torrifluvents. Its electrical conductivity was 143.57dS m^{-1}, sodium adsorption ratio was 54.44, the exchanged sodium percentage was 41.44 and its content of calcium carbonate was 230 gm kg^{-1}. After plowing and smoothing, the soil leveling was carried out. Then the field was divided longitudinally into three sectors. Each sector contains 18 experimental units and an area of 6 m^2 with dimensions of 2×3 m. The experiment was carried out by designing randomized complete blocks according to the order of factor experiments with three replications. The experiment includes the use of humic acids (HA) and four concentrations (0.5, 1.0, 1.5, 2.0 gm l^{-1}), phosphogypsum (G) and four concentrations (0.5, 1.0, 1.5, 2.0 gm l^{-1}) mixed in the washing water to become 16 combinations in addition to washing with Euphrates water only (W) and a commercial clean salt (CS). Table 1 shows the chemical properties of the phosphogypsum and the salinity treatment used in the experiment. The soil washing process was carried out before planting by using 18 water tanks, one tank capacity of 1000 liters, one tank for each combination (16 combinations, clean salt and water only). Two pore volumes of water were added equivalent to twice the size of the soil pores for a depth of 30 cm, to reach a suitable salinity level for cultivating the corn crop. The total volume of washing water was 1507.75 liters of $plot^{-1}$ and the total water depth was 25 cm of $plot^{-1}$ and the immersion method was used using a flexible plastic tube connected to a diesel pump with a discharge of 110 liters $minute^{-1}$, which is installed and connected to all water tanks and separates each water tank to control the water between one tank and another.

Soil samples were taken by auger from depths 20-0, 40-20, 60-40, 80-60 and 80-100 cm from each experimental unit, as it was taken first before washing and it was also taken after adding the two-pore volume when the soil reached the field capacity depending on the experiment of the columns. By adding the same combinations of washed water and performing the washing process [Aftan and Al-Hadethi (2021)]. After adding two volumes of porous phosphogypsum and humic acids, the maize crop was planted and then water-only irrigation operations were performed and the crop was served throughout the growing season. Take grain yield and dry matter yield as indicators of

Table 1: Some chemical properties of phosphogypsum and clean salt.

	Phosphogypsum					Clean Salt	
EC	**pH**	**Ca**	**Mg**	**Na**	**K**	**N**	**Ca**
1:1	**1:1**	**mmol l^{-1}**				**%**	
3.89	5.67	65.13	11.04	0.32	2.11	10	14

plant growth after harvest. Soil samples were taken from all the experimental units after harvesting plants. The electrical conductivity was measured and the sodium adsorption ratio was calculated, to know the nature of the movement and distribution of salts and the sodium adsorption ratio in the soil within a depth of 1 m.

3. Results and Discussion

3.1 The electrical conductivity in the depths of the soil after adding two pore volumes of washing combinations

Fig. 1 shows the effect of washing combinations with humic acids, phosphogypsum, washing with water and a commercial clean salt in electrical conductivity (EC: dS m^{-1}) with the depth of the soil after adding the two-pore volumes. From the figure, it is noticed that the electrical conductivity exhibited similar behavior in terms of depth and direction and for all washing combinations. In addition to washing with water and with a commercial clean salt processor, it is noticed that the electrical conductivity decreased at the depth 0-20, 20-40 and 40-60 cm, as it reached as a general average for all washing and washing combinations with water and with a commercial clean salt processor to 15.65, 21.96 and 26.41 dS m^{-1} in comparison to the electrical conductivity before washing, which was 143.57, 69.63 and 30.83 dS m^{-1}, respectively, while the electrical conductivity increased in-depth 60-80 and 80-100, which reached 41.06 and 48.35 dS m^{-1}, compared to what was the conductivity before washing, which was 15.41 and 8.54 dS m^{-1}. The reason for the decrease in electrical conductivity after adding the two-pore volume from the washing water combinations at depths 0-20, 20-40 and 40-60 cm are because the amount of

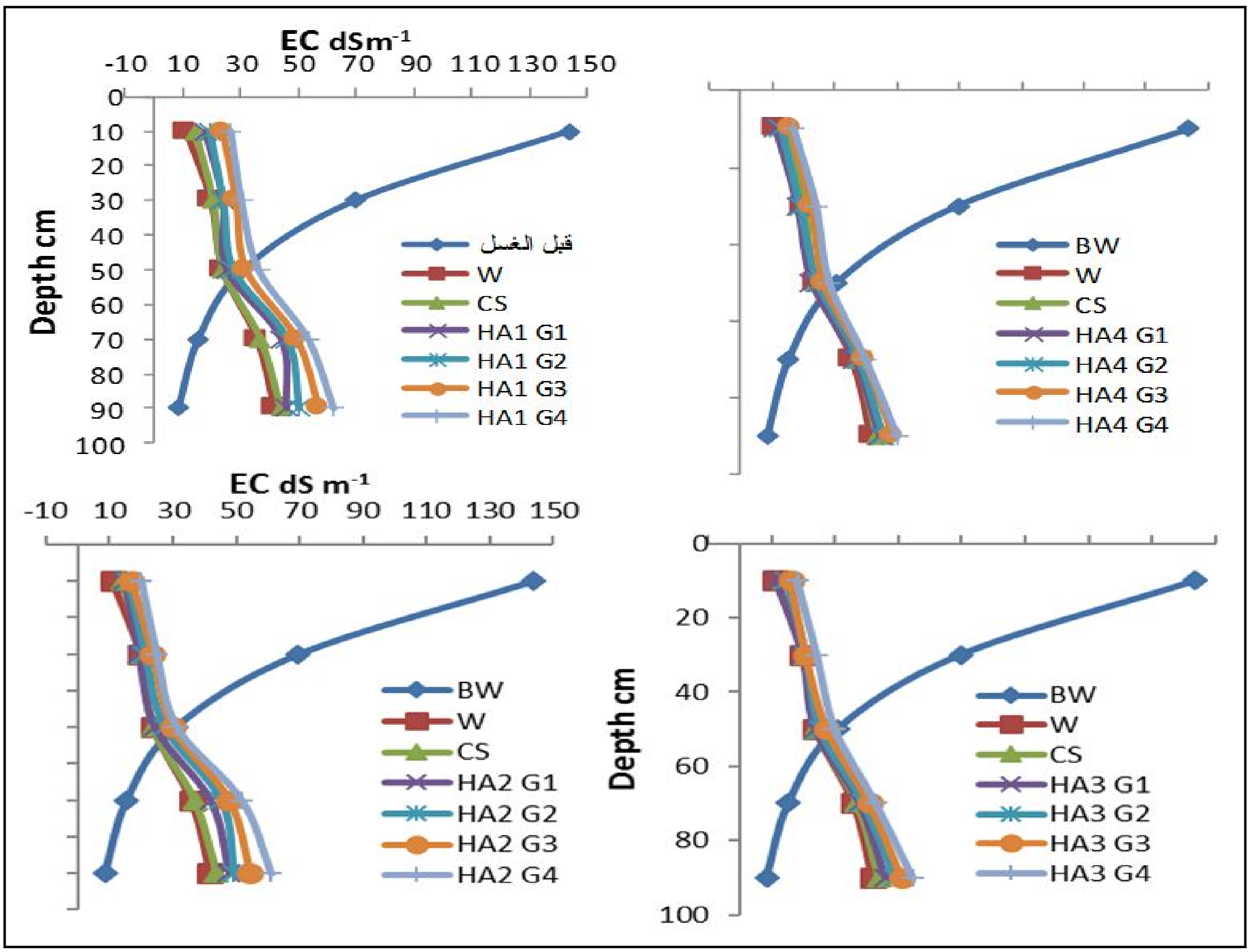

Fig. 1: The relationship between the electrical conductivity (EC: dS m^{-1}) with the depth of the soil washed with combinations of humic acids and phosphogypsum added to the wash water, water, and a commercial clean salt after adding the two-pore volume

water was sufficient to wash out the largest amount of salts, in addition to that the salts were more soluble, which facilitated the process of washing them into lower. These results are consistent with Al-Alwani and Al-Hadethi (2019) who indicated that electrical conductivity decreased in the lower depths when washing water was added to the soil.

When comparing the washing combinations with each other, it is noticed that the electrical conductivity of a depth of 0-30 cm increased when the concentration of phosphogypsum increased in the washing mixtures and decreased relatively when the concentration of humic acids increased and this is true for the rest of the soil depths, as the combination gave HA_1G_4 (0.5 gm l^{-1} humic acids and 2.0 gm l^{-1} phosphogypsum) the highest electrical conductivity as it reached 26.63 dS m^{-1}, while the combination HA_4G_1 (2.0 gm l^{-1} humic acids and 0.5 gml^{-1} phosphogypsum) gave the lowest electrical conductivity as it reached 11.42 dS m^{-1}, compared to the combination of HA_1G_1 (0.5 gml^{-1} humic acids and 0.5gml^{-1} phosphogypsum), as it reached 17.83 dS m^{-1}. The reason for the increase in electrical conductivity with the increase in phosphogypsum is due to the increase in the saturation of the soil solution with ions, which leads to an increase in the electrolyte concentration and thus increased electrical conductivity [Dick (2000)]. As for the reason for the decrease in electrical conductivity with the increase of humic acids, it is because humic acids contain functional groups such as carboxyl and hydroxyl that work to form easy-to-move complexes with sodium and less mobile complexes with calcium. Consequently, electrical conductivity values decrease [Tchiadje (2007)]. These results are consistent with Al-Alwani and Al-Hadethi (2019) who indicated that the electrical conductivity values increased with the addition of phosphogypsum to the soil and decreased when humic acids were added to the soil.

3.2 The percentage of sodium adsorption in the depths of the soil after adding two porous volumes of the washing mixtures

Fig. 2 shows the effect of the combinations of washing with humic acids, phosphogypsum, washing with water and with a commercial clean salt on the sodium adsorption ratio (SAR) with the depth of the soil after adding the second pore volume of washing water and from the figure, it is noticed that the sodium adsorption ratio exhibited similar behavior in terms of depth and direction for all combinations of washing in addition to washing with water and with a commercial clean salt. It is noticed from the figure that the sodium adsorption ratio decreased at the depth of 0-20, 20-40 and 40-60 cm, as it reached as a general rate for all washing and washing combinations with water and with a commercial clean salt of 9.20, 10.76 and 10.95 compared to the sodium adsorption ratio before washing was 51.71, 34.44 and 12.10, while the sodium adsorption ratio increased in-depth 60-80 and 80-100, which reached 12.71 and 17.20, compared to the same sodium adsorption ratio before washing, which was 7.72 and 7. 62 and the reason for the low values of sodium adsorption ratio in the depths 0-20, 20-40 and 40-60 is because the amount of water was sufficient to wash the largest amount of sodium salts, in addition to that the salts were more soluble, which facilitated the process of washing them down. These results are consistent with Al-Alwani and Al-Hadethi (2019) who indicated that the sodium adsorption ratio values decreased at the upper depths and increased at the lower depths when washing water was added to the soil.

From the above, we conclude that the sodium adsorption ratio values decreased when increasing the concentration of phosphogypsum for washing mixtures with an increase in the concentration of humic acids and this is true for the rest of the depths of the soil, as the combination gave HA_1G_1 (0.5 gml^{-1} humic acids and 0.5 gml^{-1} phosphogypsum). The highest value of the sodium adsorption ratio was 8.88 and the combination HA_4G_4 (2.0 gm l^{-1} humic acids and 2.0 gm l^{-1} phosphogypsum) gave the lowest value for the sodium adsorption ratio reached 0.83 while washing with water (W) and with a salinity treatment was given. The highest value for sodium adsorption ratio was 23.79 and 15.28, respectively. The reason for the decrease in the values of the sodium adsorption ratio with the increase in phosphogypsum is due to the increase in the saturation of the soil solution with calcium, the source of which is phosphogypsum, according to Coulomb's law, which states that the strength of the bond between the cation and the clay grain increases with the increase in the electrical charge, as the divalent cations have a charge higher than the monovalent, so they have stronger bonding to the colloidal surface and the higher the valence of the cation, the greater its ability to dissolve on the surface of the clay granule replacing the

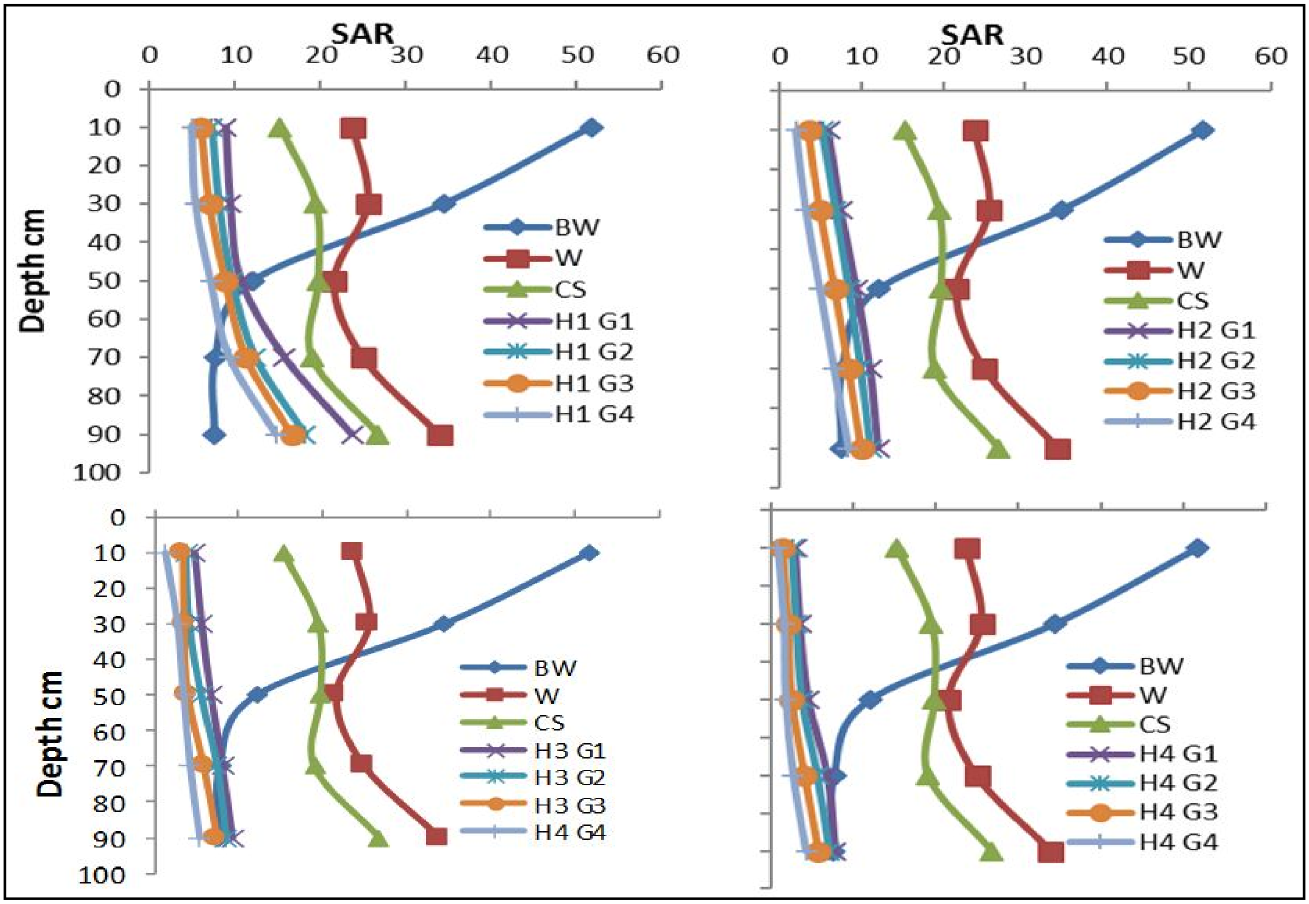

Fig. 2: The relationship between sodium adsorption percentages (SAR) with soil depth washed with humic acid combinations and phosphate gypsum added to wash water, water, and commercial clean salt after adding the second pore volume

monovalent cations such as sodium [Dick (2000)]. As for the reason for the decrease in the values of the sodium adsorption ratio with the increase in humic acids, it is attributed to the fact that humic acids contain functional groups such as carboxyl and hydroxyl that work to form easy-to-move complexes with sodium and less mobile complexes with calcium and thus the values of the sodium adsorption ratio decrease in addition to the functional groups of humic acids working on the formation of less mobile complexes with the calcium ion, which leads to the increase and saturation of the exchange surfaces with the calcium ion [Tchiadje (2007)]. These results are consistent with Al-Alwani and Al-Hadethi (2019) who indicated that the sodium adsorption ratio values decreased by adding phosphogypsum to the soil and also decreased when humic acids were mixed with the soil.

3.3 The electrical conductivity in the surface layer (0-20 cm) after adding the second pore volume

Table 2 shows the effect of washing a saline-sodic soil with combinations of humic acids, phosphogypsum, water and a commercial clean salt on the electrical conductivity characteristic of the soil (dS m^{-1}) after adding the two-pore volume, as noted from the table that a significant increase in the electrical conductivity of the soil when adding the commercial clean salt to washing water, as the electrical conductivity reached 14.28 dS m^{-1}, with an increase of 27.15% compared to its value when washing with water (W), in which the electrical conductivity was 11.23 dS m^{-1}. Soil washing with HA_1G_4 combination showed the highest significant increase in electrical conductivity it amounted to 26.63 dS m^{-1}, with an increase of 86.48% and 137.13% compared to the two treatments of soil washing with a commercial clean salt (CS) and washing with water (W) according to the order, while washing with a combination HA_4G_1 gave the least significant increase, as the electrical conductivity reached 11.42 dS m^{-1}, with an increase of 1.69% compared to the wash with water treatment (W), according to the order electrical conductivity 11.42 dS m^{-1}. The reason for the increase in the electrical conductivity values with the increase in the level of phosphogypsum in the combination is

Table 2: Effect of washing of saline-sodic soil with combinations of humic acids, phosphogypsum, water, and commercial clean salt on electrical conductivity and sodium adsorption ratio after adding two pores volumes.

humic acids (gm l^{-1})	phospho gypsum (gm l^{-1})	combi nation	EC dS m^{-1}	SAR
			after adding two pores volumes	
HA1 (0.5)	G1 (0.5)	HA1G1	17.83	8.87
	G2 (1.0)	HA1G2	19.33	7.23
	G3 (1.5)	HA1G3	23.92	5.98
	G4 (2.0)	HA1G4	26.63	4.93
mean G1			13.96	5.64
mean HA1			21.93	6.75
HA2 (1.0)	G1 (0.5)	HA2G1	14.98	5.98
	G2 (1.0)	HA2G2	15.84	5.24
	G3 (1.5)	HA2G3	16.92	3.55
	G4 (2.0)	HA2G4	19.98	1.96
mean G2			15.81	4.69
mean HA2			16.93	4.18
HA3 (1.5)	G1 (0.5)	HA3G1	11.62	4.75
	G2 (1.0)	HA3G2	14.88	3.68
	G3 (1.5)	HA3G3	16.15	3.35
	G4 (2.0)	HA3G4	18.11	1.26
mean G3			18.21	2.24
mean HA3			15.19	1.95
HA4 (2.0)	G1 (0.5)	HA4G1	11.42	2.97
	G2 (1.0)	HA4G2	13.18	2.61
	G3 (1.5)	HA4G3	15.83	1.40
	G4 (2.0)	HA4G4	17.05	0.83
mean G4			20.44	2.24
mean HA4			14.37	1.95
	W		11.23	23.57
	CS		14.28	15.28
LSD_G			0.02	0.07
LSD_{HA}			0.02	0.07
LSD_{G*HA}			0.04	0.13

due to the increase in the saturation of the soil solution with ions (Ca^{++} and SO_4^{--}), which leads to an increase in the concentration of the electrolyte solution and thus the electrical conductivity values increase [Dick (2000)]. As for the reason for the decrease in the electrical conductivity values by the increase in the level of humic acids in the combination, it is because humic acids contain functional groups such as carboxyl and hydroxyl that form complexes with sodium that are easy to move while the complexes formed with calcium are less mobile and thus the values of electrical conductivity decrease [Tchiadje (2007)]. These results are consistent with Al-Alwani and Al-Hadethi (2019) who indicated that the electrical conductivity values increased with the addition of phosphogypsum to the soil and the conductivity values decreased when humic acids were mixed with the soil.

3.4 The sodium adsorption ratio in the surface layer (0-20 cm) after adding the second pore volume

Table 2 shows the effect of washing a sodic saline soil with combinations of humic acids, phosphogypsum, water and a commercial clean salt on the characteristic of the sodium adsorption ratio after adding the second pore volume. It is noted from the table a significant decrease in the sodium adsorption ratio when adding a commercial clean salt (CS) to the washing water. The rate of sodium adsorption ratio was 15.28, a decrease of 35.17% compared to the washing with water treatment (W), which was 23.57. Soil washing with HA_4G_4 combination showed the highest significant decrease in the rate of sodium adsorption ratio, which reached 0.83, with a decrease of 94.56% and 96.47%. in comparison with the two treatments of washing the soil with a commercial clean salt (CS) and washing with a water treatment (W), which amounted to 15.28 and 23.57, respectively, while washing with a combination of HA_1G_1 gave the least significant decrease, as it had a sodium adsorption ratio of 8.87, with a decrease of 41.62 and 62.36% compared to washing with clean salt (CS) and water. A decrease in the sodium adsorption ratio values with the increase of phosphogypsum increases the saturation of the soil solution with Ca^{++} ions, which leads to the displacement of the sodium ion and its substitution and thus the sodium adsorption ratio values decrease [Dick (2000)].

As for the reason for the decrease in the values of the sodium adsorption percentage with the increase in humic acids, it is because the humic acids contain functional groups such as carboxyl and hydroxyl that form complexes with sodium that are easy to move while the complexes formed with calcium are less mobile and thus the values of the sodium adsorption ratio decrease [Tchiadje (2007)]. These results are consistent with Al-Alwani and Al-Hadethi (2019) who indicated that the sodium adsorption ratio decreased by adding phosphogypsum to the soil and also decreased by the addition of humic acids mixed with the soil.

3.5 Grain yield (gm plate^{-1})

Table 3 shows the effect of combinations of humic acids, phosphogypsum, water and a commercial clean salt on the grain yield (gm plate^{-1}). It is noticed that washing with HA_4G_4 combination achieved the highest significant increase in grain yield, reaching 1209 gm plate^{-1}, with an increase of 115.50% and 190.62%, compared to the two treatments of washing soil with a commercial clean salt (CS) and washing with a water treatment (W), in which the grain yield was 561 and 416 gm plate^{-1}, respectively, while washing with a combination HA_1G_1 gave the least significant increase, as the grain yield was 574 gm plate^{-1}, with a rate of 2.31% and 37.98%, compared with the treatment of soil washing with a commercial clean salt (CS) and washing with water (W). As can be noted from the table, there was a significant increase in the yield of corn crops when adding the washing treatment with a commercial clean salt (CS) in which the grain yield reached 561 gm plate^{-1}, with an increase of 34.85% compared to the treatment with water washing (W), in which the grain yield reached 416 gm plate^{-1}, according to the arrangement. The combination HA_4G_4 overcame it reached 110.62%, compared to the washing combination HA_1G_1, as the grain yield reached 574 gm plate^{-1}. These results are in accordance with the findings of Al-Alwani and Al-Hadethi (2019) who indicated that there was a significant increase in the grain yield when humic acids and phosphogypsum were mixed with the soil at different levels.

Table 3: Effect of washing saline soils with combinations of humic acids, phosphogypsum, water and Commercial clean salt on grain yield (gm plot^{-1}).

Humic Acids gm l^{-1}	Phosphogypsum (gm l^{-1})				Mean Humic Acids	
	G_1(0.5)	G_2(1.0)	G_3(1.5)	G_4(2.0)		
HA_1(0.5)	574	657	673	731	659	
HA_2(1.0)	836	904	922	958	905	
HA_3(1.5)	976	1009	1068	1160	1053	
HA_4(2.0)	1187	1198	1202	1209	1199	
W	416				21	LSD_{HA}
Cs	561					
	42					
Mean Phospho -gypsum	893	942	966	1014		
LSD_G	21					

3.6 Total dry matter yield (gm plot^{-1}) ten plants

Table 4 shows the effect of combinations of humic acids, phosphogypsum, water and commercial clean salt on the dry matter weight yield (gm plate^{-1}). It is noticed that washing with HA_1G_1 combination achieved the least significant increase in the plant's dry matter weight as it reached 1059 gm and by 33.88% compared to the soil wash treatment. With water (W) in which the weight of plant straw reached 791 gm, while the same combination did not show a significant increase compared to the soil washing treatment with a commercial clean salt (CS).

An increase of 39.78% and 67.00% compared to the two treatments of soil washing with a commercial clean salt (CS) and washing with a water treatment (W) in which the weight of plant dry matter reached 945 and 791 gm, respectively, as it is noticed from the table that there was an insignificant increase in the average dry matter weight. For yellow corn plants when adding a soil wash treatment with a commercial clean salt (CS) compared with a washing treatment with water (W), while washing the soil with a combination HA_2G_1 gave the least significant increase in the plant's dry matter weight as it reached 1059 gm, with a rate of 22.96% compared with the washing treatment. The soil with a commercial clean salt (CS), in which the dry matter weight of the plant was 945 gm. However, HA_4G_4 was synthesized with a highly significant increase in all wash combinations, by a rate of 24.74

Table 4: The effect of washing saline soils with combinations of humic acids, phosphogypsum, water, and a commercial clean salt on the total dry matter yield of the plant (gm plot^{-1}).

Humic Acids gm l^{-1}	Phosphogypsum (mg l^{-1})				Mean Humic Acids	
	G_1(0.5)	G_2(1.0)	G_3(1.5)	G_4(2.0)		
HA_1(0.5)	1059	1068	1090	1093	1078	
HA_2(1.0)	1162	1167	1182	1188	1175	
HA_3(1.5)	1206	1212	1226	1237	1220	
HA_4(2.0)	1298	1305	1316	1321	1310	
W	791				11	LSD_{HA}
Cs	945					
LSD	21					
Mean Phospho -gypsum	1181	1188	1204	1210		
LSD_G	11					

compared to HA_1G_1 wash combination, in which the average plant dry matter weight was 1059 gm. These results are consistent with the findings of Al-Alwani and Al-Hadethi (2019) who indicated to a significant increase in the dry matter weight of the barley plant when humic acids and phosphogypsum were added to the soil at different levels.

3.7 The values of electrical conductivity in the depths of the soil after harvesting

Fig. 3 shows the effect of adding irrigation water (regular irrigation water) throughout the growing season with the addition of washing requirements (LR) with the season for the same combinations, washing water and clean salt with depth after harvest and from the figure, it is noticed that the electrical conductivity exhibited similar behavior in terms of depth and direction and for all combinations washing in addition to washing with water and with a commercial clean salt, as it is noticed that the electrical conductivity decreased in all depths 0-20, 20-40, 40-60, 60-80 and 80-100 cm, as it reached as a general rate for all washing and washing combinations with water and with a commercial salinity processor 3.23 and 4.41 and 4.99, 5.52 and 9.47 dS m^{-1} compared to what was the electrical conductivity before planting (Fig. 1) (after adding the second pore volume from the wash water combinations), which amounted to 15.65, 21.96, 26.41, 41.06 and 48.35 dS m^{-1}, respectively.

From the above, we conclude that the electrical conductivity increased when increasing the concentration of phosphogypsum for the washing mixtures and relatively decreased when increasing the concentration of humic acids. This is true for the rest of the soil depths, as the combination gave HA_1G_4 (0.5 gm l^{-1} humic acids and 2.0 gm l^{-1} phosphogypsum) (the highest electrical conductivity as it reached 4.55 dS m^{-1}, while the combination HA_4G_1 (2.0 gm l^{-1}) humic acids and 0.5 gm l^{-1} phosphogypsum (the lowest electrical conductivity was 2.55 dS m^{-1} compared to HA_1G_1). That is, 0.5 gm l^{-1} humic acids and 0.5 gm l^{-1} phosphogypsum, as it reached 3.89 dS m^{-1}. The reason for the increase in electrical conductivity with the increase in phosphogypsum is due to the increase in the saturation of the soil solution with ions, which leads to an increase in the electrolyte concentration and consequently to the electrical conductivity [Dick (2000)]. As for the reason for the decrease in electrical conductivity with the increase of humic acids, it is because humic acids contain functional groups such as carboxyl and hydroxyl that work to form easy-to-move complexes with sodium and less mobile complexes with calcium. Consequently, electrical conductivity values decrease [Tchiadje (2007)]. These results are consistent with Al-Alwani and Al-Hadethi (2019) who indicated that electrical conductivity increased with the addition of phosphogypsum to the soil and the conductivity decreased when humic acids were mixed with the soil.

3.8 The sodium adsorption ratio in the soil depth after harvest

Fig. 4 shows the effect of adding irrigation water (regular irrigation water) throughout the growing season with the addition of washing requirements (LR) with the season for the same combinations, washing water and clean salt with depth after harvest and from the figure, it is noticed that the sodium adsorption ratio exhibited similar behavior in terms of depth and direction for all the washing combinations in addition to washing with water and with a clean salt, as it is noticed that the sodium adsorption ratio decreased at all depths 0-20, 20-40, 40-60, 60-80 and 80-100 cm, as it reached as a general rate for all the washing and washing combinations with water and with a commercial clean salt 4.62 and 4.28, 4.24, 4.34 and 6.72, as measured by the values of the sodium adsorption ratio before planting (after adding the second pore volume from the wash water combinations) (Fig. 2), which were 9.20, 10.76, 10.95, 12.71 and 17.20, respectively.

From the above, we conclude that the sodium adsorption ratio values decreased when increasing the concentration of phosphogypsum for washing mixtures with an increase in the concentration of humic acids and this is true for the rest of the depths of the soil, as the combination gave HA_1G_1 (0.5 gm l^{-1} humic acids and 0.5 gm l^{-1} phosphogypsum). The highest value of the sodium adsorption ratio was 1.89 and the combination HA_4G_4 (2.0 gm l^{-1} humic acids and 2.0 gm l^{-1} phosphogypsum) gave the lowest value for the sodium adsorption ratio, as it reached 0.29, while washing with water (W) and with a clean salt was given. The highest value for sodium adsorption ratio was 16.21 and 8.05, respectively. The reason for the decrease in the sodium adsorption ratio with the increase in the phosphogypsum is due to the increase in the saturation of the soil solution with calcium, whose source is the phosphogypsum, according to Coulomb's law, which states that the strength of bond the cation between the cation and the

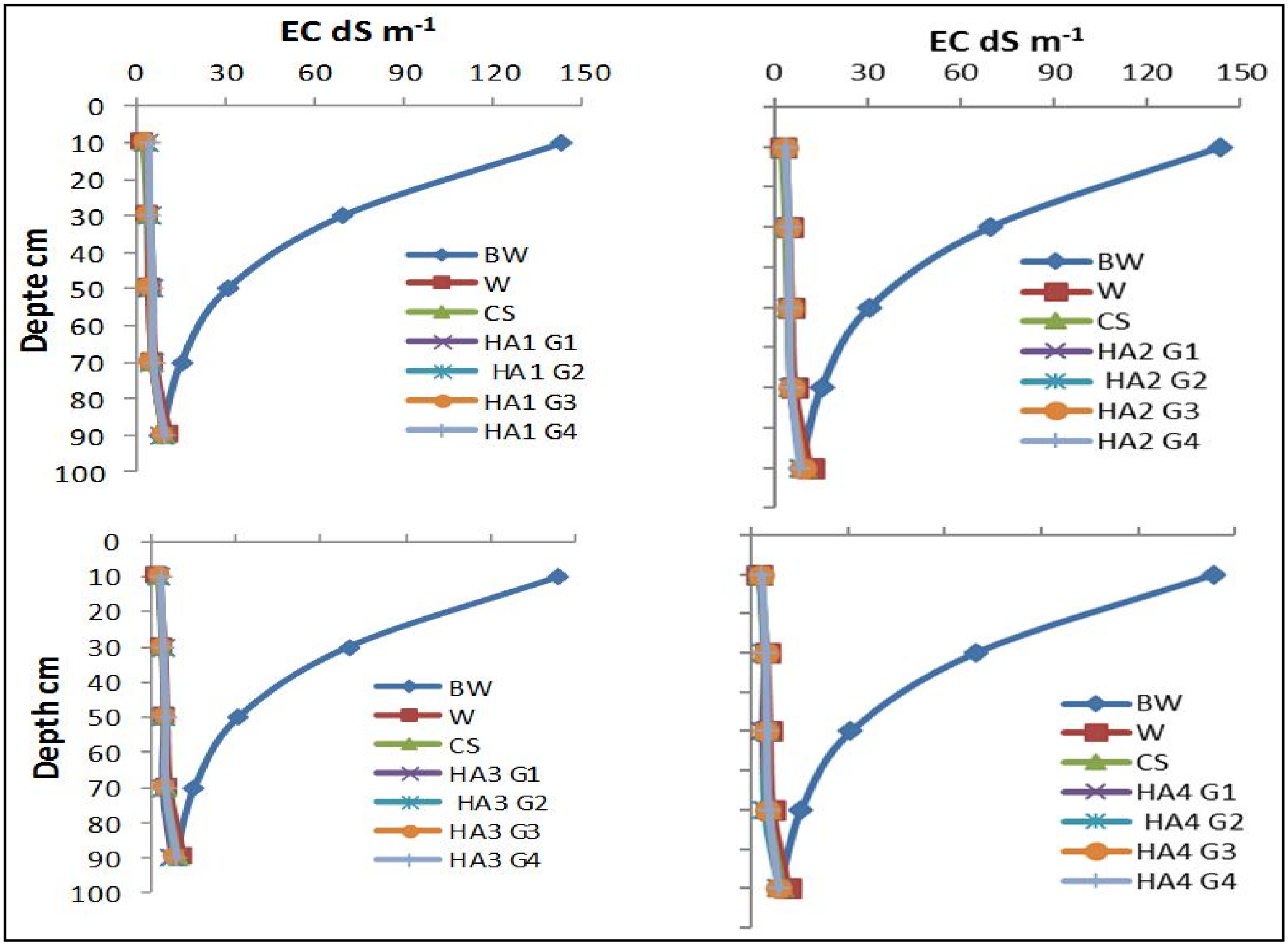

Fig. 3: The relationship between the electrical conductivity (EC: dS m^{-1}) with the depth of the soil washed with combinations

clay granule increases with the increase in the electrical charge since the divalent cations have a charge higher than the monovalent, so they are stronger bond to the colloidal surface and the higher the valence of the cation, the greater its ability to dissolve on the surface of the clay granule replacing the monovalent cations such as sodium [Dick (2000)]. As for the reason for the decrease in the sodium adsorption ratio with the increase in humic acids, it is attributed to the fact that humic acids contain functional groups such as carboxyl and hydroxyl that work to form complexes that are easy to move sodium with little movement with calcium. These results are consistent with Al-Alwani and Al-Hadethi (2019) who indicated that the sodium adsorption rate decreased by adding phosphogypsum to the soil and also decreased when humic acids were mixed with the soil.

3.9 Electrical conductivity dS m^{-1} after harvesting for the surface layer (0-20 cm)

Table 5 shows the effect of adding irrigation water (Euphrates River water) on the electrical conductivity values throughout the growing season with the addition of washing requirements (LR) with the season for the same combinations, washing water and clean salt after harvest, as it is noticed from the table that a significant increase in the electrical conductivity values of soil in the washing treatment with a commercial clean salt, in which the electrical conductivity value was 2.82 dS m^{-1} and an increase of 2.17% compared to its value when the washing with water treatment (W), in which the electrical conductivity was 2.76 dS m^{-1}. The HA_1G_4 washing combination showed the highest significant increase in the electrical conductivity was 4.54 dS m^{-1}, with an increase of 60.99% and 64.49% compared to the two treatments of soil washing with a commercial clean salt (CS) and washing with water (W), respectively, while washing with a combination HA_4G_3 gave the least significant increase, in which the electrical conductivity was achieved 3.08 dS m^{-1}, with an increase of 9.21% and 11.59% compared to the two washing treatments with the commercial clean salt (CS) and

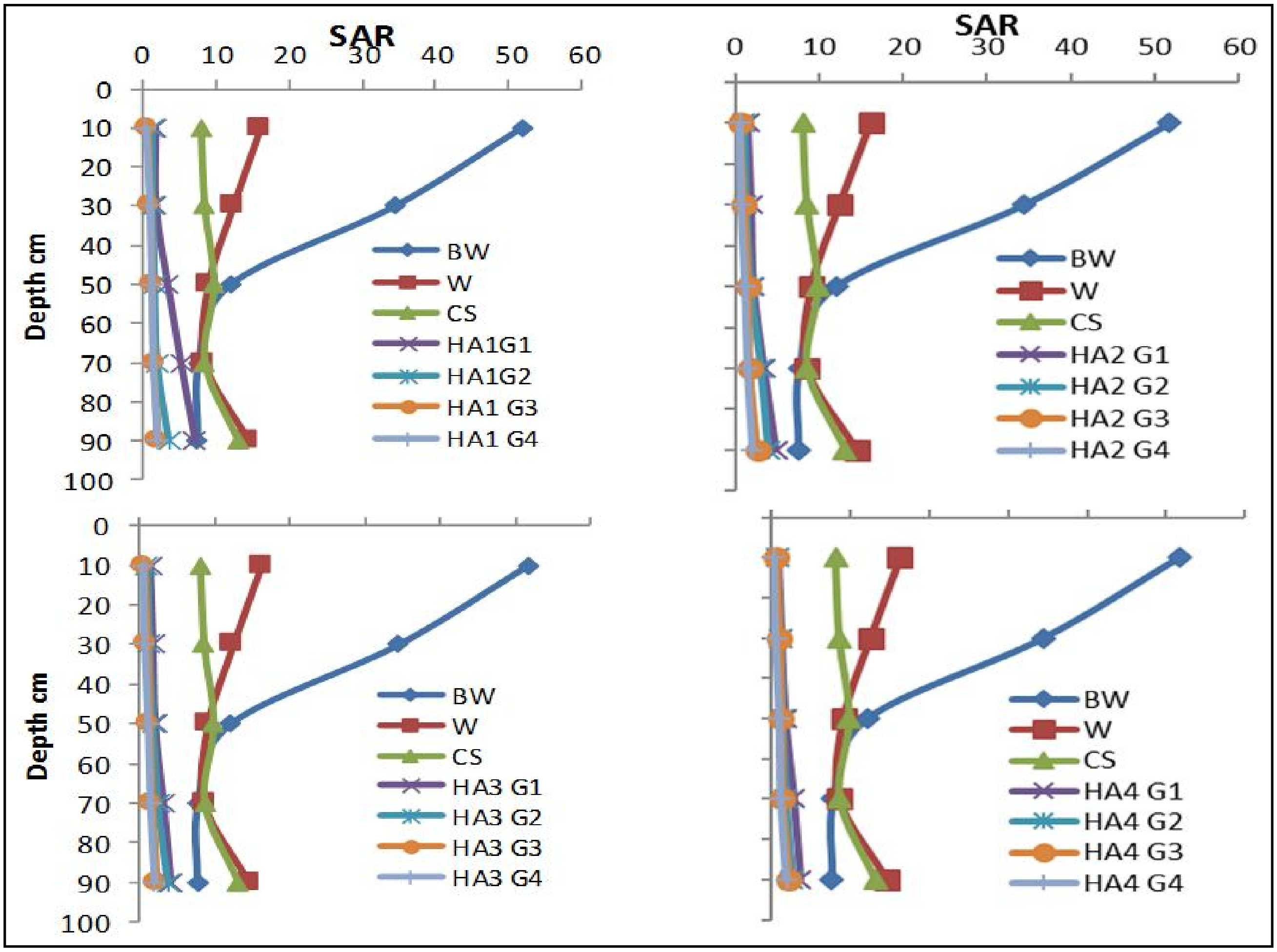

Fig. 4: Relationship between Sodium Absorption Ratio (SAR) with the depth of soil washed with combinations of humic acids

washing with water (W), respectively. HA_1G_4 outperformed with a significant increase overall wash combinations, by 26.29% compared to the combination of the washing machine was HA_4G_3, in which the conductivity value was 3.08 dS m^{-1}. The reason for the increase in the electrical conductivity values with the increase in the level of phosphogypsum in the mixture is due to the increase in the saturation of the soil solution with ions (Ca^{++}) and (SO_4^{--}), which leads to an increase in the concentration of the electrolyte solution and thus the electrical conductivity values increase. Sodium chloride is rapidly dissolving, which leads to washing the negatively charged chlorine ion down, which is reflected in reducing the electrolytic conductivity of the solution and thus saturating the exchange complexes with sodium ion [Dick (2000)]. As for the reason for the decrease in electrical conductivity values by increasing the level of humic acids. In the combination, it is attributed that the humic acids contain functional groups such as carboxyl and hydroxyl that form complexes with sodium that are easy to move while the complexes formed with calcium are less mobile and consequently, the electrical conductivity values decrease [Tchiadje (2007)]. These results are consistent with Al-Alwani and Al-Hadethi (2019) indicated that the electrical conductivity values increased by adding phosphogypsum to the soil. The conductivity values decreased when the humic acids were mixed with the soil.

3.10 Sodium adsorption ratio for the surface layer (0-20 cm)

Table 5 shows the effect of adding irrigation water (Euphrates water) throughout the growing season with adding requirements for washing (LR) with a season for the same combinations, washing water and commercial clean salt after harvest. CS in which the sodium adsorption ratio reached 8.05, with a significant decrease of 50.21% compared to the water wash treatment (W), which was 16.17. HA_4G_4 combination showed the highest significant decrease in the sodium adsorption ratio, reaching 0.26, with a decrease of

96.39% and 98. 39%, compared to the two treatments of soil washing with commercial clean salt (CS) and washing with water treatment (W), which were 8.05 and 16.17, respectively, while washing with HA_1G_1 gave the lowest significant decrease, in which the sodium adsorption ratio was 1.88, with a decrease of 76.64 and 88.37 % compared to washing with a commercial clean salt (CS) and washing with water (W) which were 8.05 and 16.17, respectively. HA_4G_4 outperformed in reducing the sodium adsorption ratio over all the washing blends by 86.17% compared to HA_1G_1 washing, in which the sodium adsorption ratio was 1.88.

Table 5: Effect of washing of saline-sodic soil with combinations of humic acids, phosphogypsum, water, and commercial clean salt on some soil chemical properties after harvesting.

humic acids (gm l^{-1})	phospho gypsum (gm l^{-1})	combi nation	EC dS m^{-1}	SAR
			after Harvesting	
HA1 (0.5)	G1 (0.5)	HA1G1	3.89	1.88
	G2 (1.0)	HA1G2	4.01	1.34
	G3 (1.5)	HA1G3	4.16	0.77
	G4 (2.0)	HA1G4	4.55	0.55
mean G1			3.25	1.38
mean HA1			4.15	1.13
HA2 (1.0)	G1 (0.5)	HA2G1	3.45	1.53
	G2 (1.0)	HA2G2	3.47	1.07
	G3 (1.5)	HA2G3	3.51	0.61
	G4 (2.0)	HA2G4	3.76	0.53
mean G2			3.35	1.01
mean HA2			3.55	0.93
HA3 (1.5)	G1 (0.5)	HA3G1	3.13	1.37
	G2 (1.0)	HA3G2	3.15	1.03
	G3 (1.5)	HA3G3	3.37	0.58
	G4 (2.0)	HA3G4	3.42	0.37
mean G3			3.53	0.62
mean HA3			3.27	0.84
HA4 (2.0)	G1 (0.5)	HA4G1	2.55	0.76
	G2 (1.0)	HA4G2	2.75	0.63
	G3 (1.5)	HA4G3	3.08	0.55
	G4 (2.0)	HA4G4	3.10	0.29
mean G4			3.71	0.44
mean HA4			2.87	0.56
	W		2.76	16.17
	CS		2.82	8.05
LSD_G			0.02	0.04
LSD_{HA}			0.02	0.04
LSD_{G*HA}			0.03	0.07

The reason for the decrease in the sodium adsorption ratio values with the increase in phosphogypsum is attributed to the increase in the saturation of the soil solution with Ca^{++} ions, which leads to the displacement of the sodium ion and its substitution and thus the values of the sodium adsorption ratio [Dick (2000)]. As for the reason for the decrease in the values of the sodium adsorption ratio with the increase in humic acids, it is because the humic acids contain functional groups such as carboxyl and hydroxyl that form complexes with sodium that are easy to move while the complexes formed with calcium are less mobile and thus the values of the sodium adsorption ratio [Tchiadje (2007)]. These results are consistent with Al-Alwani and Al-Hadethi (2019) who indicated that the sodium adsorption ratio decreased by adding phosphogypsum to the soil and also decreased by the addition of humic acids mixed with the soil.

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