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EFFECT OF IONIC STRENGTH FROM DIFFERENT SALT RESOURCES ON BORON ADSORPTION IN CALCAREOUS SOIL

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Abstract

This study was conducted in the laboratories of Soil and water resources department, college of Agricultural sciences engineering, University of Baghdad for the purpose of disclosing the effect of ionic strength from different salt mixtures on the adsorption of boron in a silty clay calcareous soil taken from the prior location of the college of Agriculture in Abu Ghraib, after a quite equilibrium of boron solution prepared from Boric acid at 0, 1, 5, 7.5, 10 and 20 μmole $B.ml^{-1}$ at 298 Kalvin. Three ionic strength solutions were used 0.1, 0.2, 0.3 $mole.L^{-1}$ of four different salts $CaCl_2$, $MgCl_2$, NaCl. And composed salt of the three salts at 3:1:1 ratios respectively. Langmuir single surface line equation was used for better description of the reactions of Boron adsorption in soil and calculating the constants of this equation (Xm and K).

Results showed a significant increase in Boron adsorbed quantity in soil with the increase of the applied Boron, where the highest adsorbed quantity of boron was 56 μmole B. gm^{-1} soil of $CaCl_2$ treatment of the ionic strength 0.3 $mole.L^{-1}$. The increase in ionic strength led to a significant increase in adsorbed Boron for all salts with different rates, where it was 16.61 μmole B. gm^{-1} soil of $CaCl_2$ treatment of 0.1 mole.L-$^{-1}$ then increased to 24.31, 28.03 μmoleB. gm^{-1} soil of the ionic strength of 0.1, 0.2, 0.3 $mole.L^{-1}$ respectively while it was 15.37μmole B. gm^{-1}in $MgCl_2$ treatment and increased to 22.68 and 26.85μmole B. gm^{-1} soil of the ionic strength 0.1 K 0.2 and 0.3mole.L^{-1} respectively. In NaCl treatment, it was 13.78 then increased up to 14.63, 15.96μmoleB. gm^{-1} soil of the mentioned ionic strengths. In the mixture salt, adsorbed Boron was 16.70 then increased to 19.53 and 22.15μmole B. gm^{-1} soil for the same ionic strengths.

These different salts showed significant differences in adsorbed quantity of Boron, where $CaCl_2$ treatment was exceeded followed by $MgCl_2$, mixture salt, then NaCl treatments as an averages of the three ionic strengths where it reached 68.95, 65.26, 58.38, then 44.37μmole B. gm^{-1} soil respectively and at maximum adsorption capacity (Xm) at 58.26, 55.92, 47.90, 46.17 mg B. Km^{-1} soil, while bonding energy to soil particles (K) was 0.279, 0.244, 0.244, 0.125ml μB for the mentioned salts respectively.

In general, soil is considered to have a high maximum adsorption capacity (42.88 mg B. Kg^{-1} soil) and low bonding energy (0.216 ml μ^{-1} B) .

Key words: Langmuir isotherm, boron maximum adsorption capacity, ionic strength, calcareous soil.

Introduction

Boron is considered as one of the necessary elements for plant and it comes in the seventh order of the micro elements necessary for plant growth (Gupta, 1993), plant uptakes this element from soil solution as B_4O_7, BO_3, HBO_2 and H_2BO_3. Its availability depends on soil chemical and physical properties, where carbonate minerals, organic matter, soil reaction, soil salinity and cycles of wetting and drying are affecting boron adsorption in soil (Abid Nias *et al.*, 2007, Goldberg *et al.*,1993, Hoshan, 2016, Kadir Saitali *et al.*, 2005). Knowledge in boron distribution in each liquid and solid phase of soil is important to know the range of availability and reactions that occur in soil, where the available concentrations of this element in soil solution are related to adsorption and release of this element on soil particles (Kusum Kumari *et al.*, 2017, Majidi *et al.*, 2010). In general, 33% of the soils are suffering from Boron deficiency (Shukla *et al.*, 2012). (Alfalahi, 2000) showed that the quantity if adsorbed boron in soil is increasing with the increased applied quantity to soil and it depends on the kind of sorbent part and temperature (Kusum

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Kumari *et al.*, 2017, Tamuli *et al.*, 2017). (Das, 2000) referred that soluble boron in soil solution is staying in a dynamic equilibrium status with the adsorbed forms in soil therefore, it is difficult to be leached, also boron deficiency symptoms appear on plants in most soils especially the coarse textured low organic matter soils also in calcareous alkali soils. Using the adsorption isotherms curves shows the quantity of the adsorbed material on the sorbent part throughout equilibrium and fixed temperature, in a form that could be mathematically represented by Langmuir linear equation of one surface where the equation's constants could be used to describe the adsorption characteristics of soils and determine fertilizers recommendations (Barrow, 1989, Gupta, 1993, Shafiq *et al.*, 2008).

(Keren and O'Conner, 1982) showed that boron adsorption is being higher when Ca^{++} is available more than Na+ where sodium ions lead to decrease the adsorption of boron. (Hoshan, 2016) indicated that $CaCl_2$ application treatment had exceeded boron adsorption when compared to NaCl application treatment in calcareous soil. Also, (Goldberg, 1993) showed that adsorption of boron is depending on the increase in carbonate minerals, clay percentage and electrical conductivity and carbonate minerals are working as collector of boron in calcareous soils (Kashmolah, 2003). Due to the lack in related studies that deal with knowing the effect of ionic strength and salt type in Boron adsorption in calcareous soils this study was conducted for.

Materials and methods

Soil sample was taken from one of College of Agriculture, university of Baghdad (old campus in Abu Ghraib). Air dried, cleaned and grinded with wood hummer and windowed through 2mm opining sieve and kept in plastic jars to be ready for lab analysis. Some of the physical and chemical properties of the soil were measured according to (Alfalhi, 2000, Tamuli *et al.*, 2017) as shown in table 1. Boron adsorption was determined by taking 5 gm of dried and 2mm opining sieved in a 100ml test tube. 50ml of salt solutions were added to each test tube containing boron that prepared from Boric acid at 0, 1, 5, 7.5, 10, 20 μmoleB. ml^{-1}. Three levels of ionic strength (0.1, 0.2, 0.3) of $CaCl_2$, $MgCl_2$, NaCl and a mixture salt of those three salts at 3:1:1 ratio were used. Each treatment was replicated three times and designed under complete randomized design (CRD) of a factorial experiment. Test tubes were stoppered and shacked for 24 hours using quiet shaker to make sure that no destruction occur to soil particles in constant temperature (293 Kalvin) and after shaking is ended, tubes were left for another 24 hours for dynamic equilibrium, then the aliquot was centrifuged from precipitate at 3000 RPM for 10 minutes. Boron was then determined according to (Gupta, 1993) using Carmine as a developing coloring material using spectrophotometer at 585 nanometer. Then boron quantity adsorbed on soil particles was determined for each treatment according to:

X= (A-C)V/S

Where:

X= adsorbed boron on surface (μ mole.gm^{-1} soil)

C= soluble boron concentration in equilibrium solution (μ moleB.ml^{-1})

S= weight of soil sample

V= solution volume.

Adsorbed/soluble boron was described by the linear Langmuir equation of one layer as:

C/X = (1/Kxm) + (C/Xm)

Where C = Boron concentration in equilibrium solution (μ moleB.ml^{-1})

X = adsorbed boron (μ moleB.gm^{-1} soil)

Xm = constant representing the maximum adsorption capacity or highest limit of adsorption (μ moleB.gm^{-1} soil)

K = a constant represents bonding energy of the

Table 1: Some physical and chemical properties of studied soil.

Value	Units	Characteristics
1.81	$dS.m^{-1}$	EC 1:1
7.60	-	pH 1:1
10.00	$g.Kg^{-1}$	Organic Matter
241.00	$g.Kg^{-1}$	$CaCO_3$
23.51	Cmole + Kg^{-1}	CEC
-	$mmole.L^{-1}$	Soluble Cations and Anions
18.60	$mmole.L^{-1}$	Calcium Ca^{+2}
13.20	$mmole.L^{-1}$	Magnesium Mg^{+2}
1.80	$mmole.L^{-1}$	Sodium Na^{+}
0.80	$mmole.L^{-1}$	Potassium K^{+}
Nil	$mmole.L^{-1}$	Carbonate CO_3
1.30	$mmole.L^{-1}$	Bicarbonate HCO_3^-
15.90	$mmole.L^{-1}$	Chloride Cl^-
0.83	$mmole.L^{-1}$	Sulphate SO_4
28.00	$mg.Kg^{-1}$	Available Nitrogen
8.31	$mg.Kg^{-1}$	Available Phosphorus
107.50	$mg.Kg^{-1}$	Available Potassium
170.00	$g.Kg^{-1}$	Sand
510.00	$g.Kg^{-1}$	Silt
320.00	$g.Kg^{-1}$	Clay
	SiCL	Soil Texture

adsorbed material (ml.gm^{-1}B) and it reflects the rate of adsorption in neutral status.

Graphing the linear relationship of C/X against C to get the slope 1/Xm from intersection 1/Kxm we can get the constant K by dividing slope over intersect.

Results and discussion

Results in table 2 and 3 showed that the soluble and adsorbed boron quantity and is increasing significantly with the increase of added boron to soil and that is parallel to the findings of (Hoshan, 2016, Goldberg *et al.*, 2004, Ferracciu *et al.*, 2000) where they indicated that there was an increase of adsorbed boron with the increase of applied boron to soil. The highest value of adsorbed boron was 56.00µ moleB.gm^{-1} soil in $CaCl_2$ treatment of 0.3 mole.L^{-1} ionic strength at 20µ moleB.ml^{-1} soil. also, soluble boron concentration is decreasing significantly with the increase of ionic strength of the solution that represented by adding different salts, where soluble Boron concentration in equilibrium solution of $CaCl_2$ 5.59µ moleB.ml^{-1} at 0.1 ionic strength and decreased to 4.96 and 4.44µ moleB.ml^{-1} when ionic strength increases up to 0.2 and 0.3 mole.L^{-1} respectively and so on for other applied salts with different amounts.

On the contrary, adsorbed boron increases significantly with the increase of ionic strength of solution of all salts in different rates, where it reached 16,61µ moleB.gm^{-1} at ionic strength 0.2 and 0.3 mole.L^{-1} respectively. in the meanwhile, a significant increase was occurred in the adsorption percentage with the increase of ionic strength where it was 236.83 mole.L^{-1} at 0.1 mole.L^{-1} ionic strength of $CaCl_2$ and increased to 369.16

Table 2: Effect of added Boron on concentration of soluble, adsorbed Boron and percentage of adsorption of Boron in soil treated by $CaCl_2$ and NaCl.

Average	Concentration of added B to soil (µ mole.L^{-1})						Concentration of Boron	Ionic strength (mole.L^{-1})	Type of added salt
	20	10	7.5	5	1	0			
5.59	16.30	7.80	5.73	3.10	0.60	0	Soluble B (C) (µmole.ml^{-1})	0.1	$CaCl_2$
16.61	37.00	22.00	17.70	19.00	4.00	0	Adsorbed B (X) (µmole.gm^{-1})		
236.83	185.00	220.00	236.00	380.00	400.00	0	Percentage of B adsorption (%) (adsorbed/ added)		
4.96	15.30	6.50	4.50	2.30	0.31	0	Soluble B (C) (µmole.ml^{-1})	0.2	
24.31	47.00	35.00	30.00	27.00	6.90	0	Adsorbed B (X) (µmole.gm^{-1})		
369.16	235.00	350.00	400.00	540.00	690.00	0	Percentage of B adsorption (%) (adsorbed/added)		
4.44	14.40	6.00	4.00	2.03	0.25	0	Soluble B (C) (µmole.ml^{-1})	0.3	
28.03	56.00	40.00	35.00	29.70	7.50	0	Adsorbed B (X) (µmole.gm^{-1})		
415.11	280.00	400.00	466.66	594.00	750.00	0	Percentage of B adsorption (%) (adsorbed/added)		
5.83	16.80	8.00	5.85	3.75	0.63	0	Soluble B (C) (µmole.ml^{-1})	0.1	NaCl
13.78	30.00	20.00	16.50	12.50	3.70	0	Adsorbed B (X) (µmole.gm^{-1})		
198.33	150.00	200.00	220.00	250.00	370.00	0	Percentage of B adsorption (%) (adsorbed/added)		
5.78	16.80	8.00	5.80	3.50	0.62	0	Soluble B (C) (µmole.ml^{-1})	0.2	
14.63	32.00	20.00	17.00	15.00	3.80	0	Adsorbed B (X) (µmole.gm^{-1})		
211.11	160.00	200.00	226.66	300.00	380.00	0	Percentage of B adsorption (%) (adsorbed/added)		
5.65	16.50	7.91	5.64	3.31	0.56	0	Soluble B (C) (µmole.ml^{-1})	0.3	
15.96	35.00	20.90	18.60	16.90	4.40	0	Adsorbed B (X) (µmole.gm^{-1})		
235.00	175.00	209.00	248.00	33.80	44.00	0	Percentage of B adsorption (%) (adsorbed/added)		
6.99	19.51	9.60	7.21	4.75	0.88	0	Soluble B (C) (µmole.ml^{-1})		Control
2.58	4.90	4.00	2.90	2.50	1.20	0	Adsorbed B (X) (µmole.gm^{-1})		
45.52	24.50	40.00	38.66	50.00	120.00	0	Percentage of B adsorption (%) (adsorbed/added)		

LSD (Soluble B)= 0.18, LSD (Adsorbed B)= 1.86, LSD (Percentage of B adsorption)= 39.16.

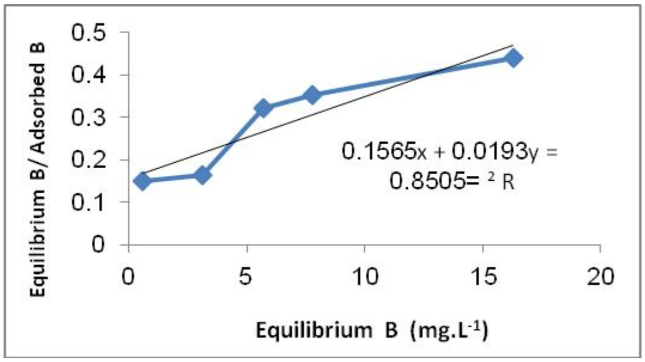

Fig. 1: Effect of added Boron on Langmuir equation constant at 0.1M $CaCl_2$

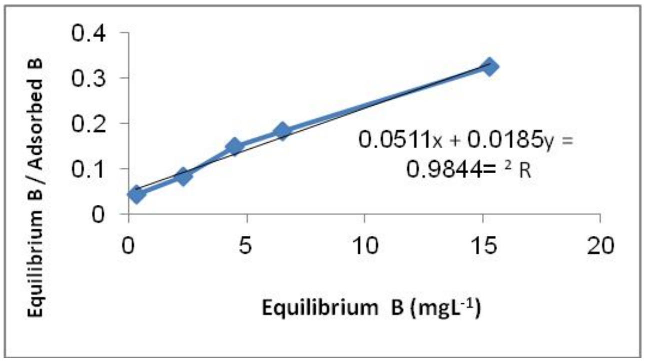

Fig. 2: Effect of added Boron on Langmuir equation constant at 0.2M $CaCl_2$

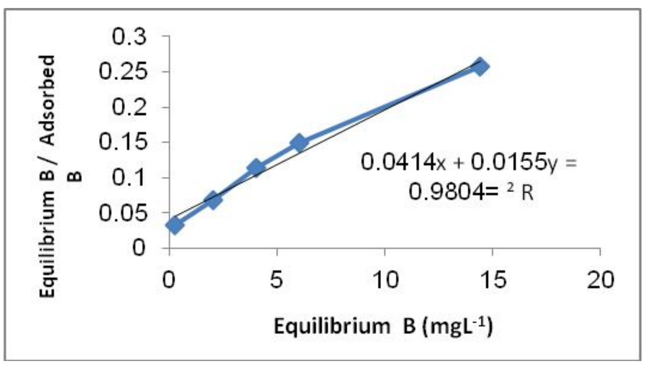

Fig. 3: Effect of added Boron on Langmuir equation constant at 0.3M $CaCl_2$

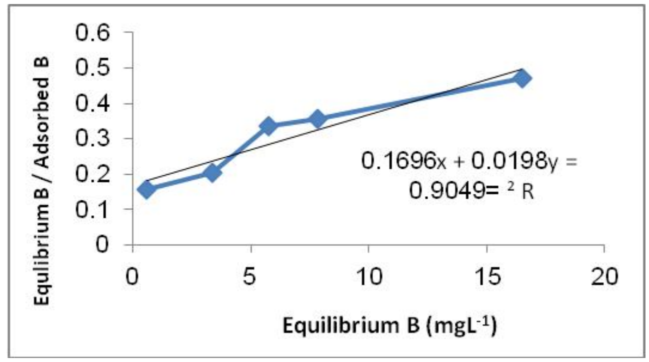

Fig. 4: Effect of added Boron on Langmuir equation constant at 0.1M $MgCl_2$

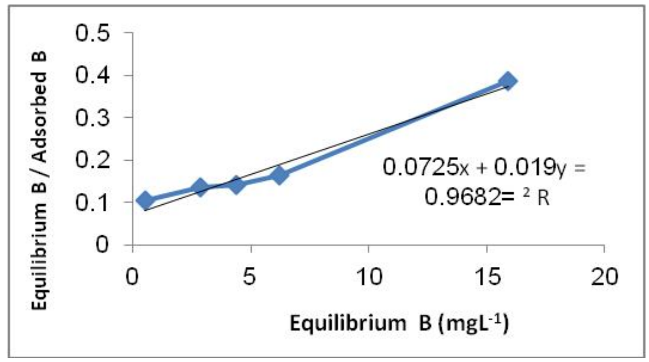

Fig. 5: Effect of added Boron on Langmuir equation constant at 0.2M $MgCl_2$

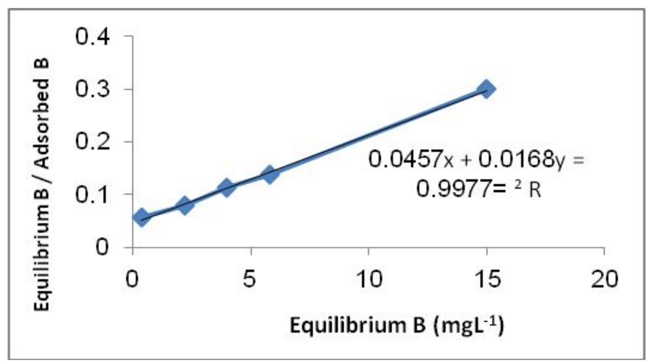

Fig. 6: Effect of added Boron on Langmuir equation constant at 0.3M $MgCl_2$

mole.L^{-1} and 415.11mole.L^{-1} of both 0.2 and 0.3mole.L^{-1} ionic strength respectively and so on for other applied salts. also it is noticed that there was a decrease in adsorbed boron percentage of the applied with an increase of the apples boron and that could occur in the early hours of the equilibrium that leads to busy adsorption location in soil and decreasing them, therefore, any increase of applied boron causes imposing effect on boron of equilibrium solution that results in diffusion boron into inner crystal composition of clay minerals. These results corresponded with the same results of each (Alobaidi and Kashmolah, 2007, Elrashidi and Oconnor, 1982).

The variation in added salts has the biggest impact in the variation of added adsorbed boron amount on soil surface, whereas the highest adsorbed amount when adding $CaCl_2$ Salt was 16.61, 24.31, 28.03µ.mole B gm^{-1} soil to the ionic power 0.1, 0.2, 0.3 mole L^{-1} respectively, while the adsorbed amount has been reduced significantly as well when NaCl added in a larger proportion. The values were 13.78, 14.63, 15.96 µ.mole B gm^{-1} soil to the ionic power above, while the salt occupied the middle rank between both $CaCl_2$ and $MgCl_2$ and on the other hand between NaCl, since it was less than the first two salts and greater than NaCl, where the adsorbed boron amounts 16.70, 19.53, 22.15 µ.mole B gm^{-1} soil to the ionic power 0.1, 0.2, 0.3 mole L^{-1} respectively.

Table 3: Effect of added Boron on concentration of soluble, adsorbed Boron and percentage of adsorption of Boron in soil treated by combine salt and $MgCl_2$.

Average	Concentration of added B to soil (µ mole.L^{-1})						Concentration of Boron	Ionic strength (mole.L^{-1})	Type of added salt
	20	10	7.5	5	1	0			
							Soluble B (C) (µmole.ml^{-1})		
5.58	16.70	7.60	530	3.34	0.54	0	Adsorbed B (X) (µmole.gm^{-1})	0.1	
16.70	33.00	24.00	22.00	16.60	4.60	0	Percentage of B adsorption		
248.38	165.00	240.00	293.33	332.00	460.00	0	(%) (adsorbed/ added)		
							Soluble B (C) (µmole.ml^{-1})		
5.29	16.20	7.10	5.00	3.00	0.48	0	Adsorbed B (X) (µmole.gm^{-1})	0.2	
19.53	38.00	29.00	25.00	20.00	5.20	0	Percentage of B adsorption		Combined
288.88	190.00	290.00	333.33	400.00	520.00	0	(%) (adsorbed/added)		Salt
							Soluble B (C) (µmole.ml^{-1})		
5.03	15.80	6.70	4.60	2.70	0.41	0	Adsorbed B (X) (µmole.gm^{-1})	0.3	
22.15	42.00	33.00	29.00	23.00	5.90	0	Percentage of B adsorption		
312.77	210.00	330.00	386.66	460.00	590.00	0	(%) (adsorbed/added)		
							Soluble B (C) (µmole.ml^{-1})		
5.67	16.50	7.81	5.78	3.36	0.61	0	Adsorbed B (X) (µmole.gm^{-1})	0.1	
15.73	35.00	21.90	17.20	16.40	3.90	0	Percentage of B adsorption		
223.55	175.00	219.00	229.33	328.00	390.00	0	(%) (adsorbed/added)		
							Soluble B (C) (µmole.ml^{-1})		
4.98	15.90	6.20	4.40	2.88	0.51	0	Adsorbed B (X) (µmole.gm^{-1})	0.2	
22.68	41.00	38.00	31.00	21.20	4.90	0	Percentage of B adsorption		$MgCl_2$
318.72	205.00	380.00	413.33	424.00	490.00	0	(%) (adsorbed/added)		
							Soluble B (C) (µmole.ml^{-1})		
4.56	15.00	5.80	4.00	2.22	0.37	0	Adsorbed B (X) (µmole.gm^{-1})	0.3	
26.85	50.00	42.00	35.00	27.80	6.30	0	Percentage of B adsorption		
387.11	250.00	420.00	466.66	556.00	630.00	0	(%) (adsorbed/added)		
							Soluble B (C) (µmole.ml^{-1})		
6.99	19.51	9.60	7.21	4.75	0.88	0	Adsorbed B (X) (µmole.gm^{-1})		Control
2.58	4.90	4.00	2.90	2.50	1.20	0	Percentage of B adsorption		
45.52	24.50	40.00	38.66	50.00	120.00	0	(%) (adsorbed/added)		

LSD (Soluble B)= 0.16, LSD (Adsorbed B)= 2.11, LSD (Percentage of B adsorption)= 38.26.

We can arrange the amounts of adsorbed boron as far as the different salts as follow:

Control< NaCl< composed salt< $MgCl_2$< $CaCl_2$

As well as, the amounts of adsorbed boron with the three ionic powers for salts as follow:

Control (2.58) m.mole B gm^{-1} soil< (44.37) NaCl< (58.38) Composed salt< (65.26) $MgCl_2$< (68.95) $CaCl_2$.

These results correspond with (Hoshan, 2016) results where it showed a highly significant distinction for $CaCl_2$ as compare with NaCl and for all levels of addition and this can be resulted to the effect of salt type in increasing the value of pH, While (Goldberg *et al.*, 2008) showed that the increasing in soil solution saltiness helps in increasing the pH where this will also increase adsorbed boron on soil surface at all added concentration of boron.

The increasing in adsorbed boron when $CaCl_2$ added was followed by increasing in forming $CaCO_3$ in calcareous soils which will result in increasing the adsorbed boron, where it works as a sinkhole for boron in calcareous soils and holding it (Alfalhi, 2000), that was corresponded to what (Abid Nias *et al.*, 2007) found, where the large effect of calcium carbonate was shown in increasing the adsorption of Boron in soil.

Also, adsorbed boron quantity when $MgCl_2$ was applied came in the second place which it is related to the effect of the applied magnesium in increasing magnesium carbonate content that has the higher ability of increasing the adsorbed boron in addition to increasing soil pH that contribute in increasing adsorbed boron. Boron was much decreased when NaCl added and that could be related to the big role of this salt in dissolving

Table 4: Effect of ionic strength for different salts on constants of Langmuir equation and Correlation coefficient of adsorbed equations of Boron in soil.

Correlation coefficient (R^2)	Bonding energy (K) (ml.µg^{-1} B)	Maximum adsorption (Xm) mg. .Kg^{-1} B)	Ionic strength (mole.L^{-1})	Type of added salt
0.850	0.121	52.63	0.1	$CaCl_2$
0.984	0.352	55.55	0.2	
0.965	0.365	66.66	0.3	
0.933	0.279	58.28	Average	
0.958	0.112	45.45	0.1	NaCl
0.935	0.124	45.45	0.2	
0.902	0.141	47.61	0.3	
0.931	0.125	46.17	Average	
0.904	0.198	43.47	0.1	Combined Salt
0.997	0.238	47.61	0.2	
0.999	0.296	52.63	0.3	
0.924	0.244	55.92	Average	
0.809	0.112	52.63	0.1	$MgCl_2$
0.968	0.264	52.63	0.2	
0.997	0.355	62.50	0.3	
0.924	0.244	55.92	Average	
0.939	0.216	42.88		Control
0.017	0.064	2.16	$LSD_{0.05}$	

Calcium Carbonate minerals and decreasing adsorption on them. that was parallel to what (Buehrer, 2001, Hoshan, 2016) found and showed that salts especially the mono salts such as NaCl have high ability to dissolve Calcium Carbonate minerals which leads to decrease the adsorbed boron, in addition to sodium ions effects by forming sodium borate that precipitates at high concentrations of boron application and they also indicated that sodium has higher impact than calcium in fixing boron and decreasing its availability and related that to the higher effect of sodium ions in increasing soil reaction.

The mixture salt behaved intermediately among all salts and that is related to the increasing of its content of calcium and magnesium comparing to sodium ions the matter that increases the formation of calcium and magnesium carbonate minerals that increases the ability of boron adsorption when compared to the negative effect of sodium ions.

Linear Langmuir equation applied on results of tables 2 and 3 and graphing the concentration of soluble boron (C) and concentration of soluble

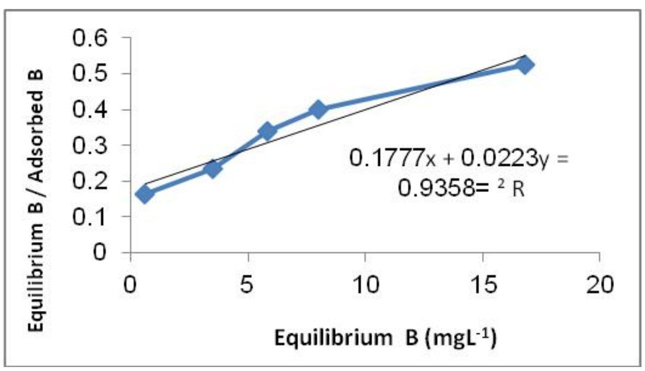

Fig. 7: Effect of added Boron on Langmuir equation constant at 0.1M NaCl

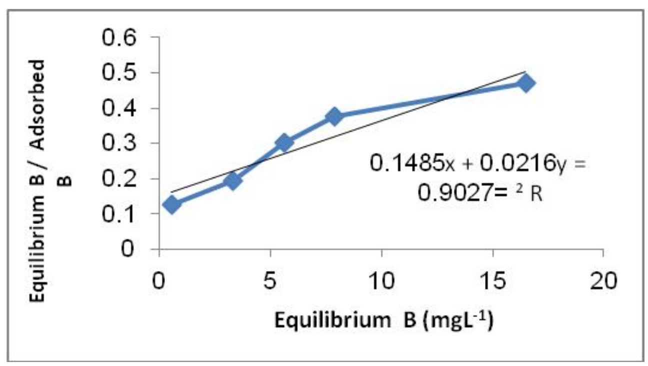

Fig. 9: Effect of added Boron on Langmuir equation constant at 0.3M NaCl

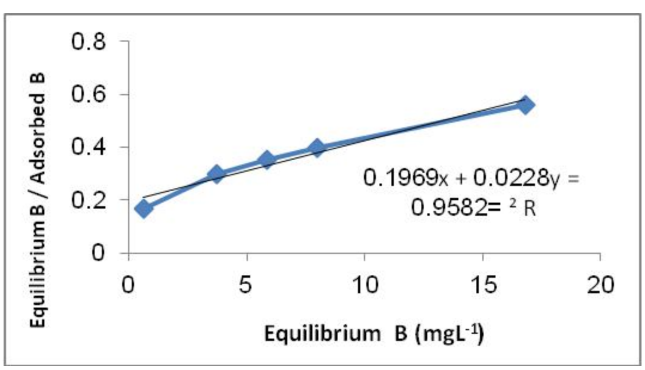

Fig. 8: Effect of added Boron on Langmuir equation constant at 0.2M NaCl

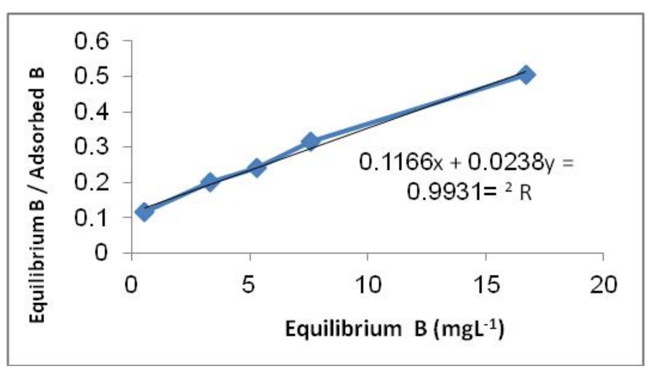

Fig. 10: Effect of added Boron on Langmuir equation constant at 0.1M Combine Salt

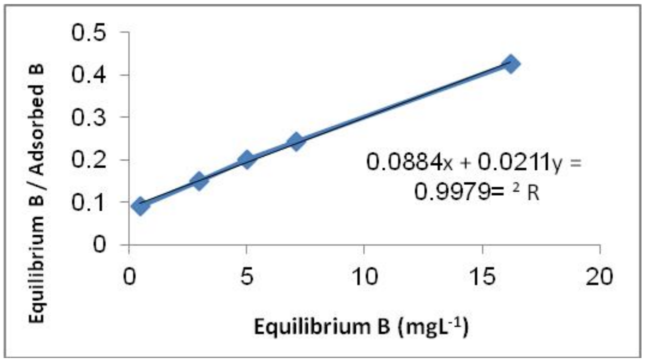

Fig. 11: Effect of added Boron on Langmuir equation constant at 0.2M Combine Salt

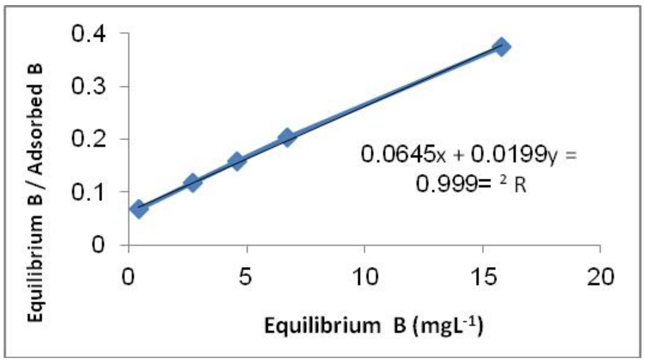

Fig. 12: Effect of added Boron on Langmuir equation constant at 0.3M Combine Salt

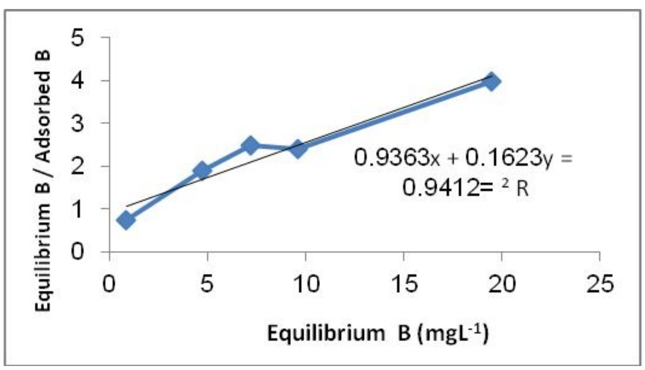

Fig. 13: Effect of added Boron on Langmuir equation constant at Control

boron (C) over adsorbed boron (X), we can get a linear correlation due to this equation with high determination coefficient (R^2) which confirms the ability of using one layer Langmuir equation to describe the adsorption of boron (Alobaidi and Khalil, 2007). Also results showed that there was a good similarity to explain adsorption behavior in different rates and high efficiency of this equation to describe the process of adsorption with a highly significant coefficient of determination (R^2) of all added salts from 0.850-0.999 with an average 0.939 as shown in fig. 1-13.

Constants of Langmuir equation was calculated from the figures, where Xm that represents the maximum range of adsorption or maximum adsorption capacity and K that represents the bonding energy of Boron with soil particles surfaces which is shown in table 4. This table showed that the increase of maximum adsorption capacity and bonding energy with soil particles for different salts, where Xm has increased in $CaCl_2$ treatment from 52.63 to 55.55 and 66.66 mg $B.kg^{-1}$ soil for the ionic strength 0.1, 0.2 and 0.3 $mole.L^{-1}$ respectively, while it was increased from 52.63 to 62.63 $mgB.kg^{-1}$ soil in magnesium chloride treatment of the 0.1, 0.2, 0.3 $mole.L^{-1}$ ionic strength solutions. Also, for Sodium chloride treatment the maximum adsorption capacity has increased from 46.45 to 47.61 $mgB.kg^{-1}$ soil of the same ionic strength mentioned above. while in the mixture salts it increased from 43.47 to 47.61 and 52.63 $mgB.kg^{-1}$ soil of the same ionic strength respectively. It was 2.16 $mgB.kg^{-1}$ soil in control treatment.

While controlling among salts treatments we found that there was a significant differences where $CaCl_2$ might exceed and $MgCl_2$, then the mixture salts followed by NaCl where the average of the maximum adsorption capacity of these treatments 58.28, 55.92, 47.90, 46.17 $mgB.kg^{-1}$ respectively when compared to control treatment at 6.17$mgB.kg^{-1}$.

1. The bonding energy (K) we also found a positive significant relationship with the increase of the ionic strength of the salts, where it was 0.121 $ml\mu^{-1}$ B, in $CaCl_2$ at the ionic strength of 0.1 $mole.L^{-1}$ and increased significantly to 0.352, 0.365 $ml\mu g^{-1}B$ at the ionic strength 0.2 and 0.3 $mole.L^{-1}$.

2. It also increased significantly from 0.112 to 0.264 and 0.355 $mlmg^{-1}B$ at ionic strength 0.1, 0.2 and 0.3 $mole.L^{-1}$ of $MgCl_2$, also it increased from 0.198 to 0.238 and 0.196$ml\mu g^{-1}B$ of the mixture salts of the same ionic strength mentioned above.

It increased significantly as well in NaCl treatment from 0.112 to 0.124 and 0.148$ml\mu g^{-1}B$ of the same ionic strength above, when comparing different salts treatments, we found there were significant differences where $CaCl_2$ exceeded significantly the mixture salts treatment and $MgCl_2$ that were equal, then control treatment and finally NaCl treatment. The average bonding energy of the different treatment as follow:

$CaCl_2$ (0.279) >$MgCl_2$= mixture salts (0.244) > control treatment (0.173) >NaCl (0.125).

In general, results showed the high values of maximum adsorption capacity (Xm) where it averaged 42.88 $mgB.kg^{-1}$ of the whole treatments and a decrease in bonding energy averaged at 0.216$ml\mu g^{-1}B$ and that could be related to the high content of carbonates minerals in soil (Table 1), these results came parallel to what (Alobaidi and Kashmolah, 2007, Alobaidi and Khalil, 2005). Showed as the locations of adsorption especially on carbonate minerals surfaces in soil, where they studied a high maximum adsorption capacity with a low bonding energy when they studied boron adsorption in calcareous soils northern Iraq. These results also came parallel to (Kadir Saitali *et al.*, 2005) that they explained that boron bonding energy is low in soil where it was 0.028-0.56 mlμg^{-1}B, when they studied calcareous soils in Turkey using one layer Langmuir equation. Also, these results corresponded to what (Shafiq *et al.*, 2008) had referred to when they studied boron adsorption in Pakistan calcareous soils, where they found an increase in maximum adsorption capacity between 5.5-108.0 mgBKg^{-1}soil.

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