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EFFECT OF SULFUR AND PHOSPHATE FERTILIZERS APPLICATION ON THE AVAILABLE PHOSPHORUS AMOUNT IN RHIZOSPHERE OF*ZEA MAIZE* L.

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ABSTRACT : A pot study was conducted in the Department of Soil Sciences and water resources, College of Agriculture, university of Al-Qadisiyah, during the agricultural season of 2017-2018 according to the design Completely Randomized Design (C.R.D).Four levels of phosphate fertilizer P0, P1, P2, P3 (0, 30, 60 and 90) kg P. h^{1-} and one level of sulfuric fertilizer (agricultural and wettable) Sa and S (200) kg S.h^{1-} were used.The corn seeds of DKC 6120 cultivar were planted on 15/7/2017. Available phosphorus in the soil was estimated during plant growth periods (40, 70, and 100) days of planting to study the effect of its application levels, sulfuric fertilizer application (agricultural and wettable) fertilizers and their overlap on the amount of available phosphorus into the corn rhizosphere. Results presentthat the highest amount of the available phosphorus is achieved with the third phosphate level P3 (42.83, 31.63, and 27.21)µg.g^{-1} in the rhizosphere area. Out of the rhizosphere, SP3, P3 and P3 quantities result (50.03, 37.58 and 29.46) µg. g^{-1} soil of dates of 40, 70 and 100 days of planting, respectively. Application of agricultural sulfur itself decreases the amount of available phosphorus as compared to the control. SaP0 application level of sulfur fertilizer resulted in the lowest amount of available phosphorus (10.73, 9.84 and 7.63) µg. g^{1-} in the rhizosphere and (11.90, 10.51, 9.25) µg. g^{1-} in the outside the rhizosphere at (40 and 70 and 100) days of planting dates, respectively.

Key words : Available phosphorous, rhizosphere, *Zea maize*, fertilization, sulfur fertilizer.

INTRODUCTION

Corn plant is considered the first crop in Central America and the second one in some African countries, Hallauer (1995), Pohlan and Borgman (2000). It is a basic commercial crop with significant agricultural economic value for a variety of food products, and for the production of oils and animal feed (Irfan, 2015). In Iraq, it is grown by 151453 hectares at a production rate of 3344 kg.h^{-1} according to the Central Statistics Department (2013). In the year of 2016, cultivated area is estimated at 76000 hectares at an average of 3.415 Mg. h^{-1} (Directorate of Agricultural Statistics, 2017). Phosphorus is a major nutrient and is the second most important element after nitrogen in the bio-building and plays a distinguished role in the energy transfer and cytology, including nutrient uptake. Most of the commonly available phosphorus in the environment is in a highly oxidized state, such as phosphate and constantly forms insoluble chemical groups with calcium, iron,and aluminum, making it unsuitable for plant absorption, Adhya *et al* (2015). Chemical fertilizers application improves soil fertility, increases crop production, maintains a level of phosphorus in the rhizosphere are and increases the effectiveness of plant roots to absorb phosphorus by incorporating morphological and physiological adaptation strategies, Shen *et al* (2011). The availability of phosphorus in the rhizosphere is necessary to activate plant roots in order to absorb suitable phosphorus, which contributes greatly to crop productivity, Ullah (2014). In cultivated soil, although the total amount of phosphorus is relatively high ranging from 163 to 1050 mg. Kg^{-1}, Memon *et al* (2011), the available bioactive phosphorus is low, which represents only 1.0% mg.kg^{-1}. Soil, Vassilev *et al* (2001), Solangi *et al* (2006). In addition, applied phosphorus fertilizers directly fixed into the soil after use. Phosphorus fertilizers use efficiency varies between 10 and 25% worldwide (Khiari and Parent, 2005). There is also more than 90% of soils with very low phosphorus levels (Rehman *et al*, 2000 and Solangi *et al*, 2006). Plants absorb phosphorus from the soil solution as anion and it precipitate when reacting with cations such as Ca^{2+}, Mg^{2+}, Fe^{3+} and Al^{3+}, which is depending on soil proprieties. Approximately (75 to 90) percentage of the applied phosphate fertilizers are deposited by iron, aluminum and calcium ions in the soil, (Panhwar *et al*, 2012). Iraqi soil is composed of calcareous soils that contain large amounts of carbonate minerals

Table 1 : Physical and chemicalproprieties of the soil before planting.

	Prosperities		**Value**	**Unit**
1.	Soil reaction degreepH		7.6	-
2.	Electrical conductivity EC (1:1)		3.27	(ds/m)
3.	Cation exchange capacity CEC		22.35	Cmol. Charge. Kg^{-1} soil
4.	Carbonate minerals $CaCO_3$		276	$g.kg^{-1}$
5.	Organic matter O.M		13.6	
6.	Organic Carbon		7.82	
7.	Total phosphorus		95	$mg.kg^{-1}$
8.	Available phosphorus		11.7	
9.	Dissolved phosphorus		0.30	
10.	Total nitrogen		385	
11.	Available nitrogen in the 2 faces	$N\text{-}NH_4^+$	23.5	
12.		$N\text{-}NO_3^-$	26.4	
13.	Total potassium		1354	
14.	Available potassium		178	
15.	Available sulfates		325	
16.	Positive dissolved ions	Ca^{2+}	23	Cmol. Charge. L^{-1}
17.		Mg^{2+}	10	
18.		Na^+	42	
19.		K^+	2	
20.	Negative dissolved ions	Cl^-	43	
21.		SO_4^{2-}	20	
22.		CO_3^{2-}	Nill	
23.		HCO_3^-	19	
24.	Bulk Density		1.38	Megagram. M^{-3}
25.	Soil separators	Sand	196	$g.kg^{-1}$
26.		Loam	424	
27.		Clay	380	
28.	Soil texture		SiCL	

(calcium carbonate or magnesium), which act to precipitate phosphorus in calcium phosphate (Mahdi *et al*, 2011). Available phosphorus is the soluble phosphorus in soil solution additional to desorption and dissolving phosphorous (Mengel, 1985). Phosphorus prepared according to the Olsen method in soil was divided into Concentration less than 10 mg P. kg^{-1} considered as a low level of available phosphorous, 10-20 (average content), 20-40 (high content) and higher than 40 mg $P.kg^{-1}$ soil very high content, soil testing (2008). The objective sulfur application to agricultural soil is to improve soil chemical proprieties, especially under the conditions of calcareous soil in particular in the dry and semi-arid areas because of its acidic effect in reducing the pH values of the soil by its biologically and chemically oxidation by microbiological species. This leads to increase phosphorus availability at low soil interaction (Kazem, 2016). The objective of the study is to find out the effect of the agro-sulfur species on the amount of available phosphorus in the rhizosphere of the yellow maize plant during different growth periods (40, 70 and 100) days of planting.

MATERIALS AND METHODS

This experiment was carried out in the canopy in the College of the Agriculture, University of Al-Qadisiyah. The soil was dried, tested and sifted through a 4 mm diameter sieve. 20 kg of dry soil was placed in each pot and prepared for planting.The study was designed according to the Complete Randomized Design (C.R.D). Twelve experimental treatments were used, including the control with four replications.The treatments were randomly distributed to the 48 experimental units.Seeds of maize (*Zea maize* L.) of US DKC 6120 cultivar were planted on Jul 15, 2017, at a rate of 5 seeds per pot then rugged out to a single seedling after 15 days of the planting date.Fertilizers was applied before planting, which were potassium sulfate ($K_2O_50\%$) at a level of 100 kg $K_2O.h^{-1}$ for all experimental units, while nitrogen fertilizer (N46%) was applied at 250 kg. h^{-1} couple times, one after 15 days of planting and the second after 30 days of the first application. *Sesamia cailica* insect was controlled by applying with a 10% active diazinon pesticide on the apical meristem after 20 days of germination. The process weeding was done manually whenever necessary to eliminate the growth of bushes. Soil samples were taken before planting then dried and sifted with a 2 mm diameter sieve. Some physical and chemical properties were estimated according to the methods that are listed in Jackson (1958) and Black (1965) and others (1982) (Table 1). Available phosphorus in the rhizosphere are and outside it was estimated after 40, 70 and 100 days of cultivation using sodium bicarbonate (0.05M $NaHCO_3$) at pH of 8.5. According to the Olsen method, and developed color withammonium polysaccharides and ascorbic acid, and then estimated using the spectrophotometer at wavelength of 882 nm, as reported in Page *et al* (1982). Results were statistically analyzed by using the Statistical Analysis System (SAS, 2012) according to the complete random design (C.R.D) to study the effect of the factor (P) and its levels and the interaction with the factor (Sa) and the factor (S). The differences between the means were compared with the less difference test (LSD) and at a significant level of (0.05).

RESULTS AND DISCUSSION

Table 2 shows the effect of phosphate and sulfur fertilizers application and their overlap on the amount of available phosphorus rhizosphere area and outside it after 40 days of planting date. The results present an increase in the concentration of phosphorus in the soil as phosphate fertilization level increases. All levels of phosphate fertilizer significantly exceeded the control treatment.This is due to the sulfur fertilizer application, which reduces the degree of soil interaction and increases nutrients availability and thus increasesthe availability of phosphorus. This is in line with the findings of Al-Hassoun (2010). Salum and Ali (2011), Amran *et al* (2016) and Panahi *et al* (2016) in terms of the effect of the usingof sulfur fertilizer on phosphorus availability in soil.The 90 $kg.h^{-1}$ P additive level gave the highest quantity of the available phosphorous at 42.83 $\mu g.g^{-1}$ in the rhizosphere with an increase of 259.91% as compared to the control treatment, which gave the lowest value of 11.90 $\mu g.g^{-1}$.

Table 2 : Available phosphorous concentration (ìg.g^{1-}) after 40 days of the planting date.

Treatments		Sampling location	
Fertilization	**Treatments**	**Rhizosphere**	**Outside of rhizosphere**
Phosphorous fertilization	**Cont.**	**11.90**	**12.11**
	P1	21.75	24.62
	P2	30.56	38.21
	P3	42.83	47.49
	Average	**26.76**	**30.60**
Phosphorous fertilization with agricultural sulfur	SaP0	10.73	11.90
	SaP1	20.30	22.82
	SaP2	27.76	35.19
	SaP3	38.37	46.50
	Average	**24.29**	**29.10**
Phosphorous fertilization with wettable sulfur	SP0	11.54	12.39
	SP1	23.34	25.55
	SP2	29.88	38.90
	SP3	41.92	50.03
	Average	**26.67**	**31.71**
LSD 0.05		7.309*	

Cont = Control treatment, P = phosphorus level, Sa = agricultural sulfur, S = wettable sulfur.

This increase is due to the use of phosphate fertilizers, which is consistent with the findings of Al-Musawi (2004) and Al-Amouri (2004). Out of the Rhizosphere area, SP3 treatment resulted from the addition of the third level of phosphate fertilizer and in combination with the wettable sulfur, the highest amount of available phosphorus at 50.03 µg. g^{-1} with an increase of (313.12%) as compared to the control, which gave 12.11 µg. g^{-1}. This is due to the addition of wettable sulfur, which hasa quicksolubility, reduces soil interaction and increases phosphorus availability in the soil. This is consistent with the results of Panahi *et al* (2016) in terms of the effect of the applaying of sulfur fertilizer on reducing the soil reaction rate and increase the availability of phosphorus. The results also showed that the use of sulfuric fertilizer (agricultural and wettable) without interference with phosphate fertilizer levels reduced the amount of the available phosphorus in the soil of the rhizosphere and outside it as compared to the control. Sulfur fertilizer level of (SaP0) made the lowest amount of the available phosphorus (10.73 and 11.90 $\mu g.g^{-1}$) in the soil of the rhizosphere and outside it with a decrease of 9.83 and 1.73% as compared to the control treatment that given (11.90 and 12.11 µg. g^{-1}) for the soil of the rhizosphere and outside it respectively. Fertilizer application level of

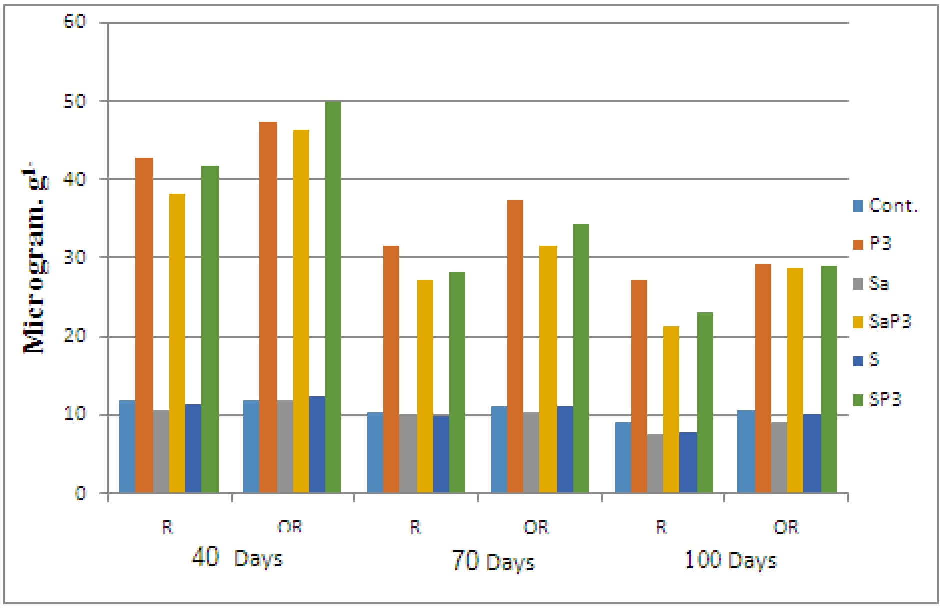

Fig. 1 : The effect of phosphate and agricultural sulfur and wettable sulfur fertilizers application on the available phosphorous in the rhizosphere and outside its areas. R: rhizosphere, OR : Outside of rhizosphere.

(SP0) gave the lowest amount of (11.54 μg.g^{-1}) for the soil of the rhizosphere with a decrease of 3.02% compared to the control treatment. In general, the phosphorus values of 40 days of soil cultivation outside the rhizosphere were higher than their values in the rhizosphere area in all studied units. All the parameters were significantly differed at 0.05 compared to the control treatment. These differences also existed within treatment. The results present that the adjusted sulfur concentration to the phosphorus concentration in the treatment of phosphate fertilizer was higher compared to the other two types of sulfur. This is due to its role in increasing the growth of the plant and thus increase the absorption of phosphorus. This confirms that the overlap of sulfur, which can be wetted with phosphate fertilizer, was the higher quantity in the soil outside of the rhizosphere compared to phosphorus levels, which confirms the importance of this type of sulfur in increasing the absorption of phosphorus by the plant. Agricultural sulfur and when combined with phosphorus, do not lead to an increase in the absorption of phosphorus but reduced when compared with levels of phosphate fertilizer.

Table 3 showed the effect of phosphate and sulfuric fertilizers application (agricultural and wettable) and the overlap between them on the amount of available phosphorus in and out of the soil rhizosphere after 70 days of planting date. Using the significant level of 0.05, all levels of phosphate and sulfur fertilizers and their overlap were significantly higher than the control treatment. The highest level of phosphorus in the soil of the rhizosphere and outside in this time test was the application of 90 kg.h^{-1} P (P3) of 31.63 μg.g^{-1} in rhizosphere soil and 37.58 μg.g^{-1} outside of the rhizosphere with an increase of 205.30 and 234.63% compared with the control treatment that had values of 10.36 and 11.23 μg.g^{-1} in the soil of the rhizosphere and outside, respectively. The application level of (SP3) that is resulted of the use of phosphate fertilizers and overlapping with wettable sulfur were 28.41 and 34.59 μg.g^{-1} for inside and outside of the rhizospherearea with an increase of 174.22 and 208.01% compared with the control treatment. The available phosphorus level of all the treatments was decreased during this period (flowering period) for the maize crop as compared to the level of phosphorus available at 40 days of planting. This indicates the increase in plant requirements for nutrients in this period, including phosphorus, with the progress of plant growth stages (Fig. 2), especially in the flowering stage. This is in line with what was found by Sahuki (1990) as a result of the depletion caused by the roots of plants on the other hand and to increase the activity of microscopic microbes in the rhizosphere and thus increase the absorption of phosphorus from the other side.

Table 4 presents the effect of phosphate and sulfuric fertilizers application (agricultural and wettable) and the overlap between them on the amount of the available phosphorus in and out of the rhizosphere area after 100 days of cultivation. The concentration of phosphorus in the soil increased by increasing levels of fertilization. All levels of phosphate and sulfuric fertilizer (agricultural and wettable) were significantly more than the control treatment.(P1, SaP1 and SP1) represented the first level of phosphorus and its interactions with sulfur in the rhizosphere. The highest level of phosphorus in the soil

Table 3 : Available phosphorous concentration ($\mu g.g^{-1}$) after 70 days of the planting date.

Treatments		Sampling location	
Fertilization	**Treatments**	**Rhizosphere**	**Outside of rhizosphere**
Phosphorous fertilization	Cont.	10.36	11.23
	P1	17.62	20.11
	P2	24.34	29.25
	P3	31.63	37.58
	Average	20.98	24.54
Phosphorous fertilization with agricultural sulfur	SaP0	9.84	10.51
	SaP1	16.32	19.46
	SaP2	21.50	26.27
	SaP3	27.39	31.71
	Average	18.76	21.98
Phosphorous fertilization with wettable sulfur	SP0	10.05	11.13
	SP1	17.20	20.35
	SP2	21.15	27.80
	SP3	28.41	34.59
	Average	19.20	23.46
LSD 0.05		6.913*	

Cont= Control treatment, P = phosphorus level, Sa = agricultural sulfur, S = wettable sulfur

Table 4 : Available phosphorous concentration ($\mu g.g^{-1}$) after 100 days of the planting date.

Treatments		Sampling location	
Fertilization	**Treatments**	**Rhizosphere**	**Outside of rhizosphere**
Phosphorous fertilization	Cont.	9.15	10.68
	P1	13.81	18.74
	P2	19.00	24.69
	P3	27.21	29.46
	Average	**17.29**	**20.89**
Phosphorous fertilization with agricultural sulfur	SaP0	7.63	9.25
	SaP1	12.57	18.00
	SaP2	16.33	23.71
	SaP3	21.40	28.92
	Average	**14.48**	**19.97**
Phosphorous fertilization with wettable sulfur	SP0	8.00	10.11
	SP1	13.18	19.29
	SP2	15.90	24.63
	SP3	23.36	29.14
	Average	**15.11**	**20.79**
LSD 0.05		7.261*	

Cont= Control treatment, P = phosphorus level, Sa = agricultural sulfur, S = wettable sulfur.

of the rhizosphere and outside of it was the application of 90 kg.h^{-1}, which yielded 27.21 ìg.g^{-1} in rhizosphere soil and 29.46 ìg. g^{-1} outside of the rhizosphere with an increased rate of 197.37 and 175.84% compared with the control treatment, which made the lowest amount of available phosphorus in this test time (9.15 and 10.68) ìg.g^{1-} in the soil of the rhizosphere and outside, respectively. Available phosphorus amount reduces as timescontinue (40, 70, 100 days) in the soil of the rhizosphere and outside and for all transactions.The results also showed a significant effect on the application of sulfuric fertilizer (agricultural and wettable) on the amount of the available phosphorus in the soil of the rhizosphere and beyond. Sulfur fertilizer uses (SaP0) without using phosphorus fertilization made the lowest value of available phosphorous (7.63 and 9.25) ìg. g^{-1} in the rhizosphere soil and outside it with a decrease of 16.6 and 13.38% compared with the control treatment, which gave a quantity of phosphorus of 9.15 and 10.68 ìg.g^{-1} for the rhizosphere soil and outside, respectively, in this period. The application of wettable sulfur fertilization has also achieved a quantity of available phosphorus (8.00 and 10.11) ìg.g^{-1} for rhizosphere soil and outside respectively, with a decrease of 12.56% and 5.33% compared to control treatment.

The results shown in Tables 2, 3 and 4 present that the values of phosphorus are reduced as growth periods increase in phosphate fertilizers treatments and their interactions in and outside the rhizosphere compared with 40-70 days of planting. This indicates that the processed phosphorous was less available than the consumed phosphorous by plants and there was no increase to compensate for the depletion of the plant. This confirms the high degree of soil interaction in this period of 7.3 and thus becomes fixed as calcium phosphonate. The non-available mineral phosphorus is charged with a negative charge and easily reacted with the (Ca^{2+}) to form a relatively insoluble compound that is not available to be absorbed by the plant and is considered a fixed. This is in line with the findings of the Adhya *et al* (2015). In general, the highest values were found in the soil outside the rhizosphere of the soil of the rhizosphere in all studied periods (40, 70 and 100) days of cultivation in all fertilization treatments and their interactions (Fig. 1). The results show that comparing phosphorus levels with phosphorus interactions with agricultural and wettable sulfur at each level showed that the differences were not significant in all treatments and in both soils of in and out of the rhizosphere, although they decreased when interfering with sulfur. This is due to the increase of plant growth by the treatment of interference and thus increase the depletion of phosphorus from the soil, which confirms that the values of the available phosphorus in the rhizosphere area is less than its value in the soil outside the rhizosphere.

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