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Article

Effect of different types and levels of phosphorous fertilizers on kinetics of phosphorous release in the soil

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Abstract: A field experiment was carried out in one of the fields of Diwaniya governorate for the agricultural season 2019 to study the effect of adding organic fertilizer and sources of phosphate fertilizer during the growth stages of the maize plant (Zea mays. L) and its reflectance on growth and productivity of the plant. The experiment was conducted according to the design of the (split-split plots and included two levels of the organic fertilizer(L1-L0) standing for (0- 1.5 tons) and three sources of the following fertilizers: Tri super phosphate TSP, Di-Ammonium phosphate DAP and Urea UP) as add to control treatment (p0) symbolized by p1, p2, p3, respectively. The seeds of maize (Zea mays. L) Behoth 5018s cultivar were planted in a 25 kg/H range. The kinetics of phosphorous in the soil were studied. The phosphorus release rate was determined during the stages of plant growth, and the best equation in describing the mechanism of desorption in the stages of plant growth (25, 50, 75, 100 and 125 days). The results showed that all used equations (first-order, diffusion and Elovich) have described the mechanism of phosphorous release from a solid phase to the soil solution. All equations gave a highly significant correlation (r) between released phosphorous in the stages of Plant growth. The first-order equation surpassed other equations describing the mechanism of phosphorous release in the soil. The values of the coefficient of phosphorous release rate (KP) ranged between (0.0045 - 0.004 mg. p. kg^{-1}. Day^{-1}) for the equation of first- -order, where the results showed that the linear relationship between the amount of released phosphorous as a function of time for the equation of first-order, is the best equation in describing the release, which indicates the interest in the amount and timing of addition of p fertilizers during the stages of plant growth, according to what was shown in the kinetic equations.

Keywords: Phosphorous desorption, fertilizers, maize, kinetic equations, soil solution.

Introduction

Corn (Zea mays L.) is one of the most strategic grain crops in the world due to its high nutritional value for human food in the first step and for the foder in the second, food industry and the increasing demand for food, and biofuel purposes make this crop occupies the second place scientifically after the wheat in the average cultivated area, which amounted to 166 million hectares and ranked first in terms of production, also amounted to 963 million tons of the total global production of grain, which amounted to 2164 million tons [1]. In Iraq, the rate of maize production reached 340 thousand. In Iraq, the rate of maize production reached 340000 tons, while the cultivated area amounted to about 130000 hectares [2].

Phosphorous is one of the macronutrients in plant nutrition, as it is called the "key of life" for its direct role in many physiological processes such as photosynthesis, cell division and seed formation, as well as the formation of energy-rich compounds and nucleic acids that contain genetic codes for protein production as well as its role in stimulating root growth and encouraging early growth, especially cereal crops Ahmed ,2007 and [3] most of the soils of dry and semi-arid regions in the world, including Iraqi soils, are characterized by their high content of carbonate minerals and a high percentage of calcium ions in soil solution , as well as a low level in the organic matter and the high degree of soil reaction (pH), while they both lead to a significant decrease in the available phosphorous in soil solution as a result of the exposure of phosphorous in the soil or added in the form of phosphate fertilizers to the processes of reduction and precipitation that reduce its availability , which reduces the optimal use of fertilizer by the plant and its reflections on growth indicators and production, also organic fertilizers is critical administrative processes in soil management, due to their role in the different properties of the soil , because it contains many nutrients and its high ability to hold water in the soil, as well as adding organic fertilizers to the soil leads to an increase in the amount of available phosphorous, while through its role in increasing the solubility of phosphorous compounds in the soil and creating cations to ensure the association of phosphorus and its direct interaction with it and the formation of phosphorous organic compounds that is soluble and uptake by the plant in addition to that it prevents the deposition of phosphorus in the form of hydroxyapatite (HA)[4,5, 6, 7] .

The kinetic concept is one of the most important and valuable techniques to predict and evaluate the state and chemistry of many nutrients, including phosphorous [8]. However, this research aims to shed light on the fate of some phosphorous fertilizers and to show their role in phosphorous soil availability and maize nutrition besides determining the best-fit equation for describing phosphorous release from soil.

Materials and methods:

A field experiment in the agricultural fields of Diwaniyah province was carried out on maize through the spring season of the (5018) cultivar for the agricultural season 2012.

Preparation of soil

The soil was prepared for planting by plowing and leveling; some random soil samples were taken in depth (0 - 30 cm) for laboratory analysis, after drying and grinding with a plastic hammer, then sieving with a 2mm diameter sieve for physical and chemical analysis.

Three maize seeds were sown per hill at a spacing of 0.75 m (inter–row) by 0.25 m (intra–row) and later thinned to two plants per hill at 21 days after crop emergence.10% diazinon was used to control corn stalk borer in two dates, first at 2 days after emergence, second after 15 days from the first date. Three manual weeding periods were done. Organic manure was added at two levels (0,1.5) $ton.ha^{-1}$ before planting, represented by (L0 and L1), considering covering it with soil to avoid erodibility.

The chemical fertilizers, namely Tri-Super phosphate (TSP) 20% (P1), Di-Ammonium phosphate (DAP) (P2) and Urea phosphate (UP) (P3) were applied at the same level (100kg.ha^{-1}) at the time of planting along the furrows and mixed with soil to avoid direct contact with the seeds.

Urea fertilizer (46%N) was applied at level 250 kg.ha^{-1} in the planting stage and the second dose after 45 days from the first dose.

According to Page et al. (1982) table (1), some physical and chemical properties performed.

Soil samples were then taken from each experimental unit at a depth of 0-30cm to check and for five time periods (125+, 100+,75+,50+, 25+) day of the growth season for determination of both available and adsorbed phosphorus of soil and after grain maturity all plants were harvested.

property		value	unit
PH		7.8	
EC		3.48	ds.m-1
CEC		24.6	Crob.kg-1soil
Organic matter		9.15	gm.kg-1soil
Carbonate minerals(CaCO3)		242	gm.kg-1soil
Gypsum		0.41	gm.kg-1soil
Cations	Ca^{++}	1.21	Cmol.c.kg-1
	Mg^{++}	0.86	
	Na^{+}	2.73	
	K^{+}	0.22	
Anions	$CO3^{=}$	Nil	Cmol.c.kg-1
	$HCO3^{-}$	0.08	
	$SO4^{=}$	1.86	
	Cl^{-}	2.95	
Available elements	$No3^{-}$ $NH4^{+}$	23.78	mg.kg-1soil
	P	12.35	
	K	85.74	
soil separates	Sand	125	gm.kg-1soil
	Silt	563	
	Clay	312	
Texture	silty clay loam		
Bulk density		1.320	Mg.m -3

Table 1. Some physical and chemical properties of soil experiment.

Results

The effect of quality and different levels of fertilizers on phosphorus kinetics in soil:

Several kinetic equations were used to describe the release of phosphorus in soil and to show the mechanism of phosphorus desorption; the released quantity and desorption coefficient (KP) were estimated.

Under the influence of different treatments in this experiment, the accumulated quantity of released phosphorus as a function of time was used for choosing the best kinetic equations, which applied to the results and explain the release mechanism of phosphorus in the soil, which are (first order, power function, parabolic diffusion, Elovich), because they are the most common used in describing phosphorous release in soil, the comparison between equations was made according to correlation coefficient (r) and standard error (SE), which show the matching between the experiment results estimated from theoretical results of these kinetic equations, which shows that best kinetic equation in the description of the release of phosphorus in the soil is the first order equation then followed by a power function.

These two equations have achieved the highest correlation values and lower standard error values as compared to other equations, as well as equations that can be ranked in the description of the release of phosphorus from the soil as follows in Table 2:

First Order> Power Function> Parabolic Diffusion> Elovich

Fertilizer type	**Fertilizer level (ton/h)**	**First order**		**Power function**		**Parabolic diffusion**		**Elovich**	
		SE	r	SE	r	SE	r	SE	r
Control (p0)	0	0.046	0.933	0.270	0.724	0.123	0.953	0.230	0.691
	1.5	0.064	0.964	0.025	0.956	0.106	0.966	0.222	0.665
TSP*(p1)	0	0.042	0.945	0.019	0.705	0.137	0.961	0.247	0.740
	1.5	0.060	0.959	0.135	0.926	0.140	0.965	0.218	0.654
DAP(p2)**	0	0.040	0.963	0.156	0.959	0.160	0.966	0.258	0.773
	1.5	0.028	0.969	0.010	0.968	0.168	0.974	0.284	0.852
UP* (p3)**	0	0.020	0.981	0.007	0.967	0.220	0.974	0.287	0.861
	1.5	0.017	0.972	0.194	0.971	0.191	0.976	0.290	0.870

*:Tri super phosphate , **:Di Ammonium phosphate , ***:Urea phosphate

Table.2. simple correlation coefficient and estimated standard error (SE) kinetic equations used in describing phosphorous release from soil treated with different types and levels of phosphorous fertilizers.

Rate of release Coefficient (Kp):

The results showed the superiority of the parabolic diffusion and the Elovich equations, which were used in calculating the rate of release coefficient Kp, as shown in Table 3. The results also indicate the variation between the values of the treatments, where the rate of release coefficient (Kp) from the first-order equation ranged between 0.001 mg p kg- 1 day-1 for the DAP and UP at all levels to 0.007 mg p kg-1 day-1 in control treatment table 3, and this indicates that the amount released from phosphorous is low and may not meet the plant's need at the stages where the plant's need is high [19], which confirms the importance of factor the rate of release in the management of phosphate fertilization as for the rate coefficient of release (Kp) from the power function equation whose values exceeded the equation of the first order, the values of the coefficient of the speed of release of phosphorous (kp) ranged from 0.033 mg p kg-1 day-1 in the UP treatment at level 2 to 0.0315 mg p kg $^{-1}$ day^{-1} in control treatment for power function equation table 3.

Fertilizer type	Fertilizer level (ton/h)	First order	Power function	Parabolic diffusion	Elovich
Control	0	0.007	0.315	0.466	1.644
	1.5	0.002	0.109	0.458	1.597
TSP*	0	0.001	0.036	0.573	2.012
	1.5	0.002	0.089	0.615	2.145
DAP*	0	0.001	0.064	0.714	2.482
	1.5	0.001	0.048	0.814	2.843
UP*	0	0.001	0.035	0.896	3.127
	1.5	0.001	0.033	0.970	3.380

*TSP: Tri super phosphate, DAP: Di Ammonium phosphate, UP: Urea Phosphate

Table 3. Phosphorous release coefficient (Kp) mg.p.kg^{-1}.day calculated by all studied kinetic equations for research treatments.

As for the values of the rate coefficient of phosphorous release from the studied equations, in general, we can see clearly that the first order gave the lowest values, followed by the power function, then the Prapolic diffusion equation and the Elovich equation surpassed all equations and gave higher values of rate release coefficient table 3, in term of fertilizer type and level, the results showed that there are differences between types and levels where control treatment was higher values in first order and power function followed by TSP, DAP and UP, this trend was different in Prapolic diffusion, and the Elovich equations were UP fertilizer surpassed other types and control treatment followed by DAP, TSP and control, the values may vary according to the different experimental treatments and soil properties between the two figures 1,2. The linear relationship between the amount of phosphorous released as a function of time for the first-order equation and the power function was the best equation for describing phosphorous release.

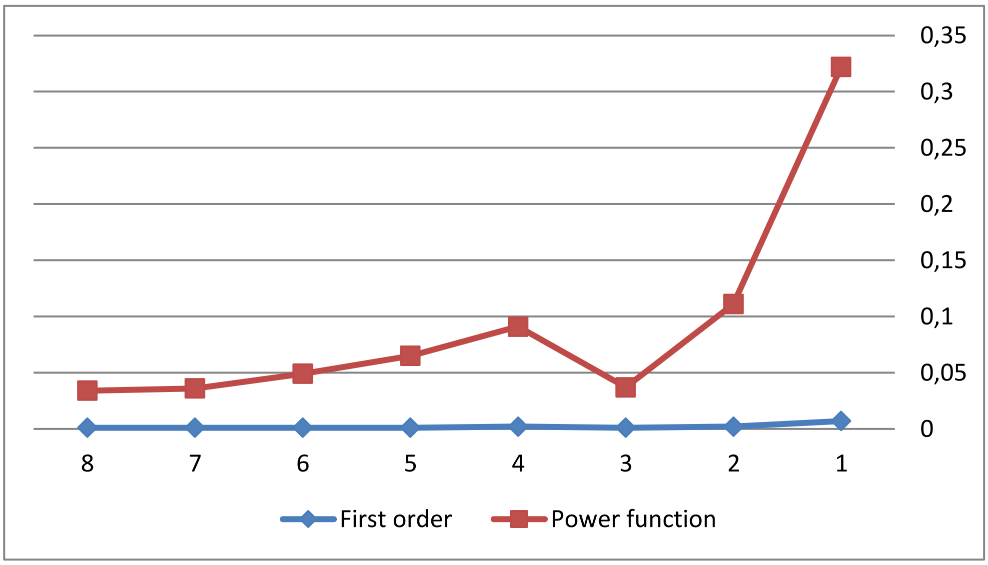

Figure 1.The quantity of released phosphorous at different periods using first order and power function.

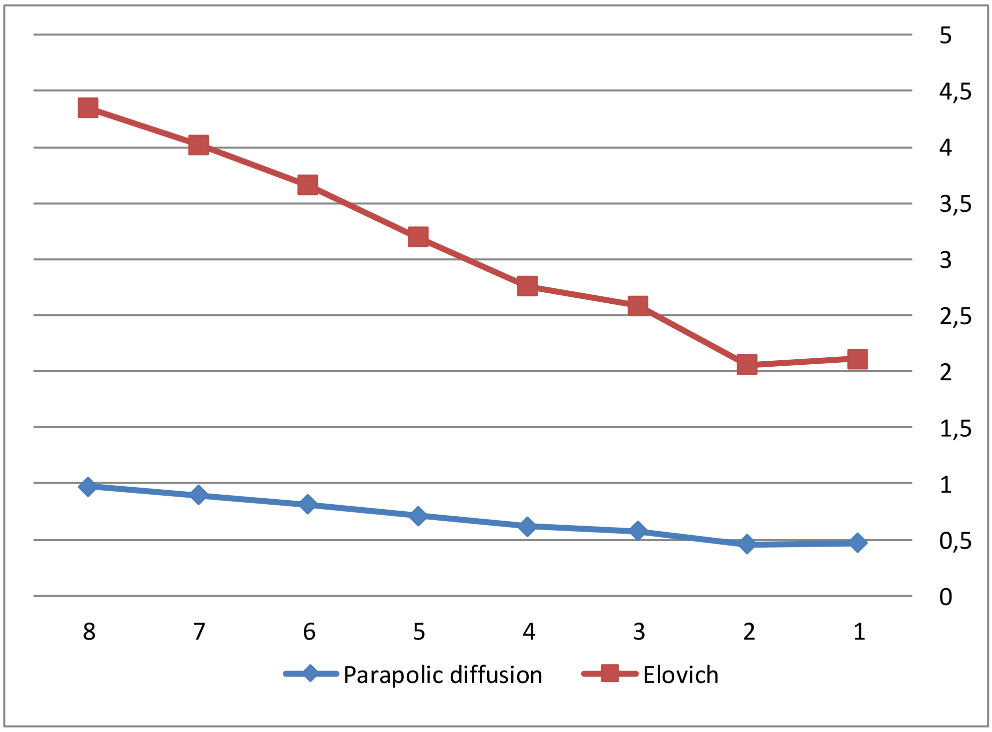

Figure 2.The quantity of released phosphorous at different periods using parabolic diffusion and Elovich equations.

Discussion

The equation of the first order, as a logarithmic ratio equation, has explained the release of phosphorus in the soil in all treatments through the release of phosphorus affected by the interaction of one of the concentrations of the experiment factors, which in turn controls the desorption of phosphorous from the soil, on the other hand, the solubility of phosphorous compounds in the soil and under the influence of the experimental conditions as indicated above also play a vital role in this process, as well as the use of organic fertilizers. Also, the other equation, namely the Power Function, accurately described phosphorous desorption as well, [9, 1]. As the equation of the Power Function and that the released amount from phosphorous depends on the time factor, it is directly proportional to time, and this seems clear through the phosphorous release curves, table (1,2), meaning that the released quantity is directly proportional to time. The time factor is the determinant of the total released amount, which showed the existence of two stages of phosphorous desorption, which depended on the time factor. These two equations clearly show that both the concentration of phosphorus, the quantity in the soil and the time factor are the determinants of the amount of released phosphorus to the soil solution and its ability to be absorbed by the plant as The plant absorbs the available phosphorous in the following phases: HPO_4 and H_2PO_4, whose transformations are greatly affected by the degree of reaction of the soil solution pH [10, 11, 5].

[0,11]. The increase of available phosphorous associated with the treatment of organic matter is attributed to the ability of humic acids to encapsulate clay particles, increase the efficiency of phosphate fertilizer, and reduce the fixation of phosphorous by calcium. The added quantities of phosphate fertilizer and the addition of organic matter to the soil increase the availability of phosphorous because it affects the sites of phosphorus adsorption in the soil, which increases its availability [10, 11, 12, 13, 14].

Figures (1 and 2) show that all the experimental values are close to the straight line of these treatments, which shows their preference in describing the release of phosphorous in soil for all treatments, which agreed with many researchers [10, 11, 12, 15].

It is evident from the application of the kinetic equations that the highest amount of phosphorous released is associated with the most appropriate periods for the need of the phosphorous plant (20, 60), which gave the highest values for phosphorous release, especially at the interaction treatments. For the role of dissolving complex phosphorous compounds in the soil, which causes releasing the most significant amount of available phosphorous for uptake by the plant [16, 17, 18].

Conclusions

Using different phosphorous fertilizers associated with different levels of organic matter is a good concept for evaluation of the fitting of four kinetic equations; power function was the best equation for describing phosphorous release from soils by giving a higher correlation coefficient and lower standard error, adding of organic matter improved phosphorous availability in the soil.

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References

1. Kaul, J., Jain, K., & Olakh, D. An overview on the role of yellow maize in food, feed and nutrition security. *International Journal of Current Microbiology and Applied Sciences*, **2019**; *8*(2), 3037-3048.
2. Lampietti, J. A., Michaels, S., Magnan, N., McCalla, A. F., Saade, M., & Khouri, N. A strategic framework for improving food security in Arab countries. *Food Security*, **2011**; *3*(1), 7-22.
3. Havlin J, Beaton J D, Tisdale S L, Nelson W L. Soil fertility and fertilizers: 7th Ed. An introduction to nutrient management. Upper Saddle River, New Jersey. The USA. **2005**.
4. Penn, C. J., & Camberato, J. J. A critical review on soil chemical processes that control how soil pH affects phosphorus availability to plants. *Agriculture*, **2019**; *9*(6), 120.
5. Weeks Jr, J. J., & Hettiarachchi, G. M. A review of the latest in phosphorus fertilizer technology: Possibilities and pragmatism. *Journal of Environmental Quality*, **2019**; *48*(5), 1300-1313.
6. Azeez, M. O., Christensen, J. T., Ravnskov, S., Heckrath, G. J., Labouriau, R., Christensen, B. T., & Rubæk, G. H. Phosphorus in an arable coarse sandy soil profile after 74 years with different lime and P fertilizer applications. *Geoderma*, **2020**; *376*, 114555.
7. Braos, L. B., Bettiol, A. C. T., Di Santo, L. G., Ferreira, M. E., & Cruz, M. C. P. Dynamics of phosphorus fractions in soils treated with dairy manure. *Soil Research*, **2020**;*58*(3), 289-298.
8. Toor, G. S., & Bahl, G. S. Kinetics of phosphate desorption from different soils as influenced by application of poultry manure and fertilizer phosphorus and its uptake by soybean. *Bioresource Technology*, **1999**;*69*(2), 117-121.
9. Sun, T., Fei, K., Deng, L., Zhang, L., Fan, X., & Wu, Y. Adsorption-desorption kinetics and phosphorus loss standard curve in erosive weathered granite soil: Stirred flow chamber experiments. *Journal of Cleaner Production*, **2022**; *347*, 131202.
10. Yang, X., Chen, X., & Yang, X. Phosphorus release kinetics and solubility capacity of phosphorus fractionation induced by organic acids from a black soil in northeast China. *Canadian Journal of Soil Science*, **2019**; *99*(1), 92-99.

11 Mei, Y., Zhu, X. H., Gao, L., Zhou, H., Xiang, Y. J., & Liu, F. Phosphorus adsorption/desorption kinetics of bioretention. *Thermal Science*, **2020**;*24*(4), 2401-2410.
12 Sanyal, S. K., & De Datta, S. K. Chemistry of phosphorus transformations in soil. In *Advances in soil science* (pp. 1-120). Springer, New York, NY. **1991**.
13 Jarallah, R., & A Abbas, N. The Effect of Sulfur and Phosphate Fertilizers Application on the Dissolved Phosphorus Amount in Rhizosphere of Zea Maize L. *Al-Qadisiyah Journal For Agriculture Sciences*, **2019**; *9*(2), 233-239.
14 Ikram, W., Akhtar, M., Morel, C., Rizwan, M., & Ali, S. Phosphate fertilizer premixing with farmyard manure enhances phosphorus availability in calcareous soil for higher wheat productivity. *Environmental Science and Pollution Research*, **2019**; *26*(31), 32276-32284.
15 Bernardo, M. P., Guimaraes, G. G., Majaron, V. F., & Ribeiro, C. Controlled release of phosphate from layered double hydroxide structures: dynamics in soil and application as smart fertilizer. *ACS Sustainable Chemistry & Engineering*, **2018**; *6*(4), 5152-5161.
16 Liu, H., Wang, R., Wang, H., Cao, Y., Dijkstra, F. A., Shi, Z., ... & Jiang, Y. Exogenous phosphorus compounds interact with nitrogen availability to regulate dynamics of soil inorganic phosphorus fractions in a meadow steppe. *Biogeosciences*, **2019**; *16*(21), 4293-4306.
17 Taghipour, M., & Jalali, M. Effect of low-molecular-weight organic acids on kinetics release and fractionation of phosphorus in some calcareous soils of western Iran. *Environmental Monitoring and Assessment*, **2013**;*185*(7), 5471-5482.
18 Dobermann, A., Cassman, K. G., Adviento, M. A. A., & Pampolino, M. F. Fertilizer inputs, nutrient balance and soil nutrient supplying power in intensive, irrigated rice system. III. Phosphorus. *Nutrient cycling in Agroecosystems*, **1996**;*46*(2), 111-125.
19 Etesami, H. Enhanced phosphorus fertilizer use efficiency with microorganisms. In *Nutrient dynamics for sustainable crop production* (pp. 215-245). Springer, Singapore. **2020**.
20 Liu, X., Yang, J., Tao, J., Yao, R., Wang, X., Xie, W., & Zhu, H. Elucidating the effect and interaction mechanism of fulvic acid and nitrogen fertilizer application on phosphorus availability in a salt-affected soil. *Journal of Soils and Sediments*, **2021**; *21*(7), 2525-2539.

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