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ORIGINAL ARTICLE

EFFECT OF AMMONIUM POLYPHOSPHATE APPLICATION ON NPK AVAILABILITY IN SOIL AND PLANT WHEAT GROWTH

Kamal H. Al-Dulaimi[1,]*, Khaleel J. Farhan and M.N.A. Al-Falahi[2]

[1]Department Soil Science and Water Resources, College of Agriculture, University of Anbar, Iraq.
[2]Planning and Databases Department, Upper Euphrates Basin Developing Center, University of Anbar, Iraq.
E-mail: kmhm81@uoanbar.edu.iq

Abstract: Phosphorus (P) represents the most deficient nutrient in agricultural soils after nitrogen affecting plant production. Therefore, a field experiment was conducted at the experimental farm, belongs to the College of Agriculture, University of Anbar in 2021 to compare the effect of ammonium polyphosphate (APP), monoammonium fertilizer (MAP) and diammonium fertilizer (DAP) on NPK availability in soil and plant wheat growth. Where three sources of Phosphorus were applied at three levels *i.e.* 0, 100, 150 kg P2O5Kg.h^{-1}. The experiment was carried out according to a randomized complete block design with three replications. The results indicate the superiority of the APP fertilizer source over the two sources of MAP and DAP in its effect on the growth traits of wheat plant such as dry matter and plant height, where the highest rate for the previous mentioned traits were 3.45 g.Pot^{-1} and 106.48 cm, respectively, followed by MAP fertilizer, which gave 3.15 g.Pot^{-1} and 95.44 cm, respectively compared to DAP fertilizer that gave 3.09 g.Pot^{-1} and 84.12 cm, respectively. Increasing application of phosphorus levels caused significant differences in growth traits, namely dry matter and plant height in addition to the availability of NPK in the soil at 50% flowering stage and after harvesting. Significant interaction was observed between the source and the applied level of phosphorus in the soil and growth traits and the availability of NPK in the soil.

Key words: Ammonium poly phosphate, Monoammonium phosphate, Diaammonium phosphate, Nutrients availability.

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1. Introduction

Wheat (*Triticum aestivum* L.) is the most important cereal crop in world and is the staple food for humans. It is one of the three cereals, alongside ice and corn, which are the most valuable food sources for people [Mahmood and Zeboon (2019), Madlul *et al.* (2020)].

In order to achieve the production sustainability to meet the human population growth, the application of fertilizers at global level is increasing, which has led to serious economic losses and environmental risks such as surface and groundwater pollution and toxicity soil deterioration and even the ecosystem change [Chen *et al.* (2018), AL-Taey *et al.* (2019)]. Nutrient inputs into production systems have increased as a result of heavy need for high yielding crops to feed the growing population across the globe. Phosphorus originates from weathering of soil minerals and other stable soil geologic materials, whereas it exists in both inorganic and organic forms of which the fraction of the former is dominant in nature [Al-Juthery *et al.* (2018), Al-Juthery *et al.* (2020)].

Accordingly, there is an urgent need to control the usage of inorganic fertilizer. Phosphorus (P) is one of essential element for plant growth. It is absorbed by plants in the form of $H_2PO_4^-$ or HPO_4^{2-} and is a crucial component of nucleic acids, phospholipids and some enzymes [Yang *et al.* (2016), AL-Taey *et al.* (2018)]. Phosphorus (P), as a major low-mobility and low solubility element reduces its availability in the soil as it is fixed by soil P-compounds [AL-Taey *et al.* (2017),

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Hamed *et al.* (2020)]. Phosphorus fixation makes it less accessible to plants over years, therefore, farmers supply excess amount of phosphorus to meet the field requirements. Consequently, phosphorus exists in the soil with considerable amount. Therefore, adequate supply of phosphorus is required to support the soil in sufficient and continuous quantities to avoid soil pollution and at the same time provide the phosphorus to the plant [McBeath *et al.* (2007), Toman *et al.* (2020)], at the same time reduces amount fixed of phosphorous in the soil. The adsorption and deposition reactions of phosphate can occur after a few days of the fertilizer application or even it may last for a few months, so should be focusing on the feeding and providing the plant with phosphorous more than focusing on presence in the soil and modern agriculture. Numerous efforts have been made to overcome the inherent harm of phosphate fertilizers (MAP, DAP and TSP) and other conventional fertilizers as a result of their widespread use for more than a century [Wang and Chu (2015)]. Nowadays, in many countries, has become trends to use the polyphosphate fertilizer because it contains large amounts of phosphorous in addition to other elements such as nitrogen. Moreover, it is slow decomposition fertilizer, which reduces the scope of their fixation in the soil. Therefore, these fertilizers have received increasing attention. Some comparative studies between sources of phosphate fertilizers and their effect on improving P absorption by plants and dry matter production indicated the advantage of using polyphosphate as a fertilizer. Gao *et al.* (2020) reported a significant increase in the growth of maize (dry matter, plant height and phosphorus uptake by plant) as a result of the use of polyphosphate. Currently, in Iraq there is little information about polyphosphate, where it is not widely used in Iraq except on a very small scale with little and limited information of the nature of their transformations and interactions in the soil, particularly in the limestone soils, as well as their effect on plant growth, which requires further research and investigation to determine the fate of polyphosphate fertilizers in the soil. Therefore, this study was aimed to know the effect of ammonium polyphosphate (APP) fertilizer application in comparison with common conventional phosphate fertilizers (MAP and DAP) on NPK availability and wheat plant growth.

2. Materials and Methods

2.1 Soil sampling and analyzed parameters

A greenhouse experiment was conducted in the agricultural field of the College of Agriculture, University of Anbar. The soil used in the greenhouse study included surface samples 0-30 cm. Where six disturbed surface (0-30 cm in depth) samples were collected randomly from each plot and mixed for getting a representative soil sample. The representative samples were preserved in plastic bags and then transferred to the laboratory and air-dried and passed through 2 mm sieve to determine the key selected soil chemical and physical properties. The percentages of sand, silt and clay for the initial soil plough horizon 0-30 cm was recorded by using the pipette method. The soil under study was classified as silty clay loam texture. According to American classification the soil was classified as calcareous soil.

2.2 Selected Chemicals Analyses

The pH and EC for the soil under study were estimated from the 1:5 soil-water suspensions by using a pH and EC meter respectively. The soil organic matter (SOM) was determined according to the acid extraction method [Jackson (1967)]. While the total nitrogen was determined using the Kjeldahl method as described by Page (1983). Olsen method was used to determine the available P [Olsen and Sommers (1982)]. Cation exchange capacity (CEC) and exchangeable base of the soil were extracted by leaching using ammonium acetate solution and the exchangeable bases were measured by atomic absorption spectrophotometry for Ca and Mg and flame photometer for that of Na and K [Polemio & Rhoades (1977)]. The soil physical and chemical properties were listed in Table 1. Regarding the sulfates, it was estimated by precipitation with barium chloride and arabic gum and measured by a color spectrophotometer and the chlorides were estimated in the extract using the colorimetric method, while the dissolved carbonates and bicarbonates were estimated in the soil extract using the colorimetric method using the Autoanalyser method, according to the method [Richards (1954)].

2.3 Pots Preparation and Wheat Cultivation

Plastic pots measuring 30 cm diameter and 30 cm height were used for cultivation. Where each pot was filled with air dried and well mixed field soil till 10 kg. After punching the pots bottom, a layer of gravel of 0.05 m diameter, was placed at the bottom of each pot to facilitate the removal of excess water. Three sources of Phosphate fertilizer were applied as the following: ammonium polyphosphate fertilizer (APP) was applied

Table 1: Some Chemical and Physical Properties of the Soil under Study before planting.

Parameter		Value	Unit
pH		7.4	$dS.m^{-1}$
EC		4.2	
Organic matter		8.9	$g.kg^{-1}$
Carbonates		236	
Ca^{+2}		9.8	$Mmol.l^{-1}$
Mg^{+2}		8.4	
Na^{+1}		12.5	
K^{+}		25.0	
SO_4^{-2}		7.6	
HCO_3^{-}		5.5	
CO_3^{-}		0	
Cl^{-}		20	
Nitrogen(N)		20.5	$g.kg^{-1}$
Phosphorous(P)		6.3	
Potassium(K)		166.8	
Cation Exchange Capacity		22.1	cmolc/kg
Soil Particles	Sand	180	$g.kg^{-1}$
	Silt	469	
	Clay	351	
Soil Texture	Silty clay loam		

as a source of polyphosphate (condensed phosphate) prepared and manufactured according to the method of Al- Khateeb *et al.* (2001). Table 2 Shows physical and chemical properties of the fertilizer, the fertilizers DAP and MAP were applied as a source of Di and Mono Ammonium Phosphate. Each fertilizer was applied in three levels 0, 100, 150 $kg.P_2O_5.h^{-1}$ (the levels of fertilizer application were symboled as the zero level of P fertilizer was designated as a control treatment, L_1 for 100 and L_2 for 150 $kg.P_2O_5.h^{-1}$) each level was applied once at planting and in two equal batches, the first application at planting and the second after 40 days of germination, in addition to the control treatment (0 phosphorous). The study was conducted as factorial treatment including 2 factors based on (RCBD) with 3 replicates. The two factors were sources of Phosphate fertilizer and the levels of phosphate fertilizer application. The sources of nitrogen and potassium were urea (46%N) for N at the rate of 80 kg $N.ha^{-1}$ and potassium sulfate (41.5%K) for K at the rate of 120 $kg.ha^{-1}$ for all treatments according to the fertilizer recommendation. Wheat seeds of Rasheed cultivar was planted on 9/11/2020 with the rate of 6 seeds per pot, then after the plants were thinned to three plants after germination, tap water was used for irrigation according to the weighted method. During the stage of 50% flowering and after harvesting, soil samples were taken from the field then transferred to the central laboratory in the College for the purpose of conducting the required analyzes.

2.4 Statistical Analysis

The obtained data was statistically analyzed using GenStat Release 12.1 program and the averages were compared using the least significant difference test L.S.D at the level of significance 0.05.

3. Results and Discussion

3.1 Dry matter of yield

Table 3 showed that there were significant differences in the trait of the dry weight of the vegetative part of the plant according to the source and type of phosphate fertilizer (APP, MAP, DAP), where the highest average of the dry weight was 3.45 $g.Pot^{-1}$ when the APP fertilizer has been used, followed by MAP and DAP fertilizers, which amounted to 3.15 and 3.09 $g.Pot^{-1}$ respectively. The results also showed that the increased levels of fertilizer application led to significant differences in the dry weight rate, where the L2 (100 $kg.P_2O_5.h^{-1}$) level was superior by giving

Table 2: Some chemical and physical properties of ammonium polyphosphate (APP) fertilizer that used in the study Al-Dulaiimi (2011).

Properties of Ammonium Polyphosphate	Value	Unit
Solubility	25	g/100 ml
Absolute melting point	200	kelvins
pH from the 1:10 fertilizer-water suspensions	7.87	
EC from the 1:10 fertilizer-water suspensions	6.5	dS/m
Percentage of Phosphorous	70	%
Percentage of nitrogen (NH_4)	21	%
molecular weight	440	g/mol
Chemical formula	$(NH_4)_6P_4O_{13}$	

the highest rate of dry weight reached 3.82 $g.Pot^{-1}$ compared to L0 and L1 levels, which gave 2.32 and 3.55 $g.Pot^{-1}$, respectively. The results listed in Table 4 presents the effect of the interaction between the source and level of phosphate fertilizer on the dry matter yield, where there were noticeable differences between APP, MAP and DAP fertilizers. But there was slight difference between the two fertilizers MAP and DAP, where the highest dry matter yield reached 4.12, 3.69 and 3.65 $g.Pot^{-1}$, respectively, at the level of 150 mg $p.kg.soil^{-1}$ for all three sources of fertilizers. While the values were 3.77, 3.46 and 3.40 $g.Pot^{-1}$, respectively, at the level of 100 mg p.kg $soil^{-1}$.

3.2 Plant height

Table 3 shows the effect of the source and level of phosphate fertilizer application on the height of wheat plant, the evidence show that the use of APP fertilizer led to significant differences in the rate of plant height, reached 106.48 cm, followed by MAP fertilizer with a height rate of 95.44 cm compared with DAP fertilizer, which reached 84.12 cm. The results also show that the level of fertilizer application has an important and significant role in plant height, where increasing the level of addition led to clear significant differences in the rate of plant height, reached 95.35 cm at the level of 150 mg p.kg $soil^{-1}$, followed by 86.79 and 67.79 cm for the two levels 100 and 0 mg p.kg $soil^{-1}$, respectively, which means an increase of 8.98 and 28.9 % respectively. Regarding the effect of the interaction between the source and the level of fertilizer application, the results listed in Table 4 show the highest rate of plant height was 106.48 cm resulted from APP fertilizer application at the level of 150 g p.kg $soil^{-1}$, followed by MAP fertilizer giving the plant height of 95.44 cm at

Table 3: Effect of source and level of phosphate fertilizer on dry matter weight, plant height and NPK availability in the soil.

Source of Variations	Dry matter weight ($g.pot^{-1}$)	Plant height (cm)	Nutrients ($ml.kg^{-1}.soil$)					
			At 50% flowering stage			After harvesting		
			N	P	K	N	P	K
Phosphate fertilizer source								
APP	3.45	91.83	9.95	2.23	113.58	23.01	12.19	146.16
MAP	3.15	83.19	31.17	6.96	156.31	20.38	10.32	137.35
DAP	3.09	74.92	24.33	5.47	145.37	18.66	9.54	130.69
$LSD_{.0.05}$	0.05188	1.420	0.2430	0.0686	0.552	0.1013	0.04364	0.1015
Level of Application (mg.kg-1.soi)								
L_0	2.32	67.79	16.29	1.51	131.97	16.03	2.30	118.10
L_1	3.55	86.79	22.01	5.18	136.07	21.90	13.76	131.66
L_2	3.82	95.35	27.06	7.96	147.22	24.12	15.99	163.54
$LSD_{.0.05}$	0.05188	1.420	0.2430	0.0686	0.552	0.1013	0.04364	0.1015

Table 4: Effect of the interaction between the source and level of phosphate fertilizer on the weight of dry matter, plant height and NPK availability in the soil.

Source of Variations	Level of Application ($mg.kg^{-1}.soi$)	Dry weight ($g.pot^{-1}$)	Plant height (cm)	At 50% flowering stage			After harvesting		
				N	P	K	N	P	K
APP	L0	2.453	74.71	8.18	1.21	107.1	121	3.77	17.8
	L1	3.77	94.29	9.63	2.6	112.33	137.3	15.2	24.51
	L2	4.117	106.48	12.04	2.88	121.3	180.3	17.6	26.7
MAP	L0	2.293	67.24	23.58	2.2	148.57	119.1	1.82	15.52
	L1	3.46	86.88	32.25	7.25	153.67	131.8	13.3	21.79
	L2	3.69	95.44	37.68	11.42	166.7	161.2	15.9	23.82
DAP	L0	2.207	61.43	140.2	1.13	17.11	116.9	1.32	14.76
	L1	3.4	79.21	142.2	5.7	24.41	126	12.8	19.41
	L2	3.65	84.12	153.7	9.58	31.48	149.2	14.5	21.8
LSD.0.05		0.08986	2.46	0.421	0.119	0.956	0.175	0.08	0.1757

the same level of fertilizer application followed by DAP fertilizer giving the plant height of 84.12 cm at the same level compared with the control treatment that gave 61.43 cm. The superiority of APP fertilizer can be attributed to the fact that the polyphosphate is slow-release fertilizer [Du *et al.* (2006)], the phosphorus released slowly to uptake by plant during its growth period, our results agree with Torres-Dorante *et al.* (2006), or probably the reason is the use of APP fertilizer led to an increase in the absorption of P, Ca, Mg, Mn, Zn and these elements are needed by the plant to complete its life cycle.

3.3 NPK availability in the soil

3.3.1 Available nitrogen in the soil at 50% flowering and after harvesting stage

It is clear from the results of Table 3 that addition of different phosphate fertilizers significantly affected the concentration of nitrogen availability in the soil, the highest rate observed when using MAP fertilizer giving 31.17 mg N.kg $soil^{-1}$ at 50% flowering stage, followed by DAP fertilizer reached to 24.33 mg N.kg $soil^{-1}$ compared to APP fertilizer, which amounted to 9.95 mg N.kg $soil^{-1}$, with an increasing rate of 21.9 and 68 %, respectively. In the stage after harvesting, the results showed that the highest rate of nitrogen availability was obtained when APP fertilizer was applied giving 23.01 mg $N.kg^{-1}$ soil, followed by MAP and DAP fertilizer by giving 20.38 and 18.66 mg N.kg $soil^{-1}$ respectively with an increasing rate of 11.43 and 18.9%, respectively. The evidence also show that the levels of fertilizer application significantly increased the concentrations of nitrogen availability in the soil, where the L2 gave the highest rate of 27.06 mg N.kg $soil^{-1}$ at 50% flowering stage compared to the lowest rate of 16.03 mg N.kg $soil^{-1}$ after harvest, with an increasing rate of 40.8%. In terms of interaction, the source and the level of addition recorded a significant effect on the concentration of nitrogen availability (Table 4). The L2 level of MAP fertilizer superior to other fertilizer levels by giving 37.68 mg N. kg $soil^{-1}$ at 50% flowering stage, while the other levels (L0 and L1) gave 23.58, 32.25 mg N. kg $soil^{-1}$, with an increase of 37.4 and 14.4%, respectively. Whereas, the interaction between the source and the level of addition recorded a significant effect on the concentration of nitrogen availability after harvest, where the APP with the L2 significantly superior the other levels by giving 26.70 mg N.kg $soil^{-1}$ compared to the L0 and L1 levels, which gave 17.8 and 24.51 mg $N.kg^{-1}$ of soil, with an increase of 33.3 and 8.2%, respectively.

3.3.2 Available phosphorous in the soil at 50% flowering and after harvesting stage

Table 3 shows that the addition of different phosphate fertilizers significantly affected the concentration of phosphorus availability in the soil, where the highest rate of phosphorus availability was obtained after harvest when APP fertilizer was applied giving 12.19 $mg.kg^{-1}$ of soil, followed by MAP fertilizer, giving the phosphorous availability of 10.32 mg p.kg $soil^{-1}$ while the DAP fertilizer gave 9.54 mg p.kg $soil^{-1}$, with an increase of 15.3 and 21.7%, respectively. Conversely, the results differed at the 50% flowering stage, the DAP fertilize source achieved the highest value of available P in soil reached to 6.96 $mg.P^{-1}$, followed by DAP fertilizer which gave 5.47 mg p.1 kg of soil, followed by APP fertilizer at a rate of 2.23 mg p. soil kg^{-1}. The results of the table also show that the levels of phosphorous addition significantly affected the increase in the concentration of phosphorus availability in the soil, where the L2 gave the highest rate of 15.99 mg p. 1 kg of soil after harvest compared to the lowest rate of 1.51 mg p. kg $soil^{-1}$ at 50% flowering stage, with an increase of 90.6%. The results of the interaction between the source and the fertilizer addition level listed in Table 4 shows there was a significant effect on the concentration of phosphorus availability in the soil after harvest, the L2 level and the APP source were superior to 17.57 mg p. kg $soil^{-1}$ at the L0 and L1 levels, reaching 3.77 and 15.23 mg p. kg $soil^{-1}$ with an increase of 78.54, 13.31 %, respectively. Whereas, the interaction between the fertilizer source and the level of addition at the 50% flowering stage had a significant effect on the phosphorous rate, where the APP was superior by giving 11.42 mgp. kg $soil^{-1}$ at the L2 compared to L0 and L1 levels which gave 2.20, 7.25 mg p. 1 kg of soil, with an increase of 80.74, 36.51%, respectively.

3.3.3 Available potassium in the soil at 50% flowering and after harvesting stage

The results of the statistical analysis listed in Table 3 shows the different sources of phosphorus fertilizers had a significant effect on the concentration of potassium availability in the soil, where the highest potassium availability was at the 50% flowering stage as results of using MAP fertilizer reached 156.31 mg k kg of soil, followed by DAP fertilizer at a rate of 145.37 mg. 1 kg of soil compared to APP fertilizer with an average of 113.58 mg k. 1 kg soil. While the highest value of potassium after harvest when using APP fertilizer was 146.16 mg k. 1 kg of soil, followed by MAP fertilizer at a rate of 137.35 mg. kg $soil^{-1}$ and then fertilizer DAP at a rate of 130.69 mg k. 1 kg soil. The results also showed that the levels of fertilizer application had a significant effect on the concentration of potassium availability in the soil, where the L2 superior at a rate of 163.54 mg k. 1 kg of soil after harvest compared to the lowest rate of 118.10 mg k. 1 kg soil that obtained from the control treatment. The interaction between the fertilizer source and the application level listed in Table 4. Recorded significant effect on the concentration of potassium availability in the soil after harvest, where the APP source with L2 gave the highest concentration of available potassium reached 180.25 mg k. kg $soil^{-1}$ compared to the lowest concentration of available potassium which obtained from the control treatment (L0) of DAP fertilizer giving 116.9 mg k. 1 kg of soil with an increase of 35.15%. Regarding the flowering stage, the interaction between the source and the level at the 50% flowering stage had a significant effect, where the highest rate was 166.70 mg. $soil^{-1}$ kg at MAP and L2 compared to the lowest rate of 107.10 mg k. 1 kg of soil for the control (L0) treatment of APP source with an increase of 37.8%, the superiority of APP over other fertilizer sources probably due to the fact that APP fertilizer is rich with the elements of phosphorous and nitrogen because it contains good proportions of the two elements as it contains 28.1 P% and 19.1 N% (Table 2). Also, the increase in the levels of phosphate fertilizer application led to a modification of the nutritional balance, which helped in increasing the main nutrients of the plant, consequently, positively reflected in plant growth.

4. Conclusion

The study findings proved that the APP fertilizer had better performance in the later stages of wheat plant growth (after harvest) and this confirms that the fertilizer has slow release properties suitable for plant growth. Therefore, recommended to use this type of fertilizer as a good source of phosphorous and other nutrients because this type of fertilizer is less susceptible to fix in the soil.

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