



## Influence of Mono-ammonium and Di-ammonium Phosphate on Phosphorus Use Efficiency of Maize and Bread Wheat Plants

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### ABSTRACT

Phosphorus fixation in soils is a big problem, for that, it affects negatively on phosphorus use efficiency of the plant. The amount of phosphorus which had fixed depends on orthophosphate ions and some soil properties. The goal of two experiments [In the first maize (*Zea mays L.*) and the second bread wheat (*Triticum aestivum L.*)] to know the different influence of mono-ammonium phosphate [MAP  $\text{NH}_4\text{H}_2\text{PO}_4$ ] and di-ammonium phosphate [DAP  $(\text{NH}_4)_2\text{HPO}_4$ ] fertilizers when were applied in the soil at rates (0, 30, 60 and 90  $\text{mg P}_2\text{O}_5 \text{ kg}^{-1}$ ) on phosphorus use efficiency under greenhouse condition. Completely Randomized Design (CRD) was arranged for both experiments in four replications in first experiment and three in the second.

Results cleared that plant dry weight (PDW,  $\text{g pot}^{-1}$ ) and plant phosphorus uptake (PPU,  $\text{mg P pot}^{-1}$ ) were increased with increasing doses of MAP and DAP fertilizers in both experiments according to control (0 ppm). Furthermore, apparent recovery phosphorus use efficiency (ARPUE, %) increased in DAP at maize and decreased in MAP at wheat trial when increasing phosphorus doses. All parameters had highly significantly affected by phosphorus. Also, fertilizers were a highly significant effect on PDW, PPU and agronomic phosphorus use efficiency (APUE) in maize and PPU in the wheat trial. Otherwise, interaction (F×P) had a highly significantly affected on PPU, physiological phosphorus use efficiency (PPUE) and ARPUE in wheat and APUE in maize. Additionally, PDW had a significant effect on interaction. When the MAP and DAP were increasing, that means increased PDW and PPU but MAP is better than DAP. Additionally, the results of the MAP in phosphorus use efficiency are better than DAP too.

### 1. Introduction

Phosphorus, nitrogen and potassium together are the most important elements as plant nutrients. Available phosphorus isn't enough in about 20% of Turkey agricultural soils (Sonmez and Ozbahce 2018). Phosphorus is primary for agriculture production, however, its use is not without entanglements. Attention to sustainable phosphorus use is no longer solely focused on reducing the detrimental environmental effect, but also explicitly linked to food and feed security (Schroder et al. 2010). Additionally, complete soil nutrients deficiency by chemical fertilization is very necessary for perfect nutrition to increase yield and decreased seed emptiness. Because soil nutrients deficiency reflected in vegetative growth and grain yield (Salvagiotti et al. 2017). Goos and Johnson (2001) stated that phosphorus fertilization very important for good establishing in spring wheat and it is very necessary for planting time

in spite of the soil has a high level of phosphorus. No one can deny in the soil which phosphorus defective, phosphorus fertilizers are very essential to rise yield and yield component in cereal crops (Saeed et al. 2017). In that time the weak wheat production reasons in the world are poor phosphorus use efficiency (Ali et al. 2017; Hashmi et al. 2017). Noor et al. (2017) found that when phosphorus fertilizers are applied in calcareous and basic soil the sedimentation of phosphorus by  $\text{Ca}^{+2}$  and  $\text{Mg}^{+2}$  made phosphorus use efficiency less than 25% for that the availability of phosphorus be so limited. On the other way the importance of cereal crops in the world, wheat is the first and after rice, maize is a third as food and feed crops (Amanullah et al. 2009). In that time from now up to 2030 may use a double quantity of chemical fertilizers to save person production at the same level (Gilland 1993).

Irfan et al. (2018) found that when increased phosphorus quantity (0, 30, 60, 120 and 240  $\text{mg P}_2\text{O}_5 \text{ kg}^{-1}$ ) so significant ( $p < 0.05$ ) increased in plant phosphorus uptake and plant dry weight and in same time was

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significant ( $p < 0.05$ ) decreased agronomic P efficiency (APE), Physiological P efficiency (PPE) and phosphorus recovery efficiency (PRE) of wheat plant under greenhouse condition. In greenhouse condition, increasing phosphorus doses (0, 25, 50, 100, 150 and 200 mg kg<sup>-1</sup>) that is to say, increased shoot dry weight, plant phosphorus uptake and physiology phosphorus uptake efficiency of two cultivars (Pasban-90 and MH-97) of bread wheat (*Triticum aestivum L.*) according to control (Akhtar et al. 2011). In that time, Saeed et al. (2017) stated that, in field condition in Faisalabad Pakistan in seasons 2014 and 2015 when increasing phosphorus doses (0, 50, 100, 150 and 200 kg P ha<sup>-1</sup>) in the soil, plant dry weight and grain yield of maize (*Zea mays L.*) were increased. Addition to that increasing of phosphorus amount, that means increased on agronomic phosphorus use efficiency in 2015 season. In the other direction, in field condition the yield of maize plant had no significant effect and cleared a negative affected by increasing an amount of phosphorus (0, 23, 46, 69 and 92 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>) when applied with planting method (1 and 2 seed hill-1) and method of phosphorus application (Spot and strip) (Mazengia 2011). Khalili-Rad and Hosseini (2017) found that increased of phosphorus doses so were increased two wheat cultivars shoot dry weight. In the same way, increased the mono-ammonium phosphate (MAP) (0, 0.2, 0.4 and 0.8%) when applied as inorganic amendments fertilizer, that is to say, increased on plant dry weight depending on control (0) (Qayyum et al. 2017). Papadopoulos (1985) found that phosphorus doses (0, 15, 30 and 35 mg P Kg<sup>-1</sup>) and different phosphorus fertilizers (mono-ammonium phosphate, di-ammonium phosphate and superphosphate) were significantly affected (5%) on P availability in calcareous soil and recovery of P (%), in addition to non-significantly affected on plant dry weight of barely.

Phosphorus fixation in soils is a big problem, for that, its effect negatively on phosphorus use efficiency of the plant. The amount of phosphorus which had fixed depends on orthophosphate ions and some soil properties. The use of mono-ammonium phosphate and di-ammonium phosphate as a phosphorus chemical fertilizer is very abundant in the agriculture sector. Which one from these is good in phosphorus use efficiency of the plant. To reply to that question two trials in maize and bread wheat purpose to explain the impact of mono-ammonium phosphate and di-ammonium phosphate on phosphorus use efficiency.

## 2. Materials and Methods

Two experiments were conducted in computer-controlled research greenhouse (Temperature was 25 ± 3 °C, solar radiation was 1750 ± 50 kcal.m<sup>-2</sup> and rela-

tive humidity was 60 ± 10%) of Soil Science and Plant Nutrition Department of Faculty of Agriculture, Selcuk University, Konya, Turkey. According to soil analysis, the soil which was used is poor in available phosphorus (<8 mg P kg<sup>-1</sup>), and Sulphur (8.6 mg SO<sub>4</sub><sup>-2</sup> kg<sup>-1</sup>), slightly alkaline (pH 7.38), sandy clay loam (SCL) in texture and very poor in organic matter (Motsara and Roy, 2008). In addition to, saltless (EC 92 µS/cm), very limey (20%), insufficient nitrogen limit (5.70 mg N kg<sup>-1</sup>), excess K (290 mg kg<sup>-1</sup>) and Ca (8728 mg kg<sup>-1</sup>), sufficient in Mg, (235 mg kg<sup>-1</sup>), Zn (0.51 mg kg<sup>-1</sup>), Mn 5.56 mg kg<sup>-1</sup> and Cu (1.12 mg kg<sup>-1</sup>) and poor in Fe and B (2.31 and 0.45 mg kg<sup>-1</sup>, respectively).

The factors of two experiments composed to fertilizers (F) as a first factor [Mono-ammonium phosphate (MAP) and Di-ammonium phosphate (DAP)] and Phosphorus (P) doses [0, 30, 60 and 90 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup>] as a second factor. The dry soil was weighted in a pot (3 kg dry by oven) and before one day of planting MAP and DAP as a chemical fertilizer were applied and mixed to the soil, then the soil was transferred to the pot again. Ammonium nitrate (AN %33 N) as nitrogen (200 mg N kg<sup>-1</sup>) fertilization for two experiments was applied.

In addition to, two experiments, one was planted by bread wheat (*Triticum aestivum L.*) Bayraktar-2000 variety after vernalization for one month in three replicates (2×4×3= 24 treatments) and the second was planted by maize (*Zea mays L.*) Anti.cin 98 as popcorn variety in four replicates (2×4×4= 32 treatments). Two experiments were arranged in a Completely Randomized Design (CRD) in two factors. Two experiments were irrigated in the optimum stage until harvested.

Bread wheat and maize experiments were harvested after 2 and 2.5 months from planting respectively. After harvesting the samples were taken to the lab and dried in the oven in 70 °C till to stable weight and plant dry weight g/plot (PDW) was measured. After that plant samples were ground using an electric grinder and 0.2 g was weighted, then 5 ml HNO<sub>3</sub> + 2 ml H<sub>2</sub>O<sub>2</sub> accompanied by high temperature (210 °C) microwave device (CEM MarsXp-ress) was dissolved and the volume was completed to 20 ml, thereafter the blue band (Whatman no 42) filter paper was used for filtering. Then total P (mg kg<sup>-1</sup>) was measured by ICP device and after that plant phosphorus uptake mg P pot<sup>-1</sup> was calculated. Additionally, phosphorus use efficiency (Agronomic phosphorus use efficiency (APUE), Physiology phosphorus use efficiency (PPUE) and Apparent recovery phosphorus use efficiency % (ARPUE)) was calculated according to Noor et al. (2017) equations:

- (APUE) = 
$$\frac{\text{Fertilized (Phosphorus) Biomass} - \text{Unfertilized Biomass}}{\text{Amount of applied P2O5}}$$
- (PPUE) = 
$$\frac{\text{Fertilized (Phosphorus) Biomass/plot} - \text{Unfertilized Biomass/plot}}{\text{Phosphorus uptake by plant in fertilizer/plot} - \text{Phosphorus uptake by plant in unertilizer/plot}}$$
- ARPUE(%) = 
$$\frac{\text{Phosphorus uptake by plant in fertilizer/plot} - \text{Phosphorus uptake by plant in unertilizer/plot}}{\text{Amount of applied P2O5}} \times 100$$

All results were statistically analyzed by Computer program Minitab (Minitab 16) and mean separation

was performed by using LSD (Least Significant Difference) procedure.

### 3. Results and Discussion

#### 3.1. Dry Weight and Phosphorus Uptake of Plants

The result cleared that phosphorus doses had a highly significantly affected ( $p < 0.01$ ) on plant phosphorus uptake (PPU) and plant dry weight (PDW) in both experiments (Table 3 and 4). The similar result that, plant phosphorus uptake and biological yield ( $t\ ha^{-1}$ ) of maize in 2014 and 2015 seasons had a highly significant effect ( $p < 0.01$ ) by phosphorus (Saeed et al., 2017). In the same time, Khalili-Rad and Hosseini (2017) stated, that phosphorus had a significant effect ( $p < 0.05$ ) on total phosphorus and shoot dry weight of wheat. Moreover, (Mazengia 2011) who determined that phosphorus application had a non-significant effect on biomass yield of maize as the opposite result. Also, the effect of fertilizer was highly significantly ( $p < 0.01$ ) on PPU in two experiments and PDW in maize experiment, moreover in wheat trial fertilizer had non-significantly affected on PDW (Table 3 and 4). Similar results were found by Papadopoulos (1985) in calcaric soil that, different phosphorus source (mono-ammonium phosphate, di-ammonium phosphate and superphosphate) had a significantly affected on phosphorus availability in calcaric soil and in that time as opposite results that, different phosphorus source had a non-significantly affected on plant dry weight of barley. On the other hand, interaction ( $F \times P$ ) was a highly significant effect ( $p < 0.01$ ) on PPU in bread wheat trial and significantly affected ( $p < 0.05$ ) on PDW in maize. However, PDW in wheat and PPU in maize were non-significant affected by interaction (Table 3 and 4).

In these experiments while increased amount of phosphorus, PDW in maize trail at MAP in range 81 - 223% in addition to at DAP in range 26 - 119% and in bread wheat at MAP between 20 - 31% in addition to at DAP between 14 - 26% were increased depend on control ( $0\ mg\ P_2O_5\ kg^{-1}$ ) (Table 1). Additionally, increased phosphorus doses, PPU in maize at MAP between 58 - 164% in addition to at DAP between 54 -

160% and in bread wheat at MAP in range 45 - 107% in addition to at DAP in range 34 - 210% were increased according to control (Table 1). In these researches, results explained that when applied different amount MAP ( $H_2PO_4^-$ ) and DAP ( $HPO_4^{2-}$ ) in the soil, PDW and PPU of wheat and maize had a high increased stage and MAP is better than DAP. The same results that, while increasing amount of phosphorus that means increased on barely plant dry weight at MAP between (10 - 13%) in addition to at DAP in range 9 - 13% and the phosphorus availability in Calcaric soil at MAP 146 - 592% in addition to at DAP in range 115 - 515% according to control ( $0\ mg\ kg^{-1}$ ) depending on control ( $0\ mg\ kg^{-1}$ ) (Papadopoulos 1985). Similar result too by Khalili-Rad and Hosseini (2017) in wheat and Saeed et al. (2017) in maize were found that when was increasing phosphorus amount, that means increased on a biological yield and phosphorus uptake. Opposite results stated that increasing in phosphorus amount that means decreased a biomass yield (Mazengia 2011).

The highest dose of phosphorus ( $90\ mg\ P_2O_5\ kg^{-1}$ ) had the largest average of PDW at MAP ( $27.68\ g/pot$ ) and at DAP ( $18.94\ g\ pot^{-1}$ ) in maize and at MAP ( $23.98\ g\ pot^{-1}$ ) and DAP ( $25.19\ g\ pot^{-1}$ ) in bread wheat (Table 1). In addition to the highest dose of phosphorus ( $90\ mg\ kg^{-1}$ ) too had the largest average of PPU at MAP ( $24.67\ mg\ P\ pot^{-1}$ ) and at DAP ( $21.08\ mg\ P\ pot^{-1}$ ) in maize and at DAP ( $34.40\ mg\ P\ pot^{-1}$ ). Additionally, the largest average of PPU in bread wheat at MAP ( $22.47\ mg\ P\ pot^{-1}$ ) by  $60\ mg\ P_2O_5\ kg^{-1}$  dose (Table 1). In the other direction, the smallest mean of PDW at MAP ( $8.57\ g/pot$ ) and at DAP ( $8.65\ g\ pot^{-1}$ ) in maize farther at MAP ( $18.35\ g\ pot^{-1}$ ) and at DAP ( $20.00\ g/pot$ ) in wheat by control ( $0\ mg\ P_2O_5\ kg^{-1}$ ) (Table 1). In addition to the smallest mean of PPU at MAP ( $9.35\ g/pot$ ) and at DAP ( $8.11\ g\ pot^{-1}$ ) in maize farther at MAP ( $10.85\ g\ pot^{-1}$ ) and at DAP ( $11.11\ g\ pot^{-1}$ ) in wheat by control ( $0\ mg\ P_2O_5\ kg^{-1}$ ) too (Table 1).

Table 1  
Plant Dry Weight and Phosphorus Plant Uptake of Bread Wheat and Maize

Treatments	Plant Dry Wheat (g pot <sup>-1</sup> )			Phosphorus Plant Uptake (mg P pot <sup>-1</sup> )		
	Plants	Phosphorus doses (mg P <sub>2</sub> O <sub>5</sub> kg <sup>-1</sup> )	Mono-ammonium Phosphate (MAP)	Di-ammonium Phosphate (DAP)	MAP	DAP
Maize		0	8.57	8.65	9.35	8.11
		30	15.48	10.88	14.76	12.50
		60	21.60	13.89	20.38	15.70
		90	27.68	18.94	24.67	21.08
Bread Wheat		0	18.35	20.00	10.85	11.11
		30	21.93	22.89	15.69	14.93
		60	23.83	21.93	22.47	14.61
		90	23.98	25.19	16.89	34.40
Plants		Maize	Bread Wheat	Maize	Bread Wheat	
Least Significant Different (LSD)						
Fertilizers (F) 5%		1.91	No Significant (N.S)	1.66	2.18	
LSD 5% of Phosphorus (P)		2.70	2.58	2.34	3.08	
LSD 5% of interaction (F×P)		3.82	N.S	N.S	0.75	
Standard Error of F (SE±)		0.93	0.88	0.80	0.75	
SE± of P		0.65	0.62	0.57	0.53	
SE± of interaction F× P		1.31	1.25	1.14	1.06	

### 3.2. Agronomic Phosphorus Use Efficiency, Physiology Phosphorus Use Efficiency and Apparent Recovery Phosphorus Use Efficiency of Plants

The result revealed that, Agronomic Phosphorus Use Efficiency (APUE), Physiology Phosphorus Use Efficiency (PPUE) and Apparent Recovery Phosphorus Use Efficiency (ARPUE) of maize and bread wheat were a highly significantly affected ( $p < 0.01$ ) by phosphorus doses (Table 3 and 4). Similar results by Irfan et al. (2018) and Akhtar et al. (2011) in wheat, Saeed et al. (2017) in maize and Papadopoulos (1985) in barely who were stated that Phosphorus had significantly affected on agronomic P efficiency (APE), Physiological P efficiency (PPE) and Phosphorus recovery efficiency (PRE). Also, the effect of fertilizer was highly significantly ( $p < 0.01$ ) on APUE and PPUE in maize and had significantly affected ( $p < 0.05$ ) on ARPUE in bread wheat. Moreover, fertilizer had non-significantly affected on ARPUE in maize in addition to APUE and PPUE in bread wheat trial (Table 3 and 4). Similar results were found by Papadopoulos (1985) in calcareous soil that, different phosphorus source (mono-ammonium phosphate, di-ammonium phosphate and superphosphate) had a significantly affected ( $p < 0.05$ ) on phosphorus recovery (%) of barley. On the other hand, interaction (F×P) was a highly significant effect ( $p < 0.01$ ) on APUE in popcorn and ARPUE in bread wheat. But PPUE and ARPUE in popcorn addition to APUE and PPUE bread wheat were non-significantly affected by interaction (Table 3 and 4).

So generally, phosphorus use efficiency (APUE, PPUE and ARPUE) of wheat and maize in MAP application is higher than DAP application. Papadopoulos (1985) who found that phosphorus recovery (%) of

barely in MAP is better than DAP. In addition to, while increased amount of phosphorus that means APUE at DAP in range 12 - 53% and ARPUE at DAP too between 7 - 21% in maize trial were increased moreover, APUE in bread wheat at MAP between 23 - 48% in addition to at DAP in range 40-67% were decreased according to the smallest quantity of phosphorus (30 mg kg<sup>-1</sup>) (Table 2). The same result to maize and in that time opposite result for bread wheat was found by Saeed et al. (2017) who stated while phosphorus doses were increasing that means increased agronomic efficiency of maize. Moreover, the opposite result for maize and the same result for wheat that, increased of phosphorus quantity, decreased of Agronomic P efficiency (APE) of the wheat plant depending on the lowest amount of phosphorus (Irfan et al. 2018). Furthermore, PPUE in corn at MAP in range 8 - 10% also, in wheat at MAP between 13 - 42% in addition to at DAP in range 38 - 69% were decreased depending on the smallest quantity of phosphorus (30 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup>) (Table 2). Similar result found that increased in phosphorus amount, that means decreased in phosphorus physiological efficiency of maize (Saeed et al. 2017). As an opposite result, an increased amount of phosphorus that is to say physiology phosphorus use efficiency of wheat was increased (Akhtar et al. 2011). Also when phosphorus was ascending, ARPUE in maize at DAP between 7 - 21% were increased moreover in wheat at MAP in range 50 - 38% was decreased depending on the smallest amount of phosphorus (30 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup>) (Table 2). Similar result for wheat and the opposite result for maize was found by Papadopoulos (1985) stated that, increasing amount of phosphorus that means decreased phosphorus recovery (%) of barely at MAP between 62 - 47% and at DAP 56 - 65% accord-

ing to the smallest quantity of phosphorus (15 mg P kg<sup>-1</sup>).

The highest mean of APUE of maize at MAP was 60 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose (80.55) and at DAP was 90 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose (45.06) and of wheat was 30 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose (39.74) and (32.11) at MAP and DAP respectively (Table 2). Also, the highest mean of PPUE of maize was 90 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose (555) and (338) at MAP and DAP respectively in addition to of wheat was 30 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose (356) and (343) at MAP and DAP respectively too (Table 2). Furthermore, the highest mean of ARPUE of maize at MAP was 60 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> (14.04%) and at DAP 90 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose (11.00%) and of wheat at MAP was 30 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose (14.32%) and at DAP 90 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose (18.36%) (Table 2). In other direction, the smallest

mean of APUE of maize at MAP was 90 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose (70.78) and at DAP was 30 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose (29.50) and of wheat at MAP was 90 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose (20.85) and DAP was 60 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose (10.74) (Table 2). Additionally, the smallest mean of PPUE of maize at MAP was 30 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose (504) and at DAP 60 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose (299) in addition to, of wheat at MAP was 60 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose (206) and at DAP was 90 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose (108) (Table 2). In addition to, the smallest mean of ARPUE of maize at MAP was 90 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> (9.36%) and at DAP 30 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose (9.06%) and of wheat at MAP was 60 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose (5.16%) and (4.95%) at MAP and DAP respectively (Table 2).

Table 2  
Phosphorus Use efficiency of Bread Wheat and Maize

Treatments	Agronomic Phosphorus (P) Use Efficiency			Physiology P Use Efficiency		Apparent Recovery P Efficiency (%)		
	Plants	Phosphorus doses (mg P <sub>2</sub> O <sub>5</sub> kg <sup>-1</sup> )	Mono-ammonium Phosphate (MAP)	Di-ammonium Phosphate (DAP)	MAP	DAP	MAP	DAP
Maize		0	0.00	0.00	0	0	0.00	0.00
		30	76.83	29.50	504	312	13.77	9.06
		60	80.55	33.06	546	299	14.04	9.66
		90	70.78	45.06	555	338	9.36	11.00
Bread Wheat		0	0.00	0.00	0	0	0.00	0.00
		30	39.74	32.11	356	349	10.32	9.70
		60	30.42	10.74	206	218	5.16	4.45
		90	20.85	19.20	308	108	6.49	18.36
Plants		Maize	Bread Wheat	Maize	Bread Wheat	Maize	Bread Wheat	
Least Significant Different (LSD) Fertilizers (F) 5%		7.70	No Significant (N.S)	117	N.S	N.S	2.35	
LSD 5% of Phosphorus (P)		10.90	14.19	166	94	3.64	3.32	
LSD 5% of interaction (F×P)		15.41	N.S	N.S	N.S	N.S	4.70	
Standard Error of F (SE±)		3.73	4.86	57	32	1.25	1.14	
SE± of P		2.64	3.44	40	23	0.88	0.80	
SE± of interaction F×P		5.28	6.87	80	45	1.76	1.61	

#### 4. Conclusions

Phosphorus use efficiency of calcareous soil is very low. So increase of plant phosphorus use efficiency, that means decreased the use of phosphorus fertilizers. In these researches, while MAP and DAP fertilizers doses were increasing, highly significantly increased on PDW and PPU according to 0 mg P<sub>2</sub>O<sub>5</sub> kg<sup>-1</sup> dose, but MAP was better than DAP. Generally, while MAP and DAP fertilizers doses were increasing, at DAP

APUE and ARPUE of popcorn were increased moreover, in bread wheat plant APUE at MAP and DAP in addition to, ARPUE at MAP were decreased and general MAP was better than DAP too. Also, when MAP and DAP fertilizers doses were increasing, that means in popcorn at MAP and in bread wheat at MAP and DAP PPUE was decreased and generally MAP was better than DAP too. Finally, when increased phosphorus doses, phosphorus use efficiency was decreased and MAP was better than DAP generally.

Table 3  
Variance analysis of parameters of maize

Treatments	Degree Freedom	Mean square				
		Plant Dry Weight	Plant Phosphorus Uptake	Agronomic phosphorus use efficiency	Physiology phosphorus use efficiency	Apparent recovery phosphorus use efficiency
Fertilizers (F)	1	219.713**	69.205**	7265.287**	215804.30**	27.739 NS
Phosphorus (P)	3	316.518**	292.684**	6296.885**	364525.14**	252.512**
F×P interaction	3	31.368*	4.556 NS	1016.585**	24974.27 NS	20.091 NS
Error	24	6.864	5.154	111.484	25904.38	12.434
Total	31	-	-	-	-	-

(\*\*) Highly significantly affected (1%), (\*) Significantly affected (5%), (N.S) non-significantly affected

Table 4  
Variance analysis of parameters of bread wheat

Treatments	Degree Freedom	Mean square				
		Plant Dry Weight	Plant Phosphorus Uptake	Agronomic phosphorus use efficiency	Physiology phosphorus use efficiency	Apparent recovery phosphorus use efficiency
Fertilizers (PF)	1	1.392 NS	31.271**	314.369 NS	14220.150 NS	41.627*
Phosphorus (P)	3	30.633**	229.228**	1301.929**	126798.422**	184.370**
F×P interaction	3	3.876 NS	174.178**	119.245 NS	15220.008 NS	56.919**
Error	16	4.687	3.343	141.753	6208.853	7.770
Total	23	-	-	-	-	-

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