World Applied Sciences Journal 31 (12): 2045-2050, 2014
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2014.31.12.637

Effect of Low and High Frequency of Phosphorus Fertigation on Movement of Different Forms of Phosphorus Fertilizers in Sandy Calcareous Soils

Mamdouh A. Eissa

Department of Soils and Water, Faculty of Agriculture, Assiut University, Assiut 71526, Egypt

Abstract: Using of phosphorus fertilizers in agriculture production affects on environmental quality, to minimize chances of negative environmental impact from over fertilization we should place them in correct form and with suitable application way. Water solubility and acidity of phosphate fertilizers used in fertigation are critical parameters in choosing the phosphate fertilizers. A column experiment was conducted out to study the effect of phosphorus fertilizers forms (mono-ammonium phosphate (MAP), mono-potassium phosphate (MKP), urea phosphate (UP) and phosphoric acid (PA), fertigation frequencies (every 3 and 6 days) and amount of irrigation water (0.66 and 1.32 L day^{-1}) on the movement and availability of P in sandy calcareous soils. Increasing the amount of irrigation water revealed a highly significant effect (p<0.01) on the distribution of available P underneath the dripper through the soil column. Urea-phosphate and phosphoric acid (acidic P fertilizers) were more mobile compared to the other P fertilizers. Continuous injection of P fertilizer with irrigation water (high-frequency P drip fertigation, P injection every 3 days) significantly (p<0.01) increased the Olsen's extractable P in the surface layers. Based on our results, it may be concluded that amount of water irrigation and fertigation frequency are major factors influenced P availability and movement in sandy calcareous soils. Phosphorus fertilizers in sandy calcareous soils must be added in high frequency with low concentrations.

Key words: Phosphorus Fertilizers · Fertigation · Frequency · Drip Irrigation

INTRODUCTION

Phosphorus fertilizers have different solubility in irrigation water. Some of them make problems when added to the drip irrigation systems. In that respect, special care should be taken with phosphate fertilizers in alkaline and high calcium containing irrigation waters and in calcareous soils, since calcium and magnesium precipitate easily with phosphate. For that reason, it is important to use completely soluble and acidic phosphate fertilizers. This is why acidic fertilizers like mono-ammonium phosphate (MAP), mono-potassium phosphate (MKP), urea phosphate (UP) and phosphoric acid (PA) represent suitable options. High rates of P (80 kg P /ha) applied as mono calcium phosphate (MCP), mono ammonium phosphate (MAP) and ammonium poly phosphate (APP) reduce soil pH by 0.2 and 0.3 unite respectively [1]. Soil pH depression difference may be due to source were mainly caused by the release of H_3PO_4, reaction of MCP with basic cations and nitrification of the added ammonium in MAP and APP. The effect of application rate of drip applied phosphorus fertilizers (rate of P fertigation) consequently is very high as a result of applying the phosphorus over a very small surface area. For example if 20 Ib / acre were applied uniformly through 2500 emitters/acre, this would provide 0.008 Ib P / emitters. If the phosphorus were applied within 4 in. of the emitter, phosphorus concentration within this 4 in. radius would be equivalent to 1000 Ib P /acre. Moreover drip irrigation alone can have an extraordinary effect on phosphorus availability in soil. Bacon and Davey [2] reported elevated concentrations of extractable phosphorus in the wetted zone beneath the emitter for 6 to 23 hours after water only irrigation cycle. Through fertigation nutrients are applied directly into the wetted volume of soil immediately below the emitter where root activity can be concentrated and

Corresponding Author: Mamdouh A. Eissa, Department of Soils and Water, Faculty of Agriculture, Assiut University, Assiut 71526, Egypt.

consequently fertilizer-use-efficiency can be improved over broadcast application. Soil acidification below the emitters resulted in a significant increases the EDTA-extractable Fe, Mn, Zn and Cu [3]. Acid fertilizers can provide several advantages when applied to alkaline calcareous soils. Among these is the enhancement of Fe availability in localized zones of the soil [4]. There are several additional benefits of using acidic fertilizers: enhancing efficiency of phosphate and micro-nutrients and decreasing losses of nitrogen by volatilization. But increasing P movement under drip irrigation may be caused an environmental pollution by phosphorus. Phosphorus movement has received increasing attention in recent years due to its implication in polluting water bodies. The general census about phosphorus movement is that it moves very little from the point of its application [5, 6] but using acid phosphorus fertilizers increased its movement especially under drip irrigation [7].

This study aims to show the effect of different phosphorus fertilizes, the way of application and amount of irrigation water on the movement and availability of P in sandy calcareous soils under drip irrigation

MATERIALS AND METHODS

Distribution of phosphorus was studied in PVC columns 11.0 X 40 cm. Each column filled with soil to 20 cm depth and water added to the columns by drip irrigation system. The variables in this experiment were 1- tow amount of irrigation water 0.66 and 1.32 $Lday^{-1}$, 2- two frequencies of P fertigation (every 3 and 6 days) and 3- phosphorus fertilizer form (Mono ammonium phosphate (MAP) 12% N and 61 % P_2O_5-Mono potassium phosphate (MKP) 34% K_2O and 52% P_2O_5-Urea-phosphate (UP) 18% N and 44% P_2O_5-Phosphoric acid (PA) 61% P_2O_5 - Water extract of superphosphate solution (SP ext.)) Phosphorus was applied by fertigation in drip irrigation system using $4Lh^{-1}$ dripper. Amount of added phosphorus at the end of the experiment was 1.5 gm P / column

Soil mechanical analysis was carried out by the pipette method, according to Day [8]. Soil reaction (pH) was measured in 1:1 (soil: water) suspension using a glass electrode.For studying the effect of fertilization on soil reaction soil pH was measured in 1:2 0.01 M $CaCl_2$ [9]. Calcium carbonate content was measured gas metrically using a volumetric calcium carbonate calcimeter [10]. Organic matter content was determined using the modified Walkely and Black method [11]. Field capacity: was estimated according to the method described by Black *et al*. [10]. Available phosphorus was extracted by 0.5 M Sodium bicarbonate solution at pH 8.5 according to Olsen *et al* [12] and phosphorus was determined colorimetrically using the chlorostannous-phosphomolybdic acid method [9]. The collected data were statically analyzed using MSTAT computer program as described by Michigan State University [13].

RESULTS AND DISCUSSION

Characteristics of Stock Solution for Different Forms of P Fertilizers: Data presented in Table (2) shows the P concentration and pH of the stock solutions of P fertilizers, as well as, the pH of the irrigation water at the drippers after injecting of the P fertilizers solutions. It is quit clear that the concentrated solutions of water extraction of superphosphate (SP ext.), urea-phosphate (UP) and phosphoric acid (PA) have the lowest pH (2.72, 1.71 and 1.66, respectively), while the concentrated solution of mono-ammonium phosphate (MAP) and mono-potassium phosphate (MKP) were moderately acidic and have pH of 5.27 and 5.61, respectively.

These variations in the pH of the concentrated solution of P fertilizers had reflected on the pH of irrigation water at the drippers. Injecting UP and PA concentrated solutions with irrigation water reduced the pH of irrigation water down to 2.16 and 2.14, respectively, while injection the SP solution reduced the pH of irrigation water to 4.06. Injecting of the concentrated solution of MAP and MKP had little effects on the pH of irrigation water, *i.e.* 6.24 and 6.38, respectively.

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

Soil Properties	
Sand (%)	88.7
Silt (%)	8.0
Clay (%)	3.3
Texture	Sandy
Field capacity. %	14.9
Chemical properties	
$CaCO_3$ (%)	14.5
pH (1:1suspention)	8.10
Organic matter (%)	0.60
Olsen P mg /kg	4.50

Table 2: Phosphorus concentration and pH of the stock solution of P fertilizers as well as pH of irrigation water at the drippers.

P Fertilizers form	P fertilizers in stock solutiongm L^{-1}	P Con. in stock solutiongm L^{-1} (calculated)	pH of stock solution	pH of irrigation water at the dripper
Water extract of Super Phosphate (SP ext.)	-	4.99	2.72	4.06
Mono-Ammonium Phosphate (MAP, 12:61:00)	19.11	4.99	5.27	6.24
Mono-Potassium Phosphate (MKP, 00:52:34)	21.98	4.99	5.61	6.38
Urea-Phosphate (UP)	25.97	4.99	1.71	2.16
Phosphoric Acid (PA)	18.56	4.99	1.66	2.14

Table 3: Soil pH and Olsen P in the different layers of soil

Treatments		pH				Available P (ppm)			
		Soil depth (cm)							
Irrigation water amount (I)	P form (Pf)	0-5	5-10	10-15	15-20	0-5	5-10	10-15	15-20
I_1 0.66 ld^{-1}	SP ext.	7.34	7.44	7.54	7.70	204	77	40	32
	MAP	7.35	7.32	7.53	7.65	193	73	42	32
	MKP	7.58	7.55	7.53	7.64	164	69	66	33
	UP	7.33	7.37	7.55	7.70	197	48	39	33
	H_3PO_4	7.34	7.46	7.52	7.68	201	71	40	36
	Mean	7.38	7.43	7.53	7.67	191	68	45	33
I_2 1.32 ld^{-1}	SP ext	7.50	7.47	7.63	7.68	178	93	40	36
	MAP	7.55	7.53	7.52	7.56	168	90	47	37
	MKP	7.61	7.55	7.57	7.62	143	65	63	54
	UP	7.50	7.54	7.67	7.64	187	74	68	56
	H_3PO_4	7.51	7.57	7.69	7.70	167	82	55	42
	Mean	7.53	7.54	7.61	7.64	168	81	55	45
	LSD_I	0.02	0.02	0.02	0.03	6.7	6.8	3.9	4.2
	LSD_{Pf}	0.03	0.02	0.02	0.05	9.5	9.6	5.5	6
	LSD_{I*Pf}	0.05	0.04	0.04	0.07	15.0	15.1	8.6	9.4

SP ext.= water extract of superphosphate, MAP= mono-ammonium phosphate, MKP=mono-potassium phosphate, UP=urea-phosphate and H_3PO_4 = phosphoric acid.

Each value of fre, Pf and fre*Pf represents the mean of 40, 16 and 8 replications, respectively.

ns = insignificant.

Effect of Amount of Irrigation Water on Soil Ph and Movement of P in Soil: The initial value of soil pH averages was around 8.1 (Table, 1). After P fertigation (the addition of P fertilizers with irrigation water) the pH of the soil, especially in the surface layer (0-5 cm), was remarkably changed (Table, 3). The magnitude of this change was associated with both the form of P fertilizers and the amount of irrigation water. Using a low amount of irrigation water, the pH of the surface layer (0-5 cm) was less affected by the addition of MKP (pH = 7.58), while the other P fertilizers had almost the same effect (pH ranged between 7.33-7.35). The pH of the lower layers followed the same trend. This data emphasized that the acidic form of P fertilizers (UP and PA) has a noticeable reducing effects on soil pH. With increasing the amount of irrigation water, MKP fertigation lowered the pH of the surface layer to 7.61, Other P fertilizers (more acidic form) had almost the same effects and reduced the pH to 7.50 –7.55, which showed that the effectiveness of P fertilizers in reducing the soil pH was decreased by increasing the irrigation level. This may be due to the dilution effect of P fertilizer solution. The decrease of soil pH as a result of adding acid P fertilizers was noticed by Mikkelsen and Jarrell [7]. A great diversity in available P was observed among P fertilizers (Table, 3). Mono-potassium phosphate (MKP) gave the lowest amount of Olsen's extractable P compared to other P fertilizers that produced almost the same level of available P and ranged between 143 and 204 ppm. This diversity may relate the differences between P fertilizers in their solution acidity and reaction with the soil constituents. As mentioned above, the concentrated solution of MKP had the highest pH compared with other P fertilizers (5.61). Moreover, injecting the concentrated solution of MKP into irrigation water gave the highest pH (6.38). Therefore, MKP was probably more legitimist to convert to less available form compared to the other P fertilizers.

Table 4: Effect of P fertigation frequency and forms of phosphorus fertilizers on soil pH and distribution of available P with soil depth.

Treatments		pH				Available P (ppm)			
		Soil depth (cm)							
P Fertigation frequency (Fre)	P form (Pf)	0-5	5-10	10-15	15-20	0-5	5-10	10-15	15-20
High fre. (every 3 days)	SP ext.	7.33	7.42	7.57	7.65	203	90	40	37
	MAP	7.44	7.40	7.58	7.63	192	88	49	31
	MKP	7.55	7.50	7.53	7.61	161	78	62	43
	UP	7.36	7.49	7.61	7.61	198	58	60	40
	H_3PO_4	7.37	7.40	7.52	7.61	192	83	46	37
	Mean	7.41	7.44	7.56	7.61	189	79	51	37
Low fre. (every 6 days)	SP ext	7.51	7.56	7.60	7.74	179	80	40	31
	MAP	7.45	7.44	7.47	7.58	169	75	40	37
	MKP	7.64	7.61	7.58	7.64	146	56	67	44
	UP	7.48	7.42	7.62	7.72	187	64	47	49
	H_3PO_4	7.48	7.62	7.69	7.77	176	71	49	41
	Mean	7.51	7.53	7.59	7.69	171	69	48	40
	LSD_{fre}	0.02	0.02	0.02	0.03	6.70	6.8	3.9	ns
	LSD_{Pf}	0.03	0.02	0.02	0.05	9.49	9.6	5.5	6
	LSD_{fre*Pf}	0.05	0.04	0.04	0.07	ns	ns	8.6	ns

SP ext. = water extract of superphosphate, MAP= mono-ammonium phosphate, MKP=mono-potassium phosphate, UP=urea-phosphate and H_3PO_4 = phosphoric acid.

Each value of fre, Pf and fre*Pf represents the mean of 40, 16 and 8 replications, respectively.

ns = insignificant.

Increasing the amount of irrigation water revealed a highly significant effect (p<0.01) on the distribution of available P underneath the dripper through the soil column. Changes in available P were most apparently directly in the upper layers (0-5 and 5-10 cm layers). Increasing the amount of irrigation water from 0.66 to 1.32 l d^{-1} resulted in reducing the amount of available P in surface layer (0-5 cm); however the available P in the subsurface layers (5-10, 10-15 and 15-20 cm) was increased. Increasing the amount of irrigation water with using the completely soluble and high acidic P fertilizers resulted in moving the phosphate with irrigation water to subsurface layers. The movement of phosphate with irrigation water did not exceed the upper 10 cm of the soil column; therefore, the risk of loss the soluble phosphate with down movement of water is limited. Maintenance of relatively high moisture status and high frequency irrigation lead to greater P mobility and movement of phosphate ions from the upper 5 cm to the lower next 5 cm layer. Increased mobility of P dissolved in irrigation water with increased irrigation frequency has been observed, especially in sandy soils [2, 14, 15]. The improved mobility has been attributed to movement of P in mass flow with irrigation waters after saturation of reaction sites near the zone of P application. The extent of P mobility is illustrated from the fertigation studies carried out by many investigators [16, 17].

Movement of phosphate with irrigation water was to some extent varied with P fertilizer. Changing the companion ions with phosphate may affect the mobility of phosphate with downstream of irrigation water [18]. Phosphate movement with irrigation water showed some diversity with the form of P fertilizer. Urea-phosphate and phosphoric acid (acidic P fertilizers) were more mobile compared to the other P fertilizers. The acidity of the solution of P fertilizer may keep the phosphate ions in soluble form and expose more to move with irrigation water. This result is expected because the chemical species of phosphorus present in the soil solution is determined by soil solution pH.

Effect of Frequency of P on Soil Ph and Availability of P in Soil: Table (4) shows the effects of frequency of P fertigation with different P fertilizers on P availability (Olsen's P) and P distribution in soil layers. Continuous injection of P fertilizer with irrigation water (high-frequency P drip fertigation, P injection every 3 days) significantly (p<0.01) increased the Olsen's extractable P in the surface layers.

Contrary to this, with low-frequency P drip fertigation (P injection every 6 days), the available P was substantially decreased. With low P fertigation frequency the reaction time with soil constituents like calcium carbonate and magnesium carbonate was increased, therefore, either precipitation and/or adsorption reactions of phosphates may have increased and finally reduced the amount of available P. With low-frequency P drip fertigation, the time span after application of P fertilizer was increased making the conditions more favorable for adsorption and / or precipitation reactions to occur. Similar results were obtained by Silber et al [19]. This effect was more pronounced with P fertilizers that had low acidic solution i.e. MAP and MKP. The reduction in available P due to low frequency P fertigation ranged between 11.0 and 12.5 %. In the case of using more acidic P fertilizers i.e. PA and UP, the reduction in available P in surface layers were less and ranged between 5-8%.

High-frequency phosphorus fertigation may increase the time-averaged P concentration in the soil solution above that expected from P solubility considerations. Al-Khateeb *et al*. [20]. in their studies on the phase equilibria and kinetics of orthophosphate, reported that the concentration of water soluble P decreased after 0.5 hr from P addition. They showed that precipitates of dicalcium phosphate dihydrate, octacalcium phosphate and B-tricalcium phosphate were formed after 3000 hr from P addition. Urea phosphate (UP) and phosphoric acid (PA) were the most effective forms of P fertilizers. More amount of Olsen's extractable P was obtained compared to other P fertilizers under the different frequency of P fertigation. The superiority of urea phosphate and phosphoric acid is possibly due to the acidity of these fertilizers. With each application of acid forms of P fertilizers the newly added acid dissolves some of the previously formed Ca phosphate. Mikkelsen and Jarrell [7]. found that application of acid solublized native soil P. Garcia *et al*. [21]. studied the effect of different forms of phosphorus fertilizers on phosphate availability and found that phosphate availability and therefore, plant phosphorus absorption increased when fertilizing with urea phosphate. P applied through drip irrigation system is more mobile and available especially in sandy calcareous soils [22-24].

CONCLUSIONS

Low mobility and availability of phosphorus specially in calcareous soils are the great challenge that face the fertilization management in such soils. Increasing rate of P fertilization to avoid its precipitation and obtain high economic return, may be caused an environmental problems, to achieve high yield without rising P rates, frequent P fertigation in low concentration must be used. From our results we found that increasing amount of irrigation water increased the movement and availability of phosphorus under drip irrigation especially with acid fertilizers.High-frequency of phosphorus fertigation increased the availability of phosphorus in soil and reduced soil pH and this may be lead to more P use efficiency and reduced loss of phosphorus from soil system.

REFERENCES

1. Al-Showk, A.M., R.L. Westerman and D.L. Weeks, 1987. Influence of phosphorus source and rates on soil pH, extractable phosphorus and DTPA-extractable micronutrients. J. Soil Sci., 144(1): 36-42
2. Bacon, P.E. and B.G. Davey, 1982. Nutrient availability under trickle irrigation: I. Distribution of water and Bray no. 1 phosphate. Soil Sci. Soc. Am. J., 46: 981-987.
3. Haynes, R.J. and R.S. Swift, 1987. Effect of trickle fertigation with three forms of nitrogen on soil pH, levels of extractable nutrients below the emitter and plant growth. Plant and Soil, 102: 211-221.
4. Wallace, A., 1988. Acid and acid-iron fertilizers for iron-deficiency control in plants. J. Plant Nutr., 11(6-11): 1311-1319.
5. Baker, J.L., K.L. Campbell, H.P. Johnson and J. Jhanway, 1975. Nitrate, phosphorus and sulfate in subsurface drainage water. J. Environ. Qual., 4: 406-412.
6. Papadopoulos, I., 1992. Phosphorus fertigation of trickle-irrigated potato. Fertil. Res., 31: 9-13.
7. Mikkelsen, R.L. and W.M. Jarrell, 1987. Application of urea phosphate and urea sulfate to drip irrigated tomatoes grown in calcareous soil.Soil Sci. Soc. Am. J., 51: 464-468.
8. Day, P.R., 1965. Particle fraction and particle size analysis. p. 545-567. In O.D. Evans, L.E. Ensminger, J.L. White and F. E. Clark (eds.). Methods of soil analysis, Part I. ASA Inc., Madison, WI, USA.
9. Jackson, M.L., 1973. Soil chemical analysis. Prentice–Hall, India.
10. Black, C.A., D.D. Evans, J.L. White, L.E. Ensminger and F.E. Clark, 1965. Methods of soil analysis part II. Am. Soc. Agron. Inc. Madison, USA.
12. Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean, 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S.D.A. Dept. Agric.Cir. 939.Beltsville, MD

13. Michigan State University, 1983. MSTAT-C Micro-Computer Statistical Program, Version 2. Michigan State University, East Lansing, USA.
14. Mbagwu, J.S.C. and J.O. Osuigwe, 1985. Effect of varying levels and frequencies of irrigation on growth, yield, nutrient uptake and water use efficiency of maize and cowpeas on a sandy loam ultisol. Plant Soil, 84: 181-192.
15. Kargbo, D., J. Skopp and D. Knudsen, 1991. Control of nutrient mixing and uptake by irrigation frequency and relative humidity. Agron. J., 83: 1023-1028
16. Sharma, P.K., A. K Sinha and T.N. Chaudhary, 1985. Movement of surface and deep placed phosphorus in a sandy loam soil in relation to initial soil wetness, amount of water applied and evaporation potentials. Soil Sci., 140(4): 256-363.
17. Ben-Gal, A. and L.M. Dudley, 2003. Phosphorus availability under continuous point source irrigation. Soil Sci. Soc. Am. J. 67: 1449-1456.
18. Basak, R.K., 2000. fertilizers. A text Book Kalyani pub. Ludhiana-New Delhi, Noida (UP) Hyderabad-Chennal–Calcutta–New Delhi, pp: 167-232.
19. Silber, A., G. Xu, I. Levkovitch, S. Soriano, A. Bilu and R. Wallach, 2003. High fertigation frequency: the effects on uptake of nutrients, water and plant growth. Plant and Soil, 253: 467-477.
20. Al-Khateeb, I.K., M.J. Raihan and S.R. Asker, 1986. Phase equilibria and kinitics of orthophosphate in some Iraqi soils. Soil Sci., 141(1): 31-37.
21. Garcia, M.C., J.A.Diez, A. Vallejo, L. Garcia and M.C. Cartagena, 1997. Effect of applying soluble and coated phosphate fertilizers on phosphate availability in calcareous soils on P absorption by a Rye-Grass crop. J. Agric. Food Chem., 45: 1931-1936.
22. Eissa, M.A., M. Nafady, H. Ragheb and K. Attia, 2010. Management of Phosphorus Fertigation for Drip Irrigated Wheat under Sandy Calcareous Soils. World Journal of Agricultural Sciences, 6(5): 510-516.
23. Eissa, M.A., M. Nafady, H. Ragheb and K. Attia,. 2013. Effect of Soil Moisture and Forms of Phosphorus Fertilizers on Corn Production under Sandy Calcareous Soil. World Applied Sciences Journal, 26(4): 540-547, 2013 ISSN 1818-4952
24. Eissa, M.A., 2014. Improving Yield of Drip-Irrigated Wheat under Sandy Calcareous Soils. World Applied Sciences Journal, 30(7): 818-826.