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Evaluation of Phosphorus Sources and Rates on The Yield and Quality of Fertigated Potato Grown in Sandy Soil

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A FIELD experiment was performed in the sandy soil at El-Sadat City, Menoufiea Governorate, Egypt, for two consuctive seasons (2013 and 2014) to investigate the effect of different sources and rates of phosphorus fertilizers on yield and tuber quality of potato (*Solanum tuberosum* L.*)* Cv. Diamante grown on sandy soil. The experiment was conducted under drip irrigation system in split design with three replicates. Four sources of phosphorus were used: phosphoric acid (H_3PO_4), mono ammonium phosphate (MAP), ammonium poly phosphate (APP) and urea phosphate (UP) with three rates, 50, 75 and 100 kg P_2O_5/fed applied through irrigation water.The results showed significant differences among the sources and rates of phosphorus fertilizers on total yield, tuber weight, tuber diameter, specific gravity and starch content of tuber. The data revealed that UP and APP were the best among other sources. Data also showed that yield and quality of tuber increased with increasing phosphorus rates up to 100 kg P_2O_5/fed. The data also presented that in both seasons, UP gave the highest P concentration in soil compared with other sources of phosphorus.

Keywords : Potato, Phosphorus fertilizers, Fertigation, Tuber quality.

Introduction

Potato (*Solanum tuberosum* L.) is one of the most important vegetables in Egypt which gained a considerable importance as an export to European markets (Eleiwa et al., 2012). Potato is a short-cycle crop and present high production capacity, it is highly influenced by the application of different nutrients to the soil (Luz et al., 2013).

It has been usually applied high rates of phosphate fertilizers in the cultivation, aimed at achieving high levels of tuber yield and larger tuber (Luz et al., 2013). Phosphorus has various effects on tuber quality, such as tuber size and percentage of dry matter (indicated by specific gravity) of the tuber (Freeman et al., 1998 and Rosen et al., 2014).

Kafkafi (1994) considered fertigation as an efficient method for providing and supplying available forms of immobile elements such as P, at a desirable level in root zone. Also successful P-fertigation has been reported by Papadopoulos, (2000). As regards to the effect of P source on yield, Brito et al. (2000) revealed that the highest commercial yield was obtained with H_3PO_4 applied through trickle irrigation. Papadopoulos and Ristimaki-Leena (2000) indicated that UP as a source of P gave the highest yield compared with DAP and MAP.

This study was initiated to evaluate the effect of different sources and rates of phosphorous fertilizers on yield and quality of potatoes tuber grown in sandy soil under fertigation system.

Material and Methods

A field experiment was established at El-Sadat City, Menoufia Governorate, Egypt, during two successive Fall (nili) seasons 2013 and 2014. Potato (*Solanum tuberosum* L.). Cv. Diamante was chosen as an indicator plant in this study. The split plot design was used with three replicates under drip irrigation system. The plot area was 17.5 m^2 (3.5 m x 5m). Some physical and chemical properties of initial soil under investigation are shown in Table 1.

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TABLE 1. Particles size distribution and chemical analysis of soil sample of the experimental site

Particle size distribution (g/kg)		Chemical analysis	
• Clay	47	• pH (1:2.5)	8.0
• Silt	50	• EC (dS/m^{-1})	0.39
• Fine sand	228	• $CaCO_3$ (g/kg)	38
• Coarse sand	675	• OM (g/kg)	0.7
• Texture class	Sandy	• Available nutrients (mg/kg)	N 35 P 4.9 K 66

The sources of phosphorus are as follow :

T_1: Phosphoric acid [H_3PO_4]
T_2: Mono ammonium phosphate (MAP) [$NH_4H_2PO_4$]
T_3: Ammonium polyphosphate (APP) [$(NH_4)_3 HP_2O_7+NH_4H_2PO_4$]
T_4: Urea phosphate (UP) [$CO(NH_2)_2.H_3PO_4$]

Three rates of phosphorus were used 50, 75 and 100 kg P_2O_5/Fed, assigned as R_1, R_2 and R_3 respectively. Both nitrogen and potassium were applied according to recommendation of Ministry of Agriculture and Land Reclamation. All P sources H_3PO_4, MAP, APP and UP were applied three times/week.

Whole seed tubers were planted in row 0.70 m apart and 0.25 m within the row on October 15^{th}.

Soil analysis

Soil samples (0-30 cm) were taken from the experimental site at the beginning and the end of the experiment. Particle size distribution was carried according to Gee and Bander (1986). Total $CaCO_3$ was dertermined using Collins calicimeter (Sparks, 1996). pH, EC, organic matter , available K, P and N were determined according to Sparks, (1996).

Data for plant recorded

Each experimental plot was harvested after 120 days of planting, then total tuber yield (ton/fed) were recorded. For each plot h arvested tubers were graded into three categories according to tuber weight i.e. small (< 30g), medium (30-60 g) and large tubers (> 60 g). Specific gravity of tubers was estimated, where :

specific gravity = weight in the air/weight in the air-weight in the water.

Starch (%) was determined according to the method described by Nandutu et al. (2002). Phosphorus was determined in the fourth leaf from the top after 75 days from planting and in tubers according to the method described by Pierzynski (2000). The obtained data were statically analyzed according to Snedecor and Cochran (1990).

Results and Discussion

Yield

The tuber weight of each class category as affected by phosphorus fertilizer sources at harvest is presented in Tables 2 & 3. The data indicated significant differences between the sources and the rates of P fertilizer in terms of the grades of tuber weight. In both seasons potatoes of APP treatment had significantly lower yield of small tuber compared to that obtained with other sources.

Also, UP and APP had significantly higher tuber yield of medium and large size compared to those supplied with other P sources. These results were in agreement with Salem et al. (2004). The data showed that, as the P rate increased, the yield of medium (30-60g) and large (> 60 g) size tubers increased. In both seasons, potatoes of the treatment of 100 P_2O_5/fed. had significantly lower weight of small tuber size comparing to other P fertilizer rates. These results agree with those of Curless et al. (2004).

Data of Table 3 indicate that in both seasons, total yield was significantly affected by the P fertilizer sources. Potato of the treatments of APP and UP had significantly highest total yields comparing to other sources. These results are in agreement with Papadopoulos (2000) who found that UP gave the highest yield.

The results showed that the increase of the yield was proportionally with the increase of P rate of application. Agreeing with these results, Luz et al. (2013) mentioned that application of high rates of phosphate fertilizers produced high levels of both potatoes yield and larger tubers.

TABLE 2. Effect of source and rate of P fertilizers on yield of small and medium potato tubers

Sources	Yield (ton/fed)							
	Small tubers				Medium tubers			
	Season 2013							
	Rate of P application							
	R1	R2	R3	Mean	R1	R2	R3	Mean
T1	0.950	0.900	0.880	0.911a	6.46	6.92	7.16	6.85b
T2	0.942	0.890	0.870	0.901b	6.51	7.20	7.45	6.94b
T3	0.736	0.617	0.609	0.654c	7.60	7.92	8.49	8.00a
T4	0.730	0.610	0.600	0.647d	7.65	8.00	8.56	8.07a
Mean	0.839a	0.755b	0.740c		6.97c	7.51b	7.92a	
LSD 0.05	Source		0.003			0.177		
	Rate		0.002			0.150		
	Season 2014							
T1	1.01	0.950	0.880	0.947a	5.78	6.00	6.59	6.13c
T2	0.985	0.940	0.870	0.932b	5.90	6.12	6.99	6.34b
T3	0.785	0.710	0.660	0.718c	8.13	8.85	9.16	8.71a
T4	0.780	0.702	0.653	0.712d	8.15	8.85	9.17	8.72b
Mean	0.890a	0.825b	0.766c		6.99c	7.46b	7.97a	
LSD 0.05	Source		0.002			0.014		
	Rate		0.003			0.025		

TABLE 3. Effect of source and rate of P fertilizers on large tubers and total yield of potato

Sources	Yield (ton/fed)				Total yield (ton/fed)			
	Large tubers							
	Season 2013							
	Rate of P application							
	R1	R2	R3	Mean	R1	R2	R3	Mean
T1	1.95	2.00	2.19	2.05c	9.36	9.82	10.23	9.80c
T2	2.10	2.19	2.25	2.18b	9.55	10.28	10.57	10.13b
T3	2.70	3.00	3.30	3.01a	11.04	11.54	12.40	11.66a
T4	2.73	3.01	3.31	3.02a	11.11	11.62	12.47	11.73a
Mean	2.37c	2.56b	2.76a		10.27c	10.82b	11.42a	
LSD 0.05	Source		0.095			0.110		
	Rate		0.079			0.079		
	Season 2014							
T1	2.03	2.15	2.30	2.16b	8.82	9.10	9.77	9.23c
T2	2.10	2.20	2.38	2.23b	8.98	9.26	10.24	9.49b
T3	2.80	2.99	3.49	3.08a	11.72	12.55	13.31	12.53a
T4	2.88	3.00	3.51	3.14a	11.81	12.55	13.33	12.56a
Mean	2.45c	2.59b	2.92a		10.33c	10.86b	11.66a	
LSD 0.05	Source		0.141			0.105		
	Rate		0.081			0.066		

Data in Table 4 indicated that all sources of phosphorus had similar effect on tuber weight and size in both seasons. Both UP and APP were superior than the other P fertilizers sources.

In both seasons, increasing phosphorus rate significantly affected tuber weight and size. For all sources of P fertilizers, application of 100 kg P_2O_5/fed produced maximum tuber weight and size. These results agree with those of Alvarez-Snchez et al. (1999).

Tuber quality

The tuber specific gravity is a measure of quality of potato tuber which is related to the dry matter content of the tuber, The specific gravity was positively affected by P fertilization (Table 5). The specific gravity of potatoes of treatments of the high rate of UP and APP were lower than those recorded for other sources and rates of P fertilizers treatments. Significant differences were obtained between both UP and APP and the other sources in both seasons, while the differences

between UP and APP were insignificant. In this concern, Rosen et al. (2014) found that the specific gravity levels were maximized by the lowest rates of P applied. Also, Freeman et al., (1998) observed reduction in the specific gravity of potato tuber as a function of P rates. These results were in agreement with Khan et al. (2010) where they reported that potatoes with low specific gravity are preferred for preparation of chips and French fries. Potatoes with low specific gravity are used for canning. However, potatoes of very high specific gravity (1.10 g/cm^3) may not be suitable for French Fries production because they become hard or biscuit like. So purpose of growing potato should be kept in mind.

TABLE 4. Effect of source and rate of P fertilizers on weight and size of potato tubers

Sources	Average tuber weight (g)				Tuber size (cm)			
	Season 2013 Rate of application							
	R1	R2	R3	Mean	R1	R2	R3	Mean
T1	151.2	158.3	160.2	156.57b	6.24	6.30	6.48	6.37b
T2	152.3	159.9	162.3	162.17b	6.35	6.45	6.59	6.48b
T3	155.3	158.2	173.3	162.27a	6.65	6.70	6.80	6.72a
T4	157.6	160.2	174.5	164.10a	6.70	6.79	6.88	6.79a
Mean	154.1c	159.2b	167.57a		6.52b	6.56ab	6.69a	
LSD 0.05	Source		2.739			0.148		
	Rate		1.298			0.152		
	Season 2014							
T1	152.1	158.3	162.2	157.53b	6.36	6.45	6.53	6.45b
T2	154.0	159.4	165.3	159.57b	6.40	6.55	6.66	6.54b
T3	160.3	168.2	174.3	167.6a	6.80	6.90	7.10	6.93a
T4	161.2	169.3	176.7	169.07a	6.85	6.99	7.20	7.01a
Mean	156.9c	163.8b	169.62a		6.60c	6.72b	6.87a	
LSD 0.05	Source		3.702			0.153		
	Rate		1.117			0.073		

TABLE 5. Effect of source and rate of P fertilizers on specific gravity and starch content of potato

Sources	Specific gravity (gm/cm3)				Starch (%)			
	Season 2013 Rate of P application							
	R1	R2	R3	Mean	R1	R2	R3	Mean
T1	1.092	1.089	1.082	1.088a	12.22	12.50	13.16	12.63c
T2	1.090	1.086	1.080	1.085a	14.11	14.30	15.25	14.55b
T3	1.075	1.063	1.061	1.066b	17.10	17.21	19.99	18.10a
T4	1.071	1.060	1.059	1.063b	17.25	17.36	20.48	18.36a
Mean	1.082a	1.074b	1.071b		15.17b	15.34b	17.22a	
LSD 0.05	Source		0.006			1.163		
	Rate		0.007			0.622		
	Season 2014							
T1	1.094	1.089	1.082	1.088a	12.71	13.10	13.82	13.21b
T2	1.090	1.085	1.080	1.085a	12.82	13.25	13.93	13.33b
T3	1.079	1.069	1.066	1.071b	18.23	19.85	21.70	19.93a
T4	1.073	1.066	1.061	1.067b	18.30	19.90	21.72	19.97a
Mean	1.084a	1.077b	1.072c		15.51c	16.52b	17.79a	
LSD 0.05	Source		0.013			0.511		
	Rate		0.003			0.723		

Data in Table 5 illustrate that starch in potato tuber was significantly affected by both sources and rates of P application. Among all P sources, starch content of UP treatment was the highest.

In both seasons, increasing phosphorus rate significantly affected starch content in potato tuber. These results are in agreement with those of Stark and Love (2003) who reported that, the

influences of P on solids are expected as P tends to increase starch synthesis and hasten crop maturity. Also, Fernandes et al. (2015) found that as the rate of P increased, the starch content increased. Phosphorus participates in a number of key enzymes involved in the regulation of starch synthesis (sucrose phosphate synthase, fructose- 1,6 – bisphosphatase and ADP-glucose pyrophosphorylase) (Taiz and Zeiger, 2013) and is also part of its composition, being connected to the amylopection fraction of starch, in the form of phosphate ester (Nielsen et al. 1994).

Phosphorus content in potato leaves and tubers

Data in Table 6 indicated that sources of P fertilizer had significant effect on P percentage of leaves and tubers at harvest (120 days after planting). In both seasons, P percentage in leaves and tubers of potatoes which supplied with UP was significantly higher than those fertilized with other sources. These results are similar to those reported by Al-Showk et al. (1987). Eissa (2014) also found that phosphate availability and therefore, plant phosphorus absorption increased with urea phosphate.

The data also indicated that increasing phosphorus rate significantly affected P percentage in leaves and tuber. Similar trend was obtained by Fernandes et al. (2015).

Available phosphorus

Phosphorus content in soil at the beginning and the end of experiment are presented in Table 7. The soil P content significantly increased as the rate of applied P increased.

Regarding, P source, the data illustrated that UP and APP give the highest values of P content in soil comparing with other sources. Similar results were obtained by Papadopoulos, (2000) who found that more positive results obtained with UP. Also, he reported that the concentration of P in soil solution is increased due to the induced acidification by UP. Eissa (2014) and Eissa et al. (2010) reffered the superiority of urea phosphate to the acidity of this fertilizer .

TABLE 6. Effect of source and rate of P fertilizers on phosphorus (%) of potato leaves and tubers

Sources	Leaves				Tuber			
	Season 2013							
	Rate of P application							
	R1	R2	R3	Mean	R1	R2	R3	Mean
T1	0.340	0.390	0.420	0.383d	0.210	0.240	0.260	0.237d
T2	0.360	0.401	0.440	0.400c	0.220	0.250	0.280	0.250c
T3	0.405	0.447	0.504	0.452b	0.295	0.315	0.355	0.322b
T4	0.410	0.450	0.510	0.457a	0.300	0.320	0.360	0.327a
Mean	0.379c	0.422b	0.469a		0.256c	0.281b	0.314a	
LSD 0.05	Source		0.006			0.007		
	Rate		0.005			0.005		
	Season 2014							
T1	0.370	0.421	0.460	0.417d	0.230	0.240	0.255	0.242d
T2	0.382	0.435	0.470	0.429c	0.240	0.256	0.269	0.255c
T3	0.443	0.490	0.553	0.495b	0.335	0.340	0.360	0.344b
T4	0.450	0.500	0.560	0.509a	0.340	0.350	0.365	0.351a
Mean	0.411c	0.462b	0.515a		0.286c	0.296b	0.312a	
LSD 0.05	Source		0.009			0.003		
	Rate		0.007			0.003		

TABLE 7 . Phosphorus content in soil (mg/kg) at the beginning and the end of experiment

Sources	At the beginning of experiment				At the end of experiment			
					Season 2013			
	Rate of P application							
	R 1	R2	R3	Mean	R1	R2	R3	Mean
T1	7.50	9.12	11.50	9.37b	9.30	11.20	13.87	11.46b
T2	7.62	9.19	11.63	9.48b	9.40	11.31	13.90	11.54b
T3	8.05	10.45	12.18	10.22a	9.95	12.75	14.75	12.48a
T4	8.10	10.50	12.20	10.27a	10.00	12.83	14.80	12.55a
Mean	7.82c	9.81b	11.88a		9.67c	12.02b	14.33a	
				L.S.D 0.05				
Sources		0.177				0.107		
Rates		0.075				0.085		
					Season 2014			
T1	7.90	9.38	11.61	9.53b	9.98	13.68	15.33	12.99 b
T2	7.95	9.45	11.70	9.70b	10.00	13.76	15.40	13.05b
T3	8.80	10.20	12.50	10.50a	10.70	13.80	15.60	13.37a
T4	8.89	10.25	12.54	10.56a	10.79	13.86	15.61	13.42a
Mean	8.31c	9.82b	12.09a		10.36c	13.78b	15.48a	
				L.S.D 0.05				
Sources		0.184				0.079		
Rates		0.162				0.083		

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تقييم مصادر ومعدلات الأسمدة الفوسفاتية على محصول وجودة البطاطس النامية فى الأراضي الرملية تحت نظام الري التسميدي

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أقيمت تجربة حقلية فى تربة رملية بمدينة السادات – مصر لموسمين متعاقبين (٢٠١٣-٢٠١٤) وذلك لتقييم تأثير مصادر ومعدلات مختلفة من الأسمدة الفوسفاتية على المحصول الكلى وجودة درنة البطاطس لصنف دايمونت.

نفذت التجربة تحت نظام الري بالتنقيط وأستخدم فيها التصميم الإحصائى لنظام القطع المنشقة في ثلاث مكررات. أستخدم ٤ مصادر مختلفة من الأسمدة الفوسفاتية وهى حامض الفوسفوريك ، فوسفات أحادي الأمونيوم ، بولي فوسفات الأمونيوم ، فوسفات اليوريا وذلك بثلاث معدلات وهى ٥٠ ، ٧٥ ، ١٠٠ كجم P_2O_5 للفدان تم إضافتهم فى نظام الري بالتنقيط.

وبمقارنة مصادر ومعدلات أسمدة الفوسفات المختلفة ، أوضحت النتائج أن هناك إختلافات معنوية بين مصادر ومعدلات الأسمدة الفوسفاتية على كلاً من المحصول الكلى ووزن وقطر الدرنة والكثافة النوعية ومحتوى الدرنة من النشا. وأظهرت النتائج أن فوسفات اليوريا وفوسفات أحادي الأمونيوم كان أفضل مقارنة بباقى المصادر الأخرى.

وأوضحت النتائج أن كلاً من المحصول وجودة الدرنة تزيد بزيادة معدلات الفوسفور حتى ١٠٠ كجم P_2O_5 للفدان. وأن فوسفات اليوريا أعطى أعلى تركيز فوسفور في التربة مقارنة بباقى المصادر الأخرى.