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EFFICIENT USE OF PHOSPHATE FERTILIZER THROUGH PHOSPHATE SLURRY METHOD IN TRANSPLANTED TOMATO

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ABSTRACT

A pot experiment was carried out to study the response of tomato (Nemathoda 1400 CV.) to broadcasting, band and slurry phosphate fertilizer placement methods and their combinations. Phosphate fertilizer was applied at two rates; i.e. 10 and 20 mg P_2O_5 kg^{-1} soil for each method comparing with a 0 mg P_2O_5 kg^{-1} soil serving as a control. Tomato seedlings were grown in pots containing 25 kg P-deficient loamy sand soil for 45 days after transplanting.

Results showed that shoot, root dry weight, root length, root surface area and N, P and K content of tomato shoot were significantly lower for broadcasting P placement method than all other P methods and slurry method provide the superiority amoung the other methods.

Shoot dry matter production ratio was higher for the broadcasting method and the unfertilized P treatments. Phosphorus use efficiency was greater at lower P rates than at higher P ones. Applying P fertilizer as slurry recorded the highest value of phosphorus use efficiency compared to the other P placement methods.

Keywords: Phosphate fertilizer, slurry, band, P-use efficiency and P-placement methods.

INTRODUCTION

A primary limitation of crop production in soils of arid and semiarid regions is the lack of available nutrients, especially phosphorus. In these regions, application of P fertilizers (e.g., supper phosphate) is a common agricultural practice to attain high yields. However, after its application, a large proportion of P-fertilizer is converted to insoluble forms due to high pH and high $CaCo_3$ content (Al-Karaki and Al-Omoush, 2002).

Soils of Egypt are normally basic in reaction; therefore, the low availability of phosphorus to plants is common especially in highly calcareous soils.

Efficient use of phosphate fertilizers is important from both an economic viewpoint and the conservation of world's phosphate resources. The development of sustainable agricultural system will requires new techniques that help to minimize fertilizer application rate, while maintaining adequate crop yields. Method of phosphate fertilizers application is currently an active field of research that may hold promise for the future. There are several methods of P placement. Broadcasting is the most common method of application for crops. However, in soil with high phosphate fixation and low levels of available P, the application of P in bands generally increases productivity relative to broadcasting (Ahmed *et al.*,2004, Malhi *et al.*, 2001; Rogerio and Mallarino, 2001; Truk and Tawaha, 2001 and 2002; Rashid and Awan, 2002 and Sims and Smith, 2002). It has been reported that banding phosphate with seeds gives early availability of P and in many cases total dry matter and grain yield production increased, even in soils with medium–to-high levels of available P (Jackson *et al.*, 1997 and El- Maghraby, 2000). Patel and Patel (1995) recorded that grain yield and phosphorus use efficiency of rice were highest with 10 Kg P_2O_5 through slurry compared with 40-80 kg P_2O_5 ha^{-1} by broadcasting. This study aimed to evaluates the early growth and uptake of some nutrients of tomato plants as will as P-use efficiency in response to different P-application methods.

MATERIALS AND METHODS

A pot experiment was conducted to evaluate the response of tomato plants (Nemathoda 1400 cv.) to P placement methods at different P application rates in P-deficient soil. Surface soil sample was taken from Nubaria, Behera Governorate. The soil used was P-deficient soil ($NaHCO_3$-extractable P in soil was 3.5 mg kg $soil^{-1}$) determined after Olsen *et al.*, (1954). The soil characteristics were: pH 7.6 (1:1 soil: water ratio) after Richarads (1954), organic matter percent was 0.45 determined by oxidizing with cromic acid according to Walkley and Black (1934). Calcium carbonate percent was 4 estimated using collions calcimeter according to Wright (1939).

Foam plates of 42×30×25 cm dimensions were filled with soil sample (25 kg soil per plate). After packing, the soil was wetted using tap water to settle the soil. Five tomato seedlings (25 days old) were transplanted in the center of each pot in the top 7 cm (the depth of seedlings root was 7 cm). Supper phosphate (15.5% P_2O_5) was added to soil at two application rates; 10 and 20 mg P_2O_5 kg $soil^{-1}$, respectively with a 0 mg P_2O_5 kg $soil^{-1}$ serving as a control treatment. At each level of applied P, there were seven P-placement methods examined as follows:

(1) Broadcasting: where P fertilizer was spread over the soil broadcasting and incorporated in the top 7 cm.
(2) Band: was established by placing P-fertilizer along the bottom of an narrow excavated farrow which extended from one side of the pot to the other. The farrow ran parallel to the soil broadcasting at 5 cm below seedlings bed (12 cm from the soil broadcasting) and at 5 cm to the side of seedlings bed at its closest point (5×5 cm configuration).
(3) Phosphate slurry: the recommended rate (s) of phosphate fertilizer (Supper phosphate) was added to a mixture of clay soil and water (soil: water ratio was 1.5:1). All components mixed well several times for the uniformity. Roots of tomato seedlings were dipped in this slurry several times until all the roots coated well with a thin layer of the slurry, then seedlings transplanted in the top 7cm of each plate.
(4) Broadcasting + band: in this method of P-application, half of the P-fertilizer rate was applied as broadcasting and the other half was applied as band.
(5) Broadcasting + slurry: in this method, half of P-fertilizer was applied as broadcasting and the other was applied as slurry.
(6) Band + slurry: in this method, half of P-fertilizer was applied as band and the other applied as slurry.

(7) Broadcasting + band + slurry: in this method, third of P-fertilizer rate was applied as broadcasting and second third was applied as band and the latter was applied as slurry.

All treatments were arranged in randomized complete design with three replicates of each treatment. A basal dose of nitrogen and potassium fertilizers equivalent to 25 mg N and 30 mg K_2O kg soil^{-1}, respectively were added as ammonium nitrate, potassium sulphate and mixed thoroughly with the soil before transplanting. Soil moisture content was kept near field capacity during the experimental period which extended to 45 days after transplanting. Shoots and roots were removed from each pot using a water jet.

Evaluation of the tested phosphorus placement methods and P-levels were carried out through the following parameters:

1- Dry weight of shoots and roots (recorded after oven drying at 70°C)
2- Root length (fresh roots used for root length measurements by using method described by Newman, 1966).
3- Root surface area (RSA): was calculated using the equation:
RSA = $2\pi r_0 L$ (Hays *et al.*, 2004),
Where, r_0 = root radius (mm)
L = root length (mm)
and r_0 was calculated according to the following equation (Rayser and Famber, 1995),

4- $$r_0 = 2 \times \sqrt{\text{root fresh weight} / \text{root length} \times \pi}$$

apparatus, Black et al. (1982).
5- Phosphours content in shoots was determined according to El-Hineidy and Agiza (1959).
6- Potassium content in shoot was estimated photometerically (Black *et al.*, 1982)
7- Dry matter production efficiency ratio DMPE and phosphorus fertilizer use efficiency (PFUE) were calculated (El-Hamdy and Woodard, 1995 and Malhi *et al.*, 2001) as follows:

$$DMPE = \frac{\text{dry} - \text{matter yield (DMY)}}{P - \text{uptake}}$$

$$PFUE = \frac{\text{DMY in P–fertilized soil} - \text{DMY in zero P-control}}{\text{Rate of applied P}}$$

Statistical analysis were performed according to (Snedecor and cachran, 1980)

RESULT AND DISCUSSION

1- Shoot and root dry weight:

Data in Table 1 clearly show that there was a significant increase in shoot and root dry weight as a result of phosphorus applications. Shoot and root dry weight increased as the level of P applied was increased and the addition of 20 mg P_2O_5/kg soil provide the superiority. This increment in shoot and root dry weight of tomato plants could have been expected since the available P in soil used in this study was low (El-Hamdi and Woodard, 1995 and Regerio and Mallarino, 2003).

As regards the placement methods, the increase in shoot and root dry weight was significantly higher for slurry, band, broadcasting+ band, broadcasting + slurry, band + slurry and broadcasting +bland + slurry compared to broadcasting method (Table 1).

Shoot and root dry weight in response to P placement method could be ranked slurry>band +slurry > broadcasting +slurry> broadcasting + band+ slurry > band> broadcasting + band> broadcasting method.

The superiority of slurry and band + slurry compared to broadcasting P placement methods may be due to: (1) The placement of P fertilizer in soil, if P fertilizer is broadcasting and incorporated, the phosphorus is exposed to a greater amount of broadcasting, hence more fixation takes place than if the same amount of P fertilizer had been banded or added in contact with plant roots (slurry). Similar findings were observed by Singh and Kamath (1990) and Patel and Patel (1995) and (2) Plants supplied with P fertilizer as slurry and band placement had longer roots and higher root broadcasting area than that supplied with P fertilizer as broadcasting and incorporated in soil (Table 2), longer roots decisive for efficient P acquisition from soil (Linkohr *et al.*, 2002).

Table 1: Shoot and root dry weight (g pot^{-1}) of tomato plant as affected by phosphorus application methods and phosphorus levels.

Phosphorus application methods	Shoot				Root			
	P-levels (PPm - P_2O_5)				P-levels (PPm -P_2O_5)			
	P_0	P_1	P_2	Mean	P_0	P_1	P_2	Mean
Broadcasting	5.3	7.63	8.23	7.06 e	1.51	2.07	2.20	1.93 f
Band	5.3	9.50	10.97	8.60 cd	1.51	2.44	2.70	2.22 e
Slurry	5.3	13.10	14.37	10.92 a	1.51	3.71	3.90	3.04 a
Broadcasting + Band	5.3	9.20	10.60	8.37 d	1.51	2.67	2.92	2.37 e
Broadcasting + Slurry	5.3	10.57	10.87	8.91 c	1.51	2.89	3.20	2.53 c
Band + Slurry	5.3	11.37	11.93	9.53 b	1.51	3.18	3.41	2.70 b
Broadcasting + Band + Slurry	5.3	10.47	10.77	8.84 cd	1.51	2.80	3.08	2.46 c
Mean	5.3 A	10.26 B	11.10 C		1.51 A	2.82 B	3.06 C	
LSD 0.05	M= 0.502 L =0.329 ML= 0.870				M= 0.079, L=0.052, ML =0.138			

M= Methods of P application, L= P levels

Results in Table 1 show that the interaction between P levels and P placement methods significantly affected shoot and root dry weight. The highest values obtained when P applied as slurry at 20 mg P_2O_5 kg soil.

2- Root length and root surface area:

Root growth is important for acquisition of P that is immobile in soil. The data in Table 2 show that roots become longer as the phosphorus application levels increased. Also, the data in Table 2 indicated that root surface area was increased significantly by increasing P levels (regardless P placement methods), which could be attributed to the increase in both root radius and root length under these condition.

On the other hand both root length and root surface area differed significantly in response to P placement methods. P placement as slurry alone or slurry in combination with band recorded the highest values of root length and root surface area. The relative increase in root length in response to P placement as slurry and slurry + band methods compared to broadcasting P placement were 78 and 64%, respectively, the corresponding values of root surface area were 41 and 35%.

Table 2: Root length (mm $plant^{-1}$) and root surface area (mm^2) of tomato plants as affected by phosphorus application methods and phosphorus levels

Phosphorus application methods	Root length				Root surface area			
	P-levels (PPm - P_2O_5)				P-levels (PPm – P_2O_5)			
	P_0	P_1	P_2	Mean	P_0	P_1	P_2	Mean
Broadcasting	107.6	140.3	151.5	133.1 f	166499	221328	240751	209526 f
Band	107.6	181.7	225.4	171.6 e	166499	253545	309719	243252 e
Slurry	107.6	296.5	305.6	236.6 a	166499	347826	374430	296252 a
Broadcasting + Band	107.6	226.9	255.1	196.5 d	166499	286553	331938	261664 d
Broadcasting + Slurry	107.6	245.4	264.9	206.0 c	166499	308275	340864	271879 c
Band + Slurry	107.6	263.2	282.8	217.9 b	166499	325457	359628	283861 b
Broadcasting + Band + Slurry	107.6	231.9	255.2	198.2 d	166499	295053	323956	261836 d
Mean	107.6 A	226.5 B	248.6 C		166499 A	291148 B	325898 C	
LSD 0.05	M= 5.66, L =3.70, ML= 9.80				M= 7258, L= 4751, ML = 12570			

M= Methods of P application, L= P levels

Results in Table 2 indicated that the interaction between P levels and P placement methods significantly affect both root length and root surface area. The highest values were obtained when P applied as slurry at 20 mg P_2O_5 kg $soil^{-1}$. Ram *et al.* (2000) postulated that the presence of long root and large surface area might well explain the superior phosphorus acquisition when plants grown under P-deficiency.

3- N, P and K content of tomato shoots:

N, P and K content of tomato shoots increased significantly with increasing P levels with all P placement methods and were higher in plants supplied with 20 mg P_2O_5 kg $soil^{-1}$ compared to 10 mg P_2O_5 kg $soil^{-1}$ and control. The higher N, P and K content associated with the higher P level due to the dry matter production and the higher N, P and K concentrations in plant shoots. The obtained results are in accordance with those obtained by Shama (1996) and Abou-Baker (2003).

Data in Table 3 show generally that adding P fertilizer to soil through band, slurry, broadcasting + band, broadcasting +slurry, band + slurry and broadcasting + band +slurry methods increased N, P and K content of tomato shoots compared with broadcasting method.

Table 3: Shoot Nitrogen, phosphorus and potassium content (mg pot^{-1}) of tomato plants as affected by phosphorus application methods and phosphorus levels.

Phosphorus application methods	Nitrogen				phosphorus				potassium			
	P-levels (PPm - P_2O_5)				P-levels (PPm - P_2O_5)				P-levels (PPm -P_2O_5)			
	P_0	P_1	P_2	Mean	P_0	P_1	P_2	Mean	P_0	P_1	P_2	Mean
Broadcasting	174.9	259.5	288.2	240.9 e	9.28	14.50	16.06	13.28 f	129.8	187.0	208.3	175.1 c
Band	174.9	342.0	405.8	307.6 cd	9.28	19.00	22.48	16.92 de	129.8	242.3	285.1	219.1 b
Slurry	174.9	510.9	567.5	417.8 a	9.28	32.83	37.35	24.49 a	129.8	353.7	395.1	292.9 a
Broadcasting + Band	174.9	331.2	381.6	295.9 d	9.28	18.58	21.37	16.53 e	129.8	239.1	275.6	214.9 b
Broadcasting + Slurry	174.9	385.7	396.6	319.1 c	9.28	22.40	23.13	18.27 c	129.8	258.9	271.7	220.2 b
Band + Slurry	174.9	409.2	429.6	337.9 b	9.28	25.58	27.45	20.77 b	129.8	295.5	310.3	245.2 e
Broadcasting + Band + Slurry	174.9	376.8	393.0	314.9 c	9.28	21.46	22.61	17.78 cd	129.8	261.7	274.6	222.1 b
Mean	174.9A	373.6B	408.9C		9.28A	22.05B	24.4C		129.8A	262.6B	288.7 C	
LSD 0.05	M=18.36, L=12.02, ML=31.8				M=1.05, L=0.69, ML=1.82				M= 12.94, L= 8.47, ML=22.41			

M=Methods of P application, L = P levels

The highest values of N, P and K content were recorded for plants supplied with P fertilizer as slurry method, while the lowest one were found with the broadcasting application.

The superiority of slurry method was probably due to the longer root length and large root broadcasting area associated with plants supplied with P fertilizer as slurry (Table 2).

The interaction between P levels and placement methods significantly affected N, P and K contents by tomato shoots. Application of high rate of P fertilizer by slurry methods gave the highest values of N, P and K contents.

4- Shoot dry matter production efficiency ratio:

The mean shoot dry matter production efficiency (DMPE) ratio, calculated as the shoot dry matter weight (mg pot^{-1}) /shoot P content (mg pot^{-1}), was greater for the 0 mg P_2O_5 kg $soil^{-1}$ than for 10 and 20 mg P_2O_5 kg $soil^{-1}$ application rates (Table 4). DMPE ratio for 10 mg P_2O_5 kg $soil^{-1}$ was greater than those for 20 mg P_2O_5 kg $soil^{-1}$ rate. This may be attributed to higher levels of soil P availability under 20 mg P_2O_5 kg $soil^{-1}$ rate. This result is in agreement with that obtained by El-Hamdi and Woodard (1995) and Abou-Baker (2003).Where they reported that DMPE ratio was greater for unfertilized plants than for fertilized plants.

DMPE ratio was greater for the broadcasting P placement than for all other P placement methods. This response reflected a higher P utilization efficiency with lower P availability from the broadcasting method compared to band method. Similar result was obtained by El-Hamdi and Woodard (1995) and Abou-Baker (2003).

5- Phasphorus fertilizer use efficiency (PFUE):

Phasphorus fertilizer use efficiency (PFUE) was calculated as the difference between shoot dry weight of a P fertilized treatment (mg pot^{-1}) and an unfertilized treatment, divided by the P application rate (mg P /pot).Generally, phosphorus fertilizer use efficiency (PFUE) was greater at lower than at higher P levels. Similar results were reported by Malki *et al.* (2001). Applying P fertilizer to the soil through slurry or slurry + band increased P availability to tomato plants as indicated by higher shoot PFUE compared to broadcasting P application. Malhi *et al.*, (1992) found that surface applied P fertilizer to established forage stands remains near the broadcasting soil and much of it is not potentially available to plant. Appartently to this reason, P fertilizer placed below the surface (band placement) or contact to plant roots (slurry method) has been found more effective than broadcasting applied P to increase crop yield of annual crops and alfalfa. In addition banding and slurry reduces the contact between the P fertilizer and the soil, which could reduce the proportion of P fertilizer converted to less soluble P compounds and/or adsorbed by soil (Anghinoni and Barber, 1980), thus leaving more P fertilizer available for crop uptake.

The interaction between P-levels and P-placement methods significantly affected phosphorus use efficiency. The application of P-fertilizer as slurry recorded the highest values of P-use efficiency at the two P-levels amoung the other P-placement methods.

Table (4): Shoot dry matter production efficiency ratio and phosphorus fertilizer use efficiency of tomato in response to phosphorus application methods and phosphorus levels

Phosphorus application methods	Shoot dry matter production efficiency ratio				Phosphorus fertilizer use efficiency		
	P-levels (PPm - P_2O_5)				P-levels (PPm - P_2O_5)		
	P_0	P_1	P_2	Mean	P_1	P_2	Mean
Broadcasting	571.1	526.3	512.8	536.7 a	21.3	13.4	17.35 e
Band	571.1	499.9	487.9	519.6 ab	38.5	26	32.25 d
Slurry	571.1	400.1	384.4	491.9 d	71.5	41.5	56.5 a
Broadcasting + Band	571.1	494.8	486.9	517.6 ab	35.7	24.3	30 d
Broadcasting + Slurry	571.1	471.0	465.9	502.7 bc	48.3	25.5	36.9 c
Band + Slurry	571.1	444.0	433.9	483.0 c	55.6	30.4	43 b
Broadcasting + Band + Slurry	571.1	487.0	475.9	511.3 b	47.4	25.1	36.25 c
Mean	571.1 A	474.7 B	463.9 C		45.47 A	26.6 B	
LSD 0.05	M= 21.6, L =14.14, ML= 37.41				M= 2.37, L= 0.86, ML = 2.97		

M= Methods of P application, L= P levels

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الاستخدام الكفؤ للسماد الفوسفاتى من خلال طريقة روبه الفوسفات فى الطماطم المنزرعة شتلاً

يوسف على عبد العال
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نفذت تجربة أصص لدراسة استجابة الطماطم (صنف نيماتودا 1400) لطرق أضافة السماد الفوسفاتى حيث شملت الإضافة السطحية والأضافة تحت سطحية فى خط والأضافة من خلال روبه الفوسفات وكذلك التوافيق المختلفة لهذه الطرق. أضيف السماد الفوسفاتى بمعدلين هما 10، 20 ملليجرام فو2أ5 لكل كيلو جرام تربه مع وجود معامله بدون أضافة سماد فوسفاتى للمقارنة (كنترول). نميت شتلات الطماطم فى أصص تحتوى على 25كجم تربة طمييه رمليه فقيرة فى محتواها من الفوسفور الصالح بطريقة أولسن وذلك لمدة 45 يوماً من الشتل.
دلت النتائج على أن الوزن الجاف للأجزاء الخضرية والجذور وطول الجذور ومساحة سطح الجذر ومحتوى الأجزاء الخضرية من النتروجين والفوسفور والبوتاسيوم كان أقل بدرجة معنوية فى حالة الأضافة السطحية بالمقارنة بباقى الطرق المستخدمة وأن طريقة روبه الفوسفات كانت الأفضل فى هذا المجال.
كانت نسبة انتاج المادة الجافة للأجزاء الخضرية عالية فى حالة الأضافة السطحية للسماد الفوسفاتى ولمعاملات عدم الأضافة. (كنترول). وكانت كفاءة استخدام الفوسفور عالية عند مستويات الفوسفور المنخفضة بالمقارنة بالمستويات العالية وأن أضافة السماد الفوسفاتى من خلال روبه الفوسفات سجل أعلى قيمة لكفاءة استخدام الفوسفور بالمقارنة بالطرق الأخرى لأضافة السماد الفوسفاتى.