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Full Length Research Paper

Effect of mineral and biofertilization of phosphorus and foliar spraying with potassium on yield, its attributes and seed quality of new sesame variety

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Three field experiments were conducted during 2008, 2009 and 2010 seasons at the Experimental Farm, Faculty of Agriculture, Suez Canal University at Ismailia to study the effect of mineral and biofertilization of phosphorus and foliar with potassium on yield, its attributes and seed quality of new sesame variety (Taka 2 cv.) in newly reclaimed sandy soils of Ismailia, Egypt. The experimental design was split plots with five replications. Four levels of mineral and bio phosphorus fertilizer (57, 76, 95 and 76 kg P_2O_5/ha plus Phosphorin biofertilizer containing phosphate dissolving bacteria) were arranged randomly in the main plots and three concentrations of potassium sulphate as foliar spraying namely water (control), 1% and 2% were distributed at random in the sub plots. Increasing phosphorus fertilizer rate up to 95 kg P_2O_5/ha significantly increased plant height, fruiting zone length, number of branches and capsules/plant, 1000-seed weight, seed yield/plant, seed oil content (%) and seed and oil yields/ha of sesame. Appling biofertilizer (Phosphorin) plus 76 kg P_2O_5/ha exceeded significantly all mineral phosphorus levels (57, 76 and 95 kg P_2O_5/ha) in the aforementioned characters except number of branches/plant. Increasing potassium concentration as foliar spraying up to 2% induced significant increases in all the studied characters.

Key words: Biofertilization, phosphorus, potassium, sesame, yield, yield attributes.

INTRODUCTION

Sesame (*Sesamum indicum* L.) could be considered as one of the most important oil crops in the world because its seeds have high content of oil as well as protein. The expansion in cultivation of sesame should be taken in newly cultivated sandy soils in Egypt, which face many problems like low fertility in essential nutrients such as phosphorus. Thakur et al. (1998) reported that increasing P_2O_5 up to 30kg/ha significantly increased plant height, number of branches and capsules/plant, weight of seeds/capsule, 1000-seed weight and seed and oil yields/ha. It was also reported that application of P_2O_5 up to 40kg/ha (Patra, 2001), 45kg/ha (Shehu et al., 2010) and 60kg/ha (Okpara et al., 2007) produced significant increases in growth and yield attributes of sesame.

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The sandy soils of Egypt are alkaline which causes the conversion of phosphorus content to unavailable form, mainly as tricalcium phosphate. Application of phosphate solubilizing bacteria increases the availability of phosphorus in this type of soils. Several researchers emphasized the effect of biofertilization (phosphate dissolving bacteria) in increasing plant growth, seed yield, yield quality and yield components of oil crops. Ahmed et al. (1997) observed that application of Microbien (phosphate dissolving bacteria) increased number of pods, weight of pods and seeds/plant, seed yield/ha and seed oil content (%). Other researchers have equally reported that application of biofertilizer significantly increased growth and yield parameters of sesame (Abdel-Wahab et al., 1999; Abdel-Mohsen et al., 2002; Abdel-Mottaleb and Hafiz, 2006; Sabannavar and Lakshman, 2009).The sandy soils face many problems like low content of potassium as well as high loss of it by leaching. The positive effect of applying potassium was reported by many researchers. Dasmahapatra et al. (1990) stated that potassium fertilization (20-80 Kg K_2O /ha) increased seed yield/ha, seed oil content (%) and 1000-seed weight. Mondal et al. (1992) reported that increasing K_2O from 33.6 to 67.2 kg/ha increased plant height, number of branches and capsules/plant, 1000-seed weight and seed yield /ha. Some investigators such as Mekki et al. (1993), Salwau and Hassanein (1994) also reached that foliar application of potassium increased growth and yield components of sesame.

MATERIALS AND METHODS

Three field experiments were conducted during 2008, 2009 and 2010 seasons at the Experimental Farm, Faculty of Agriculture, Suez Canal University at Ismailia to study the effect of mineral and biofertilization of phosphorus and foliar spraying with potassium on yield, its attributes and seed quality of new sesame variety (Taka 2 cv.) This variety was developed by Nuclear Research Center, Atomic Energy Authority in Egypt.

The soil of the experiments was sandy with the following properties: pH, 7.68, 7.59 and 7.41; available N, 3.85, 4.62 and 4.93 ppm: available P, 1.60, 1.75 and 1.80 ppm; available K, 10.55, 10.70 and 10.93 ppm and organic matter, 0.058, 0.063 and 0.069% in the three seasons, respectively.

Every experiment included 12 treatments which were the combinations of four levels of mineral and bio-phosphorus fertilizer 57, 76, 95 and 76 Kg P_2O_5/ha plus Phosphorin (phosphate dissolving bacteria) and three concentrations of potassium sulphate (48% K_2O) as foliar spraying namely water (control), 1% and 2% potassium sulphate. The experimental design was split plots with five replications. Four levels of mineral and bio-phosphorus fertilizer were arranged randomly in the main plots, while three concentrations of potassium sulphate as foliar spraying were distributed randomly in the sub plots. Each experimental sup plot consisted of 6 ridges, 4 m in length and 50 cm in width (plot area was 12 m^2). Seeds of sesame Taka 2 variety were sown on one side of the ridge in hills 15 cm apart on May 10, 8 and 7 in 2008, 2009 and 2010 seasons, respectively. After 21 days from sowing, sesame plants were thinned to two plants per hill. A basal dose of nitrogen in the form of ammonium sulphate (20.5% N) at the rate of 143 KgN/ha was applied at three equal doses: after thinning, 35 and 50 days from sowing. Phosphorus in the form of calcium superphosphate (15.5% P_2O_5) at the previous rates was applied at two equal doses, before sowing and after thinning (mixed with the top soil). A basal dose of potassium sulphate (48% K_2O) was added at the rate of 120 Kg/ha at two equal doses, after thinning and 45 days from sowing.

Biofertilizer (Phosphorin) contained phosphate dissolving bacteria namely *Bacillus megatherium* var. Phosphaticum as a commercial packet was produced by Ministry of Agriculture in Egypt. The treatment of Phosphorin was inoculated with sesame seeds coated by Arab gum immediately before sowing. Foliar spraying with potassium sulphate was done three times after 35, 50 and 65 days from sowing with volume spray of 400 liter/ha. The normal cultural practices for growing sesame crop at Ismailia were followed.

At harvest time, after 110 days from sowing, samples of 10 tagged plants were randomly taken from the inner ridges in each sub plot to estimate plant height (cm), fruiting zone length (cm), number of branches and capsules/plant, 1000-seed weight, seed yield/plant. While seed yield (ton/ha) was determined from the plants of the two middle ridges (the 3rd and 4th ridges) in each sub plot and the yield per ha was calculated. Seed oil content (%) was determined by using Soxhelt continuous extraction apparatus with petroleum ether as an organic solvent according to A.O.A.C. (1975) and oil yield (ton/ha) was calculated by multiplying seed oil content (%) and seed yield/ha.

The analysis of variance of split plot design was used according to Snedecor and Cochran (1982). Means followed by the same letter(s) are not statistically different according to Least significant different (LSD) at the 5% level of significance.

RESULTS AND DISCUSSION

Effect of phosphorus fertilization

Data in Table 1 reveal that increasing phosphorus fertilizer rate from 57 to 76 and 95 Kg P_2O_5/ha significantly increased sesame plant height in the three growing seasons. These results might be due to the stimulating effect of phosphorus on metabolic activity, cell division and expansion, leading to higher plants (Marschner, 1986). Similar results were obtained by Thakur et al. (1998).

Fruiting zone length as well as number of branches and capsules/plant of sesame were significantly increased as phosphorus fertilizer increased up to 95 Kg P_2O_5/ha in 2008, 2009 and 2010 seasons (Tables 1 and 2). These results were expected since P enhances the meristemic activity consequently increased number of branches/plant. While, positive effect of applying phosphorus on number of capsules/plant might be due to that P increases number of flowers/plant and capsules setting percentage as well as decreases percentage of flowers and capsules abscission (Moursi et al., 1976). These results are in line with those reported by Thakur et al. (1998), Patra (2001) and Okpara et al. (2007).

Results in Table 2 show that the high level of mineral phosphorus fertilizer (95 Kg P_2O_5/ha) significantly outweighted moderate and low levels (76 and 57 Kg P_2O_5/ha) in 1000-seed weight with significant difference between them and that was true in the three seasons. These results were expected since phosphorus

Table 1. Effect of phosphorus fertilization and spraying with potassium sulphate on plant height, fruiting zone length and number of branches/plant through 2008, 2009 and 2010 seasons.

Treatments	Plant height (cm)			Fruiting zone length (cm)			Number of branches /plant		
Seasons	**2008**	**2009**	**2010**	**2008**	**2009**	**2010**	**2008**	**2009**	**2010**
				Phosphorus fertilization (Kg P2O5/ha)					
57 Kg P2O5/ha	118.33 D	128.35 D	133.36 D	60.00 D	64.49 D	68.14 D	6.66 C	6.51 C	7.00 D
76 Kg P2O5/ha	133.98 C	142.97 C	148.66 C	66.27 C	70.98 C	74.51C	7.37 B	7.63 B	7.95 C
95 Kg P2O5/ha	149.67 B	159.33 B	166.67 B	70.33 B	77.81 B	81.02 B	8.47 A	8.73 A	9.11 B
76 Kg P2O5/ ha + Phosphorin	151.67 A	162.87 A	170.59 A	80.05 A	86.25 A	90.83 A	8.57 A	9.07 A	9.65 A
F test	*	*	*	*	*	*	*	*	*
				Spraying with potassium sulphate					
0	134.25 C	143.98 C	150.24 C	65.50 C	70.40 C	74.73 C	7.40 B	7.60 B	8.11 C
1%	139.25 B	148.65 B	155.38 B	68.61 B	74.46 B	78.59 B	7.51 B	7.93 B	8.45 B
2%	141.74 A	152.51 A	158.83 A	73.78 A	79.78 A	82.57 A	8.38 A	8.45 A	8.72 A
F test	*	*	*	*	*	*	*	*	*
Interaction P x K	Ns	Ns	Ns	Ns	Ns	Ns	*	*	*

NS, * = non-significant and significant probability level at 5%, respectively.

encourages photosynthesis rate and amount of metabolites synthesized by plants. Also, P enhances translocation of metabolites from the leaves to reproductive oranges such as seeds. This type of result was reported by Ali and Sakr (2002).

Seed yield/plant significantly increased by increasing phosphorus fertilizer up to 95 Kg P_2 O_5/ha in 2008, 2009 and 2010 seasons (Table 2). These results might be due to the increasing in yield attributes such as number of branches and capsules/plant as well as 1000-seed weight. Similar results were recorded by Ali and Sakr (2002) and Shehu et al. (2010).

Table 3 shows that there were significant and consistent increases in seed yield/ha of sesame by increasing phosphorus fertilizer level from 57 to 76 and 95 Kg P_2 O_5/ha in the three growing seasons. The positive effect of phosphorus fertilization on seed yield/ha of sesame might be attributed to the soil of the experimental site which was very poor in its phosphorus content. This necessitated the high demand of phosphorus by the crop. P is known to enhance the development of good root system (Russel, 1973) which in turn increases efficiency of the roots in absorbing various nutrients. This was evident in plant growth as expressed by plant height and number of branches/plant in response to P addition. P stimulates photosynthesis, carbohydrate metabolism and synthesis of protein (Marschner, 1986) in turn increasing the amount of metabolites synthesized by sesame plants. Also, P plays important role in enhancing translocation of metabolites which might be the reason for the increases observed on seed yield/plant and 1000-seed weight subsequently increased seed yield/ha.

Table 3 shows that fertilizing sesame plants up to 95 Kg P_2 O_5/ha caused significant increases in seed oil content (%) throughout the three growing seasons. The increase in seed oil content (%) by adding phosphorus fertilization might be attributed to important role of phosphorus in metabolism of lipids (Marschner, 1986). These results are in accordance with those reported by Ali and Sakr (2002).

The data recorded in Table 3 reveals that oil yield/ha significantly increased as phosphorus fertilizer rate was increased up to 95 Kg P_2 O_5/ha in the three seasons. The positive effect of P application on oil yield/ha could be due to the increase in seed yield/ha and seed oil content (%). These findings are in conformity with those reported by Patra (2001) and Ali and Sakr (2002).

Tables 1, 2 and 3 show that application of biofertilizer (Phosphorin) plus 76 Kg P_2 O_5/ha performed significantly better than all mineral phosphorus levels in all characters measured in the three seasons with exception of number of branches per plant in 2008 and 2009 where there was no significant difference between application of 95 Kg P_2 O_5/ha and biofertilizer (phosphorin) plus 76 Kg P_2O_5/ha. The positive responses with applied biofertilizer (Phosphorin) might be attributed to its effect in

Table 2. Effect of phosphorus fertilization and spraying with potassium sulphate on number of capsules /plant, 1000-seed weight (gm) and seed yield/plant (gm) through 2008, 2009 and 2010 seasons.

Treatments	Number of capsules /plant			1000-seed weight (gm)			Seed yield/plant (gm)		
Seasons	**2008**	**2009**	**2010**	**2008**	**2009**	**2010**	**2008**	**2009**	**2010**
Phosphorus fertilization (KgP2O5/ha)									
57 Kg P2O5/ha	73.67 D	76.47 D	80.49 D	2.98 D	3.21 D	3.19 D	14.36 D	15.04 D	15.82 D
76 Kg P2O5/ha	85.00 C	88.71 C	97.90 C	3.39 C	3.63 C	3.60 C	16.53 C	17.43 C	18.24 C
95 Kg P2O5/ha	102.00 B	104.67 B	112.00 B	3.67 B	4.12 B	4.19 B	18.08 B	19.78 B	20.95 B
76 Kg P2O5/ ha + Phosphorin	107.28 A	115.69 A	123.93 A	4.08 A	4.30 A	4.40 A	19.77 A	21.20 A	22.56 A
F test	*	*	*	*	*	*	*	*	*
Spraying with potassium sulphate									
0	87.00 C	91.45 C	97.73 C	3.25 C	3.51 C	3.59 C	15.97 C	16.76 C	17.67 C
1%	92.00 B	96.50 B	102.57 B	3.63 B	3.83 B	3.86 B	17.58 B	18.50 B	19.54 B
2%	96.96 A	101.00 A	108.20 A	4.00 A	4.11 A	4.09 A	18.75 A	19.83 A	20.97 A
F test	*	*	*	*	*	*	*	*	*
Interaction P x K	Ns	*	Ns	*	Ns	Ns	*	*	*

NS, * = non-significant and significant probability level at 5%, respectively.

Table 3. Effect of phosphorus fertilization and spraying with potassium sulphate on seed yield (ton/ha), seed oil content (%) and oil yield (ton/ha) through 2008, 2009 and 2010 seasons.

Treatments	Seed yield (ton/ha)			Seed oil content (%)			Oil yield (ton/ha)		
Seasons	**2008**	**2009**	**2010**	**2008**	**2009**	**2010**	**2008**	**2009**	**2010**
Phosphorus fertilization (KgP2O5/ha)									
57 Kg P2O5/ha	1.914 D	1.931 D	2.022 D	50.07 D	50.33 D	50.79 D	0.958 D	0.972 D	1.026 D
76 Kg P2O5/ha	2.202 C	2.274 C	2.299 C	54.70 C	55.14 C	55.67 C	1.204 C	1.254 C	1.279 C
95 Kg P2O5/ha	2.542 B	2.640 B	2.726 B	59.21 B	61.16 B	61.53 B	1.505 B	1.614 B	1.677 B
76 Kg P2O5/ ha + Phosphorin	2.634 A	2.769 A	2.879 A	61.40 A	62.32 A	63.59 A	1.617 A	1.726 A	1.831 A
F test	*	*	*	*	*	*	*	*	*
Spraying with potassium sulphate									
0	2.129 C	2.157 C	2.203 C	52.60 C	53.58 C	54.09 C	1.119 C	1.156 C	1.192 C
1%	2.343 B	2.443 B	2.537 B	57.11 B	57.97 B	58.58 B	1.338 B	1.416 B	1.486 B
2%	2.499 A	2.611 A	2.703 A	59.33 A	60.17 A	61.61 A	1.483 A	1.571 A	1.649 A
F test	*	*	*	*	*	*	*	*	*
Interaction P x K	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns

NS, * = non-significant and significant probability level at 5%, respectively.

solubilizing fixed form of phosphate in soil because under alkaline soil conditions, monovalent phosphate in phosphatic fertilizer is rapidly fixed and becomes unavailable for plant absorption which is well known in Egyptian soils. So biofertilizer (Phosphorin), which contains phosphate dissolving bacteria, plays a significant role in converting the fixed form of phosphate to a soluble form ready for plant nutrition which

Table 4. Effect of the interaction between phosphorus fertilization and spraying with potassium sulphate on number of branches /plant and seed yield/ plant (gm) of sesame (The combined data).

Phosphorus fertilization	Number of branches /plant			Seed yield/plant (gm)		
	Spraying with potassium sulphate			Spraying with potassium sulphate		
	Water	1%	2%	Water	1%	2%
57 Kg P2O5/ha (P1)	6.30	6.60	7.36	13.43	15.16	16.60
76 Kg P2O5/ha (P2)	7.20	7.60	7.93	15.66	17.46	19.10
95 Kg P2O5/ha (P3)	8.46	8.70	8.96	18.60	20.13	21.30
76 Kg P2O5/ ha + Phosphorin (P4)	8.86	9.16	9.36	19.70	21.36	22.43
LSD 0.05		0.457			0.921	

consequently enhances plant growth and yield attributes. Also, application of phosphorus is known to enhance lipids metabolism, subsequently increased seed oil content (%). These results are in a same trend with those obtained by Kabesh et al. (1989) with Phosphorin, Ahmed et al. (1997) and Abdel-Wahab et al. (1999).

Effect of foliar spraying with potassium

Data in Table 1 show that foliar spraying sesame plants with 1 or 2% potassium sulphate caused significant increases in plant height, fruiting zone length and number of branches/plant compared to unsprayed plants in the three growing seasons. Also, spraying of 2% potassium sulphate produced significantly higher values than spraying of 1% potassium sulphate in the aforementioned characters. There was no significant difference between 1% potassium sulphate and unsprayed plants on number of branches/plant. These findings were expected since potassium plays a major role in cell extension and osmoregulation, and enhances metalabolic processes and various enzymes (Marschner, 1986).

Increasing the level of spraying from 0 to 2% potassium sulphate significantly increased number of capsules/plant, 1000-seed weight and seed yield/plant in all the three seasons (Table 2). The beneficial effect of potassium on the mentioned characters might be attributed to its important role plays in many enzymatic systems, photosynthesis, and synthesis of proteins and carbohydrates (Marschner, 1986). Moreover, K enhances translocation from leaves to capsules and seeds. These findings are in harmony with those obtained by Mondal et al. (1992) who found that number of capsules/plant and 1000-seed weight were increased by fertilizing sesame plants with potassium. Also, Mekki et al. (1993) Salwau and Hassanein (1994) and Kalaiselvan et al. (2002) observed that foliar spraying of potassium increased the above mentioned characters.

Table 3 shows that foliar application of potassium sulphate caused significant increase in seed yield/ha compared to unsprayed control in all the three seasons. Meanwhile the high concentration significantly outyielded the low one regarding the effect on this character.

Significant increase obtained in seed yield/ha after foliar spraying of potassium sulphate on sesame plants could be attributed to the marked increases observed on growth and yield attributes of sesame plants which in turn enhanced the seed yield/ha of sesame plants. Similar result was obtained by Salwau and Hassanein (1994), El-Emam et al. (1997), Bassien and Anton (1998) and Gaber (1998).

Table 3 reveals that foliar spraying of 1 or 2% potassium sulphate significantly increased seed oil content (%) of sesame when compared to unsprayed control in all the three seasons. Meanwhile the plants that received 2% potassium sulphate produced higher seed oil content (%) than plants that received 1% potassium sulphate in the three growing seasons. The positive effect of potassium on seed oil content (%) might be due to important role K plays in enhancing enzymes activity and metabolism of lipids (Marschner, 1986). Similar finding were reported by Bassien and Anton (1998) and Gaber (1998).

Table 3 shows that increasing the level of spraying from 0 to 2% potassium sulphate significantly increased oil yield/ha of sesame in the three growing seasons. The increase observed in oil yield/ha of sesame by increasing K concentration could be due to the increase in seed yield/ha and seed oil content (%). These results are in line with those reported by Salwau and Hassanein (1994).

Interactions effects

The combined analysis of the data of three seasons reveals that there was significant interaction between phosphorus fertilization and spraying with potassium on number of branches/plant and seed yield yield/plant (Table 4).

Fertilizing sesame plants with 76 Kg P_2 O_5/ha plus biofertilizer (Phosphorin) and spraying with 2% potassium sulphate significantly outnumbered all phosphorus levels under every potassium concentrations except 76 Kg P_2 O_5/ha plus Phosphorin and spraying with 1% K as well as 95 Kg P_2 O_5/ha and spraying with 2% K in number of branches/plant. On the other hand, the lowest value was achieved by adding 57 Kg $P_2 O_5$/ha and unsprayed control followed by sprayed with 1% K. The two treatments gave significant decrease as compared with all treatments. This result was similar to the one obtained by Ali (2002).

Applying 76 Kg $P_2 O_5$/ha plus biofertilizer (Phosphorin) and foliar nutrition with 2% potassium sulphate produced the highest seed yield/plant and significantly exceeded the other treatments. Moreover, the same phosphorus treatment and spraying 1% K as well as treatment of 95 Kg $P_2 O_5$/ha and foliar application of 2% K gave significant increases compared to the other treatments in seed yield/plant. On the other hand, the lowest value of seed yield/plant was achieved from plants fertilized by 57 Kg $P_2 O_5$/ha without spraying with potassium and this treatment was significantly decreased compared to all other treatments. These findings were similar to those obtained by Ali (2002).

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