World Journal of Agricultural Sciences 5 (S): 810-818, 2009
ISSN 1817-3047

Enhancing Fresh and Seed Yield of Okra and Reducing Chemical Phosphorus Fertilizer via Using VA-Mycorrhizal Inoculants

[1]K.A.A. El-Shaikh and [2]M.S. Mohammed

[1]Dept. Hort. Fac. Agric. Sohag University, Sohag, Egypt
[2]Hort. Res. Inst., Agricultural Research Center, Giza, Egypt

Abstract: This investigation was carried out at the Experimental Farm of Shandaweel Agriculture Research Station during 2006 and 2008 seasons. This experiment amid to investigate the efficiency of VA-mycorrhizae as a biofertiizer and an effective alternative for phosphorus chemical fertilizer on okra green fruits and seed yield. Okra El-Balady cultivar (*Abelmoschus esculentus* (L.) Moench) was used in this study. The obtained data indicated that inoculation of okra seeds with VA-mycorrhizae in presence or absence of different doses of phosphorus chemical fertilizer significantly increased vegetative growth, total green fruits yield (ton/fed.) and total seed yield (kg/fed.) as compared to the uninoculated ones in both seasons. Moreover, fertilizing okra plants with chemical phosphorus fertilizer significantly increased all studied characters in both seasons. The highest values were achieved when okra plant received the highest phosphorus level i.e., 45 kg P_2O_5/fed. as compared to the others phosphorus levels in both seasons. The interaction between VA-mycorrhizae inoculants and phosphorus chemical fertilizer significantly enhanced vegetative growth characters, green fruits yield characters and its components as well as total seed yield characters and its components. Furthermore, the combination between VA-mycorrhizae inoculants and 15 kg P_2O_5/fed. significantly increased total green fruits yield (ton/fed.) and its components. Meanwhile, seed yield characters and its components were significantly improved by the combination between VA-mycorrhizae inoculants and 30 kg P_2O_5/fed. in both seasons. Moreover, it was interesting to note that (vegetative growth and green fruits yield components characters) showed highly significant positive correlations with total green fruits yield (ton/fed.). In addition, the same general trend was found between total seeds yield (kg/fed.) and number of mature fruits/plant, number of seeds/fruit, seeds weight/plant (g) and weight of 1000-seeds (g) in the two seasons. Therefore, the most attractive result summarized in using of VA-mycorrhizal inoculants as biofertilizer may replace the application of 50% and 33.3% of the recommended dose of phosphorus chemical fertilizer for both total green fruits yield (ton/fed.) and total seed yield (kg/fed.), respectively.

Key words: Okra · Fresh yield · Seed yield · Phosphorus VA-mycorrhizae

INTRODUCTION

The need of increased food production in most developing countries becomes an ultimate goal, to meet the dramatic expansion of their populations. Okra (*Abelmoschus esculentus* (L.) Moench) is an important fresh delicious vegetable crop in spring and summer for cooking, also used as dry fruits, canned, or frozen for all year round cooking In West Africa, leaves buds and flowers, are also, consumed. The dried seeds provide oil, protein, vegetable curd and a coffee additives or substitutes. Okra dry seeds are reported to contain 18-20% oil and 20-25% crude protein. It has an average nutritive value of 3.21 that is higher than tomato, eggplant and most cucurbits [1]. In okra, it is possible to raise green and seed yield as well as the quality by improving agricultural practices.

The necessity of phosphorus as a plant nutrient is emphasized by the fact that it is an essential constituent of many organic components that are very important for metabolic processes, blooming and root development [2]. Deficiency of phosphorus leads to reduce plant growth, green and seed yield. The response of okra to phosphorus fertilizer levels was studied by Majanbu ***et al.*** [3], Arora ***et al.*** [4] and Lenka ***et al.*** [5]. who reported that plant height, number of fruits, fruit size and total green

Corresponding Author: Dr. K.A.A. El-Shaikh, Dept. Hort. Fac. Agric. Sohag University, Sohag, Egypt

fruit yield were significantly improved by application of phosphorus from 0-60 kg P_2O_5/ha. El-Maziny *et al.* [6], Naik and Srinivas [7], Bhat and Dhar [8] found that fruit length, number of fruits/plant, number of seeds/fruit and 1000-seed weight recorded the highest values with the highest phosphorus rate. The same general trend was found by Naik and Singh [9], Amjad *et al.* [10], Chattopahyay and Sahana [11], Patton *et al.* [12], Singh [13] and El-Shaikh [14].

In most soils, in spite of the considerable addition of phosphorus fertilizers, the available P for plants is usually low since it is convert to unavailable form by its reaction with the soil constituents. This could explain why the cultivated soils in Egypt needs high amount of mineral phosphorus fertilization to fulfill requirements of plants. However, the increase in the rate of applied phosphorus fertilizer may be at the expense of increasing production costs and environmental pollution [15].

Therefore, it's become essential to use the untraditional fertilizers as a substitute or supplement for chemical fertilizers. Hence, the symbiotic relation between higher plants and mycorrhizae, particularly vesicular-arbuscular mycorrhizae (VAM) fungi represents one of the most striking biological phenomena. Mycorrhizal symbiosis with onion plants has attracted more attention for many benefits, such as contributing some promoting substances for plant growth (GA, IAA and CKS) as well as enhancing uptake of phosphorus and several micronutrients, i.e. Fe, Zn, Mn and Cu [16].

Moreover, Saleh and Al-Raddad [17] mentioned that inoculation of okra plants with VA mycorrizae significantly increase root, shoot, plant weight and dry matter as compared to the control. Furthermore, Senapati *et al.* [18] found that plant height, number of leaves/plant, number of fruits/plant, pod length and number of seeds/pod were significantly higher in inoculated plants than in non-mycorrizal controls. In addition, the same general trend was reported by Abd-Allah *et al.* [19]. On other hand, Sharma *et al.* [20], Charron *et al.* [21] and El-Shaikh [22] worked on onion and found that using of biofertilizers may replace the application of 75% of the recommended dose of nitrogen and phosphorus chemical fertilizers.

Singh and Chaudhary [23] mentioned that selecting for yield characters with significant positive relationship both genotypically and phenotypically will automatically increase yield. To evaluate relationships, correlation analyses are used such that the values of two characters are analyzed on a paired basis, results of which may be either positive or negative. The result of correlation is of great value in the determination of the most effective procedures for selection of superior traits [24-26].

The present investigation was design as an attempt to use an important physiological role of vesicular arbuscular mycorrhizae (V.A.M) to record the following goals:

- Reduce the possible health hazard due to the pollution of soil, water and plant tissues.
- Reduce the production costs through replace all or part of phosphorus chemical fertilizer
- Enhance fresh and seed yield of okra plants.

MATERIALS AND METHODS

The present study was carried out during the summer seasons of 2007 and 2008 at the Experimental Farm at Shandaweel Agriculture Research Station, Sohag Governorate, Egypt.

Seeds of okra El-Balady cultivar (*Abelmoschus esculentus* L. Moench) was used in this study (obtained from Vegetable Seed Production Technology Dept., Hort. Res. Inst., Agric. Res. Center, Giza, Egypt).

VA-mycorrizal inoculants: Two species of endomycorrhizal fungi (*Glomus fasiculatum* & *Glomus mosseae*) supplied by Botany Dept., Fac. Agric. Kafr EL-Sheikh, Tanta University, Egypt, were used.

For preparing VA-mycorrhizal inoculums, fried pots of 30 cm in diameter were filled with autoclaved clay loam soil. The soil of each pot was inoculated with two species of endomycorrhizal fungi. Ten onion seedlings were transplanted in each pot as a host plant. At the end of the growth stage of onion, plants were uprooted. The soil of the used pots were mixed together and VAM spores counted as described by Musandu and Giller [27]. The spore count was found to be 100-110 spores/g soil. This soil containing mixture of VAM spores, mycelia and chopped roots. The prepared VAM inoculum's was added at rate of 6 kg of soil for each plot, which drilled in the ridges just before first irrigation. Each ridge received equal quantity from VA-mycorrhizal inoculum's i.e. (400 gm).

Phosphorus levels: Phosphorus fertilizer was added during soil preparation at four levels i.e. (0, 15, 30 and 45 kg P_2O_5/fed.) in the form of calcium super phosphate (15% P_2O_5).

Table 1: Soil characterization of the experimental site

Analysis Seasons	Texture	pH	O.M %	Available nutrients (ppm) N	P	K
2007	Clay loam	7.7	0.92	15.0	8.90	315
2008	Clay loam	7.9	0.87	14.0	9.00	300

The experiment was conducted in split plots design with four replications. VA-mycorrhizal inoculums was arranged in the main plots i.e. (inoculated and non-inoculated ones) and four phosphorus levels were assigned in the sub-plots.

Each experimental unit was 10.5 m^2 consisted of five ridges 60 cm apart and 3.5 m length (three ridges were used to determine the green yield parameters and the other two ridges for determine the dry seed yield parameters). Sowing was done in 1 and 2 April in the first and second seasons, respectively by sowing three seeds per hill at 30 cm spacing.

Growing plants were thinned to leave one plant / hill just before first irrigation. Normal cultural procedures known for commercial okra production other than the applied treatments were followed. Fruits harvesting were done at every three days.

Ten plants were randomly chosen in each plot to determine the flowing characters:

- Plant height cm (at the end of harvesting).
- Number of branches/plant (at the end of harvesting).
- Weight of green fruits/plant (g) fruits were picked with all pedicels in the morning every three days.

In addition, the following data were recorded:

- Green fruit length (cm)
- Green fruit diameter (cm)
- Total green fruits yield (ton/fed.)

Also, seed yield and its components were measured:

- Number of mature fruits /plant
- Number of seeds /fruit (Average 50 mature fruit from each plot).
- Seeds weight /plant (g).
- Weight of 1000 seeds (g).
- Total seeds yield (kg/fed).
- Germination % was determined after harvested mature seeds

Statistical analysis: Data obtained during the two seasons of the study were statistically analyzed according to Gomez and Gomez [28] and treatments means were compared using the Duncan's multiple range test [29]. Also, phenotypic correlation coefficients among traits were calculated.

RESULTS AND DISCUSSION

Vegetative Growth Characteristics: Data presented in Table (2) clearly showed that VA-mycorrhizal inoculants significantly increased vegetative growth characteristics expressed as plant height (cm) and number of branches/plant as compared to uninoculated plants in the two studied seasons. The inoculated plant exceeded uninoculated ones by (5.9, 3.5% and 16.8, 14.97%) for plant height (cm) and number of branches/plant in the first and second season, respectively. Such results may suggest that inoculation with VA-mycorrhizal fungi have the ability to supply the plants by plant promoting substances, mainly Indole Acitic Acid, Gebberellic Acid and Cytokinne-like substances, which could stimulate plant growth traits, absorption of nutrients, efficiency of nutrient and metabolism of photosynthesis [16]. Moreover, several investigators reported that VA-mycorrhizal fungi allow better absorption of nutrients by plants [30, 31].

Data in Table (2) also indicated that phosphorus fertilization levels significantly increased plant height (cm) and number of branches/plant in both seasons. However, the tallest plants and highest number of number of branches/plant i.e. (203.9, 207.7 cm and 5.1, 6.0 cm) were produced by the highest phosphorus level i.e., 45 kg P_2O_5/fed in the first and second season, respectively. On the other hand, the shortest plants and the lowest number of branches/plant resulted from unfertilized treatments (control). These results held true in the two experimental seasons. Many researchers proved the importance of phosphorus in plant vegetative growth such as Patton *et al.* [12], El-Shaikh [14] and Omotoso and Shittu [32].

Table 2: Effect of VA-mycorrhizal inoculants and phosphorus fertilizer levels on plant height, number of branches/plant and weight of green fruits/plant of okra plants in 2007 and 2008 seasons

Treatments		Characters					
		Plant height (cm)		Number of branches/plant		Weight of green fruits/plant (g)	
Myco. (A)	Phosphorus (B) (kg P_2O_5/fed)	2007	2008	2007	2008	2007	2008
With Myco.	0.0	186.7 de	202.0 ab	4.7 c	5.2 bc	363.0 ab	350.8 c
	15	197.4 bc	205.2 ab	4.6 cd	5.1 bc	387.4 a	406.4 a
	30	205.2 ab	211.3 a	5.5 a	6.0 a	365.8 ab	379.6 b
	45	207.6 a	211.4 a	5.5 a	6.2 a	364.0 ab	421.3 a
Mean (A_1)	199.2 a	207.5 a	5.1 a	5.6 a	370.0 a	389.5 a	
Without Myco.	0.0	178.1 f	195.6 b	3. 7 e	3.8 d	307.5 c	318.8 e
	15	179.9 ef	200.1 b	4.3 d	4.4 cd	321.6 c	329.9 de
	30	191.7 cd	201.1 ab	4.4 cd	5.2 bc	350.3 b	348.4 cd
	45	200.2 ab	204.1 ab	4.5 cd	5.7 ab	355.5 b	364.3 bc
Mean (A_2)	187.5 b	200.2 b	4.2 b	4.8 b	333.7 b	340.3 b	
Mean (B)	0.0	182.4 d	198.8 b	4.2 b	4.5 b	335.3 c	334.8 d
	15	188.7 c	202.6 ab	4.4 b	4.8 b	354.5 bc	368.2 c
	30	198.5 b	206.2. ab	4.8 a	5.6 a	358.1 ab	369.0 b
	45	203.9 a	207.7 a	5.1 a	6.0 a	359.8 a	392.8 a

* Means followed by the same letter or letters are not significantly difference at level 5 %

Table 3: Effect of VA-mycorrhizal inoculants and phosphorus fertilizer levels on green fruits length (cm), green fruits diameter (cm) and Total green fruits yield (ton/fed.) of okra plants in 2007 and 2008 seasons

Treatments		Characters					
		Green fruit length (cm)		Green fruit diameter (cm)		Total green fruits yield (ton/fed**.)	
Myco (A)	Phosphorus (B) (kg P_2O_5/fed)	2007	2008	2007	2008	2007	2008
With Myco.	0.0	4.6 c	4.8 bc	1.89 b	2.11 ab	4.176 c	4.263 c
	15	5.2 a	5.6 a	1.96 ab	2.07 ab	5.495 a	5.563 a
	30	5.0 ab	5.0 abc	2.00 ab	2.16 a	5.533 a	5.600 a
	45	5.2 a	5.5 ab	2.03 a	2.15 ab	5.553 a	5.567 a
Mean (A_1)	5.0 a	5.2 a	1.97 a	2.12 a	5.189 a	5.248 a	
Without Myco.	0.0	3.8 d	4.7 c	1.92 ab	1.99 b	2.897 f	2.762 f
	15	4.4 c	4.9 abc	1.97 ab	2.06 ab	3.315 e	3.298 e
	30	4.6 bc	4.9 abc	1.95 ab	2.06 ab	3.853 d	3.814 d
	45	4.8 b	5.0 abc	1.99 ab	2.13 ab	4.570 b	4.583 b
Mean (A_2)	4.4 b	4.9 b	1.96 a	2.06 a	3.659 b	3.614 b	
Mean (B)	0.0	4.2 c	4.8 b	1.90 b	2.05 a	3.537 d	3.513 d
	15	4.8 b	5.3 a	1.97 ab	2.06 a	4.405 c	4.431 c
	30	4.8 b	5.0 b	1.98 ab	2.11 a	4.693 b	4.707 b
	45	5.0 a	5.3 a	2.01 a	2.14 a	5.061 a	5.075 a

*Means followed by the same letter or letters are not significantly difference at level 5 %

** One feddan = 4200 m^2

The interactions between VA-mycorrhizal inoculants and phosphorus fertilization levels affect significantly in okra growth measurements in both seasons. Moreover, the combination between inoculation with VA-mycorrhizal inoculants and the highest phosphorus level i.e., 45 kg P_2O_5/fed. Achieved the highest values of vegetative growth measurements in the first and second seasons, respectively. Further significant increases in values of these measurements were achieved when okra plants inoculated with VA-mycorrhizae and fertilized with 30 kg P_2O_5/fed. in both seasons. On contrary, the plants have no inoculation and not fertilized with phosphorus significantly decreased plant height (cm) and number of branches/plant in both seasons. This may be due to the high efficiency of VA-mycorrhizae in supplying growing plants with their phosphorus requirements. These finding are in line with those found by Musandu and Giller [27].

Green Fruits Yield and its Components: Weight of green fruits/plant (g), green fruits length (cm) and green fruits diameter (cm) were determined for plants of each treatment as indicators for total green fruits yield (ton/fed.). As shown in Table (2 and 3) VA-mycorrhizae inoculum's significantly improved all above-mentioned characteristics except green pod diameter in both seasons.The inoculated plants surpassed uninoculated ones by (11.3, 8.7, 1.5 and

30.3%) for the all studied characters in both seasons, respectively. This positive result could be explained in the light of the fact that the hyphae of VA-mycorrhizae explore much greater volume of soil. It can be suggested that mycorrhizal roots can obtained up to 60 times of the soil minerals as the amount that can be taken from the soil by non-mycorrhizal roots [33].

In addition, the increments due to inoculation with VA-mycorrhizae which, induced in vegetative growth character, weight of green fruits/plant (g), green fruits length and diameter (cm) surely reflect on total green fruits yield (ton/fed.) as shown in Table (2 and 3) the same general trend was mentioned by Mohd and Siddiqui [31].

Results illustrated in Table (2 and 3) clearly show that applying phosphorus to okra significantly increased the abovementioned characteristics in both seasons. Okra plants which received the highest phosphorus level i.e., 45 kg P_2O_5/fed. produced the highest values of all green pods yield characters and its components as compared to the lowest values resulted in unfertilized plants in both seasons. These results may be attributed to the beneficial effect of phosphorus on cell division and the formation of carbohydrates as well as reducing abscission of flowers and small fruits. The importance of phosphorus to fresh yield of okra plant assured by many investigators such as Naik and Singh [7], Chattopahyay and Sahana [11], El-Shaikh [14] and Omotoso and Shittu [32].

Regarding the effect of interaction between the two studied factors, data in Table (2 and 3) obviously revealed that green fruits yield characters and its components significantly affected by the interaction in both seasons. However, the most interesting result was that the combination between inoculation with VA-mycorrhizae and low phosphorus level i.e., 15 kg P_2O_5/fed. which gave high values of total green fruits yield (ton/fed.) and did not differ significantly with values resulted from the combination between VA-mycorrhizae and high phosphorus levels i.e., 30 or 45 kg P_2O_5/fed. in the first and second seasons, respectively. This finding from the economical point of view led to spare enormous amount of phosphorus fertilizer and minimized both okra production costs and environmental pollution. These positive results could be explained in the light of significant increments induced in green fruits yield component characteristics which reflect on weigh of green pod yield ton/fed. in both seasons. These results are in accordance with those reported by Abd-Allah *et al.* [19]. Moreover, Sharma *et al.* [20], Charron *et al.* [21] and El-Shaikh [22] found that the use of biofertilizers may replace the application of 75% of the recommend dose of nitrogen and phosphorus chemical fertilizers in onion plants.

Seed Yield and its Components: Results listed in Tables (4 and 5) revealed that the inoculation of okra seeds with VA-mycorrhizal fungi separately or combined with phosphorus levels dramatically increased seed yield and its components expressed as number of mature fruits/plant, number of seeds/fruit, seeds weight/plant (g), weight of 1000 seeds (g), total seed yield (kg/fed.) and germination percentage.

Inoculation with VA-mycorrhizae significantly enhanced total seed yield (kg/fed.) and germination percentage, these results held well in the two experimental seasons as compared to uninoculated treatments. Furthermore, inoculated plants gave total seed yield (kg/fed.) exceeded uninoculated ones by (17.4 and 18.2%) in the first and second seasons, respectively. The positive effect of VA-mycorrhizae total seed yield (kg/fed.) of okra may be due to its significant increases in seed yield components characters i.e., number of mature fruits/plant, number of seeds/fruit, seeds weight/plant (g) and weight of 1000 seeds (g) which considered an important seed yield component of okra where, it reflects the relationship between source and sink of photogene that during pod filling Also, these results may be due to high efficiency of the applied VA-mycorrhizae inoculants in supplying the grown okra plants with the required P and other nutrients, However, the hyphae of VA-mycorrhizae explore much greater volume of soil reach from (1-10 m) and collect more nutrients Marschner [34]. These results are in agreement with those reported by Semapati *et al.* [18].

Application phosphorus levels to okra plants significantly increased seed yield and its components in both seasons. The highest values were produced by the highest phosphorus level i.e. 45 kg P_2O_5/fed as compared to unfertilized plants in both seasons. The positive effect of phosphorus fertilizer on okra vegetative growth and green fruits yield as well as its components previously discussed surely reflected on seed yield and its components in both seasons. Moreover, Marschner mentioned that, phosphorus positively effect on metabolic processes including cell division, expansion and formation and movement of carbohydrate. Also, encouraging blooming, fruits setting, fertility, weight of 1000-seed, seed yield and germination percentage. These results are in harmony with those found by Majanbu *et al.* [3], Lenka *et al.* [5] and El-Shaikh [22].

Table 4: Effect of VA-mycorrhizal inoculants and phosphorus fertilizer levels on number of mature fruits/plant, number of seeds/fruit and seeds weight /plant (g) of okra plants in 2007 and 2008 seasons

Treatments		Characters					
		Number of mature fruits/plant		Number of seeds/fruit		Seeds weight /plant (g)	
Myco. (A)	Phosphorus (B) (kg P_2O_5/fed)	2007	2008	2007	2008	2007	2008
With Myco.	0.0	10.10 b	10.56 abc	68.17 de	77.03 c	38.93 ef	55.72 bc
	15	10.17 b	10.67 abc	74.51 bc	86.40 abc	52.00 b	55.94 abc
	30	10.77 a	11.10 ab	79.33 a	91.45 a	64.93 a	58.07 ab
	45	11.00 a	11.63 a	81.84 a	93.50 a	66.76 a	61.83 a
Mean (A_1)	10.51 a	10.99 a	75.96 a	87.10 a	55.66 a	57.89 a	
Without Myco.	0.0	8.73 d	9.63 c	66.60 e	77.03 c	35.26 f	38.18 d
	15	9.27 c	10.31 bc	67.83 e	79.97 bc	41.19 de	50.74 c
	30	10.53 ab	10.81 ab	72.12 cd	85.47 abc	43.29 cd	50.69 c
	45	10.67 ab	10.57 abc	78.00 ab	88.77 ab	46.36 c	56.46 abc
Mean (A_2)	9.80 b	10.33 b	71.14 b	82.81 a	41.53 b	49.02 b	
Mean (B)	0.0	9.42 b	10.10 b	67.38 d	77.03 c	37.10 c	46.95 c
	15	9.72 b	10.49 ab	71.17 c	83.18 bc	46.59 b	53.34 b
	30	10.65 a	10.95 a	75.73 b	88.46 ab	54.11 a	54.38 b
	45	10.83 a	11.10 a	79.92 a	91.13 a	56.56 a	59.15 a

* Means followed by the same letter or letters are not significantly difference at level 5 %

Table 5: Effect of VA-mycorrhizal inoculants and phosphorus fertilizer levels on weight of 1000 seeds (g), total seeds yield (kg/fed.) and germination % of okra plants in 2007 and 2008 seasons

Treatments		Characters					
		Weight of 1000 seeds (g)		Total seeds yield (kg/fed.)		Germination (%)	
Myco (A)	Phosphorus (B) (kg P_2O_5/fed)	2007	2008	2007	2008	2007	2008
With Myco.	0.0	64.34 c	61.37 d	610.40 d	610.44 c	83.67 abc	82.00 ab
	15	69.35 b	66.97 b	660.03 b	661.43 b	85.32 ab	85.74 ab
	30	71.40 ab	72.17 a	705.76 a	707.00 a	87.00 a	85.00 ab
	45	72.67 a	72.07 a	707.62 a	709.13 a	87.33 a	86.67 a
	Mean (A_1)	69.44 a	68.14 a	670.95 a	672.00 a	85.83 a	84.89 a
Without Myco.	0.0	49.85 f	48.90 g	484.87 g	483.48 f	78.61 d	78.70 b
	15	52.14 e	55.30 f	530.41 f	522.67 e	80.67 cd	79.23 b
	30	59.46 d	58.50 e	576.24 e	577.92 d	82.67 bc	79.00 b
	45	56.10 c	63.03 c	625.65 c	615.77 c	87.00 a	87.33 b
Mean (A_2)	56.64 b	56.43 b	554.29 b	549.96 b	82.25 b	81.06 b	
Mean (B)	0.0	57.09 d	55.13 d	547.64 d	546.96 d	81.17 c	80.35 b
	15	60.74 c	61.13 c	595.22 c	592.05 c	82.99 bc	82.48 ab
	30	65.43 b	55.33 b	641.00 b	642.46 b	84.83 ab	82.00 b
	45	68.88 a	67.55 a	666.64 a	662.45 a	87.17 a	87.00 a

* Means followed by the same letter or letters are not significantly difference at level 5 %

Concerning the influence of interaction between VA-mycorrhiza and phosphorus fertilizer levels on okra seed yield and its components, results in Table (4 and 5) clearly revealed that the studied interaction significantly increased total seed yield and its component as well as germination percentage. These finding held true in the two experimental seasons. Meanwhile, the highest values were resulted in the combination between inoculation with VA-mycorrhizae and both 30 and 45 kg P_2O_5/fed with out any significant differences between the two phosphorus levels. Hence, we can mentioned that using the interaction between VA-mycorrhizae and 30 kg P_2O_5/fed. Achieved the objectives of this study through recording the highest seed yield and reduce phosphorus fertilizer level, consequently reduced environmental pollution and seed production costs. Increasing in total seed yield (kg/fed.) may be due to the increases in seed yield components i.e., number of mature fruits/plant, number of seeds/fruit, seeds weight /plant (g), weight of 1000 seeds (g) and total seed yield kg/fed. In addition, seed germination percentage take all most the same general trend as in all seed yield characters in the two experimental seasons. These finding are in harmony with those reported by Abd-Allah *et al.* [19].

The most prominent effect of the fungus is improved phosphorus nutrition of the host plant (okra plants) in soils with low phosphorus levels [34]. However, uptake of nitrogen, zinc, copper and minor nutrients are enhanced

Table 6: Correlation coefficient values (r) between total green fruits yield (ton/fed.) and each of other five characters in okra at 2007 and 2008 seasons.

	Correlation coefficient values (r)	
Characteristics	2007 season	2008 season
Plant height (cm)	0.93**	0.93**
Number of branches/plant	0.78**	0.86**
Weight of green fruits/plant (g)	0.89**	0.94**
Green fruit length (cm)	0.95**	0.78**
Green fruit diameter (cm)	0.62*	0.80**

* and ** Significant and highly significant level 0.05 and 0.01 level, respectively.

Table 7: Correlation coefficient values (r) between total seeds yield (kg/fed.) and each of other four characters in okra at 2007 and 2008 seasons

	Correlation coefficient values (r)	
Characteristics	2007 season	2008 season
Number of mature fruits/plant	0.88**	0.89**
Number of seeds/fruit	0.68*	0.83**
Seeds weight /plant (g)	0.90**	0.90**
Weight of 1000 seeds (g)	0.93**	0.99**

* and ** Significant and highly significant level 0.05 and 0.01 level, respectively.

as well improved plant nutrition due to increasing root surface through extra radical hyphae, degradation of organic material and alteration of the microbial composition in the rhizosphere [35]. In addition, improve soil aggregation [36] and promote overall plant health [37]. In this investigation, the obtained results reveal that values of the highest total green fruits yield (ton/fed.) and the highest total seed yield (kg/fed.) were produced by interaction between VA-mycorrhizae and both (15 and 30 kg P_2O_5/fed.) in both seasons, respectively. Therefore, it seems that in the light of presumptive evidences, we can use VA-mycorrhizae inoculants to replace 1/2 and 1/3 of phosphorus recommended dose for both the highest total green fruits yield (ton/fed.) and the highest total seed yield (kg/fed.), respectively. Hence, inoculation of okra seed with VA-mycorrhizae reduced the production costs, enhance both total green fruits yield (ton/fed.) and total seed yield (kg/fed.) and reduced environmental pollution. Finally, studies must be conducted to find different ways to replace or reduce using various chemical fertilizers, which use in enormous quantities and accumulate in plant tissues.

Correlation studies: The results of correlation coefficient values (r) is of great value in the determination of the most effective procedures for selection of superior traits. When there is positive association of major yield characters, component breeding would be very effective but when these characters are negatively associated, it would be difficult to exercise simultaneous selection for them in developing a variety. In the present study correlation between total green fruits yield (ton/fed.) and (vegetative growth and green fruits yield components characters), as well as the correlation between total seeds yield (kg/fed.) and (number of mature fruits/plant, number of seeds/fruit, seeds weight/plant (g) and weight of 1000-seeds (g) were evaluated in both seasons.

Correlation coefficient values (r) between total green fruits yield (ton/fed.) and (vegetative growth and green fruits yield components characters) in 2007 and 2008 seasons are shown in Table (6). Results clearly indicated that it was interesting to note that most of the characters showed highly significant positive correlations with total green fruits yield (ton/fed.). This is an indication that these characters influence total green fruits yield directly [34, 26].

Concerning the correlation between total seeds yield (kg/fed.) and (number of mature fruits/plant, number of seeds/fruit, seeds weight/plant (g) and weight of 1000-seeds (g)) in 2007 and 2008 seasons. Data presented in Table (7) obviously showed that all characters recorded highly significant positive correlations with total seeds yield (kg/fed.) in the two experimental seasons. On the other hand, weight of 1000-seeds (g) had a highly and significant positive relationship with total seeds yield (kg/fed.) i.e., (0.93** and 0.99**) in the first and second season, respectively. This suggests that any increase in weight of 1000-seeds (g) will lead to corresponding increase in total seeds yield (kg/fed.).

Selection for all the abovementioned character especially weight of 1000-seeds (g), will therefore, be very rewarding in the improvement of total seeds yield (kg/fed.). Singh and Chaudhary [23] mentioned that selecting for yield characters with significant positive relationship both genotypically and phenotypically will automatically increase yield.

REFERENCES

1. Sharma, B.R., 1993. Genetic improvement of vegetable crops. Ed. by Kalloo G and Bergh, B.O. Pergamon press oxford and New York, pp: 751-769.
2. Russell, E.J., 1950. Soil Conditions and Plant Growth. Longmans, Green and Co. London, pp: 30-36 and pp: 38-39.
3. Majanbu, I.S., V.B. Ogunlela, M.K. Ahmed and J.D. Olarewaju, 1985. Response of two okra (*Abelmoschus esculentus* L. Moench) varieties to fertilizers: yield and yield components as influenced by nitrogen and phosphorus application. Fertilizer-Research, 6(3): 257-267.
4. Arora, S.K., N. Kumar and B.R. Sharma, 1994. Effect of nitrogen and phosphorus fertilization on growth and yield components in okra (*Abelmoschus esculentus* L. Moench). Haryana J. Hort. Sci., 20(3-4): 261-266. (CAB Abst. 1990-1995).
5. Lenka, P.C., D.K. Das and H.N. Mishra, 1989. Effect of nitrogen and phosphorus on seed yield of Bhindi cv. Parbhanikranti. Orissa J. Agric. Res., 2(2): 125-127.
6. El-Maziny, M.Y., M.A. Hassan and M.M. Farrag, 1990. Effect of plant density and NPK rate on okra. Minia J. Agric. Res. Dev., 12(1): 283-297.
7. Naik, L.B. and K. Srinivas, 1994. Influence of nitrogen and phosphorus fertilization on seed crop of okra (*Hibiscus esculentus*). Indian J. of Agron., 37(4): 769-771.
8. Bhat, K.L. and R.K. Dhar, 1999. Effect of nitrogen and phosphorus on seed yield of okra (*Abelmoschus esculentus* L. Moench). Vegetable Sci., 26: 1: 89-90.
9. Naik, L.B. and R.V. Singh, 1999. Response of okra (*Abelmoschus esculentus*) to nitrogen, phosphorus and spacing J. Res. Birsa Agric. Univ., 11(1): 35-37.
10. Amjad, M., M.A. Anjum and A. Ali, 2001. Effect of phosphorus and planting density on seed production in okra (*Abelmoschus esculentus* L. Moench). Intl. J. Agric. Biol., 3(4): 380-383.
11. Chattopahyay, A. and B.C. Sahana, 2001. Response of okra seed crop to nitrogen and phosphorus fertilization in acidic soil of old Alluvial Zone, West Bengal. Res. Crops, 1(2): 176-180.
12. Patton, W., A. Sema and C. Maiti, 2002. Effect of different levels of nitrogen and phosphorus on growth, flowering and yield of okra cv. Arka Anamika grown under the foothills. Hort. J., 15(1): 81-88.
13. Singh, R.V., 2002. Effect of intercrop and N, P fertilization on performance of okra (*Abelmoschus esculentus*). J. Res., Birsa Agric. Univ., 13(1): 41-44.
14. El-Shaikh, K.A.A., 2005. Effect of phosphorus and potassium fertilization on green yield, seed production and quality of two okra cultivars in reclaimed soils. Assiut J. Agric. Sci., 36(1): 51-68.
15. Mahmoud, S.A.Z. and A.M. Abdel-Hafez, 1982. The role of phosphate mobilizing bacteria in plant nutrition. The 1st OAU/STRC Inter. African Conf. on biofertilizers "Cairo, Egypt, 22-26 March, 1982."
16. Lambert, D.H., D.E. Baker and H. Cole, 1979. The role of mycorrhizae in interactions of phosphorus with Zinc, Copper and other elements. Soil Soc. Amer. J., 43: 976-980.
17. Saleh, H. and A. Al-Raddad, 1987. Response of okra to two vesicular arbuscular mycorrizal fungal isolates. Direst. 14:2, 119-122, Jordan.
18. Senapati, H.K., A.K. Pal and S.K. Swain, 1987. Effect of mycorrhiza on the growth characteristics of okra in laterite soil. Indian J. Hort., 44: 1-2, 93-95.
19. Abd-Allah, S.A.M., S.M.A. Mansour and Rawhia M. Wahba, 2004. Effect of bio nitrogen fertilizers on okra. Egypt. J. Agric. Res., 82(2): 173-185.
20. Sharma, M.P., Alok-Adholera and A. Adholya, 2000. Enhanced growth and productivity following inoculation with indigenous AM fungi in four varieties of onion in an alfisol. Biological-Agric. and Hort. 18: 1, 1-14.
21. Charron, G., V. Furlan, M. Bernier-Cardou and G. Doyon, 2001. Response of onion plants to arbuscular mycorrhizae. I-Effect of inoculation method and phosphorus fertilization on biomass and bulb firmness. Mycorrhizae, 11(4): 187-197.
22. El-Shaikh, K.A.A., 2005. Growth and yield of onion as affected by biofertilization and application of nitrogen and phosphorus fertilizers under south valley condition. Assiut, J. Agric. Sci., Vol. 36, No. 1, 2005
23. Singh, R.K. and S.D. Chaudhary, 1985. Biometrical methods in Quantitative Genetical Analysis. pp: 205-214.
24. Ariyo, O.J., 1989. Variation and heritability of fifteen characters in okra (*Abelmoschus esculentus* (L.) Moench). Trop. Agric. J. Trinidad, 67: 215-216.
25. Damarany, A., 1994. Estimates of genotypic and phenotypic correlation, heritability and potence of gene set in cowpea (*Vigna unguiculata* (L.) Walp). Assiut J. Agric. Sci., 25(4): 1-8.
26. Akinyele, B.O. and O.S. Osekita, 2006. Correlation and path coefficient analyses of seed yield attributes in okra (*Abelmoschus esculentus* (L.) Moench) African J. Biotechnol., 5(14): 1330-1336.

http://www.academicjournals.org/AJB.

27. Musandu, A.A.O. and K.E. Giller, 1994. Effect of vesicular arbuscular mycorrhizae on kudza (*Pueraria phaseoloides*) growth in phosphate fixing Keneya soil. African Crops Sci., J., 2 (3): 285-290.
28. Gomez, K.A. and A.A. Gomez, 1984. "Statistical Procedure for Agric. Res., " 2nd Ed. John-Wiley and Sons, Inc. New York 680 page.
29. Duncan, D.B., 1958. Multiple Range and Multiple F test. Biometrics, 11: 1-42.
30. Khalifa, M.R. and M.M. Badr, 1992. Interaction between fusarium root rot disease of faba bean and inoculation with mycorrhizal fungi and/or *Rhizobium leguminosarum* under different levels of NPK fertilization, Egypt J. Appl. Sci., 12: 851-863.
31. Mohd, S.A. and Z.A. Siddiqui, 2008. Arbuscular mycorrhizal fungi as potential bioprotectants against plant pathogens.Sustainable Agriculture and forestry, Chapter 3, 61-97.
32. Omotoso, S.O. and O.S. Shittu, 2007. Effect of NPK fertilizer rates and method of application on growth and yield of okra (*Abelmoschus esculentus* (L.) oench). Res. J. Agron., 1(2): 84-87.
33. Bieleski, R.L., 1973. Phosphate pools, phosphate transport and phosphate availability. Ann. Rev. of Plant Physiol., 24: 225-252.
34. Marschner, 1995. Mineral Nutrition of Higher Plants. Academic press, London, pp: 889.
35. Hodge, A. and C.D. Campbell, 2001. An arbuscular mycorrhizal fungus accelerates decomposition and acquires nitrogen directly from organic material. Nature, 413: 297-299
36. Andrade, G., K.L. Mihara, R.G. Linderman and G.J. Bethlenfalvay, 1998. Soil aggregation status and rhizobacteria in the mycorrhizosphere. Plant Soil, 202: 89-96
37. Linderman, R.G., 1992. Vesicular-arbuscular mycorrhizae and soil microbial interactions. In: Mycorrhizae in Sustainable Agriculture. Madison, USA., pp: 45-70.