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Maximizing Productivity of Some Garden Pea Cultivars and Minimizing Chemical Phosphorus Fertilizer via VA-Mycorrhizal Inoculants

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Abstract: This investigation was carried out at the Experimental Farm of Shandaweel Agriculture Research Station during 2007/2008 and 2008/2009 seasons. The experiment aimed to investigate the efficiency of VA-mycorrhizal inoculants, as an effective alternative for phosphorus chemical fertilizer, on the productivity of some garden pea cultivars. Three garden pea cultivars (Master B, Early Perfection and Progress no.9) were studied. Phosphorus fertilizer was added during soil preparation at four rates (11.25, 22.5, 33.75 and 45 kg P_2O_5/fed.). Seeds of studied cultivars were inoculated by VA-mycorrhizal after sowing or left without inoculation. The obtained results indicated that inoculation with VA-mycorrhizal significantly increased vegetative growth & pods characteristics, the total green pods yield (ton/fed.) and the yield components compared to control for both seasons. It also allowed early flowering and green maturity for all studied cultivars. However, significant difference was found among the studied cultivars in both seasons. Early perfection cultivar gave the highest number of branches/plant (3.56 and 3.23), number of pods/plant (31.93 and 32.46) and total green pods yield (5.270 and 5.520 ton/fed.) as compared to other studied cultivates in first and second seasons, respectively. Phosphorus fertilizer significantly increased vegetative growth & pods characteristics, the total green pods yield (ton/fed.) and the yield components in both seasons. The highest values were obtained when garden pea plants received the highest phosphorus rate compared to the other rates for both seasons. The interaction effect was significant for most studied characteristics. The most interesting result was found with the interaction among VA-mycorrhizal inoculants, Early perfection cultivar and 22.5 kg P_2O_5/fed. that resulted in the highest number of pods/plant and the highest total green pods yield. So, this interaction could be recommended for the highest productivity using suitable rate of phosphorus fertilization. It could reduce the cost of garden pea production and the pollution of environment.

Key words: *Pisum sativum* L. peas · VA-mycorrhiza · Phosphorus fertilizer

INTRODUCTION

Garden pea (*Pisum sativum* L.) is one of the most important favorable vegetable crops grown in Egypt for both local consumption and exportation. Phosphorus has a key role in the energy metabolism of plant cells and particularly in legume crops [1]. Garden pea has relatively high requirement for phosphorus [2-3]. Yield and its components can be enhanced by phosphorus fertilizer in soil testing low in phosphorus [4-8].

In most soils, in spite of the considerable addition of phosphorus fertilizers, the available phosphorus for plants is usually low since it is converting 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 [9]. Evidence has accumulated from a number of experiments indicating that there is a wide range of differences among garden pea cultivars in vegetative growth, flowering, pod characteristics yield and its components [10-14].

The biofertilziers are of a great agricultural importance since they can be used as alternatives for chemical fertilizers and hence the production costs of agricultural crops can be reduced and environmental

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pollution can be avoided [15]. Therefore, it becomes essential to use the untraditional fertilizers as a substitute or a 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 pea plants has attracted more attention for many benefits, especially enhancing uptake of phosphorus in soils with low phosphorus levels [16] due to the ability of the (VAM) to grow beyond the phosphate depletion zone that quickly develops around the root. Hence, the nutritional status of the host plant is improved by transferring phosphate. In some instances total mycorrhizal root surface was increased 30 times more than non mycorrhizal roots [17]. Moreover, several micronutrients, i.e. Fe, Zn, Mn and Cu are transferred from the soil to the plant through the VAM hyphae with some promoting substances for plant growth such as GA, IAA and CKS [18-20]. There is extensive evidence for the decrease in the number of arbuscules under high external phosphorus [21]. Inoculation of legumes crops with VAM fungi in presence or absence of different doses of P-chemical fertilizer highly increased growth, yield and its components of garden pea plants and many others legumes [22-31].

The present investigation was designed as an attempt to get benefit from the important physiological role of vesicular arbuscular mycorrhizae (V.A.M) to achieve the following objectives:

- Maximize the total green pods yield (ton/fed.) of garden pea plants.
- Reduce the possible health hazard due to the pollution of soil, water and plant tissues.
- Reduce the production costs through the replacement of the whole or a part of phosphorus chemical fertilizer.

MATERIALS AND METHODS

The present study was carried out during the winter seasons of 2007/2008 and 2008/2009 at the Experimental Farm at Shandaweel Agriculture Research Station, Sohag Governorate, Egypt, to investigate the efficiency of VA-mycorrhizal inoculants as a biofertiluzer and an effective alternative for phosphorus chemical fertilizer on productivity of some garden pea cultivars.

VA-Mycorrizal Inoculants: Two species of endomycorrhizal fungi were used in this study (*Glomus fasiculatum* & *Glomus mosseae*). They were supplied by Microbiology Dept., Fac. Agric. Minia University, Egypt. For preparing VA-mycorrhizal inoculants, fried pots of 30 cm in diameter were filled by sterilized clay loam soil. The soil of each pot was inoculated with the 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. Soil of the used pots was mixed together then VAM spores were counted as described by Musandu and Giller [32]. The spore count was found to be 95-100 spores/g soil. This soil contained mixture of VAM spores, mycelia and chopped roots. The prepared VAM inoculants were added at a rate of 4 kg of soil per plot and drilled in the ridges just before the first irrigation. Each ridge received equal quantity from VA-mycorrhizal inoculants (1 kg per ridge).

Cultivars: Three garden pea cultivars (Master B, Early perfection and Progress No.9) were used in this study. They were obtained from Vegetables Seed Production Technology Dept., Horti. Res. Inst., Agric. Res. Center, Giza, Egypt.

Phosphorus Rates: Phosphorus fertilizer was added during soil preparation at four rates (11.25, 22.5, 33.75 and 45 kg P_2O_5/fed.) in the form of calcium super phosphate (15% P_2O_5). The four rates represent 1/4, 1/2, 3/4 and the whole recommended dose according to the Ministry of Agriculture. The experiment was conducted in split-split plot design with four replications. The use of VA-mycorrhizal inoculants (with or without) was arranged in the main plots, the three studied cultivars were allocated in sub-plots and the four phosphorus rates were assigned in the sub sub-plots. Each experimental unit was 10.5 m^2 consisting four ridges at 75 cm apart and 3.5 m length. Sowing was done in 10th and 11th of October in the first and second seasons, respectively. Two seeds were sown per hill on the both sides of ridge at 10 cm spacing for Master B cultivar and 15 cm spacing for both Early perfection and Progress No. 9 cultivars. Standard agricultural practices known for commercial garden pea production other than the applied treatments were followed. Fruits were harvested regularly every three days. The physical and chemical characteristics of the experimental site were as shown in Table (1).

Table 1: The physical and chemical characteristics of the experimental site

Analysis				Available nutrients (ppm)		
Seasons	Texture	pH	O.M%	N	P	K
2007/2008	Clay loam	7.9	0.98	16.0	9.4	320
2008/2009	Clay loam	7.8	0.93	15.0	9.2	310

Ten plants were randomly chosen from each plot to determine the following characteristics:

Vegetative Growth Characteristics:

- Stem length (cm), from cotyledonary node to the top of the main stem.
- Number of branches/plant Days to both flowering and green maturity characteristics:
- Days to flowering: recorded as the number of days from sowing to 50% flowering.
- Days to green maturity: recorded as the number of days from sowing to the beginning of harvesting.

Pods Characteristics:
Fifty Pods Were Taken at Random from Each Harvest to Determine the Following:

- Number of seeds per pod.
- Seeds setting percentage calculated as follows: Seeds setting % = number of seeds per pod / number of ovules per pod x 100.

Yield and its Components:

- Number of green pods per plant.
- Weight of 100-green seeds (g),
- Shell out percentage, it was calculated by dividing the weight of green seeds per pod by the weight of whole green pod multiplied by 100.
- Total green pods yield (ton/fed.).

Statistical Analysis: Data obtained during the two seasons of the study were statistically analyzed and treatments means were compared using the Duncan's multiple range tests [33].

RESULTS AND DISCUSSION

Stem Length (cm) and Number of Branches/Plant: Data presented in Table (2) clearly show that VA-mycorrhizal inoculants significantly increased vegetative growth characteristics expressed as stem length (cm) and number of branches/plant as compared to uninoculated plants in both seasons. The inoculated plants exceeded uninoculated ones by (5.3, 5.4% and 16.4, 26.0%) for stem length (cm) and number of branches/plant in the first and second season, respectively. Such results may suggest that inoculation with VA-mycorrhizal fungi has the ability to supply garden pea plants by plant promoting substances, mainly Indole Acitic Acid, Gibberellic Acid and Cytokinne-like substances, which could stimulate plant growth traits, absorption of nutrients, efficiency of nutrient and metabolism of photosynthesis [18, 20]. The three garden pea cultivars significantly differed in their stem length (cm) and number of branches/plant. The tallest plants (71.97 and 71.50 cm) were produced by progress No. 9 cultivar. However, early perfection cultivar resulted in the highest number of branches/plant (3.56 and 3.23). These results held well in the first and second season, respectively. These results are in accordance with those found by EI-Shobakey [10] and El-Murabaa *et al.* [11]. Results given in the same Table indicated that phosphorus fertilization rates significantly increased stem length (cm) and number of branches/plant from the lowest up to the highest phosphorus rate in both seasons. The importance of phosphorus in garden pea vegetative growth was assured by Pulung [4] and Murat *et al.* [8]. Data in Table (2) show that all possible interactions affect significantly the garden pea growth measurements except the interaction of cultivars × phosphorus rates and the triple interaction for number of branches/plant in both seasons. The combination among VA-mycorrhizal inoculants, Early perfection cultivar and 22.5 kg P_2O_5/fed. recorded the highest number of branches/plant in the two studied seasons. Moreover, fertilizing Master B cultivar with 11.25 P_2O_5/fed. without inoculation gave the lowest values (45.95, 44.08 and 1.40, 1.48) for stem length (cm) and number of branches/plant in the first and second season, respectively. This may due to the high efficiency of VA-mycorrhizae in supplying growing plants with their phosphorus requirements. These findings are in line with those found by Fares [25], Ibijbijen *et al.* [27] and Musandu & Giller [32].

Days to Both Flowering and Green Maturity: Results presented in Table (3) reveal that inoculation of garden pea plants with VA-mycorrhizal fungi significantly reduced days till flowering and marketable green maturity in the two studied seasons. The earliness induced by VA-mycorrhizal fungi in the two studied characteristics may be attributed to the absorption of micronutrients as Fe, Zn, Mn and Cu transferred through the VA-mycorrhiza

Table 2: Effect of VA-mycrorrhizal inoculants, cultivars, phosphorus rates and their interactions on stem length (cm) and number of branches/plant in 2007/2008 and 2008/2009 seasons

		Stem length (cm)										Number of branches /plant									
		2007/2008					2008/2009					2007/2008					2008/2009				
		Phosphorus rates (P_2O_5, kg/fed.) (C)					Phosphorus rates (P_2O_5, kg/fed.) (C)					Phosphorus rates (P_2O_5, kg/fed.) (C)					Phosphorus rates (P_2O_5, kg/fed.) (C)				
A-mycorrhiza (A)	Cultivars (B)	11.25	22.5	33.75	45	Mean	11.25	22.5	33.75	45	Mean	11.25	22.5	33.75	45	Mean	11.25	22.5	33.75	45	Mean
VA-mycorrhiza	Master B	48.70	49.37	49.03	48.60	48.93	47.33	47.90	47.47	47.40	47.53	1.60	1.73	1.70	1.67	1.68	1.73	1.87	1.83	1.80	1.81
	Early perfection	62.47	63.53	63.47	63.33	63.20	61.67	62.93	63.17	62.77	62.63	3.47	3.57	3.53	3.47	3.51	3.67	3.83	3.77	3.73	3.75
	Progress No. 9	70.60	73.43	73.63	75.33	73.25	71.13	72.77	72.63	72.53	72.27	2.83	2.90	2.87	2.77	2.84	2.97	3.17	3.13	3.03	3.08
	Mean	60.59	62.11	62.04	62.42	61.79	60.04	61.20	61.09	60.90	60.81	2.63	2.73	2.70	2.63	2.68	2.79	2.96	2.91	2.86	2.88
With out																					
VA-mycorrhiza	Master B	43.20	43.53	45.27	46.80	44.70	40.83	41.73	42.87	43.73	42.29	1.20	1.33	1.43	1.57	1.38	1.23	1.37	1.53	1.63	1.44
	Early perfection	57.43	59.43	61.27	62.33	60.12	56.30	58.30	61.10	62.40	59.53	2.77	2.93	3.10	3.23	3.01	2.43	2.60	2.77	3.00	2.70
	Progress No. 9	67.83	69.87	72.10	72.93	70.68	69.53	69.97	70.83	72.60	70.73	2.13	2.23	2.37	2.53	2.32	2.00	2.13	2.30	2.50	2.23
	Mean	56.16	57.61	59.54	60.69	58.50	55.56	56.67	58.27	59.58	57.52	2.03	2.17	2.30	2.44	2.24	1.89	2.03	2.20	2.38	2.13
Cultivars																					
X phosphorus	Master B	45.95	46.45	47.15	47.70	46.81	44.08	44.82	45.17	45.57	44.91	1.40	1.53	1.57	1.62	1.53	1.48	1.62	1.68	1.72	1.63
	Early perfection	59.95	61.48	62.37	62.83	61.66	58.98	60.62	62.13	62.58	61.08	3.12	3.25	3.32	3.35	3.56	3.05	3.22	3.27	3.37	3.23
	Progress No. 9	69.22	71.65	72.87	74.13	71.97	70.33	71.37	71.73	72.57	71.50	2.48	2.57	2.62	2.65	2.58	2.48	2.65	2.72	2.77	2.65
	Mean	58.37	59.86	60.79	61.57		57.80	58.93	59.68	60.24		2.33	2.45	2.50	2.54		2.34	2.49	2.56	2.62	
LSD at 0.5 Level for																					
VA-mycorrhiza	(A)					0.27					0.68					0.07					0.01
Cultivars	(B)					0.34					0.31					0.05					0.04
Phosphorus rates	(C)					0.31					0.29					0.04					0.05
	(A) x (B)					0.48					0.43					0.07					0.06
	(A) X (C)					0.44					0.41					0.04					0.07
	(B) x (C)					0.54					0.50					NS					NS
	(A) X (B) x (C)					0.76					0.71					NS					NS

Table 3: Effect of VA-mycrorrhizal inoculants, cultivars, phosphorus rates and their interactions on days to both flowering and green maturity in 2007/2008 and 2008/2009 seasons

		Days to flowering										Days to green maternity									
		2007/2008					2008/2009					2007/2008					2008/2009				
		Phosphorus rates (P_2O_5, kg/fed.) (C)					Phosphorus rates (P_2O_5, kg/fed.) (C)					Phosphorus rates (P_2O_5, kg/fed.) (C)					Phosphorus rates (P_2O_5, kg/fed.) (C)				
VA-mycorrhiza (A)	Cultivars (B)	11.25	22.5	33.75	45	Mean	11.25	22.5	33.75	45	Mean	11.25	22.5	33.75	45	Mean	11.25	22.5	33.75	45	Mean
VA-mycorrhiza	Master B	45.00	44.00	45.33	45.00	44.83	45.00	44.00	45.33	46.00	45.08	65.00	64.00	65.67	67.00	65.42	65.00	64.00	65.67	67.67	65.58
	Early perfection	65.00	64.00	65.33	65.33	64.92	64.67	64.00	65.67	66.67	65.25	86.33	85.00	86.33	87.00	86.17	85.00	84.00	85.67	86.33	85.25
	Progress No. 9	67.00	66.00	66.67	67.33	66.75	66.67	65.33	67.33	67.33	66.67	90.67	89.33	90.67	91.67	90.58	87.00	86.00	87.33	89.00	87.33
	Mean	59.00	58.00	59.11	59.22	58.83	58.78	57.78	59.44	60.00	59.00	80.67	79.44	80.89	81.89	80.72	79.00	78.00	79.56	81.00	79.39
With out																					
VA-mycorrhiza	Master B	47.67	47.00	46.00	45.67	46.58	47.33	46.33	45.66	46.00	46.33	70.33	68.67	69.67	70.00	69.67	69.67	68.33	69.00	68.00	68.75
	Early perfection	67.00	66.33	66.00	65.67	66.25	67.00	66.00	65.67	65.00	65.92	90.33	88.67	90.00	90.67	89.92	92.00	91.00	89.67	89.00	90.42
	Progress No. 9	70.67	70.67	69.33	68.67	69.67	70.67	70.00	69.33	68.67	69.67	93.33	91.67	93.00	93.67	92.92	94.33	93.67	91.67	90.33	92.50
	Mean	61.78	61.11	60.44	60.00	60.83	61.67	60.78	60.22	59.89	60.64	84.67	83.00	84.22	84.78	84.17	85.33	84.33	83.44	82.44	83.89
Cultivars																					
X phosphorus	Master B	46.33	45.50	45.67	45.33	45.71	46.17	45.17	45.50	46.00	45.71	67.67	66.33	67.67	68.50	67.54	67.33	66.17	67.33	67.83	67.17
	Early perfection	66.00	65.17	65.67	65.50	65.58	65.83	65.00	65.67	65.83	65.58	88.33	86.83	88.17	88.83	88.04	88.50	87.50	87.67	87.67	87.83
	Progress No. 9	68.83	68.00	68.00	68.00	68.21	68.67	67.67	68.33	68.00	68.17	92.00	90.50	91.83	92.67	91.75	90.67	89.83	89.50	89.67	89.92
	Mean	60.39	59.56	59.78	59.61		60.22	59.28	59.83	59.94		82.67	81.22	82.56	83.33		82.17	81.17	81.50	81.72	
LSD at 0.5 Level for																					
VA-mycorrhiza	(A)					0.75					0.52					0.32					0.95
Cultivars	(B)					0.17					0.30					0.33					0.26
Phosphorus rates	(C)					0.23					0.31					0.36					0.30
	(A) x (B)					0.24					0.42					0.46					0.37
	(A) X (C)					0.33					0.44					0.51					0.42
	(B) x (C)					NS					NS					NS					0.52
	(A) X (B) x (C)					NS					NS					NS					0.73

Table 4: Effect of VA-mycrorrhizal inoculants, cultivars, phosphorus rates and their interactions on number of seeds/pod and seeds setting % in 2007/2008 and 2008/2009 seasons

		Number of seeds/pod										Seeds setting%									
		2007/2008					2008/2009					2007/2008					2008/2009				
		Phosphorus rates (P_2O_5, kg/fed.) (C)					Phosphorus rates (P_2O_5, kg/fed.) (C)					Phosphorus rates (P_2O_5, kg/fed.) (C)					Phosphorus rates (P_2O_5, kg/fed.) (C)				
VA-mycorrhiza (A)	Cultivars (B)	11.25	22.5	33.75	45	Mean	11.25	22.5	33.75	45	Mean	11.25	22.5	33.75	45	Mean	11.25	22.5	33.75	45	Mean
VA-mycorrhiza	Master B	8.30	8.77	8.63	8.57	8.57	8.47	8.77	8.70	8.57	8.63	85.93	86.43	86.33	86.17	86.22	86.43	87.13	86.97	86.83	86.84
	Early perfection	7.10	7.47	7.37	7.27	7.30	7.43	7.87	7.80	7.77	7.72	82.33	83.27	83.23	82.90	82.93	83.10	83.87	83.73	83.47	83.54
	Progress No. 9	7.03	7.13	7.03	6.93	7.03	7.03	7.33	7.23	7.17	7.19	73.70	74.10	74.40	73.77	73.99	74.17	75.00	74.90	74.93	74.75
	Mean	7.48	7.49	7.68	7.59	7.63	7.64	7.99	7.91	7.83	7.84	80.66	81.27	81.32	80.94	81.05	81.23	82.00	81.87	81.74	81.71
With out																					
VA-mycorrhiza	Master B	7.73	7.90	8.10	8.37	8.03	7.67	7.90	8.10	8.20	7.97	81.20	82.23	82.87	83.03	82.33	81.63	82.43	82.83	84.63	82.88
	Early perfection	6.73	6.83	7.07	7.27	6.98	7.13	7.37	7.57	8.00	7.52	80.60	81.43	81.93	82.70	81.67	78.60	79.47	80.47	81.53	80.02
	Progress No. 9	6.67	6.83	7.13	7.27	6.98	6.67	7.03	7.33	7.70	7.18	62.58	63.20	64.30	65.54	63.91	61.73	62.98	63.33	64.18	63.06
	Mean	7.04	7.19	7.43	7.63	7.33	7.16	7.43	7.67	7.97	7.56	74.80	75.62	76.37	77.09	75.97	73.99	74.96	75.54	76.78	75.32
Cultivars																					
X phosphorus	Master B	8.02	8.33	8.37	8.47	8.30	8.07	8.33	8.40	8.38	8.30	83.57	84.33	84.60	84.60	84.28	84.03	84.78	84.90	85.73	84.86
	Early perfection	6.92	7.15	7.22	7.27	7.14	7.28	7.62	7.68	7.88	7.62	81.47	82.35	82.58	82.80	82.30	80.85	81.67	82.10	82.50	81.78
	Progress No. 9	6.85	6.98	7.08	7.10	7.00	6.85	7.18	7.28	7.43	7.18	68.14	68.65	69.35	69.65	68.95	67.95	68.99	69.12	69.56	68.90
	Mean	7.26	7.49	7.56	7.61		7.40	7.71	7.79	7.90		77.73	78.44	78.84	79.02		77.61	78.48	78.71	79.26	
LSD at 0.5 Level for																					
VA-mycorrhiza	(A)					0.09					0.05										0.46
Cultivars	(B)					0.03					0.04										0.22
Phosphorus rates	(C)					0.04					0.05										0.22
	(A) x (B)					0.04					0.06										0.32
	(A) X (C)					0.06					0.07										0.31
	(B) x (C)					0.08					0.09										NS
	(A) X (B) x (C)					0.11					0.13										NS

hyphae and some promoting substances as GA, IAA and CKS [18-19]. Results in the above mentioned Table clearly show that the three studied garden pea cultivars significantly differed in days till flowering and marketable green maturity in both seasons. Master B cultivar was the earliest cultivar meanwhile, the latest one was Progress No.9 in both seasons. These results may due to genetic variation among garden pea cultivars [11, 14]. Results illustrated in Table (3) clearly indicate that applying phosphorus rates to garden pea plants significantly improved earliness i.e., days till flowering and marketable green maturity in both seasons. Garden pea plants which received the lowest phosphorus rate i.e., (11.25 kg P_2O_5/fed.) showed the highest days number till flowering and marketable green maturity as compared to other phosphorus rates 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 [1]. Concerning the interaction effect, data in Table (3) reveal that all possible interactions affect significantly garden pea earliness except the interaction of cultivars × phosphorus rates and the triple interaction in both seasons. The combination among VA-mycorrhizal inoculants, Master B cultivar and 22.5 kg P_2O_5/fed. resulted in the least days number till flowering and marketable green maturity in the two studied seasons.

Number of Seeds per Pod and Seeds Setting Percentage: Results listed in Table (4) show that inoculation of garden pea plants with VA-mycorrhizal fungi highly increased pods characteristics expressed as the number of seeds/pod and seeds setting percentage as compared to uninoculated plants in both seasons. The inoculated plants exceeded uninoculated ones by (3.9 and 7.1%) as mean of two seasons for number of seeds /pod and seeds setting percentage, 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. In some cases, total mycorrhizal root surface was increased 30 times more than non mycorrhizal roots [17]. Garden pea cultivars significantly differed in pods characteristics in the two experimental seasons. Master B cultivar gave the highest values (8.30 and 84.57 %) as compared to the lowest ones (7.09 and 68.93%) of Progress No. 9 cultivar as mean of two seasons for the number of seeds/pod and seeds setting percentage, respectively. These results may be due to that Master B cultivar produce one pod per node. These findings are in accordance with those reported by El-Shobakey [10],

Table 5: Effect of VA-mycrorrhizal inoculants, phosphorus rates and their interactions on number of pods/plant and weight of 100- green seeds (g) in 2007/2008 and 2008/2009 seasons

		Number of pods/plant										Weight of 100- green seeds (g)									
		2007/2008					2008/2009					2007/2008					2008/2009				
		Phosphorus rates (P_2O_5, kg/fed.) (C)					Phosphorus rates (P_2O_5, kg/fed.) (C)					Phosphorus rates (P_2O_5, kg/fed.) (C)					Phosphorus rates (P_2O_5, kg/fed.) (C)				
VA-mycorrhiza (A)	Cultivars (B)	11.25	22.5	33.75	45	Mean	11.25	22.5	33.75	45	Mean	11.25	22.5	33.75	45	Mean	11.25	22.5	33.75	45	Mean
VA-mycorrhiza	Master B	20.50	21.27	19.23	18.20	19.80	19.90	21.03	20.43	19.83	20.30	48.87	50.20	50.17	49.47	49.68	50.83	51.43	51.30	51.17	51.18
	Early perfection	34.43	35.80	34.23	33.20	34.42	34.53	36.30	35.83	35.33	35.50	36.13	37.13	36.87	36.40	36.63	35.30	35.53	35.60	35.47	35.48
	Progress No. 9	30.40	31.63	30.40	30.10	30.63	30.40	31.73	30.93	30.40	30.87	70.03	69.87	70.00	69.47	69.84	70.83	71.27	71.10	70.50	70.93
	Mean	28.44	29.57	27.96	27.17	28.28	28.28	29.69	29.07	28.52	28.89	51.68	52.40	52.34	51.78	52.05	52.32	52.74	52.67	52.39	52.53
With out																					
VA-mycorrhiza	Master B	14.43	15.40	16.40	18.53	16.19	13.53	15.40	17.33	18.77	16.26	44.87	45.07	45.87	46.53	45.58	40.33	41.17	42.47	43.20	41.87
	Early perfection	26.27	28.33	30.73	32.43	29.44	26.60	28.47	30.37	32.23	29.42	29.10	30.00	31.07	32.77	30.73	28.80	29.97	31.17	31.70	30.41
	Progress No. 9	19.17	21.93	23.73	25.30	22.53	18.77	21.37	23.80	26.93	22.72	61.30	62.53	64.03	65.73	63.40	61.07	61.93	63.10	63.90	62.50
	Mean	19.96	21.89	23.62	25.42	22.72	19.63	21.74	23.83	25.98	22.80	45.09	45.87	46.99	48.34	46.57	43.40	44.36	45.68	46.27	44.93
Cultivars																					
X phosphorus	Master B	17.47	18.33	17.82	18.37	18.00	16.72	18.22	18.88	19.30	18.28	46.87	47.63	48.02	48.00	47.63	45.58	46.30	47.03	47.18	46.53
	Early perfection	30.35	32.07	32.48	32.82	31.93	30.57	32.38	33.10	33.78	32.46	32.62	33.67	33.97	34.58	33.68	32.05	32.75	33.38	33.58	32.94
	Progress No. 9	24.78	26.78	27.07	27.70	26.58	24.58	26.55	27.37	28.67	26.79	65.67	66.20	67.02	67.60	66.21	65.95	66.60	67.10	67.20	66.71
	Mean	24.20	25.73	25.79	26.29		23.96	25.72	26.45	27.25		48.38	49.13	49.67	50.06		47.86	48.55	49.17	49.32	
LSD at 0.5 Level for																					
VA-mycorrhiza	(A)					0.50					0.47					0.50					0.76
Cultivars	(B)					0.25					0.16					0.32					0.29
Phosphorus rates	(C)					0.26					0.25					0.43					0.49
	(A) x (B)					0.35					0.22					0.45					0.40
	(A) X (C)					0.37					0.35					0.53					0.69
	(B) x (C)					0.45					0.42					NS					NS
	(A) X (B) x (C)					0.64					0.60					0.92					NS

Table 6: Effect of VA-mycorrhizal inoculants, cultivars, phosphorus rates and their interactions on shellout% and total green pods yield (ton/fed.) in 2007/2008 and 2008/2009 seasons

		Shellout %										Total green pods yield (ton/fed.)									
		2007/2008					2008/2009					2007/2008					2008/2009				
		Phosphorus rates (P_2O_5, kg/fed.) (C)					Phosphorus rates (P_2O_5, kg/fed.) (C)					Phosphorus rates (P_2O_5, kg/fed.) (C)					Phosphorus rates (P_2O_5, kg/fed.) (C)				
VA-mycorrhiza (A)	Cultivars (B)	11.25	22.5	33.75	45	Mean	11.25	22.5	33.75	45	Mean	11.25	22.5	33.75	45	Mean	11.25	22.5	33.75	45	Mean
VA-mycorrhiza	Master B	54.47	56.00	55.90	55.50	55.47	55.47	56.37	56.33	56.23	56.10	5.267	5.358	5.268	5.043	5.234	5.441	5.617	5.467	5.370	5.474
	Early perfection	49.80	50.37	50.27	50.03	50.12	50.23	50.77	50.10	48.93	50.01	5.545	5.656	5.533	5.458	5.548	5.698	5.847	5.724	5.596	5.716
	Progress No. 9	47.60	48.53	48.43	48.30	48.22	46.80	47.60	46.67	46.70	46.94	4.035	4.192	4.122	4.012	4.090	4.024	4.271	4.127	4.068	4.123
	Mean	50.62	51.63	51.53	51.28	51.27	50.83	51.58	51.03	50.62	51.02	4.035	5.069	4.975	4.838	4.958	5.054	5.245	5.106	5.012	5.104
With out																					
VA-mycorrhiza	Master B	47.53	48.60	50.03	52.17	49.58	45.67	46.20	47.27	48.93	47.02	3.876	4.084	4.422	5.216	4.400	4.479	4.655	4.864	5.065	4.766
	Early perfection	43.83	45.27	45.77	46.57	45.36	43.50	44.60	45.77	46.27	45.03	4.507	4.791	5.184	5.482	4.991	4.964	5.132	5.440	5.758	5.324
	Progress No. 9	41.57	42.57	43.77	45.23	43.28	42.80	43.67	46.03	48.40	45.23	2.798	3.122	3.365	3.466	3.187	2.770	2.979	3.270	3.720	3.185
	Mean	44.31	45.48	46.52	47.99	46.08	43.99	44.82	46.36	47.87	45.76	3.727	3.999	4.323	4.721	4.193	4.071	4.255	4.525	4.849	4.425
Cultivars																					
X phosphorus	Master B	51.00	52.30	52.97	53.83	52.53	50.57	51.28	51.80	52.58	51.56	4.571	4.721	4.845	5.130	4.817	4.960	5.136	5.165	5.218	5.120
	Early perfection	46.82	47.82	48.02	48.30	47.74	46.87	47.68	47.93	47.60	47.52	5.026	5.224	5.359	5.470	5.270	5.331	5.490	5.582	5.677	5.520
	Progress No. 9	44.58	45.55	46.10	46.77	45.75	44.80	45.63	46.35	47.55	46.08	3.416	3.657	3.743	3.739	3.639	3.397	3.625	3.698	3.894	3.654
	Mean	47.47	48.56	49.03	49.63		47.41	48.20	48.69	49.24		4.338	4.534	4.649	4.780		4.563	4.750	4.815	4.930	
LSD at 0.5 Level for																					
VA-mycorrhiza	(A)					0.05					0.21					57.26					37.57
Cultivars	(B)					0.11					0.43					24.59					21.60
Phosphorus rates	(C)					0.22					0.32					29.28					27.71
	(A) x (B)					0.16					0.60					34.77					30.54
	(A) X (C)					0.32					0.46					41.40					39.19
	(B) x (C)					0.39					0.56					50.70					47.99
	(A) X (B) x (C)					0.55					0.79					71.71					67.87

El-Murabaa *et al.* [11] and Mohamed [14]. Data in Table (4) show that increasing phosphorus rates significantly increased pods characteristics expressed as the number of seeds /pod and seeds setting percentage for both seasons. Garden pea plants which received the highest phosphorus rate (45 kg P_2O_5/fed.) produced the highest values for pod characteristics as compared to the lowest ones resulted from plants fertilized with lowest phosphorus rate (11.25 kg P_2O_5/fed.) 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 [1]. These results are in accordance with those reported by Kasturikrishna & Ahlawat [7] and Murat *et al.* [8]. Results in the above mentioned Table obviously reveal that the interaction significantly affected the number of seeds /pod and seeds setting percentage in both seasons. However, the interaction (VA-mycorrhizal inoculants × Master B cultivar × 22.5 kg P_2O_5/fed.) achieved the highest number of seeds/pod and seeds setting percentage in both seasons. Saini [28], Abd El-Ati *et al.* [29] and Kristek1 *et al.* [30] came to the same general trend.

Number of Pods/Plant, Weight of 100-green Seeds (g), Shellout Percentage and Total Green Pods Yield (Ton/Fed.): Results illustrated in Tables (5 and 6) clearly show that inoculation of garden pea seeds with VA-mycorrihzal inoculants significantly increased yield and its components expressed as the number of pods/plant, weight of 100-green seeds (g), shellout percentage and total green pods yield (ton/fed.) as compared to uninoculated ones in both seasons. Meanwhile, the highest values were (28.6, 52.3, 51.1 and 5.031) as the mean of two seasons for number of pods/ plant, weight of 100-green seeds (g), shellout percentage and total green pods yield (ton/fed.), respectively. This positive result could be explained by the greater volume of soil explored by VA-mycorrhizae hyphae. In some instances total mycorrhizal root surface was increased 30 times more than non mycorrhizal roots [17]. Moreover, several micronutrients as Fe, Zn, Mn and Cu transferred through the VA mycorrhizal hyphae [19]. In addition, the increments of the previously discussed characteristics due to the inoculation with VA-mycorrhizal inoculants surely reflect positively on yield and its components. Data presented in Tables (5 and 6) obviously show that garden pea cultivars markedly differed in yield and its components in both seasons. Furthermore, Early perfection cultivar produced the highest values for number of pods per plant and the total green pods yield (ton/fed.) as compared to the other studied cultivars in both seasons. These findings may be due to that Early perfection cultivar produces two pods per node and the highest number of branches/plant. These results are in accordance with those reported by El-Shobakey [10] and Jangpo *et al.* [13]. Regarding the effect of various applied rates of phosphorus fertilizer, the obtained results reveal that applying phosphorus fertilizer gradually increased number of pods per plant, weight of 100-green seeds (g), shellout percentage and total green pods yield (ton/fed.) from the lowest rate (11.25 kg P_2O_5/fed.) up to the highest one (45 kg P_2O_5/fed.). 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. Garden pea yield and its components can be enhanced by phosphorus fertilizer [7-8].

Concerning the interaction effect, data show that most possible interactions were significant for the yield and its components. However, the most interesting result was that the interaction among VA-mycorrhizal inoculants, Early perfection cultivar and 22.5 kg P_2O_5/fed. resulted in the highest total green pods yield (5.656 and 5.847 ton/fed.) in the first and second season, respectively. This may be due to that the same interaction produces the highest number of pods/ plant. Smith and Smith [21] mentioned that there is extensive evidence for a decrease in the number of arbuscules under high external phosphorus. El-Shaikh and Mohammed [31] worked on okra plants and found that 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. Under such conditions, the interaction among VA-mycorrhizal inoculants, Early perfection cultivar and 22.5 kg P_2O_5/fed. could be recommended to achieve the highest total green pods yield, save enormous amount of phosphorus fertilizer (50% from the recommended dose) and minimize both garden pea production costs as well as the environmental pollution.

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