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Effect of varying plant population density on aphid infestation level and yield of faba bean

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Abstract

Four plant populations: 8, 16, 24 and 32 plants per square meter were tested for their effects on aphid infestation levels and yield potentiality of faba bean (*Vicia faba* L.) Giza 843 variety, grown under natural infestation in Sids Agricultural Research Station, Beni-Suef Governorate, throughout two consecutive seasons of 2009/10 and 2010/11. Results indicated that a greater number of cowpea aphids infested the lower dense plant populations. Insect population increased with time in all plant populations tested. Dense planting satisfactorily decreased the proportion of plants infested with cowpea aphid by 27.55 and 34.53 % in 2009/10 and 23.10 and 27.26 % during 2010/11 season at plant population of 24 and 32 plants /m². There has been negative relation between aphid abundance and plant density per unit area observed. Also, there was a positive response of seed yield with higher plant population densities; 24 and 32 plants /m² confirmed in the two successive seasons. The seed yield of faba bean crop cultivated at the rate of 24 and 32 plants /m² increased by (19.02 % and 20.50 %), and (14.66 and 34.02 %), over the two lower plant population densities 8 and 16 plants /m²., in the first and second seasons, respectively. The overall results lead to the conclusion that yields of faba bean Giza 843 variety under environment of infestation with cowpea aphid, *A. craccivora* in middle Egypt region, could be successfully maximized by planting the crop at 24-32 plants /m² plant density (sowing at 2 seeds /hill in double rows or one seed /hill in three rows, 20 cm hill to hill distance on ridges 60 cm apart).

Keywords: Faba bean, Plant Density, Aphids, Seed Yield.

Introduction

Cowpea aphid (*Aphis craccivora* Koch.) is the most serious insect pest affecting the plant growth of faba bean (*Vicia faba* L.) in the field. Yield losses depend on the time and intensity of aphid infestation (Bishara *et al*., 1984). This aphid species is the most common species in the Middle Region of Egypt, as well; it can transmit many viruses efficiently (Bos and Makkouk, 1994 and Srivastava *et al*., 2010).

Crop production practices may enhance or suppress survival, abundance, and severity of damage of faba bean insect pests. These practices can be used to avoid conditions that favor insect pests or activate conditions detrimental to an increase in insect abundance or damage. Therefore, several cultural practices can be applied in faba bean crop to protect it against aphid attacking, mainly through impact of closing spacing by green cultivation. Since this pest survival in different alternate host plants (Megahed, 1979), management of farming system has paramount importance in its cultural control (Risch, 1987; Ferro, 1987 and López-Bellido *et al*., 2005**).** Therefore, the present work was carried out to evaluate the effects of different plant population densities on aphid infestation and yield potentiality of the local cultivar Giza 843.

Materials and methods

A field experiment was conducted at Sids Agricultural Research Station, Beni-Suef Governorate, middle Egypt in 2009/10 and 2010/11 winter growing seasons. The present work aimed to find out the optimum plant population of faba bean (*Vicia faba* L.) Giza 843 variety grown under natural infestation with cowpea aphids. The crop was sown in the 1st week of November in both tested seasons. Four plant densities (PD1= 8, PD2= 16, PD3= 24 and PD4= 32 plants /m² by means 33600, 67200, 100800, and 134400 plants /fed.) were tested. The experimental plot was 6 x 7 m² (1/100 fed.), laid out in a randomized split block design with four replications. Spraying against insect pests or diseases were omitted but the whole experimental area was hand-weeded twice and weeds were kept well controlled. The plots were harvested between 5–10 May in the two seasons. The final harvested seed yield was calculated from a net area of 25 m² /plot. During the vegetative growth stages, in any sampling date, 10 plants /plot were randomly chosen and replicated 4 times at each field plot of the respective treatments (four plant population densities) were followed. The activity and abundance of cowpea aphid, *Aphis craccivora* Koch, were weekly recorded starting from the 1st week of December 2009 and 2010 until the end of the season in the 2nd week of April 2010 and 2011. Insects on the upper most two-

thirds of plants (one central shoot /plant) were checked using the inverse binomial sampling technique (Hafez, 1964). The mean of the 4 replicates was worked out to represent population density. Data were tabulated and statistically analyzed adopting the procedure of Snedecor and Cochran (1980).

Results and discussion

1. Aphid in relation to plant population:

Fluctuations in population density of *Aphis craccivora* of faba bean plants grown under four plant population densities viz., 8, 16, 24 and 32 plants per square meter were estimated weekly after three weeks from seeding date and continued until the infestation almost disappeared in the field lasting 19 and 18 weeks throughout the first and second seasons, respectively. Obtained data are presented in Table 1. This species was more abundant during 2009/10 than 2010/11 season. Statistical analysis of the data showed that plant population density had significant effects on weekly mean counts of the cowpea aphid existed on faba bean plants, throughout the nineteen and eighteen successive counts ($P = > 0.001$).

During 2009/10 season, faba bean field plots planted at the density of 8 and 16 plants /m² confronted higher population density of aphid (614.5 ± 32.5 and 551.2 ± 27.7 individuals /plant shoot), forming one group (GI) with nonsignificant difference. On contrary, field plots planted at the higher rate 24 and 32 plants /m², comparatively harbored lower infestations rates of aphids being (422.4 ± 22.7 and 381.5 ± 21.8 individuals /plant shoot), and also forming one group (GII) with nonsignificant difference. During the second season 2010/11, the same trend of aphid abundance on faba bean plants existed. Faba bean plots planted at lower plant density per square meter (8 and 16 plants /m².) exhibited the highest response to cowpea aphid infestations; while those planted at higher population densities 24 and 32 plants /m², harbored lower numbers of cowpea aphids.The four means of seasonal aphid counts sustained the faba bean plants being 291.1 ± 13.5, 268.9 ± 13.1, 215.3 ± 10.5 and 203.6 ± 10.1 insects /plant shoot, for the field plots cultivated at the rate of 8, 16, 24 and 32 plants /m², respectively. Data further referred; there were highly significant relationships between aphid number and plant densities (E.V. = 96.34 and 94.39 %, in the first and second seasons, respectively). The higher and the lower rates of plant densities were negatively affected by *A. craccivora* population in the two successive seasons 2009/10 and 2010/11 (r = -0.9815 and -0.9716, respectively). The lowest aphid population was obtained when planting took place at higher density 24 and 32 plants /m²; meanwhile, the lower rate of plant populations 8 and 16 plants /m², sustained the higher aphid populations in the two tested seasons (Fig., 1). The negative relation between aphid abundance and plant density per unit area observed is in agreement with the results of Auclair (1989) that related usually higher fecundity and reproductive periods of this aphid species. Interestingly, aphid abundance was strongly correlated with plant population density of the tested cultivar Giza 843 variety. These results agree with the findings of Holt and Wratten, 1986; El-Defrawi *et al.,* 1998 and Asin and Pons, 2001. Salem (1998) found that infestation with *A. craccivora* on broad bean during February was higher on plants cultivated on two sides or alternative on both sides of a row than that on plants sown on one side with nonsignificant difference.

The fore-mentioned results lead to the conclusion that dense planting of faba bean satisfactorily decreases the proportion of plants infested with cowpea aphids by (27.55 % and 34.53 %) in 2009/10; and (23.10 % and 27.26 %), in the second season 2010/11, at the plant population rates of 24 and 32 plants /m², and in turn, reduces the subsequent rate of multiplication of aphids and finally the size of the population per unit area, probably because individual plants in dense stands are less nutritious and have a shorter maturation time than those in low stands as anatomized by Way and Heathcote (1966). Furthermore, in such crops of similar high density, plants with narrower spacing between hills had smaller peak numbers of aphids than those with wider spacing (A'Brook, 1977; Helaly *et al*., 1994 and Muhammed *et al*., 2006).

2. Seed Yield Potentiality:

Seed yield per unit area was increased with increasing plant density with nonsignificant difference between 24 and 32 plants /m² in the two tested seasons 2009/10 and 2010/11 as shown in Fig., 2. These findings coordinated with El-Deeb (1982) and Amer (1986) who found no reliable yield increases due to plant densities above 24 plants /m². However, Mohamed (1985), observed yield increases due to plant densities between 11 and 47 plants /m². This is expected since the maximization of seed yield is depending on the genotype and controlled environments. The number of plants per unit area at harvest followed a pattern similar to that of seed yield. Higher rate of plant populations 24 and 32 per square meter produced (20.02 and 21.50 Kg /100 m².) in 2009/10 season and (40.57 and 35.02 Kg /100 m²), in the second season 2010/11, out yielding other plant population densities.

Table 1. Changes in the population density of *A. craccivora* on faba bean plants cultivated under four plant population densities during 2009/10 and 2010/2011 seasons, sids, ARS, Beni-Suef governorate, middle Egypt.

Sampling date (Month /week no.)		Mean number of aphids / plant shoot at indicated plant density									
		2009/10 season					2010/11 season				
		Plant density /m²					Plant density /m²				
		8	16	24	32	Mean	8	16	24	32	Mean
November	2nd.W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3rd.W.	78.5	66.2	70.7	56.5	68.0	28.3	21.4	30.6	23.1	25.9
	4th.W.	101.5	136.5	100.4	74.5	103.2	137.0	141.1	135.5	101.9	128.9
December	1st.W.	230.1	249.4	161.7	148.7	197.5	289.8	266.4	190.3	176.8	230.8
	2nd.W	331.7	350.9	239.6	190.2	278.1	315.3	307.3	282.6	235.7	285.2
	3rd.W.	387.8	399.2	267.2	210.6	316.2	369.1	369.5	330.1	304.8	343.4
	4th.W.	667.6	548.1	419.8	391.2	506.7	672.7	677.8	513.3	524.5	597.1
January	1st.W.	1083.1	936.0	837.6	783.1	910.0	866.2	820.0	650.7	618.5	738.9
	2nd.W	1772.5	1622.8	1135.8	1261.0	1448.0	752.8	741.6	622.8	583.6	675.2
	3rd.W.	2097.8	1753.8	1452.8	1333.0	1659.4	332.3	282.0	268.4	215.8	274.6
	4th.W.	1398.0	1108.8	932.3	805.0	1061.0	203.4	166.8	132.7	190.1	173.3
February	1st.W.	1041.0	1036.5	891.5	737.5	926.6	140.4	106.7	86.1	82.7	104.0
	2nd.W	837.8	785.5	589.3	425.3	659.5	174.6	149.0	100.6	95.2	129.9
	3rd.W.	433.0	360.5	236.5	197.8	307.0	186.6	158.3	112.2	110.1	141.8
	4th.W.	481.5	483.3	280.8	272.0	379.4	511.4	403.1	250.1	237.7	350.6
March	1st.W.	538.3	399.5	252.0	231.5	355.3	189.8	152.8	93.0	112.5	137.0
	2nd.W	123.8	172.0	98.5	70.5	116.2	33.2	35.3	36.9	36.3	35.4
	3rd.W.	50.5	33.8	40.0	42.3	41.7	23.7	17.0	21.4	8.0	17.5
	4th.W.	17.5	26.0	15.3	16.8	18.9	12.7	23.2	17.8	8.0	15.4
April	1st.W.	4.0	3.0	2.8	1.0	2.7	-	-	-	-	-
Mean ± S.E.		614.5 ± 32.5	551.2 ± 27.7	422.4 ± 22.7	381.5 ± 21.8	492.4 ± 26.2	291.1 ± 13.5	268.9 ± 13.1	215.3 ± 10.5	203.6 ± 10.1	244.7 ± 11.8
"F" values		19.96 (>0.001)					18.7 (>0.001)				
L.S.D. (0.05)		69.3					27.6				
Rank		GI 32 plants /m² (381.5 insects) 24 plants /m² (422.4 insects)		GII			GI 32 plants /m² (203.6 insects) 24 plants /m² (215.3 insects)		GII		
				16 plants /m² (551.2 insects) 8 plants /m² (614.5 insects)					16 plants /m² (268.9 insects) 8 plants /m² (291.1 insects)		

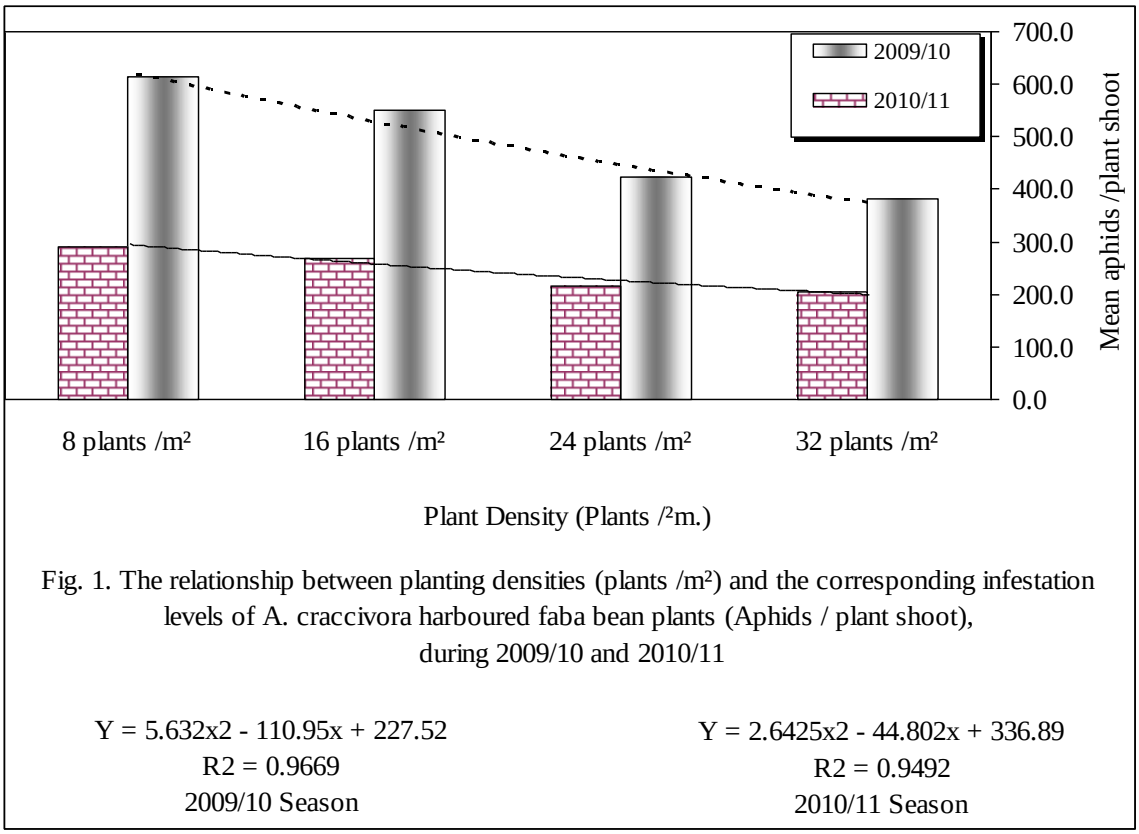

Fig. 1. The relationship between planting densities (plants /m²) and the corresponding infestation levels of A. craccivora harboured faba bean plants (Aphids / plant shoot), during 2009/10 and 2010/11

The seed yield of faba bean crop cultivated at the rate of 24 and 32 plants per square meter increased by (19.02 % and 20.50 %), and (14.66 and 34.02 %), than the two lower plant population densities 8 and 16 plants /m², in the first and second seasons, respectively. In general, there has been a constant association between number of plants per unit area and seed yield obtained (Fig. 2). These results indicate the possibility of increasing the productivity of faba bean yield by using a population density between (24 and 32 plants /m²), which are corresponding to 100800 and 134400 plants /fed. (1 fed = 4200 m²).

The aforementioned results in Table 1 and illustrated in Fig. 1 and 2 revealed, that the dense canopies (24 and 32 plants /m²) harbored lower levels of aphid abundance and significantly produced higher seed yield than sparse densities due to direct impact of insects on the physiological processes of plants. Infestation may also cause severe disruption of plant tissues or even the death of plants (Forrest *et al*., 1973; Dantuna and Thomson, 1983 and Tosh, 1998). The relationship between aphid abundance and seed yield of the recommended cultivar Giza 843 variety in the two tested seasons was strong and linear (r = -0.9089 and -0.8882, *P* >0.001), with explained variance of 82.61 % and 78.89 %, in the two tested seasons, respectively. This implying that aphid abundance on plants was dependent upon environmental differences which have impact on seed yield. Accordingly, the change in yield potentiality and corresponding number of aphids on plants in the four plant densities may be used as parameter, it could be predicated as the increase in aphids per plant (X) is usually followed by decrease in yield (Y), expressed as follows: Y = (-82.789 X + 699.36, R^2 = 0.9634) and (-31.589 X + 323.68, R^2 = 0.9439), resulted in the two tested seasons, respectively (Fig., 1). Similar effects of infestation have been recorded in many aphid species. However, different aphid species may have different effects on the same host plant. For example, *Aphis fabae* causes a reduction in the weight of seeds and the number of seeds per pod in *Vicia faba*, while *Acyrthosiphon pisum* may only reduce seed weight (Bouchery, 1977). Similar findings were obtained by Mohamed (1985), who observed yield increases due to plant densities between 11 and 67 plants /m². This is expected since the maximization of seed yield is depending on genotype as well the controlled environments. Many authors (Sprent *et al*., 1977; Abo El-Zahab *et al*., 1981 and Poulain, 1984) recorded that increases in plant density lead to reductions in branching and pod numbers /plant without much change in either seed size or seeds /pod.

Yield losses in faba bean due to *A. craccivora* have also been shown to depend on the timing and intensity of colonization (Salem, 1998 and Hossni, 2004). They also pointed out that infested cultivars of faba bean by relatively low aphid numbers (few per plant shoot) showed a simulative effect on plant growth and reduced their susceptibility to aphids.

Fewer crops stand (lower plant population) harboring higher number of insect pests that could lead to increased damage of crop leaves, stems and yield components. Eventually, crop yield is inversely affected at lower plant populations attracting increased number of insect pests. El-Defrawi, 2009 reported that faba bean seeds and straw yield damages by cowpea aphid increased when plant populations decreased from 33, 25 to 11 plants /m² in sole cropping close to legume crops such as fenugreek, chickpea and lentil. Plant population density, nevertheless, contributed to the total seed yield of the crop. The present results showed a positive response of seed yield with higher plant population densities, 24 and 32 plants /m². These results are in agreement with the findings of El-Deeb, 1982; Mohamed, 1985; Amer, 1986 and Hossni, 2004. Many authors pointed out that physiological changes have been recorded in plants following aphid infestation. Those included reduction in water permeability and the level of carbohydrate reserves (Putritch and Talmon-deI'Armee, 1971 and Christine *et al.*, 2005) and higher and lower levels of growth-inhibiting and growth-promoting substance, respectively, in the radish, *Raphanus sativus*, after infestation by *Myzus. persicae* (Hussain *et al*., 1974). As cowpea aphid, delivers toxic substances by salivary secretions, it is generally assumed that their effect on growth is mainly due to removal of phloem sap from their host plants. Thus, aphid infestation reduces the mass flow of nutrients into the primary growth zone (Mittler and Sylvester, 1961; Pollard, 1973).

The overall results of the present investigation indicate that seed yields of faba bean Giza 843 variety under environment of infestation with cowpea aphid, *A. craccivora* which commonly common attack plants annually in Beni-Suef Governorate, middle Egypt, could be successfully maximized by means of reducing the reduction caused by insect pest attack to faba beans by planting the crop at 24-32 plants /m² plant density (sowing at 2 seeds /hill in double rows or one seed /hill in three rows, 20 cm hill to hill distance on ridges 60 cm apart) proved to reduce the cowpea aphids damage.

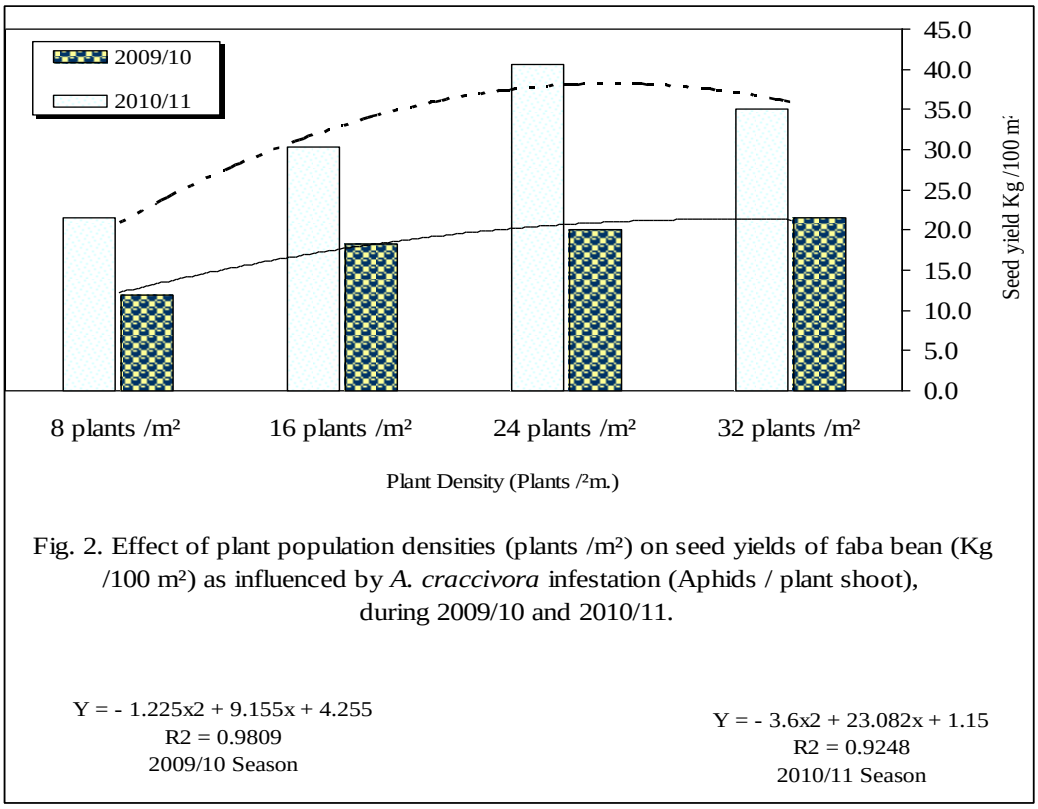

Fig. 2. Effect of plant population densities (plants /m²) on seed yields of faba bean (Kg /100 m²) as influenced by *A. craccivora* infestation (Aphids / plant shoot), during 2009/10 and 2010/11.

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تأثير أختلاف الكثافة النباتية على مستوى الإصابة بحشرات المن وإنتاجية الفول البلدي

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تعتبر الكثافة النباتية في وحدة المساحة فى الفول البلدي من أهم التوصيات الفنية المرتبطة بتعظيم الإنتاج لدى المزارعين، وحيث لا تتوافر معلومات علمية كافية يمكن الاعتماد من خلالها في إمكانية تعديل كثافات زراعة الفول البلدي بهدف درء الإصابات الوبائية المتكررة بحشرات المن الناقلة للأمراض الفيروسية، لذا أجريت هذه الدراسة في محطة سدس للبحوث الزراعية – محافظة بنى سويف – إقليم مصر الوسطي خلال موسمي 2010/2009 و 2011/2010 باستخدام جيزة 843 صنف محلى من الفول البلدي بهدف دراسة تأثير أربعة كثافات نباتية 8، 16، 24 و 32 نبات في المتر المربع أي (33600، 67200، 100600 و 134400 نبات في الفدان) على قابلية هذه الصنف للاصابة بحشرة من اللوبيا *Aphis craccivora* ومدى قدرته على إنتاج محصول البذرة تحت هذه الظروف وكذا أيجاد أنسب كثافة نباتية تعمل على خفض الإصابة إلى أدنى حد وتحقق إنتاجية عالية دون استخدام مبيدات حشرية أو كيماويات ملوثة للبيئة.

1. أظهرت النتائج وجود اختلاف معنوي لتعداد حشرة من اللوبيا التي أصابت نباتات الفول البلدي صنف جيزة 843 حيث تميزت نباتات الفول ذات الكثافات العالية بنقص شدة إصابتها بهذه الحشرة.
2. انخفاض شدة الإصابة بحشرات المن بنسبة 27.55 % و 34.53% خلال الموسم الأول وبنسبة 23.10 % و 27.26 % في الموسم الثاني في القطع التجريبية ذات الكثافات النباتية العالية 24 و 32 نبات في المتر المربع على الترتيب.
3. تفوقت الكثافات النباتية العالية 24 و 32 نبات في المتر المربع على الزراعات ذات الكثافة المنخفضة 8 و 16 نبات في كمية المحصول بوحدة المساحة بنسبة 19.02 و 20.50 % في الموسم الأول و 14.66 و 34.02 % في الموسم الثاني على التوالي.

وبناء على النتائج المتحصل عليها يمكن التوصية بزراعة محصول الفول البلدي في منطقة مصر الوسطي بكثافة نباتية تتراوح بين 100800 و 134400 نبات في الفدان أى بمعدل 24–32 نبات في المتر المربع لتقليل الإصابة بحشرات المن في تلك المنطقة ولضمان إنتاج وفير من البذور بوحدة المساحة تحت هذه الظروف.