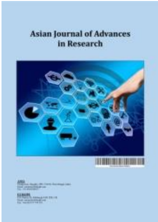

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Effect of Plant Density and Biofertilization Treatment in Some Productivity and Quality Indicators of Two Peanut Varieties in Tartous, Syria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The research was carried out during the 2022 agricultural season at Zahid Water and Irrigation Research Station - Center for Scientific Agricultural Research in Tartous-Syria .The research aimed to study the effect of agricultural density (20 × 50 and 30 × 50 cm) and spraying with EM1 biofertilizer concentrations (0, 3 and 6 ml/L) in some productivity (number of pods/plants, 100 seed weight, and pod yield) and quality (protein and oil content (%)) indicators of two peanut varieties (Soori 2, Giza 6)**.** The experiment was designed as a spilt-split plot design with three replications per treatment; where plant density the main plots, the biofertilization treatments the sub-plots, and the varieties the sub-sub-plots. The results showed that there was a significant effect (*P<0.05*) of plant density on all the studied traits. The plant density (30 × 50 cm) achieved the highest 100 seed wiegh (115.81 g), the number of pods (53.70 pod/plant), and the protein (27.16 %) and oil (43.58 %) contents, While the plant density (20 × 50 cm) achieved the highest pod yield per hectare(4285.37kg/ha). The results indicated a significant effect (*P<0.05*) of the biofertilization on all the studied traits; where the rate of 6 ml/L showed the highest number of pods (55.20 pods/plant), the 100seed weight (110.91 g), pod yield (4342.08 kg/ha) and the protein (27.85 %) and oil (44.91 %) contents. The Giza 6 variety was significantly superior (*P<0.05*) to Soori 2 in all the traits studied, the interaction between the biofertilization and plant density and variety had also a significant effect (*P<0.05*) on all studied traits**.**

Keywords: Peanuts; plant density; biofertilization; quality; productivity.

1. INTRODUCTION

Peanuts *Arachis hypogaea* L. is an annual herbal legume with self-pollinated, and that is considered as a very important food crop throughout the tropics and sub-tropics [1]. All species in the genus *Arachis* are unusual among legumes in that they produce their fruit below the ground [2].

Peanut seeds contain a high percentage of oil, up to 60 %, and rich in protein, up to 35 %. This protein includes most of the essential amino acids and has a high nutritional value due to the presence of lysine and tryptophan, which makes it close to animal protein, and therefore can be considered an excellent food source, especially for children and people who depend on a vegetarian diet and need a balanced diet to compensate for their lack of animal protein [3].

Peanut crop also has an agricultural importance as it is included in the agricultural cycle, improving soil properties, and restoring its depleted fertility by fixing atmospheric nitrogen through bacterial nodes on the roots [4].

There are many factors that affect peanut production, which include agricultural practices and methods, especially the agricultural density used. Konlan et al. [5] suggested that maximum yield is only possible if the plant produces enough leaf area optimize photosynthesis. Equidistant spacing between plants is also important to minimize intra-row competition between plants for resources.

The results indicated the significant effect of plant density (6.66, 8, 10 and 13.33 plants/m^2) on increasing productivity of peanut; the density (13.333 plant/m^2) achieved the highest productivity of pods (2990 kg/h) and seed yield (2428 kg/h) [6].

In an experiment conducted in Kenya on the effect of agricultural density (148.149; 213.331 and 333.334 plant/h) in peanut crop, the results showed a significant effect of plant densities on the number of pods/plant and pods productivity per hectare, while there were no significant differences in the number of seeds/pod and the number of empty pods/plants [7]. The results of Onat et al. [8] in a study to evaluate the impact of plant densities on pod yield and some agronomic characteristics, and where five different intra-rows spacing (5, 10, 15, 20 and 25 cm) were used in single row planting pattern, showed that pod number and weight per plant and 100 seed weight values were decreased when the plant density was increased, but shelling index, pod and kernel yield and protein percentage values were increased. The oil content was not affected by the plant density.

Biofertilizers are preparations that contain growth regulators and microorganisms, which are used through the soil, sprayed on plants, or mixed with seeds during planting. Treating plants with these compounds stimulates plant growth and increases the yield and the plants resistance to biotic and abiotic stresses [9]. In an experiment on the effect of biofertilization on growth and productivity of peanut crop in Syria, four rate of biofertilizer were used (0, 2, 4 and 6 cm^3/L); the result showed that spraying bio-fertilizer at a rate of 2 cm^3/L conducted significant effect in all traits, (plant height, leaf area, number of pods/plant, number of leaves/plant, biological and seed yield/h), except weight of 100 seed and shelling index [10]. The application of biofertilizer EM1 at a rate of 1.5 ml/L indicated an increase in (plant height, and dry matter weight, the content of chlorophyll, carotene, protein, oil, amino acids and carbohydrates) for the soybean crop [11]. Spraying peanut plants with Sea Bloom bioorganic fertilizer increased the plant height, the number of branches/plants, the number of leaves /plants and leaf area index [12]. The objective of this study was to determine the effect of plant density and bio fertilization on some productivity and quality indicators of two peanut varieties in Tartous- Syria.

2. MATERIALS AND METHODS

2.1 Research Site

The research was carried out during the agricultural season 2021- 2022 in Zahid Water and Irrigation Research Station, Agricultural Scientific Research Center in Tartous-Syria, which has a moderate climate suitable for growing peanut.

The station is 4.5 km from the Mediterranean Sea and 11 m above sea level.

2.2 Preparation of Soil

Two perpendicular plowings were carried out, the first at a depth of 30 cm (to disassemble and ventilate it), and the second at a depth of 10 cm (to soften it), then the land was divided according to the design of the experiment.

Phosphate and potash fertilizers were added completely when preparing the land for agriculture with the second cultivation at a rate of 174 kg/ha P_2O_5 and 120 kg/ha K_2O. The nitrogen fertilizer was added at a rate of 30 kg/ha N after planting, half the amount before flowering and the second at the beginning of formation pods. The planting was done on 4/1/2022 and all recommended service operations for this crop were implemented from planting to harvest.

An analysis of the soil to be cultivated was conducted to determine its texture and content of nutrients, after samples were taken from different places on the ground after plowing. They were air-dried and sifted to pass through a sieve with 2 mm holes and were subjected to laboratory analysis to determine some of their physical and chemical properties such as pH was determined by a pH meter, Electrical conductivity (EC) was determined using an electrical conductivity meter, Organic matter: by wet digestion method and using a Spectrophotometer, Total lime: It is estimated by the volumetric method and effective lime by titration with ammonium oxalate [13], Total nitrogen content Kjeldahl method as specified by C.A.O.A. [14] Available phosphorus by spectrophotometer [15], Mechanical analysis of soil using the hydrometer method and determination of texture using the texture triangle according to the American classification (USDA). which are shown in Table (1). The soil is non-calcareous clay, tending to be alkaline, poor in organic matter and nitrogen, and with a low content of phosphorus and potassium.

2.3 Experiment Design

The research was carried out with a split-split plot design with three replicates, where the density, the biofertilizer and the varieties occupied the main plots, the sub-plots and the sub-sub plots, respectively. The experiment contained 3 factors:

(1) plant density**:**

- about 100.000 plants/ha (20 × 50 cm) (the distance between the plants is 20 cm and the distance between the lines is 50 cm).
- about 66.666 plants/ha (30 × 50 cm) (the distance between the plants is 30 cm and the distance between the lines is 50 cm).

(2) Biofertilization:

Treatment with biofertilizer EM1 (a natural product, a natural biological product in the form of a solution containing more than 60 types of beneficial microorganisms. It is a joint Japanese-Syrian production produced by Al-Anam Company under the supervision of the Japanese Imero Corporation). was carried out by foliar spraying (spraying plants until wet) at three concentrations (F1: Control without spraying, F2: 3 ml/L, F3: 6 ml/L) during three stages (branching and flowering stage and the beginning of pod formation).

Table 1. Physical and chemical analysis of the soil of the planting site (Akkar Plain - Tartous)

Mechanical Analysis %			Total content N (%)	Content ppm Dry Soil		Total content %		Effective lime %	EC dS/m	PH
clay	**silt**	**Sand**	**N**	**P2O5**	**K2O**	**O M**	**$CaCO_3$**			
56	22	22	071	6.12	109	1.34	Impacts	Impacts	1.18	7.57

(3) Varieties:

Two varieties of peanut *Arachis hypogaea* L. were studied, (Soori 2, Giza 6) obtained from the General Commission for Scientific Agricultural Research in Damascus- Syria.

Each experimental plot contained 4 lines with a distance of 50 cm between them. The dimensions of the experimental plot were (2 × 3 m), thus its area was 6 m^2.

The number of treatment combinations: 2 × 2 × 3= 12, and the experimental units: 12 × 3= 36.

2.4 Studied Qualities and Characteristics

Productive Traits: Number of pods/plants: 10 random plants were taken from each experimental plot, and the pods were counted for each plant and then the average was calculated.

Weight of 100 seeds (g)**:** after uprooting the plant, separating the pods from it and extracting the seeds, a random sample of 100 seeds was taken with three replicates, after air drying the treatments, they were weighed with a sensitive balance and the averages were calculated.

Pod yield per hectare (kg/ha): The dry pods of each experimental plot were weighed, then the productivity was calculated in unit area (kg/ha)

Qualitative Traits: Determination of oil %**:** The oil was extracted from peanut seeds using (Soxhlet), and the percentage was estimated according to Association of Official Analytical Chemists [13].

Determination of protein %: The nitrogen percentage in seeds was estimated using (Micro-Kjeldahl) method according to Association of Official Analytical Chemists [13]. Protein percentage was calculated according to the following equation;

Protein % = Nitrogen percentage (N %) × 6.25

2.5 Statistical Analysis

Analysis of variance was performed using CoStat - Software version 6.4, and the L.S.D 5 % value was calculated to compare the means.

3. RESULTS AND DISCUSSION

The results of analysis of variance for the plant densities, biofertilization, and varities and their interactions are presented in Table 2.

3.1 Effect of Plant Density, Biofertilization and the Interaction on the Number of Pods (Pod/Plant)

The data in Table (3) showed significant differences (*P<0.05*) between the studied treatments in terms of pods number/plants for the two varieties**.** The plant density (20 × 50 cm) resulted in a significant decrease, reaching value of (40.5 pods/plant), while the density (30 × 50 cm) led to a significant increase (53.7 pods/plant), and this can be explained by the increase in the nutritional area and in exploit light interception that allow to more effective photosynthesis at low plant density (30 × 50 cm) as compared to higher density (20 × 50 cm), and in addition to reduce plant competition for all other inputs; this result is consistent with Mohammad et al. [6]**.**

Table 2. analysis of variance for various traits

Source of Variation	**df**	**Mean squares (MS)**				
		pods number (pods. plant^{-1})	**100 kernel weight(g)**	**oil content (%)**	**protein content (%)**	**pod yield (kg ha-1)**
D	1	1559.59*	3614.61*	65.52*	24.15*	22602365*
F	2	1104.11*	479.45*	75.0*	30.59*	5146285*
D.F	2	122.72*	142.27 NS	0.18NS	0.40NS	835531.76*
V	1	296.01*	1019.20*	49.21*	12.35*	9733880*
D. v	1	26.88*	58.19 NS	8.15*	0.14 NS	2.58NS
F.V	2	6.76 NS	3.87NS	0.55*	0.52*	1.38NS
D.F. V	2	1.46 *	8.26*	1.84*	0.57*	1.45NS

NS = non-significant

The number of pods/plants was significantly affected by spraying with EM1 (Table 3), where the high concentrations led to an increase in this indicator. The plant reached its highest pods number (55.2 pods) when sprayed with a concentration of 6 ml/L, as compared to the lowest pods number in the control treatment (36.5 pods). This can be explained by the role of biofertilization in enhancing vegetative growth and thus increasing the rate of photosynthesis, which led to an increase in the formation of organic materials, which is necessary to complete the flowering process, and thus increasing the number of pods/plant. These findings are consistent with the results of Mouhanna [10] that relived the importance of EM1 in driving photosynthesis and increasing vegetative growth and pods number. The Giza 6 variety with 50 pods/plant was significantly superior to the Soori 2 (44.3 pods/plant), which may due to genetic variety traits. The interaction between plant density and biofertilization and variety had a significant effect (*$P<0.05$*) on the number of pods (Table 3), as the Giza6 fertilized at a rate of 6 ml/L EM1 under the low density achieved the highest value of this indictor (68.10 pods/plant).

3.2 Effect of Plant Density, Biofertilization and the Interaction on 100 Seed Weight (g)

The plant density had significant effects (*$P<0.05$*) on 100 seed weight, where the low density was significantly superior to the high density, with a mean of 53.70 and 40.50 g, respectively (Table 3). The high value observed in the 100 seed weight of plant under the low density condition is due to the increase in the share of each plant of the nutritional and moisture requirements present in the soil; as the greater the distance between plants, the greater the chance of intercepting sunlight from most of the plant leaves, and thus the efficiency of photosynthesis and its products will increase, which are transferred to the seeds to increase their fullness and thus increase their weight, these results agreed with the results of Alam et al. [16] on peanut.

The biofertilizer had a significant effect (*$P<0.05$*) on 100 seed weight, and this positive influence was noted as the used rate of the compound increased; the 6ml/L concentration was significantly superior as compared to the other concentration and the control, with a mean of 55.20, 49.70 and 36.50 g, respectively (Table 3). Indeed, the spraying with biofertilizer EM1 is thought to improve plant growth and stimulate its metabolic processes, thus improving the process of photosynthesis and transferring its products to the seeds, thus giving a positive effect on seed weight. These results agreed with the results of Mahakavi et al. [12], who found that an increase in the rate of biofertilization led to high value in seed index of peanut. The Giza 6 was superior, as it gave the highest mean of 111.10 g as compared to the Soori 2 (100.46 g). The variation between the varieties is due to the size of the seeds, as the varieties with large seeds (Giza 6), that are significantly superior in the weight of 100 seeds (seed index). The interaction between plant density and bio fertilization had a significant effect (*$P<0.05$*) (Table 3), as the Giza 6, that is fertilized at 6 ml/L EM1 under the low density (30 × 50 cm) achieved the highest pods number (59.10 g).

3.3 Effect of Plant Density, Biofertilization, and the Interaction Pod Yield per Hectare (kg/ha)

The plant density had significant effects (*$P<0.05$*) on pod yield, where the high density was significantly superior to the low density, with a mean of 4557.75and 2973.02kg/ha, respectively (Table 3). The high value observed in the pod yield of plant under the high-density condition is due to the increase in plant number per unit area, which achieved an increase in pod yield. despite the increase in the productivity of one plant of pods due to the decrease in the number of plants present in the hectare from 100000 plant/ha when planting at a distance of (20 x 50 cm) to 66666 plants/ha when planting at a distance of (30 x 50), these results agreed with the results of Bakal et al. [17] on peanut.

The biofertilizer had a significant effect (*$P<0.05$*) on pod yield, and this positive influence was noted as the used rate of the compound increased; the 6ml/L concentration was significantly superior as compared to the other concentration and the control, with a mean of 4342.08, 3900 and 3053.45 kg/ha, respectively (Table 4). Indeed, the spraying with biofertilizer EM1 is thought to improve plant growth and stimulate its metabolic processes, thus improving the process of photosynthesis and transferring its products to the pods, thus giving a positive effect on pod yield. These results agreed with the results of Mahrous et al. [18], who found that an increase in the rate of biofertilization led to high value in pod yield of peanut. The Giza 6 was superior, as it gave the highest mean of 4285.37

Table 3. Effect of bio fertilization and plant density on pods number and seed index*

Density	Biofertilization	Variety	Pods number/plant (pods. plant^{-1})	100seeds weight (g)	pod yield (Kg. ha^{-1})
20x50	0 ml/l	Giza 6	34.8^{h}	97.83^{cd}	4753.55
		Soori2	32.1^{h}	87.51^{e}	3536.11
	3ml/l	Giza 6	43.1^{ef}	**100**.06^{c}	5067.66
		Soori2	39.4^{f}	91.09^{de}	4120.77
	6 ml/l	Giza6	49.7^{d}	101.54^{c}	5223.33
		Soori2	43.8^{e}	96.53^{cd}	4645.11
30X50	0 ml/l	Giza6	43.1^{ef}	**110**.96^{c}	2554.16
		Soori2	35.7^{g}	98.57^{cd}	1370
	3ml/l	Giza6	61.1^{b}	126.62^{a}	3770.55
		Soori2	55.1^{c}	113.11^{c}	2643.55
	6 ml/l	Giza6	68.1^{a}	129.60^{a}	4343
		Soori2	59.1^{b}	**115**.95^{b}	3156.88
L.S.D $_{5\%\ D}$	4.30			**5.69**	300.96
Mean Density 20X50			40.50^{b}	95.76^{b}	4557.75^{a}
30X50	53.70^{a}			115.81^{a}	2973.02^{b}
L.S.D $_{5\%}$ F	2.89			2.72	157.71
Mean Bio Fertilization 0ML/L	36.50^{c}			98.72^{c}	3053.45^{c}
3ML/L	49.70 ^{b}			107.73^{b}	3900.63^{b}
6ML/L	55.20^{a}			110.91^{a}	4342.08^{a}
L.S.D $_{5\%}$	1.61			**3.28**	170.37
Mean Verity V					
Giza6	50.0^{a}			**111.10**^{a}	4285.37^{a}
Soori2	44.2 ^{b}			**100.46**^{b}	3245.40^{b}
L.S.D $_{5\%\ DXFXV}$	1.01			3.24	NS

**Means followed by the different letters are significantly different at = 0.05*
D=density, F=biofertilization, V=variety NS = Non-Significant

kg/ha as compared to the Soori 2 (3245.40kg/ha). The interaction between plant density and bio fertilization had no significant effect, this indicates that the effect of the studied factors on pod yield was independent.

3.4 Effect of Plant Density, Biofertilization, and the Interaction on Protein Content (%)

As shown in Table 4, there were significant differences (*P<0.05*) between plant densities for the protein content, that was varied between 25.98 and 27.16 %. The protein content was decreased when the planting density increased. The protein content was 25.98 % under planting space (20 × 50 cm), and it increased to 27.16 % at (30 × 50 cm). These results could be attributed to that in wider spacing the plants is able to from more metabolites to synthesize more protein in the seeds and the activity of protein synthesis is higher than at narrow spacing. These results are in agreement with Onat et al. [8]. In this study, protein contents of peanut seeds were significantly (*P<0.05*) increased at 3 and 6 ml/L of EM1, respectively, as compared to untreated plants (Table 4**).** The rate at 6 ml/L was significantly superior to 3 ml/L and the control, with a mean of 27.85, 27.08 and 24.78 %), respectively. This positive effect may be due to the increased availability of nutrients needed by the plant, especially nitrogen, which plays a role in building amino acids, which effectively contribute to the synthesis of protein and then its transfer to storage parts. These results agreed with Saeed et al. [11]. The Giza 6 was superior, as it gave the highest mean of 27.39 % compared to Soori 2 (25.75 %). The differences between the varieties for the protein value may be caused by the genetic factors. The interaction between plant density and biofertilization had a significant effect (*P<0.05*) (Table 4), as Giza 6 that is fertilized at 6 ml/L EM1 under the low density (30 × 50 cm) achieved the highest protein content (29.89 %).

3.5 Effect of Plant Density, Biofertilization, and the Interaction on Oil Content (%)

It can be seen in Table 4, that the differences between the plant spaces were significant (*P<0.05*) for oil content. These indictor values varied between 41.25-43.58 %. The oil content was decreased when the plant space was reduced, and the highest oil content (43.58 %) was obtained under the plant space (20 × 50 cm). This can be explained that at low plant densities, the competition between the plants for nutrients, sunlight, water and air is very less, and therefore the plants grow better and finally produce the higher oil content. While in the higher plant densities, they have restricted conditions for development and thus produce the lower oil content in their seeds. The similar result was found by Gulluoglu [18].

The biofertilizer had a significant effect (*P<0.05*) on oil content, and it was noted that this influence increased as the concentration of fertilizer increased (Table 4). The rate at 6 ml/L was significantly superior to the 3 ml/L and the control, with a mean of 44.91, 42.42, and 39.91 %, respectively. This can be explained by the positive role of biofertilizer in improving growth and increasing the nutrient content of seeds. These results agreed with the results of Awadalla and Abbas [1**9**] on peanut.

The Giza 6 was superior, as it gave the highest mean of oil content 43.76 %, as compared to Soori 2 (41.07 %). The differences between the varieties for the oil value may be caused by the genetic factors. The interaction between plant density and biofertilization had a significant effect (*P<0.05*) on oil content (Table 4), as the Giza 6 that fertilized at a rate of 6 ml/L EM1 under the low density (30 × 50 cm) achieved the highest oil content (48.45 %).

Table 4. Effect of bio fertilization and plant density on protein and oil content*

Density	Biofertilization	Variety	Protein content (%)	Oil content (%)
20x50	0 ml/l	Giza6	24.72^{f}	39.62^{h}
		Soori2	23.62^{g}	37.74^{i}
	3ml/l	Giza6	26.65^{d}	**41**.49^{f}
		Soori2	25.63^{e}	40.68^{f}
	6 ml/l	Giza6	27.46^{c}	44.17^{c}
		Soori2	26.43^{d}	42.70^{d}
30X50	0 ml/l	Giza6	25.72^{e}	**42**.14de
		Soori2	25.06^{ef}	40.16^{gh}
	3ml/l	Giza6	28.51^{b}	45.64^{b}
		Soori2	27.55^{c}	41.86^{ef}
	6 ml/l	Giza6	29.89^{a}	48.45^{a}
		Soori2	27.62^{c}	**44**.34^{c}
L.S.D $_{5\%}$D	1.07			**1**.05
Mean Density 20X50		25.98^{b}		41.25 ^{b}
30X50	27.16^{a}			43.58 ^{a}
L.S.D $_{5\%}$F	0.53			0.34
Mean Bio Fertilization 0ML/L	24.78^{c}			39.91 ^{c}
3ML/L	27.08^{b}			42.42 ^{b}
6ML/L	27.85^{a}			44.91 ^{a}
L.S.D $_{5\%}$V	0.27			**0**.27
Mean Verity				
Giza6	27.39^{a}			**43**.76 ^{a}
Soori2	25.75^{b}			**41**.07 ^{b}
L.S.D $_{5\%DXFXV}$	0.68			0.66

**Means followed by the different letters are significantly different at = 0.05*
D=density ,f=biofertilization ,v=variety

4. CONCLUSIONS

The plant density had a significant effect on all studied traits of peanut. The low density was superior in: the number of pods, seed index, and oil and protein content. The biofertilization had a significant effect on seed index, the number of pods, the protein and oil content. The interaction between plant density and biofertilization had a significant effect on all studied characteristics, so the study should continue on fertilizing peanut with EM1 and other biofertilizer in terms of the rates to be added, and the dates of addition.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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