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Effect of Foliar Spray with Ascorbic Acid and Plant Density on the Yield and Quality of Chickpea (*Cicer arietinum* L.) Seeds

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ABSTRACT

A field experiment was conducted at the experimental research farm of Al-Azhar University in Assiut during the 2022/2023 and 2023/2024 seasons to study the effect of plant density at three densities (33, 22, and 17 plants/m²) and three concentrations of ascorbic acid (0, 2, and 4 ml/L) on the yield, its components, and quality of chickpea seeds. The experiment was designed as a split-plot in a randomized complete block design for main plots with three replicates, where main plots were allocated to the three plant densities and subplots allocated to the ascorbic acid concentrations. The results of this study showed that planting distance had a significant effect on all measured traits (plant height, number of branches and pods per plant, 100-seed weight, seed yield per plant, total seed yield in kg/feddan, straw yield in tons/feddan, and seed protein content) in both growing seasons. The highest values for most traits were recorded at a plant density of 33 plants/m², except for the number of branches per plant, which peaked at a plant density of 17 plants/m² in both experimental seasons. Foliar application of ascorbic acid at high concentration (4 ml/L) resulted in significant and increasing improvements in all studied traits in the first and second seasons of this study. This research study recommends applying a plant density of 33 plants/m² with foliar spraying with ascorbic acid at a rate of 4 ml/L to improve chickpea productivity under the prevailing conditions of the research area.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is one of the most important food legume crops widely cultivated in Egypt for seed production. Its seeds are rich in nutrients, as they contain 62.51% carbohydrates, 25.20% protein, 14.7% fiber, 5.48% fat, and 4.27% ash. They also contain some essential amino acids such as lysine and tryptophan. Its seeds, green or dried, are used as human food. Chickpeas are also used for many medicinal purposes. Chickpea yields can be increased by introducing high-yielding varieties and applying optimal agricultural practices (El-Said and Ahmed, 2021). Planting density is one of the agricultural treatments that significantly impacts the quality of growth and productivity of agricultural crops. Under optimal plant density conditions, plants with more extensive and well-distributed root systems can access a larger area of soil, improving their efficiency in using water and nutrients, which positively impacts productivity and quality (Ahmed, 2020). El- Murshedy (2008) found that plant density had a significant effect where the lowest plant density i.e. 33 plants/m^2 gave the highest number of branches and pods per plant, and significantly higher seed yield/plant and seed index, it gave the shortest plants with the lowest number of pods, the lowest average seed yield per plant and percentage of protein in seeds. Mehdi *et al.* (2010) reported that increasing the plant density from 12.5 to 20 plants/m² resulted in a significant effect and a significant increase in the biological and economic yields. Atif *et al.* (2017) pointed out that increasing plant density resulted in a decrease in the number of pods and seed yield per plant, but increased the productivity per unit area, while the number of seeds per pod and harvest index remained largely unaffected. Ascorbic acid plays a crucial and important role in plants as an essential metabolite, acting as an enzyme cofactor, antioxidant, and signaling molecule in many important physiological processes in plants such as cell wall formation, hormone regulation, photoprotection, and stress tolerance (Wolucka *et al.* 2005). Research by Khafaga *et al.* (2014) showed that higher rates of ascorbic acid significantly improved seed and pod yield, 100-seed weight, and number of branches per plant over two experimental seasons. Khalifa *et al.* (2020) indicated that foliar application of ascorbic acid was reported to have a significant effect and improvement in seed yield and crop characteristics in both growing seasons. Consequently, this study aimed to examine the effects of planting density and foliar application of ascorbic acid on the productivity and quality of chickpea.

MATERIALS AND METHODS

The current study was successfully conducted at the experimental research farm of Al-Azhar University in Assiut Governorate, Egypt, during the 2022/2023 and 2023/2024 seasons, to study the effect of plant density at three densities (33, 22 and

17 plants/m^2) and three rates of ascorbic acid (0, 2 and 4 ml/L) on the yield, its components and quality of chickpeas (cv. Giza-195). The statistical design of the experiment split-plot in a randomized complete block design for main plots with three replicates, where main plots were successfully identified and allocated to the plant densities, and subplots were allocated and placed for ascorbic acid. Each experimental plot measured was 10.5 m², comprising five ridges (3.5 m long and 0.60 m wide). The three plant densities (33, 22, and 17 plants/m^2) were obtained by varying the distances between the hills (10, 15, and 20 cm) on both sides of the hill and thinning to one plant/hill. Foliar spraying of plants with ascorbic acid at rates (0, 2, and 4 ml/L was applied twice; the first one was 25 days after planting, and the other was a month after the first foliar spray, using a hand-held compressed air sprayer at a rate of 10 liters per plant. The previous crop was corn in both seasons. Planting was carried out on November 19th in both successive seasons, after inoculation with root nodule bacteria (*Rhizobium leguminosarum*) and irrigated immediately after planting, while the chickpea crop was harvested after 145 and 150 days in both experimental seasons, respectively. Other standard agricultural treatments for the chickpea crop were applied successfully until time according to scientific recommendations for the conditions of the research area. Some physical and chemical analyses of the experimental site are shown in Table 1.

Table 1: Some physical and chemical analyses of soil field experiments in the two seasons (22022/2023 – 2023/2024).

Physical analysis	2022/2023	2023/2024	Chemical analysis	2022/2023	2023/2024
Sand (%)	25.80	24.90	Organic matter (%)	0.95	1.01
Silt (%)	37.80	39.10	Available N (ppm)	74.70	76.50
Clay (%)	36.40	36.00	Available P(ppm)	9.40	10.56
Soil texture	Clay loam		Available K (ppm)	355.35	363.25
			pH (s.p. 65)	7.71	7.99
			E.C. (ds. m^{-1})	1.18	1.17
			Total $CaCo_3$ (%)	2.86	2.61

Recorded data:-

A- Yield and its components:

At the harvest time, ten guarded plants were successfully taken at random from the inner ridges and the following characters were recorded: plant height (it is defined and measured in cm as the height from the ground surface to the terminal bud), branches and pods number /plant, weight of 100 seeds (the weight of 100 seeds was calculated and measured, with the average of ten random samples taken from each plot. The weight was measured in grams), seed yield /plant (g), seed yield per feddan (kg) and straw yield (ton/fad.).

The final seed and straw yields were recorded on the basis of all plants/ plot. The calculated values were used to estimate the corresponding value per feddan.

B- Quality analysis:

At harvest time, chickpea seed samples were ground, processed, and stored for chemical analysis.

Protein percentage of seeds:-

Nitrogen was determined using the modified Micro-Kjeldahl A.O.A.C. (1980). The protein content of the seeds was calculated by multiplying the total nitrogen content by a factor of 6.25.

Appropriate statistical analyses were performed for all studied data according to Gomez and Gomez (1984). The differences between the means of the different experimental parameters were successfully compared using the least significant difference (LSD) test at a significance level of 0.05 by Freed *et al.* (1989).

RESULTS AND DISCUSSION

A- Yield and its components:-

1- Influence of planting density:

The data presented in Tables (2, 3, and 4) indicate that planting distances significantly influenced all evaluated traits, including plant height, number of branches and pods per plant, 100-seed weight, seed yield per plant, seed yield (kg/fad.), and straw yield (ton/fad.) across both seasons. The highest values for most traits were recorded at a planting density of 33 plants/m² in both seasons, except for the number of branches per plant, which peaked at 17 plants/m² in both years. Maximum seed yield per plant was achieved at 33 plants/m² (with 10 cm between hill spacing), likely due to the increased light energy absorbed by the plant canopy per unit area and the increased nutrient uptake at this plant density. These findings are consistent with those of El- Murshedy (2008), Mehdi *et al.* (2010) and Atif *et al.* (2017).

2- Influence of ascorbic acid:

According to the results in Tables (2, 3, and 4), different rates of ascorbic acid application significantly enhanced yield and its components, such as plant height, number of branches per plant, number of pods per plant, 100-seed weight, seed yield per plant, seed yield (kg/fad.) and straw yield (ton /fad.) during the 2022/2023 and 2023/2024 seasons.

Table 2: Means of plant height (cm) and branches number/plant as affected by the interaction between plant density and ascorbic acid of chickpea in 2022/2023 and 2023/2024 seasons.

Plant density (plants/m^2)	Ascorbic acid (m/L)	Plant height (cm)		Branches number/plant	
		Seasons			
		2022/2023	2023/2024	2022/2023	2023/2024
33	0	80.91	81.89	4.09	4.28
	2 m/L	82.15	83.16	4.69	4.83
	4 m/L	86.51	86.00	5.20	4.95
Mean		83.19	83.68	4.66	4.68
22	0	75.85	76.58	4.51	4.77
	2 m/L	78.63	78.19	5.09	5.35
	4 m/L	80.96	79.99	5.57	5.82
Mean		78.48	78.25	5.05	5.31
17	0	70.75	72.01	4.89	5.20
	2 m/L	73.00	74.35	5.77	5.81
	4 m/L	75.83	76.26	5.69	5.98
Mean		73.19	74.20	5.45	5.66
All means of ascorbic acid	0	75.83	76.82	4.49	4.75
	2 m/L	77.92	78.56	5.18	5.33
	4 m/L	81.10	80.75	5.48	5.58
L.S.D. at 0.05					
Density (D)		0.50	0.36	0.10	0.13
Ascorbic acid (A)		0.33	0.26	0.18	0.16
D X A		0.57	0.45	NS	NS

Table 3: Means of pods number/plant and 100-seed weight (g) as affected by plant density and ascorbic acid of chickpea in 2022/2023 and 2023/2024 seasons.

Plant density (plants/m^2)	Ascorbic acid (m/L)	Pods number/plant		100-seed weight (g)	
		Seasons			
		2022/2023	2023/2024	2022/2023	2023/2024
33	0	61.33	62.50	21.09	21.80
	2 m/L	65.39	67.00	21.85	22.43
	4 m/L	69.00	69.76	22.50	22.98
Mean		65.24	66.42	21.81	22.40
22	Control	58.11	59.57	19.67	20.64
	2 m/L	62.30	65.30	20.70	21.30
	4 m/L	65.98	69.21	21.29	21.85
Mean		62.13	64.69	20.55	21.26
17	0	53.91	55.20	19.18	20.00
	2 m/L	58.20	60.31	20.00	20.61
	4 m/L	61.87	63.95	20.59	21.30
Mean		57.99	59.82	19.92	20.63
All means of ascorbic acid	0	57.78	59.09	19.98	20.81
	2 m/L	61.96	64.20	20.85	21.44
	4 m/L	65.61	67.64	21.46	22.04
L.S.D. at 0.05					
D		0.41	0.24	0.30	0.17
A		0.32	0.22	0.37	0.14
D X A		NS	0.37	NS	NS

Table 4: Means of seed yield (g)/plant, seed yield (kg/fad.) and straw yield (ton/fad.)as affected by the interaction between plant density and ascorbic acid of chickpea in 2022/2023 and 2023/2024 seasons.

Plant density (plants/m^2)	Ascorbic acid (m/L)	Seed yield (g)/plant		Seed yield (kg/fed.)		Straw yield (ton/fed.)	
		Seasons					
		2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024
33	0	24.15	25.74	795.65	800.51	1.22	1.25
	2 m/L	25.98	25.81	829.00	830.56	1.26	1.27
	4 m/L	27.73	27.90	857.59	861.31	1.29	1.30
Mean		25.95	26.48	827.41	830.79	1.25	1.27
22	0	22.49	23.62	759.32	764.87	1.19	1.22
	2 m/L	24.28	25.71	788.35	790.31	1.23	1.26
	4 m/L	25.89	27.01	801.50	812.31	1.25	1.28
Mean		24.22	25.44	783.05	789.16	1.22	1.25
17	0	20.35	21.55	701.98	706.46	1.15	1.17
	2 m/L	22.26	23.00	739.35	729.31	1.18	1.22
	4 m/L	24.51	25.35	760.99	759.52	1.23	1.26
Mean		22.37	23.30	734.10	731.76	1.18	1.21
All means of ascorbic acid	0	22.33	23.63	752.31	757.28	1.18	1.21
	2 m/L	24.17	24.84	785.56	783.39	1.22	1.25
	4 m/L	26.04	26.75	806.69	811.04	1.25	1.28
L.S.D. at 0.05							
D		0.30	0.46	2.37	1.03	0.01	0.03
A		0.27	0.19	1.72	1.25	0.02	0.01
D X A		NS	0.33	2.98	2.16	NS	NS

The best results for all measured traits were recorded when ascorbic acid was applied at the highest rate of 4 m/L in both seasons. The beneficial effects of ascorbic acid may be attributed to its essential role as a primary metabolite in plants, functioning as an enzyme cofactor, antioxidant, and signaling molecule involved in many vital physiological processes including cell wall biosynthesis, hormone and secondary metabolite regulation, photoprotection, stress tolerance, and cell division and growth (Wolucka *et al.* 2005). These findings are consistent with those reported by Bolkhina *et al.* (2003), Khafaga *et al.* (2014) and Khalifa *et al.* (2020).

3- Interaction effects:

The results in Tables (2, 3, and 4) illustrate that the significant effect interaction between (D x A) was only found for plant height and seed yield/feddan in both seasons, and number of pods /plant and seed yield /plant in the second season. According to Tables 2, 3, and 4, the highest values for seed yield (857.59 and 861.31 kg/fad) were obtained when plant density was 33 plants/m^2 and foliar spraying with 4 m/L ascorbic acid in both

B- Quality analysis:-

Protein percentage of seeds:

1- **Influence of planting density:**

The results displayed in Table 5 revealed that planting density had a significant effect on seed protein content during both the 2022/2023 and 2023/2024 seasons. The highest protein percentages (27.33% and 26.16%) were recorded at a density of 33 plants/m² in the respective seasons. The increase in protein content at this density may be attributed to reduced interplant competition for nutrients, water, light, and space, thereby improving the plant's capacity for photosynthesis and nutrient uptake. This enhancement in assimilate production was ultimately reflected in elevated seed protein levels. These findings are in agreement with those of El-Murshedy (2008) and Ahmed (2020).

2- Influence of ascorbic acid:

According to Table 5, foliar application of ascorbic acid significantly improved the protein content of chickpea seeds in both seasons. The highest protein percentages were observed in treatments receiving the highest ascorbic acid concentration of 4 ml/L. These outcomes corroborate the findings reported by Bolkhina *et al.* (2003) and Khalifa *et al.* (2020).

3- Interaction Effect:

As shown in Table 5, the interaction between (D X A) significantly influenced seed protein content in the second season, only. The combination of 33 plants/m² and 4 ml/L of ascorbic acid produced the highest protein values, reaching 27.70% and 26.96%

in the first and second seasons, respectively.

Table 5: Protein percentage (%) as affected by the interaction between plant density and ascorbic acid of chickpea in 2022/2023 and 2023/2024 seasons.

Seasons	2022/2023				2023/2024			
Plant density	Ascorbic acid (m/L)				Ascorbic acid (m/L)			
(plants/m^2)	0	2 m/L	4 m/L	Mean	0	2 m/L	4 m/L	Mean
33	26.63	27.68	27.70	27.33	25.79	26.18	26.96	26.31
22	25.59	26.72	26.80	26.37	25.89	26.53	26.42	26.28
17	25.45	25.95	26.38	25.92	25.68	26.00	26.40	26.02
Mean	25.89	26.58	26.96		25.78	26.23	26.59	
L.S.D. at 0.05								
D	0.89				0.12			
A	0.61				0.16			
D X A	NS				0.13			

CONCLUSION

Based on the findings of this study, the most favorable outcomes in terms of seed yield and quality of chickpea were achieved when plants were grown at a density of 33 plants/m² and treated with a foliar application of 4 ml/L ascorbic acid. This combination proved optimal under the environmental conditions of the present experiment.

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الملخص العربي

تأثير الرش الورقي بحمض الأسكوربيك والكثافة النباتية علي المحصول والجوده في بذور الحمص

حجاجي عبد الحفيظ أحمد وأحمد عبدالموجود حافظ
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أقيمت تجربتان حقليتان بالمزرعة البحثية بكلية الزراعة– جامعة الأزهر بأسيوط، مصر موسمي 2022/2023 و 2023/2024 م لدراسة إستجابة صنف الحمص جيزه–195 لتأثيرالكثافة النباتية بمعدل ثلاثة كثافات (33, 22 و17 نبات /م^2) والرش الورقي بحمض الأسكوربيك بتركيز (صفر، 2 و4 مل /لتر) وأثر ذلك علي المحصول وجودته، وقد أستخدم تصميم القطاعات الكاملة العشوائية في قطع منشقة مرة واحدة في ثلاث مكررات حيث وزعت الكثافات النباتية في القطع الرئيسية بينما معدلات حمض الأسكوربيك وزعت علي القطع المنشقة. أشارت النتائج إلى أن مسافات الزراعة كان لها تأثير معنوي كبير على جميع الصفات تحت الدراسة (ارتفاع النبات، عدد الفروع / النبات، عدد القرون/ النبات، وزن 100 بذرة، محصول البذور/ النبات، محصول البذور (كجم/ فدان)، محصول القش(طن/ فدان) ومحتوى البروتين في البذور) في كلا موسمي النمو. لوحظت أقصى قيم لجميع الصفات عندالزراعة بكثافة نباتية 33 نباتً / م^2 في كلا الموسمين، باستثناء عدد الفروع/ النبات الذي لوحظ عند الزراعة بكثافة نباتية 17 نباتً / م^2 في الموسمين الأول والثاني. أدي الرش بحمض الأسكوربيك من صفر، 2 إلى 4 مل/ لترإلي زيادة معنوية وتدريجية في جميع الصفات المدروسة في الموسمين التجريبيين. لذلك، توصي الدراسة بزراعة الحمص صنف جيزة– 195 بكثافة نباتية 33 نباتً/ م^2 والرش بحمض الأسكوربيك بتركيز 4 مل/ لتر من أجل تحسين إنتاج الحمص تحت ظروف محافظة أسيوط.