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LETTUCE FLOWERING AND SEED PRODUCTION UNDER THE INFLUENCE OF PLANT DENSITY AND FOLIAR SPRAYING WITH GIBBERLLIC ACID

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ABSTRACT

The effects of three levels of plant density (10, 14 and 28 plants/m^2) and four GA_3 concentrations (0, 5, 10 and 15 p.p.m.) on Romaine c.v. were studied during the growing seasons of 1994 and 1995. The results indicated that the flowering stem height, percentage of mature inflorescence, no. of flower head inflorescence, percentage of heavy seed and seed yield/m^2 reflected significant and successive increments as a result of increasing the plant density. However, the no. of inflorescences / plant, flower heads quality, percentage of light seed and seed yield/plant, reflected reversal trends. The plant density had no effect on seed weight/flower head, seed index and germination percentage. Spraying lettuce plants with GA_3, up to 10 p.p.m. increased successively the percentage of mature inflorescences, no. of inflorescences/plant, no. of flower heads/inflorescence, flower head quality, percentage of heavy seed and total seed yield per plant and per square meter. The seed index values and germination percentage of produced seeds were not effected by GA_3 concentration. The best treatment combination for the production of high seed yield and quality was found to be that of sowing lettuce plants at the highest plant density (28 plants/m^2) and spraying the growing plants with 10 p.p.m of GA_3.

INTRODUCTION

Seed is a key factor determining the quantity and quality characteristics of any crop. It was found difficult to obtain high seed yield with good quality for lettuce plants, due to the elongation of flowering period, which may continue for two months or longer, increase number of inflorescences branches, variation in the time of inflorescences ripening and seed maturity in flower heads, when the entire crop was harvested at once.

Plant density is one of the most important agronomic practices in seed production of rosette species. Previous studies by Gray (1981), Gray and Stechel (1983), Noland and Maguire (1990), Ruben *et al* (1988) and Feleafel (1992) showed that variation in plant density was mainly practiced in changing the degree of inflorescences branching. Fewer flower heads, resulting from a relatively high plant density, is considered desirable for commercial seed production of lettuce, due to the fast and more uniform ripening of produced good seeds.

Application of gibberellic acid was noticed to promote seed stalk formation, flowering earlinese and uniformity, and increased seed yield; as reported by Harrington (1959) Shafi (1973), Tsytovich (1974) ,Globerson and Ventura (1974), Aguiar (1982), Abdel-Razik and Barakat (1990), and Miccolic *et al* (1994).

This study was conducted to clarify the proper plant density and to find out the appropriate concentration of GA_3 application for maximizing seed yield and quality of lettuce.

MATERIALS AND METHODS

Two field experiments were carried out during the two seasons of 1994 and 1995 at the Experimental Station Farm of the Faculty of Agriculture, Alexandria University. Lettuce cultivar Romaine was used in this study. A split-plot system in a randomized complete blocks design, with three replications, was used. Three plant densities were assigned to the main plots; whereas, four different levels of Gibberellic acid (GA_3) were considered as the sub-plots. Each sub-plot, in both seasons, consisted of three rows, 4 meter long and 0.70 meters apart. Therefore, the total area of the smallest experimental unite was about 8.4 square maters. A guard row was left without planting to separate each two sub-plots. Transplanting dates were the 7^{th} and 15^{th} of January in the seasons of 1994 and 1995, respectively. The seedlings were transplanted into the two sides of the rows. Interplant spacings, within rows were 10, 20 and 30 cm to give the three different plant densities of 28, 14 and 10 plants/m^2, respectively. There were 12 treatment combinations in each experiment, consisting of all the combinations of the three plant densities and four concentrations (0, 5, 10 and 15 p.p.m) of GA_3 foliar spraying in two applications. The first application was 4-6 leaves stage and the second was two weeks later.

Fertilizers were used at the rates of 250 kegs. of ammonium sulfate (20.5% N), 200 kegs. of calcium super- phosphate (16-18% $p_2 0_5$) and 50 kegs. of potassium sulfate (48% k_2O) per feddan. These amounts of fertilizers were added to the growing plants in three equal applications. The first portion was three weeks after transplanting, the second was three weeks later; whereas, the third application was during flowering period. Other cultural practices were applied whenever they were necessary and as, commonly, recommended in commercial lettuce seed production.

Ten plants, randomly selected, were chosen from the first row of each treatment at harvesting to measure the average plant height (in cm.), number of inflorescences/plant inflorescence number of flower heads and percentage of mature inflorescences. Plants of the second and third rows in each treatment were harvested at seed maturity. Collected infloresences were sun dried for 3 days, then the seeds were used for the determination and calculation of the following characters:

1- Flower head quality: It was estimated as number of seeds per flower head.
2- Seeds weight/flower head (in mg.)
3- Percentage of light seeds per plant.
4- Percentage of heavy seeds per plant.
5- Seeds yield per plant (in gm.).
6- Seeds yield per square meter (in gm.).

7- Seeds index of light and heavy seeds (in mg.)
8- Germination percentages of light and heavy seeds.

Correlation coefficient (r) among some characters of lettuce plant, in both growing seasons of 1994 and 1995, were estimated. The data were statistically analyzed according to the design used. The comparisons among the means of different treatments were carried out, using the Revised L.S.D. test, as illustrated by Waller and Duncan (1969).

RESULTS AND DISCUSSION

Flowering characters:

The results reflecting the general effects of plant density and GA_3 concentrations on flowering characters of lettuce plants, in both growing seasons, 1994 and 1995, are listed in Table (1). The effects of plant density on the flowering characters resulted in the appearance of clear and significant differences among the three evaluated plant population sizes, in both seasons. The different comparisons, obviously, indicated that flowering stem height, mature inflorescences percentage and number of flower head per inflorescence were increased by increasing the plant density; whereas, the number of inflorescences per plant was significantly reduced as the plant density was increased from 10 to 14 plants/m^2, in 1994 season, or from 10 to 28 plants/m^2, in 1995 season. In case of flower head quality, significant reductions were only detected when the plant density was raised from 14 to 28 plants/m^2. However, seed weight/flower head character was noticed to be insignificantly affected by differing the plant densities, in both seasons. Such results might be related to the expected increased competition among the growing lettuce plants for nutrition and light as a result of raising the high plant densities. Under a high plant density, the relatively low light intensity is expected to somewhat encourage the flowering stem elongation of lettuce plants. Also, the degree of inflorescence branching in lettuce plant is sensitive and positively correlated with plant density. Such relationships were also noticed and reported by El-Oksh (1966), Gray *et al* (1983) and Ruben *et al*. (1988) on carrot plants.

The comparisons among the effects of GA_3 treatments showed that increasing the used concentration from 0 to 5 and 10 p.p.m. reflected corresponding and significant increments on mature inflorescences percentage and number of inflorescences per plant, in both seasons. In case of number of flower heads per inflorescence, significant increases were detected when GA_3 level was raised from 5 to 10 and 15 p.p.m. Flowering stem height of lettuce plants reflected significant increases only when the plants were sprayed with GA_3 at 5 p.p.m., in both seasons. The results in Table (1) illustrated also that spraying the growing lettuce plants with 5 and 10 p.p.m. of GA_3 increased significantly the flower head quality. However, spraying the plants with the highest GA_3 level (15 p.p.m.) reduced significantly the flower head quality, as compared with the three other levels, in the two growing seasons. On the contrary, the effects of the various GA_3 concentrations on seeds weight/flower head did not reflect any significant

differences. The enhancing effects might be related to the positive role of GA_3 in activating the elongation and branching of lettuce seedstalks. These results, generally, agreed with those reported by Aguiar (1982), Abedel-Razik and Barakat (1990), and MiccoLis *et al.* (1994), who stated that GA_3s promoted early flowering, and flower stem emergence and elongation, irrespective of the used rate.

Seed yield and its quality:

Data in Table (2) showed that growing lettuce plants at the widest spacing; i.e., at the lowest plant density (10 plant/m^2); favoured significantly the total seed production per plant and increased also the percentage of light seeds. Moreover, it was generally noticed that each increase in plant density was associated with a corresponding and significant reduction in the light seed yield and the total seed yield per plant. However, the heavy seed percentage and the total seed yield per square meter reflected reversal trends and showed significant and successive increments as a results of increasing the plant density. The results indicated also that the seed index values and germination percentages of light and heavy seeds were not differently affected by changing the plant density, in the two growing seasons. The increased total seed yield/m^2 as a result of increasing plant density might be expected on the basis of increasing the number of growing lettuce plants per the unit area. On the other hand, estimates of correlation coefficients, in Table (4), showed that the total seed yield per plant was significantly and positively correlated with each mature inflorescences percentage, number of inflorescences per plant and number of flower heads per inflorescence. Similar results were reported by Ruben *et al*. (1988), who found that carrot seed yield per plant declined continuously as the population increased from 4 to 25 plants/m^2. Gray *et al* (1983), Feleafel (1992) and Noland and Maguire (1988) reported generally similar trends.

The seed yield and its components were significantly affected by the foliar application of GA_3, in the two growing seasons. The heavy seed percentage and total seed yield per plant and per square meter tended to increased consistently and significantly with each increase in the used GA_3 concentration, for spraying the growing lettuce plants up to 10 p.p.m. However, the light seed percentage reflected a reversal trend and decreased significantly with each increase in the used GA_3 level up to 10 p.p.m., in both seasons. The results illustrated that seed index values and germination percentages of light and heavy seeds were not affected by the different levels of GA_3. These results might be attributed to the detected increase of the mature inflorescences percentage, number of inflerescences and number of flower heads per inflorescence as a result of spraying lettuce plants with successive levels of GA_3. These results, generally, agreed with those reported by Aguiar (1982), Abdel-Razik and Barakat (1990), Tei and Ciriciofolo (1993), and Kochankov (1996).

The comparisons, presented in Table (3), illustrated the presence of some significant interaction effects, between plant density and GA_3, on the number of inflorescences, flower head quality and seed yield and its components. Generally, it was noticed that the highest seed yield per square

meter was obtained from the treatment combination involving the highest plant density (28 plants/m^2) with the foliar spraying with 10 p.p.m. of GA_3.

Table (2) Effects of plant density and GA_3concentration on seed yield and its components, and seed quality of lettuce plants in 1994 and 1995 growing seasons.

Treatments	seed yield and its components				seed quality			
	seed yield per plant			seed yield/ m^2	Seed index		Germination percentage	
	Light seed %	Heavy seed %	Total Weight (g.)		Light seed (mg.)	Heavy seed (mg.)	Light seed	Heavy seed
1994								
Plant density (plants/ m^2)								
10	13.1a	86.9c	10.60a	105.5c	59.9a	79.3a	71.8a	83.1a
14	9.7b	90.3b	8.58b	120.3b	57.6a	71.4a	69.4a	81.5a
28	6.7c	93.7a	7.49c	194.4a	152.7a	72.5a	64.3a	86.7a
GA_3 concentrations (P.P.m)								
0	12.1a	87.9c	5.79c	86.5c	61.9a	72.7a	73.6a	87.5a
5	10.0b	90.0b	7.84b	127.9b	53.3a	72.2a	71.1a	86.7a
10	8.2c	91.8a	10.28a	169.3a	54.7a	76.8a	68.5a	90.1a
15	8.8c	91.2a	10.85a	168.6a	57.2a	76.1a	67.3a	82.5a
1995								
Plant density (plants/ m^2)								
10	12.9a	87.1c	11.36a	119.3c	61.9a	76.5a	74.9a	89.3a
14	9.8b	90.2b	8.80b	122.9b	58.3a	79.3a	72.3a	91.2a
28	7.0c	93.0a	7.32c	189.9a	52.2a	75.4a	69.9a	86.3a
GA_3 concentrations (P.P.m)								
0	12.0a	88.0c	5.91c	94.2c	60.9a	71.5a	72.7a	89.5a
5	10.7b	89.3b	8.18b	128.3b	56.8a	73.6a	77.3a	85.3a
10	8.4c	91.6a	10.79.a	174.7a	53.9a	77.7a	75.1a	83.1a
15	8.5c	91.5a	11.81a	179.2a	58.3a	76.3a	69.3a	86.1a

Values having the same alphabetical letter in common, within a particular group of means in each character , do not significantly differ , using L.S.D. test at 0.05 level.

Data in Table (4), generally, revealed positive significant correlations among seed yield per plant and each of the mature inflorescences percentage, number of inflorescence per plant, number of flower heads per inflorescences and heavy seed percentage. However, seed yield/plant appeared to be significantly and negatively correlated with the light seed percentage.

Based upon these results, it can be concluded that sowing lettuce plants at the highest plant density (28 plants / m^2) and spraying the growing plants with 10 p.p.m. GA_3 might be considered an adequate treatment combination for the production of high seed yield and quality of lettuce.

Table 3

Table (4): Correlation coefficients (r) among seed yield per plant and some important characters related to seed production of lettuce plant.

Characters	Seed yield/ plant	Characters	Seed yield/ Plant
Flowering stem height	0.137	**Flower heads quality**	-0.415
No. of inflorescences /plant	0.597*	**Seed weight/ flower head**	0.394
Mature inflorescence percentage	0.851**	**Light seed percentage**	-0.563*
No. of flower heads/ inflorescence	0.577*	**Heavy seed percentage**	0.579*

*** ,** Significant correlation at 5% and 1% , respectively .**

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الإزهار و إنتاج البذرة في الخس تحت تأثير الكثافة النباتية و الرش بحمض الجبريلليك

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أجري هذا البحث في عامي 1994 و 1995 لدراسة تأثير الكثافة النباتية (10 ، 14 ، 28 نبات/ متر مربع) و رش النباتات بتركيزات مختلفة من حمض الجبريلليك (صفر ، 5 ، 10 ، 15 جزء في المليون) على الإزهار و إنتاج البذرة في صنف الخس روميني . و قد أوضحت الدراسة أن زيادة الكثافة النباتية قد أدت إلى زيادة متتابعة و معنوية في كل من ارتفاع الساق الزهرية، النسبة المئوية للنورات الناضجة ، عدد الرؤوس الزهرية بكل نورة و النسبة المئوية للبذور الثقيلة و المحصول البذري لكل متر مربع ، في حين نجد أن عدد النورات لكل نبات ، وجودة الرؤوس الزهرية و النسبة المئوية للبذور الخفيفة و المحصول البذري لكل نبات كانت قد نقصت معنوياً مع زيادة الكثافة النباتية . رش نباتات الخس بحمض الجبريلليك حتى تركيز 10 جزء في المليون كانت قد أدت إلى زيادة متتابعة و معنوية في النسبة المئوية للنورات الناضجة و عدد النورات لكل نبات و عدد الرؤوس الزهرية لكل نورة و النسبة المئوية للبذور الثقيلة و المحصول البذري لكل من النبات و المتر المربع ، و قد أعطى ارتفاع الساق الزهرية نفس الاستجابة ، في حين لم يتأثر وزن 200 بذرة أو النسبة المئوية لإنبات البذور الناتجة عن الرش بحمض الجبريلليك . كما أظهرت نتائج الدراسة أن أفضل معاملة تداخلية بالنسبة للمحصول البذري هي تلك التي فيها زرعت النباتات على أعلى كثافة نباتية (28 نبات لكل متر مربع) ورشت بتركيز 10 جزء في المليون من حمض الجبريلليك.

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Table (1): Effects of plant density and GA_3 concentration on flowering characters of lettuce plants in 1994 and 1995 growing seasons.

Treatments	Flowering	Inflorescences characters			Flower heads characters	
	Stem Height (Cm.)	Mature Inflorescence %	No. of Inflorescence / plant	No. of flower heads/ Inflorescence	Flower** head quality	Seed weight /flower head(mg.)
1994						
Plant density (plants/m^2)						
10	104.3 c*	70.77 c	26.3 a	37.0 b	48.3 a	15.0 a
14	106.4 b	76.18 b	17.7 b	47.0 a	50.6 a	15.4 a
28	111.9 a	86.51 a	16.3 b	55.0 a	42.6 b	15.6 a
GA_3 concentration (p.p.m.)						
0	97.7 b	77.91 c	16.3 c	36.1 c	46.5 b	17.1 a
5	107.2 a	81.13 b	19.0 b	37.5 c	49.9 a	14.8 a
10	109.2 a	83.56 a	22.2 a	46.5 b	51.1 a	15.0 a
15	108.0 a	84.67 a	22.9 a	50.5 a	41.1 c	14.1 a
1995						
Plant density (plants/m^2)						
10	105.8 c	69.35 c	27.8 a	36.5 b	49.4 a	14.6 a
14	107.9 b	77.91 b	20.5 b	41.3 a	49.7 a	15.4 a
28	112.8 a	83.77 a	18.2 c	52.3 a	45.1 b	15.2 a
GA_3 concentration (p.p.m.)						
0	102.7 b	81.30 c	15.2 c	34.7 c	47.8 b	16.9 a
5	109.5 a	83.17 b	21.3 b	38.8 c	50.8 a	15.0 a
10	109.7 a	86.61 a	25.2 a	44.7 b	51.3 a	14.6 a
15	109.6 a	87.55 a	24.4 a	50.5 a	42.3 c	14.4 a

- **Values having the same alphabetical letter in common , within a particular group of means in each character , do not significantly differ , using L.S.D. test at 0.05 level.**

**** Flower head quality = No. of seed / flower head.**

Table (3): Interaction effects of plant density and GA_3 concentration on number of Inflorescences, head quality and seed yield and its components in 1994 and 1995 growing seasons.

Plant density (plants/m^2)	GA_3 conc. (p.p.m.)	No. of Inflorescences /plant	Head** quality	Seed yield and its components			
				Light seed %	Heavy seed %	Seed yield/ plant (g.)	Seed yield/ m^2 (g.)
1994							
10	0	21.0 c*	52.3 a	6.3 c	93.7 a	5.91 c	64.75 d
	5	23.8 b	44.9 b	7.4bc	92.6 a	9.20 b	97.70 c
	10	29.3 a	40.8 b	9.6 b	90.4 b	10.96ab	115.59b
	15	31.0 a	32.5 c	15.0a	90.5 b	13.80 a	143.53a
14	0	14.7 c	45.6 c	8.1 a	91.9 b	6.36 b	65.55 c
	5	17.4 b	51.7 b	6.8ab	93.2ab	6.99 b	97.87 b
	10	18.7ab	57.6 a	6.5ab	95.1 a	10.62a	148.70a
	15	20.1 a	47.7bc	5.3 b	94.7ab	10.45a	146.32 a
28	0	13.2bc	41.6 b	22.0a	78.0 c	5.16 b	129.33 d
	5	15.8ab	53.1 a	15.9b	84.1 b	7.27 a	188.18c
	10	18.7 a	54.9 a	8.4 c	91.6 a	9.26 a	243.80a
	15	17.6 a	43.4 b	6.1 c	93.9 a	8.29 a	216.29b
1995							
10	0	19.1 b	55.9 a	6.6 c	93.4 a	6.82 c	73.67bb
	5	27.9 a	46.4 b	8.6 bc	92.4 a	10.91b	114.57ab
	10	29.2 a	43.2 b	10.6 b	89.4 b	11.87b	124.34a
	15	29.0 a	35.1 c	14.1 a	85.9 c	15.90 a	164.72a
14	0	14.9 c	45.4 b	9.0 a	91.0 b	5.62 b	78.95c
	5	19.6 b	52.8 a	7.2 ab	92.8ab	6.87 b	96.50bc
	10	25.6 a	54.3 a	6.3 bc	93.7 a	11.36a	159.04a
	15	21.8 b	46.3 b	5.4 c	94.6 a	11.24 a	157.45a
28	0	15.3 c	42.2 b	20.5 a	79.5 d	5.22 c	129.90c
	5	17.3bc	53.3 a	16.9 b	83.2 c	6.76bc	173.86bc
	10	20.7 a	56.5 a	8.3 c	91.7 b	9.15 a	240.66a
	15	19.5ab	45.5 b	5.8 d	94.3 a	8.24b	215.22ab

*** Values having the same alphabetical letter in common , within a particular group of means in each character , do not significantly differ , using L.S.D. test at 0.05 level.**

****Flower head quality = No. of seed / flower head.**