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Effect of Plant Spacing and Nitrogen Levels on Growth and Yield of Sunflower (*Helianthus Annus* L.)

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Abstract. To study the effect of plant density and N fertilizer levels on seed yield and its components of sunflower, a field experiment was conducted in Al-Hassa, Saudi Arabia during 2003 and 2004. The treatments comprised five rates of nitrogen (0, 50, 100, 150 and 200 kg N ha^{-1}) and four plant spacing (20, 25, 30 and 35 cm between hills). Plant height, stem diameter, head diameter, number of seeds $head^{-1}$, 100-seed weight, seed yield ha^{-1}, seed oil percentage and oil yield ha^{-1} were estimated. Plant spacing significantly affected all estimated characters, except seed oil percentage. Twenty-five cm was observed as a suitable plant spacing, whereas higher or lower plant spacing had a negative effect on seed and oil yields ha^{-1}. Nitrogen application markedly enhanced growth and yield, but resulted in sharp decrease in seed oil percentage. Two-hundred kg N ha^{-1} produced the highest seed yield ha^{-1}, whereas the highest oil yield ha^{1} was obtained with the addition of 150 kg N ha^{1}. Considering the superiority of 25 cm plant spacing and $150^{-2}00$ kg N ha^{1} for seed and oil yields, it appears that they could be recommended for producing desirable yield under Al-Hassa area conditions.

Introduction

Sunflower is one of the most widely cultivated oil crops in the world. In recent years, the planted area has increased because its high oil yield. Due to the sunflower ability to tolerate short periods of water deficit [1], the potential exists for it to become an important crop in sub-arid environments and wherever available irrigation water is limited. In such environments, early sowing allows the crop to benefit from late winter rainfall and irrigation water can be given only as supplementary amount to sustain yield. Plant density and nitrogen fertilizer levels are among factors affecting sunflower yield and seed oil percentage. The highest oil yield resulted from a hill spacing of 30 cm and the lowest from a hill spacing of 15 cm [2]. Seed and oil yields and seed oil percentage were positively correlated with plant density, but plant height, head diameter, 100-seed weight and seed yield $plant^{-1}$ all decreased with increasing plant density [3]. Increasing plant population of sunflower decreased head diameter, seed number and weight per plant. Seed and oil yields increased with increasing plant population and reached a maximum at population of 6.66 plants m^{-2} with 25 cm between plants in rows [4]. Increasing plant density had an incremental effect on plant height and negatively affected stem and head diameters. A plant density of 85000 plants ha^{-1} was observed as a suitable plant density, whereas the higher plant density had a negative effect on seed yield [5].

Many growers believe that sunflowers do not require as much applied fertilizer as cereals. Sunflowers have an extensive root system which may help in utilizing residual soil nutrients. Nitrogen application at a rate of 120 kg N ha^{-1} gave the highest seed and oil yields/ha [2]. Kasem and El-Mesilhy [6] pointed that head diameter, 100-seed weight, seed yield/head, seed yield $plant^{-1}$, and seed, straw and biological yields were increased by the N application. Harvest index and seed oil percentage were decreased by the N application. The application of 175 kg N ha^{-1} encouraged growth and gave the highest seed and oil yields, but seed oil percentage was decreased with increasing N application rate [3-5, 7, 8]. Nitrogen fertilizer up to 150 kg ha^{-1} increased the grain yield and biological yield, whereas higher levels of N fertilizer decreased both yields [5].

The interaction between plant spacing and N rate significantly affected seed and oil yields [2]. The highest seed and oil yields were obtained with the application of 175 kg N ha^{-1} and a plant density of 80000 plants ha^{-1} [3]. The optimum plant population and N rate for sunflower were 6.66 plants m^{-2} and 69 kg N ha^{-1} [4], but in another study [5], the superiority for seed and oil yields ha^{-1} was achieved using 150 kg N ha^{-1} and plant density of 85000 plants ha^{-1}.

The present investigation was planned to study the effects of plant spacing and different N fertilizer levels on growth, yield and its components in sunflower "cv. Giza 1" under Al-Hassa conditions.

Material and Methods

The present study was conducted during 2003 and 2004 growing seasons at the Agricultural and Veterinary Experimental Station, King Faisal University. The experimental design was split-plot using four replications. The main plots were assigned to four plant spacings (20, 25, 30 and 35 cm between hills), while the sub plots were assigned to five nitrogen fertilizer levels (0, 50, 100, 150 and 200 kg N ha^{-1}). Each sub plot (experimental unit) had seven ridges, each of 60 cm in width and 5.0 m in length, occupying an area of 21.0 m^2.

The experimental field was well prepared through deep plough, good harrowing, leveling, ridging and thereafter, dividing the experimental land into main and sub-plots by construction irrigation canales and alleys. Sunflower seeds were hand-planted as the usual dry planting method on one side of ridges, 60 cm apart and the evaluated hill spacings, were established as previously mentioned. Sunflower was seeded on the last week of February in both seasons. Plants were thinned two times, the first was done at

15 days after emergence to secure 2-3 plants $hill^{-1}$ and the second was at 25 days after emergence to secure one healthy plant $hill^{-1}$. Phosphorus (15.5% P2O5) at a rate of 31.0 kg P2O5 ha^{-1} and potassium as potassium sulphate (48% K2O) at a rate of 48 kg K2O ha^{-1} were applied during seedbed preparation. Nitrogen as urea (46.6% N) was applied at the above mentioned levels. It was added into three equal portions, the first third was applied prior planting, during land preparation. The second third was applied after 15 days of emergence and the rest was added at the bloom stage (40 days after emergence). Plots were weeded as needed through hand hoeing. Other normal agronomic practices for sunflower production were followed.

At harvest, when sunflower leaves and stems turned a straw color, backs of the heads were yellow and seeds became hard, 10 guarded plants were randomly selected from each experimental unit, harvested, tied and left to head dry, thereafter the following characters were estimated: plant height (PH) in cm, stem diameter (SD) in cm, head diameter (HD) in cm, number of seeds/head (S/H No.) and 100-seed weight (100-seed wt) in gram. Plants in the two central ridges in each plot were harvested for seed yields m^{-2} and converted to record seed yield (SY) in t ha^{-1}. Seed oil percentage (seed oil %) was determined on dry weight basis according to the method used by the Association of Official Agricultural Chemists (A.O.A.C.) [9] using soxhelt apparatus and petroleum ether as an organic solvent. Oil yield (OY) in kg ha^{-1} was calculated by multiplying seed yield (t ha^{-1}) by seed oil %.

Collected data of each year were statistically analyzed according to Gomez and Gomez [10]. Thereafter, the assumption of normality and the homogeneity of variances of the experimental errors was checked according to Bartlet method which revealed an appropriate homogeneous variance. Therefore, the proper combined analysis of variance (over the two years) of the split-plot design was done using the following model:

$$X_{ijkm}=\mu+Y_i + R(Y)_{ij} + A_k + (Y*A)_{ik} + R*A(Y)_{ijk} + B_m + (Y*B)_{im} + (A*B)_{km} + (Y*A*B)_{ikm} + R*B(Y)(A)_{ijkm}$$

where, μ: is the general mean, Y: Years , R: Replicates, A: Space between hills, B: N-levels, $R*A(Y)_{ijk}$: Error a, $R*B(Y)(A)_{ijkm}$: Error b.

Baysian Least Significant Difference (BLSD) at 0.05% level of significance was used to compare the treatment means [11]. Computations were done using SAS software [12].

Results and Discussion

Plant spacing effects

Plant spacing significantly affected all estimated sunflower characters, except seed oil percentage (Table 1). Data in Tables 2 and 3 showed that stem diameter, head diameter, number of seeds $head^{-1}$ and 100-seed weight were significantly increased as the space between plants increased from 20 up to 35 cm with the highest at 35 cm plant spacing. The highest seed and oil yields ha^{-1} were produced when sunflower plants were planted at 25 cm. Increasing plant spacing from 20 to 25 was associated with marked increase in plant height, while no significant difference was noticed between 30 and 35 cm. The increase in seed yield/plant with increasing plant spacing might be attributed to the increase in head diameter, number of seeds head^{-1} and 100-seed weight which were increased with the increase in plant spacing. Similar results were also reported by other researchers [3-5].

Table 1. Results of the statistical analysis (ANOVA) of the collected data (combined over 2003 and 2004 seasons)

Source of variation (S.V.)	Degrees of freedom (D.F.)		PH	SD	HD	S/H No.	100 seed wt	SY	Seed oil %	OY
Years (Y)	y^{-1}	1	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Replicates/Years	$y(r^{-1})$	6								
Space (A)	a^{-1}	3	*	*	*	*	*	*	N.S	*
AY	$(a^{-1})(y^{-1})$	3	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Error a	$y(r^{-1})(a^{-1})$	18								
Nitrogen (B)	b^{-1}	4	*	*	*	*	*	*	*	*
BY	$(b^{-1})(y^{-1})$	4	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
AB	$(a^{-1})(b^{-1})$	12	*	*	*	*	N.S	N.S	*	*
ABY	$(a^{-1})(b^{-1})(y^{-1})$	12	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Error b	$Ya(r^{-1})(b^{-1})$	96								
Total	$yrab^{-1}$	159								

N.S.: no significant difference ($P<0.05$).
* Significant at 5% ($P \geq 0.05$).

Results of statistical analysis over both seasons showed that seed yield ha^{-1} increased from 2.440 t ha^{-1} to 3.576 t ha^{-1} when plant spacing was increased from 20 to 25 cm. The differences in seed yield with increasing plant spacing from 25 to 30 and 35 cm were not significant ($P>0.05$). The increase in seed yield/ha with sowing sunflower at 25 cm might be due to the suitable compensation between seed yield plant^{-1} and number of plants unit^{-1} area. Similar results were reported by others [5].

Oil yield/ha increased from 941.5 kg/ha to 1360.8 kg ha^{-1} with increasing plant spacing from 20 to 25 and 30 cm, respectively (Table 3). However, at 35 cm plant spacing marked reduction appeared in oil yield compared with 25 and 30 cm. The higher values oil yield ha^{-1} with sowing sunflower at 25 cm could be attributed to the increased seed yield ha^{-1}.

Table 2. Plant height, stem diameter, head diameter and number of seeds/head as affected by plant spacing and nitrogen fertilizer levels (combined over 2003 and 2004 seasons)

Treatments	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	Seeds/head (No.)
Plant spacing				
20 cm	178.8 c	2.1d	12.7 c	532.6 b
25 cm	189.9 a	2.3 c	15.1bc	657.3 a
30 cm	185.2 b	2.6 b	15.9 ab	666.6 a
35 cm	182.5 bc	2.8 a	18.6 a	691.3 a
N- levels				
0 kg N ha^{-1}	142.4 d	1.8 d	12.0 c	440.8 d
50 kg N ha^{-1}	176.9 c	2.3 c	14.5 b	576.3 c
100 kg N ha^{-1}	192.2 b	2.6 b	16.5 ab	679.5 b
150 kg N ha^{-1}	203.2 a	2.7 ab	17.3 a	734.3 a
200 kg N ha^{-1}	205.9 a	2.8 a	17.8 a	754.1 a

Values followed with the same letter(s) is(are) not significantly different at $P< 0.05$.

Table 3. 100-seed weight, seed oil %, seed and oil yields/ha as affected by plant spacing and nitrogen fertilizer levels (combined over 2003 and 2004 seasons)

Treatments	100-seed weight (g)	Seed oil (%)	Seed yield (t/ha)	Oil yield (kg/ha)
Plant spacing				
20 cm	5.4 c	39.0 a	2.440 b	941.5 c
25 cm	7.6 b	39.2 a	3.576 a	1384.6 a
30 cm	8.9 ab	39.4 a	3.491 a	1360.8 a
35 cm	9.3 a	39.0 a	3.338 a	1290.1 b
N- levels				
0 kg N ha^{-1}	5.1 d	40.7 a	1.874 d	762.9 d
50 kg N ha^{-1}	7.6 c	41.1 a	2.620 c	1075.2 c
100 kg N ha^{-1}	8.5 b	39.7 b	3.478 b	1382.6 b
150 kg N ha^{-1}	8.9 a	38.2 c	3.953 a	1510.7 a
200 kg N ha^{-1}	9.0 a	36.0 d	4.131 a	1489.7 a

Values followed with the same letter(s) is(are) not significantly different at $P< 0.05$.

Nitrogen level effects

Results of statistical analysis showed that nitrogen fertilizer levels significantly affected all studied characters (Table 1). Plant height, stem diameter, head diameter, number and weight of seeds $head^{-1}$, 100-seed weight and seed yield ha^{-1} were significantly increased as nitrogen fertilizer levels increased (Tables 2 and 3). The highest values of the previously mentioned characters, except seed oil percentage and oil yield ha^{-1}, were obtained with the highest nitrogen level (200 kg N ha^{-1}). Similar results were reported by others [13]. The increase in growth characters and yield components with the increase in nitrogen levels might be due to the role in nitrogen in stimulating vegetative growth. Nitrogen is a constituent of the proteins, nucleic acids and nucleotides that are essential to the metabolic function of a plant [14].

Seed yield ha^{-1} was increased from 1.874 to 2.620, 3.478, 3.953 and 4.131 t ha^{-1} with increasing nitrogen level from 0 to 50, 100, 150 and 200 kg N ha^{-1}, respectively (Table 3). These increases represent 39.8, 85.6, 110.9 and 120.4%, respectively compared to the control. The increase in seed yield with the increase of nitrogen level might be due to the role of nitrogen in activating the growth and yield components. Similar results were reported by others [3, 5, 8].

The increase in nitrogen level to more than 50 kg N/ha was associated with a decrease in seed oil percentage. Seed oil % raised from 40.7 to 41.1 with increasing nitrogen level from 0 to 50 kg N ha^{-1}. The further levels of nitrogen (100, 150 and 200 kg N ha^{-1}) resulted in seed oil reduction as compared to the control. The significant negative relations between seed oil content and high nitrogen fertilization were also reported [15, 16]. The decrease in seed oil percentage with the increase in nitrogen application could be probably attributed to the sugar translocation affecting oil synthesis [14]. Alternating enzymes imbalance could also contribute in this reduction. Similar results were reported by others [13, 17].

Although the percentage of seed oil percentage decreased with the increase in nitrogen level more than 50 kg N ha^{-1}, the total oil yield/ha significantly increased as nitrogen level increased up to 150 kg N ha^{-1}. Oil yield/ha increased from 762.9 to 1075.2, 1382.6, 1510.7 and 1489.7 kg ha^{-1} with increasing nitrogen from 0 to 50, 100, 150 and 200 kg N ha^{-1}, respectively. The increase in oil yield with the increase in nitrogen application up to 150 kg N/ha despite the decrease of seed oil content might be attributed to the increase in seed yield/ha. Similar results were reported by others [18].

Interaction effects

The interaction between plant spacing and nitrogen levels significantly affected plant height, stem diameter, head diameter, number of seeds $head^{-1}$, seed yield ha^{-1} and seed oil yield ha^{-1}. Plant height reached its maxima (218 cm) with sowing sunflower on 25 cm and adding 200 kg N ha^{-1}. However, the highest values of stem diameter (3.1 cm), head diameter (20.1 cm) and number of seeds $head^{-1}$ (798) were obtained with sowing sunflower on 35 cm and adding 200 kg N ha^{-1} (Figs. 1, 2 and 3). The highest seed yield (4.924 t ha^{-1}) was produced with sowing sunflower on 25 cm and adding 200 kg N ha^{-1}, but the difference in seed yield did not reach the level of significance by reducing nitrogen to 150 with the same plant space. On the contrary, the lowest seed yield (1.333 t ha^{-1}) was obtained from unfertilized plants at 20 cm spacing (Fig. 5). Oil yield followed seed yield producing the highest values (1800 and 1780 kg $ha^{-1}$with sowing sunflower on 25 cm and adding 200 or 150 kg N ha^{-1} , while the lowest oil yield (542 kg ha^{-1}) was produced with sowing sunflower on 20 cm and without adding nitrogen fertilization (Fig. 6). Similar observations were reported by others [12].

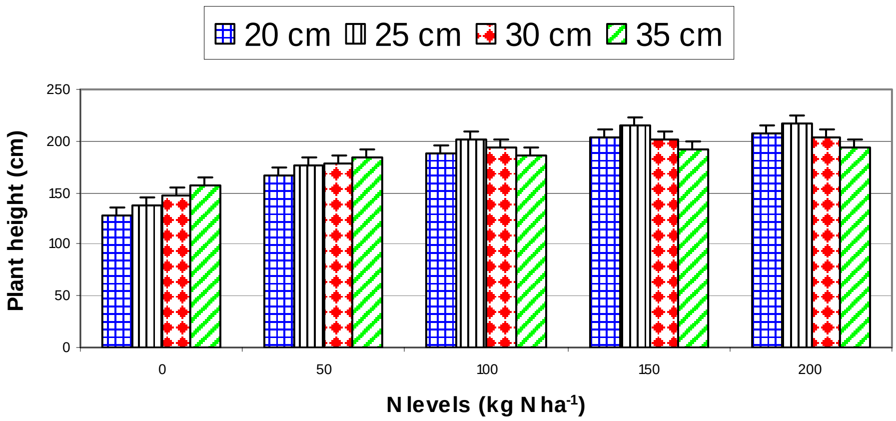

Fig. 1. Plant height (cm) as affected by the interaction between plant spacing and nitrogen levels. Lines =BLSD 0.05.

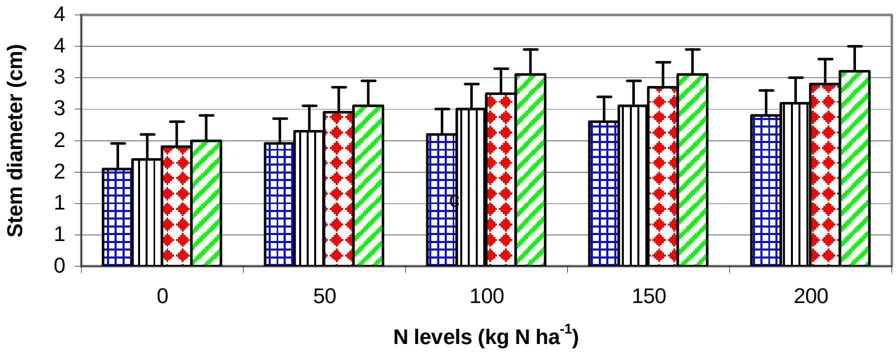

Fig. 2. Stem diameter (cm) as affected by the interaction between plant spacing and nitrogen levels. Lines =BLSD 0.05.

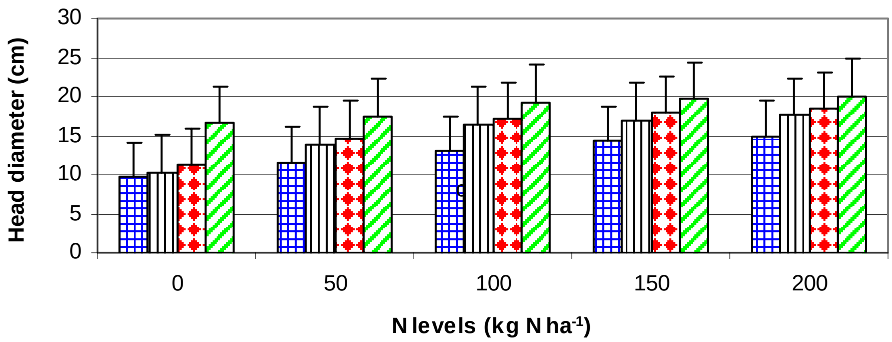

Fig. 3. Head diameter (cm) as affected by the interaction between plant spacing and nitrogen levels. Lines =BLSD 0.05.

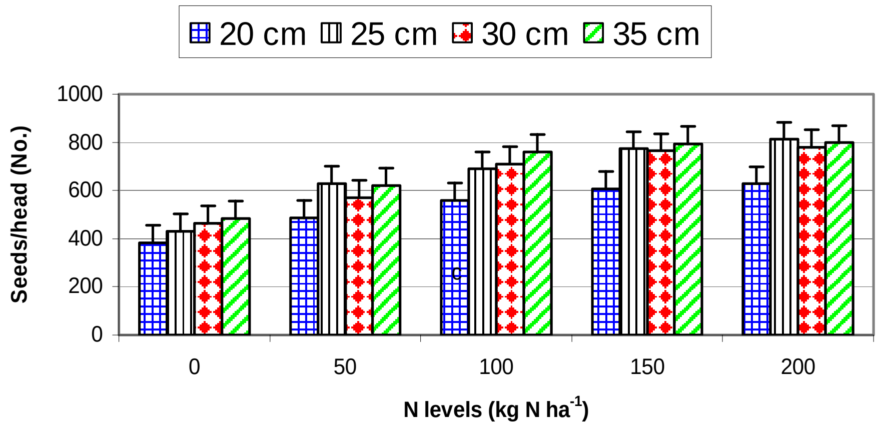

Fig. 4. Number of seeds head^{-1} as affected by the interaction between plant spacing and nitrogen levels. Lines =BLSD 0.05.

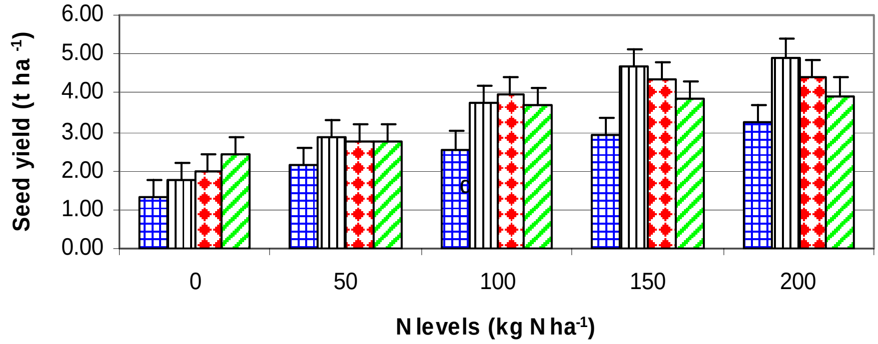

Fig. 5. Seed yield (kg ha^{-1}) as affected by the interaction between plant spacing and nitrogen levels. Lines =BLSD 0.05.

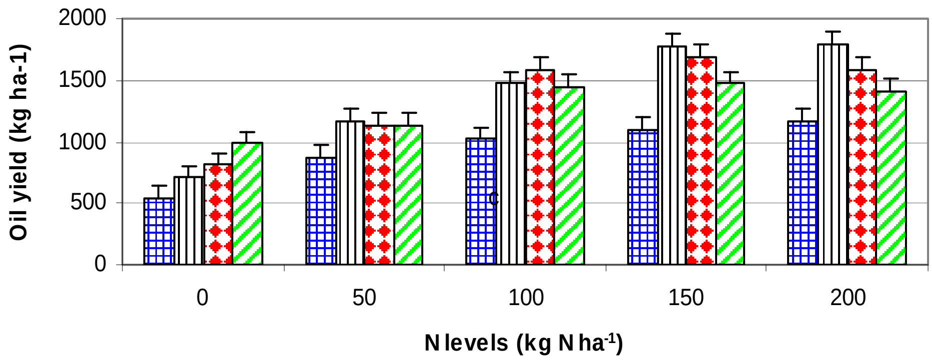

Fig. 6. Oil yield (kg ha^{-1}) as affected by the interaction between plant spacing and nitrogen levels. Lines =BLSD 0.05.

It seems that seed yield under 150 and 200 kg N ha^{-1} and 25 cm spacing was much related to both plant height and number of seeds $head^{-1}$. The higher plant height may indicate higher chances for light interception and consequently higher photosynthesis rate. It is worth mentioning that the higher number of seeds $head^{-1}$ along with higher plant height may give advantage for the increase of pollination rate by both wind and insects. The significant increase in oil yield ha^{-1} under 150 and 200 kg N ha^{-1} and 25 cm spacing seems to be much related to seed yield. Although the results of the present study showed significant decrease in seed oil % with higher N fertilization, it is quite evident that N fertilization with 200 kg N ha^{-1} did not reach threshed hold level.

In conclusion, the rate of N fertilization in sunflower seems to be always related to oil yield which is the economic production of sunflower plantation in all the world. Sowing sunflower on 25 cm and the application of 150 kg N ha^{-1} was the recommended treatment to raise sunflower seed and oil yields under the environmental conditions of this study.

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تأث ا سافة النباتية والتسميد النيتروجي على و و صول دوار الشمس

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ملخص البحث. لدراسة تأثير الكثافة النباتية ومستويات السماد النيتروجيني على نمو ومحصول دوار الشمس، أقيمت تجربة حقلية بمحطة التدريب والأبحاث الزراعية والبيطرية بجامعة الملك فيصل خلال عامي ٢٠٠٣م و٢٠٠٤م، وشملت الدراسة خمسة مستويات من النيتروجين (صفر، ٥٠، ١٠٠، ١٥٠و ٢٠٠ كجم ن/هكتار) وأربع مسافات (٢٠، ٢٥، ٣٠، ٣٥ سم) بين النباتات. وقد تم قياس طول النبات وقطر الساق والقرص، وعدد البذور/قرص، ووزن ١٠٠ بذرة ومحصول البذور/هكتار، ونسبة الزيت بالبذور ومحصول الزيت/هكتار. وقد أثرت المسافة بين النباتات معنويا على كل الصفات بالدراسة، عدا نسبة الزيت بالبذور. كانت زراعة دوار الشمس على مسافة ٢٥ سم الأفضل حيث زاد معها محصول الزيت والبذرة/هكتار. وأدت إضافة السماد النيتروجيني إلى تشجيع النمو والمحصول، إلا أنها أحدثت نقصا معنويا في نسبة الزيت بالبذور، حيث زاد محصول البذور/هكتار بزيادة مستوى النيتروجين حتى ٢٠٠ كجم/هكتار، إلا أن أعلى محصول زيت/هكتار قد نتج عند مستوى ١٥٠ كجم ن/هكتار.

وبصفة عامة، فإن زراعة دوار الشمس على مسافة ٢٥ سم بين النباتات وتسميده بمعدل١٥٠—٢٠٠ كجم ن/هكتار كانت هي المعاملة التي نتج معها أعلى إنتاجية من البذور والزيت تحت ظروف منطقة الأحساء.