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RESPONSE OF SUNFLOWER TO IRRIGATION, BORON SPRAYING AND PLANT DENSITY UNDER NEW VALLEY CONDITIONS

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ABSTRACT

Two field experiments were carried out in the Desert Research Center (D.R.C.), Agricultural Experimental station at EL-Kharga, New Valley Governorate, during two late summer growing seasons of 2004 and 2005, to study the effect of irrigation amounts (80, 100 and 120 % at ETa); B spraying rates (0, 226 and 339 ppm) and plant density (28000, 35000 and 46666 plants/fed.) on sunflower (*Helianthus annuus*, L. hybrid Vidoc). Results showed that adding irrigation water at 120 % ETa was the potent treatment for increasing SPAD value, LAI and dry matter/plant. The highest values of SPAD, LAI and dry matter/plant achieved with spraying B at the rate of 339 ppm. Plant density of 28000 plants/fed. gave the significantly maximal values of SLW and dry matter/plant. While, the highest value of LAI was obtained with high plant density (46666 plants/fed.). Generally, plant height, head diameter, seeds number/head, seed weight/head, 1000-seed weight as well as oil % and oil, straw and seed yields/fed. significantly enhanced with increasing irrigation levels and showed the highest values with irrigation at 120 % ETa, which were statistically at par with those of 100 % ETa in water use efficiency.. Application of 339 ppm B as foliar spraying recorded the significantly maximal values of yield and its components and oil yield/fed. Decreasing plant density from 46666 to 28000 plant/fed. caused significant increases in yield attributes of sunflower, while plant density of 46666 plants/fed. recorded the maximum straw, seed and oil yields/fed. There were positively and highly significant correlation coefficients between seed yield and dry matter/plant, seeds number and weight/head and 1000-seed weight.

Key words: Sunflower, irrigation, B, plant density, water use efficiency, simple correlation

INTRODUCTION

There are some promising newly reclaimed lands in Egypt. In this respect, one of the most suitable locations is the New Valley region (located at the Western Desert of Egypt) with its oasis, which represents large land resources and a good hope for agriculture expansion. In this region, weather is hot and dry, and cultivation depends mainly on ground water, so agricultural expansion in this case needs application of special management for better use of land and water resources.

Moreover, there is a dire need for increasing the production of plant oils due to over population nowadays, which created a wide gap between production and consumption of vegetable oils reached 90.8 %.

Great emphasis has been given to sunflower for oil industry due to its adaptability to various environmental conditions in addition to rich seeds of oil (33-55 %). Additionally, there is no place in the present existing rotation of the old Valley and Delta for sunflower as non-traditional crop to be cultivated. Therefore, the future prospect will be apparent in the new lands, and fortunately, research work proved the success of sunflower in these lands.

The productivity of such crop could be increased by cultivating high yielding genotypes and by improving the cultural practices, such as irrigation amount, boron application and plant density.

Irrigation water is a limiting factor in new reclaimed areas, due to the shortage in water resources, which causes serious crop damages. Therefore, it is necessary to determine the optimum water requirement in order to reach the maximum crop production. Sunflower has been considered as a drought resistant crop due to its deep-root system. Also, it responds to higher levels of irrigation (Tomar *et al.*, 1997). Increasing available soil moisture from 20-25 to 60-65 % maximized seed oil content and oil yield of sunflower per feddan (Khalil, 1997). Abdel Hafez *et al.* (2000) recorded gradual increases in sunflower ET_{crop} and WUE values by increasing water amount per irrigation.

On the other hand, boron (B) is an essential micronutrient required for normal plant growth and its deficiency affects the production of viable pollen grains in the flowers, so it is an important factor in flower fertilization process. Plants which lack B may grow normally but seed yield may be severely reduced (Gupta 1993). B deficiency resulted in reduced growth, dry matter, head size, seed weight and tissue B contents of sunflower plants (Chatterjee and Noutiyal 2000). While, the yield and its attributes of sunflower were statistically affected by B foliar application, 0.2 % borax (as source of B) gave higher values of head diameter, number of seeds/head, 100-seed weight, seed yield, biological yield, harvest index, oil percentage and oil yield compared to nil B (EL-Sadek *et al.*, 2004).

It is worth noticing that determining of the optimal plant density that achieves the minimal intra-specific competition is essential to maximize the usage of water and nutrients per land unit area resulting in increasing productivity under these conditions. In this regard, each increase in plant density of sunflower from 24000 to 28000 and 33600 plants/fed. (Allam and Galal, 1996) or from 20000 to 28000, 40000 and 56000 plants/fed. (Sharief, 1998) markedly increased seed yield and oil percentage and yield/fed.

The objective of this investigation is to determine the optimum levels of irrigation water amount, boron spraying and plant density on sunflower production under New Valley conditions.

MATERIALS AND METHODS

Two field experiments were carried out in the Desert Research Center (D.R.C.), Agricultural Experimental station at EL-Kharga Oasis (30.53 longitude, 25.45 latitude and elevation 78.8.), New Valley Governorate, during the two late summer growing seasons of 2004 and 2005. The soil texture of the site was sandy clay loam containing 2.04 % organic matter, 0.58 ppm boron, pH 8.3 and EC 4.4 dS/m .

Each experiment included twenty seven treatments, which were the combinations of three irrigation levels {80, 100 and 120 % at ETa}; three boron spraying rates {0, 226 and 339 ppm boron} as well as three plant densities, i.e. 28000, 35000 and 46666 plants/fed. which were achieved by planting sunflower in hills in one side of the ridge and the distances between hills were 25, 20 and 15 cm, respectively).

Boron was applied as foliar application in the form of Borax ($Na_2B_4O_7$-$10H_2O$, 11.3 % B) at 50 % flowering stage. Knapsack sprayer with water volume of 300 l. /fed. was used.

The experiment was laid out in a split-split plot design with six replicates. Irrigation treatments were arranged in the main plots, boron treatments were allocated in the sub plots, and plant density treatments occupied the sub-sub plots. Each experimental unit area was 10.5 m^2 and contained five ridges (3.5 m length and 60 cm apart).

Well water was the source for irrigation containing 0.075 ppm boron, pH 7.3 and EC 1.08 dS/m. Network of drip irrigation system was used. Water amounts for irrigation levels were calculated based on evapotranspiration rate for every growth phase during each growing season. Sunflower crop water requirement was calculated by determining the following:

1- Reference evapotranspiration (ETo), according to climatic data of the region (modified equation of Penman (1984).
2- Crop coefficient (Kc), from FAO (1984).
3- Calculation of the crop evapotranspiration (ETa), according to the following equation:-

$$ETa = ETo. Kc$$

The preceding crop was wheat in the first season and barley in the second one. Phosphorus fertilizer was applied in the form of calcium super phosphate (15 % P_2O_5) at the rate of 30 kg P_2O_5 /fed. during soil preparation.
Sunflower (*Helianthus annuus*, L.) hybrid Vidoc) was sown on 22nd August in both seasons. At 22 days after sowing, plants were thinned to secure one plant per hill. Nitrogen fertilizer was added in the form of urea (46.5 % N) at the rate of 60 kg N /fed in two equal portions, the first was applied after thinning and the second one after the first portion by two weeks. Potassium fertilizer was applied in the form of potassium sulfate (48 % K_2O) at the rate of 24 kg K_2O /fed after 50 days from sowing. All recommended common agricultural practices were adopted throughout the two experimental seasons.

Assessments:-

A-Growth traits:

At 70 days from sowing, five guarded plants were chosen randomly from each experimental unit of three replicates to estimate dry matter /plant (g), leaf area index (LAI), specific leaf weight (SLW) and total leaves chlorophyll content (SPAD value), which was determined by chlorophyll meter {SPAD-502), Soil Plant Analysis Department Section, Minolta Camera Co., Osaka, Japan} as reported by (Minolta Camera Co., 1989).

B-Yield and its attributes:

Sunflower plants were harvested on 6th and 13th December in the 1st and 2nd seasons, respectively. At harvest, ten guarded plants were taken randomly from the rest of the other three replicates to measure plant height, head diameter, number of seeds/head, seed weight/head and weight of 1000 seeds. Moreover, all plants of the experimental unit (10.5m2) were collected to evaluate straw yield/fed., seed yield/fed., harvest index and water use efficiency.

C-Seed chemical composition:

Samples of sunflower seeds were dried at 70 oC for 24 hours and seed oil content was measured by extraction using Soxhlet apparatus and hexane as an organic solvent according to A.O.A.C (1980). Then, oil yield/fed. was calculated.

Simple correlation:

All possible coefficients of simple correlation (r) were calculated (according to Snedecor & Cochran, 1980) among LAI, dry matter/plant, head diameter, seeds number and weight/head, 1000-seed weight, and seed yield/fed. in sunflower under over all the experiment.

Statistical analysis:

All the obtained data from each season were exposed to the proper statistical analysis of variance according to Gomez and Gomez (1984). The combined analysis of variance for the data of the two seasons was performed after testing the error homogenity, and LSD at 0.05 level of significance was used for the comparison between means.

RESULTS AND DISCUSSION

1- Growth traits:

A-Effect of irrigation:

Available results in Table (1) reveal that irrigation treatments had a significant effect on the studied growth criteria, i.e. total chlorophyll (SPAD value), LAI, SLW and dry matter /plant. Herein, adding irrigation water at 120 % ETa was the potent treatment for increasing SPAD value, LAI and dry matter/plant. Such traits showed the minimal values with irrigation at 80 % ETa. The sufficient moisture by irrigation level at 120 % ETa may help the plant to absorb more amount of water and nutrients from soil and save adequate water requirements for growth demand which enhanced cell division, elongation and expansion as well as increased photosynthetic activity and accumulation of metabolites. On the contrary, irrigation level at 100 %

ETa surpassed 120 % ETa in SLW. This may reflect the efficiency of irrigation at 120 % ETa for promoting metabolites translocation from source (leaves) to sink (other plant organs), and for increasing plant leaves area. Similar trend was obtained by Teama & Mahmoud (1994), Mandal & Giri (2002). and Ashoub *et al.* (2003)

Table (1): Effect of irrigation levels, boron spraying and plant density on growth traits of sunflower after 70 days from sowing (combined analysis of 2004 and 2005 seasons).

Treatments	SPAD value	LAI	SLW (mg/cm^2)	Dry matter/ plant (g)
Irrigation level at Eta				
80 %	44.70	6.39	4.36	89.76
100 %	46.86	7.39	4.61	111.39
120 %	48.02	7.47	4.03	116.37
LSD (0.05)	**1.09**	**0.24**	**0.12**	**1.84**
B rate (ppm)				
0	45.57	6.97	4.37	103.83
226	46.10	7.07	4.36	106.56
339	47.91	7.20	4.27	107.14
LSD (0.05)	**0.72**	**0.12**	**0.07**	**0.01**
Plant density (plants /fed.)				
28000	45.45	5.40	4.52	110.03
35000	46.19	6.89	4.33	107.19
46666	47.94	8.95	4.15	100.32
LSD (0.05)	**NS**	**0.11**	**0.09**	**2.16**

B-Effect of boron:

Aforementioned growth criteria significantly responded to B spraying treatments (Table 1). The highest values of SPAD, LAI and dry matter/plant were achieved with spraying B at the rate of 339 ppm. Such superior treatment possessed 5.1, 3.3 and 3.2 % increases in the previously mentioned traits, respectively, compared to nil B (0 ppm). Unlike, without B spraying, maximum SLW value was recorded. The B requirement of dicots is generally higher than that of monocots (Gupta *et al.*, 1985). The role of B within the plant includes cell wall synthesis, sugar transport, cell division, differentiation, membrane functioning, root elongation, and regulation of plant hormone levels (Marschner, 1995). Concerning the superiority of nil B treatment in SLW compared with the treatment of 339 ppm. B may be attributed to the role of B in affecting cell division and cell wall structure, consequently leaf area increased, while SLW decreased. These results are in harmony with those of Plesnicar *et al.* (1997) who stated that B deficiency caused reduction in leaf chlorophyll content, leaf area and dry matter of sunflower plants.

C-Effect of plant density:

According to the data in Table (1), LAI was markedly decreased whereas SLW and dry matter/plant were statistically increased with decreasing plant density. In this respect, plant density of 28000 plants/fed. gave the maximal values of SLW and dry matter/plant. While, the highest value of LAI was obtained with high plant

density (46666 plants/fed.).The superiority of low plant density (28000 plant/fad.) in SLW and dry matter/plant may be due to the low intra-specific competition between plants for growth factors such as water, light and nutrients. Contrarily, reducing the distance between plants in high plant density (46666 plant/fed.) might be the cause for increasing LAI. These findings are in agreement with those of Kamel *et al.* (1985), Sharief & Said (1993) and Sharief (1998).

D-Effect of interactions:

The impacts of possible interactions between the three studied factors on growth traits of sunflower are presented in Tables (2, 3, 4 and 5).

Irrigation X boron:

Data in Table (2) show the significant impact of the interaction between irrigation levels and boron spraying treatments on some growth parameters of sunflower. Combination of irrigation at 120 % ETa with spraying B at 339 ppm recorded the maximum values of SPAD and dry matter/plant. While, irrigation at 100 % ETa with no B was the most effective for enhancing SLW.

Table (2): Effect of interaction between irrigation levels and boron spraying on growth traits of sunflower after 70 days from sowing (combined analysis of 2004 and 2005 seasons).

Irrigation level at ETa	B rate (ppm)	SPAD value	LAI	SLW (mg/cm^2)	Dry matter/ plant (g)
80 %	0	44.28	6.25	4.42	91.57
	226	43.78	6.39	4.36	90.21
	339	46.03	6.53	4.30	87.52
100 %	0	45.64	7.28	4.67	107.94
	226	46.61	7.38	4.61	112.37
	339	48.33	7.50	4.55	113.87
120 %	0	46.78	7.39	4.03	111.99
	226	47.91	7.45	4.11	117.09
	339	49.38	7.57	3.95	120.04
LSD (0.05)		0.64	NS	0.03	0.28

Irrigation X plant density:

Considerable effect of the interaction between irrigation levels and plant density treatments on LAI, SLW and dry matter/sunflower plant as shown in Table (3). In this connection, irrigation at 120 % ETa with each plant density of 46666 and 28000 plants/fed. gave the highest values of LAI and dry matter/plant, respectively. Moreover, SLW showed the maximum increase by irrigation at 100 % ETa with plant density of 28000 plants/fed.

Boron X plant density:

There is a significant effect of interaction between B spraying and plant density treatments on LAI, SLW and dry matter/sunflower plant (Table, 4). B spraying at the rate of 339 ppm recorded the highest LAI value with plant density of 46666 plants/fed. and the heaviest dry matter/plant with plant density of 28000 plants/fed. Without B spraying x plant density of 28000 plants/fed. achieved the maximum increase in SLW.

Table (3): Effect of interaction between irrigation levels and plant density on growth traits of sunflower after 70 days from sowing (combined analysis of 2004 and 2005 seasons).

Irrigation level at ETa	Plant density (plants /fed.)	SPAD value	LAI	SLW (mg/cm^2)	Dry matter/ plant (g)
80 %	28000	43.65	4.87	4.54	94.44
	35000	44.20	6.24	4.30	90.28
	46666	46.24	8.06	4.23	84.57
100 %	28000	45.93	5.63	4.77	114.96
	35000	46.49	7.18	4.62	113.16
	46666	48.17	9.34	4.44	106.06
120 %	28000	46.77	5.70	4.24	120.67
	35000	47.88	7.26	4.07	118.12
	46666	49.41	9.44	3.77	110.32
LSD (0.05)		NS	0.06	0.02	1.57

Table (4): Effect of interaction between boron spraying and plant density on growth traits of sunflower after 70 days from sowing (combined analysis of 2004 and 2005 seasons).

B rate (ppm)	Plant density (plants /fed.)	SPAD value	LAI	SLW (mg/cm^2)	Dry matter/ plant (g)
0	28000	44.47	5.32	4.57	107.88
	35000	44.68	6.81	4.33	104.63
	46666	47.55	8.79	4.21	98.99
226	28000	45.20	5.40	4.55	110.65
	35000	45.88	6.87	4.39	107.91
	46666	47.22	8.95	4.15	101.12
339	28000	46.68	5.49	4.44	111.55
	35000	48.01	7.00	4.28	109.03
	46666	49.05	9.11	4.09	100.85
LSD (0.05)		NS	0.06	0.04	1.61

Irrigation X boron X plant density:

Both SLW and dry matter/plant were significantly affected by the second-order interaction (among irrigation, B and plant density), while SPAD and LAI values did not being affected. Herein, combinations included plant population of 28000 plants/fed. showed the highest values of SLW and dry matter/plant when applied with irrigation at 100 % ETa x nil B and irrigation at 120 % ETa x 339 ppm B, respectively.

2- Yields, yield attributes and water use efficiency:-

A-Effect of irrigation:

Available results in Table (6) show that all yield and its components of sunflower were markedly affected by irrigation levels. Generally, plant height, head diameter, seeds number/head, seed weight/head, 1000-seed weight as well as straw and seed yields/fed. were significantly enhanced with increasing irrigation levels. So, irrigation at 120 % ETa was the efficient treatment in this respect being recorded the

highest values of the abovementioned traits. Such potent treatment surpassed both of irrigation at 100 and 80 % ETa by 6.8 and 36.0 % for seeds number/head; 19.7 and 88.5 % for seed weight/head, 11.9 and 35.7 % for 1000-seed weight as well as 14.1 and 46.2 % for seed yield/fed., respectively. Moreover, irrigation at 80 % was the inferior treatment in this concern. The enhancements in sunflower yield and its components due to increasing irrigation water might be attributed to the positive effect of irrigation on growth and photosynthetic capacity of irrigated plots with 120 % ETa (Table, 1). This afforded them more dry matter accumulation in their yield components, i.e. head diameter, seeds number and weight/head, 1000-seed weight, which reflected on straw and seed yields/fed. Additionally, increasing irrigation amount (to the optimal) increases the capacity of crop plants to utilize the environmental factors. This in turn increases the amounts of metabolites synthesized (by crop plants), yield and yield components. These results are in agreement with those of Singh et al. (1995), Tomar et al. (1997) and Mandal & Giri (2002).

Table (5): Effect of interaction among irrigation levels, boron spraying and plant density on growth traits of sunflower after 70 days from sowing (combined analysis of 2004 and 2005 seasons).

Irrigation level at ETa	B rate (ppm)	Plant density (plants /fed.)	SPAD value	LAI	SLW (mg/cm^2)	Dry matter/ plant (g)
80 %	0	28000	43.05	4.78	4.59	95.33
		35000	43.08	6.11	4.34	91.75
		46666	46.70	7.85	4.32	87.62
	226	28000	43.32	4.87	4.54	94.50
		35000	43.27	6.22	4.32	91.08
		46666	44.77	8.07	4.22	85.05
	339	28000	44.58	4.97	4.50	93.50
		35000	46.25	6.38	4.25	88.00
		46666	47.27	8.25	4.16	81.05
100 %	0	28000	44.65	5.54	4.89	112.22
		35000	44.62	7.11	4.62	108.38
		46666	47.67	9.20	4.49	103.22
	226	28000	45.78	5.64	4.75	115.78
		35000	46.35	7.15	4.63	114.25
		46666	47.70	9.35	4.46	107.08
	339	28000	47.35	5.72	4.66	116.88
		35000	48.52	7.29	4.61	116.85
		46666	49.13	9.48	4.37	107.88
120 %	0	28000	45.70	5.63	4.23	116.08
		35000	46.35	7.20	4.03	113.75
		46666	48.28	9.33	3.83	106.13
	226	28000	46.50	5.69	4.35	121.67
		35000	48.03	7.23	4.22	118.38
		46666	49.20	9.42	3.76	111.22
	339	28000	48.12	5.78	4.15	124.27
		35000	49.27	7.33	3.98	122.23
		46666	50.75	9.58	3.73	113.62
LSD (0.05)			NS	NS	0.06	2.64

The calculated data of harvest index and water use efficiency reveal that there is a significant impact of irrigation levels on these traits. Herein, irrigation at 120 % ETa achieved the significantly highest values of harvest index, but statistically at par with those of 100 % ETa in water use efficiency.

Results in Table (6) divulge that oil % and yield/fed. were significantly affected by irrigation levels. In this regard, irrigation water use at 120 % ETa was the excelsior practice. Potency of this treatment for such traits amounted to 6.8 and 21.2 %, respectively, than those of irrigation at 100 % ETa as well as 16.5 and 69.5 %, respectively compared to irrigation at 80 % ETa. The improvement in oil yield/fed. with increasing water quantity is mainly due to the improvement in seed yield. Additionally, the sufficient moisture has favorable effect on physiological processes in plant, i.e. photosynthetic activity and accumulation of metabolites. These results are in good line with those stated by Khalil (1997), Mandal & Giri (2002) and Ashoub *et al.* (2003).

B- Effect of boron:

Data presented in Table (6) indicate that all sunflower yield and its attributes markedly responded to B spraying treatments, except plant height. Application of 339 ppm B recorded the significantly maximal values of yield and its components. Such efficient treatment increased head diameter, seeds number/head, seed weight/head, 1000-seed weight as well as straw and seed yield/fed. by 5.0, 7.2, 17.5, 7.5, 4.2 and 13.0 %, respectively, compared to nil B spraying. It is clear that the increase in B level improved sunflower yield and its attributes. B fertilization stimulated SPAD value, LAI and dry matter of sunflower plants (Table, 1), and this in turn increased photosynthetic areas and activity as well as dry matter accumulation in seeds and heads. Similar results were obtained by Tamak *et al.* (1997), Vyakaranahal *et al.* (2001) and El-Sadek *et al.* (2004).

The spraying of B at the rate of 339 ppm secured the highest values of harvest index and water use efficiency, exceeding the other treatments in this respect.

According to the data in Table (6), abundant of B fertilizer markedly enhanced oil % and yield/fed. of sunflower. In this regard, spraying of 339 ppm B significantly increased such two traits by 10.4 and 24.3 %, respectively, compared with the control (without B). Results of oil yield as affected by B spraying may be ascribe to the improvement in oil % and seed yield. Similar results were obtained by Murthy *et al.* (1999) and Vyakaranahal *et al.* (2001).

C- Effect of plant density:

Plant density had significant effects on sunflower yield and its components as shown in Table (6). Concerning the yield components, i.e. head diameter, seeds number/head, seed weight/head and 1000-seed weight, decreasing plant density from 46666 to 28000 plants/fed. caused significant increases. So, plots included 28000 plants/fed. secured the significant highest values of the aforementioned traits. Whereas, the reverse was true in straw and seed yields/fed., i.e. plant density of 46666 plants/fed. recorded the maximum straw and seed yield/fed. These observations refer to low compensation ability of sunflower

plants. Increase percentages in straw and seed yields due to this excelsior treatment than those of 28000 plants/fed. amounted to 6.6 and 11.7 %, respectively. The low intra-specific competition among sunflower plants under low plant population may be the reason for enhancing the most plant growth traits, i.e. SLW and dry matter (Table, 1). This enables sunflower plants to make good use of the environmental resources, reflecting on yield attributes as recorded in their highest values with low plant density. Contrarily, the highest yields/fed. was obtained with high plant density and vice versa. This result could be attributed to the increase in number of harvested plants/unit area, in addition to the increase in LAI (Table, 1), and in turn yields/fed. Confirming results of Zeiton (1992), Allam and Galal (1996), Metwally (1997) and Sharief (1998).

On the other side, harvest index and water use efficiency were markedly affected by plant density as shown in Table (6). High density of sunflower plants (i.e. 46666 plants/fed.) attained the greatest values of the aforementioned computed parameters.

An examined view to the results in Table (6) appeared that plant density practices had a considerable effect on oil % and yield/fed. Highest population of sunflower plants, i.e. 46666 plants/fed. produced the highest values. Such increments amounted to 8.9 and 21.3 %, respectively, over those of plant density of 28000 plants/fed. The enhancement in oil yield due to high plant density pattern might be attributed to its efficiency in increase oil % and seed yield/fed. These results are generally in concordance with those obtained by Allam & Galal (1996) and Sharief (1998).

D- Effect of interactions:

First order interactions, i.e. irrigation x boron; irrigation x plant density and boron x plant density are presented in Tables (7, 8 and 9) as well as the second order interaction, i.e. irrigation x boron x plant density is shown in Table (10).

Irrigation X boron:

The interaction between irrigation levels and B spraying divulged remarkable effect on sunflower yield and its components (Table 7). In this respect, the combination of irrigation at 120 % ETa x 339 ppm B recorded the maximum values of plant height, head diameter, seeds number/head, seed weight/head, 1000-seed weight and seed yield/fed. Additionally, under the same irrigation level, spraying B at the rate of 226 ppm was the best treatment for improving straw yield. Otherwise, irrigation at 80 % ETa x nil B gave the *minimal* values of all yield and yield parameters.

Harvest index attained the highest values when sunflower plants were irrigated at 120 % ETa and treated by 339 ppm B, while irrigating sunflower plants at 100 % ETa x 339 ppm B was the effective interaction for increasing water use efficiency.

Combination of irrigation at 120 % ETa x 339 ppm boron was the most effective treatment for promoting oil % and yield/fed.

Table (6): Effect of irrigation levels, boron spraying and plant density on yield, yield components and water use efficiency of sunflower (combined analysis of 2004 and 2005 seasons).

Treatment	Plant height (cm)	Head			Weight of 1000-seed (g)	Yield (kg/fed.)		Harvest index (%)	Oil		Water use efficiency (kg/m³)
		Diameter (cm)	Seeds number	Seed weight (g)		Straw	Seed		%	Yield (kg/fed.)	
Irrigation level at ETa											
80 %	153.92	20.34	977.31	66.01	68.59	1822.67	820.04	30.94	31.61	260.33	0.4041
100 %	160.67	22.80	1244.87	103.95	83.22	2310.52	1050.64	31.22	34.48	364.06	0.4394
120 %	161.85	23.10	1328.97	124.43	93.09	2367.80	1199.18	33.63	36.82	441.28	0.4353
LSD (0.05)	**5.85**	**1.12**	**17.81**	**1.35**	**1.38**	**153.42**	**59.65**	**0.35**	**0.74**	**32.75**	**0.0206**
B rate (ppm)											
0	157.09	21.54	1139.25	91.59	78.76	2113.87	951.24	30.83	32.54	313.27	0.3947
226	158.95	22.07	1190.21	95.20	81.44	2183.87	1043.32	32.26	34.43	362.98	0.4353
339	160.40	22.63	1221.70	107.61	84.70	2203.24	1075.30	32.70	35.93	389.43	0.4487
LSD (0.05)	**NS**	**0.08**	**0.72**	**0.03**	**0.10**	**2.28**	**0.08**	**0.25**	**1.04**	**4.81**	**0.0013**
Plant density (plants /fed.)											
28000	156.75	22.97	1219.40	101.68	83.43	2091.83	960.15	31.20	32.75	318.04	0.3978
35000	158.71	22.50	1189.11	99.29	82.03	2179.17	1036.82	32.15	34.49	361.77	0.4324
46666	160.98	20.76	1142.65	93.43	79.44	2229.98	1072.88	32.44	35.67	385.88	0.4486
LSD (0.05)	**NS**	**0.32**	**22.69**	**2.14**	**2.10**	**82.11**	**31.82**	**0.26**	**0.28**	**17.45**	**0.0136**

Table (7): Effect of interaction between irrigation levels and boron spraying on yield, yield components and water use efficiency of sunflower (combined analysis of 2004 and 2005 seasons).

Irrigation level at ETa	B rate (ppm)	Plant height (cm)	Head			Weight of 1000-seed (g)	Yield (kg/fed.)		Harvest index (%)	Oil		Water use efficiency (kg/m³)
			Diameter (cm)	Seeds number	Seed weight (g)		Straw	Seed		%	Yield (kg/fed.)	
80 %	0	149.87	19.41	933.30	62.16	66.19	1762.78	745.06	29.56	29.37	219.28	0.3672
	226	155.64	20.24	984.42	66.41	68.50	1809.94	844.78	31.79	31.65	267.44	0.4162
	339	156.26	21.38	1014.23	69.48	71.08	1895.28	870.28	31.47	33.80	294.27	0.4290
100 %	0	161.66	22.23	1191.26	94.99	80.34	2228.78	943.51	29.78	33.30	315.60	0.3946
	226	159.13	22.97	1252.33	98.51	83.48	2353.67	1084.91	31.53	34.66	377.84	0.4537
	339	161.21	23.19	1291.03	118.34	85.83	2349.11	1123.51	32.35	35.49	398.75	0.4698
120 %	0	159.74	22.97	1293.19	117.60	89.76	2350.06	1165.14	33.15	34.96	404.92	0.4224
	226	162.07	22.99	1333.88	120.69	92.33	2388.00	1200.28	33.47	36.99	443.67	0.4360
	339	163.74	23.32	1359.83	135.01	97.18	2365.33	1232.11	34.27	38.50	475.26	0.4474
LSD (0.05)		**1.35**	**0.02**	**1.57**	**0.01**	**0.12**	**2.30**	**0.35**	**0.12**	**0.49**	**4.13**	**0.0005**

Table (8): Effect of interaction between irrigation and plant density on yield, yield components and water use efficiency of sunflower (combined analysis of 2004 and 2005 seasons).

Irrigation level at ETa	Plant density (plants /fed.)	Plant height (cm)	Head			Weight of 1000-seed (g)	Yield (kg/fed.)		Harvest index (%)	Oil		Water use efficiency (kg/m^3)
			Diameter (cm)	Seeds number	Seed weight (g)		Straw	Seed		%	Yield (kg/fed.)	
80 %	28000	150.62	21.08	1012.06	71.64	70.33	1721.00	717.89	29.33	30.40	218.39	0.3538
	35000	153.92	21.08	982.68	67.82	68.81	1836.56	842.28	31.43	31.70	267.96	0.4151
	46666	157.23	18.86	937.20	58.58	66.63	1910.44	899.94	32.06	32.72	294.64	0.4434
100 %	28000	158.88	23.84	1282.65	106.90	85.06	2229.17	985.36	30.65	32.79	324.49	0.4119
	35000	160.62	23.09	1248.41	105.09	83.71	2327.56	1063.57	31.33	34.81	371.39	0.4448
	46666	162.50	21.46	1203.56	99.85	80.89	2374.83	1102.99	31.68	35.84	396.30	0.4613
120 %	28000	160.74	23.99	1363.48	126.48	94.90	2325.33	1177.20	33.63	35.07	411.22	0.4276
	35000	161.60	23.32	1336.23	124.96	93.57	2373.39	1204.62	33.67	36.96	445.95	0.4374
	46666	163.22	21.98	1287.20	121.86	90.80	2404.67	1215.71	33.59	38.43	466.68	0.4409
LSD (0.05)		0.87	0.07	NS	0.22	NS	8.78	3.10	0.13	0.24	3.94	0.0016

Table (9): Effect of interaction between boron spraying and plant density on yield, yield components and water use efficiency of sunflower (combined analysis of 2004 and 2005 seasons).

B rate (ppm)	Plant density (plants /fed.)	Plant height (cm)	Head			Weight of 1000-seed (g)	Yield (kg/fed.)		Harvest index (%)	Oil		Water use efficiency (kg/m^3)
			Diameter (cm)	Seeds number	Seed weight (g)		Straw	Seed		%	Yield (kg/fed.)	
0	28000	155.69	22.58	1175.04	95.26	80.43	2027.78	882.32	29.88	31.47	282.00	0.3629
	35000	156.89	21.98	1144.46	92.34	79.18	2133.06	969.94	31.14	32.54	318.22	0.4037
	46666	158.70	20.05	1098.25	87.16	76.68	2180.78	1001.44	31.48	33.61	339.59	0.4176
226	28000	156.36	22.80	1225.78	99.28	83.50	2133.78	975.17	31.27	32.70	321.88	0.4053
	35000	158.73	22.52	1195.52	96.87	81.76	2199.17	1058.01	32.43	34.67	371.17	0.4416
	46666	161.74	20.88	1149.33	89.46	79.05	2218.67	1096.78	33.09	35.93	395.90	0.4591
339	28000	158.19	23.53	1257.37	110.49	86.36	2113.94	1022.96	32.46	34.08	350.23	0.4252
	35000	160.52	22.99	1227.34	108.66	85.14	2205.28	1082.52	32.87	36.25	395.91	0.4519
	46666	162.50	21.36	1180.38	103.67	82.59	2290.50	1120.42	32.76	37.46	422.14	0.4691
LSD (0.05)		0.78	0.03	NS.	0.04	0.11	1.80	0.24	0.07	0.53	5.02	0.0008

Table (10): Effect of interaction between irrigation levels, boron spraying and plant density on yield, yield components and water use efficiency of sunflower (combined analysis of 2004 and 2005 seasons).

Irrigation level at ETa	B rate (ppm)	Plant density (plants /fed.)	Plant height (cm)	Head			Weight of 1000-seed (g)	Yield (kg/fed.)		Harvest index (%)	Oil		Water use efficiency (kg/m³)
				Diameter (cm)	Seeds number	Seed weight (g)		Straw	Seed		%	Yield (kg/fed.)	
80 %	0	28000	147.37	20.17	968.1	67.80	67.53	1666.33	599.00	26.44	28.70	170.84	0.2953
		35000	150.40	20.03	938.5	63.80	66.50	1810.33	786.83	30.30	29.19	230.15	0.3878
		46666	151.85	18.02	893.3	54.88	64.55	1811.67	849.33	31.93	30.22	256.85	0.4183
	226	28000	151.02	20.73	1019.7	73.78	70.68	1739.67	764.83	30.54	30.08	229.91	0.3768
		35000	155.20	21.20	989.8	69.45	68.60	1841.67	858.00	31.79	31.91	273.78	0.4227
		46666	160.70	18.78	943.8	55.98	66.22	1848.50	911.50	33.04	32.96	298.63	0.4492
	339	28000	153.48	22.33	1048.4	73.35	72.78	1757.00	789.83	31.01	32.42	254.43	0.3893
		35000	156.15	22.02	1019.8	70.22	71.32	1857.67	882.00	32.20	33.99	299.94	0.4348
		46666	159.13	19.78	974.6	64.87	69.13	2071.17	939.00	31.20	34.99	328.44	0.4628
100 %	0	28000	160.57	23.53	1229.1	98.08	82.27	2070.17	904.83	30.42	31.93	290.77	0.3782
		35000	161.75	22.83	1195.3	95.47	80.78	2239.00	952.50	29.85	33.44	317.89	0.3985
		46666	162.67	20.33	1149.4	91.43	77.97	2377.17	973.20	29.05	34.52	338.15	0.4070
	226	28000	157.38	23.90	1289.8	101.85	85.37	2309.83	985.23	29.91	32.65	321.85	0.4120
		35000	158.83	23.07	1255.2	99.95	84.00	2379.83	1110.52	31.83	35.10	391.17	0.4643
		46666	161.17	21.93	1212.0	93.73	81.07	2371.33	1158.97	32.85	36.24	420.48	0.4848
	339	28000	158.68	24.08	1329.1	120.77	87.53	2307.50	1066.02	31.61	33.78	360.86	0.4457
		35000	161.28	23.38	1294.8	119.87	86.33	2363.83	1127.70	32.31	35.90	405.11	0.4715
		46666	163.67	22.10	1249.3	114.38	83.63	2376.00	1176.80	33.14	36.78	430.28	0.4922
120 %	0	28000	159.13	24.03	1327.9	119.88	91.48	2346.83	1143.13	32.76	33.79	384.39	0.4152
		35000	158.52	23.08	1299.6	117.77	90.25	2349.83	1170.48	33.26	35.00	406.60	0.4248
		46666	161.58	21.80	1252.1	115.15	87.53	2353.50	1181.80	33.44	36.10	423.76	0.4273
	226	28000	160.68	23.77	1367.8	122.20	94.45	2351.83	1175.45	33.37	35.37	413.88	0.4270
		35000	162.17	23.28	1341.6	121.22	92.68	2376.00	1205.52	33.67	37.00	448.57	0.4378
		46666	163.37	21.93	1292.3	118.67	89.87	2436.17	1219.87	33.38	38.58	468.58	0.4432
	339	28000	162.42	24.18	1394.7	137.37	98.77	2277.33	1213.02	34.76	36.04	435.39	0.4407
		35000	164.12	23.58	1367.5	135.90	97.78	2394.33	1237.87	34.09	38.86	482.68	0.4495
		46666	164.70	22.20	1317.3	131.75	95.00	2424.33	1245.45	33.95	40.60	507.70	0.4522
LSD (0.05)			1.40	0.04	NS	0.04	0.16	2.60	0.55	0.19	0.41	4.64	0.0014

Irrigation X plant density:

Remarkable influence of the interaction between irrigation level x plant density on all yield and yield traits was obtained, except for seeds number/head and 1000-seed weight, which were not significantly affected (Table, 8). Herein, the effective combinations were irrigation at 120 % ETa with plant density of 46666 plants/fed. for increasing plant height and straw and seed yields/fed., as well as irrigation at 120 % ETa with plant density of 28000 plant/fed. for promoting head diameter and seed weight/head.

Moreover, irrigation at 120 % ETa x plant density of 35000 plant/fed. secured the maximum harvest index, and irrigation at 100 % ETa x 46666 plants/fed. recorded the highest water use efficiency.

The combination of high levels of irrigation (120 % ETa) and plant density (46666 plants/fed. gave the highest increases of oil % and yield /fed. (Table 8).

Boron X plant density:

Head diameter, seed weight/head and 1000-seed weight values were continuously increased as B concentration increased and plant population decreased. Therefore, a rate of 339 ppm B with 28000 plants/fed. recorded the largest diameter of head and heaviest seed weight/head and 1000-seed weight. The tallest sunflower plants and the maximum yields of straw and seed/fed. and water use efficiency were achieved with the combination of 339 ppm B x 46666 plants/fed.

Application of 226 ppm B x plant density of 46666 plants/fed attained the maximum values of harvest index.

Under high density of sunflower plants, i.e. 46666 plants/fed., spraying B at a rate of 339 ppm recorded the highest increases in oil % and yield/fed.

Irrigation X boron X plant density:

Remarkable effect of the interaction among irrigation levels, B spraying and plant density on plant height, head diameter, seed weight/head, 1000-seed weight and straw as well as seed yield/fed. were illustrated as shown in Table (10). Plots irrigated by 120 % ETa and treated with 339 ppm B recorded the highest values of head diameter, seed weight/head and 1000-seed weight when sunflower plants were at low density (28000 plants/fed.) as well as plant height and seed yield/fed. when plants were at high density (46666 plants/fed.). While, straw yield/fed showed the maximum increase with the interaction of irrigation at 120 % ETa x 226 ppm B x plant density of 46666 plants/fed.

Under irrigation level of 120 % ETa, the rate of 339 ppm boron x plant density of 28000 plants/fed. recorded the maximal harvest index, while the interaction among irrigation at 100 % ETa x 339 ppm boron x plant density of 46666 plants/fed. was the most effective for enhancing water use efficiency.

Oil % and yield/fed. values progressively increased as irrigation amount, B rate and plants number/fed. were increased. So, combination of irrigation at 120

% ETa x 339 ppm B x plant density of 46666 plants/fed. possessed the maximal increases. While, the interaction of irrigation at 80 % ETa x nil B x plant population of 28000 plants/fed. manifested the lowest values, in this respect.

So, it could be recommended (for maximizing sunflower productivity) to sowing sunflower at 46666 plants/fed. in conjunction with spraying B at a rate of 339 ppm and irrigation at 120 % ETa.

Simple correlation study:

Data in Table (11) illustrate all possible coefficients of correlation of sunflower between seed yield, LAI, dry matter/plant, head diameter, seeds number and weight/head and 1000-seed weight under over all the experiment. Seed yield correlated positively and highly significant with dry matter/plant, seeds number and weight/head and 1000-seed weight. Moreover, the association between seed yield with head diameter was positive reaching the 5 % level of significance. Also, positive and highly marked correlation coefficients were recorded between each pair of dry matter/plant, head diameter, seeds No./head, seed weight/head and weight of 1000-seed. Positive and highly significant correlation coefficients were reported among seed yield with head diameter, seeds number and weight/head and 100-seed weight (Abdel-Aal, 1992 and El-Bially & Abd El-Samie, 1997).

Table (11): Simple correlation coefficient (r) sunflower seed yield/fed. in association with LAI, dry matter/plant, head diameter, seeds No./head, seed weight/head and weight of 1000-seed.

Variables	1	2	3	4	5	6
LAI (1)						
Dry matter/plant (2)	0.017					
Head diameter (3)	-0.200*	0.768**				
Seeds No./head (4)	0.107	0.905**	0.726**			
Seed weight/head (5)	0.208**	0.931**	0.714**	0.895**		
Weight of 1000-seed (6)	0.179*	0.929**	0.756**	0.890**	0.972**	
Seed yield (7)	0.047	0.217**	0.188*	0.232**	0.252**	0.245**

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استجابة دوارالشمس للرى والرش بالبورون والكثافة النباتية تحت ظروف الوادى الجديد

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أجريت تجربتان حقليتان بمحطة التجارب الزراعية بالخارجة التابعة لمركز بحوث الصحراء ، محافظة الوادى الجديد ، أثناء موسمى الزراعة الصيفية المتأخرة (اغسطس – ديسمبر) لموسم ٢٠٠٤، ٢٠٠٥ وذلك لدراسة تأثير كميات ماء الرى (٨٠، ١٠٠، ١٢٠% من البخر نتح الفعلى) ، الرش بالبورون (صفر ، ٢٢٦ ، ٣٣٩ جزء فى المليون من البورون) والكثافة النباتية (٢٨٠٠٠ ، ٣٥٠٠٠ ، ٤٦٦٦٦ نبات بالفدان) وذلك على نبات دوار الشمس صنف فيدوك . أظهرت النتائج أن أضافة ماء الرى عند ١٢٠% من البخر نتح الفعلى كانت المعاملة الفعالة فى زيادة قيمة الكلوروفيل الكلى ، دليل مساحة الاوراق والمادة الجافة / نبات . وأعلى قيمة معنوية من الكلوروفيل الكلى ودليل مساحة الاوراق والمادة الجافة/نبات أحرزت بواسطة الرش بالبورون عند معدل ٣٣٩ جزء فى المليون . أعطت الكثافة النباتية ٢٨٠٠٠ نبات/فدان أعلى قيمة معنوية من الوزن النوعى للاوراق والمادة الجافة/ نبات . بينما كانت أعلى قيمة من دليل مساحة الاوراق مع أعلى كثافة نباتية ٤٦٦٦٦ نبات/ فدان. يمكن القول بوجه عام ، زيادة ارتفاع النبات ، قطر القرص ، عدد البذور/ قرص ،

وزن البذور/ قرص ، وزن ١٠٠٠ بذرة بالاضافة الى النسبة المئوية للزيت ومحصول الزيت والقش والبذور معنويا بزيادة مستويات الرى وكانت أعلى القيم المتحصل عليها عند معاملة الرى بـــ ١٢٠% من البخر نتح الفعلى ، والتى كانت احصائيا متساوية مع معاملة الرى بـــ ١٠٠% من البخر نتح الفعلى فى كفاءة استخدام الماء. سجل أضـــافة ٣٣٩ جزء فى المليون من البورون كرش أعلى قيمـــة مـــن المحصـــول ومكوناتـــه ومحصول الزيت/ فدان . سبب نقص الكثافة النباتية من ٤٦٦٦٦ الى ٢٨٠٠٠ نبـــات/ فدان زيادة معنوية فى مكونات المحصول لنبات دوار الشمس ، بينما ســـجلت الكثافـــة ٤٦٦٦٦ نبات/ فدان أعلى قيمة لمحصول القش والبـــذور والزيـــت/ فـــدان . ارتـــبط محصول البذور ارتباطا موجبا و عالى المعنوية مع كلا من الوزن الجاف/نبات و عدد ووزن البذور/قرص ووزن الالف بذرة.