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EFFECT OF IRRIGATION INTERVALS ON SOME PHYSIOLOGICAL AND YIELD TRAITS OF BARLEY UNDER SPRINKLER IRRIGATION SYSTEM

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ABSTRACT: Two field experiments were carried out in Ismaillia Experimental Research Station during 97/98 and 98/99 seasons to study some physiological characters in addition to yield and yield - components as affected by water insufficiency at different barley growth stages. Four irrigation treatments (to resemble water stress at the specified stage) were used. They are irrigation every: a) 4 days (D) as a control; b) 4 D till anthesis thereafter every 8 D; c) 8 D till anthesis thereafter every 4 D; and d) 8 D during the whole barley growing season. Two barley (*Hordeum vulgare* L.) varieties Giza 123, Giza 124 in addition to one hulless barley line [LHB 93/2 (CI 13346) HANNA, which was chosen from Barley Breeding Program (96/97)] were used.

Exposing barley plants to water stress led to decrease most of the morphological, physiological and yield studied characters. Flag leaf area was decreased in the 4th irrigation treatment by 45.4% and its dry weight by 32.2% compared to control. Leaf relative water content (RWC) was decreased by water deficit depending on stress period and plant growth stage.

Barley yield and its components were affected by imposed irrigation treatments in both seasons. Characters such as: spike length (Sp L; mm), no. of spikes per square meter (no. Sp/m^2), no. of grains per spike (no. G/Sp), grain weight per spike (G_{wt}/Sp), biological yield (BY; T/ha) and grain yield (GY; T/ha) were decreased as the plants suffer more water stress. Giza 123 was the

best one, which tolerates water deficit and had the tallest plants in both seasons of study.

We could conclude that the most drought sensitive period in barley developmental stages is around the anthesis time.

INTRODUCTION

Adequate water supply is an essential need for normal plant growth and development and also to obtain better yields. water supply often results in disruption of the plant physiological processes causing consequent reduction in both growth and yield. Barley tends to be grown on poorer soils and the drier marginal region of cereal cultivation (Cooper *et al*., 1987 and Ceccarelli *et al*., 1991). In Egypt, it is cultivated in rain-fed northern coasts or in newly reclaimed lands, which confront drought stress due to either lake of precipitation or scarcity of irrigation water. The morphological and physiological responses of plants to water deficits generally vary with the severity as well as the duration of the stress. Only, the most sensitive processes are altered by a very mild stress. As the stress increases, these changes intensify, and additional processes become affected. In addition to the degree and duration of water stress, the stage of plant growth (in which stress occurs) is also important in determining the effects of water stress on plant growth and yield (Fageria, 1992).

Leaf relative water content (RWC) was proposed as a good indicator of plant water status (Sinclair and Ludlow, 1985) because RWC, through its relation to cell volume, may more closely reflect the balance between water supply to the leaf and transpiration rate. Matin et al., (1989) mentioned some measurements that relate directly or indirectly to plant response to water deficits. RWC, canopy temperature and air-canopy temperature difference was some examples.

Wells and Dubetz (1970) showed that, for barley, the number of grains per ear and the mean grain mass could be affected by drought during the reproductive and grain-filling period. Other study of Innes and Blackwell (1981), have indicated that wheat is particularly sensitive to drought in the two weeks immediately preceding anthesis.

Grain yield as well as biomass yield reduces with stress, especially during the reproductive plant growth stage when stress may cause flower abortion and poor grain filling (Blum, 1993). An improved understanding of the basis for differences in drought resistance could lead to the use of these characteristics as a selection criterion.

Therefore, drought stress timing and duration on barley plants need to be well studied in order to improve growth and productivity. Our work aimed to study barley physiological parameters as well as yield characters under water deficiency at different growth stages in sandy soils.

MATERIALS AND METHODS

This work was performed during 1997/1998 and 1998/1999 seasons at Ismaillia Experimental Research Station (30^0 36'N, 32^0 14'E) to represents the newly reclaimed sandy soil and sprinkler irrigation conditions. Two barley (*Hordeum vulgare* L.) varieties Giza 123, Giza 124 in addition to one hulless barley line [HBL 93/2 (CI 13346) HANNA] chosen from Barley Breeding Program (96/97) were planted at 30th and at 27th Nov. for the two seasons respectively. Using sprinkler irrigation system, four irrigation treatments were used, it was irrigation every:

- 4 days (D) as a control treatment (no water stress; I_1),
- 4 D till anthesis thereafter every 8D (water stress during grain filling stage; I_2),
- 8 D till anthesis thereafter every 4 D (water stress during vegetative stage; I_3) and
- 8 D during the whole barley-growing season (water stress during the whole plant life cycle, I_4).

No detectable rainfall during the two growing seasons was occurred at the experimental site (The Monthly Weather Report of the Egyptian Ministry of Agriculture and Land Reclamation).

A split plot design was used, in which the main plots were allocated to the irrigation treatments and the sub-plots were allocated for barley cultivars. Leaf relative water content(RWC, %) was measured once at 108 days after sowing (DAS) during the first season. We decided to measure it twice at 90 and 115 DAS during the second one to test better this time of plant life.It was calculated according to the equation mentioned by *Schonfeld et al* (1988).

RWC (%) = 100 (FW – DW) / (TW – DW)

Where: FW = leaf fresh weight, TW = turgid weight and DW = dry weight(oven drying at 70 °C).

Remote sensing using Infrared Thermometer instrument (Scheduler Plant Stress Monitor) was used during 1:00 and 2:00 PM to detect the plant stress status. It measures canopy and air temperature, relative humidity and light intensity and compute the stress-index (SI) value for the plants.

In addition, flag leaf area and its dry weight were recorded during the 1st season at 108 and 120 DAS.

Heading date as well as yield determinations were recorded.

Analysis of variance and least significant differences for split-plot design were used to assess variations among barley varieties and irrigation treatments for all measured variables according to Snedecor and Cochran, 1980. The statistical package MSTATC was used in performing all statistical analysis.

RESULTS AND DISCUSSION

Physiological and morphological traits: Barley flag leaf area (FLA; cm^2) and its dry weight (DW; mg) as affected by the irrigation treatments were shown in table 1.Both characters recorded at 108 and 120 DAS were decreased significantly under I_2, I_3 and I_4 treatments compared to control treatment (I_1). At the first sample (108 DAS), FLA was decreased by 24.6% for I_2, 43.6 % for I_3 and 45.4 % for I_4 in comparison with I_1 (the control treatment). Flag leaf dry weight was also decreased, it was lesser than control by 19.8 % for I_2, 35.7 % for I_3 and 32.2% for I_4. The highest FLA and its DW values were recorded for G124 variety under control irrigation treatment. Whereas, the least FLA value (6.38 cm^2) was noticed at I_4 treatment for G124 with the lowest value of Flag leaf DW (52.03mg) was recorded at I_3 treatment for G123. There were no significant differences between tested barley varieties and line.

At the second sampling time (120 DAS), we could notice the same previous response in FLA and its dry weight (DW) as affected by water treatment and varieties. Compared to control, FLA was decreased by 17.6% for I_2, 37.8% for I_3 and 41.6% for I_4. FLA of both I_3 and I_4 was not differed significantly. The highest FLA value was recorded for G124

Table 1: Flag-leaf area and its dry weight of barley varieties recorded at both 108 and 120 DAS as affected by irrigation treatments (97/1998):

		Flag leaf area (cm^2)				Flag leaf DW (mg)			
	Treatments	L	G123	G124	Mean	L	G123	G124	Mean
108 DAS	I_1	9.73	13.00	14.85	12.53	71.90	94.55	103.40	89.95
	I_2	9.68	10.54	8.11	9.45	72.69	79.88	63.75	72.11
	I_3	8.22	6.57	6.41	7.07	68.49	52.03	53.08	57.87
	I_4	7.42	6.71	6.38	6.84	67.49	56.27	59.09	60.95
	Mean	8.76	9.21	8.94		70.14	70.69	69.83	
	LSD (0.05):								
	Treatments		1.201				7.54		
	Varieties		NS				NS		
	Interaction		2.001				16.24		
120 DAS	I_1	12.11	15.59	19.24	15.65	81.68	110.82	125.23	105.91
	I_2	13.08	12.71	12.89	12.89	89.01	77.90	99.49	88.80
	I_3	11.90	8.18	9.11	9.73	88.59	69.26	68.60	75.48
	I_4	9.26	10.09	8.08	9.14	71.77	87.61	67.00	75.46
	Mean	11.59	11.64	12.33		82.76	86.40	90.08	
	LSD (0.05):								
	Treatments		1.598				15.69		
	Varieties		NS				NS		
	Interaction		1.677				17.59		

at control irrigation treatment, while the least one was found for the same cultivar under the fourth irrigation treatment (I_4).

Flag leaf dry weight at 120,decreased under water stress treatments (I_2, I_3 and I_4) when compared to control (I_1), it was decreased by 16.2 % for I_2, 28.7 % I_3 and 28.8 % for I_4. The highest flag leaf dry weight value was found for G 124 at I_1 and the lowest one was recorded at I_4.

It was clear that G 124 was more affected by implemented water stress, where both flag leaf area and flag leaf dry weight were decreased sharply by water stress treatments. On the other hand, hulless line (HBL) was reveled some water stress avoidance expressed as both FLA and its DW.

As expected, exposing plants to drought stress led to decrease the relative water contents (RWC) of barley leaves. On the contrary, stress index was increased as the plants suffer less soil water availability. This was true at the three tested sampling times (at 108 DAS in 97 / 1998 season, 90 and 115 DAS in 98/ 1999 season), tables (2) and (3).

At 108 DAS in the 1st season (table, 2), RWC was decreased significantly from 48.8 % for the control treatment I_1 to 44.9% for the I_2, 42.1 % for I_3 and 39.2 % for I_4 treatment. Barley varieties, also, differed significantly for their RWC Values. Since, G 124 and G 123 had the values of 45.5 % and 44.5 %, while it was 41.2 % for hulless line. The highest RWC was found for G 123 at I_1 treat-ment, whereas, the lowest one was 35.3 % for hulless line at I_4.

Canopy temperature (CT, ^{0}C) was increased by irrigation stress treatments from 17.4 ^{0}C for control to 18.4 ^{0}C for I_2, 18.9 ^{0}C for I_3 and 19.7 ^{0}C for I_4. Both G123 and G124 had no significant differences in CT. The lowest CT value was recorded for G123 at control, but the highest one was found to be for hulless line (HBL) at I_4 treatments.

Stress-index (SI) at 108 DAS was increased with drought stress as shown in table 2. G 123 had the least SI value at control (I_1) treatment, but HBL had the highest, SI value at I_4-irrigation treatment.

At 90 DAS in the 2nd season (table, 3), RWC was decreased from 80.2 % for the control to 57.1% for the I_4 treat. RWC of G124 leaves were highest

Table 2: Relative water contents (RWC %) canopy temperature (°C) and stress index (SI) of barley varieties as affected by irrigation treatments in 97/98 Season, (mean air temp. is 17.4 °C and RH is 33.2) .

Tim	Treatm	RWC (%)				Canopy Temperature (°C)				Stress Index			
		L	G123	G124	Mean	L	G123	G124	Mean	L	G123	G124	Mean
108 DAS 1st Season	I_1	45.27	52.01	49.06	48.78	18.03	16.73	17.50	17.42	3.73	2.50	2.80	3.01
	I_2	42.99	45.02	46.76	44.92	18.33	18.33	17.93	18.37	4.73	4.13	3.63	4.17
	I_3	41.35	40.96	44.08	42.13	18.90	18.90	18.83	18.88	5.07	4.60	4.17	4.61
	I_4	35.33	39.99	42.16	39.16	20.23	19.50	19.30	19.68	6.43	4.93	5.50	5.62
	Mean	41.24	44.50	45.15		19.00	18.37	18.39		4.99	4.04	4.03	
	LSD (0.05):												
	Treatments		1.770				0.807				0.525		
	Varieties		1.854				0.496				0.326		
	Interactions		3.708				0.993				0.652		

(84.9 %) at control, while it was the least (54.0 %) under I_4 treatment.

Canopy temperature (CT, ℃) was increased with increasing water stress imposed by irrigation treatments (table, 3). This finding was true for both sampling times at the 2nd season.

Stress-index values at 90 DAS increased significantly from 0.9 for control to 3.3 for I_4 treatment. Concerning the interaction between irrigation treatment and barley varieties, SI was highest (5.0) for HBL under I_4 whereas, it was the lowest (0.1) for G 123 at control irrigation treatment (I_1).

At 115 DAS, in the 2nd season, RWC was decreased significantly from 49.3% for I_1 (the control) to 30.9% for I_4 treatment. RWC averaged 41.2% for G124, 37.9% for G123 and 29.3% for HBL. For the interaction, G124 had the best RWC value of 52.5% at I_1 whereas; G 123 had the least one (29.7%) at I_4, table (3).

Stress-index at 115 DAS was increased significantly from 1.7 for the control irrigation treatment to 4.6 for the I_4. G124 had the least SI value at the control treatment I_1, while G 123 had the highest of 5.7 under I_4 treatment conditions.

Fig (1) showed that plant height (cm) was affected by using irrigation treatments in both 1997/1998 and 1998/1999 seasons. It was decreased by imposed water stress. It valued 93.3 cm for the control (on the first season), then decreased to 58.8 cm under I_4 irrigation treatment. On the 2nd season, it was 78.1 cm for the I_1 control, 76.6 cm for I_2, 57.3 cm for I_3 and 54.6 cm for I_4. With respect to barley cultivars, G123 grown under control condition had the tallest plants (95 cm and 80.7cm in the 1st and 2nd seasons, respectively). The least plant height value was recorded for G124 at I_4 (54.7 cm) in the 1st season and G124 at I_4 (50.3 cm) in the 2nd one.

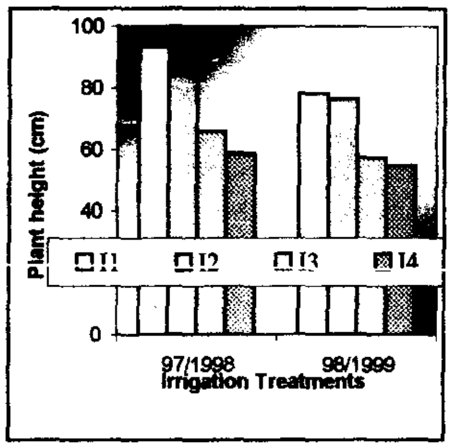

Fig. (1): Barley plant height as affected by irrigation treatments in the two seasons.

Table 3: Relative water contents (RWC.%), canopy temperature(°C) and stress index (SI) of barley varieties as affected by irrigation treatments in 98/99 Season, (air temp. is 22.7 °C, 22.0 °C and RH is 41.1, 39.6 for two times).

Time	Treatment	RWC (%)				Canopy Temperature (°C)				Stress Index			
		L	G123	G124	Mean	L	G123	G124	Mean	L	G123	G124	Mean
90 DAS 2nd Season	I_1	75.45	80.22	84.88	80.18	21.33	20.13	20.63	20.70	1.87	0.13	0.67	0.89
	I_2	70.30	73.86	75.78	73.31	21.73	21.17	21.10	21.33	2.30	0.47	0.90	1.22
	I_3	66.61	70.16	70.13	68.96	21.73	20.90	21.07	21.23	2.57	1.17	1.27	1.67
	I_4	59.11	58.21	54.00	57.11	23.57	22.30	21.33	22.40	5.00	3.17	1.80	3.32
	Mean	67.87	70.61	71.20		22.09	21.13	21.03		2.93	1.23	1.16	
	LSD (0.05):												
	Treatments			1.931			0.374				0.350		
	Varieties			2.159			0.294				0.208		
	Interactions			4.318			0.587				0.417		
115 DAS 2nd Season	I_1	48.07	47.36	52.54	49.32	21.53	21.03	20.73	21.10	2.30	1.40	1.33	1.68
	I_2	43.33	39.17	41.69	41.40	21.20	21.40	21.27	21.29	2.90	2.03	2.17	2.37
	I_3	35.61	35.29	37.43	36.11	21.57	23.33	22.83	22.58	3.40	4.50	3.33	3.74
	I_4	30.11	28.70	33.00	30.94	22.43	23.97	22.77	23.06	4.10	5.73	3.90	4.58
	Mean	39.28	37.88	41.16		21.68	22.43	21.90		3.17	3.42	2.68	
	LSD (0.05):												
	Treatments			3.117			0.677				0.089		
	Varieties			1.796			0.575				0.195		
	Interactions			3.592			1.151				0.391		

Yield and its components:

Table 4, showed barley yield and its components as affected by imposed irrigation treatments (which caused drought stress) in both seasons. All yield component characters such as: spike length (Sp L; mm), no. of spikes per square meter -(no. Sp/m^2), no. of grains per spike (no. G/Sp), grain weights per spike (G_{wt}/Sp), biological yield (BY; T/ha) and grain yield (GY; T/ha) all were decreased as the plants suffer more from water stress. Barley varieties as well as HBL were slightly differed, while the main effect was found for water treatments.

Heading time was delayed as the water stress increased. This delay was only significant in the 1st season. The spike length (mm) decreased by 12.6 % for I_2, 22.3 % for I_3 and 20.9 % for I_4 in the 1st season, and 9.1 % for I_2, 13.7% for I_3 and 22.1% for I_4 in the 2nd one compared to control. The more reduction in spike length the more suffering of water availability as in I_3 and I_4 treatments. No. of spikes per square meter (no. Sp/m^2) was decreased by irrigation water treatments than control, the percentage decrease was 29.1% for I_3 and 33.8% for I_4 in the 1st season and 19.0% for I_3 and 29.9% for I_4 in the 2nd one.

Compared to the control, no. of grains per spike (no. G/Sp) was also less by 16.1% and 10.2% for I_2, 30.1% and 23.5% for I_3, and 30.1%, 33.7% for I_4, in the two seasons, respectively.

Grain weight per spike (G_{wt}/Sp; g), was decreased significantly by implemented water stress in both seasons than control, It was less by 23.1% for I_3 and 23.8% for I_4 in the 1st season and 13.7% for I_3 and 21.2% for I_4 in the 2nd one.

Biological yield (T/ha) was decreased by irrigation water treatments. The decrease perce-ntage was 25.9% and 25.4% for I_2, 32.9% and 36.8% for I_3, and 58.8%, 51.9% for I_4, in the two seasons ,respectively. The HBL had less biological yield than G123 or G124 in the 2nd season.

It was clear that when the available water was insufficient, grain yield(T/ha) was decreased. It was less by 27.3% and 25.9% for I_2, 22.7% and 40.2% for I_3, and 58.7%, 50.3% for I_4, in the two seasons, respectively. It was differed significantly among the tested barley varieties and line in the 2nd season only.

Table 4: Barley yield and its components as affected by irrigation intervals during 97/1998 and 98/1999 seasons.

		HD	Sp L (mm)	No. Sp/m2	No. G/Sp	G wt/Sp (g)	1000G wt (g)	BY (T/ha)	GY (T/ha)	HI (%)
First Season	Treatments:									
	I_1	87.00	79.44	434.8	47.8	1.64	33.09	9.491	1.995	21.32
	I_2	86.67	69.44	354.8	40.1	1.35	31.91	7.037	1.450	20.51
	I_3	96.44	61.67	308.1	33.4	1.26	32.52	6.366	1.543	24.63
	I_4	95.89	62.78	267.9	33.4	1.25	32.14	3.912	0.824	21.30
	Varieties:									
	L	92.67	68.33	342.1	38.0	1.36	32.1	6.094	1.276	21.00
	G123	89.67	67.50	347.3	38.6	1.39	32 5	7.014	1.501	21.66
	G124	92.17	69.17	349.7	39.5	1.37	32.6	6.996	1.581	23.17
	LSD (0.05):									
	Treatments	8.123	8.198	78.74	7.112	0.116	NS	1.871	0.518	NS
	Varieties	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Interaction	NS	NS	48.34	NS	NS	NS	1.586	0.357	4.441
Second Season	Treatments:									
	I_1	94.56	85.56	364.4	43.0	1.46	38.60	10.389	2.148	20.91
	I_2	93.89	77.78	311.1	38.6	1.33	38.16	7.749	1.592	20.75
	I_3	94.00	73.89	295.0	32.9	1.26	37.79	6.563	1.285	19.79
	I_4	93.67	66.67	256.6	28.5	1.15	38.66	5.002	1.067	21.50
	Varieties:									
	L	95.83	96.67	318.3	38.0	0.70	36.92	5.591	1.181	21.43
	G123	93.42	63.75	287.9	42.9	1.57	38.82	7.969	1.580	20.03
	G124	92.83	67.50	313.3	44.1	1.63	39.16	8.717	1.807	20.75
	LSD (0.05):									
	Treatments	NS	6.61	30.4	6.39	0.19	NS	1.89	0.329	NS
	Varieties	NS	13.65	NS	3.35	0.242	1.922	1.011	0.2	NS
	Interaction	NS	15.53	66.24	3.81	0.275	2.166	1.149	0.228	2.355

Water stress affects all plant characters with different extents. This effect depends on the timing and duration of waters deficient suffering. As water availability decreases to a plant, the whole plant activities as well as physiological and morphological processes are influenced. Plant net assimilation and nutrient translocation were lowered. Respiration was increased. Therefor growth declained, so all physiological or growth attributes will be deteriorated owing to the degree of water stress suffering.

RWC represents the leaf plant water status. It was decreased from nearly 100% at turgid state to become less according to water scarcity in the surrounding plant environment. Canopy temperature increased than air temperature as the plants decreased its transpiration due to the closed stomata as the soil available water was declined to preserve water. Therefore the canopy temperature increased. So suffering water stress would inhibit growth and influence yield too. The obtained results are agreed with many investigators concerning drought (Turner *et al*, 1987; Entz and Fowler, 1988; Schonfeld *et al*, 1988; *Matin et al*, 1989, Blum, 1993 and Dakheel *et al*, 1994).

CONCLUSION

As seen from the obtained data, the most sensitive period in barley is around anthesis stage. That means if the plants received sufficient supply of water during the two weeks before and after anthesis, we could obtain reasonable growth and yield.

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تأثير الفترة بين الريات على بعض الصفات الفسيولوجية والمحصول في الشعير تحت نظام الري بالرش

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أقيمت تجربتان حقليتان بمحطة البحوث الزراعية بالإسماعيلية خلال موسمي ٩٧ / ٩٨ ، ٩٨ / ١٩٩٩ ، بهدف دراسة أثر العطش في مراحل مختلفة من نمو الشعير وأثر ذلك على المحصول ومكوناته.

وكانت معاملات الري أربعة معاملات هي :

١ – الري كل أربعة أيام طوال فترة نمو المحصول (كنترول) .

٢ – الري كل أربعة أيام حتى مرحلة التزهير ثم الري كل ثمانية أيام حتى الحصاد .

٣ – الري كل ثمانية أيام حتى مرحلة التزهير ثم الري كل أربعة أيام حتى الحصاد .

٤ – الري كل ثمانية أيام طوال موسم النمو حتى الحصاد.

الأصناف المنزرعة : أجريت الدراسة على صنفين من الشعير المغطى هما جيزة ١٢٣ ، جيزة ١٢٤ ، وسلالة مبشرة من الشعير العاري Hulless barley .

وصممت التجربة في قطع منشقة مرة واحدة ، شغلت معاملات الري القطع الرئيسية بينما احتوت القطع المنشقة علي الأصناف .وفيما يلي أهم النتائج المتحصل عليها :

١ – أ ثر العطش (عند أي مرحلة من مراحل النمو) تأثيرا سلبيا على جميع الصفات المورفولوجية الفسيولوجية للنبات وتتوقف درجة هذا التأثير على مرحلة النمو التي حدث فيها العطش وطول هذه الفترة.

٢ –نقصت مساحة ورقة العلم بزيادة الإجهاد المائي حيث ظهر أن أكثر المعاملات تأثيرا هي معاملة الري الرابعة فأدت إلى نقص مساحتها بحوالي ٤و٤٥% ونقص وزنها الجاف بحوالي٢ و ٣٢ %.

٣– نقص محتوى الأوراق النسبي من المياه كلما طالت الفترة بين الريات في حين زاد دليل الإجهاد لعدم حصول النبات على الماء اللازم للعمليات الحيوية.

٤ – اتضح أن الصنف جيزة ١٢٣هو الأكثر قدرة على تحمل العطش وكانت نباتاته هي الأطول خلال موسمي الزراعة بينما كان الصنف جيزة ١٢٤ هو الأقصر طولا.

٥ – تأثرت الصفات المكونة للمحصول (طول السنبلة ، عدد السنابل / م^{2} ، عدد حبوب السنبلة ، وزن حبوب السنبلة ، المحصول البيولوجي ومحصول الحبوب بالفدان) بالإجهاد المائي حيث انخفضت قيمها بإطالة الفترة بين الريات.

ومن ذلك يتضح أهمية عدم تعريض نباتات الشعير لأي إجهاد مائي خلال فترة أسبوعين قبل وبعد التزهير.