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Effect of irrigation water stress on earliness, yield and yield components traits of cotton in Toshka region, Egypt

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ABSTRACT

Two field experiments were conducted in the 2021 and 2022 growing seasons at the Water Studies and Research Complex (WSRC) station, National Water Research Center, Toshka, Egypt, to determine the effects of various irrigation conditions, sowing dates, and planting distances on the earliness and yield of the Egyptian cotton cultivar Giza 95. The primary impacts of irrigation treatments, sowing dates, and planting spacing, as well as their first-order interactions, resulted in statistically significant differences ($P<0.05$ or 0.01) in seed cotton yield and most traits evaluated in both seasons. Results indicated significantly increased cotton yields in 100% A.W. irrigation by 3.16% and 6.27% compared to 75% A.W. irrigation during the 2021 and 2022 growing seasons, respectively. Also, most traits are the same trend with differing ratios. Significantly higher cotton yields and most studied traits for February sowings compared to January and March were found; this is a 1.19% and 3.60% increase in cotton yields as average in both seasons, respectively. By 6.01, 4.65, 3.55, 2.26, and 1.24% increase in cotton yields at 35 cm plant spacing relative to absolute 10, 15, 20, 25, and 30 cm plant distances as average in both seasons were observed, respectively. Seed cotton yield and most studied traits were higher in early sowings and wide planting distances than in late sowings and narrow planting distances under deficit irrigation conditions. The February sowing date with wider plant spacing under 75% A.W. irrigation may be a better way to increase seed cotton output in the experimental region under research, according to mean performances, stress tolerance index, principle component analysis. Furthermore, strategies for improving agricultural methods and raising Egyptian cotton's productivity will be developed with the aid of these data in the Toshka region of Egypt.

Keywords: Cotton yield, Irrigation conditions, sowing dates, planting distances, stress tolerance index (STI), principle component analysis (PCA).

INTRODUCTION

Cotton is the most important crop for natural textile fiber worldwide and an essential local crop for Egypt's textile industry, as well as it has a high economic value and is important to the global economy (Yehia *et al.,* 2024). It is also the primary source of cattle feed and oil (Salimath *et al.,* 2021). The world average for cotton output, yield, and harvested area in December 2024–2025 is 42.61 million metric tons, 1.41 metric tons ha^{-1}, and 30.31 million ha; in Egypt, the corresponding numbers are 0.13 million metric tons, 0.99 metric tons ha^{-1}, and 0.13 million metric tons (USDA, 2025). Through variations in temperature and precipitation, climate change modifies the environmental factors that govern crop growth, including sunlight, moisture, and soil. These changes effect cotton's phenology period, growth potential, and cropping system, ultimately influencing yields (Li *et al.,* 2024). Cotton is experiencing numerous abiotic and biotic challenges as a result of changing climatic circumstances, which is having a detrimental effect on crop productivity. Heat, salt, and drought are examples of abiotic stresses that are making a worldwide issue worse by interfering with normal plant growth and morphological and physiological development processes, which lowers agricultural output (Abdelraheem *et al.,* 2019).

The performance of cotton grown in fields is significantly impacted by drought stress, one of the abiotic stresses (Naseer *et al.,* 2023). Worldwide cotton output is seriously threatened by frequent droughts. The way cotton reacts to drought stress depends on its stage of growth. Drought stress affects practically every stage, from germination to fiber formation. During the vegetative growth phase, cotton has a moderate tolerance to drought stress. However, drought stress can affect cotton's ability to reproduce (Iram *et al.,* 2024). A 34% yield loss occurs when cotton fiber is produced under heat and drought stress (Ullah *et al.,* 2020). The way that cotton reacts to drought stress depends on its stage of growth. At every stage of the fiber's development, adequate water must be provided for increased fiber yield and quality (Zhao *et al.,* 2019).

Therefore, improving water use efficiency and implementing water conservation measures are the primary challenges facing irrigated agriculture today (Zafar *et al.,* 2023). Climate and agronomic techniques, such as plant density, timing of sowing, irrigation, and fertilizer, have a significant impact on cotton yields (Tuttolomondo *et al.,* 2020). Cotton growth and development are greatly influenced by a number of important parameters, including type selection, sowing technique, date and time, plant spacing, water requirement, seed treatment, and proper fertilizer administration. To optimize cotton output potential, better management strategies must be planned (Ibrahim *et al.,* 2022; Yehia *et al.,* 2024).

Making the right crop planting decisions is one way to lessen the effects of climate change on agricultural output (Bisbis *et al.,* 2018; Eissa *et al.,* 2023; Hegazy *et al.,* 2024). Choosing the right planting date is a straightforward, practical, and efficient way to lessen the effects of climate change while also improving water use (Srivastava *et al.,* 2022). Cotton is sensitive to its surroundings; therefore, planting at the right time is crucial to achieving its maximum production potential. One significant environmental component that affects planting times globally is temperature. It is referred to as a planting window and can last anywhere from a few days to weeks (Afzal *et al.,* 2020). The findings demonstrate that the planting date has less of an effect on the stability and sustainability of cotton production, but that these factors improve as irrigation quota increases. This suggests that raising the irrigation quota can successfully lessen the negative effects of climate change on crop yield (Niu *et al.,* 2016). If the planting window allows for the effective completion of the crops vegetative and reproductive growth stages, it is deemed optimal. According to (Afzal *et al.,* 2020), there is an ideal period to plant, and any additional delay significantly lowers the yield of seed cotton. Because it affects growth, yield, and fiber quality, the planting date is very important (Iqbal *et al.,* 2020). Higher yields were obtained with earlier sowing dates, even when the yield components differed (Tlatlaa *et al.,* 2023).

Planting density is the second important crop management strategy after planting date for good seed cotton production (Ali *et al.,* 2011). Even more so than climate, planting density is responsible for 46% of reported production variability (Li *et al.,* 2020). Another important factor in the kinetics of cotton development is planting density. Due to rising seed prices, cotton farmers are finding that optimizing plant population density has become a more significant economic concern in addition to production consequences (Sapkota *et al.,* 2023). To maximize dry matter partitioning and encourage balanced cotton development, the ideal planting density must be established (Zhang *et al.,* 2024). Plant density is typically chosen by producers and growers more for personal preference than variety requirements, which might result in yield losses (Maklad *et al.,* 2023; Jalilian *et al.,* 2023). The yield level was higher at medium and high planting densities than at low planting densities. The average boll weight and seed index of early plantings were higher than those of late plantings, regardless of planting density (Kassambara *et al.,* 2024). The use of high-density planting strategies to increase cotton yield is becoming more and more popular. Additionally, it is appropriate for mechanical harvesting, which lowers labor expenses, improves the efficiency of input use, guarantees timely harvesting, preserves cotton quality, and has the potential to boost output and profitability. For high-density cotton planting to be successful, water management is essential (Manibharathi *et al.,* 2024).

According to (Iqbal *et al.,* 2024), choosing the right planting date and density is crucial for enhancing crop performance in the face of climate change. Planting density, planting timing, and cultivar selection are important factors that should be maximized for seed cotton output (Kassambara *et al.,* 2024). The timing of sowing and plant density can have a major impact on the phenology, growth, and development of a cotton crop (Khan *et al.,* 2017). In arid regions with deficit irrigation, increasing crop density may be a practical way to increase nitrogen use efficiency (Wu *et al.,* 2024). In dry conditions, using high plant density under deficit irrigation may be a viable substitute for conserving water without sacrificing cotton yield (Zhang *et al.,* 2016). Planting should occur early, with planting densities greater than 41,666 plants/ha, due to important interactions in maximizing cotton yields (Kassambara *et al.,* 2024). Regarding the relationship between plant density and irrigation, the yield of seed cotton under low irrigation was only 2.9% less than the control (Wu *et al.,* 2024). Future research could concentrate on improving other agronomic procedures in addition to planting dates and densities to guarantee the thorough development of cotton farming methods appropriate for semi-arid regions (Iqbal *et al.,* 2024).

This study employs cotton cultivated under mulch drip irrigation in the Toshka region of Egypt to confirm the effects of sowing dates and distances under normal and deficit irrigation conditions on the earliness, yield, and yield components of the Egyptian cotton cultivar Giza 95. The objectives of this study are to comprehend the complex relationships among sowing dates and planting distances under normal and deficit irrigation conditions on the studied traits of the Egyptian cotton cultivar Giza 95 in the Toshka region of Egypt as well as to increase the sustainability and profitability of cotton production under water-limited conditions.

MATERIAL AND METHODS

Study region:

A set of two field experiments were carried out in the 2021 and 2022 growing seasons in the Toshka of Egypt. The Toshka area, which is part of the Aswan Governorate, is situated between latitudes 22°30′ and 23°30′ N and longitudes 30°30′ and 32°00′ E. It covers a total area of 518400 feddan in the southern region of the Western Desert. It is made up of numerous connected depressions. The primary River Nile irrigation water supply is the Sheikh Zayed Canal. It carries water from the Nile through four subbranches to irrigate various areas (Al-Soghir *et al.*, 2022). Besides Lake Nasser, Toshka is a potential place where groundwater-dependent activities are expanding. As such, it is critical to offer a sustainable development strategy and evaluate the environmental effects that follow (Aly *et al.,* 2023). As part of the latest mega project termed the "1.5 million feddan Project," the Egyptian government wants to extend the project by about 100,000 feddan dependent on surface water irrigation and 25,000 feddan depending on groundwater (via 102 wells) (Sharaky *et al.* 2018). Enclosed between latitudes 22°30′ N and 23°30′ N and longitudes 31°00′ E and 32°00′ E, the development area spans approximately 25,000 acres (Aly *et al.*, 2023).

Weather data of study region as monthly minimum and maximum temperature (^{0}C), as well as relative humidity (%) during 2021 and 2022 growing winter years, are presented in (Fig. 1). The Toshka area has characteristics of an arid climate (Aly *et al.*, 2023). The highest temperature usually was found in July and August in both growing years. The highest relative humidity was recorded in January and December months in both growing years under study.

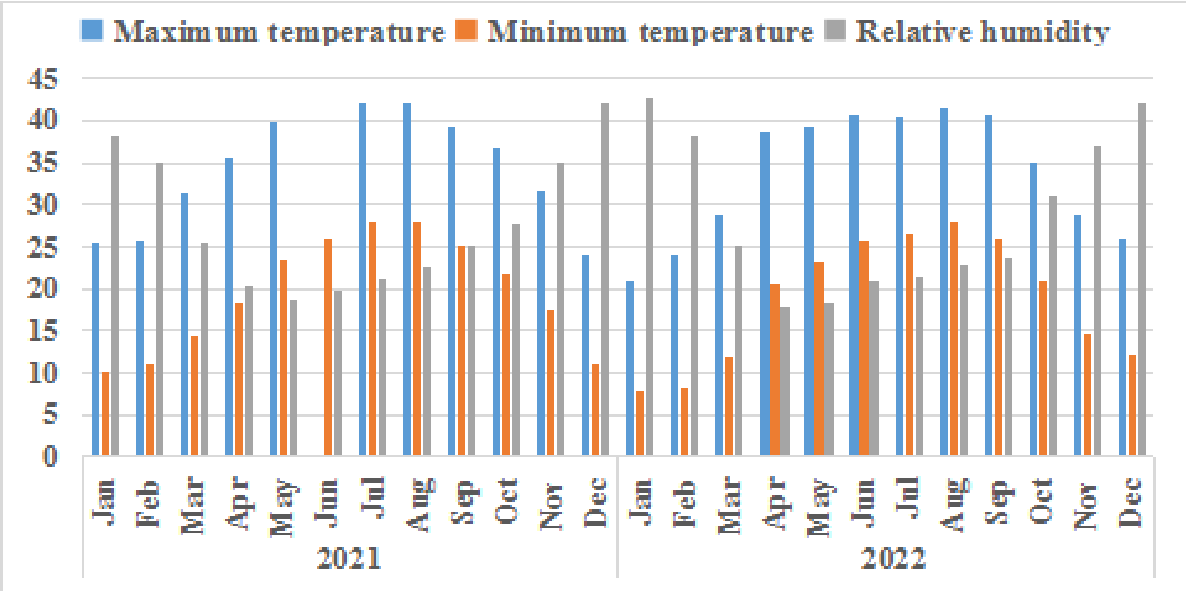

Fig. 1. Weather data at Toshka region, Egypt during the 2021 and 2022 growing years.

Experimental design and treatment details:

Egyptian cotton cultivar Giza 95 was brought from the Cotton Research Institute, Agriculture Research Center, Giza, Egypt, and was planted in the Toshka region conditions of Egypt. In both years, cottonseed was planted on three different sowing dates (January 25, February 25, and March 25) with six different planting distances (10, 15, 20, 25, 30, and 35 cm) between hales under with two irrigation treatments (100% A.W. and 75% A.W.). Each year, the experimental design was a split-split plot in a randomized complete blocks design with three replicates. Irrigation conditions including two irrigation treatments (100% A.W. and 75% A.W.) were considered as main plots, as shown in (Table 1). Three sowing dates and six planting distances were assigned to the sub-plots and sub-sub plots, respectively. Each experimental plot included five rows of 4 m long and 0.7 m width, forming a 14 m^2 net plot area. To reduce environmental variability as much as possible, all suggested cultural practices for cotton production in the area were followed, including sowing the cottonseed in the same day and maintaining similar field conditions. The guarded plants in each plot from the middle rows were harvested to determine the cotton yield and other traits under study in the field and laboratory after the boundary effects were eliminated.

Table 1. Total amount of irrigation water (m^3) applied to the three sowing dates during the 2021 and 2022 seasons.

Seasons	Sowing dates	Irrigation treatments	
		100% A.W.	**75% A.W.**
2021	25 January	3511	2633
	25 February	3855	2891
	25 March	4166	3124
2022	25 January	3722	2792
	25 February	3967	2975
	25 March	4233	3176

Irrigation water applied (IWA):

The daily reference evapotranspiration (ET_o) values were estimated based on FAO Penman-Monteith method using the latest five-year average of weather data from the meteorological station at Toshka region, where our experiment was conducted (Allen *et al.,* 1998) equation. The crop water requirements expressed as crop evapotranspiration (ET_c; mm d^{-1}) according to (Allen *et al.,* 1998) equation was calculated as follows:

$$ET_c = ET_o x K_c$$

where, ET_o and K_c, denotes evapotranspiration (mm d^{-1}) and crop coefficient value, respectively, which differs from one growth stage to another as described by (Brouwer and Heibloem, 1986; Allen *et al.,* 1998). The K_c values for cotton were considered 0.45 for initial (0–25 DAP), 0.75 for developmental stage (26–70 DAP), 1.15 for boll development (71–120 DAP), and 0.7 for maturity stage (121 DAP to harvesting time). The amount of IWA per experimental plot during the irrigation regime was computed following the equation given by (Allen *et al.,* 1998) as follows:

$$IWA(m^2) = \frac{ET_c x A x I_i}{Eax1000x(1 - LR)}$$

where ET_c, A, I_i, Ea, and LR, respectively, are the crop water requirements (mm d^{-1}), experimental plot area (m^2), irrigation intervals (d), efficiency of irrigation system, which was considered 0.6, and leaching water requirements.

Using one PVC (polyvinyl chloride) pipe (50 mm diameter × 1 m length) for each plot, the IWA was transferred to cover the whole plot surface area. The irrigation water quota transferring across each PVC pipe for each plot was calculated following the equation given by (Israelsen and Hansen, 1962) as follows:

$$Q = \frac{CA\sqrt{2gh}}{1000}$$

where Q, C, A, g, and h, are the irrigation water discharge (l s^{-1}), discharge coefficient, PVC pipe's cross section area (cm^2), gravity acceleration (cm s^{-2}), effective head of water (cm) over the center of piper making flow free, respectively. A guard border of 2 m width between the adjacent experimental plots was in each replication to avoid the border effects. Likewise, another one with 5 m width as a separator under two irrigation treatments (100% A.W. and 75% A.W.) was maintained to avoid water infiltration from one to another treatment.

Studied traits:

Three hand harvests from each condition were used to calculate the seed cotton yield for the factors under study. After air drying, the bolls' moisture content dropped to less than 11%, and the boll weight of 100 bolls' worth of seed cotton was measured at the first harvest. Position of the first fruiting node (F.F.N.), seed cotton yield (S.C.Y., K/Feddan), lint cotton yield (L.C.Y., K/Feddan), boll weight (B.W., g), lint percentage (L.%), and seed index (S.I., g) are the characteristics for which data were recorded in this study.

Statistical Approaches:

According to (Steel and Torrie's, 1980) methodology, the measured data were subjected to a three-way ANOVA test and the coefficient of variation (CV%) to identify any significant variations in the impact of experimental factors and their interactions. According to (Gomes, 2009), the CV% estimations were divided into four categories: extremely high (CV≥21%), high (15.0%≤CV≤21.0%), moderate (10%<CV≤15%), and low (CV<10%). The stress tolerance index (STI) was calculated using (Fernandez, 1992). For a deeper comprehension of the link between the investigated qualities across experimental conditions, principal component analysis (PCA) was used. The computer software applications Origin Pro 2021 version b 9.5.0.193 and SPSS version 20 were used to do the PCA and ANOVA, respectively.

RESULTS

Analysis of Variance:

Table (2) gives the probability of the three experimental factors' effects on earliness, yield, and yield components across the 2021 and 2022 growing seasons. Seed cotton yield and all studied traits were significantly influenced by irrigation treatments (I), sowing dates (D3), and planting distances (D6) in both growing seasons ($p < 0.05$ or 0.01), except the position of the first fruiting node in both seasons (D3) and seed index (D3) and lint percentage (I) in the 2022 season. As for the first-order interactions, there was a significant interaction on most studied traits between the factors studied in both seasons. Statistically, seed cotton yield and other studied traits in both seasons were significantly ($p < 0.05$ or 0.01) affected by I x D3 and I x D6 interactions, except the position of the first fruiting node in the 2021 season with I x D3 interaction, which had an insignificant difference. As for the D3 x D6 interaction, the seed and lint cotton yields traits showed highly significant differences in both seasons, while other measured traits had insignificant differences in both seasons. In both seasons, there were also the second-order interaction (I x D3 x D3) influenced highly significantly on the seed and lint cotton yields traits only, the same trend of D3 x D6 interaction. Seed cotton yield and other traits assessed under the three experimental investigations had modest coefficients of variation (CV%), except the position of the first fruiting node in the 2021 growing season, which had a moderate value of 10.19%.

Table 2. Analysis of variance for earliness, yield and yield components of cotton under irrigation treatments (I), sowing dates (D3), and planting distances (D6) at 2021 and 2022 growing seasons.

S.O.V	F.F.N.		S.C.Y. (K/F)		L.C.Y. (K/F)		B.W. (g)		L.%		S.I.(g)	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
I	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.22^{ns}	0.00^{**}	0.00^{**}
D3	0.21^{ns}	0.17^{ns}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.01^{*}	0.17^{ns}
D6	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}
IxD3	0.12^{ns}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.01^{*}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{*}	0.06^{*}
IxD6	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}
D3xD6	0.99^{ns}	0.34^{ns}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.97^{ns}	0.94^{ns}	0.96^{ns}	0.75^{ns}	0.71^{ns}	0.72^{ns}
IxD3xD6	0.90^{ns}	0.40^{ns}	0.00^{**}	0.00^{**}	0.00^{**}	0.00^{**}	0.96^{ns}	0.97^{ns}	0.95^{ns}	0.99^{ns}	0.70^{ns}	0.72^{ns}
C.V.%	10.19	6.94	1.20	1.94	1.90	3.02	4.18	2.70	1.66	1.93	2.87	3.93

Statistically significant differences at $^*p \leq 0.05$ and $^{**}p \leq 0.01$; ns: indicate the non-significant difference. FFN: position of the first fruiting node; SCY: seed cotton yield (K/F); LCY: lint cotton yield (K/F); BW: boll weight (g); L%: lint percentage; SI: seed index (g).

Three Experimental Factors effects:

Table (3) shows the average irrigation treatments, sowing dates, and planting distances for seed cotton yield and other evaluated traits in the 2021 and 2022 growing seasons. Both the irrigation amounts have a highly significant impact on the seed cotton yield and other evaluated traits in both seasons, except lint percentage in the 2022 growing seasons. Seed cotton yield and all studied traits were better under 100% A.W. irrigation than under 75% A.W. irrigation in both growing seasons, except for lint percentage in both seasons and seed index in the 2021 season. Seed cotton yield and other measured traits were significantly ($p < 0.05$ or 0.01) affected by the sowing dates factor, except the position of the first fruiting node in both seasons and the seed index in the 2022 season. In both seasons, seed cotton yield, lint cotton yield and lint percentage traits increased with the February sowing date, while boll weight and seed index traits increased with the March and January sowing dates, respectively. In both seasons, seed cotton yield and all examined traits under 35 cm spacing were higher than those under other evaluated plant spacing's. The best earliness and productivity of cotton cultivar Giza 95 were typically generated by sowing in February with a wide plant spacing and 100% A.W. irrigation treatment.

The first-order interactions effect:

Generally, seed cotton yield and most studied traits were influenced by irrigation conditions and sowing dates interaction across the 2021 and 2022 growing seasons (Table 4). Under 100% A.W. condition in both seasons, a significantly best values of seed cotton yield and all studied traits were recorded when the sowing date was used as February, except boll weight and seed index traits with March sowing date. While under 75% A.W irrigation, the minimum value of position of the first fruiting node (desirable) and the maximum values of seed cotton yield and other studied traits were recorded in the early sowing of cotton variety Giza 95 (January month) in both growing seasons.

Table 3. Average earliness, yield and yield components at irrigation treatments, sowing dates, and planting distances across 2021 and 2022 growing seasons.

Factors		F.F.N.		S.C.Y. (K/F)		L.C.Y. (K/F)		B.W. (g)		L.%		S.I. (g)	
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Irrigation treatments													
100% A.W.		9.71	10.40	8.38	8.13	10.61	10.04	2.88	3.24	39.16	39.08	9.37	10.11
75% A.W.		11.19	12.61	7.82	7.17	9.84	8.90	2.77	2.74	39.88	39.26	9.76	9.88
LSD at	0.05	0.41	0.31	0.04	0.06	0.07	0.11	0.05	0.03	0.25	NS	0.11	0.15
	0.01	0.54	0.41	0.05	0.08	0.10	0.15	0.06	0.04	0.33	NS	0.14	0.20
Sowing dates													
25 January		10.23	11.47	8.21	7.68	10.54	9.41	2.69	2.93	39.18	38.81	9.66	10.09
25 February		10.44	11.35	8.51	7.90	10.73	9.91	2.81	2.96	39.98	39.65	9.57	9.96
25 March		10.68	11.70	7.58	7.38	9.41	9.09	2.97	3.08	39.40	39.04	9.46	9.92
LSD at	0.05	NS	NS	0.05	0.07	0.09	0.13	0.06	0.04	0.31	0.36	0.13	NS
	0.01	NS	NS	0.06	0.09	0.12	0.18	0.07	0.05	0.41	0.47	NS	NS
Planting distances													
10 cm		8.76	9.48	6.62	6.24	8.21	7.58	2.80	2.97	38.79	38.53	9.56	9.65
15 cm		8.81	10.09	7.32	6.83	9.18	8.20	2.85	2.92	39.28	38.08	9.51	9.67
20 cm		10.38	11.05	7.79	7.39	9.86	8.98	2.83	2.93	39.57	38.57	9.42	9.92
25 cm		10.59	11.45	8.39	8.01	10.53	9.97	2.75	2.98	39.30	39.48	9.55	10.10
30 cm		11.23	12.85	8.82	8.54	11.23	10.85	2.82	2.98	39.90	40.07	9.53	9.96
35 cm		12.93	14.13	9.63	8.91	12.35	11.24	2.89	3.17	40.27	40.27	9.81	10.65
LSD at	0.05	0.71	0.53	0.06	0.10	7.58	0.19	0.08	0.05	0.44	0.50	0.18	0.26
	0.01	0.94	0.70	0.09	0.13	0.17	0.25	NS	0.07	0.58	0.67	0.24	0.35

The studied traits key names can be found in (Table 2).

Table 4. Average earliness, yield and yield components at irrigation treatments and sowing dates interaction across 2021 and 2022 growing seasons.

Irrigation	Sowing dates	F.F.N.		S.C.Y. (K/F)		L.C.Y. (K/F)		B.W. (g)		L.%		S.I. (g)	
		Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2
100% A. W	25 January	9.79	10.74	7.78	7.64	10.23	9.16	2.70	3.05	38.54	37.98	9.36	10.10
	25 February	9.53	10.02	9.28	8.65	11.70	10.96	2.87	3.23	40.01	40.17	9.32	10.05
	25 March	9.81	10.45	8.07	8.11	9.90	10.00	3.07	3.44	38.92	39.08	9.41	10.16
75% A. W	25 January	10.67	12.20	8.64	7.72	10.86	9.65	2.88	2.80	39.96	39.64	9.95	10.08
	25 February	11.35	12.68	7.73	7.16	9.75	8.86	2.69	2.70	39.81	39.13	9.82	9.87
	25 March	11.56	12.96	7.08	6.64	8.92	8.18	2.74	2.73	39.87	39.00	9.51	9.69
LSD at	0.05	NS	0.53	0.06	0.10	0.13	0.19	0.08	0.05	0.44	0.50	0.18	NS
	0.01	NS	0.70	0.09	0.13	0.17	0.25	NS	0.07	0.58	0.67	0.24	NS

The studied traits key names can be found in (Table 2).

In both seasons, seed cotton yield and other traits under study were highly significantly impacted by the interaction between irrigation treatments and planting distances, as shown in (Table 5). For this interaction effect, the highest seed cotton yield and most studied traits were obtained from cotton grown with all planting distances under 100% A.W irrigation compared with 75% A.W irrigation in both seasons. During 75% A.W irrigation conditions, the lowest position of the first fruiting node was obtained under 10 cm spacing of cotton plants in both seasons. At the same time, the highest seed cotton yield and other evaluated traits were recorded under 35 cm spacing of cotton plants in both seasons. Generally, the Egyptian cotton variety Giza 95 performed best for seed cotton yield and other studied attributes at high plant spacing under drought irrigation treatment in both seasons.

In Table (6), the sowing dates and planting distances interaction effect on only seed and lint cotton yields were highly significantly varied, but no significant differences effects on the remaining studied traits. The best values for the position of the first fruiting node and seed index traits on the January sowing date, for seed cotton yield, lint cotton yield, and lint percentage on the February sowing date, and boll weight on the March sowing date were obtained under all planting distances under study in both seasons. Seed index on the January sowing date, seed cotton yield, lint cotton yield, and lint percentage traits on the February sowing date, and boll weight on the March sowing date were registered the highest values with 35 cm spacing of cotton plants in both seasons. Statistical analysis showed that the broadest plant spacing yielded the best values of cotton production attributes under both irrigation conditions on the February sowing date in both seasons, although diverse patterns were observed in all of the first-order interactions. On the other hand, the first fruiting node's position exhibited the reverse trend.

Table 5. Average earliness, yield and yield components at irrigation treatments and planting distances across 2021 and 2022 growing seasons.

Irrigation	Planting Distances	F.F.N.		S.C.Y. (K/F)		L.C.Y. (K/F)		B.W. (g)		L.%		S.I. (g)	
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
100% A.W	10 cm	8.50	9.67	6.66	6.39	8.31	7.89	2.94	3.45	38.53	39.14	10.15	10.12
	15 cm	8.55	9.99	7.49	7.09	9.54	8.45	3.02	3.21	39.34	37.78	9.58	9.76
	20 cm	10.19	10.31	8.05	7.82	10.32	9.40	2.89	3.14	39.63	38.12	9.12	10.20
	25 cm	9.71	10.19	8.82	8.66	11.08	10.81	2.77	3.19	38.82	39.60	9.39	10.17
	30 cm	10.59	10.79	9.31	9.20	11.89	11.80	2.93	3.11	39.54	40.66	9.00	9.82
	35 cm	10.72	11.45	9.94	9.63	12.53	11.89	2.73	3.35	39.09	39.15	8.97	10.57
75% A.W	10 cm	9.02	9.30	6.59	6.09	8.10	7.28	2.67	2.49	39.06	37.91	8.97	9.19
	15 cm	9.07	10.18	7.14	6.57	8.82	7.95	2.69	2.63	39.22	38.38	9.45	9.58
	20 cm	10.57	11.78	7.54	6.96	9.39	8.56	2.76	2.71	39.51	39.02	9.73	9.65
	25 cm	11.47	12.72	7.96	7.36	9.98	9.13	2.74	2.77	39.79	39.35	9.72	10.03
	30 cm	11.87	14.90	8.34	7.87	10.58	9.89	2.84	2.85	40.26	39.88	10.06	10.11
	35 cm	15.14	16.80	9.33	8.19	12.17	10.58	2.91	3.00	41.44	40.99	10.65	10.73
LSD at	0.05	1.00	0.75	0.09	0.14	0.18	0.27	0.11	0.08	0.62	0.71	0.26	0.37
	0.01	1.33	1.00	0.12	0.19	0.24	0.36	0.15	0.10	0.82	0.94	0.34	0.49

The studied traits key names can be found in (Table 2).

Table 6. Average earliness, yield and yield components at sowing dates and planting distances across 2021 and 2022 growing seasons.

Sowing Dates	Planting Distances	F.F.N.		S.C.Y. (K/F)		L.C.Y. (K/F)		B.W. (g)		L.%		S.I. (g)	
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
25 January	10 cm	8.62	9.80	6.55	6.12	8.26	7.46	2.69	2.87	38.45	38.65	9.78	9.93
	15 cm	8.53	9.94	7.49	6.94	9.54	8.25	2.73	2.86	38.89	37.68	9.62	9.81
	20 cm	9.95	10.62	7.91	7.51	10.17	9.02	2.67	2.89	39.21	38.13	9.54	10.06
	25 cm	10.50	11.83	8.40	8.13	10.69	9.98	2.64	2.94	38.78	38.99	9.62	10.07
	30 cm	11.25	12.67	8.90	8.48	11.57	10.61	2.73	2.93	39.76	39.74	9.55	10.00
	35 cm	12.54	13.96	9.78	8.89	12.45	11.10	2.70	3.09	39.98	39.67	9.84	10.68
25 February	10 cm	8.91	9.48	7.10	6.46	8.77	7.89	2.79	2.95	39.22	38.69	9.54	9.48
	15 cm	8.75	9.98	7.68	6.97	9.65	8.44	2.86	2.88	39.85	38.43	9.55	9.70
	20 cm	10.64	11.11	8.23	7.51	10.43	9.25	2.83	2.89	40.15	39.09	9.51	10.03
	25 cm	10.54	10.76	8.96	8.23	11.26	10.39	2.69	2.95	39.91	39.99	9.57	10.11
	30 cm	10.94	12.67	9.31	8.99	11.81	11.61	2.89	2.96	40.27	40.83	9.51	9.89
	35 cm	12.85	14.10	9.99	9.26	13.03	11.89	2.81	3.15	40.48	40.89	9.74	10.58
25 March	10 cm	8.76	9.17	6.23	6.13	7.59	7.39	2.93	3.09	38.71	38.24	9.36	9.55
	15 cm	9.15	10.35	6.78	6.59	8.35	7.91	2.98	3.02	39.09	38.14	9.37	9.50
	20 cm	10.55	11.42	7.24	7.15	8.97	8.66	2.99	3.01	39.34	38.50	9.21	9.68
	25 cm	10.73	11.77	7.82	7.67	9.64	9.54	2.93	3.05	39.21	39.44	9.46	10.12
	30 cm	11.51	13.21	8.26	8.14	10.31	10.32	2.96	3.07	39.68	40.17	9.53	10.00
	35 cm	13.40	14.31	9.13	8.58	11.58	10.72	3.05	3.27	40.34	39.72	9.83	10.69
LSD at	0.05	NS	NS	0.11	0.17	0.22	0.33	NS	NS	NS	NS	NS	NS
	0.01	NS	NS	0.15	0.23	0.30	0.44	NS	NS	NS	NS	NS	NS

The studied traits key names can be found in (Table 2).

The second-order interactions effect on cotton traits:

The data of the second-order interactions are presented in (Table 7), and had highly significant effects on seed and lint cotton yield traits but did not affect other studied traits in both seasons. The plants obtained on the February sowing date under 100% A.W. irrigation with all planting distances were recorded the highest values of seed and lint cotton yields in both seasons. Giza 95 plants produced higher yields (seed and lint cotton) on the January sowing dates with 35 cm spacing under 75% A.W. irrigation conditions in both seasons. However, the second-order interaction effect does not give other features under study a clear direction. Generally, the Egyptian cotton variety Giza 95 performed best for seed cotton yield and other studied attributes at the early sowing and high plant spacing under drought irrigation treatment in both seasons, according to the results of the effect of experimental factors as well as the first and second-order interactions.

Table 7. Average earliness, yield and yield components traits at irrigation treatments (100% A.W and 75% A.W), sowing dates, and planting distances across 2021 and 2022 growing seasons.

Sowing dates	Planting distances	.FF.N.				S.C.Y. (K/F)				L.C.Y. (K/F)			
		2021		2022		2021		2022		2021		2022	
		100%	75%	100%	75%	100%	75%	100%	75%	100%	75%	100%	75%
25 January	10 cm	8.37	8.87	10.10	9.50	6.09	7.02	6.06	6.19	7.94	8.59	7.35	7.58
	15 cm	8.36	8.70	10.10	9.77	6.97	8.02	6.52	7.36	9.23	9.86	7.50	9.00
	20 cm	10.40	9.50	10.86	10.37	7.41	8.42	7.27	7.74	9.85	10.50	8.45	9.60
	25 cm	10.00	11.01	10.63	13.03	8.16	8.65	8.14	8.12	10.64	10.74	9.85	10.11
	30 cm	10.70	11.80	11.20	14.14	8.69	9.11	8.70	8.26	11.51	11.63	10.84	10.39
	35 cm	10.93	14.14	11.53	16.40	9.38	10.61	9.14	8.64	12.21	13.84	10.95	11.25
25 February	10 cm	8.60	9.22	9.78	9.19	7.44	6.76	6.76	6.17	9.21	8.33	8.53	7.25
	15 cm	8.10	9.41	9.78	10.18	8.30	7.06	7.61	6.32	10.50	8.79	9.34	7.55
	20 cm	10.07	11.20	9.88	12.34	8.95	7.52	8.35	6.67	11.44	9.41	10.33	8.17
	25 cm	9.62	11.47	9.48	12.04	9.80	8.12	9.20	7.26	12.25	10.27	11.81	8.97
	30 cm	10.37	11.51	10.07	15.26	10.28	8.33	9.76	8.23	13.08	10.54	12.85	10.36
	35 cm	10.43	15.27	11.13	17.07	10.94	8.62	10.19	8.32	13.75	11.14	12.92	10.85
25 March	10 cm	8.54	8.97	9.13	9.21	6.47	5.99	6.34	5.92	7.79	7.39	7.78	7.00
	15 cm	9.18	9.11	10.11	10.59	7.22	6.34	7.14	6.04	8.88	7.81	8.52	7.30
	20 cm	10.11	11.00	10.21	12.63	7.78	6.70	7.84	6.46	9.68	8.27	9.43	7.89
	25 cm	9.51	11.94	10.47	13.07	8.52	7.12	8.63	6.71	10.36	8.93	10.78	8.30
	30 cm	10.71	12.31	11.11	15.32	8.94	7.58	9.15	7.13	11.06	9.57	11.72	8.91
	35 cm	10.79	16.01	11.68	16.94	9.51	8.75	9.56	7.60	11.63	11.53	11.79	9.65
LSD at	0.05	NS		NS		0.16		0.24		0.32		0.47	
	0.01	NS		NS		0.21		0.32		0.42		0.62	
Sowing dates	Planting Distances	B.W. (g)				L.%				S.I.(g)			
		2021		2022		2021		2022		2021		2022	
		100%	75%	100%	75%	100%	75%	100%	75%	100%	75%	100%	75%
25 January	10 cm	2.76	2.63	3.26	2.49	38.03	38.87	38.43	38.87	10.15	9.41	10.12	9.75
	15 cm	2.84	2.62	3.02	2.69	38.74	39.04	36.55	38.81	9.58	9.66	9.76	9.86
	20 cm	2.71	2.63	2.96	2.82	38.83	39.59	36.89	39.36	9.12	9.97	10.20	9.92
	25 cm	2.59	2.70	3.00	2.88	38.17	39.38	38.45	39.54	9.39	9.86	10.17	9.97
	30 cm	2.75	2.71	2.93	2.92	38.97	40.55	39.54	39.94	9.00	10.10	9.82	10.18
	35 cm	2.55	2.84	3.16	3.03	38.52	41.44	38.03	41.31	8.97	10.71	10.57	10.79
25 February	10 cm	2.93	2.64	3.43	2.47	39.31	39.12	40.04	37.33	10.10	8.98	10.07	8.89
	15 cm	3.01	2.70	3.20	2.56	40.18	39.52	38.93	37.93	9.53	9.57	9.71	9.69
	20 cm	2.89	2.77	3.13	2.65	40.58	39.73	39.27	38.90	9.07	9.94	10.15	9.91
	25 cm	2.76	2.62	3.17	2.72	39.68	40.15	40.74	39.24	9.34	9.80	10.12	10.10
	30 cm	2.93	2.85	3.10	2.81	40.38	40.16	41.79	40.00	8.95	10.06	9.77	10.01
	35 cm	2.73	2.88	3.33	2.97	39.92	41.05	40.26	41.40	8.92	10.57	10.51	10.64
25 March	10 cm	3.13	2.73	3.66	2.52	38.24	39.17	38.95	37.54	10.20	8.52	10.17	8.93
	15 cm	3.21	2.75	3.41	2.63	39.09	39.10	37.87	38.42	9.63	9.12	9.81	9.19
	20 cm	3.08	2.90	3.34	2.67	39.47	39.21	38.20	38.80	9.16	9.27	10.25	9.11
	25 cm	2.95	2.91	3.39	2.72	38.60	39.82	39.63	39.26	9.43	9.49	10.22	10.02
	30 cm	3.12	2.97	3.31	2.83	39.28	40.08	40.65	39.69	9.04	10.03	9.87	10.13
	35 cm	2.92	3.01	3.55	2.99	38.83	41.84	39.16	40.27	9.01	10.65	10.62	10.75
LSD at	0.05	NS		NS		NS		NS		NS		NS	
	0.01	NS		NS		NS		NS		NS		NS	

The studied traits key names can be found in (Table 2).

Stress tolerance index (STI):

The STI values of studied cotton traits affected by sowing dates and planting distances in 2021 and 2022 growing seasons are presented in (Table 8). The cotton variety Giza 95 plants in February sowing date under all planting distances for seed cotton yield, lint cotton yield, and lint percentage traits had the highest STI values in both seasons. While boll weight and seed index traits recorded the greatest values of STI at January and March sowing dates with all planting distances in both seasons, respectively. Also, the widest plant spacing of the variety Giza 95 produced the highest values of STI for seed cotton yield and all evaluated traits at all sowing dates in both growing seasons. Generally, from the results of STI values, the widest plant spacing at the February sowing date of the variety Giza 95 produced the best productivity under deficit irrigation.

Table 8. Stress tolerance index for the studied cotton traits as affected by sowing dates and planting distances across both growing seasons.

Sowing dates	Planting distances	F.F.N.		S.C.Y. (K/F)		L.C.Y. (K/F)		B.W. (g)		L.%		S.I. (g)	
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
25 January	10 cm	0.79	0.89	0.61	0.57	0.61	0.55	0.87	0.77	0.96	0.98	1.09	0.97
	15 cm	0.77	0.91	0.80	0.73	0.81	0.67	0.90	0.77	0.99	0.93	1.05	0.94
	20 cm	1.05	1.04	0.89	0.85	0.92	0.80	0.86	0.79	1.00	0.95	1.04	0.99
	25 cm	1.17	1.28	1.00	1.00	1.01	0.99	0.84	0.82	0.98	1.00	1.06	0.99
	30 cm	1.34	1.46	1.13	1.09	1.19	1.12	0.90	0.81	1.03	1.03	1.04	0.98
	35 cm	1.64	1.75	1.42	1.19	1.50	1.22	0.87	0.91	1.04	1.03	1.10	1.12
25 February	10 cm	0.84	0.83	0.72	0.63	0.68	0.61	0.93	0.81	1.00	0.98	1.03	0.88
	15 cm	0.81	0.92	0.83	0.73	0.82	0.70	0.98	0.78	1.04	0.97	1.04	0.92
	20 cm	1.20	1.13	0.96	0.84	0.96	0.84	0.96	0.79	1.05	1.00	1.03	0.98
	25 cm	1.17	1.05	1.13	1.01	1.12	1.05	0.87	0.82	1.04	1.05	1.04	1.00
	30 cm	1.27	1.42	1.22	1.21	1.22	1.32	1.01	0.83	1.06	1.09	1.03	0.96
	35 cm	1.69	1.76	1.43	1.28	1.63	1.39	0.95	0.94	1.07	1.09	1.07	1.09
25 March	10 cm	0.81	0.78	0.55	0.57	0.51	0.54	1.03	0.88	0.98	0.96	0.99	0.89
	15 cm	0.89	0.99	0.65	0.65	0.62	0.62	1.06	0.85	1.00	0.95	1.00	0.88
	20 cm	1.18	1.19	0.74	0.77	0.71	0.74	1.08	0.85	1.01	0.97	0.97	0.91
	25 cm	1.20	1.26	0.86	0.88	0.82	0.89	1.03	0.88	1.00	1.02	1.02	1.00
	30 cm	1.40	1.57	0.96	0.99	0.94	1.04	1.12	0.89	1.03	1.06	1.03	0.98
	35 cm	1.83	1.83	1.18	1.10	1.19	1.13	1.06	1.01	1.06	1.03	1.09	1.12

The studied traits key names can be found in (Table 2).

Principal component analysis (PCA):

In the 2021 and 2022 growing seasons, PC analysis was calculated to improve the discriminatory power for classifying the seed cotton yield and other investigated traits according to their associations under irrigation treatment, sowing dates, and planting distances (Fig. 2). A total of six PCs were acquired, but only the first two PC1 and PC2 with eigenvalues > 1 (3.35 and 1.73, respectively), were considered significant and explained about 84.79% of the total variability of the evaluated data under study. The PC1 explained 55.89% of the total variability, and seed cotton yield and all studied traits contributed positively to PC1. As for PC2, the position of the first fruiting node, boll weight, and seed index features on the path to a positive direction were the main factors that described the PC2, which accounted for 28.90% of the overall variability. However, the features of lint percentage, lint cotton yield, and seed cotton yield contributed negatively to PC2. In any additional data analysis, the PC1 and PC2 results can be utilized to provide an overview of the original variables and to explain the overall variance and PCs collection. Stronger positive correlations (very sharp angles) were noticed among seed cotton yield, lint cotton yield, and lint percentage traits, as well as between seed index with the position of the first fruiting node and boll weight traits. Boll weight had a negative association with lint cotton yield and lint percentage traits (obtuse angles), and a very low positive association with seed cotton yield. While other correlations among studied traits were positive because the angle between them is sharp.

The relationships among irrigation treatments, sowing dates, and planting distances with seed cotton yield and other traits under investigation showed distinct patterns throughout the course of the two growth seasons (Fig. 2). A significant amount of the overall variation for the position of the first fruiting node, boll weight, and seed index traits in the 2022 growing season, which were associated with the highest PC1 and PC2 in the first quarter, was caused by the February sowing date with planting distances of 25, 30, and 35 cm under 100% A.W. irrigation conditions. February sowing date with planting distances of 25, 30, and 35 cm under 75% A.W. contributed to a great proportion of the total variation for seed cotton yield, lint cotton yield, and lint percentage traits in the 2021 growing season, which were related to highest PC1 and lowest PC2 in the fourth quarter. Generally, the February sowing date under drought stress with a 35 cm spacing was found to be close to the cotton yield characteristics in both growth seasons. Unlike PC2, PC1 can be utilized to choose treatments for drought tolerance because it often has a high productivity potential.

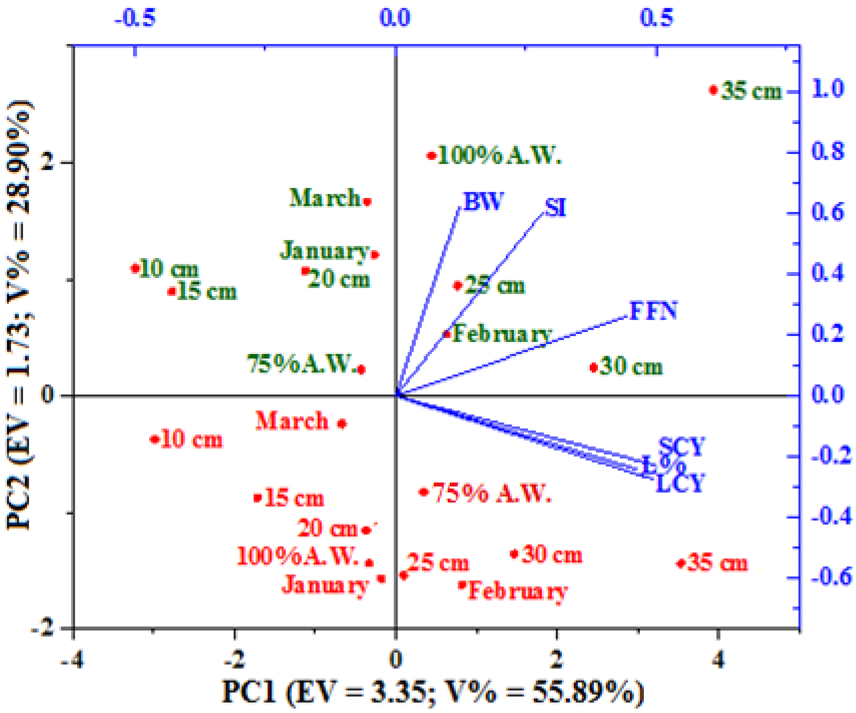

Fig. 2. Relationships among the studied traits and treatments (irrigation conditions, sowing dates and planting distances) across the 2021 (red color) and 2022 (green color) growing seasons. EV: eigenvalues; V%: variance %. The studied traits key names can be found in (Table 2).

DISCUSSION

The sustainable growth of agriculture in dry places will be significantly hampered by drought stress as a result of the changing global climate (Lin *et al.,* 2024). A novel method for improving cotton's water consumption efficiency in arid regions is deficit irrigation (Zhang *et al.*, 2016). Drought stress disrupts the molecular-level water balance in plants, and severe water scarcity in cotton plants can be fatal (Wang *et al.*, 2024). Cotton output can be increased by high plant density and deficit irrigation. The length of time that different phenological stages, including the initial square, bloom, and boll split on 50% population, as well as the duration of the entire crop, are determined by the sowing time (Afzal *et al.*, 2020). Therefore, the objective of this study was to explore the tolerance of cotton plants to water stress under and normal irrigation and deficit irrigation conditions. In this study, we carefully examine the roles of two irrigation treatments (100% A.W. and 75% A.W.), three sowing dates, and six planting distances, as well as their interactions, during the 2021 and 2022 growing seasons in order to assess the earliness, yield, and yield component traits of the Egyptian cotton variety Giza 95 under sand soil conditions in the Toshka region of Egypt.

Significant differences between irrigation treatments, sowing dates, and planting distances were observed for seed cotton yield and the most studied traits in both seasons. These results suggest that there might be variation among the experimental treatments that were studied, suggesting that it would be feasible to increase cotton productivity in the Toshka region of Egypt with sand soil, particularly when drought stress is present. Our findings are similar to the results of (Abbas *et al.,* 2018; Mudassir *et al.*, 2022; Tlatlaa *et al.,* 2023; Zuo *et al.*, 2023; Iqbal *et al.*, 2024; Kassambara *et al.*, 2024) reported that the main effects (irrigation amount, planting dates, and planting density) had a significant effect on cotton seed yield and yield component traits. In terms of how the experimental treatments interacted, several notable patterns surfaced, the most prominent of which was the substantial impact of irrigation conditions along with sowing dates and planting spacing on every trait analyzed over both growth seasons. The first-order interactions effect (irrigation treatments x sowing dates and irrigation treatments x planting distances) was significant for seed cotton yield and most studied traits. Only the interaction of sowing date and planting density and the second-order interactions effect were highly significant on seed and lint cotton yields in both seasons. This result appears to conflict with (Khan *et al.,* 2017; Iqbal *et al.,* 2024; Kassambara *et al.*, 2024) who mentioned that the interaction of sowing date and plant density was non-significant for seed cotton yield and all cotton studied traits. While (Sapkota *et al.*, 2023) stated that plant population density did not affect lint yield, however, irrigation and plant population interacted. These findings suggested that the large variations in seed cotton production and other assessed characteristics of the Giza 95 variety under study were caused by the combined effects of the weather, sowing dates, and planting spacing under irrigation conditions.

Compared with 100% A.W. irrigation, 75% A.W. irrigation significantly increased the position of the first fruiting node and lint percentage in both seasons, and seed index in the 2021 season but significantly decreased seed cotton yield (-3.16% and -6.27%) and other studied traits in 2021 and 2022 growing seasons, respectively. When compared to full irrigation, deficit irrigation considerably improved cotton water use efficiency (7.39%) but reduced cotton output (-15.00%) (Xu *et al.*, 2024). According to (Himanshu *et al.,* 2019), water deficits have a major impact on the yield of seed cotton, especially during the germination and seedling emergence stage to the squaring stage, late bloom, and boll opening stage. Cotton yield, water indices, and growth and development were all significantly impacted by the irrigation module. Crop Phen phases, yield, contributing characteristics, and productivity indicators were all negatively impacted by water stress (Brar and Singh, 2022; Ghanem *et al.,* 2022; Yehia *et al.,* 2023; Sheta *et al.,* 2024b).

The growth of cotton leaves, internode elongation, dry matter production, and assimilate distribution throughout different plant parts are all significantly impacted by the sowing date, which in turn affects cotton yield (Dai and Dong, 2014). The sowing date has an impact on cotton production; thus, picking the right date will increase cotton productivity (Guo *et al.*, 2023). The position of the first fruiting node and seed index traits on the January sowing date, boll weight on the March sowing date and other studied traits on the February sowing date showed the best values in both seasons. February sowing date significantly increased seed cotton yield compared to January (0.62% and 1.76%) and March (4.30% and 2.89%) sowing dates in 2021 and 2022, respectively. Zhang *et al.*, (2017) corroborated our findings, stating that the middle planting date outperformed the other planting dates in terms of cotton yield and all assessed variables. Early planting typically increases yield by lengthening the growing season, while late planting decreases yield due to the shorter growing season (Afzal *et al.,* 2020). In semi-arid conditions, early planting has increased the percentage of lint and is the best method for obtaining a higher yield of cotton and yield components (Singh *et al.,* 2017; Iqbal *et al.,* 2024). Selecting for enhanced seed vigor and cold germination with acceptable yield and fiber quality attributes could be one way to adapt genetics to an early planting strategy (Mauget *et al.,* 2019). Cotton aboveground biomass and yield rise with an increase in irrigation quotas when planting dates coincide (Fan *et al.,* 2024). The crop's phenological development was greatly hampered by delayed cotton sowing, especially when it was done in a deficit moisture regime. Additionally, the crop's susceptibility to insect pests and diseases was increased, which ultimately resulted in lower crop productivity (Mauget *et al.,* 2019; Kumar *et al.,* 2020; Brar and Singh, 2022; Fei *et al.,* 2022; Kassambara *et al.,* 2024).

Even at the same location, the population density threshold for maximizing cotton lint yield varies somewhat depending on the cotton germplasm, environmental circumstances, and possibly other factors (Sapkota *et al.,* 2023). According to (Tlatlaa *et al.,* 2023), maximizing the dates of sowing can increase cotton production's financial returns and advance sustainability. When there are enough plants in a given area, the population of plants will receive optimal lighting and ventilation, which will raise the concentration of chlorophyll and promote photosynthesis in the leaves of the main stem (Yehia *et al.,* 2024). By enhancing dry matter accumulation and potassium fertilizer absorption, an appropriate planting density can also increase cotton output (Khan *et al.,* 2017). Along with light interception, moisture availability, nutrient uptake, humidity, and weed infestation, plant density also affects plant height and fruiting behavior (Ibrahim *et al.,* 2022). High plant distances significantly increased seed cotton yield and all studied traits, except the position of the first fruiting node, had desirable values with 10 cm plant spacing in both seasons. 35 cm plant spacing showed a higher seed cotton yield compared to 10, 15, 20, 25, and 30 cm plant distances with values of 6.20%, 4.76%, 3.79%, 2.55%, and 1.67% in the 2021 season and with values of 5.81%, 4.53%, 3.31%, 1.96%, and 0.81% in the 2022 season, respectively. Although the difference was not statistically significant, low plant density produced a 12.3% higher seed yield than high plant density (Zhang *et al.*, 2024). Additionally, according to (Dhillon *et al.,* 2006), plants with increased plant spacing generated a higher seed index. The yields from medium and high densities were comparable, while the yields from high densities were higher than those from low densities. According to (Zhi *et al.,* 2016; Kassambara *et al.,* 2024), the decrease in seed cotton yield at low planting density was probably caused by a decrease in the density of cotton bolls. Increased competition for resources including sunlight, water, and nutrients resulted in a significant decrease in yield (Iqbal *et al.,* 2024).

The cotton crop's growth and development were significantly impacted by the planting density and the dates of sowing (Iqbal *et al.,* 2024). Generally, the Egyptian cotton variety Giza 95 performed best for seed cotton yield and other studied attributes at the early sowing and high plant spacing under drought irrigation treatment in both seasons, according to the results of the effect of experimental factors as well as the first and second-order interactions. We can conclude that many environmental factors can lessen the effects of irrigation treatments, sowing dates, and planting spacing through non-significant interactions. A degraded environment may lessen the effect of the planting date (Guo *et al*., 2023). Planting earlier could be a practical way to boost cotton output in light of the consequences of climate change (Deho, 2023; Yehia *et al.*, 2024).

According to yield potentials in situations with and without water deficits, the STI enables the differentiation of cotton cultivars with varying predicted tolerance levels (Quevedo *et al.*, 2022). Generally, from the results of STI values, the widest plant spacing at the February sowing date of the variety Giza 95 produced the best productivity under deficit irrigation. Thus, cotton plants on the February sowing date with the widest plant spacing had the lowest susceptibility to drought stress. Varieties differed significantly in the STI (Quevedo *et al.,* 2022). In order to create stress-resident cotton cultivars, STI of drought stress response indicators and growth rate also show promise (Mahmood *et al.*, 2022). According to (Kassambara *et al.,* 2024), the variation in seed cotton suggested that some genotypes would have greater STI than the others evaluated because of higher values of seed cotton under lower water availability.

A useful statistical method for reducing dimensionality and extracting expressive information from a complex dataset with many connections is PCA (Bahrami *et al.,* 2014). To understand the links between irrigation conditions, sowing dates, and planting distances that led to variances for the attributes under investigation, we employed PCA analysis in this work. According to (Yehia *et al.,* 2024), PCAs outcomes may enhance cotton productivity under planting dates and spacing treatments. The PC1 and PC2 were considered significant and explained about 84.79% of the total variability of the evaluated data under study. The first two PCs contributed 60.90%, 66.80%, and 69.74%, towards variability under planting dates and plant density, according to (Sarwar *et al.*, 2021; Jalilian *et al.,* 2023; Yehia *et al.*, 2024), respectively. The PC1 showed 55.89% of the total variation and correlated with all studied traits on the February sowing date with a 35 cm spacing under normal irrigation and drought stress. According to (Wang *et al.*, 2023), PC1 could account for 83.43% of the overall variation under the sowing and density cultivation modes. PC1 was shown to be the most important element in understanding the experimental treatments in both seasons because it explained over half of the variation overall. Unlike PC2, PC1 can be utilized to choose treatments for drought tolerance because it often has a high output potential, and thus can be known as “yield potential". Earliness, seed cotton yields, and boll weight all exhibited a strong positive association with the PC1, which was able to distinguish between treatments (Wang *et al.*, 2023). As a result, PC1 and PC2 can be interpreted as reactions to the experimental conditions that affect cotton yield and yield component qualities in both positive and negative ways. These findings align with those of (Sarwar *et al.,* 2021; Sheta *et al.,* 2024a; Yehia *et al.*, 2024). The angle between trait vectors in PCA biplots shows how correlated they are. In our study, stronger positive correlations were noticed among seed cotton yield, lint cotton yield, and lint percentage traits, as well as between the seed index with the position of the first fruiting node and boll weight traits. A strong positive relationship between other characteristics and seed cotton yield (Yehia and El-Hashash, 2021; Wang *et al.*, 2023). According to (Guo *et al.*, 2024), the PCA biplot makes it clearer how many indicators relate to one another under drought and well-watered conditions, as well as how each trait contributes to the main components. Overall, our results indicated that when planted in February with wide plant spacing and drought treatment (75% A.W.), the Egyptian cotton variety Giza 95 might high yield production in the Toshka region of Egypt with sand soil conditions.

CONCLUSION

The primary impacts of irrigation treatments, sowing dates, and planting spacing, as well as their first-order interactions, resulted in statistically significant improvements in seed cotton yield and the majority of the traits under study in both seasons. Early plantings produced more cotton yield than late plantings, regardless of planting density. These experimental treatments are likely suitable for the Egyptian cotton variety Giza 95 in the Toshka region of Egypt, as the February sowing date and larger plant spacing under drought stress can enhance earliness and cotton productivity. Knowing how sowing dates and density relate to one another in drought-stressed situations can help guide management decisions for Egyptian cotton and enhance the earliness and cotton yield. Therefore, we recommended doing long-term studies under drought stress conditions regarding sowing dates and wider plant spacing at the experimental region under the Toshka region of Egypt.

REFERENCES

Abbas, G. H., Rehman, H., Malik, A., Salman, S., Ali, Q., & Mahmood, A. (2018). Influence of sowing time and plant population on seed cotton yield. *Journal Ecological Research*, *6*, 1691-1702.

Abdelraheem, A., Esmaeili, N., O’Connell, M., & Zhang, J. (2019). Progress and perspective on drought and salt stress tolerance in cotton. *Industrial Crops and Products*, *130*, 118-129.

Afzal, M. N., Tariq, M., Ahmed, M., Abbas, G., & Mehmood, Z. (2020). Managing planting time for cotton production. In *Cotton production and uses: Agronomy, crop protection, and postharvest technologies* (pp. 31-44). Singapore: *Springer Singapore.*

Ali, H., Afzal, M., Ahmad, F., Ahmad, S., Akhtar, M., & Hameed, R. A. (2011). Effect of sowing dates, plant spacing and nitrogen application on growth and productivity on cotton crop. *International Journal of Scientific and Engineering Research,* 2(9), 1–6.

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. *FAO, Rome*, *300*(9), D05109.

Al-Soghir, M. M., Mohamed, A. G., El-Desoky, M. A., & Awad, A. A. (2022). Comprehensive assessment of soil chemical properties for land reclamation purposes in the toshka area, Egypt. *Sustainability*, *14*(23), 15611.

Aly, M. M., Abd Elhamid, A. M., Abu-Bakr, H. A. A., Shalby, A., & Fayad, S. A. (2023). Integrated management and environmental impact assessment of sustainable groundwater-dependent development in toshka district, Egypt. *Water*, *15*(12), 2183.

Bahrami, F., Arzani, A., & Karimi, V. (2014). Evaluation of yield-based drought tolerance indices for screening safflower genotypes. *Agronomy Journal*, *106*(4), 1219-1224.

Bisbis, M. B., Gruda, N., & Blanke, M. (2018). Potential impacts of climate change on vegetable production and product quality–A review. *Journal of Cleaner Production*, *170*, 1602-1620.

Brar, H. S., & Singh, P. (2022). Pre-and post-sowing irrigation scheduling impacts on crop phenology and water productivity of cotton (*Gossypium hirsutum* L.) in sub-tropical north-western India. *Agricultural Water Management*, *274*, 107982.

Brouwer, C., & Heibloem, M. (1986). Irrigation water management: irrigation water needs. *Training manual*, *3*, 1-5.

Dai, J., & Dong, H. (2014). Intensive cotton farming technologies in China: Achievements, challenges and countermeasures. *Field Crops Research*, *155*, 99-110.

Deho, Z. A. (2023). Planting dates affects on seed cotton yield and contributed characters of cotton advance lines under changing climatic conditions of Tandojam, Sindh Pakistan. *Advances in Agriculture and Animal Science*, *39*(1), 10-15.

Dhillon, G. S., Chhabra, K. L., & Punia, S. S. (2006). Effect of crop geometry and integrated nutrient management on fibre quality and nutrient uptake by cotton crop.

Eissa, A., Elsaid, R., & Morad, S. (2023). Evaluation of some rice (*Oryza sativa* L.) genotypes under drought stress conditions by using morphological, physiological and molecular characteristics. *Al-Azhar Journal of Agricultural Research*, *48*(2), 179-193.

Fan, H., Xue, L., & Ma, H. (2024). Optimization of planting date and irrigation strategy for sustainable cotton production. *Frontiers in Sustainable Food Systems*, *8*, 1431339.

Chabi Simin Najib, D., Fei, C., Dilanchiev, A., & Romaric, S. (2022). Modeling the impact of cotton production on economic development in Benin: A technological innovation perspective. *Frontiers in Environmental Science*, *10*, 926350.

Fernandez, G.C.J. (1992). Effective selection criteria for assessing stress tolerance. In: Kuo, C.G., Ed., Proceedings of the International Symposium on Adaptation of Vegetables and Other Food Crops in Temperature and Water Stress, AVRDC Publication, Tainan, 257-270.

Ghanem, K. Z., Hasham, M. M., El-Sheshtawy, A. N. A., El-Serafy, R. S., & Sheta, M. H. (2022). Biochar stimulated actual evapotranspiration and wheat productivity under water deficit conditions in sandy soil based on non-weighing lysimeter. *Plants*, *11*(23), 3346.

Gomes, F. P. (1985). Curso de estatística experimental.

Guo, C., Zhu, L., Sun, H., Han, Q., Wang, S., Zhu, J., ... & Li, C. (2024). Evaluation of drought-tolerant varieties based on root system architecture in cotton (*Gossypium hirsutum* L.). *BMC Plant Biology*, *24*(1), 127.

Guo, S., Liu, T., Han, Y., Wang, G., Du, W., Wu, F., ... & Feng, L. (2023). Changes in within-boll yield components explain cotton yield and quality variation across planting dates under a double cropping system of cotton-wheat. *Field Crops Research*, *293*, 108853.

Hegazy, M., Azab, A. M., Mesbah, E. S. A., & Abu Tahon, A. M. (2024). Effect of irrigation regimes and potassium foliar spraying on some quinoa cultivars in sandy soils. *Al-Azhar Journal of Agricultural Research*, *49*(2), 50-58.

Himanshu, S. K., Ale, S., Bordovsky, J., & Darapuneni, M. (2019). Evaluation of crop-growth-stage-based deficit irrigation strategies for cotton production in the Southern High Plains. *Agricultural Water Management*, *225*, 105782.

Ibrahim, I. A., Yehia, W. M., Saleh, F. H., Lamlom, S. F., Ghareeb, R. Y., El-Banna, A. A., & Abdelsalam, N. R. (2022). Impact of plant spacing and nitrogen rates on growth characteristics and yield attributes of Egyptian cotton (*Gossypium barbadense* L.). *Frontiers in Plant Science*, *13*, 916734.

Iqbal, B., Kong, F., Ullah, I., Ali, S., Li, H., Wang, J., Khattak, W.A., & Zhou, Z. (2020). Phosphorus application improves the cotton yield by enhancing reproductive organ biomass and nutrient accumulation in two cotton cultivars with different phosphorus sensitivity. Agronomy, 10(2), 153.

Iqbal, J., Khaliq, T., Ali, B., Iqbal, J., Niaz, Y., Nadeem, M. A., ... & El Sabagh, A. (2024). Optimization of planting date and density of cotton through crop mechanistic model and field experimentation in semi-arid conditions. *Pakistan Journal of Botany*, *56*(4), 1451-1459.

Iram, S., Saba, A., Ali, J.J., Ali Zulfiqar, A., Muqadas, A., Rahil, S., Jehanzeb, F., Imran, K.M., Waheed, A., & Farrukh, E. (2024). Multiomics approaches to explore drought tolerance in cotton. *Journal of Cotton Research,* 7, 32.

Israelsen, O. W., & Hansen, V. E. (1962). Irrigation principles and practices. John Willey and Sons. *Inc., New York*.

Jalilian, S., Madani, H., Vafaie-Tabar, M., & Sajedi, N. A. (2023). Plant density influences yield, yield components, lint quality and seed oil content of cotton genotypes. *OCL*, *30*, 12.

Kassambara, E. M., Loison, R., Sissoko, S., Traoré, A., & Bretaudeau, A. (2024). Effects of planting date and density on cotton cultivars in sub-Saharan Africa rainfed conditions: A case study in Mali. *Agronomy Journal*, *116*(6), 2764-2775.

Khan, A., Najeeb, U., Wang, L., Tan, D. K. Y., Yang, G., Munsif, F., ... & Hafeez, A. (2017). Planting density and sowing date strongly influence growth and lint yield of cotton crops. *Field Crops Research*, *209*, 129-135.

Kumar, V., Kular, J.S., Kumar, R., Sidhu, S.S., & Chhuneja, P.K. (2020). Integrated whitefly (*Bemisia tabaci* (Gennadius)) management in Bt-cotton in North India: an agroecosystem-wide community-based approach. *Current Science,* 119, 618-624.

Li, N., Li, Y., Yang, Q., Biswas, A., & Hezhong Dong, H. (2024). Simulating climate change impacts on cotton using AquaCrop model in China. *Agricultural Systems,* 216, 103897.

Li, N., Lin, H., Wang, T., Li, Y., Liu, Y., Chen, X., & Hu, X. (2020). Impact of climate change on cotton growth and yields in Xinjiang, China. *Field Crops Research,* 247, 107590.

Lin, M., Wang, L., Lv, G., Gao, C., Zhao, Y., Li, X., He, L., & Sun, W. (2024). Deficit irrigation effects on cotton growth cycle and preliminary optimization of irrigation strategies in arid environment. *Plants,* 13(10), 1403.

Mahmood, T., Iqbal, M.S., Li, H., Nazir, M.F., Khalid, S., Sarfraz, Z., Hu, D., Baojun, C., Geng, X., Tajo, S.M., Dev, W., Iqbal, Z., Zhao, P., Hu, G. & Du, X. (2022). Differential seedling growth and tolerance indices reflect drought tolerance in cotton. *BMC Plant Biol,* 22, 331.

Maklad, K. (2023). Effect of plant density and nanometric fertilization on the productivity of sunflower (*Helianthus annuus* L.) crop grown in sandy soil.. *Al-Azhar Journal of Agricultural Research,* 48(3), 110-120.

Manibharathi, S., Somasundaram, S., Parasuraman, P. Alagesan S., Veerasamy R., & Narayanan M.B. (2024). Exploring the impact of high-density planting system and deficit irrigation in cotton (*Gossypium hirsutum* L.): a comprehensive review. Journal of Cotton Research, 7, 28.

Mudassir, M.A., Rasul, F., Khaliq, T., & Yaseen, M. (2022). Conformance of sowing dates for maximizing heat use efficiency and seed cotton yield in arid to semi-arid cotton zone of Pakistan. *Environmental Science and Pollution Research,* 29, 11359–11373.

Naseer, M.A., Nengyan, Z., Ejaz, I., Hussain, S., Asghar, M.A., Farooq, M., & Xiaolong, R. (2023). Physiological mechanisms of grain yield loss under combined drought and shading stress at the post-silking stage in maize. *Journal of Soil Science and Plant Nutrition,* 23(1), 1125-1137

Niu, G., Li, Y.P., Huang, G.H., Liu, J., & Fan, Y.R. (2016). Crop planning and water resource allocation for sustainable development of an irrigation region in China under multiple uncertainties. Agric. *Water Manag,* 166, 53-69.

Quevedo, Y.M., Moreno, L.P., & Barragán, E. (2022). Predictive models of drought tolerance indices based on physiological, morphological and biochemical markers for the selection of cotton (*Gossypium hirsutum* L.) varieties. *Journal of Integrative Agriculture,* 21(5), 1310-1320.

Salimath, S. S., Romsdahl, T. B., Konda, A. R., Zhang, W., Cahoon, E. B., Dowd, M. K., ... & Chapman, K. D. (2021). Production of tocotrienols in seeds of cotton (*Gossypium hirsutum* L.) enhances oxidative stability and offers nutraceutical potential. *Plant Biotechnology Journal*, *19*(6), 1268-1282.

Sapkota, B.R., Adams, C.B., Kelly, B., Rajan, N., & Ale, S. (2023). Plant population density in cotton: Addressing knowledge gaps in stand uniformity and lint quality under dryland and irrigated conditions. *Field Crops Research,* 290, 108762.

Sarwar, G., Nazir, A., Rizwan, M., Shahzadi, E., & Mahmood, A. (2021). Assessment of genetic diversity of cotton cultivars by using correlation and principal component analysis for clcud tolerance, yield and quality traits. *Journal of Agricultural Research (JAR)., 59*(1), 1-5.

Sheta, M.H., Hasham, M.M.A., Ghanem, K.Z., Bayomy, H.M., El-Sheshtawy, A.-N.A., El-Serafy, R.S., & Naif, E. (2024a). Screening of wheat genotypes for water stress tolerance using soil–water relationships and multivariate statistical approaches. *Agronomy,* 14(5), 1029.

Sheta, M. H., Abd El-Wahed, A. H., Elshaer, M. A., Bayomy, H. M., Ozaybi, N. A., Abd-Elraheem, M. A., ... & Moustafa, M. M. (2024). Green synthesis of zinc and iron nanoparticles using *Psidium guajava* leaf extract stimulates cowpea growth, yield, and tolerance to saline water irrigation. *Horticulturae*, *10*(9), 915.

Singh, M., Sidhu, H. S., Mahal, J. S., Manes, G. S., Jat, M. L., Mahal, A. K., ... & Singh, Y. (2017). Relay sowing of wheat in the cotton–wheat cropping system in North-West India: technical and economic aspects. *Experimental Agriculture*, *53*(4), 539-552.

Srivastava, R. K., Mequanint, F., Chakraborty, A., Panda, R. K., & Halder, D. (2022). Augmentation of maize yield by strategic adaptation to cope with climate change for a future period in Eastern India. *Journal of Cleaner Production*, *339*, 130599.

Steel, R.G.D., & Torrie, J.H. (1980). Principles and procedures of statistics. 2nd edition. McGraw Hill Book Company Inc., New York.

Tlatlaa, J. S., Tryphone, G. M., & Nassary, E. K. (2023). Effects of sowing dates and phosphorus levels on cotton growth and yield: soil analysis and implications. *Frontiers in Sustainable Food Systems*, *7*, 1298459.

Tuttolomondo, T., Virga, G., Rossini, F., Anastasi, U., Licata, M., Gresta, F., ... & Santonoceto, C. (2020). Effects of environment and sowing time on growth and yield of upland cotton (*Gossypium hirsutum* L.) cultivars in Sicily (Italy). *Plants*, *9*(9), 1209.

Ullah, A., Ul Qamar, M. T., Nisar, M., Hazrat, A., Rahim, G., Khan, A. H., ... & Yang, X. (2020). Characterization of a novel cotton MYB gene, GhMYB108-like responsive to abiotic stresses. *Molecular Biology Reports*, *47*(3), 1573-1581.

USDA, United States Department of Agriculture (2025). World agricultural production. Available online: https://apps.fas.usda.gov/psdonline/circulars/production.pdf (accessed on 2 January 2024).

Wang, L., Lin, M., Han, Z., Han, L., He, L., & Sun, W. (2024). Simulating the effects of drought stress timing and the amount irrigation on cotton yield using the CSM-CROPGRO-cotton model. *Agronomy,* 14(1),14.

Wang, S., Sun, H., Zhu, L., Zhang, K., Zhang, Y., Zhang, H., ... & Liu, L. (2023). Effects of spraying with Ethephon and early topping on the growth, yield, and earliness of cotton under late-sowing and high-density cultivation modes. *Agronomy*, *13*(5), 1244.

Wu, F., Tang, Q., Cui, J., Tian, L., Guo, R., Wang, L., & Lin, T. (2024). Deficit irrigation and high planting density improve nitrogen uptake and use efficiency of cotton in drip irrigation. *Agronomy*, *14*(9), 1876.

Xu, Q., Dong, X., Huang, W., Li, Z., Huang, T., Song, Z., ... & Chen, J. (2024). Evaluating the effect of deficit irrigation on yield and water use efficiency of drip irrigation cotton under film in Xinjiang based on meta-analysis. *Plants*, *13*(5), 640.

Yehia, W., & El-Hashash, E. (2021). Correlation and multivariate analysis across non-segregation and segregation generations in two cotton crosses. *Egyptian Journal of Agricultural Research*, *99*(4), 380-390.

Yehia, W., El-Hashash, E. F., Sherif, M. M., & EL-Abassy, M. A. (2024). Improving the quality and productivity of cotton under a drip irrigation system in Toshka, Egypt. *Egyptian Journal of Agricultural Research*, *102*(3), 448-463.

Yehia, W. M. B., Zaazaa, E. E. D. I., El-Hashash, E. F., Abou El-Enin, M. M., & Shaaban, A. (2024). Genotype-by-environment interaction analysis for cotton seed yield using various biometrical methods under irrigation regimes in a semi-arid region. *Archives of Agronomy and Soil Science*, *70*(1), 1-23.

Zafar, S., Afzal, H., Ijaz, A., Mahmood, A., Ayub, A., Nayab, A., ... & Moosa, A. (2023). Cotton and drought stress: An updated overview for improving stress tolerance. *South African Journal of Botany*, *161*, 258-268.

Zhang, Y., Chen, Y., Sun, S., Zhang, P., Zhang, Z., Wang, X., Tang, X., Yang, M., Xiang, D., Wang, S., Fen, Ji., & Zhang, L. (2024). Chemical topping and planting density interactively affect cotton growth and partitioning index. *Agronomy,* 14(12), 3011.

Zhang, D., Luo, Z., Liu, S., Li, W., & Dong, H. (2016). Effects of deficit irrigation and plant density on the growth, yield and fiber quality of irrigated cotton. *Field Crops Research,* 197, 1-9.

Zhang, G. W., Zhang, X., Chen, H., & Zhou, Z.G. (2017). Effect of sowing dates on cotton yield, fiber quality, and uptake and utilization of nutrients in Inner Mongolia west desert area, China. *Ying Yong Sheng Tai Xue Bao,* 28, 863-870.

Zhao, W., Dong, H., Zahoor, R., Zhou, Z., Snider, J.L., Chen, Y., Siddique, K.H.M., & Wang, Y. (2019). Ameliorative effects of potassium on drought-induced decreases in fiber length of cotton (*Gossypium hirsutum* L.) are associated with osmolyte dynamics during fiber development. *The Crop Journal,* 7(5), 619-634.

Zhi, X., Han, Y., Li, Y., Wang, G., Du, W., Li, X., Mao, S., & Feng, L. (2016). Effects of plant density on cotton yield components and quality. *Journal of Integrative Agriculture,* 15(7), 1469–1479.

Zuo, W., Wu, B., Wang, Y., Xu, S., Tian, J., Jiu, X., Dong, H., & Zhang, W. (2023). Optimal planting pattern of cotton is regulated by irrigation amount under mulch drip irrigation. *Frontiers of Plant Science,* 14, 1158329.

تأثير إجهاد مياه الري على صفات التبكير والمحصول ومكونات المحصول للقطن بمنطقة توشكي، مصر

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تم إجراء تجربتين حقليتين خلال موسمي النمو 2021 و2022 في محطة مجمع البحوث والدراسات المائية (WSRC)، المركز القومي لبحوث المياه، توشكى، مصر، لدراسة تأثير ظروف مياه الري المختلفة ومواعيد الزراعة ومسافات الزراعة على صفات التبكير والمحصول ومكونات المحصول لصنف القطن المصري جيزة 95. أشارت النتائج الى أن التأثيرات الرئيسية لمعاملات الري ومواعيد الزراعة ومسافات الزراعة، بالإضافة إلى تفاعلاتها من الدرجة الأولى قد أظهرت فروق ذات دلالة إحصائية (P <0.05 أو P <0.01) على محصول القطن الزهر ومعظم الصفات المدروسة في كلا موسمى النمو. كما أوضحت النتائج وجود زيادة معنوية في محصول القطن الزهر عند الريّ المائي الكامل (100%) بنسبة 3.16% و6.27% مقارنةً بمعاملة الرى تحت الإجهاد (75%) خلال موسمي 2021 و2022 على التوالي. بالإضافة إلى ذلك، أظهرت معظم الصفات نفس الاتجاه ولكن بنسب متفاوتة. كما أظهرت النتائج ارتفاع معنوى في محصول القطن ومعظم الصفات المدروسة لموعد الزراعة فى شهر فبراير مقارنةً بشهري يناير ومارس؛ حيث بلغت الزيادة في محصول القطن الزهر 1.19% و3.60% كمتوسط خلال موسمي 2021 و2022 على التوالي. كما لوحظت زيادة في محصول القطن بنسبة 6.01%، و4.65%، و3.55%، و2.26%، و1.24% عند مسافة الزراعة 35 سم بين النباتات، مقارنةً بالمسافات الاخرى 10، و15، و20، و25، و30 سم كمتوسط في كلا موسمي النمو 2021 و2022 على التوالي. وأوضحت النتائج أن محصول القطن الزهر ومعظم الصفات المدروسة كانت أعلى في الزراعة المبكرة ومسافات الزراعة الواسعة مقارنةً بالزراعات المتأخرة ومسافات الزراعة الضيقة تحت ظروف الاجهاد (75%). و وفقا لبيانات متوسط الأداء، ومؤشر تحمل الإجهاد، وتحليل المكونات الأساسية، وجد أن موعد الزراعة في شهر فبراير مع تباعد مسافات الزراعة بين النباتات تحت ظروف الاجهاد (75%) ربما يكون الوسيلة الأفضل لزيادة محصول القطن في المنطقة التجريبية تحت الدراسة. علاوة على ذلك، سيتم تطوير استراتيجيات تحسين الأساليب الزراعية ورفع إنتاجية القطن المصري بمساعدة هذه البيانات في منطقة توشكي في مصر.

الكلمات المفتاحية: محصول القطن، ظروف الري، مواعيد الزراعة، مسافات الزراعة، مؤشر تحمل الإجهاد (STI)، تحليل المكونات الأساسية (PCA).