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Impact of Skipping Irrigation and Foliar Spraying with Antitranspiration on Sunflower Plants (*Helianthus annuus* L.)

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FIELD experiment was conducted to evaluate the effect of three levels of irrigation (normal and skip irrigation during vegetative growth and during flowering stage) and foliar spraying with different concentrations of antitranspiration agents; salicylic acid (0, 150, and 300 mg/L) and ascorbic acid (0, 200, and 400 mg/L) on the growth, yield and it's components of sunflower under Assiut Governorate conditions. The experiment was conducted at the research farm of the Faculty of Agriculture, Al-Azhar University, Assiut Branch, during the summer seasons of 2023 and 2024. A randomized complete block design (RCBD) using strip plot arrangement with three replications. Irrigation was applied in vertical plots while horizontal plots were sprayed with different concentrations of anti-transpiration. The results showed that normal irrigation was superior significantly to skip irrigation during vegetative and flowering stage in growth traits such as plant height (cm), stem diameter (cm), plant dry weight (g) and leaf area index, as well as in yield traits and its components such as head diameter (cm) at the first seasons only, 100-seeds weight (g), seeds yield/head (g), biological yield (ton/fad.), seeds yield (ton/fad.) and oil yield (kg/fad.) while the percentage of oil in seeds increased when skip irrigation was applied during flower development. Regarding spraying with anti-transpiration, spraying 150 mg/L of salicylic acid gave the highest values for all traits.

Keywords*:* Sunflower, Skipping irrigation, Antitranspiration, salicylic acid.

Introduction

Oil crops are considered strategic and important crops, both in Egypt and countries of the world, because they represent a major source of food. Egypt is considered one of the largest consumers of cooking oil. Vegetable oils in Egypt are among the most important commodities with a food gap between production and consumption, as Egypt produces local seeds 5.7%, imported seedss12.4% and imports oils 81.9% of the total local consumption (Egypt, Economic affairs sector 2023) Sunflower (*Helianthus annuus* L.) is one of the most important oilseeds crops in the world. They belong to the Asteraceae family and are characterized by their large, radial flowers that rotate with the sun, hence their name. They are also useful in raising and producing honeybees, and they grow in a wide range of environmental conditions, making their cultivation possible (Nayel *et al.,* 2021). Water scarcity is increasingly becoming a major constraint to agricultural productivity, particularly in arid and semi-arid regions. Climate change has intensified the frequency and severity of drought events, exposing crops to prolonged periods of water stress and threatening global food security (Cattivelli *et al*., 2008). Sunflower (*Helianthus annuus* L.), a moderately drought-sensitive oilseeds crop, is especially vulnerable to water deficit during critical growth stages such as flowering and seeds development, leading to substantial reductions in yield and oil quality (Ashraf and Harris, 2013). Water stress exerts

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adverse effects on plant growth and development through several physiological and biochemical pathways. These include reduced cell expansion, impaired photosynthetic efficiency, stomatal closure, hormonal imbalance, and accumulation of reactive oxygen species (Farooq *et al*., 2009). Such disturbances ultimately result in restricted biomass production and diminished yield. When sunflower plants were exposed to different levels of drought (normal irrigation, drought during vegetative growth and drought during flowering), the control was superior in number of seeds/head, seeds yield (kg ha-^{1}), biological yield (kg ha-^{1}), harvest index and oil percentage compared to the other levels (Bukhsh *et al.*, 2009). To mitigate the impact of water stress, researchers have explored various agronomic and physiological strategies. Among these, foliar application of antitranspirants has gained attention for its potential to improve water-use efficiency and enhance crop tolerance to drought. Antitranspirants reduce water loss by either forming a physical barrier on the leaf surface or modulating stomatal conductance (Kociecka *et al.,* 2023). In recent years, particular interest has been directed toward the use of naturally occurring compounds such as salicylic acid (SA) and ascorbic acid (ASA) as biochemical antitranspirants. Salicylic acid is a plant signaling molecule known to induce stomatal closure, enhance antioxidant enzyme activity, and regulate plant responses under drought stress (Khan *et al.,* 2015). Ascorbic acid, on the other hand, acts as a powerful non-enzymatic antioxidant that protects plant cells from oxidative damage, supports chlorophyll stability, and helps maintain turgor by improving osmotic adjustment (Athar *et al*., 2008). When applied as foliar sprays, both Salicylic acid and Ascorbic acid have demonstrated their capacity to reduce transpiration losses and sustain plant growth under water-limited conditions.

Salicylic acid ($C_6H_4(OH)COOH$) is a phenolic plant hormone that plays a vital role in enhancing sunflower tolerance to drought. It improves leaf water content, osmolyte accumulation (proline, glycine betaine, soluble sugars), and boosts antioxidant enzyme activity (CAT, APX, GPX), while reducing SOD and GPOX activity. These effects help protect photosynthetic pigments and support plant resilience. However, further research is needed to determine optimal application timing, dosage, and economic feasibility (Damalas and Koutroubas 2022).

Youssef *et al.,* 2017 noted that increasing the rate of salicylic acid from 0 to 1.4 mM led to a significant increase in leaf area, plant height, and all yield components of sunflower plants. Therefore, spraying with a concentration of (1.4mM) led to an increase in the plant height, leaf area/plant, head diameter, seeds yield/head, seeds yield (t fed^{-1}) and oil percentage.

Ascorbic acid is a common component of plants and biological fluids and is characterized by its antioxidant activity. Its inhibitory activity depends on its ability to bind or withdraw active oxygen. Therefore, ascorbic acid plays a vital role in protecting plants from stress (Abd El-Rheem *et al.,* 2018). The study showed that the values of leaf area at different ages, plant height, stem diameter, head diameter, 100-seeds weight, seeds yield (kg/acre), and oil percentage of sunflower plants sprayed with ascorbic acid (As) at a concentration of (300 mg L-^{1}) witnessed a significant increase in their values compared to other treatments (0.0 As, 150 mg L-^{1}, and citric acid at a concentration of 250 and 500 mg L-1) (El Mantawy, 2017).

Therefore, this study aims to evaluate the interactive effects of water stress and foliar application of salicylic acid and ascorbic acid on the growth, physiology, and yield of sunflower plants. The outcomes of this research may contribute to the development of practical management strategies for enhancing sunflower performance under drought-prone environment

Materials and Methods

The investigation was conducted at the farm of the Faculty of Agriculture, Al-Azhar University, Assiut Branch, during the two summer agricultural seasons of 2023 and 2024 AD, to studying the effect of three irrigation levels (normal and skip irrigation during vegetative growth and during flowering stage) with foliar spraying with anti-transpiration agents (salicylic acid and ascorbic acid) and its impact on yield and quality of sunflower variety (Giza 102) under the conditions of Assiut Governorate. Seeds were sown in 25 cm-spaced hills along the line, and the seeds were thinned to one plant per hill before the first irrigation. The sub-plot area was 10.5 m² (3 × 3.5 m), equivalent to 1/400 of fad. (fad. = 4200m^2) In both seasons.

Experiment site

During the two consecutive summer seasons of 2023 and 2024, an agricultural experiment was conducted at the experimental farm of the Faculty of Agriculture (27° 12′ 16.67″ N, 31° 09′ 36.86″ E, 51 m above sea level), Assiut Governorate, Egypt. The map of the studied area, Assiut governorate, Egypt, is shown in Fig. 1.

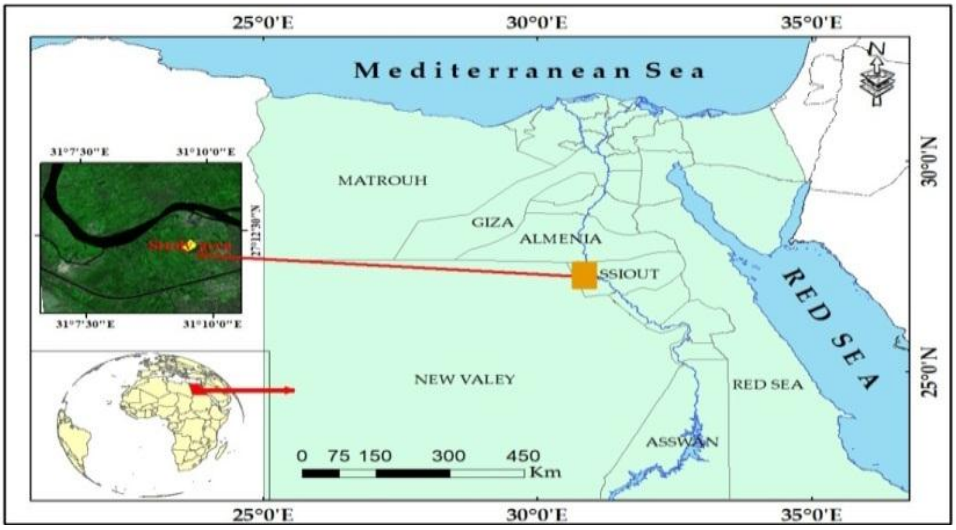

Fig. 1. Map of the studied area, Assiut Governorate.

Soil analysis

The chemical and physical properties of the investigated site were determined according to **(Page *et al*.**, 1982; **Klute**, 1986) and they are shown in **Table 1** presents the physical and chemical properties of the experimental soil during 2023 and 2024 seasons. The soil texture at both depths (0–15 and 15–30 cm) was classified as clay loam, with clay content ranging between 34.9 and 35.8%. The organic matter (OM) content was low (1.17–1.46%), which is typical of arid and semi-arid soils. The bulk density (BD) values ranged from 1.26 to 1.33 g cm^{-3}, indicating moderate soil compaction. The field capacity (FC) and wilting point (WP) averaged 43% and 21%, respectively, with available water (AW) around 21%, suggesting good water-holding capacity. The infiltration rate (IF) was relatively low (0.14 cm h^{-1}), reflecting the fine texture of the soil.

The chemical analysis showed a slightly alkaline soil reaction (pH 7.84–7.88) and non-saline conditions (EC ≈ 1.0 dS m^{-1}). The sodium adsorption ratio (SAR) was about 4, which is within the safe range for most crops. Soluble cations were dominated by Ca^{2+} and Na^{+}, while Cl^{-} and SO_4^{2-} were the major anions. The available nitrogen and phosphorus contents were moderate (N: 75–85 ppm; P: 10–12 ppm). Overall, the soil can be characterized as non-saline, slightly alkaline clay loam with low organic matter and moderate fertility status.

Table 1. Some physical and chemical properties of the tested site Physical properties.

year	Soil depth (cm)	Particle size			Texture E class	OM (%)	$CaCO_3$ (%)	FC (%)	WP (%)	AW (%)	BD (g/cm^2)	IF cm/h
2023		sand	silt	clay								0.14
	0-15	26.30	38.62	35.08	C	1.34	3.32	43.10	21.15	21.95	1.28	
	15-30	25.50	39.60	34.90	C	1.17	3.20	42.90	21.23	21.67	1.33	
	mean	25.90	39.11	34.99	C	1.26	3.26	43.00	21.19	21.81	1.31	
2024		25.11	39.09	35.80	C	1.46	3.26	43.37	21.16	22.21	1.26	0.14
		24.56	39.80	35.64	C	1.20	3.17	42.08	21.22	20.86	1.31	
	mean	24.84	39.44	35.72	C	1.33	3.22	42.73	21.19	21.54	1.29	

C= clay loam OM = organic matter FC = field capacity WP = welting point AW = available water BD = bulk density IF = infiltration rate.

Chemical properties

year	Soil depth (cm)	SP	pH	EC ds/m	Soluble ions (me q/L)							SAR	Available Nutrients (ppm)	
					CO_3+H CO_3	CL	SO_4	Ca	Mg	Na	K		N	P
2023	0-15	87.0	7.84	1.07	2.44	1.25	6.13	2.64	1.32	5.93	0.15	4.18	83.00	12.18
	15-30	86.0	7.86	1.00	2.24	1.17	6.00	2.53	1.17	5.85	0.26	4.00	75.00	10.01
mean		86.5	7.85	1.03	2.34	1.21	6.07	2.59	1.25	5.89	0.21	4.09	79	11.09
2024	0-15	86	7.85	1.10	2.40	1.20	6.10	2.66	1.33	5.90	0.16	4.20	85.00	12.20
	15-30	85	7.88	1.02	2.22	1.13	5.97	2.52	1.15	5.77	0.25	4.01	78.00	10.00
mean		85.5	7.87	1.06	2.32	1.17	6.04	2.59	1.24	5.84	0.21	4.11	81.5	11.10

SP= saturation percent pH= soil reaction EC= electrical conductivity SAR= sodium adsorption ratio.

Studied factors

Irrigation operations

Three irrigation operations were used (normal (N), skip irrigation during vegetative growth (S.V) and floral stage (S.F)).

Foliar spraying with Antitranspiration

Spraying was carried out with three levels of salicylic acid (00 , 150 and 300 mg/L) and ascorbic acid with three levels (00 , 200 and 400 mg/L).It was sprayed twice at a rate of (250 L/fad.) after 35 and 50 days of sowing, respectively.

Experimental design

The experiment was carried out in randomized complete block design (RCBD) using strip plot arrangement with three replicates. The irrigation was arranged in the vertical, while foliar spray allocated in horizontal plots.

Studied characters

At harvest, five plants were selected randomly from 3^{th} inner rowsof every treatment in three replications were chosen to determine the following data:

Growth characters:

Vegetative readings were taken at 75 days of planting**:**

1-Plant height (cm).
2-Dry weight of the plant (g)**.**
3-Stem diameter (cm).
4-Leaf area index, it was calculated as the ratio of leaf area to ground area**:**

LAI = Leaf area (m^2) / Land area occupied by the plant (m^2)

Yield and Its Components:

1-Head diameter (cm).
2-100 – seeds weight (g).
3-Seeds yield / head (g).
4-Seeds yield (t/fad.).
5-Biological yield (t/fad.).
6- Seedss husks percentage.

Chemical analysis:

1-Oil yield (kg/fad.).
2-Seedss oil content (%) was determined according to A.O.A.C. (1984) by using Soxhlet.

Irrigation measurements:

Irrigation water applied (m^3/fad.)

Irrigation water delivered. submerged flow orifice with fixed dimension was used to convey and measure the irrigation water applied, as the following equation (Michael, 1978). $Q= CA \sqrt{2gh}$

Where:
Q = Discharge through orifice, (cm^3 sec^{-1}).
C= Coefficient of discharge (0.61).
A= Cross sectional area of orifice, cm^2.
G= Acceleration due to gravity, cm / sec^{-2}.
H= pressure head, over the orifice center cm.

Note: Amount of water delivered was calculated by multiplied Q × T
T: where, T time of plot irrigation.

Field water use efficiency (Kg/ m3).

Economic feasibility.

1- Total cost with rent/fad.
2-Total revenue) Main crop value and Straw crop value) Bulletin of statistical cost production and net return, Egypt (2022).

3- Net return = Total revenue L.E/fad - Total cost with rent/fad. 4- Benefit-cost ratio = Net return L.E / Total cost with rent/fad.

Statistical analysis

The data collected were analyzed using the ANOVA technique as described by Snedecor and Cochran (1972). Mean comparisons were made through computer-based statistical analysis using the Statistix 10 program for Windows (Statistix, 2013). Additionally, the analysis of variance and level of significance, along with the Revised Least Significant Difference (R-LSD) test, were performed in R software (R Core Team, 2025) following the procedure of Steel and Torrie, (1981).

Results and Discussion

Growth characters:

The data presented in Table 2. indicate that all the evaluated traits (plant height, stem diameter, dry weight/plant and leaf area index) were significantly affected by the irrigation regimes and foliar spray treatments, as well as their interaction during the 2023/2024 growing seasons.

Normal irrigation (N) consistently recorded the highest values across all measured traits as Abdelaal , 2023 ; Badr *et al* 2025 reached. also outperforms the foliar salicylic acid at 150 mg/L over all other concentrations gives the highest values for all the characteristics in the Table 2. Followed by spraying with ascorbic acid 200 mg/L. These results are similar to what Hamza *et al* 2025 achieved.

The application of salicylic acid (SA) at a concentration of 150 mg/L under normal irrigation conditions resulted in the highest plant height (216.56 and 206.22 cm), stem diameter (2.20 and 2.28cm), dry weight/plant (124.01 and 130.68g) and leaf area index (3.20 and 3.21) in both seasons 2023 and 2024. The results demonstrated the critical role of irrigation and antitranspiration foliar spray enhancing Sunflower productivity under water stress the constant superiority of normal irrigation (N) emerge the importance of sufficient water supply during crop growth stage (Saudy *et al.* 2023) . Water stress during flowering stage had negative effect compared with stress during vegetative growth this will reflected in at character obtained. These results are similar to what was found by Abdel-Motagally *et al.*2015; Saeed *et al.*2015; Kaviya *et al* 2018; Elfaki *et al.* 2021;aeed *et al.* 2025 that normal irrigation with spraying with salicylic acid is best.

In contrast, optimum irrigation during the vegetative growth stage (S.V) caused a moderate reduction in all evaluated parameters. However, plants showed resilience during this stage, especially when treated with antitranspirants. On the other hand, skipping irrigation during the flowering stage led to a more pronounced reduction in all measured traits. Moreover, the interaction effects between irrigation regimes and foliar treatments were statistically significant in most cases, indicating that response to foliar treatment varied depending on the irrigation regimes (Bukhsh *et al* 2009).

Yield Components

Table 3. demonstrates that all evaluated traits (head diameter, 100-seeds weight, seeds yield /head and biological yield) were significantly influenced by irrigation regimes, foliar spray treatments, and the interaction between them during the 2023/2024 seasons.

Normal irrigation (N) consistently recorded the highest values for all traits as happened with Kaleri *et al* 2023 ; Younis *et al* 2025 . Also, Spraying with 150 mg/L salicylic acid gave the highest value for all the traits measured in the Table.3 Notably, the application of salicylic acid (SA) at 150 mg/L under normal irrigation conditions produced the highest head diameter (21.78 and 22.67 cm) in the first and second seasons, respectively, seeds yield /head (94.61 and 93.48 g) in the both seasons, respectively , weight 100 seeds (8.29 and 8.18g) in the both seasons, respectively and biological yield (4.64 t/fad) recorded in 2023 season. The sharp declines in head diameter, seeds weight, and yield under skipped irrigation during the flowering stage confirm that drought at this stage severely disrupts assimilate accumulation and reproductive success. Foliar application of salicylic acid (SA) proved effective in mitigating the adverse effects of water stress. This may be attributed to SA's role in enhancing antioxidant defense mechanisms, reducing transpiration losses, and improving photosynthetic efficiency, thereby supporting plant growth and productivity under drought conditions. These results are consistent with what was found Dawood *et al.*, 2012; Saeed *et al.*, 2015; Elfaki *et al.*, 2021.

Table 2. Effect of irrigation skip and foliar spraying with antitranspiration and their interaction on (plant height, stem diameter, dry weight/plant and leaf area index) in the 2023 and 2024 seasons.

Irrigation (I)	SPRAY (S)	plant height (cm)		stem diameter (cm)		dry weight /plant (g)		leaf area index	
		2023	2024	2023	2024	2023	2024	2023	2024
N	0	197.11	186.78	1.83	1.86	86.37	93.03	2.18	2.19
	SA 150	216.56	206.22	2.20	2.28	124.01	130.68	3.20	3.21
	SA 300	197.67	187.33	2.03	1.94	108.60	115.26	2.58	2.57
	ASA 200	205.67	195.67	2.12	1.96	11.75	125.42	2.77	2.77
	ASA 400	198.22	187.89	2.03	1.93	105.82	112.49	2.55	2.56
Mean		203.04	192.78	2.04	1.99	108.71	115.38	2.65	2.66
S.V	0	190.89	175.89	1.72	1.73	80.13	89.46	2.12	2.13
	SA 150	198.22	183.22	2.00	1.99	108.10	117.43	3.12	3.13
	SA 300	191.11	176.11	1.84	1.86	88.48	97.82	2.43	2.44
	ASA 200	193.34	178.34	1.92	1.91	97.38	106.71	2.72	2.73
	ASA 400	191.22	176.22	1.90	1.81	90.30	99.64	2.41	2.40
Mean		192.96	177.96	1.88	1.86	92.88	102.21	2.56	2.56
S.F	0	190.67	175.67	1.66	1.65	75.92	85.59	1.88	1.92
	SA 150	195.22	180.22	2.03	1.92	102.23	111.90	2.33	2.38
	SA 300	191.45	176.22	1.82	1.78	92.55	102.45	2.06	2.11
	ASA 200	194.22	179.22	2.00	1.89	96.79	106.45	2.24	2.28
	ASA 400	191.22	176.22	1.81	1.82	93.30	102.97	2.13	2.18
Mean		192.56	177.56	1.86	1.81	92.16	101.83	2.13	2.18
All means of Anti-transpiration	0	192.89	179.44	1.74	1.74	80.80	89.36	2.06	2.08
	SA 150	203.33	189.89	2.07	2.06	111.45	120.01	2.88	2.96
	SA 300	193.41	184.41	1.90	1.86	96.54	105.10	2.36	2.37
	ASA 200	197.74	179.96	2.01	1.92	104.31	112.86	2.57	2.59
	ASA 400	193.56	180.11	1.91	1.85	96.47	105.03	2.36	2.38
R- LSD	I	4.85	4.65	0.04	0.05	2.64	2.65	0.02	0.02
	S	1.71	1.58	0.04	0.04	2.89	2.89	0.03	0.03
	I × S	4.50	4.45	0.06	0.07	4.46	4.48	0.04	0.05

SA= salicylic acid **ASA=** ascorbic acid **N=**normal **S.V=** skip irrigation during vegetative growth **S.F=** skip irrigation during floral growth **SA=** salicylic acid **ASA=** ascorbic acid**.**

In contrast, skipping irrigation during the vegetative growth stage (S.V) caused moderate reductions in all measured parameters. However, plants showed resilience at this stage especially when treated with antitranspirants on the other side. skipping irrigation during the flora stage resulted in the most pronounced reduction in all traits partially in the untreated (Control) where seeds/head and biological yield (Bukhsh *et al*., 2009).

Data in Table 3. showed a significant decrease foliar application of salicylic acid and ascorbic acid improved all measured traits under both normal and stress conditions. Salicylic acid at 150 mg/L proved to be more effective than ascorbic acid at 200 or 400 mg/L in improving growth and productivity. This is similar to what was found by Saeed and Zafar-ul-hye 2024; Saeed *et al.,* 2025. The interactions effect of (I x S) were statistically significant in most cases indicating that the response to foliar treatments varied depending on the irrigation regimes (El-Bially *et al.* 2022).

Table 3. Effect of irrigation skip and foliar spraying with anti-transpiration and their interaction on (head diameter, weight 100 seeds, seeds yield/head and biological yield) in the 2023 and 2024 seasons.

Irrigation (I)	SPRAY (S)	Head diameter (cm)		Weight 100 seeds (g)		Seeds yield/head (g)		Biological yield (t/fad.)	
		2023	2024	2023	2024	2023	2024	2023	2024
N	0	19.11	18.67	6.68	6.19	79.83	78.80	3.52	3.46
	SA 150	21.78	22.67	8.29	8.18	94.61	93.48	4.64	4.67
	SA 300	20.44	20.00	7.74	7.14	88.59	86.94	4.22	4.25
	ASA 200	20.77	20.44	7.87	7.24	90.46	89.48	4.33	4.43
	ASA 400	20.00	19.56	7.45	6.80	88.52	87.22	4.16	4.13
Mean		20.42	20.26	7.60	7.11	88.40	87.18	4.19	4.19
S.V	0	18.66	18.63	6.46	6.11	76.91	74.67	3.19	3.33
	SA 150	20.66	20.22	7.89	7.50	93.25	91.19	4.27	4.40
	SA 300	19.66	19.55	7.11	6.99	83.68	83.73	3.99	4.22
	ASA 200	20.00	19.67	7.48	7.10	89.35	88.20	4.07	4.31
	ASA 400	20.00	19.56	7.28	6.97	86.45	84.83	4.00	4.22
Mean		19.80	19.52	7.24	6.93	85.93	84.52	3.90	4.10
S.F	0	17.11	16.67	6.13	5.91	66.59	67.07	3.14	3.11
	SA 150	20.00	19.89	7.09	6.95	84.50	83.72	4.18	4.16
	SA 300	18.66	19.00	6.28	6.18	71.60	71.03	3.71	3.74
	ASA 200	19.33	19.00	6.92	6.71	79.51	79.38	4.05	4.00
	ASA 400	19.00	19.22	6.63	6.29	76.86	76.34	3.83	3.84
Mean		18.82	18.82	6.61	6.41	75.81	75.51	3.78	3.77
All means of Anti-transpiration	0	18.29	17.99	6.42	6.07	74.44	73.51	3.28	3.30
	SA 150	20.81	20.93	7.76	7.54	90.79	89.46	4.36	4.41
	SA 300	19.59	19.52	7.04	6.77	81.29	80.57	3.97	4.07
	ASA 200	20.03	19.81	7.42	7.02	86.44	85.69	4.18	4.25
	ASA 400	19.66	19.44	7.12	6.69	83.94	82.79	3.99	4.06
R- LSD	I	0.43	N.S	0.16	0.23	1.46	2.93	0.08	0.08
	S	0.73	0.59	0.21	0.25	1.97	4.61	0.09	0.10
	I × S	0.58	0.67	0.26	0.25	1.42	N.S	0.11	0.10

N=normal **S.V=** skip irrigation during vegetative growth **S.F=** skip irrigation during floral growth
SA= salicylic acid **ASA=** ascorbic acid **N.S**= not significant.

Yield Seeds chemical analyses

The data in Table 4. indicated that both irrigation regimes and foliar spraying treatments significantly affected seeds yield (t/fad.), oil yield (kg/fad.), and seeds oil content and husks seeds oil percentage in both seasons of 2023 and 2024, and their interaction between irrigation and foliar spray.

Normal irrigation achieved consistently. The highest results for seeds yield (t/fad.), oil yield (kg/fad.) and husks seeds (%) in both seasons. the mean value (1.44 and 1.38 t/fad.) for seeds yield, (442.63 and 438.74 kg/fad.) for oils yield and husks seeds (25.71 and 27.07%) in 2023 and 2024 seasons, respectively. While giving skip irrigation during flowering to a height seeds oil content (34.50 and 35.33%) in both seasons, respectively. Skipping irrigation during flower stage. (S.F) recorded the lowest value for seeds yield, oil yield and husks seeds the mean value of seeds yield was(1.07 and 1.09 t/fad.), oil yield (372.81 and 389.57 kg/fad.) and husks seeds (23.81 and 23.71%) in 2023 and 2024 seasons, respectively. While, skipping irrigation during vegetative growth gave intermediate values. foliar spray salicylic acid at 150 mg/L gave the highest value compared with control specially seeds yield (t/fed) , oil yield (kg/fad.), seeds oil content (%) in both season and husks seeds (%) in 2023 season only.

Ascorbic acid at rate 400mg/L also had significantly positive impact particularly on husks seeds (%) achieved up 28.63 in 2024 season. The consistent superiority of normal irrigation emphasizes the importance of an adequate water supply throughout the various growth stages of sunflower. Water stress during the flowering stage (SF) had more severe negative effects compared to stress during the vegetative stage. This is consistent with known physiological responses, as water deficiency during the reproductive stage significantly reduces photosynthesis, leading to poor seeds development and decreased oil biosynthesis. Moreover, the results highlighted the role of salicylic acid (SA) in enhancing antioxidant defense mechanisms, stabilizing cell membranes, improving water use efficiency, scavenging reactive oxygen species (ROS), and maintaining cellular functions all of which contributed to improved seeds yield under drought conditions. These results are similar to what Dawood *et al.*, 2012; Saeed *et al.*, 2015 proved, while they differ from what Elfaki *et al.*, 2021 reached. The control treatment spray (0) recorded the lowest performance in all measured treatments. The interaction between normal irrigation and SA 150 mg/L resulted in the highest overall yield of (1.62 and 1.59 t/fad.) seeds yield, (528.82 and 548.61 kg/fad) oil yield and husks seeds (27.37 % in 2023 season). Also, the interaction between normal irrigation and ASA 400 mg/L resulted in the highest husks seeds of (28.63%). The lowest yield observed under skipping irrigation during flowering stage combined with no spray. Seeds oil content was highest with SA 150 mg/L under skipping irrigation during flower stage reaching up to (37.22 and 38.20%) in 2023 and 2024 season. While husks seeds were slightly affected by treatment with minor variation the lowest husk % (23.04%) was recorded by S.F with (0) spray in 2023 season. These results are similar to what was achieved (Mostafa and Afify, 2022) low and incomplete irrigation led to improved oil content.

The results clearly demonstrated the critical role of irrigation and anti-transpiration. Foliar spray enhancing sunflowers particularly under water stress conditions. The consistent superiority of normal irrigation regime emerges the importance of sufficient water supply during crops growth stage. Water stress during flowering Stage (S.F) had negative effects compared with stress during vegetative growth. (S.V.). This agrees with known physiological responses where water deficiencies during reproductive stage significantly reduced photosynthesis processes. This is what Karam *et al.*, 2007 came up with.

Table 4. Effect of irrigation skip and foliar spraying with anti-transpiration and their interaction on (seeds yield, oil yield, Seeds oil content and husks seeds) in the 2023 and 2024 seasons.

Irrigation (I)	SPRAY (S)	Seeds yield (t/fad.)		Oil yield (kg/fad.)		Seeds oil content (%)		husks seeds (%)	
		2023	**2024**	**2023**	**2024**	**2023**	**2024**	**2023**	**2024**
N	0	1.21	1.22	326.69	351.19	26.81	28.86	24.08	25.15
	SA 150	1.62	1.59	528.82	548.61	32.51	34.47	27.37	28.49
	SA 300	1.45	1.37	447.72	426.06	30.83	31.05	25.04	26.29
	ASA 200	1.55	1.44	453.41	437.49	29.11	30.33	25.56	26.79
	ASA 400	1.38	1.30	456.53	430.36	33.04	33.10	26.44	28.63
Mean		1.44	1.38	442.63	438.74	30.46	31.56	25.71	27.07
S.V	0	1.02	1.04	296.60	330.98	29.10	31.89	24.12	24.32
	SA 150	1.40	1.38	514.07	506.72	36.65	36.70	25.18	26.01
	SA 300	1.32	1.32	429.21	431.49	32.53	32.83	24.55	25.08
	ASA 200	1.35	1.33	489.9	457.82	36.28	34.36	24.60	25.60
	ASA 400	1.33	1.31	401.26	444.68	30.07	34.04	26.10	26.70
Mean		1.28	1.27	426.22	434.34	32.92	33.96	24.91	25.54
S.F	0	0.80	0.91	265.60	306.58	32.90	33.58	23.04	23.85
	SA 150	1.29	1.26	480.31	480.10	37.22	38.20	24.66	24.03
	SA 300	1.01	1.05	349.29	355.95	34.37	34.04	23.47	23.40
	ASA 200	1.13	1.15	377.50	397.56	33.23	34.48	23.58	23.56
	ASA 400	1.12	1.12	391.32	407.64	34.80	36.33	24.29	23.72
Mean		1.07	1.09	372.81	389.57	34.50	35.33	23.81	23.71
All means of Anti-transpiration	0	1.01	1.06	296.30	329.58	29.60	31.44	23.75	24.44
	SA 150	1.43	1.41	507.73	511.81	35.46	36.46	25.74	26.38
	SA 300	1.26	1.25	408.74	404.50	32.57	32.64	24.35	24.92
	ASA 200	1.34	1.31	440.30	430.96	32.87	33.06	24.58	25.32
	ASA 400	1.27	1.24	416.37	427.56	32.64	34.49	25.61	26.35
R- LSD	I	0.06	0.03	11.52	32.07	1.01	1.63	0.57	0.32
	S	0.08	0.05	24.54	27.42	0.55	1.46	0.85	0.58
	I × S	0.07	0.06	34.22	28.99	1.58	1.22	0.92	1.25

N=normal **S.V=** skip irrigation during vegetative growth **S.F=** skip irrigation during floral growth
SA= salicylic acid **ASA=** ascorbic acid

Irrigation measurements

Irrigation water applied (m^3/fad).

Field water use efficiency (Kg/ m^3).

Data in **Table 5.** present the effect of different irrigation treatments on the water applied, seeds yield, and water use during the 2023 and 2024 season. The data showed that normal irrigation recorded the highest amount of water applied in bath season (2658 and 2651 m³/fad.), while skipping irrigation during vegetative growth or floral stage significantly reduced the amount of water applied the lowest value recorded from skipping irrigation during the vegetative stage during in both seasons (2134 and 2142 m3/fad. respectively). This reflects in reduced water uses regarding seeds yield the highest value was achieved under normal irrigation in 2023and 2024 seasons (1440 and 1380 kg/fad. respectively). flowed by skipping irrigation during vegetative growth in other head, the lowest value was observed under (S.F) especially 2023 and 2024 (1070 and 1090 kg/fad.) indicating that water Stress during (S.F) stage has more detrimental impact on productivity in the sine table water use efficiency. (WUE) indicted how effectively. The plants convert water into yield the highest water use efficiency was recorded that (S.V) in 2023 (0.60 kg/m³). We found that skipping irrigation during vegetative growth stage can save water while maintaining good productivity. Also, (S.V) maintained high

(WUE) in 2024 (0.5kg/m^3). The lowest (WUE) occurred under (S.F) especially in 2023 and 2024 (0.50 and 0.50 kg/m³) reinforcing the negative effect of water stress during flowering. So, we suggest that skipping irrigation during vegetative stage is promising strategy for water sowing without significantly affecting yield, this improving water productivity. In contrast skipping irrigation during flowering stage led to poor yields an in efficient water use making it an unsuitable practice for maximizing returns. There for time of irrigation is critical and avoiding water stress during flowering stage essential for achieving high productivity and water use efficiency. These results are consistent with what the scientist found by Elsheikh *et al.*, 2015; Mahmoud and Ahmed 2016; Abdallah *et al.*, 2020; Elfaki *et al.*, 2021.

Table 5. Irrigation water applied and water production.

Growing season	**Treatments**	**Irrigation water applied (m^3/ fad.)**	**Seeds yield (kg/ fad.)**	**Field water use efficiency (Kg/ m^3)**
2023	N	2658	1440	0.54
	S.V	2134	1280	0.60
	S.F	2146	1070	0.50
2024	N	2651	1380	0.52
	S.V	2142	1270	0.59
	S.F	2151	1090	0.50

Economic feasibility

1-Total cost with rent/fad.

2-Total revenue (Main crop value and Straw crop value) Bulletin of statistical cost production and net return, Egypt (2022).

3-Net return = Total revenue L.E/fad - Total cost with rent/fad.

4-Benefit-cost ratio = Net return L.E / Total cost with rent/fad.

As illustrated in Table 6. the normal irrigation regime significantly improved the economic performance of sunflower production. It led to the highest total revenues (40,638.5 and 39,083.5 L.E/fad) and net returns (24,302.1 and 20,296.6 L.E/fad), as well as the most favorable benefit-cost ratios (1.49 and 1.08) during the two successive seasons. These results were followed by the treatment involving skipped irrigation during the vegetative stage, which still maintained relatively high economic returns.

These findings are consistent with previous research. For example, El sheikh *et al.*, 2015; Gomes *et al.*, 2018 reported that more frequent irrigation (every 10 days) significantly enhanced seeds yield and water productivity of sunflower in Sudan, contributing to improved farm profitability.

In contrast, treatments that included skipping irrigation during the flowering stage resulted in the lowest economic returns. This approach resulted in lower total revenues, net returns, and profit-loss ratios, highlighting the negative impact of water shortages during the reproductive stage on crop productivity and economic viability Karam *et al.*, 2007; Mila *et al.*, 2017; Sahoo *et al.* (2018).

Together, these studies reinforce the economic value of maintaining optimal irrigation during critical growth stages in sunflower cultivation.

Table 6. Economic feasibility study for different irrigation methods.

Items \ Year		2023			2024		
		N	S.V	S.F	N	S.V	S.F
Seeds yield (kg/fad.)		1440.00	1280.00	1070.00	1380.00	1270.00	1090.00
Straw yield (heml/fad.)		11.00	10.40	10.80	11.20	11.30	10.70
Total cost with rent/fad.		16336.40	15676.40	15676.40	18786.90	17872.90	17872.90
Revenue	**Main crop value**	38328.50	34069.80	28480.20	36731.50	33803.60	29012.50
	Straw crop value	2310.00	21048.00	2268.00	2352.00	2373.00	2247.00
Total revenue		40638.50	36253.80	30748.20	39083.50	36104.60	31259.50
Net return		24302.10	20577.40	15071.80	20296.60	18231.70	13386.60
Benefit-cost ratio		1.49	1.31	0.96	1.08	1.02	0.75

As shown in **Table 7.** foliar spraying with anti-transpiration agents significantly improved the economic performance of sunflower cultivation. This treatment achieved the highest total return, as spraying with salicylic acid at a rate of 150 mg/L resulted in a total revenues (40519.3 and 40049.9 L.E /fad.), net returns (24185.3 and 21465.9 L.E/fad.), and cost-benefit ratios (1.48 and 1.16) over two consecutive seasons. Conversely, treatments using anti-transpiration sprays (0 or non-spraying) achieved the lowest economic returns. This approach resulted in lower total revenues (28773.2 and 30083.0L.E /fad.), net returns (13683.2 and 12730 L.E/fad.) and benefit-cost ratio (0.91 and 0.73) in both seasons 2023 and 2024, highlighting the positive impact of anti-transpiration sprays on crop productivity and economic viability, especially in water-scarce situations. Moreover, the use of anti-transpiration agents has been shown to mitigate the negative effects of water scarcity by enhancing plant physiological responses, improving yield and economic outcomes under water-stress conditions. These results underscore the importance of combining an appropriate irrigation schedule with the use of anti-transpiration agents to improve sunflower production and increase profitability (Youssef *et al.* 2023).

Table 7. Economic feasibility study for spraying with anti-transpiration.

Items \ Year		2023					2024				
		Control	SA 150	SA300	ASA200	ASA400	Control	SA150	SA300	ASA200	ASA400
Seeds yield (kg/fad.)		1010	1430	1260	1340	1270	1060	1410	1250	1310	1240
Straw yield (heml/fad.)		9.00	11.70	10.80	11.30	10.80	8.90	12.00	11.20	11.70	11.2
Total cost with rent/fad.		15090	16334	16578	16290	16490	17353	18584	18864.7	18533.5	18763.5
Revenue	**Main crop value**	26883.2	38062.3	33537.4	35666.8	333803.6	28214.00	37529.90	33271.30	34868.30	33005.10
	Straw crop value	1890.00	2457.00	2268.00	2373.00	2268.00	1869.00	2520.00	2352.00	2457.00	2352.00
Total revenue		28773.2	40519.3	35805.4	38039.8	36071.6	30083	40049.90	35623.30	37325.30	35357.10
Net return		13683.2	24185.3	19227.4	21749.8	19581.6	12730.0	21465.90	16758.60	18791.80	16593.60
Benefit-cost ratio		0.91	1.48	1.16	1.24	1.19	0.73	1.16	0.89	1.01	0.89

The results clearly demonstrate that both irrigation scheduling and foliar application of antitranspirant significantly influence sunflower growth, yield components, and water use efficiency. Normal irrigation (N), particularly when combined with foliar spraying of salicylic acid at 150 mg/L.

(SA 150), resulted in superior performance in plant height, stem diameter, dry weight per plant, leaf area index, head diameter, seeds weight, seeds yield per head, biological yield, and field water use efficiency. Skipping irrigation during the floral stage (S.F) caused the most reduction in all traits, while skipping during the vegetative stage (S.V) had a moderate impact. However, the use of salicylic acid and ascorbic acid, especially SA 150 mg/L,

Conclusion

effectively mitigated these reductions by enhancing physiological tolerance and promoting growth and yield under stress conditions.

Moreover, the highest field water use efficiency was achieved with SA 150 mg/L under S.V treatment, indicating that moderate water stress with proper antitranspirant application can balance between water saving and yield maintenance.

Overall, integrating antitranspirants particularly salicylic acid at 150 mg/L with a well-planned irrigation strategy (avoiding stress at floral stage) provides a practical and efficient approach to enhance sunflower performance and water productivity under limited irrigation conditions

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تأثير إسقاط رية والرش الورقي بمضادات النتح على نباتات دوار الشمس (*Helianthus annuus* L.)

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أُجريت هذه الدراسة لتقييم تأثير ثلاث مستويات من الري (ري منتظم، واسقاط رية خلال مرحلة النمو الخضري، واسقاط رية خلال مرحلة التزهير) والرش الورقي بتركيزات مختلفة من مضادات النتح وهي كالاتي: حمض الساليسيليك (٠، ١٥٠، ٣٠٠ ملغم/لتر) وحمض الأسكوربيك (٠، ٢٠٠، ٤٠٠ ملغم/لتر) على نمو وإنتاجية محصول دوار الشمس ومكوناته تحت ظروف محافظة اسيوط.

نُفذَت التجربة في المزرعة البحثية بكلية الزراعة، جامعة الأزهر، فرع أسيوط، خلال الموسم الصيفي لعامي ٢٠٢٣ و٢٠٢٤ ميلاديا والتصميم المستخدم تصميم القطاعات الكاملة العشوائية (RCBD) بنظام الشرائح المتعامدة في ثلاث مكررات حيث تم وضع معاملات الري في القطع الرأسية ومعاملات الرش الورقي بمضادات النتح في القطع الأفقية.

أظهرت النتائج المتحصل عليها أن الري المنتظم تفوق بشكل معنوي على مستويات الري الأخرى في صفات النمو مثل ارتفاع النبات، وقطر الساق، والوزن الجاف للنبات ودليل مساحة الأوراق بالإضافة إلى صفات المحصول ومكوناته مثل قطر القرص، ووزن ١٠٠ بذرة، ومحصول البذور لكل قرص، والمحصول البيولوجي (طن/فدان)، ومحصول البذور للفدان (طن/فدان) ومحصول الزيت للفدان (كجم/فدان) وعلى العكس من ذلك لوحظ ارتفاع في نسبة الزيت بالبذور عند اسقاط رية خلال مرحلة التزهير.

أما بالنسبة للرش الورقي، فقد أعطى الرش بحمض الساليسيليك بتركيز ١٥٠ ملغم/لتر أعلى القيم في جميع الصفات المدروسة.