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Effect of Osmoregulators and Amino Acids on Dill Growth and its Secondary Compounds Content under Water Stress Conditions

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Abstract

Dill plant *Anethum graveolens* L. is one of the important leafy green plants, with medicinal and nutritional importance. The research was conducted to study the effect of adding osmotic regulators and amino acids in resisting water stresses on Dill plant, belongs to the Apiaceae family. It included three factors, the first factor was spraying with osmotic regulators 0, 1 and 2 g L^{-1}, the second factor was spraying with amino acids 0, 1 and 2 ml L^{-1}, and the third factor was two levels of irrigation interval 7 and 14 days. The results showed that: the superiority of the triple interaction treatments represented by spraying with osmotic regulators at a concentration of 1 g L^{-1}, amino acids 2 ml L^{-1} and an irrigation interval of 7 days, as it gave the best results for plant height 57.97cm, number of branches 18.57, relative chlorophyll content in leaves 69.83 mg $100g^{-1}$ fresh weight, dry weight 25.17g $plant^{-1}$, number of leaves 36.57 leaf $plant^{-1}$, percentage of Protein 23.60%, number of Inflorescences 45.27, plant yield 2.319 kg m^{-2}, and percentage of volatile oil in leaves 3.67 %,. The results also proved the response of dill plant to spraying with osmotic regulators and amino acids in giving the best results of growth, yield and volatile oil under water stress conditions.

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Introduction

Dill plant *Anethum graveolens* L. is one of the most important green plants with medicinal and nutritional importance. It is an annual or biennial plant with a taproot and an erect stem ranging in height from 20- to 60 cm. Its leaves are compound pinnate divided into threadlike, ribbon-like parts and, its stems are smooth, tender and hollow. Its flowers are complete and gathered in compound terminal umbel inflorescences of yellow color (Hassan, 2015). Its original habitat is the Mediterranean Basin, Southern and Eastern Europe, Central and Southern Asia (El-Gamal and Ahmed, 2016). It is consumed fresh or cooked and is used in the food and cosmetics industry. Dill is an aromatic herb that has been used for thousands of years to treat indigestion, flatulence, reduce cholesterol, is an antispasmodic, enhances appetite, regulates heart and lung function, and reduces blood sugar by balancing insulin production (El-Sayed *et al.*, 2017). It contains many therapeutic compounds that are antioxidants in addition to its nutritional importance because it contains proteins and carbohydrates It also contains essential oils (Chahal *et al*., 2017), it has a high nutritional value and is rich in vitamins, in addition to the antioxidants it contains and polyphenols (Salman *et al.,* 2019). Treats patients with high blood pressure stimulates appetite, is an antispasmodic, treats indigestion and vomiting in children, and increases breast milk (Sachet et *al.,* 2021). Plant nutrition through foliar spraying is an effective way to ensure better nutrient transfer within the plant and contribute to improving growth, increasing yield in quantity and quality and avoiding obstacles facing elements in the soil (Ahmad, 2024).

Water stress is one of the abiotic stresses that directly affects plant growth and its vital and physiological activities, as water is a medium that transports the products of photosynthesis, salts and nutrients absorbed by root hairs (Fanaei *et al*., 2015). It is also a good solvent and contributes to activating and supporting cementing cells through turgor pressure and regulates the temperature inside plant tissues and enters into chemical reactions. Increased water stress leads to the accumulation of ethylene in the plant due to increased transpiration and decreased water quantity (Johan *et al*, 2019).

To reduce the effect of water stress, osmotic regulators were used, which are nutritional compounds in the form of water-soluble granules consisting of organic materials, multiple sugars and acids Free amino acids and calcium, which play an influential role in chemical and biological functions, as for potassium, which is one of the most important factors influencing the control of auxiliary cells in the stomata and controlling their opening and closing according to the availability of the plant's moisture content, especially since the thirst period is long with the advancement of the plant's age and high temperatures, which in turn works to maintain the turgor pressure of the cells in resisting drought stresses (Afzal *et al.*, 2016), and improving the nutritional and ionic balance in the plant, which is reflected in improving and increasing production per unit area and amino acids, when added as a spray to the plant, are a basic source for encouraging the building of proteins and enzymes and providing energy that encourages and activates vegetative and root growth and improves the quality of production (Azza and Yousef*,* 2015).

Using osmotic protectors as foliar sprays enhances the plant's tolerance to environmental stresses like drought. Protein synthesis is boosted, antioxidants are activated, and vitamins, enzymes, and hormones are formed, these protectors also support chlorophyll production, improve ion availability in tissues, and increase cell membrane permeability. Plant growth and yield have also been improved by foliar amino acid application, in a study on Cherry tomato Salman and Sadeq (2017), found that spraying with amino acids gave the best results in vegetative and root growth indicators. Gleikh and Jaafar (2020) proved that spraying okra plants with amino acids led to increasing the efficiency of the photosynthesis process and thus giving the best growth results and total yield and improving the qualitative characteristics of the fruits, water consumption is increasing worldwide due to population growth, climate change, deterioration of water programs, and declining rainfall due to global warming, which has caused droughts in large areas of the world, including Iraq, causing serious economic and social problems. Therefore, the research aimed to know the effect of osmotic regulators by interacting with amino acids in resisting water stresses and the possibility of increasing growth indicators, yield, and production of volatile oil of medical importance for dill.

Materials and Methods

The experiment was carried out in one of the fields of the Biology Department, College of Education for Pure Sciences Ibn Al-Haitham, University of Baghdad, from 15/10/2023 to 2/4/2024, to study the effect of spraying amino acids and osmotic regulator and their interaction under water stress conditions on vegetative growth indicators and production of active compounds in dill plant.

Study factors

1- Osmotic regulator (Disper) is a water-soluble granules nutritional compounds consisting of 47% organic matter, 4.3% free amino acids, 4.2% dissolved calcium oxide, 3% calcium oxide complex, 1.2% chelated calcium oxide with EDTA, 12.5% potassium oxide, 9% sugars, and a pH of 4-9, where concentrations 0, 1, and 2 g L^{-1} were used as spraying on the vegetative group. Osmotic treatments were symbolized by the symbol O_1, O_2, and O_3 respectively. The spraying process was carried out for three sprays between each spray and the other for a period of two weeks.

2- Spraying with amino acids which consists of the following components: Organic matter 45% Free amino acids 12% Organic carbon 20% Organic nitrogen 4% pH 4-6. at concentrations 0, 1, and 2 ml L^{-1} and symbolized by the symbol A_1, A_2, and A_3 respectively with three sprays between each spray and the other for two weeks, provided that the amino acids spray was one week after spraying the osmotic regulator.

3- Irrigation interval: at two levels of irrigation every (7 and 14 days) symbolized by the symbols (S_1, S_2) respectively, Irrigation Intervals are determined by:

Calculate the number of days between two successive periods of irrigation of the field, and depends on the moisture content and the rate of water consumption around the root zone, and can be calculated from the following equation:

$$\text{Irrigation period / days} = \frac{\text{Soil moisture at irrigation - soil moisture at field capacity}}{\text{The highest rate of soil moisture depletion by the crop}}$$

(FAO, 1998).

If the treatments were watered by flooding for the first month until the plant reached an age at which it could tolerate the stress treatments, the concentrations were prepared according to the treatments and sprayed in the early morning until complete wetting when the plants reached the stage of 4-5 true leaves, with 3 sprays for the first osmotic regulator on 12/12/2023, 26/12/2023, and 10/1/2024, and with 3 sprays for the first amino acid on 19/12/2023, 27/12/2023, and 3/1/2024.

Experimental Design

The field was prepared with a single-knife plow to facilitate the work of the panels. Then the panels were made with dimensions of (1×1.5) m^2. Calibration irrigation was given. Before that, three samples were taken from the field soil before planting at different depths of the soil (15, 25, and 35) cm. Then they were mixed well to ensure the homogeneity of the sample and a sample was selected and analyzed in college laboratories (Table 1).

Table 1. Analysis of chemical properties of field soil

Properties	**O.M**	**Mg^{2+}**	**Cl^-**	**Ca^{2+}**	**K**	**P**	**N**	**EC**	**pH**
Unit	g kg $^{-1}$	m mol L^{-1}	m mol L^{-1}	m mol L^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	dS m^{-1}	-
Measurement	1.7	0.58	3.67	1.56	22.04	3.27	14.23	2.12	7.21

Dill seeds, a local variety, were obtained from the Baghdad agricultural offices. The seeds were planted in rows on the panels, with a distance of 15 cm between each row, with 5 rows on each panel. 30 plants per experimental unit. The studied properties:

1. Plant height (cm)

Five plants were selected from each experimental unit, and their lengths were measured from the soil surface to the end of the plant and the average was taken.

2. Total number of branches (branch plant^{-1})

The number of branches was counted for five plants per experimental unit, and the average was taken.

3. Estimation of Relative content of chlorophyll in leaves (mg 100g^{-1} fresh weight)

Chlorophyll was extracted from fresh leaves of dill plant using acetone (concentration 80%), the leaves were crushed with acetone in a ceramic bowl, until the plant tissue dissolved, the solution was placed in tightly closed and opaque glass bottles and left until the next day, then the light absorption of the sample was measured, using a spectrophotometer at wavelengths of 663 nm and 645 nm, after which the total chlorophyll concentration (mg L^{-1}) was estimated according to the following equation (Goodwin, 1976) :

Total Chlorophyll (mg L^{-1}) = 20.2D (645) + 8.02D (663)

4. Dry weight of plant (g plant^{-1})

The leaves of the plant were dried in an electric oven at a temperature of 65 - 70 C°, taking into account ventilation with an air vacuum, until complete drying and weight stability.

5. Number of Leaves of dill plant

The number of leaves per plant for 5 plants was calculated and the average was taken.

6. Protein content of dill plant leaves

Protein was estimated by measuring or estimating the percentage of nitrogen in the leaves using a Microkjeldahl device, and then protein was estimated according to the equation (A.O.A.C, 1970).

The product of the nitrogen percentage by the constant coefficient 6.25

Protein percentage = N % × 6.25

7. Number of Inflorescences of dill plant

The total number of inflorescences of five plants from each experimental unit, formed on the main stem and its branches, was calculated, and then the average for each plant was calculated.

8. Total vegetative yield (kg m^{-2})

The vegetative yield was collected at the onset of flowering. Five random plants were harvested from each experimental unit, and their weights were calculated in kilograms. The average weight of each plant was then calculated, and the values were multiplied by the number of plants per square meter to obtain the yield in kg m^{-2}.

9. Percentage of volatile oil in the leaves (%)

The oil was extracted using the water steam distillation method mentioned by Chalchat *et al*. (1991). 20 g of fresh leaf samples were taken, placed in a glass flask and 100 ml of distilled water was added to it and placed in the Clevenger device for three hours to obtain the largest amount of volatile oil. After that, the resulting oil was collected and 20 ml of Hexane (C_6H_{14}) was added to it to separate the oil from the water droplets. The oil was collected with the oil, then the oil was collected for each treatment, and stored in opaque bottles in the refrigerator. The percentage of volatile oil was estimated according to the equation mentioned by Guenther (1972):

Percentage of volatile oil = (weight of oil produced (g) / weight of plant sample (g) × 100

Statistical analysis

The experiment was designed under the factorial experiment system, according to the Nasted design and using Randomized Complete Block Design (RCBD). The factorial experiment treatments were distributed randomly, with three replicates for each treatment. The number of experimental units is 54 experimental units, resulting from (2×3×3×3). The averages were compared using the Least Significant Difference (LSD) test at the probability level of 0.05 (Gulluoglu *et al.,* 2017). The data were analyzed according to the Genstat program, version 12.

Results and Discussion

1. Effect of osmoregulators and amino acids on the Plant height of dill under water stress conditions (cm)

From Table 2, the results showed that the effect of the single study factors and the double and triple interactions on the trait of dill plant height, as the foliar spray treatment with amino acids 2 ml L^{-1} was superior and gave the highest height of 51.52 cm $plant^{-1}$ compared to the control treatment which gave 32.76 cm $plant^{-1}$, and the double interaction treatment (1 ml L^{-1} osmotic regulator and 2 ml L^{-1} amino acids) was superior and recorded 55.28 compared to the comparison treatment which recorded 29.73 cm $plant^{-1}$, and the triple interaction treatment (irrigation for 7 days with spraying with osmotic regulator 1 mg L^{-1} with spraying with amino acid 2 ml L^{-1}) showed the best results and recorded the highest values of 57.97 cm $plant^{-1}$ compared to the comparison treatment which recorded the lowest values of 32.00 cm $plant^{-1}$.

2. Effect of osmoregulators and amino acids on the Number of branches of dill under water stress conditions

The results showed the significant effect of the single study factors and the binary and triple interactions on the number of branches trait, as the foliar spray treatment with amino acids 2 ml L^{-1} was superior and gave the highest number of 14.93 branches $plant^{-1}$ compared to the control treatment which gave 8.03 branches $plant^{-1}$. In the binary interactions, the treatment (1 mg L^{-1} osmotic regulator and 2 mL L^{-1} amino acids) was superior and recorded 16.68 compared to the comparison treatment which recorded 6.88 branches $plant^{-1}$. The triple interaction treatment (irrigation for 7 days with spraying with osmotic regulator 1 mg L^{-1} with spraying with amino acid 2 ml L^{-1}) showed the best results and recorded the highest values of 18.57 branches $plant^{-1}$ compared to the comparison treatment which recorded the lowest values of 7.63 branches $plant^{-1}$ (Table 2).

3. Effect of osmoregulators and amino acids on the Relative content of chlorophyll in leaves of dill under water stress conditions (g 100 mg^{-1})

The study factors had a significant effect on the chlorophyll in the leaves, as the treatment of spraying with amino acids 2 mL L^{-1} was superior and gave the highest value of 66.76 compared to the control treatment which gave 51.27 g 100 mg^{-1}. The treatment of the dual interaction (1 mg L^{-1} osmotic regulator and 2 mL L^{-1} amino acids) was superior and recorded 68.17 compared to the control treatment which recorded 47.82 g 100 mg^{-1}For the triple interactions the treatment (irrigation for 7 days with spraying with the osmotic regulator 1 mg L^{-1} amino acid 2 mL L^{-1}) was superior and recorded the highest values of 69.83 compared to the lowest value in the comparison treatment which reached 49.47 g 100 mg^{-1} (Table 2).

4. Effect of osmoregulators and amino acids on the Dry weight of dill under water stress conditions (g)

The factors of the single study and the double and triple interactions were superior in increasing the dry weight of the shoot in the dill plant, as the treatment of spraying with amino acids 2 mL L^{-1} was superior and gave the highest value of 20.76 g $plant^{-1}$ compared to the control treatment which gave 9.19 g $plant^{-1}$, and the double interaction treatment (1 mg L^{-1} osmotic regulator and 2 mL L^{-1} amino acids) recorded 23.63 compared to the control treatment which recorded 7.58 g $plant^{-1}$, and the triple interaction treatment (7 days with spraying with osmotic regulator 1 mg L^{-1} with amino acid 2 mL L^{-1}) gave the highest value of 25.17 g $plant^{-1}$ compared to the comparison treatment which recorded 8.57 g $plant^{-1}$ (Table 2).

5. Effect of osmoregulators and amino acids on the Number of Leaves of dill under water stress conditions

The factors of the single study and the double and triple interactions recorded an increase in the Number of Leaves of the dill plant, as the treatment of spraying with amino acids 2 ml L^{-1} was significantly superior and recorded 30.79 compared to the control treatment which recorded 18.64 leaf $plant^{-1}$ and the double interaction treatment (1 mg L^{-1} osmotic regulator and 2 mL L^{-1} amino acids) was superior and recorded 33.93 compared to the comparison treatment which recorded 16.37 leaf $plant^{-1}$ and the triple interaction treatment (7 days with spraying with osmotic regulator 1 mg L^{-1} with amino acid 2 ml L^{-1}) gave the highest value of 36.57 compared to the comparison treatment which recorded 17.00 leaf $plant^{-1}$ (Table 2).

Table 2. Effect of osmotic regulators and amino acids on water stress resistance on the vegetative trait's dill plant

Treatment	Height (cm $plant^{-1}$)	Number of branch	Chlorophyll (g 100 mg^{-1})	Dry weight (g $plant^{-1}$)	Number of leaves
S_1	45.20 a	12.31 a	62.10 a	16.49 a	26.22 a

S_2	41.58 b	11.15 b	59.88 b	14.72 b	24.53 b
L.S.D	0.650	0.269	0.222	0.420	0.267
O_1	38.16b	9.49 b	58.51 c	11.74 c	21.44 c
O_2	45.62a	12.83 a	61.48 b	17.34 b	27.13 b
O_3	46.40a	12.86 a	62.98 a	17.72 a	27.56 a
L.S.D	0.796	0.329	0.272	0.514	0.327
A_1	32.76 c	8.03 c	51.27 c	9.19 c	18.64 c
A_2	45.90 b	12.23 b	64.94 b	16.86 b	26.69 b
A_3	51.52 a	14.93 a	66.76 a	20.76 a	30.79 a
L.S.D	0.796	0.329	0.272	0.514	0.327
S_1O_1	40.43 d	9.94 e	59.14 e	12.54 d	22.06 e
S_1O_2	47.79 a	13.80 a	62.27 b	18.56 a	28.61 a
S_1O_3	47.39 a	13.18 b	64.88 a	18.36 a	28.00 b
S_2O_1	35.88 e	9.04 f	57.87 f	10.94 e	20.83 f
S_2O_2	43.46 c	11.87 d	60.69 d	16.13 c	25.64 d
S_2O_3	45.41 b	12.54 c	61.08 c	17.08 b	27.11 c
L.S.D	1.125	0.466	0.385	0.727	0.463
S_1A_1	33.93 e	8.42 e	53.49 e	9.71 e	19.10 e
S_1A_2	48.46 c	12.82 c	65.27 b	17.92 c	27.41 c
S_1A_3	53.22 a	15.68 a	67.53 a	21.82 a	32.16 a
S_2A_1	31.58 f	7.63 f	49.04 f	8.67 f	18.18 f
S_2A_2	43.34 d	11.64 d	64.61 d	15.79 d	25.98 d
S_2A_3	49.82 b	14.18 b	65.98 c	19.70 b	29.43 b
L.S.D	1.125	0.466	0.385	0.727	0.463
O_1A_1	29.73 g	6.88 g	47.82 g	7.58 g	16.37 h
O_1A_2	41.53 d	10.30 d	63.37 d	12.58 d	22.63 e
O_1A_3	43.20 c	11.30 c	64.33 c	15.07 c	25.33 d
O_2A_1	33.37 f	8.17 f	50.33 f	9.37 f	18.68 g
O_2A_2	48.22 b	13.35 b	65.93 b	19.03 b	28.77 c
O_2A_3	55.28 a	16.98 a	68.17 a	23.63 a	33.93 a
O_3A_1	35.17 e	9.03 e	55.65 e	10.62 e	20.87 f
O_3A_2	47.95 b	13.05 b	65.52 b	18.95 b	28.68 c
O_3A_3	56.08 a	16.50 a	67.77 a	23.58 a	33.12 b
L.S.D	1.378	0.571	0.471	0.890	0.567
$S_1O_1A_1$	32.00 k	7.63 m	49.47 l	8.57 m	17.00 m
$S_1O_1A_2$	45.03 ef	10.60 ij	63.43 i	12.97 hi	22.97 j
$S_1O_1A_3$	44.27 f	11.60 gh	64.53 gh	16.10 g	26.20 h
$S_1O_2A_1$	34.00 ijk	8.40 lm	50.50 k	9.50 lm	19.07 l
$S_1O_2A_2$	51.40 c	14.43 d	66.47 d	21.00	30.20 e
$S_1O_2A_3$	57.97 a	18.57 a	69.83 a	25.17 a	36.57 a
$S_1O_3A_1$	35.80 i	9.23 kl	60.50 j	11.07 jk	21.23 k
$S_1O_3A_2$	48.93 d	13.43 e	65.90 df	19.80 e	29.07 f

$S_1O_3A_3$	57.43 a	16.87 b	68.23 b	24.20 ab	33.70 b
$S_2O_1A_1$	27.47 l	6.13 n	46.17 m	6.60 n	15.73 m
$S_2O_1A_2$	38.03 h	10.00 jk	63.30 i	12.20 ij	22.30 j
$S_2O_1A_3$	42.13 g	11.00 hi	64.13 h	14.03 h	24.47 i
$S_2O_2A_1$	32.73 jk	7.93 m	50.17 k	9.23 lm	18.30 l
$S_2O_2A_2$	45.03 ef	12.27 fg	65.40 ef	17.07 fg	27.33 g
$S_2O_2A_3$	52.60 c	15.40 c	66.50 d	22.10 cd	31.30 d
$S_2O_3A_1$	34.53 ij	8.83 l	50.80 k	10.17 kl	20.50 k
$S_2O_3A_2$	46.97 e	12.67 ed	65.13 fg	18.10 f	28.30 f
$S_2O_3A_3$	54.73 b	16.13 bc	67.30 c	22.97 bc	32.53 c
L.S.D	1.949	0.807	0.666	1.259	0.802

*S: Irrigation interval; O: Osmotic regulator; A: Amino acids.
*Values that have different letters within a column are significantly different from each other according to LSD test at 0.05 probability level.
*Values that have the same letters within a column are not significantly different from each other according to LSD test at 0.05 Probability level.

The osmotic regulators and amino acids affected the increase in growth indicators, as the results showed (Table 2) that spraying with osmotic compounds and amino acids, which coincided with the most appropriate period for irrigation, had a positive effect on improving and increasing growth, as it increased the concentration of chlorophyll, which was positively reflected on the activity of vital activities within the plant and increased the process of carbon metabolism and increased the number of branches and increased vegetative growth and its positive reflection on increasing the weight of the plant, as nitrogen stimulates the plant to produce auxins (Said-Al Ahl and Sarhan, 2015), and manufacture proteins and activate plant hormones that work to stimulate the division and elongation of meristematic cells (Hussein *et al*., 2015), and its contribution to the process of carbon metabolism and respiration and providing the energy necessary to form new cells, in addition to the fact that amino acids lead to reducing the osmotic potential of the cell, which reduces its water potential (Salman and Sadeq, 2017), thus increasing the cell's ability to draw water and nutrients dissolved in it Spraying with supported osmotic compounds with amino acids and free sugars, which in turn have (active carboxyl and hydroxyl groups), which are scavengers or inhibitors of active reactive oxygen species resulting from water stress (Nieves *et al*, 2016), it may have contributed to increasing the permeability of cell membranes, which facilitates the transfer of nutrients and vital compounds produced by their effect on the hydrophilic and hydrophobic sites on the surfaces of cells, as environmental stresses affect growth and yield, and osmotic compounds work as a protective factor in improving the course of various physiological processes, especially cell division and elongation ,the reason for the plant's resistance to free radicals may also be attributed to stimulating some genes to produce proteins that work to confront the accumulation of active radicals by binding to them, and this is what the two factors contributed to by providing amino acids, in addition to the role of potassium, which is necessary in activating the enzymes that manufacture amino acids and proteins, which helps in the manufacture of chlorophyll, which is important in the process of photosynthesis (Alaarage and Alamery, 2023) and the formation of sugars, proteins and energy compounds ATP, which increased the products of carbon metabolism and the accumulation of the products of this process and its reflection on the increase in the quotient in addition to the plant reaching a state of balance The appropriate nutritional and its positive effect on increasing production (Ziyad *et al*., 2024).

6. Effect of osmoregulators and amino acids on the Protein (%) content of dill under water stress conditions

The factors of the single study and the double and triple interactions recorded an increase in the percentage of protein in the leaves of the dill plant, as the treatment of spraying with amino acids 2 ml L^{-1} was significantly superior and recorded 19.71% compared to the control treatment which recorded 9.74%, and the double interaction treatment (1 mg L^{-1} osmotic regulator and 2 ml L^{-1} amino acids) was superior and recorded 22.18 compared to the comparison treatment which recorded 8.42%, and the triple interaction treatment (7 days with spraying with osmotic regulator 1 mg L^{-1} with amino acid 2 ml L^{-1}) gave the highest value of 23.60 compared to the comparison treatment which recorded 9.27% (Table 3).

7. Effect of osmoregulators and amino acids on the Number of Inflorescences of dill under water stress conditions

The results of the research showed a clear significant effect of the study factors in increasing the number of inflorescences, as the treatment of spraying with amino acids 2 ml L^{-1} was superior and gave the highest value of 38.21 compared to the control treatment, which gave 21.07 inflorescences $plant^{-1}$. The double interaction treatment (1 mg L^{-1} osmotic regulator and 2 ml L^{-1} amino acids) recorded 42.55 compared to the comparison treatment, which recorded 19.07 inflorescences $plant^{-1}$. The triple interaction treatment (7 days with spraying with osmotic regulator 1 mg L^{-1} with amino acid 2 ml L^{-1}) gave the highest value of 45.27 compared to the comparison treatment, which recorded 20.27 inflorescences $plant^{-1}$ (Table 3).

8. Effect of osmoregulators and amino acids on the Vegetative yield of dill under water stress conditions (kg $plant^{-1}$)

The factors of the single study and the double and triple interactions were superior in increasing the dry weight of the green group in the dill plant, as the treatment of spraying with amino acids 2 ml L^{-1} was superior and gave the highest value of 1.597 compared to the control treatment which gave 0.832, and the double interaction treatment (1 mg L^{-1} osmotic regulator and 2 ml L^{-1} amino acids) recorded 1.850 kg m^2 compared to the comparison treatment which recorded 0.672, and the triple interaction treatment (7 days with spraying with osmotic regulator 1 mg L^{-1} with amino acid 2 ml L^{-1}) gave the highest value of 2.319 compared to the irrigation for 14 days with spraying with osmotic regulator 0 mg L^{-1} with spraying with amino acid 0 ml L^{-1} treatment which recorded 0.343 kg (Table 3).

9. Effect of osmoregulators and amino acids on the percentage of volatile oil (%) of dill under water stress conditions

The factors of the single study and the double and triple interactions recorded an increase in the percentage of volatile oil in the leaves of the dill plant, as the treatment of spraying with amino acids 2 ml L^{-1} was significantly superior and recorded 3.243 % compared to the control treatment which recorded 2.225 %, and the double interaction treatment (1 mg L^{-1} osmotic regulator and 2 ml L^{-1} amino acids) was superior and recorded 3.502 % compared to the control treatment which recorded 2.125 %, and the triple interaction treatment (7 days with spraying with osmotic regulator 1 mg L^{-1} with amino acid 2 ml L^{-1}) gave the highest value of 3.670% compared to the irrigation for 14 days with spraying with osmotic regulator 0 mg L^{-1} with spraying with amino acid 0 ml L^{-1} treatment which recorded 2.100 % (Table 3).

Table 3. Effect of osmotic regulators and amino acids on water stress resistance on qualitative characteristics and yield of dill plant

Treatment	Protein (%)	Number of inflorescences	Yield (Kg plant^{-1})	Volatile oil (%)
S_1	15.97 a	31.71 a	1.524 a	2.872 a
S_2	14.53 b	29.15 b	0.858 b	2.701 b
L.S.D	0.316	0.288	0.0192	0.069
O_1	11.86 b	25.02 c	0.964 b	2.50 b
O_2	16.78 a	32.94 b	1.300 a	2.928 a
O_3	17.12 a	33.32 a	1.309 a	2.929 a
L.S.D	0.386	0.353	0.0235	0.084
A_1	9.74 c	21.07 c	0.832 c	2.225c
A_2	16.31 b	32.01 b	1.144 b	2.891b
A_3	19.71 a	38.21 a	1.597 a	3.243a
L.S.D	0.386	0.353	0.0235	0.084
S_1O_1	12.68 d	26.13 e	1.226 c	2.559 c
S_1O_2	17.79 a	34.96 a	1.712 a	3.073 a
S_1O_3	17.46 a	34.03 b	1.635 b	2.990 a
S_2O_1	11.03 e	23.90 f	0.702 f	2.446 c
S_2O_2	15.78 c	30.93 d	0.888 e	2.786 b
S_2O_3	16.79 b	32.61 c	0.982 d	2.866 b
L.S.D	0.547	0.499	0.0333	0.119
S_1A_1	10.07 e	21.64 e	1.248 d	2.250 d
S_1A_2	17.19 c	33.80 c	1.445 b	3.016 b
S_1A_3	20.67 a	39.68 a	1.880 a	3.357 a
S_2A_1	9.42 f	20.49 f	0.416 f	2.200 d
S_2A_2	15.43 d	30.21 d	0.843 e	2.767 c
S_2A_3	18.74 b	36.74 b	1.313 c	3.130 b
L.S.D	0.547	0.499	0.0333	0.119
O_1A_1	8.42 g	19.07 g	0.672 f	2.125 f
O_1A_2	12.32 d	25.95 d	1.003 d	2.540 d
O_1A_3	14.83 c	30.03 c	1.218 c	2.842 c
O_2A_1	9.88 f	21.33 f	0.842 e	2.225 ef
O_2A_2	18.28 b	34.95 b	1.208 c	3.062 b
O_2A_3	22.18 a	42.55 a	1.850 a	3.502 a
O_3A_1	10.93 e	22.80 e	0.982 d	2.325 e
O_3A_2	18.33 b	35.12 b	1.122 c	3.072 b
O_3A_3	22.10 a	42.05 a	1.722 b	3.387 a
L.S.D	0.669	0.611	0.0407	0.146
$S_1O_1A_1$	9.27 k	20.27 n	1.000 g	2.150 hi
$S_1O_1A_2$	12.87 h	27.10 j	1.295 f	2.560 fg
$S_1O_1A_3$	15.90 g	31.03 h	1.383 e	2.967 d

$S_1O_2A_1$	9.93 jk	21.57 m	1.275 f	2.250 hi
$S_1O_2A_2$	19.83 d	38.03 e	1.542 c	3.30 bc
$S_1O_2A_3$	23.60 a	45.27 a	2.319 a	3.670 a
$S_1O_3A_1$	11.00 i	23.10 l	1.468 d	2.350 gh
$S_1O_3A_2$	18.87 e	36.27 f	1.499 cd	3.187 c
$S_1O_3A_3$	22.50 b	42.73 b	1.938 b	3.433 b
$S_2O_1A_1$	7.57 l	17.87 o	0.343 l	2.100 i
$S_2O_1A_2$	11.77 i	24.80 k	0.711 j	2.520 fg
$S_2O_1A_3$	13.77 h	29.03 i	1.053 g	2.717 ef
$S_2O_2A_1$	9.83 k	21.10 mn	0.409 l	2.200 hi
$S_2O_2A_2$	16.73 g	31.87 h	0.874 i	2.823 de
$S_2O_2A_3$	20.77 cd	39.83 d	1.381 e	3.333 bc
$S_2O_3A_1$	10.87 ij	22.50 l	0.496 k	2.300 hi
$S_2O_3A_2$	17.80 f	33.97 g	0.945 h	2.957 d
$S_2O_3A_3$	21.70 bc	41.37 c	1.505 cd	3.340 bc
L.S.D	0.947	0.864	0.0569	0.207

*S: Irrigation interval; O: Osmotic regulator; A: Amino acids.

The increase in the percentage of proteins, the number of inflorescences, the plant yield, and the percentage of volatile oil (Table 3) after spraying with osmotic compounds and amino acids at specific irrigation periods showed that the interaction between the two factors was an important reason for strengthening the plant and fortifying it from free radicals, the concentration of which increases in environmental stress conditions and with the decrease in soil moisture, the advancement of the plant's age, and the rise in temperatures, which in turn contributed to the weakness of the provision of nutrients due to the lack of water, which is the main carrier of these nutrients. Therefore, the spraying technique with the study factors can be considered to have contributed to providing nutrients and amino acids within the plant tissues through the stomata due to the apoplast mechanism to compensate for the deficiency in the root zone. If the components of amino acids have contributed to providing nitrogen, which is important in the biological composition due to its entry as a basis in the composition of proteins (Al-Zuobaiday and Al-Hamzawi, 2016), Therefore, the common factors of the experiment created a balance between the demolition process that the plant tissues were exposed to under stress conditions and the construction process inside the cell by controlling all vital activities through spraying nutrients (Salman and Abdulrasool, 2022), and osmotic protection and controlling vital processes of respiration and photosynthesis and balancing the mechanism of opening and closing the stomata because they contain potassium cations.

Conclusions

The study concluded that the 7 day irrigation period treatment (S1) was more efficient in giving the best growth indicators for dill plant and in combination with spraying with osmotic compounds at a concentration of 1mg L^{-1} (O2) with a good and balanced nutrient content, which was more effective and positive in combination with the foliar spray treatment with amino acids 2 ml L^{-1} (A3) in improving the indicators of vegetative growth quality, yield and production of active compounds in dill plants.

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Conflicts of Interest

Regarding the publication of this manuscript, the authors declare that this work does not conflict with the interests of others.

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Author Contribution

The first and the second authors wrote the original draft, the third and the fourth authors performed the experiments and collected the data, and the remaining authors reviewed and critically edited the manuscript for intellectual content. All authors have read and approved the final version of the manuscript for submission to the journal.

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