Effect of irrigation periods and spraying with jasmonic acid on the some growth characteristics of three broccoli hybrids

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Abstract

The experiment was carried out at the research station of the Department of Horticulture and Landscape Engineering, College of Agriculture, University of Diyala, during the winter agricultural season (2023-2024) for the purpose of studying the effect of irrigation periods and foliar feeding with jasmonic acid on some growth characteristics of three broccoli hybrids. Three hybrids were used in the experiment as first factor Gaith F1, Jassmine F1, and Naxos F1. Two irrigation schedules (every three days and every six days) were the second factor, and three levels of jasmonic acid (0, 10, and 20 mg L-1) were sprayed on the leaves as the third factor. The irrigation treatment every three days gave the highest values for all the studied traits, such as plant height, number of plant leaves, leaf area, dry matter in leaves, and flower disc weight, which reached 59.57 cm, 19.90 leaves per plant-1, 198.78 dm2 leaf-1, 13.82 %, and 0.881 kg plant-1, respectively. The spraying treatment with jasmonic acid at a concentration of 20 mg L-1 was significantly distinguished by giving the highest values in the previous traits, which reached 62.41 cm, 20.96 leaves per plant-1, 204.46 dm2 leaf-1, 13.76%, and 0.892 kg plant-1, respectively. The cultivar (Ghaith F1) recorded the highest value in plant height, 58.62 cm, and dry matter in the leaves, 12.77%, while the cultivar (Naxos F1) achieved the highest value in the number of plant leaves, 19.48 leaves per plant-1. Also, the Jassmine F1 cultivar is superior in leaf area, which reached 189.79 dm2 leaf-1.

Keywords. Broccoli hybrids, irrigation periods, jasmonic acid

Introduction

Broccoli (Brassica oleracea var. Italica) belongs to the Brassicaceae family and is a winter vegetable crop known for about 2700 years in the Mediterranean region and some parts of Asia; the flower disc is the food source in the plant, as the thick stalks are eaten in addition to the buds in the flowering stage [23]. The world's production of broccoli amounted to about 26,058,228.25 tons annually, China ranks first in world production, with a production rate of 37.21% of global production, while Iraq's production amounted to 14247 tons planted on an area of 1476 hectares, with a production rate of 0.05% of global production [12]. Broccoli is characterized by its high nutritional value, as it contains many nutrients, vitamins and proteins, in addition to its medical importance, as it is considered a treatment, regulator and antibiotic for many common diseases, as it helps regulate blood sugar, lowers cholesterol and contributes to protection against heart disease, it also works to lower high blood pressure, in addition to containing high concentrations of Glucosinolates, which when decomposed, give Sulforaphan, which is effective against cancer and osteoporosis, it is also one of the green plants rich in vitamins C, B, E and A, carotenoids and some minerals such as calcium, iron, sodium, phosphorus and potassium [22]. Iraq is one of the areas

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affected by drought due to the climate extremes that the country has recently witnessed, which caused a decrease in rainfall levels as well as a decrease in the level of the Tigris and Euphrates rivers, which led to the decline of agricultural areas, especially those that depend on them for irrigation. Water stress is one of the most important types of environmental stresses that affect the growth and productivity of plants. Drought or lack of soil water can be permanent in climate areas where water availability is low, or it can be random and unpredictable due to changes in weather conditions during the plant's growth season [24]. Drought stress affects the photosynthesis process directly or indirectly by affecting carbohydrate metabolism due to drought stress, Photosynthesis may decrease and competition between the vegetative and reproductive organs of the plant to obtain carbohydrates increases [2]. The introduction or adoption of broccoli varieties with different environmental needs helps in identifying the varieties that meet the desire of the producer and consumer in terms of production, both in terms of quantity and quality, and the possibility of extending the presence of the crop in the markets by choosing early varieties and others that are late in maturity, as there are many broccoli varieties that are grown to distinguish them from others. Importing varieties and hybrids is one of the cheapest and easiest methods of breeding and plant improvement, especially in developing countries, to obtain good genetic structures that can be tested under the conditions of the importing country and selecting what suits its environmental conditions by specialized scientific research centers. Accordingly, choosing the appropriate genetic structure for a crop is one of the most important pillars of its successful cultivation, and it plays an important role in increasing the yield and even occupies the first place among the factors affecting the increase in production [5]. Jasmonate compounds, namely jasmonic acid (JA) and methyl jasmonate (MeJA), along with their intermediates, are important molecular signals and are widely distributed in the plant kingdom and play important roles in responses to biotic and abiotic stresses as well as in processes related to plant growth and development, Jasmonate compounds are also involved in many developmental and vegetative growth processes, such as increasing fruit size and mass [20]. One effective way to increase the production of secondary metabolites in plants is to treat them with chemicals such as jasmonate acid, Several studies have shown that jasmonate compounds stimulate the accumulation of secondary metabolites such as glycosides, alkaloids, and anthocyanins in plants [8]. Therefore, the study aims to evaluate the effect of irrigation periods and jasmonic acid in the growth and yield characteristics of three broccoli genotypes.

Materials and methods

The experiment was carried out at the research station of the Department of Horticulture and Landscape Engineering, College of Agriculture, University of Diyala, during the winter agricultural season 2023-2024 with the aim of studying the effect of irrigation periods and foliar feeding with jasmonic acid in three broccoli hybrids (Ghaith F1, Jassmine F1 and Naxos F1) on the vegetative growth characteristics and quantitative and qualitative characteristics of the broccoli crop. Field soil samples were taken before planting and from different locations within the field boundaries in the shape of the letter (X) from different points and at a depth of (0-0.3 m). These samples were air dried, then mixed

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homogeneously, ground, and sieved with a sieve with a hole area of 2 mm in order to estimate the chemical and physical characteristics of the field soil. The soil samples were analyzed in the postgraduate laboratory of the College of Agriculture, University of Baghdad (Table 1.(

Seed planting

Broccoli seeds of Ghaith F1 cultivar were planted with a purity degree of 99% and a germination rate of 96%, Jassmine F1 seeds with a purity degree of 99% and a germination rate of 90%, and Naxos F1 seeds with a purity degree of 99% and a germination rate of 85% in plastic dishes (128 holes/dish-1) on 25/8/2023. Peat moss was used as a growing medium. The seeds were planted in one of the private nurseries in the Bani Saad district inside a wooden canopy covered with Saran; one seed was placed in each hole, and service operations were carried out on it until it reached the appropriate age for planting in the field, where it was transferred 40 days after planting.

Preparing the ground

The allocated land for the experiment was prepared for cultivation by plowing, smoothing, and leveling it. The experimental land was divided into three sectors, each sector consisting of two terraces. It was divided into 6 furrows, with a length of 40 m and a width of 120 cm, and the distance between them was 60 cm, and each furrow was divided into 9 experimental units, with a length of 3 m and a width of 120 m, and its area was 3.6 m2. Ten plants were planted in each experimental unit, the distance between plants was 50 cm, and a distance of 1 m was left between the experimental units. Organic fertilizer (poultry waste) was added by mixing it with the soil at a depth of (0-0.3 m) two weeks before planting the seedlings and the strip irrigation system was applied with two pipes for each furrow.

Plant cultivation

The seeds of the cultivars were planted in the dishes on 25/8/2023 and the seedlings were transferred to the field on 5/10/2023 and planted in two rows in each furrow with a distance of 50 cm between each plant and beside the irrigation water pipes. Plant service operations were carried out, including irrigation and weed control whenever necessary, and the harvesting process began on 27/12/2023 and continued until 15/1/2024. All plants were sprayed with the pesticide (Carbaryl-85) as a preventive spray to avoid disease, fungal, and insect infections.

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Table 1. The physical and chemical properties of soil

Measurements	Value	Unit of measurement
Texture of soil	Clay mixture	-
Sand	23.14	%
Silt	38.22	%
Clay	31.64	%
Ph	6.11	-
Ec	7.17	$ds.m^{-1}$
N	53	$mg\ kg^{-1}$
P	11.5	$mg\ kg^{-1}$
K	113	$mg\ kg^{-1}$
Organic matter	1.5	%

Experimental design

The experiment was implemented using the Split Split plot system within the Randomized Complete Block Design (RCBD) design. Irrigation period treatments were placed in the main plot, while the genetic compositions were randomly distributed in the secondary plots, sub plot and jasmonic acid concentrations in the sub-sub-plots with three replicates. The total number of experimental units was 54 experimental units, each experimental unit included 10 plants, thus the total number of plants was 540 plants. The data were statistically analyzed using the SAS program (2003) and the averages of the treatments were compared according to Duncan's multiple range test at a probability level of 5% [3.[

The study factors

The study included three factors:

The first factor is irrigation periods, which included two levels:

.1Irrigation every three days (full irrigation) and its symbol is W1 and at a rate of so many irrigations during the study period.

.2Irrigation every six days (deficient irrigation) and its symbol is W2 and at a rate of so many irrigations during the study period

The irrigation process was carried out during the early morning throughout the study period and through the irrigation system. The first general irrigation was carried out at planting on 5/10/2023 and irrigation treatments began on 7/11/2023.

The second factor is the hybrid broccoli cultivars:

.1Hybrid Ghaith F1: of Dutch origin, produced by the Dutch company HOrtON Seeds, and its symbol is V1.

.2Hybrid Jassmine F1: of Dutch origin, produced by the Delta Seeds Company, and its symbol is V2

.3Hybrid Naxos F1: of Japanese origin, produced by the seed company SAKATA, and its symbol is V3

The third factor is spraying with jasmonic acid, which included three levels:

.1The comparison treatment involves spraying with distilled water, and its symbol is JA0.

.2Spraying with jasmonic acid at a concentration of 10 mg L-1 and its symbol is JA1

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.3Spraying with jasmonic acid at a concentration of 20 mg L-1, and its symbol is JA2

The plants were sprayed twice until wet in the morning during the growing season, starting on 7/11/2023 and lasting 21 days between each spray using a 2-liter sprayer, and 0.1 liquid soap was added to it.

Vegetative growth characteristics

Five plants were randomly taken from each experimental unit and the following measurements were made on them.

Plant height (cm(

The plant's height was measured at disc maturity using a measuring tape from the soil contact to the highest leaf tip, and the average was taken.

Number of leaves (leaf plant -1(

It was calculated for five randomly selected plants from each experimental unit and then took the average.

Leaf area (dm2 leaf-1(

Five fully grown leaves were taken at the fifth to eighth node from the tip and in different directions of the plant, and the leaves were weighed to extract the average fresh weight, then 5 discs of known area were taken from them and the weight of these discs was taken to extract the average weight of one disc, and the leaf area was extracted according to the equation [10.[

Leaf area = weight of whole leaf (g) × area of disc (cm2) / weight of cut disc (g(

Dry matter in leaves(%)

Random samples were taken from the leaves of five plants from each experimental unit and weighed directly using a sensitive balance. Then they were sun-dried and then placed in perforated paper bags and placed in an electric oven at 60°C until the weight was stable. Then they were weighed and the following equation was applied to calculate the percentage of dry matter in the leaves:

Percentage of dry matter = (dry weight / wet weight) × 100 [4.[

Flower disc weight (kg plant-1(

It was calculated according to the following equation:

Average weight of the flower disc kg plant-1 = yield of the experimental unit from the floral discs / number of plants in the experimental unit

Results and discussion

Plant height

The results in Table 2 indicate that the Ghaith F1 cultivar was significantly superior in plant height, which reached 58.62 cm, compared to the Naxos F1 cultivar, which gave the lowest rate for the mentioned trait, which reached 56.82 cm. The irrigation treatment every three days gave the highest plant height, which reached 59.57 cm, with a significant difference compared to the irrigation treatment every six days, which gave the lowest rate for the mentioned trait, which reached 55.92 cm. The spraying treatment with jasmonic acid at a concentration of 20 mg L-1 was significantly distinguished by giving the highest plant height, which reached 62.41 cm, compared to the control treatment, which gave the lowest plant height, which reached 50.58 cm. The binary interaction between the cultivars and the irrigation treatment achieved significant results, as the interaction between the Ghaith F1 cultivar and irrigation every three days recorded the highest plant height of 61.31 cm, while the interaction between the Naxos F1 cultivar and irrigation every six days recorded the lowest rate for this trait of 55.62 cm. The binary interaction between irrigation treatment every three days and spraying with jasmonic acid at a concentration of 20 mg L-1 recorded significant results for plant height of 64.45 cm,

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compared to the interaction treatment of irrigation every six days and not spraying with jasmonic acid, which recorded the lowest rate for the mentioned trait of 49.10 cm. The binary interaction between cultivars and spraying with jasmonic acid had a significant effect, as the treatment of spraying with jasmonic acid at a concentration of 20 mg L-1 with the Ghaith F1 cultivar recorded the highest value for plant height, reaching 64.17 cm, compared to the treatment of not spraying with jasmonic acid with the Jassmine F1 cultivar, which recorded the lowest value for this trait, reaching 49.79 cm. The three-way interaction between cultivars, irrigation treatment, and spraying with jasmonic acid (Ghaith F1 + irrigation every three days + jasmonic acid of 20 mg L-1) was significantly superior in giving the highest plant height, reaching 68.05 cm, compared to the treatment of interaction (Naxos F1 + irrigation every six days + control), in which the plant height decreased to 48.55 cm.

Number of leaves

The results in Table 3 indicate a non-significant effect of the cultivars on the number of leaves, while the irrigation treatment every three days gave the highest number of leaves per plant, which reached 19.90 leaves per plant-1, with a significant difference compared to the irrigation treatment every six days, which gave the lowest rate for the mentioned trait, which reached 18.60 leaves per plant-1. The spraying treatment with jasmonic acid at a concentration of 20 mg L-1 was significantly distinguished by giving the highest number of leaves per plant, reaching 20.96 leaves per plant-1, with a significant difference from the control treatment, which gave the lowest percentage, reaching 16.93 leaves per plant-1. The bilateral interaction between the cultivars and the irrigation treatment achieved significant results, as the interaction treatment between the cultivar Ghaith and irrigation every three days recorded the highest rate in the number of leaves per plant, reaching 20.13 leaves per plant-1, while the interaction treatment between the cultivar Ghaith and irrigation every six days recorded the lowest rate for this trait, reaching 18.24 leaves per plant-1. As for the bilateral interaction between irrigation and jasmonic acid, the interaction treatment of irrigation every three days and spraying with jasmonic acid at a concentration of 20 mg L-1 recorded a significant difference in the number of leaves per plant, reaching 21.60 leaves per plant-1, compared to the interaction treatment of irrigation every six days and not spraying with Jasmonic acid, which recorded the lowest rate for the mentioned trait, amounted to 16.38 leaves per plant-1. The bilateral interaction between the cultivars and spraying with jasmonic acid had a significant effect, as the jasmonic acid at a concentration of 20 mg L-1 with the Naxos cultivar recorded the highest value in the number of leaves per plant, amounting to 20.98 leaves per plant-1, compared to the treatment of not spraying with jasmonic acid with the Jassmine cultivar, which recorded the lowest value for this trait, amounting to 16.83 leaves per plant-1. The triple interaction between the cultivars, irrigation and spraying with jasmonic acid (Ghaith F1 + irrigation every three days + jasmonic acid of 20 mg L-1) was significantly superior by giving the highest rate in the number of leaves per plant, amounting to 22.33 leaves per plant-1, compared to the interaction treatment (Jassmine F1 + irrigation every six days + control), which decreased the number of leaves per plant to 16.32 leaves per plant-1.

Leaf area

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The results in Table 4 indicate that the Jassmine F1 cultivar is superior in leaf area, which reached 189.79 dm2 leaf-1 compared to the Ghaith F1 cultivar, which gave the lowest rate for the mentioned trait, which reached 176.53 dm2 leaf-1. The irrigation treatment every three days gave the highest leaf area, which reached 198.78 dm2 leaf-1, with a significant difference compared to the irrigation treatment every six days, which gave the lowest rate for the mentioned trait, which reached 166.77 dm2 leaf-1, while the spraying treatment with jasmonic acid at a concentration of 20 mg L-1 was significantly distinguished by giving the highest leaf area, which reached 204.46 dm2 leaf-1 compared to the control treatment, which gave the lowest leaf area, which reached 160.94 dm2 leaf-1. The bilateral interaction between the cultivars and irrigation treatment achieved significant results, as the interaction between the second cultivar Jassmine F1 and irrigation every three days recorded the highest leaf area, reaching 208.09 dm2 leaf-1, while the interaction between the first cultivar Ghaith F1 and irrigation every six days recorded the lowest rate for this trait, reaching 155.39 dm2 leaf-1. As for the bilateral interaction between irrigation and jasmonic acid, the interaction between irrigation every three days and spraying with jasmonic acid at a concentration of 20 mg L-1 recorded the highest rate of leaf area, reaching 216.98 dm2 leaf-1, with a significant difference from the interaction between irrigation every six days and not spraying with jasmonic acid, which recorded the lowest rate for the mentioned trait, reaching 141.99 dm2 leaf-1. The binary interaction between cultivars and spraying with jasmonic acid had a significant effect on leaf area, as the treatment of spraying with jasmonic acid at a concentration of 20 mg L-1 with the Jassmine F1 cultivar recorded the highest leaf area of 217.15 dm2 leaf-1 compared to the interaction treatment of not spraying with jasmonic acid with the first cultivar Ghaith F1, which recorded the lowest value for this trait of 158.01 dm2 leaf-1. The results of the table indicate that the triple interaction treatment between cultivars, irrigation and spraying with jasmonic acid (Jassmine F1 + irrigation every three days + jasmonic acid of 20 mg L-1) was significantly superior by giving the highest leaf area of 238.86 dm2 leaf-1 compared to the interaction treatment (Ghaith F1 + irrigation every six days + control), in which the leaf area decreased to 135.59 dm2 leaf-1.

Dry matter in leaves

The results in Table 5 indicate that the Ghaith F1 cultivar was significantly superior in the percentage of dry matter in the leaves, which reached 12.77% compared to the Naxos F1 cultivar, which gave the lowest rate for the mentioned trait, which reached 12.02%, while the irrigation treatment every three days gave the highest percentage of dry matter in the leaves, which reached 13.82%, with a significant difference from the irrigation treatment every six days, which gave the lowest rate for the mentioned trait, which reached 10.73%. The spraying treatment with jasmonic acid at a concentration of 20 mg L-1 was significantly distinguished by giving the highest percentage of dry matter in the leaves, which reached 13.76% compared to the control treatment, which gave the lowest percentage, which reached 10.50%. The binary interaction between the cultivars and the irrigation treatment achieved significant results, as the interaction treatment between the first cultivar, Ghaith F1, and irrigation every three days recorded the highest percentage of dry matter in the leaves,

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reaching 15.20%, while the interaction treatment between the second cultivar, Jassmine F1, and irrigation every six days recorded the lowest rate for this trait, reaching 10.21%. As for the bilateral interaction between irrigation and jasmonic acid, the interaction treatment between irrigation every three days and spraying with jasmonic acid at a concentration of 20 mg L-1 recorded the highest rate of dry matter percentage in the leaves, reaching 15.47%, with a significant difference compared to the interaction treatment between irrigation every six days and not spraying with jasmonic acid, which recorded the lowest rate for the mentioned trait, reaching 9.10%. Also, the bilateral interaction between the cultivar Ghaith F1 and spraying with jasmonic acid at a concentration of 20 mg L-1 had the highest value for dry matter percentage in the leaves, reaching 14.34%, with a significant difference from the interaction treatment of not spraying with jasmonic acid with the second cultivar Jassmine F1, which recorded the lowest value for this trait, reaching 10.22%. The triple interaction between cultivars, irrigation, and spraying with jasmonic acid (Ghaith F1 + irrigation every three days + jasmonic acid of 20 mg L-1) was significantly superior in giving the highest percentage of dry matter in the leaves, reaching 17.11%, compared to the interaction treatment (Jassmine F1 + irrigation every six days + control), in which the percentage of dry matter decreased to 8.28%.

Flower disc weight

The results in Table 6 indicate a non-significant effect of the cultivar on flower disc weight. The irrigation treatment every three days gave the highest flower disc weight of 0.881 kg plant-1 with a significant difference compared to the irrigation treatment every six days, which gave the lowest rate of the mentioned trait of 0.714 kg plant-1. The spraying treatment with jasmonic acid at a concentration of 20 mg L-1 was significantly distinguished by giving the highest flower disc weight of 0.892 kg plant-1 compared to the control treatment which gave the lowest weight of 0.675 kg plant-1. The bilateral interaction between cultivars and irrigation achieved significant results, as the interaction between the Ghaith F1 cultivar and irrigation every three days recorded the highest flower disc weight of 0.888 kg plant-1, while the interaction between the Jassmine F1 cultivar and irrigation every six days recorded the lowest rate for this trait of 0.684 kg plant-1. As for the bilateral interaction between irrigation and jasmonic acid, the interaction between irrigation every three days and spraying with jasmonic acid at a concentration of 20 mg L-1 recorded the highest significant rate for flower disc weight of 0.995 kg plant-1, compared to the interaction between irrigation every six days and not spraying with jasmonic acid, which recorded the lowest rate for the mentioned trait of 0.610 kg plant-1. The bilateral interaction between cultivars and spraying with jasmonic acid had a significant effect, as the treatment of spraying with jasmonic acid at a concentration of 20 mg L-1 with the cultivar Jassmine F1 recorded the highest value for the weight of the flower disc, which amounted to 0.898 kg plant-1, compared to the treatment of not spraying with jasmonic acid with the second cultivar Jassmine F1, which recorded the lowest value for this trait, which amounted to 0.610 kg plant-1. The triple interaction between cultivars, irrigation and spraying with jasmonic acid (Ghaith F1 + irrigation every three days + jasmonic acid of 20 mg L-1) was significantly superior in giving the highest weight of the flower disc, which amounted to

1.01 kg plant-1, compared to the treatment of interaction (Jassmine F1 + irrigation every six days + control), in which the weight of the flower disc decreased to 0.500 kg plant-1.

The previous results show that there are significant differences between the cultivars in the traits of number of leaves per plant, leaf area, and plant height, This variation is due to the genetic content of these hybrids, which is consistent with what was stated by [1]. The Jassmine F1 cultivar may affect leaf area due to its genetic composition, This superiority may also be attributed to its efficiency in the process of carbon representation of the leaves, The results also indicate the superiority of the Naxos F1 in the trait of the number of leaves; also, the trait of plant height was significantly affected in this variety, The superiority of this hybrid may be attributed to the fact that it is the most efficient in the food conversion process in the leaves, which leads to an increase in the vegetative growth of the plant, This is consistent with what was reached by [6,15,27]. The traits of vegetative growth are mostly determined by genetic factors, but the environment can also have an effect on the growth of these genetic compositions [7,11,13,18]. The difference in genetic compositions in plant height may be attributed to the number of nodes and the length of the internodes as a result of their differences in the primary and secondary genes for shortening [21] or to the difference in their content of the hormones of gibberellin and auxin, which are responsible for cell elongation and expansion [16.[

The plant's height is attributed to maintaining optimal soil moisture along with the availability of nutrients in the soil through irrigation, which improves nutrient uptake, faster cell division, and cell enlargement [17]. These results are in agreement with [9,19]. The decrease in the characteristics of vegetative growth in the treatment of irrigation period every six days may be attributed to the fact that the damage resulting from the effect of water stress is linked to specific effects related to the change in the state of the protoplasm and that reducing water leads to an increase in the concentration of solutes according to the size of the protoplasm, which leads to shrinkage and wrinkling, which has serious effects on the chain of life processes in the living cell, and that the integrity of membranes and proteins is also affected by the process of reducing irrigation periods, which leads to the occurrence of a functional disorder in life processes, and that thirsting the plant leads to the disruption of the structure of the normal bilayer of biological membranes and that the lines of channels through which water enters will be filled with the main groups of polar phospholipids, as the membranes become permeable to fluids when hydration occurs, these channels will continue to provide large quantities of penetrating or filtering solutes between the chambers and from the cell to the intercellular spaces [26]. The results showed that jasmonic acid has a certain mitigating effect on plant stress damage, in addition, jasmonic acid can reduce the harmful effects of transport stress on broccoli by increasing its vitamin C content, inhibiting the accumulation of reactive oxygen species, and stimulating the gene expression of antioxidants and enzyme activities [25]. The reason for the increase in vegetative indicators may be due to jasmonic acid, as it is a growth regulator, as jasmonic acid affects the growth and development of the plant by accelerating cell division and elongation, which leads to an increase in vegetative indicators, which contributes to increasing the total yield and improving its quality. Improving the

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nutritional status of the plant also contributed positively to increasing vegetative indicators, which was ideally reflected in increasing the quantitative and qualitative yield of red cabbage [14.[

Conclusion

This study reveals significant variation among the studied hybrids in most traits, indicating genetic diversity, which is beneficial for farmers when severe conditions occur that may impact hybrids differently. Irrigation every three days yielded the best vegetative growth results. Additionally, foliar spraying with jasmonic acid, particularly at a concentration of 20 mg L^{-1}, significantly improved vegetative growth traits.

Table 2. Effect of irrigation periods and spraying with jasmonic acid on plant height for three broccoli hybrids

Cultivars	Irrigation periods	Jasmonic acid			Cultivars × irrigation periods
		Control	10 mg L^{-1}	20 mg L^{-1}	
Ghaith F1	3 days	52.11 g	63.77 bc	68.05 a	61.31 A
	6 days	49.27 hi	58.27 ef	60.29 edf	55.94 C
Jassmine F1	3 days	51.04 gh	62.38 cd	64.77 b	59.39 B
	6 days	48.55 i	58.05 f	62.05 cd	56.21 C
Naxos F1	3 days	53.02 g	60.49 ed	60.55 ed	58.02 B
	6 days	49.49 hi	58.60 ef	58.77 ef	55.62 C
					Average of Irrigation periods
Irrigation periods × Jasmonic acid	3 days	52.05 e	62.21 b	64.45 a	59.57 A
	6 days	49.10 f	58.31 d	60.37 c	55.92 B
					Average of cultivars
Cultivars × Jasmonic acid	Ghaith F1	50.69 c	61.02 b	64.17 a	58.62 A
	Jassmine F1	49.79 c	60.21 b	63.41 a	57.80 B
	Naxos F1	51.25 c	59.55 b	59.66 b	56.82 C
Average of Jasmonic acid		50.58 C	60.26 B	62.41 A	

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Table 3. Effect of irrigation periods and spraying with jasmonic acid on number of leaves in plant for three broccoli hybrids

Cultivars	Irrigation periods	Jasmonic acid			Cultivars × irrigation periods
		Control	10 mg L^{-1}	20 mg L^{-1}	
Ghaith F1	3 days	17.49 hi	20.58 bcd	22.33 a	20.13 A
	6 days	16.33 i	18.83 fg	19.56 def	18.24 D
Jassmine F1	3 days	17.16 hi	20.16 bcde	21.33 ab	19.55 B
	6 days	16.50 i	19.00 ef	20.58 bcd	18.69 CD
Naxos F1	3 days	17.83 gh	21.16 ab	21.16 ab	20.05 AB
	6 days	16.32 i	19.66 cdef	20.80 cb	18.92 C
					Average of Irrigation periods
Irrigation periods × Jasmonic acid	3 days	17.49 d	20.63 b	21.60 a	19.90 A
	6 days	16.38 e	19.16 c	20.26 b	18.60 B
					Average of cultivars
Cultivars × Jasmonic acid	Ghaith F1	16.91 d	19.70 bc	20.94 a	19.18 A
	Jassmine F1	16.83 d	19.58 c	20.88 a	19.09 A
	Naxos F1	17.07 d	20.41 ab	20.98 a	19.48 A
Average of Jasmonic acid		16.93 C	19.89 B	20.96 A	

Table 4. Effect of irrigation periods and spraying with jasmonic acid on leaf area for three broccoli hybrids

Cultivars	Irrigation periods	Jasmonic acid			Cultivars × irrigation periods
		Control	10 mg L^{-1}	20 mg L^{-1}	
Ghaith F1	3 days	180.44 efg	204.21 bc	208.37 b	197.67 A
	6 days	135.59 i	142.51 hi	188.08 defg	155.39 C
Jassmine F1	3 days	181.55 efg	203.87 cb	238.86 a	208.09 A
	6 days	141.86 hi	177.17 g	195.45 cd	171.49 BC
Naxos F1	3 days	177.71 g	190.34 def	203.72 cb	190.59 AB
	6 days	148.53 h	179.48 fg	192.30 cde	173.43 BC
					Average of Irrigation periods
Irrigation periods × Jasmonic acid	3 days	179.90 d	199.47 b	216.98 a	198.78 A
	6 days	141.99 f	166.38 e	191.94 c	166.77 B
					Average of cultivars
Cultivars × Jasmonic acid	Ghaith F1	158.01 e	173.36 d	198.22 b	176.53 A
	Jassmine F1	161.70 e	190.52 cb	217.15 a	189.79 A
	Naxos F1	163.12 e	184.91 c	198.01 b	182.01 A

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Average of Jasmonic acid	160.94 C	182.93 B	204.46 A

Table 5. Effect of irrigation periods and spraying with jasmonic acid on the percentage of dry matter in leaves for three broccoli hybrids

Cultivars	Irrigation periods	Jasmonic acid			Cultivars × irrigation periods
		Control	10 mg L^{-1}	20 mg L^{-1}	
Ghaith F1	3 days	13.03 de	15.48 b	17.11 a	15.20 A
	6 days	9.01 ij	10.42 gh	11.58 fg	10.33 E
Jassmine F1	3 days	12.17 ef	14.25 bcd	15.28 bc	13.90 B
	6 days	8.28 j	10.42 gh	11.94 ef	10.21 E
Naxos F1	3 days	10.51 gh	12.60 ef	14.02 cd	12.37 C
	6 days	10.03 hi	12.29 ef	12.68 fe	11.66 D
					Average of Irrigation periods
Irrigation periods × Jasmonic acid	3 days	11.90 c	14.11 b	15.47 a	13.82 A
	6 days	9.10 e	11.04 d	12.06 c	10.73 B
					Average of cultivars
Cultivars × Jasmonic acid	Ghaith F1	11.02 e	12.95 bcd	14.34 a	12.77 A
	Jassmine F1	10.22 e	12.33 d	13.61 ab	12.05 B
	Naxos F1	10.27 e	12.44 cd	13.35 bc	12.02 B
Average of Jasmonic acid		10.50 C	12.57 B	13.76 A	

Table 6. Effect of irrigation periods and spraying with jasmonic acid on flower disc weight for three broccoli hybrids

Cultivars	Irrigation periods	Jasmonic acid			Cultivars × irrigation periods
		Control	10 mg L^{-1}	20 mg L^{-1}	
Ghaith F1	3 days	0.756 de	0.900 b	1.01 a	0.888 A
	6 days	0.673 gf	0.746 de	0.760 de	0.726 B
Jassmine F1	3 days	0.720 ef	0.913 b	0.973 a	0.868 A
	6 days	0.500 h	0.730 def	0.823 c	0.684 B
Naxos F1	3 days	0.750 de	0.910 b	0.996 a	0.885 A
	6 days	0.656 g	0.750 de	0.790 cd	0.732 B
					Average of Irrigation periods
Irrigation periods × Jasmonic acid	3 days	0.742 d	0.907 b	0.995 a	0.881 A
	6 days	0.610 e	0.742 d	0.791 c	0.714 B
					Average of cultivars
Cultivars × Jasmonic acid	Ghaith F1	0.715 c	0.823 b	0.888 a	0.808 A
	Jassmine F1	0.610 d	0.821 b	0.898 a	0.776 A

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	Naxos F1	0.703 c	0.830 b	0.893 a	0.808 A
Average of Jasmonic acid		0.675 C	0.824 B	0.892 A	

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