Role of Jasmonic acid and Nano-fertilizer in the vegetative growth indicators of three cultivars of Rocket Plant (*Eruca sativa* Mill.)

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Abstract

The experiment was conducted in the orchards and nurseries development project belonging to Karbala Agriculture Directorate for the two seasons 2020-2021 and 2021-2022 to study the physiological effects of jasmonic acid (JA) and NPK Nano-fertilizer on the vegetative growth indicators of three cultivars of rocket plant (*Eruca sativa* Mill). The experiment was designed according to the split split plot design using the Randomized Complete Block Design (R.C.B.D). This experiment included 27 treatments from three factors distributed randomly with three replicates (81 experimental units). The first factor represented by three cultivars of rocket plant; (French, Turkish, and the local cultivar) was set up in the main plots. The second factor, NPK nano fertilizer (0, 2, 4) $g.L^{-1}$ was set up in the subplots, while the third factor comprised three concentrations of jasmonic acid JA (0, 15, 30) mg. L^{-1} was set up in the sub-subplots. The most important results indicated that spraying with jasmonic acid and nano fertilizer on the three varieties of rocket plants revealed significant differences in the studied indicators. The local cultivar that was sprayed with nano-fertilizer at 4 $g.L^{-1}$ significantly excelled, and jasmonic acid at 30 $mg.L^{-1}$ denoted by (V1N2J2) gave the highest results for both seasons compared to plants of the other two cultivars in all indicators of plant vegetative growth. The average plant height was (87.91 and 88.37 cm), number of leaves per plant (28.41 and 28.73 leaves), leaf area(774.67 and 717.57 $cm.plant^{-1}$), dry weight of vegetative growth(8.53 and 7.43 $g.plant^{-1}$) and the productivity of leaves (2440.7 and 2328.6 $g.m^2$) for both seasons, respectively. However, the plants of the French cultivar, which were sprayed with distilled water (J0N0V2) recorded the lowest results (55.68 and 55.89 cm) and (13.69 and 13.65 $leaves.plant^{-1}$), (327.43 and 294.80 $cm^2.plant^{-1}$), (5.83 and 5.75 $g.plant^{-1}$), and (1258.4 and 1136.5 $g.m^2$) for both seasons of the experiment, consecutively.

Keywords: Rocket plant, Nano NPK, Jasmonic acid, Vegetative growth.

Introduction

The rocket plant (*Eruca sativa* Mill.) is one of the plants of the Brassicaceae family and it is a multi-purpose vegetable plant. It is believed that its original country is central Asia and Eastern Europe, and it is cultivated well in the Mediterranean countries, Egypt, Saudi Arabia, India, and Iran (8). Rocket leaves have a high nutritional value, as they contain fats and carbohydrates as well as vitamins, including vitamins A, B1, B2, B3, and C, elements of sodium, potassium, calcium, iodine, phosphorous, iron, zinc, spicy sulfur materials, vegetable oils, and peroxide. Because of the nutritional and medicinal importance of the rocket plant, it is necessary to search for modern agricultural means to increase the leaf yield .The cultivation of cultivars and the introduction of new ones is one of the important strategies for improving production in terms of quantity and quality. It is observed that the vegetative growth of rocket plants is affected by many factors such as the genetic composition of plants (10). In recent years, modern science has turned to the use of nano-fertilizers to accelerate growth and improve production quantitatively and qualitatively. It was also noted that nanotechnology has benefits in agricultural systems where it is possible to arrange agricultural inputs and technology to increase the effectiveness of their active substances and reduce their added quantities, and decrease pollution in the ecosystem (6). Thus, the vegetative growth of a rocket and its seed yield is affected by the type of fertilizer applied, especially nitrogen (11, 20). Jasmonic acid was considered a growth regulator at the World Conference on Plant Growth Regulators held in the mid-1980s. This compound was isolated for the first time from the fungus *Lasiodiplodia theobromae*, but more attention was paid to one of the jasmonic derivatives, which is methyl jasmonate (MeJA) because of its aromatic smell, and it was extracted from the essential oils of *Jasminum grandiflorum* and *Rosmarinus officinalis*. The experiment aims to use foliar spraying of jasmonic acid and Nano-fertilizers and their effect on the vegetative growth indicators of three cultivars of the rocket plant.

Materials and Methods

Field and crop management

This research was conducted for the two seasons 2020-2021 and 2021-2022 in the orchards and nurseries development project located in Karbala Agriculture Directorate, Iraq. The field soil was ploughed followed by harrowing operations then it was divided into plots with an area of (2.5 m x 1.5 m) and each plot consisted of 8 lines, each line contanaing 10 plants.The lines of each experimental unit were divided into two parts besides the two guard lines, three lines were used for measurements of vegetative growth indicators, and the other three lines were used for measurements of seed yield and oil indicators. Three cultivars of rocket plant; (French, Turkish, and the local cultivar) were planted for two seasons aforementioned. The nano-NPK fertilizer was sprayed twice on the plant's vegetative part after the appearance of 3-4 true leaves, followed by the first spray of jasmonic acid after 20 days of planting, and the second spray of nano-NPK after 30 days of planting, followed by the second spray of jasmonic acid after 40 days of planting, i.e. the period between one spraying and another, was ten days. A third spray was applied to rocket plants after 60 days of planting. It started by spraying nano-NPK, followed by spraying jasmonic acid for ten days before the beginning of flowering (16). The crop

management was conducted as recommended like irrigation, hoeing, and weeding. The maximum and minimum temperatures, their averages, the number of hours of sunshine, and relative humidity were taken with the help of the General Authority for Meteorology and Seismic Monitoring/Meteorological Department in Karbala, Iraq.

Experimental design and treatments:

The experiment was conducted according to the split-split plot system using the Randomized Complete Block Design (RCBD) with three replicates, comprising of 81 experimental units. The cultivars were placed in the main plots, and the treatments of spraying with nano-fertilizers were placed in subplots, while the treatments of spraying with different concentrations of jasmonic acid were placed in the sub-subplots. The means were compared by Duncan's Multiple Range Test at a probability level of 0.05 (4) using SAS Version 9.4 (SAS Institute Inc. 2012).

3-The studied indicators: -

1- Plant height (cm): Ten plants were taken from each experimental unit randomly and their height was measured from the surface of the soil to the top of the plant when it reached the flowering stage, using the tape measure then the average was calculated.

2- Number of leaves per plant (leaf. plant^{-1}): A random sample of ten plants was taken for each experimental unit, according to the average.

3- Leaf area (cm^2. plant^{-1}): Five full-width leaves were taken from five plants at random in the experimental unit, and were measured by the method used by Al-Zaidi (2) and described by Sadik *et al.* (17) using a scanner with the program Digimizer loaded on the computer and then take the average to calculate the area of one sheet.

4- The dry weight of the vegetative growth (g.plant^{-1}): Ten plants were taken at random and according to their fresh weight, then they were dried in an electric oven at a temperature of 75 °C for 48 hours. After the weight of the plants was stable, the average dry weight of one plant was calculated.

5- Leaves productivity (g.m^2): All harvested plants in each experimental unit after cutting were weighed with the level of the soil surface in the field immediately after harvest, then the productivity was calculated based on square meters for both seasons of the experiment.

Results and Discussion

Plant height (cm):

Table (1) indicates the effect of jasmonic acid (JA) and nano-fertilizer on the plant height (cm) for the three cultivars of the rocket plants for both seasons of the experiment. The plants of the local cultivar significantly outperformed for both seasons compared to the plants of the other two cultivars, as well as the plants of the Turkish cultivar were superior to the French cultivar plants. This may be due to the nature of the difference between the genotypes of the rocket cultivars or the suitability of the environmental conditions for them, which led to a discrepancy in the efficiency of the photosynthesis process and thus affecting the vegetative growth stage, including plant height. This is consistent with Mahmoud (7), who proved that there is a discrepancy in the results of the studied traits of different genotypes. It was also shown that the increase in the concentration of nano-fertilizer applied had a significant effect on increasing the the

plant height for both seasons. The increase in the studied trait may be due to the distinct properties of the nano-fertilizer resulting the smallness of the particles, which led to an increase in the rate of its absorption and spread, accompanied by stimulating plant growth (12). Hence, this led to providing the plant's need for the macronutrients necessary for the processes of photosynthesis, respiration, and various metabolic processes that have a major role in the process of cell division and elongation, which is positively reflected in the plant height. It was also found that spraying with jasmonic acid (JA) had a significant effect on increasing the plant height for both seasons of the experiment. This is consistent with what was found by Sheteawi (18). The application of JA helped to increase the concentration of K, and N elements necessary for building cells and increase the activity of the carbon metabolism process and thus increasing the plant's ability to retain water, thus reflected in the increase in the number of cells and then an increase in the rate of the plant height. The triple interaction between the experimental factors had a significant effect on this trait. The local cultivar that was sprayed with nano-fertilizer at a concentration of 4 g. L^{-1} and jasmonic acid at 30 mg. L^{-1} (V1N2J2) had the highest mean in the plant height for both seasons recorded 87.91 and 88.37 cm, respectively, compared to the lowest mean were 55.68 and 55.89 cm, consecutively, which resulted from plants of the French cultivar sprayed with distilled water only (V2N0J0).

Number of leaves (leaf. $plant^{-1}$)

Table (2) refers to the effect of jasmonic acid (JA) and nano-fertilizer on the number of leaves per plant (leaf. $plant^{-1}$) for the three cultivars of rocket plants. The cultivars had a significant effect on the average number of leaves per plant. The plants of the local cultivar (V1) showed significant superiority for both seasons compared to the plants of the other two cultivars. While the plants of the

Turkish cultivar (V3) provided significant superiority in comparison with the French cultivar (V2), which recorded the lowest results in the average number of leaves. The significant variance between the studied cultivars in the average number of leaves per plant may be due to the nature of the variation between the genetic structures of the rocket cultivars or the adaptability of the varieties to the environmental circumstances, which resulted in a discrepancy in the efficiency of the photosynthesis process and then the amount of material accumulated in plants. The nutrients in plants have a significant role in the number of leaves formed during the vegetative growth stage (4), also, the nature of genetic differences between the cultivated plant varieties plays a role in the formation of leaves on the plant stem. It was also found that increasing the concentration of the nano-fertilizer had a significant increase in the number of leaves per plant for both seasons. As its effect increases with the increase in the concentration of the nano-fertilizer, this increase may be attributed to the fact that the foliar application with Nano-NPK fertilizer has a role in many physiological processes

such as photosynthesis. These results are consistent with the findings of Taiz and Zeiger (19). It is also clear that spraying with jasmonic acid has a significant effect in increasing the studied plant trait, for both seasons, at a concentration of 30 mg. L^{-1} (J2) recorded an average number of leaves 20.86 and 21.02 leaves. $plant^{-1}$, consecutively, compared to the other two treatments. The treatment (J1) was superior in this trait reaching 19.77 and 19.87 leaves. $plant^{-1}$, respectively, compared to the control treatment (J0) which recorded the lowest

results 18.28 and 18.45 leaves. plant^{-1}, consecutively. The spraying of JA helped to increase the concentration of elements activity of the carbon metabolism process,

Table 1. Effect of jasmonic acid (JA) and Nano-fertilizer on plant height (cm) for the three cultivars of rocket plant

Plant cultivars (V)	Jasmonic acid ($mg.L^{-1}$)	First season			Second season		
		Nano fertilizer ($g.L^{-1}$)			Nano fertilizer ($g.L^{-1}$)		
		$(N_0)0$	$(N_1)2$	$(N_2)4$	$(N_0)0$	$(N_1)2$	$(N_2)4$
Local cultivar V_1	(J_0) 0	62.74 m	75.38 fg	80.94 c	64.18 m-o	74.42 f-i	81.42 b-d
	(J_1) 15	68.65 jk	76.72 ef	85.29 b	69.64 i-l	77.53 d-g	84.6 ab
	(J_2) 30	70.50 i	79.29 cd	87.91 a	71.66 h-k	80.81 b-e	88.37 a
French cultivar V_2	(J_0) 0	55.68 o	67.53 k	74.67 g	55.89 q	66.63 k-n	75.46 f-h
	(J_1) 15	61.98 m	69.38 ij	76.40 efg	59.43 o-q	68.55 j-m	77.37 d-g
	(J_2) 30	62.95 m	72.51 h	79.56 cd	62.75 n-p	72.87 g-j	80.91 b-e
Turkish cultivar V_3	(J_0) 0	57.57 n	70.04 ij	77.22 e	58.72 pq	70.81 h-l	78.42 c-f
	(J_1) 15	62.37 m	72.57 h	79.12 d	62.73 n-p	72.48 g-j	81.56 b-d
	(J_2) 30	65.11 l	74.83 g	80.83 cd	65.62 l-n	75.77 e-h	83.04 bc
Plant cultivars (V)		V1	V2	V3	V1	V2	V3
		76.38 A	68.96 C	71.07 B	76.96 A	68.87 C	72.13 B
Nano fertilizer		N_0	N_1	N_2	N_0	N_1	N_2
		63.06 C	73.14 B	80.22 A	63.40 C	73.32 B	81.24 A
Jasmonic acid		J0	J1	J2	J0	J1	J2
		69.08 C	72.50 B	74.83 A	69.55 C	72.65 B	75.75 A

The averages with the same letters within each factor and the interactions are not significantly different from each other according to Duncan's multiple range test at the probability level of 0.05.

and thus increasing the ability of the plant to retain water. This is reflected in the increase in the number of cells and then in an increase in the growth characteristic Sheteawi (2007). The triple interaction between the experimental factors had a significant effect on this trait. The plants of the local cultivar that were sprayed with nano-fertilizer at a concentration of 4 g. L^{-1} and jasmonic acid at 30 mg. L^{-1} (V1N2J2) had the highest mean in the number of leaves per plant for both seasons recorded 28.41 and 28.73 leaves. plant $^{-1}$, consecutively, compared to the lowest average of 13.69 and 13.65 leaves. plant $^{-1}$, respectively, which were obtained from plants of the French cultivar that were sprayed with distilled water only (V2N0J0).

Leaf area (cm^2. $plant^{-1}$)

Table (3) shows the effect of jasmonic acid (JA) and nano-fertilizer on the leaf area (cm^2. $plant^{-1}$) for the three varieties of rocket, that the cultivar had a significant effect on the leaf area, where the plants of the local cultivar significantly excelled on both seasons of the experiment compared to the plants of the other two cultivars, as well as the Turkish cultivar excelled on French cultivar. The reason may be due to the cultivar's genetic background and the fitness of the environmental conditions, which were reflected in the vigorous growth of the root and the vegetative part of plants, which are the center of plant hormone production. It was also shown that increasing the concentration of the nano-fertilizer applied had a significant effect on increasing the leaf area for both seasons of the experiment. As its effect increased as the concentration of the applied nano-fertilizer increased, the increase in the leaf area may be due to the positive effect resulting from the application of nano-fertilizer in improving the vegetative growth of the plant by increasing the leaf area due to an increase in the surface area of the leaves, which leads to enhancing the fixation of nutrients and then its effect on increasing the area of the leaf, while potassium has an effective role in increasing absorption and obtaining the process of turgor pressure, which increases the absorption of water and nutrients, which leads to an increase in the leaf area, in agreement with Kumar (13). It is also clear that spraying with jasmonic acid has a significant effect in increasing the leaf area for both seasons, where the effect increases with the increase in the concentration of spraying with plant hormones. The results confirmed that spraying plants with jasmonic acid had a positive effect on the vegetative growth traits of the rocket plant due to its role in protecting the plant and improving growth by stimulating the process of carbon metabolism and increasing pigments, thus improving the role of the elements involved in it in a number of different metabolic processes, stimulating growth and encouraging cell walls on growth and elongation, nitrogen promotes plant growth, where the rise of CO_2 leads to an increase in the absorption of carbon by increasing the area of the leaves, and the use of phosphorus at the required level is due to permeability of the membranes to important nutrients, which leads to improving vegetative growth, including the leaf area of the plant. This agrees with Ahmad *et al*. (9). The triple interaction between the experimental factors had a significant effect on this trait, where it gave the plants of the local cultivar that were sprayed with Nano-fertilizer at a concentration of 4 g. L^{-1} and jasmonic acid 30 mg L^{-1} (V1N2J2) had the highest rate in th leaf area per plant for both seasons of the experiment. They were 774.67 and 717.57 cm^2.$plant^{-1}$, respectively, compared to the lowest average, which was recorded as 327.43

and 294.80 $cm^2.plant^{-1}$, consecutively, that resulted from plants of the French cultivar

Table 2. Effect of jasmonic acid (JA) and Nano-fertilizer on the number of leaves per plant (leaf. $plant^{-1}$) for the three cultivars of rocket plant

Plant cultivars (V)	Jasmonic acid ($mg.L^{-1}$)	First season			Second season		
		Nano fertilizer ($g.L^{-1}$)			Nano fertilizer ($g.L^{-1}$)		
		$(N_0)0$	$(N_1)2$	$(N_2)4$	$(N_0)0$	$(N_1)2$	$(N_2)4$
Local cultivar V_1	(J_0) 0	15.77 mn	18.14 h-j	24.70 c	15.94 lm	19.63 gh	24.46 c
	(J_1) 15	18.05 h-k	20.53 e-g	26.56 b	18.18 h-j	20.61 fg	26.59 b
	(J_2) 30	18.95 g-i	21.22 ef	28.41 a	19.22 g-i	21.75 ef	28.73 a
French cultivar V_2	(J_0) 0	13.69 o	17.19 i-m	20.80 e-g	13.65 n	17.46 jk	20.68 fg
	(J_1) 15	15.74 mn	18.22 h-j	21.66 e	15.47 m	18.38 h-j	21.55 ef
	(J_2) 30	16.08 l-n	19.66 f-h	22.15 de	16.13 k-m	19.47 gh	22.42 e
Turkish cultivar V_3	(J_0) 0	14.82 no	17.78 h-l	21.64 e	14.88 mn	17.88 ij	21.51 ef
	(J_1) 15	16.19 k-n	18.92 g-i	22.08 de	16.28 k-m	18.96 hi	22.80 de
	(J_2) 30	16.74 j-n	20.92 ef	23.63 cd	16.97 j-l	20.58 fg	23.91 cd
Plant cultivars (V)		V1	V2	V3	V1	V2	V3
		21.37 A	18.34 C	19.19 B	21.68 A	18.35 C	19.30 B
Nano fertilizer		N_0	N_1	N_2	N_0	N_1	N_2
		16.22 C	19.17 B	23.51 A	16.30 C	19.41 B	23.62 A
Jasmonic acid		J0	J1	J2	J0	J1	J2
		18.28	19.77	20.86	18.45	19.87	21.02

	C	B	A	C	B	A

The averages with the same letters within each factor and the interactions are not significantly different from each other according to Duncan's multiple range test at the probability level of 0.05.

Table 3. Effect of jasmonic acid (JA) and Nano-fertilizer on leaf area (cm^2. $plant^{-1}$) for the three cultivars of rocket plant

Plant cultivars (V)	Jasmonic acid ($mg.L^{-1}$)	First season			Second season		
		Nano fertilizer ($g.L^{-1}$)			Nano fertilizer ($g.L^{-1}$)		
		(N_0)0	(N_1)2	(N_2)4	(N_0)0	(N_1)2	(N_2)4
Local cultivar V_1	(J_0) 0	396.70 o	476.40 jk	638.60 c	351.70 lm	428.83 hi	587.57 cd
	(J_1) 15	417.63 n	514.53 hi	725.53 b	372.70 jkl	457.53 h	663.23 b
	(J_2) 30	448.33 l	571.47 f	774.67 a	401.40 ij	524.57 f	717.57 a
French cultivar V_2	(J_0) 0	327.43 r	410.43 n	517.53 h	294.80 o	351.63 lm	489.37 g
	(J_1) 15	344.57 q	446.50 l	563.60 f	307.37 o	367.30 kl	542.77 ef
	(J_2) 30	375.53 p	479.50 j	612.63 d	345.77 lmn	418.77 i	581.60 cd
Turkish cultivar V_3	(J_0) 0	348.60 q	431.57 m	542.73 g	316.20 no	366.57 kl	513.30 fg
	(J_1) 15	365.57 p	468.47 k	589.47 e	323.40 mno	385.57 jk	568.37 de
	(J_2) 30	394.47 o	505.57 i	635.73 c	359.37 kl	456.10 h	601.30 c
Plant cultivars (V)		V1	V2	V3	V1	V2	V3
		551.54 a	453.08 c	475.80 b	500.57 a	411.04 c	432.24 b
Nano fertilizer		N_0	N_1	N_2	N_0	N_1	N_2
		379.87	478.27	622.28 a	341.41	417.43	585.01 a

	c	b		c	b	
Jasmonic acid	J0	J1	J2	J0	J1	J2
	454.44 c	492.87 b	533.10 a	411.11 c	443.14 b	489.60 a

The averages with the same letters within each factor and the interactions are not significantly different from each other according to Duncan's multiple range test at the probability level of 0.05.

sprayed with distilled water only (V2N0J0), with significant differences for most of the.triple interactions between all factors studied experience.

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

Table (4) displays the effect of jasmonic acid (JA) and nano-fertilizer on the dry weight of the vegetative growth (g. plant^{-1}) of the three cultivars of rocket plants. The cultivar had a significant effect on the indicator of the average dry weight of the vegetative total per plant, where the plants of the local cultivar V1 recorded significantly outperfotmed for both seasons, where it reached 7.42 and 6.96 g. plant^{-1} in order compared to the plants of the French cultivar V2, which were 6.90 and 6.39 g. plant $^{-1}$, respectively, with insignificant differences for plants of the same variety V1 with plants of Turkish cultivar V3, which were 7.25 and 6.91 g. plant^{-1}. In contrast, the French cultivar plants gave the lowest results in the mean of the studied plant trait .The discrepancy between the results of the studied rocket plant cultivars in the dry weight trait of the vegetative growth (g. plant^{-1}) may be attributed to the proportion of appropriate environmental impacts with the requirements for the growth of the plant cultivar and to the efficiency in the process of photosynthesis and the accumulation of processed nutrients, which positively affect the increase in the strength of vegetative growth and roots, this agrees with Alloush (5). It was also shown that increasing the concentration of the nano-fertilizer applied had a significant effect on increasing the dry weight rate of the vegetative part for both seasons. The increase in the dry weight of the vegetative growth may be due to the increase in the efficiency of photosynthesis in the leaves, which is the basic building unit of carbohydrates, or to the role of the nano-fertilizer containing the nitrogen element, which in turn stimulates plant growth to produce cytokinins, which causes an increase in the dry weight of the leaves which increases the size of the vegetation. It was also found that spraying with jasmonic acid (JA) had a significant effect on some treatments in increasing the dry weight of the vegetative growth per plant and for both seasons of the experiment, through the significantly excelled on the treatment of spraying the plant hormone at the concentration of 30 mg. L^{-1} (J2). It reached 7.54 and 6.94 g. plant^{-1}, consecutively, compared to none-treated plants (J0), which gave 6.81 and 6.52 g. plant^{-1}. While there were no significant differences at the same sprayed concentration (J2) with treatment 15 mg L^{-1} (J1), which recorded 7.22 and 6.80 g. plant^{-1}, respectively, and the lowest results were obtained from plants sprayed with distilled water only (J0). The role of jasmonic acid represents in protecting the plant and improving growth by stimulating the process of carbon metabolism and increasing pigments, and thus improving the permeability of membranes for important nutrients. This leads to improving vegetative

growth indicators, including dry weight of the vegetative growth which positively affects the increase in plant productivity, this agrees with Ahmad et al. (2019).The triple interaction between the experimental factors had a significant effect on this character, where the local cultivar plants that were sprayed with nano-fertilizer at a concentration of 4 g. L^{-1} and jasmonic acid at 30 mg L^{-1} (V1N2J2) for both seasons recorded the highest results 8.23 and 7.43 g. $plant^{-1}$, consecutively, compared to the lowest results 5.83 and 5.75 g. $plant^{-1}$, respectively, which were obtained from plants of the French cultivar that were sprayed with distilled water only (V2N0J0).

Table 4. The effect of jasmonic acid (JA) and Nano-fertilizer on the dry weight of vegetative growth (g. plant^{-1}) of the three cultivars of rocket plant

Plant cultivars (V)	Jasmonic acid (mg.L^{-1})	First season			Second season		
		Nano fertilizer (g.L^{-1})			Nano fertilizer (g.L^{-1})		
		(N_0)0	(N_1)2	(N_2)4	(N_0)0	(N_1)2	(N_2)4
Local cultivar V_1	(J_0) 0	6.27 e-g	7.27 a-e	7.55 a-d	6.14 ef	6.88 a-e	7.12 a-c
	(J_1) 15	7.15 a-f	7.46 a-e	7.81 a-c	6.82 a-e	6.97 a-d	7.29 ab
	(J_2) 30	7.39 a-e	7.68 a-d	**8.23 a**	6.91 a-e	7.15 ab	**7.43 a**
French cultivar V_2	(J_0) 0	**5.83 g**	6.71 c-g	7.13 a-f	**5.75 f**	6.22 d-f	6.56 b-e
	(J_1) 15	6.52 d-g	6.93 b-g	7.33 a-e	6.19 d-f	6.31 c-f	6.78 a-e
	(J_2) 30	6.77 c-g	7.24 a-e	7.64 a-d	6.23 d-f	6.62 a-e	6.86 a-e
Turkish cultivar V_3	(J_0) 0	6.05 fg	7.05 a-f	7.43 a-e	6.12 ef	6.82 a-e	7.08 a-c
	(J_1) 15	6.83 c-g	7.32 a-e	7.67 a-d	6.74 a-e	6.86 a-e	7.26 ab
	(J_2) 30	7.29 a-e	7.55 a-d	8.12 ab	6.84 a-e	7.11 a-c	7.37 ab
Plant cultivars (V)		**V1**	**V2**	**V3**	**V1**	**V2**	**V3**
		7.42 a	**6.90 b**	7.25 a	**6.96 a**	**6.39 b**	**6.91 a**
Nano fertilizer		**N_0**	**N_1**	**N_2**	**N_0**	**N_1**	**N_2**
		6.67 b	**7.24 a**	**7.65 A**	**6.41 c**	6.77 B	**7.08 A**
Jasmonic acid		**J0**	**J1**	**J2**	**J0**	**J1**	**J2**
		6.81 b	**7.22 a**	**7.54 a**	**6.52 b**	**6.80 a**	**6.94 a**

The averages with the same letters within each factor and the interactions are not significantly different from each other according to Duncan's multiple range test at the probability level of 0.05.

of the leaves, nitrogen affects increasing the process of cell division and its widening, which led to an increase in the water content of the leaves (15), and phosphorous has a role in fixing nutrients, and then its effect on increasing the leaf area. As for potassium, it is important to increase absorption and to obtain the process of turgor pressure, which increases the absorption of water and nutrients, which leads to an increase in the area of the leaf, this agrees with Kumar (13). It is also clear that spraying with jasmonic acid has a significant effect in increasing the studied trait for both seasons. The effect increases as the concentration of plant hormone sprays increases. Spraying plants with jasmonic acid has a positive effect on improving vegetative growth characteristics by stimulating the process of carbon metabolism and increasing pigments, thus improving the permeability of the membranes to nutrients (9), which positively affects the Increase in productivity. The triple interaction between the studied experimental factors had a significant effect on this trait, as it gave the plants of the local cultivars that were sprayed with nano-fertilizer at a concentration of 4 g. L^{-1} and jasmonic acid 30 mg. L^{-1} (V1N2J2) had the highest rate in the leaf productivity per square meter for both seasons of the experiment, which amounted to 2440.7 and 2328.6 $g.m^2$, respectively, compared with the lowest means were 1258.4 and 1136.5 $g.m^2$ produced from plants of the French cultivar sprayed with distilled water only (V2N0J0).

5- Productivity of leaves ($g.m^2$)

Table (5) indicates the effect of jasmonic acid (JA) and nano-fertilizer on the yield of leaves ($g.m^2$) for the three cultivars of rocket plant, that the cultivar has a significant effect on the yield of leaves per square meter, where the plants of the local cultivar excelled significantly for both seasons of the experiment compared to the plants of the other two cultivars, as well as the plants of the Turkish cultivar excelled on the French cultivar. The reason for the difference in the rates of the leaf productivity of the three rocket cultivars for both seasons may be due to the genotype of each of the cultivars in the appropriateness of the environmental conditions. This is consistent with what was found Omer *et al.*(14) where he emphasized that the difference between the origins of the cultivated plants had a significant effect on the quantitative and qualitative yield indicators and that the plants differed physiologically in the representation of many raw materials formed by their biological processes, which affects their morphological formation, which is thus reflected on their productive ability and their impact on environmental factors. It was also shown that increasing the concentration of the nano-fertilizer applied had a significant effect on increasing the productivity of leaves for both seasons, as its effect increased the higher the concentration of the nano-fertilizer applied, the increase in the studied trait may be due to the role of nutrients, including nano-fertilizer, in increasing leaf area and weight. Moreover, the direct effect on increasing the productivity

Table 5. The effect of jasmonic acid (JA) and Nano-fertilizer on the yield of leaves (g.m^2) for the three cultivars of rocket plant

Plant cultivars (V)	Jasmonic acid (mg.L^{-1})	First season			Second season		
		Nano fertilizer (g.L^{-1})			Nano fertilizer (g.L^{-1})		
		(N_0)0	(N_1)2	(N_2)4	(N_0)0	(N_1)2	(N_2)4
Local cultivar V_1	(J_0) 0	1663.0 l	1955.7 g	2203.4 c	1557.5 n	1836.6 h	2124.7 c
	(J_1) 15	1745.6 k	2013.7 f	2357.6 b	1640.0 l	1905.5 f	2209.4 b
	(J_2) 30	1868.4 i	2108.5 d	2440.7 a	1727.5 j	2017.4 d	2328.6 a
French cultivar V_2	(J_0) 0	1258.4 s	1525.4 n	1745.5 k	1136.5 s	1434.8 p	1650.7 l
	(J_1) 15	1326.4 r	1593.5 m	1832.6 j	1245.6 r	1512.6 o	1741.7 ij
	(J_2) 30	1417.7 p	1660.6 l	1926.5 h	1328.7 q	1579.6 mn	1818.7 h
Turkish cultivar V_3	(J_0) 0	1387.5 q	1598.7 m	1869.7 i	1241.6 r	1517.7 o	1758.7 i
	(J_1) 15	1450.6 o	1677.5 l	1980.3 g	1338.7 q	1594.5 m	1876.5 g
	(J_2) 30	1516.7 n	1772.6 k	2071.6 e	1445.6 p	1683.5 k	1979.5 e
Plant cultivars (V)		V1	V2	V3	V1	V2	V3
		2039.6 a	1587.4 c	1702.8 b	1927.5 a	1494.3 c	1604.1 b
Nano fertilizer		N_0	N_1	N_2	N_0	N_1	N_2
		1514.9 c	1767.3 b	2047.6 a	1406.9 c	1675.8 b	1943.2 a
Jasmonic acid		J0	J1	J2	J0	J1	J2
		1689.7 c	1775.3 b	1864.8 a	1584.3 c	1673.9 b	1767.7 a

The averages with the same letters within each factor and the interactions are not significantly different from each other according to Duncan's multiple range test at the probability level of 0.05.

Conflict of Interest

The authors have no conflict of interest**.**

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