

FOLIAR APPLICATION OF NANO-TREATED ORGANIC FERTILIZER AND JASMONIC ACID ON RED CABBAGE QUANTITATIVE AND QUALITATIVE INDICATORS AND ITS CONTENT OF ANTHOCYANIN PIGMENT.

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Abstract

The study was conducted in a field located in Najaf province during the 2020-2021 growing season to test the quantitative and qualitative responses of red cabbage plants to the studied factors. The first factor was the foliar application of nano-treated organic fertilizer at three levels including 0.0, 1.5, and 3.0 ml.L⁻¹, while the second factor was three levels of Jasmonic including acid 0, 15, and 30 mg.L⁻¹. A factorial experiment following Randomized Complete Blocks Design (R.C.B.D) was adopted with three replications. Least Significant Difference Test (L.S.D) at a probability of 0.05 was used to compare among means. The results showed significant superiority of 3 ml.L⁻¹ nano-treated organic fertilizers on the quantitative and qualitative indicators by giving the highest rates of head diameter, height, weight, total yield, percentage of carbohydrates and fibers, nitrate content, anthocyanin pigment, and head compaction. Foliar application of 30 mg.L⁻¹ Jasmonic acid was significantly superior over all other concentrations by giving the highest mentioned indicators. The interaction between of 3 ml.L⁻¹ nano-treated organic fertilizer and 30 mg.L⁻¹ Jasmonic acid showed significant superiority over other treatments regarding studied indicators. This interaction treatments scored 18.35 cm head diameter, 15.62 cm head height, 1570 g head weight, 40.33 tons.ha⁻¹ total yield, 4.30% and 10.22% the percentage of carbohydrates and fibers, 0.357 mg.g⁻¹DW nitrate content of the heads, and 24.65 mg.100 g⁻¹FW anthocyanin pigment, and 12.08 kg.cm⁻² head compaction over control treatment which recorded the lowest value of 14.39 cm, 11.95 cm, 993 cm, 25.87 tons.hectares⁻¹, 2.81%, 5.23%, 0.629 mg.gm⁻¹DW, 15.34 mg.100 g⁻¹FW, and 10.90 kg.cm⁻² respectively.

Keywords: nano-organic fertilizer, Jasmonic acid, red cabbage

Introduction

Cabbage (*Brassica oleracea* var. *Capitata* L.) that belonged to the cruciferous family is believed to be native to the eastern Mediterranean region. Red cabbage is distinguished from other species by its color and nutritional value. Each 100 g of fresh leaves contains 88.8 -93.9% moisture, 6.1-11.2% dry matter, 3.0-5.4% carbohydrates, 1-2% protein, 0.2% fat, 49 mg phosphorous, 238 mg potassium, 9 mg magnesium, 1.2 mg iron, 0.05 mg vitamin B1, 30-50 mg of vitamin C, and 130 IU of vitamin A. Medically, cabbage can work on cleaning the gastrointestinal tract and treating many diseases such as constipation and hyperglycemia, in addition to treating stomach and intestinal ulcers (Porras et al., 2006 and Mustafa, 2010). Anthocyanin pigments are natural

colorants widely distributed in nature. It is responsible for the violet, red, and blue color of flowers, fruits, stems, and leaves in some plants. These pigments are present in the cell vacuole and in the outer layers of epidermal cells (Rein, 2005). Anthocyanin pigments have shown an ability to protect humans against a large number of diseases as they are antioxidants. Anthocyanin has some stronger physiological effects than any other plant compound. Also, it has a number of preventive and curative roles for a large number of diseases. Some studies showed the positive effects of anthocyanin on health through being anti-inflammatory, affecting collagen and the nervous system. In addition, Anthocyanin pigments have the ability to protect blood vessels from damage, reduce hyperglycemia that causes complications in diabetes, treat ulcers, and work as anti-obesity (He and Giusti, 2010). The organic fertilizers are used due to their positive effect on living organisms, and their main roles in improving the chemical and physical properties of the soil, improving plant growth, and increasing quantitative and qualitative production. Recently, reliance on organic fertilizer has started as a healthy and safe choice for food product for humans, and it has rapidly spread in most countries (Abu Rayan, 2010). A study was conducted by Abbas and Hammad (2016) using humic acid at three concentrations (0, 100 and 200) mg.L⁻¹. The results showed a significant increase in yield indicators of cabbage plant. The results showed that the concentration 200 mg.L⁻¹ achieved the highest rate in the total yield index reached 113.08 tons.ha⁻¹ over comparison treatments. Sadeq et al. (2016) recorded significant differences in the quantitative indicators including cabbage head weight and total yield when spraying plants with organic nutrients (Vegeamino and Algaton20) at a concentration of 1 ml.L⁻¹ for both of them. Vegeamino gave the highest indicators value of 972 g head weight and 7.60 ton.ha⁻¹ of the total yield compared to the control treatments. Al-Zaidi (2016) applied 2 ml.L⁻¹ of wheat peat and 1 ml.L⁻¹ of organic Vegamino on red cabbage. The results showed superiority in the head quality indicators represented by the percentage of carbohydrates 4.26% and the percentage of fibers 9.19% compared to control treatment.

Recently, some studies have used Jasmonic acid as a growth regulator. These results showed a positive effect on the development of some plant flowers. In addition, it impacts cellular regulation and plant development processes and its stimulation against environmental stresses such as heat, drought, and salinity (Al-Asadi and Al-Khikani, 2019). Therefore, this experiment aimed to:

- 1- Determine the best rate of nano-organic fertilizer and its reflection in some productivity indicators of the plant.
- 2- Demonstrate the effect of foliar application of Jasmonic acid on the red cabbage plant indicators and its effect on increasing quantitative and qualitative production.
- 3- Know the best interaction between the experimental factors in order to give the highest yield of the red cabbage plant.

Materials and methods

The experiment was conducted during the full season of 2020-2021 in a field located in Al-Najaf province. Laboratory analyses for the planting soil were conducted by taking ten random samples from different places at a depth of 0-30 cm. Then, these samples were mixed homogeneously to form one sample, so this sample represents the field soil. Several tests were run

to analyze some chemical and physical properties of the experimental soil. The tests were carried out in the laboratory of the Department of the Soil Sciences/ Agriculture College/ University of Kufa. The results are shown in Table 1.

Table 1: Some chemical and physical properties of field soil before planting

propertie s	p H	Ec (Siemens. m ⁻¹)	Organic matter (%)	N mg.k g ⁻¹	P mg.kg -1	K mmol charge.L ⁻¹	Clay g.L ⁻¹	silt g.L ⁻¹	sand g.L ⁻¹	Soil textur e
soil	7 4	3.2	1.5	4.11	3.59	0.62	134	179	687	sandy loam

The soil of the field was prepared by plowing, smoothing, leveling, and dividing it into three terraces. Seventy centimeters is the distance between each terrace, and the distance between one plant and another was 0.40 m.

The seeds of the red cabbage hybrid were planted. The plants are an Italian origin characterized by their large outer leaves, attractive color, and well-integrated, and the weight of their heads ranges from 750-1500 g, as well as the harvest period 80-90 days after transplanting. The seed was planted on 7/9/2020 in a nursery. The seedlings were transferred to the permanent field on 24/10/2020 when the seedlings became 15 cm high and the number of their true leaves was 4-5 leaves. The experiment field was covered with nets to protect it from birds. All agricultural operations were conducted for the cabbage crop during its growing season and whenever needed. The area of the experimental unit was 4.2 m², which came from a 6-meter length multiplied by 0.70 m distance between one terrace and another, so the experimental unit contained 15 plants (Ali, 2012).

The study was implemented as a factorial experiment according to a randomized complete block design (R.C.B.D.) with three replications. The first studied factor was nano-treated organic fertilizer called Optimus plus. This liquid fertilizer contains 30% amino acids, **3% organic nitrogen, and 5% nitrogen** produced by the Turkish company called Agre sciences. The manufacturer's recommendation is 2 ml.L⁻¹.

Three concentrations were tested including 0.0, 1.5, and 3.0 ml.L⁻¹. The foliar application was implemented three times. The first spray was 14 days after transplanting, and the second spray was 14 days after the first spray. The third spray was applied when the head was wrapped. The foliar application was carried out in the early morning reaching the stage of complete wetness using a 16-liter dorsal sprinkler. Washing detergent was added with the fertilizer as a diffuser at a rate of 0.1% to increase the efficiency of the plants in absorbing the fertilizer (Al-Sahaf, 1989).

The second factor was foliar applications of Jasmonic acid with three concentrations including 0, 15, and 30 mg.L⁻¹. Plants were sprayed three times. The first was on 11/11/2020, the second was on 11/25/2020, and the third spray was on 9/12/2020.

Studied indicators

A- Yield indicators and their components

1- Head diameter (cm)

Five heads diameter was measured for each experimental unit using a measuring tape.

2- Head height (cm)

It was calculated using a measuring tape for five heads from each experimental unit.

3- Average head weight (g)

The average head weight was calculated by dividing the sum of the head weights (after removing the outer sheets) in the experimental unit by their number.

4- Total yield (tons. hectares⁻¹)

The total product was calculated according to the following equation:

Total yield (tons. hectares⁻¹) = (Experimental unit yield (tons)* hectare area (10000 m²))/
(Experimental unit area (4.2 m²))

B- Quality indicators

1- Heads carbohydrates (%)

The percentage of carbohydrates in the heads of cabbage was estimated according to the method described by (Joslyn, 1970).

2- The head fibers (%)

It was estimated according to (A.O.A.C, 1980).

3- Nitrate content in the heads (mg.g⁻¹ dry weight)

The nitrate content of heads was measured according to the method described by Cataldo et al. (1975).

4- Anthocyanin content of the heads (mg.100gm⁻¹ fresh weight)

It was estimated in heads according to Ranganna (1977).

5- The head compactness (kg.cm⁻²)

The degree of compaction of the heads was estimated using the Penetrometer (FAO, 1995).

Results and Discussion

1- Quantitative indicators

The results in Table 2 showed a significant effect of the nano-treated organic fertilizer on red cabbage plants. The concentration of 3 ml.L⁻¹ gave the highest rates of yield indicators including head diameter, head height, head weight, and total yield, which were 17.79 cm, 15.01 cm, 1465 g, and 37.74 tons.ha⁻¹ respectively compared to the control treatment (sprayed with water only) which gave the lowest rates of 15.16 cm, 12.70 cm, 1125 g, and 29.34 tons.ha⁻¹ respectively.

These results may be related to the effect of nitrogen and the amino acids which are included in the structure of proteins and enzymes in the carbon synthesis process; therefore the nitrogen enters the plant directly. In particular, the enzymatic and hormonal activity can improve hormonal balance, which helps in increasing quantitative indicators (Al-Sahaf, 1989). In addition, it contributed to filling the nutrient gap that occurs during the growing season of the plant (Al-Khaqani, 2021). The amino acids have a positive and significant effect in reducing the damage

caused by abiotic stresses, which improves plant growth and development and therefore increases its quantitative indicators (Al-Zamili, 2018, and Al-Akaishi, 2020).

The results in Table 2 indicate significant differences among the red cabbage treatments treated with different rates of Jasmonic acid in the yield indicators represented by head diameter, height, weight, and total yield. Jasmonic acid at a concentration of 30 mg.L⁻¹ was recorded respectively 14.62 cm, 1406 cm, and 36.46 tons.ha⁻¹ versus control treatment (spray with water only), which gave the lowest rates for these indicators including 15.69 cm, 13.18 cm, 1157 cm, and 29.93 tons.ha⁻¹ respectively. The reason may be due to Jasmonic acid which is described as one of the plant hormones that contributes to accelerate cell division and elongation which was positively reflected in the increase in the indicators of vegetative growth and then increasing in the yield indicators due to the direct relationship between them (Kadhim and Kazem, 2013).

The interaction between nano-treated organic fertilizer and Jasmonic acid had a significant effect on the quantitative indicators, and the highest value were recorded with the interaction between nano-organic fertilizer at a concentration of 3 ml.L⁻¹ and Jasmonic acid at a concentration of 30 mg.L⁻¹. This interaction recorded 18.35 cm, 15.62 cm, 1570 g, and 40.33 ton.ha⁻¹ compared to the control treatment which gave the lowest rates of 14.39 cm, 11.95 cm, 993 g, and 25.87 ton.ha⁻¹ respectively.

Table 2: Effect of foliar application of nano-treated organic fertilizer and Jasmonic acid and the interaction between them on yield indicators and their components.

Parameters		Head diameter (cm)	Head height (cm)	Head weight (g)	Total yield (ton.ha ⁻¹)	
rates of Nano-treated organic fertilizer (ml.L ⁻¹)	0	15.16	12.7	1125	29.34	
	1.5	16.69	14.06	1293	33.62	
	3	17.79	15.01	1465	37.74	
L.S.D. 0.05		0.53	0.58	67.5	0.97	
Jasmonic acid rates (mg.L ⁻¹)	0	15.69	13.18	1157	29.93	
	15	16.72	13.97	1320	34.31	
	30	17.23	14.62	1406	36.46	
L.S.D. 0.05		0.53	0.58	67.5	0.97	
Nano Organic Fertilizer X Jasmonic Acid	0	0	14.39	11.95	993	25.87
		15	15.21	12.84	1162	30.26
		30	15.88	13.31	1219	31.89
	1.5	0	15.57	13.16	1134	29.51
		15	17.05	14.1	1317	34.2
		30	17.46	14.93	1428	37.15
	3	0	17.12	14.44	1343	34.42
		15	17.9	14.97	1481	38.46
		30	18.35	15.62	1570	40.33

L.S.D. 0.05	1.24	1.36	141	1.87
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2- Qualitative indicators

The results in Table 3 showed a significant effect of nano-organic fertilizer on the qualitative yield indicators including the percentage of carbohydrates, the percentage of fibers in the heads, the nitrate content of the heads, anthocyanin pigment, and the head compactness. The means for the qualitative indicators recorded 4.03%, 8.73%, 0.322 mg.g⁻¹ dry weight, 22.75 mg.100g⁻¹ fresh weight, and 11.90 kg.cm⁻² compared to the control treatment that gave the lowest rates for these indicators, which scored 2.93% and 5.57%, 0.649 mg.g⁻¹ dry weight, 17.88 mg.100g⁻¹ fresh weight, and 11.26 kg.cm⁻² respectively.

Perhaps the reason for the increase in the carbohydrate content of red cabbage is due to the role of the amino acids and the organic nitrogen that is included in the organic fertilizer. Amino acids and organic nitrogen can activate various vital processes and this is positively reflected in improving the vegetative growth, and then increasing the efficiency and outcomes of the carbon synthesis process. This leads to an increase in the carbohydrates that moves to the stored part of the heads at maturity (Al-Sahhaf, 1989).

The increase in the percentage of fiber is due to the effect of amino acids in increasing the growth of shoots and roots, thus increasing the efficiency and outcomes of the carbon synthesis process and increasing the accumulation of synthesis materials containing carbohydrates. This can be reflected in increasing the carbohydrates content of the heads. The final result is an increase in fiber because fiber is originally a complex component of carbohydrates that are found around the plant cell as well as inside it. Fiber works on resisting digestion and absorption since it consists of cellulose, hemicellulose, lignin, and pectin (Abu Dahi and Al-Younis, 1988).

As for the low content of nitrates in the heads, the reason may be due to the role of amino acids in balancing nutrition in plants that allows them to grow well without substance accumulation more than its limits. Also, nitrogen affects the building of amino acids and the result is the synthesis of flavonoids including anthocyanin (Al-Zaidi, 2016).

The results in the same table showed the significant effect of 30 mg.L⁻¹ Jasmonic acid on the yield quality indicators including the percentage of carbohydrates, the percentage of fibers in the heads, the nitrate content of the heads, anthocyanin pigments, and head compaction. These indicators recorded 3.86 %, 7.64%, 0.478 mg.g⁻¹ DW and 22.24 mg.100g⁻¹ FW, and 11.80 kg.cm⁻² compared to control treatment which gave the lowest rates for these indicators amounted to 3.22% and 6.23% and 0.416 mg.g⁻¹ DW, 18.02 mg.100g⁻¹ FW, and 11.39 kg.cm⁻² respectively.

The reason for the increase in qualitative indicators may be attributed to Jasmonic acid as it is one of the growth regulators. Jasmonic acid affects plant growth and development by accelerating cell division and elongation, which leads to an increase in vegetative indicators, and this contributes to increasing the total yield and improving its quality. The improvement of the plant's nutritional status contributed positively to the increase in the vegetative indicators, and this was ideally reflected in the increase in the quantitative and qualitative yield of the red cabbage plant (Table 3).

As for the interaction between nano-treated organic fertilizer and Jasmonic acid, it had a significant effect on the yield quality indicators. The highest values were recorded with the interaction between nano-organic fertilizer at a concentration of 3 mL.L⁻¹ and Jasmonic acid at a concentration of 30 mg.L⁻¹. These recorded 4.30%, 10.22%, 0.357 mg.g⁻¹ DW, 25.65 mg.100 g⁻¹FW, and 12.08 kg.cm⁻² compared to the control treatment which gave the lowest rates of 2.81%, 5.23%, 0.629 mg.g⁻¹ DW, 15.34 mg.100 g⁻¹ FW, and 10.90 kg.cm⁻² respectively.

The study concluded that the nano-treated organic fertilizer at a rate of 3 mL.L⁻¹ and Jasmonic acid at a rate of 30 mg.L⁻¹ gave the best value for the quantitative and qualitative indicators of the red cabbage plants.

Table 3: Effect of nano-treated organic fertilizer and Jasmonic acid and the interaction between them on yield quality indicators.

Parameters		head carbohydrates (%)	head fibers (%)	Nitrate content of heads (mg.g ⁻¹ DW)	Anthocyanin content of the heads (mg.100g ⁻¹ FW)	head compaction (kg.cm ⁻²)	
rates of nano-treated organic fertilizer (ml.L ⁻¹)	0	2.93	5.57	0.649	17.88	11.26	
	1.5	3.44	6.48	0.373	19.63	11.67	
	3	4.03	8.73	0.322	22.75	11.9	
L.S.D. 0.05		0.17	0.55	0.034	0.78	0.23	
Jasmonic acid rates (mg.L ⁻¹)	0	3.22	6.23	0.416	18.02	11.39	
	15	3.5	6.9	0.451	19.99	11.64	
	30	3.68	7.64	0.478	22.24	11.8	
L.S.D. 0.05		0.17	0.55	0.034	0.78	0.23	
Nano Organic Fertilizer X Jasmonic Acid	0	0	2.81	5.23	0.629	15.34	10.9
		15	2.89	5.58	0.646	17.88	11.35
		30	3.1	5.89	0.673	20.42	11.52
	1.5	0	3.22	6.16	0.34	17.92	11.49
		15	3.46	6.45	0.375	19.31	11.72
		30	3.64	6.82	0.404	21.66	11.81
	3	0	3.63	7.29	0.278	20.8	11.77
		15	4.15	8.67	0.331	22.79	11.86
		30	4.3	10.22	0.357	24.65	12.08
L.S.D. 0.05		0.29	1.18	0.062	1.43	0.57	

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