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Article

The Effect of Organic Fertilization and Jasmonic Acid on the Morphological, Quantitative, and Chemical Parameters of Okra (*Abelmoschus esculentus* L.) variety Hussainawiya

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ABSTRACT

A study was conducted in a field belonging to the Najaf Agriculture Directorate/Najaf/Iraq during the spring growing season of 2021. The study aimed to analyze the response of okra variety Hussainiya for two factors. The first studied factor was three levels of DPW (decomposed palm waste), including 0, 16, and 32 $tonha^{-1}$, while the second factor was three levels of a foliar application of Jasmonic acid, including 0, 15, and 30 mgL^{-1}. Randomized Complete Block Design (RCBD) was used to model the factorial experiment with three replications, and the Least Significant Differences (LSD) were selected to compare the means at the probability level of 0.05. The results showed the significant superiority of organic fertilization treatment of DPW at the level of 32-ton ha^{-1} compared with control treatments in the studied parameters, recording the highest value of the plant height, total number of leaves, total leaf area, dry weight of the vegetative system, number of fruits per plant, the yield of one plant, total yield, the percentage of nitrogen in leaves, the total chlorophyll percentage, and the total soluble carbohydrates in fruits. The foliar application of 30 mg. L^{-1} Jasmonic acid gave significantly higher values for the above indicators than control treatments. The interaction between the application of 32 tons. ha^{-1} DPW and 30 mg L^{-1} Jasmonic acids showed significant superiority over other treatments in all studied indicators. These indicators were plant height 131.66 cm, total number of leaves 42.55 leaves $plant^{-1}$, total leaf area 1.66 m^2plant^{-1}, dry weight of the vegetative system 95.48 g $plant^{-1}$, fruits number 77.15 fruit $plant^{-1}$, yield of one plant 884.75 g $plant^{-1}$, total yield 56.17 tons. ha^{-1}, nitrogen in leaves 2.262%, total chlorophyll in leaves 80.91 mg.100 g^{-1}FW, and carbohydrates in fruits 20.33%. While the interaction between non-fertilized plants sprayed with water only recorded significantly the lowest value of these indicators, which scored 77.10 cm, 20.36 leaf $plant^{-1}$, 0.59 m^2plant^{-1}, 54.11 g $plant^{-1}$, 47.23 fruit $plant^{-1}$, 237.42 g $plant^{-1}$, 15.07-ton ha^{-1}, 1.351%, 47.45 mg.100 g^{-1} fresh weight, and 6.77% respectively.

Keywords: Abelmoschus plant; decomposed palm waste; Jasmonic acid; okra, Organic fertilizer; yield indicators.

INTRODUCTION

Okra plant *Abelmoschus esculentus* L. belongs to the Malvaceae family. The original homeland is believed to be Ethiopia and Sudan. It is cultivated in open fields as a summer crop. Also, okra can grow in protected facilities [1]. Okra fruits are rich with nutritious value. Each 100 g of fresh fruits contains 85.7% water, 35 calories, 6.4 g carbohydrates, 2.4 g fats, 1.9 g protein, 1.2 g fiber, 249 mg potassium, 66 mg calcium, 56 mg Phosphorous, 53 mg Magnesium, 30 mg Sulfur, 0.35 mg Iron, 0.19 mg Copper, 520 IU Vitamin A, 0.01 mg vitamin B1, 0.07 mg vitamin B2, 0.6 mg vitamin B3, 88.21 µg vitamin B9, and 13 mg vitamin C[2]. Medically, okra fruits help treat diseases such as anemia, general weakness, urinary tract, kidney inflammation, and diarrhea [3].

The total planted area in the world amounted to 20 million hectares with a productivity of 10 million tons, while the total cultivated area in Iraq was 12,128 hectares with productivity of 68,451 tons [4]. The reason for low productivity in Iraq may be related to the failure to use modern technologies and scientific methods in crop management because of their positive impact on plant growth and development and increasing total productivity.

The decomposed organic matter is used to improve the chemical and physical characteristics of the soil because it contains humic acids. Humic acids have water-loving colloids that have a high surface area. Therefore, their absorbent capacity increases by more than 300% of their weight, affecting the water balance content. This change in the soil structure and the volume of pores activates microorganisms in the soil, improves the water condition, reduces heat stress, and reduces drought and salinity. This produces a healthy crop with fewer chemical pollutants like nitrates or oxalates. Organic fertilization is used as fertilizer and soil reformer. Moreover, it provides the necessary nutrients that positively impact the vegetative and physiological indicators of plant growth. This fertilization method improves plant and soil relations to maintain human and animal health [5,6].

Applying organic manure (sheep waste with kohl residue) to corn at 4 levels (0, 10, 15, and 20) ton ha^{-1} increased the vegetative growth indicators of zucchini squash plants [7]. The results also showed that adding 20-ton $hectare^{-1}$ recorded significantly the highest value of plant height and dry biomass of the vegetative system compared to no treated plants. A study was conducted to determine the effect of organic fertilization with date palm waste and foliar application of date seed extract on the growth and yield of cucumbers[8]. The results showed that organic fertilization with date palm residues significantly increased the quantitative indicators compared to the comparison treatment. Significant differences in the yield indicators were observed when fertilizing the cucumber plant with palm frond residues compared with the control plants [9].

Recently, some researchers have used Jasmonic acid as a growth regulator since their results showed a positive effect of this acid on the flower development of some horticultural plants. In addition, Jasmonic acid has an essential impact on the cellular system and plant development and reduces stresses such as heat, drought, and salinity [10]. Therefore, this study aims to show the effect of organic fertilization with decomposing palm waste (DPW), foliar applications of Jasmonic acid, and their interaction on okra's vegetative, chemical, and yield indicators.

MATERIALS AND METHODS

The study was conducted during the 2021 agricultural season on a field in the desert area of the Haidariya subdistrict of Najaf province / Iraq. Before planting, laboratory analyses were conducted on the field soil by taking ten random samples from different places at 0-30 cm soil depth. Irrigation water samples were also taken from the well to analyze some chemical and physical characteristics in the Department of Soil Sciences/ College of Agriculture/ Al-Kufa University, as shown in Table 1.

Characteristics	pH	Ec dS m^{-1}	Organic Matter %	N mg kg^{-1}	P mg kg^{-1}	K mmol charge L^{-1}	Clay g L^{-1}	Silt g L^{-1}	sand g L^{-1}	soil texture
Soil	7.4	3.5	1.2	4.12	3.74	0.59	128	177	695	sandy loam
Well water	7.2	4.3	——	2.26	3.31	0.78	——			

Table 1. shows some chemical and physical properties of field soil and well water before planting.

The experimental field soil was prepared by plowing, smoothing, leveling, and dividing it into three terraces. The space between terraces was 0.80 m, and each terrace was 30 m long. The distance between one plant and another was 0.35 m. Al-Hussainawiya cultivar seeds were planted after soaking in water for 24 hours on

10/3/2021 alternately on both sides of the growing lines. After three weeks from the germination, the area of the experimental unit was 2.52 m^2 (3.15 m length x 0.80 m), which contained 16 plants. A factorial experiment using a randomized complete block design (RCBD) with three replications was adopted. Two factors were tested in this study. The first factor is soil applications of organic fertilizer, which was added before the planting at three levels (0, 16 and 32) ton ha^{-1} [11]. Organic fertilizer was obtained from the Preparing Organic Fertilizers and Mushrooms Project at Najaf/Iraq, as shown in Table 2.

Characteristics	**N %**	**P %**	**K %**	**C %**	**B mg.kg^{-1}**	**pH**	**Ec (dS.m^{-1})**	**OM %**	**C/N %**
Value	1.86	0.8	1.3	40.79	13	6.6	6.95	73.33	21.93

Table 2. Some chemical indicators of decomposed palm waste.

The second factor was a foliar application of Jasmonic acid at 3 levels, including 0, 15, and 30 mg L^{-1}. The plant shoots were treated in the first light until the plants reached the entire wetness stage using a 16-liter sprinkler. A detergent was added to the spray in 0.1% as a diffuser one day after irrigation to increase the plant's efficiency in absorbing the sprayed substance [12]. Plants were sprayed three times, and 30 days were separated between each spray. The first application was 21 days after germination when the average number of leaves per plant was 4-5 real leaves. The control plants were sprayed with water only. Some vegetative indicators were measured after 150 days of planting by randomly taking five plants from each experimental unit. The estimated indicators were:

Vegetative Parameters

Some vegetative indicators were measured after 140 days of planting by randomly taking five plants and three replicates from each experimental unit. Then, the indicators' means were calculated.

Plant height (cm)

The height of the okra plants was measured using the metric tape from the point where the stem was connected to the soil to the most extended growing stem.

Total number of leaves (leaf plant^{-1})

The counted leaves were present on the main stem of the plants.

Total leaf area (m^{2}plant^{-1})

The leaf area was measured based on the scanner method using the ImageJ software program [13].

Dry weight of the vegetative system (plant^{-1})

This vegetative indicator was estimated at the end of the experiment. Four plants were selected from each experimental unit without their root systems, and their vegetative group was cut into small pieces to accelerate the surface area's moisture loss. Then, it was moved to an electric oven at 70 °C until the weight was stable [12]. Dry weight was measured at the end of this process.

Yield Parameters

The fruit number per plant (fruit plant^{-1}).

This was estimated by dividing the total cumulative number of fruits in the experimental unit by the number of plants in the same experimental unit.

Yield per plant (g plant^{-1}).

This was estimated below the equation.

Yield per plant (gplant^{-1}) = (cumulative fruits weight in the experimental unit) / (Plant number in the experimental unit).

Total yield (ton ha^{-1})

The total cumulative yield was measured by collecting fruit from 05/19 until 08/26/2021. During this period, each experimental unit [14] collected fruits 32 times.

Chemical indicators of leaves and fruits

Nitrogen Percentage in leaves (%).

The N element was measured by the Micro Kjeldahl device [15].

Total chlorophyll in leaves (mg 100g^{-1} fresh weight).

Total chlorophyll pigment in green leaves was measured using spectrophotometer [16].

The total soluble carbohydrates in okra fruits (%)[17].

RESULTS

Vegetative parameters

The results in Table 3 show the fertilization effects of DPW on okra plants. The rate of 32 ton ha^{-1} of DPW gave the highest value of vegetative growth indicators, including plant height, the total number of leaves, total leaf area, and total dry biomass of the vegetative system, which recorded 121.54 cm and 37.53 leaf plant^{-1} and 1.43 m^{2}plant^{-1} and 88.16 gplant^{-1} compared to the control plants (without DPW) which provided the lowest rates of 82.89 cm, 23.97 leaf plant^{-1}, 0.80 m^{2}plant^{-1}, and 58.84 gplant^{-1} respectively. This outcome may be due to the DPW content with nitrogen-rich nutrients. Nitrogen can positively affect the formation of amino acids that affect the synthesis of proteins, nucleic acids, DNA, and RNA. Amino acids also can affect the construction of chloroplasts, increase the protoplasm mass, accelerate cell division, and build new tissues. This can increase the vegetative system, thus increasing the size and weight of the vegetative group [18]. In addition, the rise in the vegetative dry biomass is due to the increase in plant height and total leaf number (Table 3), which is mainly associated with a rise in carbon metabolism, starch, and sugars that are accumulated in the plant, and accordingly increasing the indicator mentioned above.

The results in Table 3 showed significant differences between plants treated with Jasmonic acid in the vegetative indicators, including plant height, the total number of leaves, total leaf area, and dry biomass of the vegetative system. Jasmonic acid at a level of 30 mg L^{-1} gave the highest rates of vegetative growth indicators, which were 110.35 cm, 35.11 leaves, 1.29 m^{2}plant^{-1}, and 79.37 g plant^{-1} versus no treated plant, which gave the lowest value for these indicators recording 95.41 cm, 25.76 leaves, 0.90 m^{2}plant^{-1}, and 67.49 g plant^{-1} respectively. The reason may be related to Jasmonic acid, which is counted as a plant hormone. Thus, it can increase the division and elongation of cells, which leads to an increase in the height indicator of okra plants. Consequently, this can increase the dry biomass of the vegetative system [19].

The interaction between the fertilization treatments with 32 tons. ha^{-1} DPW and 30 mg L^{-1} Jasmonic acid significantly affected the vegetative indicators, which recorded the highest rates. Vegetative indicators recorded 131.66 cm and 42.55 leaf plant^{-1}, 1.66 m^{2}plant^{-1}, and 95.48 g plant^{-1} compared to no treated plant, which provided 77.10 cm and 20.36 leaf plant^{-1}, 0.59 m^{2}plant^{-1}, and 54.11 g plant^{-1} respectively.

Quantitative and Qualitative Indicators

The results in Table 4 showed a significant impact of fertilizing with DPW on the quantitative and qualitative yield parameters represented by the number of fruits per plant, the yield per plant, the total yield, nitrogen percentage in leaves, the total chlorophyll in the leaves, and the percentage of total carbohydrates in the fruits. These quantitative and qualitative indicators increase by increasing the level of fertilization. The level of 32 tons per hectare gave the highest rates, recording 70.42 fruit plant-$^{-1}$, 730.03 g plant^{-1}, 46.35 tons ha^{-1}, 2.04%, 72.33 mg100 g^{-1} fresh weights, and 15.04%, respectively, compared to the comparison treatment that gave the lowest rates of those indicators. They recorded 52.85 fruit plant^{-1}, 307.22 m plant^{-1}, 19.50 tons ha^{-1}, 1.51%, 53.58 mg 100 g^{-1} fresh weight, and 11.30% respectively. The reason may be due to the role of DPW in providing the necessary nutrients for plant growth and development. Also, DPW positively impacts increasing metabolism and transferring most carbohydrates from leaves to fruits. In addition, organic matter can provide plants with the necessary nutritional elements such as nitrogen and phosphorous, which enhance carbon metabolism, respiration, and protoplasts, form nucleic acids, DNA, and RNA, and accelerate cell division [20]. Thus, the presence of these nutrients in the organic matter can increase the protoplasm mass and accelerate cellular div[21]. In addition, increasing yield can be attributed to the role of organic fertilizers in improving the soil's chemical and physical properties (Table 1). Therefore, organic fertilizer helps soil retain moisture, provides suitable conditions for the roots to grow, and enhances the activity and number of microorganisms. These microorganisms can dissolve nutrients from soil particles through the mineralization process and increase their absorption by the plant [22]. The findings in the same table showed the significant impact of Jasmonic acid on the quantitative and qualitative yield parameters, including the number of fruits per plant, the yield of one plant, the total yield, the total nitrogen percentage in the leaves, the total chlorophyll in the leaves and the total carbohydrates percentage in the fruits.

Treatments			plant height cm	Total number of leaves. (leaf plant^{-1})	Total leaf area. (m^{2}plant^{-1})	dry weight for the vegetative system (g plant^{-1})
Fertilization levels with DPW (ton ha^{-1})	**0**		82.89	23.97	0.80	58.84
	16		103.88	30.38	1.08	73.70
	32		121.54	37.53	1.43	88.16
	L.S.D.0.05		2.14	1.43	0.02	1.56
Jasmonic acid rates (mg L^{-1})	**0**		95.41	25.76	0.90	67.49
	15		102.55	31.01	1.13	73.84
	30		110.35	35.11	1.29	79.37
	L.S.D.0.05		2.14	1.43	0.02	1.56
fertilization levels X spray rates	**0**	**0**	77.10	20.36	0.59	54.11
		15	82.68	23.85	0.84	59.15
		30	88.89	27.71	0.97	63.27
	16	**0**	96.73	25.18	0.91	67.94
		15	104.39	30.9	1.1	73.8
		30	110.51	35.07	1.24	79.36
	32	**0**	112.4	31.75	1.19	80.43
		15	120.57	38.29	1.45	88.57
		30	131.66	42.55	1.66	95.48
	L.S.D.0.05		4.61	3.45	0.05	3.10

Table 3. Effect of fertilizing with DPW and Jasmonic acid and their interaction on vegetative growth parameters.

Treatments		Number of fruits (fruit plant^{-1})	Yield per plant (g plant^{-1})	Total yield ton ha^{-1}	Nitrogen in leaves (%)	Total chlorophyll in leaves. (mg100 g^{-1}FW)	Total carbohydrates in fruits (%)
Fertilization levels of DPW ton ha^{-1}	**0**	52.85	307.22	19.50	1.507	53.58	11.3
	16	60.15	492.64	31.28	1.783	63.42	12.41
	32	70.42	730.03	46.35	2.044	72.33	15.04
L.S.D.0.05		1.36	1.65	3.87	0.151	1.11	0.85

Jasmonic acid rates (mg L-1)	**0**		54.54	392.98	24.95	1.569	56.14	7.61
	15		62.21	520.9	33.07	1.798	62.49	13.66
	30		66.67	616	39.11	1.967	70.69	17.48
LSD 0.05			1.36	1.65	3.87	0.151	1.11	0.85
fertilization levels X spray rates	**0**	**0**	47.23	237.42	15.07	1.351	47.45	6.77
		15	54.07	312.97	19.87	1.496	53.22	11.84
		30	57.26	371.26	23.57	1.675	60.06	15.29
	16	**0**	53.98	383.1	24.32	1.563	56.27	7.46
		15	60.88	502.83	31.93	1.822	62.9	12.95
		30	65.59	592	37.59	1.965	71.09	16.81
	32	**0**	62.41	558.43	35.46	1.794	64.71	8.6
		15	71.69	746.9	47.42	2.077	71.36	16.18
		30	77.15	884.75	56.17	2.262	80.91	20.33
L.S.D.0.05			1.78	1.93	6.49	0.347	2.84	1.64

Table 4. Effect of fertilizing with DPW and Jasmonic acid and their interaction on quantitative and qualitative parameters.

Thirty mg L^{-1} of Jasmonic acid gave the highest rates of the above parameters, which scored 66.67 fruit $plant^{-1}$, 616.00 g $plant^{-1}$, 39.11 tons ha^{-1}, 1.96%, 70.69 mg 100 g^{-1}FW, and 17.48% compared to no treated plants which recorded the lowest value of these indicators scored 54.54 fruit $plant^{-1}$ and 392.98 g $plant^{-1}$- and 24.95-ton ha^{-1}, 1.56 %, 56.14 mg 100 g^{-1} fresh weight, and 7.61% respectively. The increase in quantitative and qualitative parameters may be attributed to Jasmonic acid, one of the growth regulators. Therefore, it affects the plant's growth and development by accelerating cell division, increasing elongation, forming leaf pods, and then increasing the number of flowers in the plant. This leads to a rise in the number of fruits per plant and then increases the yield. The improvement of the plant's nutritional status contributed positively to the increase in the vegetative indicators (Table 3). This is ideally reflected in increasing the yield parameters of okra (Table 4).

The interaction between the fertilization treatments with 32 $tonha^{-1}$ DPW and 30 mg L^{-1} Jasmonic acid had significantly the highest quantitative and chemical parameters, which scored 77.15 fruit $plant^{-1}$, 884.75 g $plant^{-1}$, 56.17 tons ha^{-1}, 2.262%, and 80.91 mg 100 g^{-1} of FW, and 20.33 % compared to no treated plants which provided the lowest value of 47.23 fruit $plant^{-1}$, 237.42 g $plant^{-1}$, 15.07 $tonsha^{-1}$, 1.351%, and 47.45 mg 100 g^{-1}FW and 6.77% respectively.

CONCLUSIONS

Okra variety Hussainiya responds favorably to decomposed palm waste (DPW) and foliar jasmonic acid application. The highest yield and quality of okra fruits were obtained when DPW was applied at 32 tons/ha, and jasmonic acid was used at 30 mg/L.

Therefore, the application of decomposed palm waste and foliar jasmonic acid is a highly effective method for enhancing the growth and yield of okra. This combination has the potential to increase the profitability of okra cultivation significantly. The study concludes that fertilization with DPW is at 32 tons ha^{-1} with foliar application 30 mg L^{-1} Jasmonic acid gave the best rates for phenotypic, quantitative, and chemical parameters of okra.

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