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Effect of adding vermicompost extract and spraying with nano iron and boron on the vegetative traits of papaya trees (*Carica papaya* L.)

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Abstract. *The field study was conducted at Al-Musauib Papaya Orchard in October 2024 and June 2025. This study was carried out to assess the effect of vermicompost extract and the application of nano iron/boron foliar sprays on the fruit's mineral content. The experiment was arranged in complete randomized blocks with three factors and three replications each. The factors are vermicompost extract at 0.50 ml/L with two levels, nano boron at 0, 5, 15, and 10 mg/L, and nano iron at 0, 2, 4, and 6 mg/L. The significant findings of this experiment are as follows: the treatment with vermicompost at 50 ml/L gave the largest leaf area at 153.67 cm², the tallest stem at 403.77 cm, the largest stem diameter at 567.27 mm, and the highest chlorophyll content at 36.858 SPAD units compared to the control treatment. Boron nanoparticles at 15 mg/L resulted in the maximum leaf area (158.88 cm²), stem height (419.29 cm), stem diameter (579.64 mm), and chlorophyll content (38.656 SPAD) compared with the control. Nano iron at 6 mg/L resulted in the maximum leaf area (173.92 cm²), stem height (466.83 cm), stem diameter (678.70 mm), and chlorophyll content (45.465 SPAD) compared with the control. Combined effect of two factors resulted in the most favorable results. Combined effect of three factors resulted in optimal results with leaf area 175.00 cm², stem height 474.00 cm, stem diameter 694.00 mm, and chlorophyll content 43.753 SPAD. In contrast, the control resulted in the lowest values with leaf area 121.33 cm², stem height 277.33 cm, stem diameter 341.50 mm, and chlorophyll content 26.243 SPAD.*

Keywords: *nano boron , nano iron , papaya , vegetative, vermicompost.*

1. INTRODUCTION

The papaya plant (*Carica papaya* L.) is a fast-growing, fruiting, evergreen herbaceous plant native to tropical regions of America, possibly including northern Mexico or Central America [1]. Papaya is a fruit-bearing plant. The plant thrives in temperatures between 21-32°C, with 24°C being the optimal temperature for growth. It does not grow well in areas prone to frost, as temperatures below 10°C cause tissue death. The final fruit size depends on sufficient

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warmth during the first 46 weeks after fruit set. Global demand for tropical fruits has steadily increased over the first two decades of the 21st century, and global papaya production reached approximately 13,016,281 tons in 2017. Plants require nutrients, which can be obtained through the application of organic or chemical fertilizers. Organic fertilization is an important method for supplying plants with their nutrient needs without negatively impacting the environment, whether applied through soil or foliar application [2] . vermicompost a nutrient-rich organic fertilizer containing humus and essential macro- and micronutrients such as manganese, zinc, copper, iron, calcium, magnesium, potassium, phosphorus, and nitrogen (Mn, Zn, Cu, Fe, Ca, Mg, K, P, N, and others). It also contains beneficial microorganisms like nitrogen-fixing and phosphate-solubilizing bacteria, enzymes such as amylase, protease, and peroxidase, vitamins, and growth hormones [3]. Vermicompost is among the fertilizers with the lowest concentration of plant pathogens and the highest concentration of beneficial microorganisms. Its components are water-soluble, making them easily absorbed and utilized by plants [4]. Iron (Fe) is an essential element for plant growth and plays a vital role in photosynthesis and chlorophyll formation. It is also important in enzyme systems that are crucial for oxidation-reduction reactions in plant respiration. Iron deficiency leads to chlorophyll degradation and yellowing of plant leaves [5]. Chelated nano-iron fertilizer can be a rich and effective source of divalent iron with properties that promote plant growth. Iron chelates (Fe-EDTA) are stable in the soil and prevent iron precipitation for a moderate period.The aim of this study are:

1- To determine the optimal level of earthworm manure extract for high-quality, chemical-free production, thus protecting human health and the environment.
2- To determine the best level of nano-iron and nano-boron for developing trees resistant to adverse environmental conditions.
3- To identify the combined effects and optimal two- and three-way interactions of the experimental factors on the growth, yield, and content of active compounds in papaya trees.

2. MATERIALS AND METHODS

A field experiment was conducted on a farm in Al-Musauib Project, in the Abu al-Jasim area, located 30 km from the center of Babylon province (Lat 32.5° North, Longitude 44.3° East), planted with papaya trees. The experiment ran from the beginning of October 2024 to the end of June 2025 East, to study effect of adding vermicompost extract and spraying with nano-iron and boron on the mineral content of papaya fruit. The first factor included two levels of vermicompost addition: 0.50 ml L^{-1}The second factor involved spraying with nano-boron at concentrations of 0, 5, 15, and 10 ml L^{-1}(B0, B5, B10,B15). and spraying with nano-iron at concentrations of 0, 2, 4, and 6 mg L^{-1} F0, F2, F4, F6).

Soil analysis was performed in the laboratories of the College of Science, University of Baghdad

Table 1. Measurement of some chemical and physical properties of soil

Characteristics	Units	Value
Reaction degree pH	7.7	------

Electrical conductivity 1:1DSM -1 (EC)	1.9	decimeter m^{-1}
Clay ratio	415	g kg^{-1}
Sand ratio	186	g kg^{-1}
Organic matter O.M	399	g kg^{-1}
Total nitrogen	0.92	g kg^{-1}
Total nitrogen	31.6	g kg^{-1}
Available phosphorus	12.4	mg kg^{-1}
Total potassium	172.5	mg kg^{-1}
Na	11	mg kg^{-1}
Mg	3	mg kg^{-1}
Ca	6	mg kg^{-1}
Cl	8.8	mg kg^{-1}
Sa4	9.4	mg kg^{-1}
HCO_3	3	mg kg^{-1}
B	1.15	mg kg^{-1}
Soil texture	Silty clay soil	

The soil was analyzed in the Laboratories of the College of Science / University of Baghdad
The research will be conducted on a farm in the Al-Musayyib project planted with papaya trees during the period from the beginning of October 2024 until the end of June 2026 to study the effect of adding vermicompost extract and spraying with nano and nano iron and boron on the growth, yield, and content of active compounds in papaya trees.

2.1 Experimental factors:

Two factorial experiments were conducted, each experiment including (96) papaya trees according to the complete randomized block design with three factors (2*4*4*3) for each experiment and with three replicates, each replicate including (32) trees at a rate of (1) tree per experimental unit. Each experiment will include (32) experimental units. The distance between trees is (2) m, tree height (2.5) m, and age (3) years.
Statistical Analysis
Statistical analysis of the data will be conducted using the program (Genstat 2010) at a probability level of 0.05.

2.2.Study Traits
2.2.1.Stem length (cm):

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The stem length was measured from the point where the plant joins the soil to the end of the main stem using a metric measuring tape.

2.2.2.Leaf Area (cm²)

The leaf area was calculated by taking leaf samples starting from the fourth leaf at the apical meristem of the vegetative branches. The leaf area was measured using the dry weight of the leaf. First, a square of known area was taken and weighed, then placed in an oven at 70°C to dry. The leaf area was then calculated according to the equation developed by [6].

$$\text{Leaf Area} = \frac{Area\ of\ cut\ square\ (cm^2) \times Dry\ weight\ of\ leaf\ (g)}{Dry\ weight\ of\ cut\ square\ (g)}$$

2.2.3. Stem Diameter (mm)

To measure the stem diameter, a Vernier caliper was used 30 cm from the soil surface.

2.2. 4 Estimation of Total Chlorophyll in Leaves

The total chlorophyll in papaya leaf samples was estimated according to [7] during June 2021. 0.5 g of fresh leaves were taken, and the pigments were extracted using 80% acetone. The pigments were then quantified using a spectrophotometer. Chlorophyll a was measured at a wavelength of 663 nm and chlorophyll b at a wavelength of 645 nm. Total chlorophyll was estimated by calculating the pigment concentrations as follows:

Total Chlorophyll mg/L = (663) O.D. × 8.02 – (645) O.D. × 20.2 = The results were then converted to units of (mg/100 g fresh weight).

O.D. represents the instrument reading.

3. RESULTS AND DISCUSSION

3.1. Plant Height (cm)

Table 2 shows that adding vermicompost significantly affects plant height. The 50 ml L^{-1} treatment gave the highest plant height of 153.7 cm, while the control treatment resulted in the lowest plant height of 149.35 cm.where, spraying papaya plants with nano-boron significantly increased highest plant height of 15 ml L^{-1}, resulting in the highest plant height of 158.88 cm, compared to the control treatment which resulted in the lowest plant height of 145.04 cm.The effect of iron spraying on plant height was highly significant. The table shows that the differences were significant for both iron treatments. The 6 mg L^{-1} treatment resulted in the highest plant height of 173.92 cm, while the control treatment resulted in the lowest plant height of 133.83 cm. The results data also show that bi- interactions have a significant effect. The interaction treatment (adding 50 ml L^{-1} of vermicompost and spraying with 15 ml L^{-1} of nano boron) significantly excelled on the other treatments, gave the highest plant height of 157.92 cm. Similarly, the interaction treatment (adding 50 ml L^{-1} of vermicompost and spraying with 6 ml L^{-1} of iron) also significantly excelled on the other treatments, gave the highest plant height of 180.25 cm. The bi-interaction of spraying with 15 ml L^{-1} of nano boron and spraying with 6 ml L^{-1} of iron also significantly affected plant height, recording the highest value of 192.00 cm. The highest recorded value was 192.00 cm. In triple interaction between the factors, the treatment of adding vermicompost at a concentration of 50 ml L^{-1} and spraying boron at a level of 15 ml L^{-1}, along with spraying iron at a level of 6 mg L^{-1}, recorded the highest average plant height of 209.00 cm, while the control treatment recorded the lowest average plant height of 121.33 cm.

Table 2. Effect of Adding Vermicompost and Spraying with Nano Iron and Boron on plant height (cm)

vermicompost	nano boron	nano-iron F0	F2	F4	F6	vermicompost x nano boron
V0	B0	121.33	134.00	143.33	161.67	140.08
	B5	130.33	137.33	147.33	168.67	145.92
	B10	132.00	141.00	151.67	181.67	151.59
	B15	133.00	142.33	155.00	209.00	159.83
V50	B0	134.00	149.33	153.67	163.00	150.00
	B5	136.33	151.00	155.67	163.67	151.67
	B10	140.67	152.33	158.67	168.67	155.09
	B15	143.00	153.00	160.67	175.00	157.92
LSD 0.05		4.68**				2.34**
vermicompost		vermicompost x nano-iron				Vermicompost average
V0		129.17	138.67	149.33	180.25	149.35
V50		138.50	151.42	157.17	167.59	153.67
LSD 0.05		2.34**				1.17**
nano boron		nano boron x nano-iron				nano boron average
B0		127.67	141.67	148.50	162.34	145.04
B5		133.33	144.17	151.50	166.17	148.79
B10		136.34	146.67	155.17	175.17	153.34
B15		138.00	147.67	157.84	192.00	158.88
LSD 0.05		3.31**				1.65**
nano-iron average		133.83	145.04	153.25	173.92	
LSD 0.05		1.65**				

3.2. Leaf Area (cm²)

The results in Table (3) show that adding vermicompost had a significant effect on leaf area. The 50 ml L^{-1} treatment recorded the highest leaf area at (403.77) cm², while the control treatment resulted in the lowest leaf area at (396.17) cm². where, spraying papaya plants with nano-boron significantly increased the leaf area at (15 ml L^{-1}), resulting in the highest leaf area at (419.29) cm², compared to the control treatment which resulted in the lowest leaf area at (381.58) cm². Regarding the effect of iron spraying on leaf area, the results were highly significant. The table shows that the differences were significant for nano iron treatments. The 6 mg L^{-1} treatment resulted in the highest leaf area (466.83 cm²), while the control treatment resulted in the lowest leaf area (333.88 cm²).The results also indicate that bi- interactions had a significant effect. The interaction treatment (adding 50 ml L^{-1} of Vermicompost and spraying 15 ml L^{-1} of nano boron) significantly excelled on the other treatments, resulting in the highest leaf area (419.09 cm²). Similarly, the interaction treatment (adding 50 ml L^{-1} of Vermicompost and spraying 6 ml L^{-1} of iron) also excelled on the other treatments, resulting in the highest leaf area (486.42 cm²).The results also show that the bi- interactions (adding 50 ml L^{-1} of Vermicompost and spraying 6 ml L^{-1} of iron) resulted in the highest leaf area (486.42 cm²). ... As for triple interaction between spraying nano boron at a level of 15 ml L^{-1} and spraying iron at a level of 6 ml L^{-1}, it had a significant effect on leaf area, recording the highest value of 493.34 cm².Regarding triple interaction between the factors, the treatment with adding vermicompost at a concentration of 50 ml L^{-1}, spraying boron at a level of 15 ml

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L⁻¹, and spraying iron at a level of 6 mg L⁻¹ all recorded the highest average leaf area of 512.67 cm², while the control treatment recorded the lowest average leaf area of 277.33 cm².

Table 3.Effect of Adding Vermicompost and Spraying with Nano Iron and Boron on *Leaf Area (cm²)*

vermicompost	nano boron	nano-iron F0	F2	F4	F6	vermicompost x nano boron
V0	B0	277.33	349.00	402.33	462.00	372.67
	B5	306.00	368.33	410.00	474.67	389.75
	B10	319.01	377.33	418.33	496.33	402.75
	B15	330.00	395.33	440.00	512.67	419.50
V50	B0	345.00	379.00	407.67	430.33	390.50
	B5	354.67	384.67	414.00	437.00	397.59
	B10	367.00	396.00	421.00	447.67	407.92
	B15	372.00	403.67	426.67	474.00	419.09
LSD 0.05		5.50**				2.75**
vermicompost		vermicompost x nano-iron				Vermicompost average
V0		308.09	372.50	417.67	486.42	396.17
V50		359.67	390.84	417.34	447.25	403.77
LSD 0.05		2.75**				1.38**
nano boron		nano boron x nano-iron				nano boron average
B0		311.17	364.00	405.00	446.17	381.58
B5		330.34	376.50	412.00	455.84	393.67
B10		343.01	386.67	419.67	472.00	405.33
B15		351.00	399.50	433.34	493.34	419.29
LSD 0.05		3.89**				1.95**
average nano-iron		333.88	381.67	417.50	466.83	
LSD 0.05		1.95**				

3.3. stem diameter mm

Table 4 shows that adding vermicompost significantly affects stem diameter. The 50 ml L⁻¹ treatment resulted in the highest stem diameter (567.27 cm²), while the control treatment resulted in the lowest stem diameter (524.59 cm²).where, spraying papaya plants with nano-boron significantly increased the results of the 15 ml L⁻¹ treatment, gave the highest stem diameter (579.64 cm²) compared to the control treatment, which resulted in the lowest stem diameter (514.67 cm²). The effect of iron spraying on stem diameter was highly significant. The table shows that the differences were significant for both nanoiron treatments. The 6 mg L⁻¹ treatment resulted in the highest stem diameter (678.70 cm²), while the control treatment resulted in the lowest stem diameter (419.48 cm²). The results data also show that bi-interactions have a significant effect. The interaction treatment (adding 50 ml L⁻¹ of Vermicompost and spraying nano boron at a level of 15 ml L⁻¹) significantly excelled on the other treatments, gave the highest stem diameter of 593.00 cm². Similarly, the interaction treatment (adding 50 ml L⁻¹ of Vermicompost and spraying iron at a level of 6 ml L⁻¹) also significantly excelled on the other treatments, gave the highest stem diameter of 677.48 cm².The bi-interaction between spraying nano boron at a level of 15 ml L⁻¹ and spraying iron at a level of 6 ml L⁻¹ also had a significant effect on stem diameter, recording the highest value of 719.00 cm².The results also show that the bi-interaction between spraying nano boron at a level of 15 ml L⁻¹ and spraying iron at a level of 6 ml L⁻¹ had a significant effect on stem diameter. In triple interaction between the factors, the treatment with the addition of

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vermicompost at a concentration of 50 ml L⁻¹ and boron at a level of 15 ml L⁻¹, along with the application of iron at a level of 6 mg L⁻¹, recorded the highest average stem diameter of 744.00 cm², while the control treatment recorded the lowest average stem diameter of 341.50 mm.

Table 4. Effect of adding vermicompost and spraying with nano iron and boron on stem diameter mm

Vermicompost	Nano boron	Nano iron				Vermicompost x boron
		F0	F2	F4	F6	
V0	B0	341.50	450.92	530.33	629.67	488.11
	B5	355.42	470.83	550.67	652.17	507.27
	B10	407.33	483.92	561.75	693.83	536.71
	B15	425.25	507.83	588.00	744.00	566.27
V50	B0	426.92	493.75	588.75	655.50	541.23
	B5	454.92	503.33	607.48	675.50	560.31
	B10	469.67	520.08	623.50	684.92	574.54
	B15	474.83	565.67	637.50	694.00	593.00
		12.15**				6.08**
Vermicompost		Vermicompost x iron				Average vermicompost
V0		382.38	478.38	557.69	679.92	524.59
V50		456.59	520.71	614.31	677.48	567.27
		6.08**				3.04**
boron Nano		boron x iron				Average boron
B0		384.21	472.34	559.54	642.59	514.67
B5		405.17	487.08	579.08	663.84	533.79
B10		438.50	502.00	592.63	689.38	555.63
B15		450.04	536.75	612.75	719.00	579.64
		8.59**				4.30**
Average iron		419.48	499.54	586.00	678.70	
		4.30**				

3.4.chlorophyll pigment

The results in Table (5) show that the addition of vermicompost has a significant effect on chlorophyll intensity in leaves. The 50 ml L⁻¹ treatment recorded the highest chlorophyll content in the leaves (36.86 spad), while the control treatment gave the lowest chlorophyll content in the leaves (36.452 spad).where, spraying papaya plants with nano-boron resulted in a significant advantage for the 15 ml L⁻¹ treatment, giving the highest chlorophyll content in the leaves (38.66 spad) compared to the control treatment, which gave the lowest chlorophyll content in the leaves (34.44 spad).Regarding the effect of iron spraying on chlorophyll pigment intensity in leaves, the results were highly significant. The table shows that the differences were significant for the two iron treatments. The 6 mg L⁻¹ treatment resulted in the highest chlorophyll content in the leaves (45.46 spad), while the control treatment resulted in the lowest chlorophyll content (30.155 spad).The results also indicate that the two-dual interactions had a significant effect. The interaction treatment (adding 50 ml L⁻¹ of

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vermicompost and spraying 15 ml L⁻¹ of nano boron) significantly excelled on the other treatments, resulting in the highest chlorophyll content in the leaves (38.122 spad²). Similarly, the interaction treatment (adding 50 ml L⁻¹ of vermicompost and spraying 6 ml L⁻¹ of iron) also outperformed the other treatments, resulting in the highest chlorophyll content in the leaves (48.499 spad). Regarding triple interaction between spraying with nano-boron at a level of 15 ml L⁻¹ and spraying with iron at a level of 6 ml L⁻¹, it had a significant effect on chlorophyll intensity in leaves, recording the highest value of 48.623 spad.As for triple interaction between the factors, the treatment of adding vermicompost at a concentration of 50 ml L⁻¹, spraying with boron at a level of 15 ml L⁻¹, and spraying with iron at a level of 6 mg L⁻¹ all recorded the highest average chlorophyll intensity in leaves, at 53.4 spad, while the control treatment recorded the lowest average chlorophyll intensity in leaves, at 26.42 spad.

Table 5.The effect of adding vermicompost and spraying with nano iron and boron on chlorophyll pigment

Vermicompost	Nano boron	Nano iron				Vermicompost x boron
		F0	F2	F4	F6	
V0	B0	26.243	30.827	34.777	41.953	33.450
	B5	28.050	31.920	35.740	46.597	35.577
	B10	28.530	32.560	37.320	51.953	37.591
	B15	29.830	34.340	39.097	53.493	39.190
V50	B0	29.717	34.407	36.820	40.800	35.436
	B5	32.163	34.667	37.083	42.197	36.528
	B10	32.943	35.473	37.997	42.973	37.347
	B15	33.763	36.397	38.573	43.753	38.122
			0.706**			0.353**
Vermicompost		Vermicompost x iron				Average vermicompost
V0		28.163	32.412	36.734	48.499	36.452
V50		32.147	35.236	37.618	42.431	36.858
			0.353**			0.177**
boron Nano		boron x iron				Average boron
B0		27.980	32.617	35.799	41.377	34.443
B5		30.107	33.294	36.412	44.397	36.052
B10		30.737	34.017	37.659	47.463	37.469
B15		31.797	35.369	38.835	48.623	38.656
			0.499**			0.250**
Average iron		30.155	33.824	37.176	45.465	
			0.250**			

3.2. DISCUSSION

The data results in Tables 2, 3, 4, and 5 indicate Numerous studies have shown that organic fertilization using vermicompost plays an effective role in improving the vegetative traits of papaya trees (Carica papaya L.). It contributes to increased plant height, stem diameter,

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number of leaves, and leaf area. This is attributed to its content of readily available nutrients, in addition to improving the physical and chemical properties of the soil and activating microorganisms, which positively impacts nutrient absorption efficiency and vegetative growth [8]. Furthermore, boron is an essential micronutrient that plays a crucial role in cell division, cell wall formation, and sugar translocation. Studies have demonstrated that adding boron via foliar or soil application significantly improves papaya vegetative traits , particularly increasing the number of leaves, leaf area, and plant height compared to the control treatment, especially in soils deficient in this [9,10]. In recent years, applications of micronutrients in nanoparticle form have demonstrated higher efficiency compared to traditional fertilizers. Studies on various horticultural crops have shown that the use of nano-boron enhanced vegetative growth and improved plant physiology due to increased absorption efficiency and reduced losses. This suggests the potential application of this modern technology in papaya trees, although direct studies on it are limited to date [11]. The increased height of papaya plants with higher levels of vermicompost application may be attributed to its role in improving soil structure by increasing the weighted diameter and decreasing the bulk density of the soil . This improves soil properties, increases nutrient availability, and consequently enhances plant absorption efficiency and water retention capacity. This, in turn, promotes cell division and elongation, leading to increased plant height [10]. The effect of boron spraying may be attributed to its antitranspirant action in preserving the nutrient content of plant tissues. The increase in plant height occurs through cell division and expansion, a process known as growth. This implies the availability of cell-building materials, turgor pressure, regulation of membrane permeability, and internal hormonal balances—all of which are linked to the plant's nutrient content. Furthermore, boron reduces heat stress on the plant, thus increasing its height [12]. The increased height of papaya plants with increased iron spraying may be attributed to iron's role in the formation of nucleic acids and chlorophyll, which are involved in photosynthesis. This, in turn, leads to increased vegetative growth. Additionally, iron contains some growth regulators that increase cell division and elongation, thus increasing plant height [13]. The increase in leaf area with increased polymer application may be attributed to the fact that polymers are soil conditioners and play an important role in improving soil physical properties, including water-holding capacity. The specific surface area of the polymer allows for the absorption of a larger quantity of irrigation water on its surfaces, thus conserving it. It is released to the plant as needed [14] which helps the plant increase vegetative growth and thus increase leaf area. This is consistent with [15] who found an increase in leaf area of banana trees with increased application of vermicompost.

The increase in vegetative traits with increasing boron concentration may be attributed to achieving a balance between reducing transpiration during peak transpiration times and allowing gas exchange during moderate transpiration times. This is accomplished through the hydration of boron compounds during high transpiration rates, followed by the release of the antitranspirant layer when transpiration is low or absent. Thus, their action is regulatory rather than a complete inhibition of transpiration, allowing for growth and an increase in leaf area. Furthermore, increased reflection of direct sunlight and ultraviolet radiation leads to a reduction in light intensity and leaf temperature, which in turn contributes to increased leaf area [16]. The variation in stem diameter with increasing levels of vermicompost application is attributed to the use of super-absorbent vermicompost polymers. These polymers play a significant role in enhancing the soil's ability to absorb, store, and release large quantities of

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water to the plant. Furthermore, they improve important soil physical properties such as increasing the weighted diameter, total porosity, and bulk density. This facilitates the absorption of large amounts of water and nutrients by the roots, positively impacting vegetative growth and increasing stem diameter [17]. The increase in stem diameter with increasing levels of boron application may be due to boron spraying improving the plant's water status and reducing water stress in cells during cell division. This creates favorable conditions for the movement and translocation of synthesized nutrients. These combined effects enhance plant growth by sustaining photosynthesis, which is reflected in vegetative growth indicators, including increased stem diameter [18]. The increase in iron may be attributed to its role in the synthesis of amino acids, proteins, and mineral nutrients, which are involved in the synthesis of growth hormones such as auxins, particularly IAA. IAA plays a role in increasing the activity of the primary cambium and subsequently in increasing stem diameter [19]. The increase in total chlorophyll in papaya leaves is attributed to the role of composting in increasing water use efficiency and extending irrigation intervals. This is due to the increased time the soil reaches its permanent wilting point, improved drainage and permeability, and thus providing the plant with relatively continuous moisture and improved soil aeration [20]. This leads to increased photosynthetic efficiency in the plants, as well as reduced nutrient loss through leaching, since compost acts as a carrier, especially for macronutrients essential for pigment synthesis. These factors contribute to the increase in chlorophyll in the leaves. The effect of boron (kaolin) on increasing total chlorophyll concentration in papaya leaves may be attributed to high light reflectance and reduced solar radiation stress on the leaves, leading to improved photosynthetic efficiency and increased chlorophyll content [21]. This aligns with the findings of [22] who observed increased light reflectance and chlorophyll in grape leaves.

4. CONCLUSIONS

From the results of the current study, we conclude the following:

1-Adding a level of (5 ml L^{-1}) of vermicompost improved most vegetative traits .
2-Iron levels, especially the level of (6 mg L^{-1}), affected most of the studied traits .
3- The superiority of the boron level (15 mg L^{-1}) was observed in most of the studied traits .
4-The best interaction treatment positively affected vegetative growth traits .
5- We conclude that spraying boron and iron and adding vermicompost improved the vegetative traits of papaya trees.

DECLARATION OF COMPETING INTEREST

None

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