Original Article

Growth and Yield Responses of Apple Cultivars to Organic Manure and Plant Extracts

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Abstract

This study investigated the influence of organic manure and nettle plant extract at three concentrations on the vegetative and yield characteristics of the Starking, Granny Smith and local apple cultivar during the 2024 growing season at a private orchard in Duhok government, Iraq. Foliar spraying was conducted on the 25th of April and May, 2024. A factorial randomized complete block design with three replications was used. Statistical analysis using SAS software with Duncan's multiple range test ($p \leq 0.05$) revealed significant cultivar-specific responses. The Granny Smith cultivar demonstrated superior performance in vegetative parameters, exhibiting 97.6% greater leaf area (90.92 cm^2 against. 47.32-47.48 cm^2), 12.1% higher leaf chlorophyll content (28.38 $mg \cdot g^{-1}$), and 64.5% greater yield (183.33 $kg \cdot tree^{-1}$) compared to the Starking and local cultivars. The optimal treatments (4 $mL \cdot L^{-1}$ organic manure + 200 $mg \cdot L^{-1}$ nettle extract) significantly enhanced various physiological and yield parameters for leaf area (+97.6%), fruit peel chlorophyll (+67.2%), total soluble solids (19.67%), and anthocyanin content (98.82% in Starking), while reducing fruit acidity by 30.4% in the Granny Smith. These findings show that integrated organic amendments can effectively improve apple productivity and fruit quality, with cultivar-specific responses highlighting the importance of genotype selection in sustainable orchard management systems.

Keywords: apple, Granny Smith, organic manure, plant extract, nettle extract

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Introduction

The *Malus domestica* Borkh. of the Rosaceae family represents a phylogenetically and economically important temperate fruit crop, with anthropogenic selection driving the diversification of over 7,000 cultivars adapted to latitudes ranging from 35° to 55°N (21). While historically confined to temperate zones, contemporary cultivation has expanded into subtropical regions through the selection of low-chill cultivars (<500 chilling hours), including commercial plantings in northern Iraq (27). However, this geographic expansion has exacerbated reliance on synthetic agrochemicals, resulting in well-documented soil microbiota disruption and yield instability under prolonged use (36)

The central and northern parts of Iraq are the main apple growing areas. Because they are more adapted to warmer environments, native apple varieties that require fewer chilling hours are frequently planted in the central provinces. On the other hand, both domestic and imported apple types are grown in the northern areas due to its milder climate. Some of the more popular apple varieties there include the Starking Delicious, Golden Delicious, and Rigard Delicious. Due to the region's ideal climate, these cultivars thrive

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and produce excellent fruit that can be sold commercially or consumed domestically (27).

Granny Smith apples are the most widely cultivated in most countries of the world, accounting for 25% of apple plantings in 2008. Not all orchard sites are ideal for growing this long-season fruit. This variety has some characteristics that demand extra attention compared to the Red Delicious, a very vigorous diploid variety of chance seedling origin. The fruit is round to slightly conical and medium to large while the stem is medium length, similar to that of the Red Delicious, and the calyx is tightly closed. The fruit is bright to pale green at proper harvest time, and turns creamy green and buff yellow with advancing maturity. Its surface wax is rather greasy after long storage. It is an excellent keeper, but is susceptible to scald and bitter pit. The flesh is white, crisp, fine-grained, sweet, and tart. The trees produce upright, whippy growth with large, dark green leaves. It is one of the last varieties to drop leaves in the fall. A virus indicator for green crinkle and flat apple virus diseases (8).

Organic manures (e.g., vermicompost) and plant extracts (e.g., stinging nettle, garlic) are increasingly recognized for their role in sustainable apple (*Malus domestica*) production as they enhance soil micronutrient bioavailability (K, Ca, Mg, Fe, Zn) and improving fruit quality parameters, including total soluble solids (TSS), sugar content (fructose, glucose, sucrose), and antioxidant capacity (phenolics, flavonoids) (13, 17). These amendments stimulate soil microbial activity (e.g., Azotobacter, Pseudomonas, mycorrhizal fungi), promoting nutrient mineralization and phytohormone production (auxins, cytokinins), which enhance root uptake efficiency (36). Yet, most studies focus on single amendments or long-term effects, leaving a gap in understanding (26) how short-term foliar applications (e.g., nettle extract) compare to traditional mineral fertilizer, and in the cultivar-specific responses to integrated organic treatments.

Stinging nettle (*Urtica dioica* L.) is a perennial herb of the Urticaceae family. This plant is widespread in temperate and tropical regions across North America, Europe, and Asia due to its ability to adapt to a diverse range of climates. A monoecious species, it blooms and bears fruit during the summer. Its stems and leaves are coated with stinging hairs (trichomes) that release a fluid capable of causing skin irritation and blisters upon contact (9). It grows wild throughout Europe, Asia, North Africa, and North America in mild to moderate temperatures, particularly in woodlands and damp, shaded areas. Due to its rapid growth, it is often regarded as a nuisance or a weed (11). Common nettle is known primarily for its antioxidant, antiplatelet, hypoglycaemic, and hypocholesterolemic properties (10).

Leaf mineral content (nitrogen, phosphorus, and potassium, total soluble solids (TSS), total sugar, and decreased total acidity) of pear trees were enhanced by spraying plant extract (garlic extract at 2 and 4%, moringa extract at 2 and 4%, and licorice extract at 2 and 4 $g.L^{-1}$ (1). According to (14), TSS and anthocyanin pigment in the skin of fruits increased by spraying garlic, turmeric, or roselle extracts at 0.2% (2g of powder to 1 liter of distilled water) for each plant extract. Foliar feeding with seaweed extract at 1 $g.L^{-1}$ significantly outperformed the other treatments by producing the highest rates and ratios of seedling height (cm), number of leaves (leaf $seedling^{-1}$), leaf area (cm^2), nitrogen percentage, total leaves protein (%), and leaf chlorophyll content (mg/100 g fresh weight), while the control treatment gave the lowest rates and ratios (3). In order to improve the quality of apple fruits, there are many factors must be considered such as (mineral content in soil and nutrient state of trees), for this reasons, (35). studied the Impact of Organic Fertilizer Substitution on Apple Orchard, they noticed that the quality of fruits was improved by managing the soil nutrient states.

This study investigated the effect of bio-foliar and plant extracts spraying on the quantity and quality of three apple fruit tree cultivars. As there is a lack of field studies on the effects of the short-term extract as a

fertilizer, this research offers valuable comparisons on the long- and short-term plant-based fertilizers against mineral fertilizers.

Materials and Methods

The experiment was conducted in a private orchard in Duhok City, Kurdistan Region, Iraq, at the Majilmakht location during the 2024 growing season. The area is located between 37°00'52"N and 43°09'47" E and 1006 meters above sea level, with average temperatures of -2 °C in winter and 35 °C in summer. The total rainfall recorded was 1252 millimeters. The cultivars were budded on seedling rootstock and planted in 6 x 6 m lots. The trees were trained using the open central method, and the orchard was irrigated with a drip irrigation system. Tree pruning was done during winter. The selection of trees for the study were based on their healthy state, vigor, uniformity, shape, and age (12-years).

The vegetative growth, and yield quantitative and qualitative traits of the fruit of the Starking, Granny Smith, and local apple cultivars were determined by foliar spraying liquid organic manure (bio-foliar) at 0, 2, and 4 ml.L^{-1} and nettle plant extract at 0, 100, and 200 mg.L^{-1} concentrations, together with their interactions. Nettle leaves were collected from local plants and dried for two days in an oven at 70 °C before crushing. Fifty grams of powdered leaves were added to 1000 mL of 80% ethanol for 24 hours, and then the solution was filtered (24). Foliar application of the organic fertilizer and nettle extract was made twice, before full bloom on April 25, and after the fruits set on May 25, 2024.

The experiment was replicated thrice, with each tree serving as a single experimental unit (81 trees). A factorial randomized complete block design was used to arrange the treatments for analysis, and the SAS program was used to detect significance (32). The means of treatment were compared using Duncan's multiple range test (5).

Table 1. Properties of nettle plant extract

Parameters	Nettle powder
Moisture (%)	7.67
Protein (%)	22.17
Carbohydrate (%)	35.29
Calcium (mg/100 g)	152.74
Iron (mg/100 g)	215.39
Zinc (mg/100 g)	2.74
Magnesium (mg/100 g)	48.23

Measurements

Leaf area (cm^2): Fully expanded leaves were taken on August 15, 2024 from each experimental unit to determine the leaf area. This was achieved by photographing them on previously weighed A4 white paper. The leaf photograph was then cut out and weighed to obtain the corresponding area for each mg of A4 paper. Leaf area was calculated using the following equation (30).

$$\text{Leaf area (cm2)} = \frac{\text{area of (A4) paper cut} \times \text{part weight (g)}}{\text{Weight of (A4) paper (g)}}$$

Leaf dry weight (g): Thirty leaves were used to determine leaf area and their dry weight. The leaves were washed in tap followed by distilled water and oven-dried at 70° C for 72 hours. When their weights were stable, the leaves were weighed with an electrical balance to record their dry weight (7).

Total chlorophyll (mg.g^{-1}): Chlorophyll A, B, and total chlorophyll were determined on August 20, 2024 using leaf extractions with acetone (80%), and then filtered with a

centrifuge for five minutes at 3000 rpm. Light absorption was subsequently determined with a Spectrophotometer at 663 and 645 nm (22).

Fruit anthocyanin content in Starking and local peels (mg.g^{-1}) and chlorophyll content in Granny Smith peels (mg.g^{-1}): Determined on December 1, 2024 by weighing 5 grams of fresh fruit peel, diluting in a 100 mL mixture of 85% ethanol and 15% 1.5 N HCl, and then storing at 5 °C for 24 hours. The peels were then diluted to 500 mL with the same mixture, filtered through filter paper, and examined using a spectrophotometer at 535 nm (28 and 4).

Fruit firmness (Ibs): was measured on 30 collected fruits on July 25, September 15, and October 10, 2024 for the local, Granny Smith, and Starking cultivars, respectively using a Magness and Tylor Pressure tester with an 8-mm diameter plunger (penetrometer).

Total soluble solids (%): measured with 30 fruits using Carolzeiss hand Refractometer (20).

Total sugar (%): Measured by taking 1ml from pure juice of the fruit on December 6, 2024 and adding 1ml of phenol 5%, 18ml of distilled water, and 5ml of H2SO4 for 30 min in bath water at 60 ^{0}C, then 15 min in a centrifuge at 3000 rotate/min and placing the sample in a spectrophotometer at 490 nanometers. The standard sugar solution and standard curve were prepared using the Lane and Eynon method (18).

Total acidity (%) was determined in the fruit juice on December 6, 2024 (as malic acid) by titration with 0.1 M NaOH using phenolphthalein as an indicator (6).

Total yield kg.tree^{-1}: The weight of fruits harvested per plant at each harvest was recorded, and total yield per tree calculated and expressed in kilograms.

Results and Discussion

Leaf area cm^2: Table 2 clearly shows that the leaf area of the Granny Smith apple cultivar at 78.56 cm^2 was significantly different compared to the Starking and local cultivars at 47.32 and 47.48 cm^2, respectively.

Table 2. Effect of spraying organic manure and plant extracts on leaf area (cm^2) of the apple cultivars

Cultivars	Organic manure ml.L^{-1}	Nettle extract mg.L^{-1}			Cultivars * Organic manure	Cultivars
		0	100	200		
Starking	0	28.15 n	39.81 m	45.51 kl	37.82 h	47.32 b
	2	43.82 kl	49.49 h-j	50.54 hi	47.95 f	
	4	52.65 gh	55.73 g	60.19 f	56.19 d	
Granny Smith	0	67.93 e	73.98 d	73.72 d	71.88 c	78.56 a
	2	74.58 d	75.64 d	82.09 c	77.44 b	
	4	82.35 bc	85.85 b	90.92 a	86.37 a	
Local	0	41.95 lm	42.29 lm	43.95 kl	42.73 g	47.48 b
	2	45.00 kl	45.94 j-l	46.93 i-k	45.96 f	
	4	47.77 i-k	52.05 gh	61.41 f	53.74 e	
Nettle extract		53.80 c	57.86 b	61.69 a	Organic manure	
Cultivars * Nettle extract	Starking	41.54 g	48.34 e	52.08 d		
	Granny Smith	74.96 c	78.49 b	82.25 a		
	Local	44.91 f	46.76 ef	50.76 d		
Organic manure * Nettle extract	0	46.01 g	52.02 f	54.39 e	0	50.81 c
	2	54.47 e	57.02 d	59.85 c	2	57.11 b
	4	60.92 c	64.54 b	70.84 a	4	65.43 a

Means for each factor and their interactions sharing the same letter(s) are not statistically different at the 5% probability level, as determined by Duncan's multiple range test.

On the other hand, the high concentrations of organic manure and plant extract had a positive effect on leaf area, leading to an increase in it. Organic manure at 4 ml L^{-1} application increased leaf area in the Granny Smith more than the other concentrations and the other cultivars. Also, the high concentration of plant extract 200 mg.L^{-1} had a significant effect on the Granny Smith leaf area compared to the other combinations. In

the di-interactions between organic manure and plant extract, leaf area showed the optimum effect at 4 ml.L^{-1} and 200 mg.L^{-1} , at 70.84 cm^2, compared with the 0 ml.L^{-1} and 0 ml.L^{-1} control at 46.01 cm^2. The interactions between 4 ml.L^{-1} and 200 mg.L^{-1} with Granny Smith were the most effective in increasing leaf area, registering 90.92 cm², compared to the other combinations.

Leaf dry weight (g): As clearly evident in Table 3, the leaf dry weight of Granny Smiths at 4.19 g were significantly higher compared to the Starking and local cultivars at 3.74 and 3.82 g, respectively. Organic manure had a significant effect on improving this variable especially at 4 ml.L^{-1}, which was 4.47 g compared to the control ‘s 3.28 g. Also spraying nettle extract at 200 mg.L^{-1} led to higher leaf dry weight (4.46 g) compared with the control (3.33 g).

Table 3. Effect of spraying organic manure and plant extracts on leaf dry weight (g) of the apple cultivars

Cultivars	Organic manure ml.L^{-1}	Nettle extract mg.L^{-1}			Cultivars * Organic manure	Cultivars
		0	100	200		
Starking	0	2.52 kl	3.43 h-j	3.60 g-j	3.18 de	3.74 b
	2	3.11 j	3.31 ij	3.99 d-h	3.47 cd	
	4	4.25 d-f	4.40 ed	5.05 a-c	4.56 a	
Granny Smith	0	3.02 jk	3.58 g-j	4.14 d-g	3.58 c	4.19 a
	2	3.42 h-j	4.61 b-d	5.48 a	4.51 a	
	4	4.39 ed	4.50 c-e	4.54 b-e	4.48 a	
Local	0	2.07 l	3.42 h-j	3.75 f-i	3.08 e	3.82 b
	2	3.22 ij	4.33 d-f	4.50 c-e	4.02 b	
	4	3.96 e-h	4.03 d-h	5.10 ab	4.36 a	
Nettle extract		3.33 c	3.96 b	4.46 a	Organic manure	
Cultivars * Nettle extract	Starking	3.29 e	3.71 d	4.21 bc		
	Granny Smith	3.61 d	4.23 bc	4.72 a		
	Local	3.08 e	3.93 cd	4.45 ab		
Organic manure * Nettle extract	0	2.54 e	3.48 d	3.83 c	0	3.28 c
	2	3.25 d	4.08 bc	4.66 a	2	4.00 b
	4	4.20 b	4.31 b	4.90 a	4	4.47 a

Means for each factor and their interactions sharing the same letter(s) are not statistically different at the 5% probability level, as determined by Duncan’s multiple range test.

For the interaction between cultivars and organic manure, the third organic manure concentration had a significant effect on leaf dry weight, while that for nettle extract with Granny Smith produced a higher value at 4.72 g compared with the other interaction treatments. Alternatively, high leaf dry weight value were obtained during the interactions between 4 ml.L^{-1} and 200 mg.L^{-1}, which was 4.90 g compared to the other interaction treatments. The table also shows that the triple interaction among the three factors created a strong combination especially at 2 ml.L^{-1} and 200 mg.L^{-1} for the Granny Smith in increasing leaf dry weight compared to the rest of the combinations.

Leaf chlorophyll content (mg.g^{-1}): The leaf chlorophyll content in the Granny Smith recorded the highest value, at 28.38 mg.g^{-1}, more than for the Starking (26.93 mg.g^{-1}) and local 24.39 mg.g^{-1} cultivars. Additionally, organic manure and plant extract at high concentrations improved the chlorophyll concentration in leaves at 28.70 and 28.94 mg.g^{-1}, respectively compared with the control’s 24.69 and 23.54 mg.g^{-1}, respectively.

Organic manure at 4 ml.L^{-1} had a significant effect in increasing the concentration of chlorophyll content in the leaves of the three cultivar types compared with the control. According to the findings, the chlorophyll content for the Granny Smith with 200 mg.L^{-1} of plant extract produced the highest value over the other combinations.

Table 4. Effect of spraying organic manure and plant extracts on leaf chlorophyll content (mg.g^{-1}) of the apple cultivars

Cultivars	Organic manure ml.L^{-1}	Nettle extract mg.L^{-1}			Cultivars * Organic manure	Cultivars
		0	100	200		
Starking	0	23.02 g-i	26.60 d-g	27.48 cde	25.70 cd	26.93 b
	2	23.51 f-i	27.45 cde	28.91 bcd	26.62 bc	
	4	26.99 c-f	27.63 cde	30.78 abc	28.47 b	
Granny Smith	0	19.37 j	27.73 cde	28.63 bcd	25.24 cd	28.38 a
	2	22.20 h-j	27.53 cde	33.83 a	27.86 b	
	4	31.37 ab	32.00 ab	32.73 a	32.03 a	
Local	0	19.30 j	24.44 e-i	25.67 d-i	23.14 e	24.39 c
	2	21.93 ij	25.53 d-i	25.83 d-h	24.43 de	
	4	24.17 e-i	26.11 d-g	26.55 d-g	25.61 cd	
Nettle extract		23.54 c	27.23 b	28.94 a	Organic manure	
Cultivars * Nettle extract	Starking	24.51 d	27.23 bc	29.06 b		
	Granny Smith	24.31 d	29.09 b	31.73 a		
	Local	21.80e	25.36 cd	26.02 cd		
Organic manure * Nettle extract	0	20.56 e	26.26 c	27.26 bc	0	24.69 c
	2	22.54 e	26.84 bc	29.52 a	2	26.30 b
	4	27.51 bc	28.58 ab	30.02 a	4	28.70 a

Means for each factor and their interactions sharing the same letter(s) are not statistically different at the 5% probability level, as determined by Duncan's multiple range test.

The data in Table 4 show that the ideal combination was 2 and 4 ml.L^{-1} of organic manure + 200 mg.L^{-1} of plant extract with the Granny Smith cultivar, compared with the other combinations. Organic manure at 4 ml.L^{-1} had a significant effect in increasing chlorophyll content in the leaves of the three cultivars compared with the control. According to the findings, the chlorophyll content in the leaves of Granny Smith at 200 mg.L^{-1} yielded the highest value compared with other combinations. The table shows that the optimum combination was 2 and 4 ml.L^{-1} of organic manure + 200 mg.L^{-1} of plant extract for the Granny Smith, compared to the other combinations.

Peel anthocyanin in the local and Starking fruits (mg.g^{-1}): As clearly seen in Table 5, anthocyanin pigment content in the fruit peels of the Starking cultivar (74.64 mg.g^{-1}) showed a significant difference over the local variety at 36.75 mg.g^{-1}. The effect of organic manure is apparent in the same table, especially at 4 ml.L^{-1}, which recorded a high value of 70.40 mg.g^{-1} compared with the control (0 ml.L^{-1}) at 42.65 mg.g^{-1}.

Table 5. Effect of spraying organic manure and plant extracts on the peel anthocyanin pigment content (mg.g^{-1}) in fruits of two apple cultivars

Cultivars	Organic manure ml.L^{-1}	Nettle extract mg.L-1			Cultivars * Organic manure	Cultivars
		0	100	200		
Starking	0	58.31 e	60.02 e	62.49 e	60.27 c	74.64 a
	2	63.94 de	71.72 c	70.46 cd	68.71 b	
	4	89.14 b	96.90 a	98.82 a	94.95 a	
Local	0	21.63 j	24.93 j	28.53 ij	25.03 f	36.75 b
	2	34.70 hi	39.27 gh	44.10 fg	39.36 e	
	4	40.97 gh	46.30 fg	50.30 f	45.86 d	

Nettle extract		51.45 b	56.52 a	59.12 a	Organic manure	
Cultivars * Nettle extract	Starking	70.46 b	76.21 a	77.26 a		
	Local	32.43 e	36.83 d	40.98 c		
Organic manure * Nettle extract	0	39.97 f	42.48 ef	45.51 de	0	42.65 c
	2	49.32 d	55.49 c	57.28 c	2	54.03 b
	4	65.05 b	71.60 a	74.56 a	4	70.40 a

Means for each factor and their interactions sharing the same letter(s) are not statistically different at the 5% probability level, as determined by Duncan's multiple range test.

Moreover, organic manure had a significant effect on anthocyanin pigments in the Starking cultivar, more so than in the local cultivar, especially at 4 ml.L^{-1}. Also, spraying plant extract with its two concentrations visibly increased the pigment content in the fruits at 56.52 mg.g^{-1} (100 mg.L^{-1}) and 59.12 mg.g^{-1} (200 mg.L^{-1}) nettle extract compared with the control's 51.45 mg.g^{-1}. The most potent triple interaction, 4 ml.L^{-1} organic manure and 200 mg.L^{-1} plant extract with the Starking cultivar, were found compared with all other combinations.

The effect of organic manure was apparent in the same table, especially at 4 ml.L^{-1}, which recorded a high value of 70.40 mg.g^{-1} compared to the control (42.65 mg.g^{-1}). Moreover, the organic manure had a significant effect on anthocyanin pigments in the Starking cultivar, more so than in the local cultivar, especially at 4 ml.L^{-1}. In addition, spraying plant extract with its two concentrations had a visible effect in increasing the pigment's content in fruits at 56.52 mg.g^{-1} (100 mg.L^{-1}) and 59.12 mg.g^{-1} (200 mg.L^{-1}) nettle extract compared with control's 51.45 mg.g^{-1}. The most effective triple combination, 4 ml.L^{-1} of organic manure and 200 mg.L^{-1} of plant extract with the Starking cultivar were compared with all other combinations.

Peel chlorophyll content in Granny Smith fruits (mg.g^{-1}): Figure 1 shows that the chlorophyll pigment in the fruit peel of the Granny Smith apple cultivar treated with 4 ml.L^{-1} organic manure, which recorded 9.12 mg.g^{-1}, had a significant difference over the control's 5.76 mg.g^{-1}.

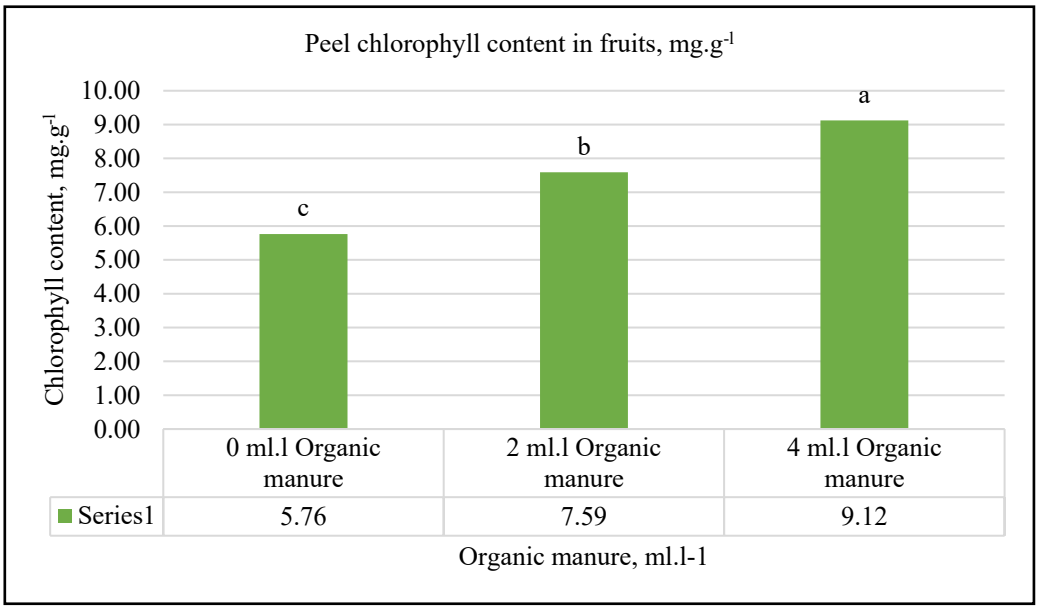

Fig. 1. Effect of organic manure on chlorophyll pigment content in the Granny Smith cultivar

The Granny Smith apple cultivar was sprayed with nettle extract to determine its effect on chlorophyll content in the fruit peel. Figure 2 shows that the chlorophyll content

increased with higher concentrations of the extract, with the highest value of 7.97 mg.g^{-1} obtained at 200 mg.L^{-1} compared to the 6.97 mg.g^{-1} for the control.

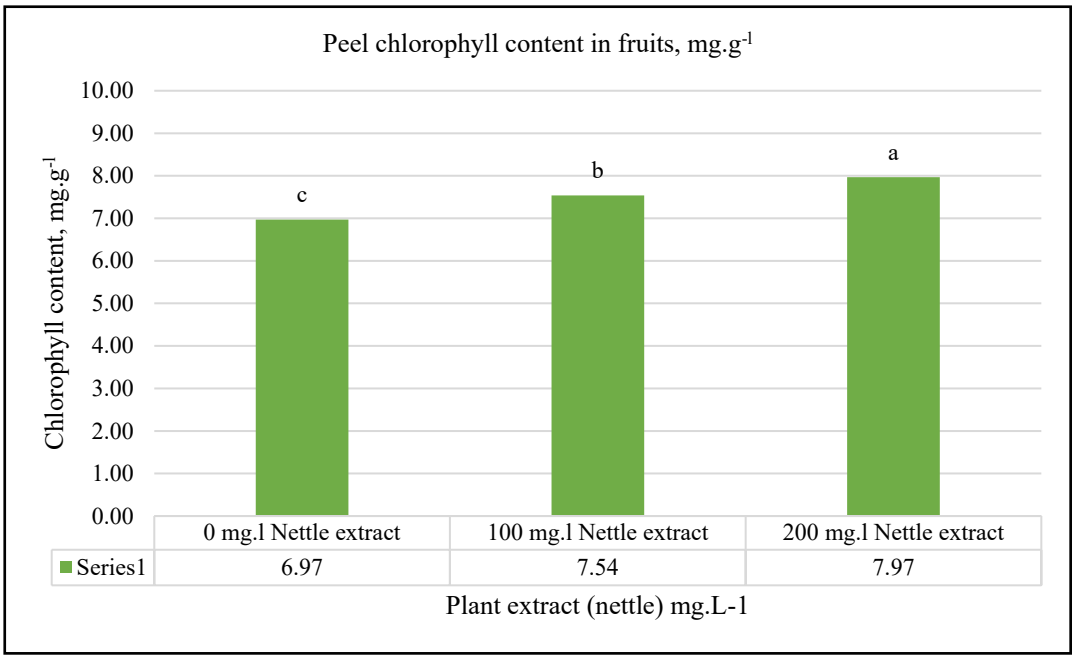

Fig. 2. Effect of plant extract on chlorophyll pigment content in the Granny Smith cultivar

Table 6 shows the effect of the interaction between organic manure and plant extract on chlorophyll pigment content in the peel of the Granny Smith. The results indicate that the best value was obtained at 4 ml.L^{-1} with 200 mg.L^{-1}, which was 9.63 mg.g^{-1} compared with the control at 5.14 mg.g^{-1} and all other combinations.

Table 6. Effect of spraying organic manure and plant extracts on the peel chlorophyll pigment content (mg.g^{-1}) in fruits of the Granny Smith apple cultivars

Organic manure ml.L^{-1}	Nettle extract mg.L^{-1}			Organic manure
	0	100	200	
0	5.14 g	5.79 f	6.37 e	5.76 c
2	7.33 d	7.53 cd	7.90 c	7.59 b
4	8.43 b	9.30 a	9.63 a	9.12 a
Nettle extract	6.97 c	7.54 b	7.97 a	

Means for each factor and their interactions sharing the same letter(s) are not statistically different at the 5% probability level, as determined by Duncan's multiple range test.

Fruit firmness (Ibs): The Granny Smith maintained the highest firmness (18.94 Ibs), significantly outperforming the local at 14.56 Ibs (Table 7) while Starking exhibited an intermediate value (16.69 Ibs). The control (0 mL.L^{-1} organic manure) yielded the firmest fruits (18.25 Ibs), with firmness declining as OM increased from 17.10 Ibs (2 mL.L^{-1}) to 14.85 Ibs (4 mL.L^{-1}). Nettle extract application reduced firmness dose-dependently. The control (0 mg.L^{-1} nettle extract) preserved firmness best at 18.35 Ibs, while the 200 mg.L^{-1} NE resulted in the softest fruits (15.38 Ibs). The Granny Smith with 0 mL.L^{-1} OM achieved peak firmness (20.39 Ibs), whereas the local at 4 mL·L^{-1} had the lowest (13.54 Ibs). Granny Smith retained higher firmness across all NE doses at 20.44 Ibs (0 mg.L^{-1}) and 17.83 Ibs (200 mg.L^{-1}), while the local was most sensitive at 13.39 Ibs (200 mg.L^{-1}). The

combination of 0 mL.L⁻¹ OM + 0 mg.L⁻¹ NE maximized firmness (20.33 Ibs), contrasting with the 14.22 Ibs for the 4 mL.L⁻¹ OM + 200 mg.L⁻¹ NE. In the triple combination, the highest value for fruit firmness (22 Ibs) was with the Granny Smith when spraying 2 mg.L⁻¹ organic manure and 0 ml.L^{-1} nettle extract.

Table 7. Effect of spraying organic manure and plant extracts on the firmness of fruits (Ibs) of the apple cultivars

Cultivars	Organic manure ml.L^{-1}	Nettle extract mg.L^{-1}			Cultivars * Organic manure	Cultivars
		0	100	200		
Starking	0	21.33 ab	19.00 a-e	16.20 d-h	18.84 a	16.69 b
	2	19.33 a-d	15.83 d-h	14.70 gh	16.62 b	
	4	15.00 f-h	15.00 f-h	13.83 h	14.61 bc	
Granny Smith	0	21.50 ab	20.17 a-c	19.5 a-d	20.39 a	18.94 a
	2	22.00 a	19.33 a-d	18.83 a-f	20.06 a	
	4	17.83 b-g	16.17 d-h	15.17 e-h	16.39 b	
Local	0	18.17 a-g	15.37 e-h	13.00 h	15.51 bc	14.56 c
	2	16.67 c-h	13.70 h	13.50 h	14.62 bc	
	4	13.33 h	13.63 h	13.67 h	13.54 c	
Nettle extract		18.35 a	16.47 b	15.38 b	Organic manure	
Cultivars * Nettle extract	Starking	18.56 ab	16.61 b-d	14.91 d-f		
	Granny Smith	20.44 a	18.56 ab	17.83 bc		
	Local	16.06 c-e	14.23 ef	13.39 f		
Organic manure * Nettle extract	0	20.33 a	18.18 bc	16.23 cd	0	18.25 a
	2	19.33 ab	16.29 cd	15.68 d	2	17.10 b
	4	15.39 d	14.93 d	14.22 d	4	14.85 c

Means for each factor and their interactions sharing the same letter(s) are not statistically different at the 5% probability level, as determined by Duncan's multiple range test.

Total soluble solids (%): Total soluble solids (TSS) were significantly influenced by cultivar selection, organic manure, and nettle extract applications, with notable interactions (Table 8). Starking exhibited the highest TSS (18.33% at 4 mL.L⁻¹ OM + 200 mg.L⁻¹ NE), followed by the local (14.43%) and Granny Smith (13.76%). TSS increased with organic manure from 13.30% (0 mg.L⁻¹ OM) to 14.34% (100 mg.L⁻¹) and 14.84% (200 mg.L⁻¹). Starking showed the strongest response to organic manure, rising from 12.87% (0 mL.L⁻¹) to 18.33% (4 mL.L⁻¹), while Granny Smith was least responsive (12.57% to 13.76%). Starking benefited most from nettle extract (16.71% at 200 mg.L⁻¹), while Granny Smith showed minimal change (13.37%). The highest TSS (16.10%) occurred at 4 mL.L⁻¹ OM + 200 mg.L⁻¹ NE, surpassing the control's 11.71% at 0 mg.L⁻¹ OM + 0 mg.L⁻¹ NE. The combination of high organic manure (4 mL.L⁻¹) and nettle extract (200 mg.L⁻¹) maximized TSS in Starking (19.67%), suggesting synergistic effects. Granny Smith's TSS remained stable across treatments, indicating cultivar-specific limitations in sugar accumulation.

Table 8. Effect of spraying organic manure and plant extracts on the total soluble solid (%) in fruits of the apple cultivars

Cultivars	Organic manure ml.L^{-1}	Nettle extract mg.L^{-1}			Cultivars * Organic manure	Cultivars
		0	100	200		
Starking	0	10.67 k	13.77 f-h	14.17 fg	12.87 e	15.54 a
	2	14.60 ef	15.37 de	16.30 cd	15.42 b	
	4	16.67 c	18.67 b	19.67 a	18.33 a	
Granny Smith	0	12.30 ij	12.70 h-j	12.70 h-j	12.57 e	13.13 c
	2	12.73 h-j	13.13 g-j	13.33 g-i	13.07 e	
	4	13.57 f-h	13.63 f-h	14.07 fg	13.76 d	
Local	0	12.17 j	12.80 h-j	14.17 fg	13.04 e	13.81 b

	2	12.80 h-j	14.50 ef	14.57 ef	13.96 cd	
	4	14.20 fg	14.53 ef	14.57 ef	14.43 c	
Nettle extract		13.30 c	14.34 b	14.84 a	Organic manure	
Cultivars * Nettle extract	Starking	13.98 c	15.93 b	16.71 a		
	Granny Smith	12.87 d	13.16 d	13.37 d		
	Local	13.06 d	13.94 c	14.43 c		
Organic manure * Nettle extract	0	11.71 d	13.09 c	13.68 c	0	12.83 c
	2	13.38 c	14.33 b	14.73 b	2	14.15 b
	4	14.81 b	15.61 a	16.10 a	4	15.51 a

Means for each factor and their interactions sharing the same letter(s) are not statistically different at the 5% probability level, as determined by Duncan's multiple range test.

Total sugar in fruits (%): Table 9 shows that total sugar in fruits was substantially higher in the local and Starking than in the Granny Smith cultivars.

Table 9. Effect of spraying organic manure and plant extracts on the total sugar percentage in fruits of the apple cultivars

Cultivars	**Organic manure ml.L^{-1}**	**Nettle extract mg.L^{-1}**			**Cultivars * Organic manure**	**Cultivars**
		0	100	200		
Starking	0	22.47 m	25.14 kl	26.85 j	24.82 f	32.60 a
	2	29.29 i	32.33 gh	35.40 f	32.34 c	
	4	38.56 e	41.13 c	42.24 c	40.64 b	
Granny Smith	0	11.19 q	14.39 p	16.33 o	13.97 h	22.67 b
	2	18.32 n	24.56 l	26.48 j	23.12 g	
	4	28.52 i	31.19 h	33.09 g	30.93 d	
Local	0	18.96 n	24.45 l	25.66 j-l	23.02 g	32.81 a
	2	25.19 kl	26.11 jk	26.84 j	26.05 e	
	4	39.84 d	49.29 b	58.93 a	49.35 a	
Nettle extract		25.82 c	29.84 b	32.43 a	Organic manure	
Cultivars * Nettle extract	Starking	30.11 d	32.87 c	34.83 b		
	Granny Smith	19.34 h	23.38 g	25.30 f		
	Local	28.00 e	33.28 c	37.14 a		
Organic manure * Nettle extract	0	17.54 i	21.33 h	22.95 g	0	20.61 c
	2	24.27 f	27.67 e	29.57 d	2	27.17 b
	4	35.64 c	40.54 b	44.75 a	4	40.31 a

Means for each factor and their interactions sharing the same letter(s) are not statistically different at the 5% probability level, as determined by Duncan's multiple range test.

The highest significance value of total sugar in fruits was obtained at 4 ml.L^{-1} (40.31 %) compared with the control (20.61 %). The same result was observed with the plant extract, where the high concentration of 200 ml.L^{-1} led to an increase in the total sugar content in the fruits compared to the control. Foliar spraying of organic manure at 4 ml.L^{-1} with the local cultivar yielded a high total sugar content in fruits compared with other combinations. The high concentration of organic manure (4 ml.L^{-1}) with plant extract (200 mg.L^{-1}) resulted in a significant increase in the total sugar content of the fruits, at 44.75%, compared to the control's 17.54%. Regarding the interaction effect of 4 ml.L-1 OM + 200 mg.L-1 plant extract, the local cultivar obtained the highest value of total sugar content compared to the other combinations.

Total acidity in fruits (%): The total acidity in the Granny Smith apple cultivar was more than in Starking and local cultivars, as shown in Table 10. Foliar spraying of organic manure and plant extract at high concentrations led to a reduction in total acidity in fruits, while total sugar levels were increased in balance. The highest total acidity (1.71 %) was recorded by Granny Smith with 0 ml.L^{-1} of organic manure compared with other treatments in combination between cultivars and organic manure. Also, the control of plant extract with

Granny Smith achieved the highest value for acidity (1.62 %) compared to the other treatments.

Table 10. Effect of spraying organic manure and plant extracts on the total acidity percentage in fruits of the apple cultivars

Cultivars	Organic manure ml.L^{-1}	Nettle extract mg.L^{-1}			Cultivars * Organic manure	Cultivars
		0	100	200		
Starking	0	1.34 de	1.08 e-g	1.16 ef	1.19 c	0.95 c
	2	0.92 f-h	0.84 f-h	0.74 gh	0.83 d	
	4	0.83 f-h	0.93 f-h	0.71 h	0.83 d	
Granny Smith	0	2.11 a	1.67 bc	1.35 c-e	1.71 a	1.43 a
	2	1.58 b-d	1.39 c-e	1.17 ef	1.38 b	
	4	1.15 ef	1.11 ef	1.31 de	1.19 c	
Local	0	1.80 b	1.07 e-h	1.57 b-d	1.48 b	1.10 b
	2	1.18 ef	0.94 f-h	0.84 f-h	0.99 d	
	4	0.82 f-h	0.84 f-h	0.84 f-h	0.83 d	
Nettle extract		1.30 a	1.10 b	1.08 b	**Organic manure**	
Cultivars * Nettle extract	Starking	1.03 cd	0.95 cd	0.87 d		
	Granny Smith	1.62 a	1.39 b	1.28 b		
	Local	1.27 b	0.95 cd	1.08 c		
Organic manure * Nettle extract	0	1.75 a	1.27 b	1.36 b	0	1.46 a
	2	1.23 bc	1.06 cd	0.92 d	2	1.07 b
	4	0.93 d	0.96 d	0.95 d	4	0.95 c

Means for each factor and their interactions sharing the same letter(s) are not statistically different at the 5% probability level, as determined by Duncan's multiple range test.

The interactions between 0 ml.L^{-1} of organic manure and 0 mg.L^{-1} of plant extract produced a significant increase (1.75%) in total fruit acidity, with the highest value obtained for the triple combination of the above amounts of organic manure and plant extract in the Granny Smith cultivar (2.11%).

Total yield kg.tree^{-1}: Table 11 shows that the Granny Smith fruit tree produced more yield per tree (183.33 kg.tree^{-1}) than the Starking and local cultivars at 111.34 and 106.34 kg.tree^{-1}, respectively. Organic manure at 4 ml.L^{-1} led to an increase in the total yield compared to other treatments, while the plant extract at 200 mg.L^{-1} increased it to 144.75 kg.tree^{-1} compared to the control's 119.29 kg.tree^{-1}. The organic manure had a significant effect in raising the total yield of Granny Smith more than the other two cultivars, especially at 2 and 4 ml.L^{-1}. The highest yield was obtained with the 200 mg.L^{-1} plant extract spraying on the Granny Smith cultivar (193.44 kg.tree^{-1}) and the lowest for the Starking at 0 mg.L^{-1} at 95.04 kg.tree^{-1}. Finally, the optimum interaction between organic manure at 4 mL.L^{-1} and plant extract at 200 mg.L^{-1} was recorded at 157.99 kg.tree^{-1}, compared with the control's 110.31 kg.tree^{-1} and the other interactions.

Table 11. Effect of spraying organic manure and plant extracts on the total yield kg.tree^{-1} of the apple cultivars

Cultivars	Organic manure ml.L^{-1}	Nettle extract mg.L^{-1}			Cultivars * Organic manure	Cultivars
		0	100	200		
Starking	0	84.97 ij	113.34 d-g	116.98 d-f	105.10 de	111.34 b
	2	91.75 g-j	115.32 d-g	119.86 d-f	108.98 c-e	
	4	108.40 e-h	117.28 d-f	134.16 d	119.95 c	
Granny Smith	0	166.00 c	171.67 bc	175.33 bc	171.00 b	183.33 a
	2	174.00 bc	189.00 a-c	194.33 ab	185.78 a	
	4	178.33 bc	190.67 ab	210.67 a	193.22 a	
Local	0	79.97 j	114.86 d-g	110.32d-g	101.72 e	106.34 b

	2	86.75 h-j	108.34 e-h	111.98d-g	102.36 de	
	4	103.40 f-i	112.28 d-g	129.16 de	114.95 cd	
Nettle extract		119.29 c	136.97 b	144.75 a	**Organic manure**	
Cultivars * Nettle extract	Starking	95.04 d	115.31 c	123.67 c		
	Granny Smith	172.78 b	183.78 ab	193.44 a		
	Local	90.04 d	111.82 c	117.15 c		
Organic manure * Nettle extract	0	110.31 c	133.29 b	134.21 b	0	125.94 b
	2	117.50 c	137.55 b	142.06 b	2	132.37 b
	4	130.05 b	140.08 b	157.99 a	4	142.71 a

Means for each factor and their interactions sharing the same letter(s) are not statistically different at the 5% probability level, as determined by Duncan's multiple range test.

Table 11 also shows that the 4 ml.L^{-1} organic manure and 200 mg.L^{-1} plant extract combination with the Granny Smith cultivar was superior in producing the highest total yield per tree compared to the other combinations.

The findings of this study demonstrate the well-documented differences among the cultivars. Various reasons are suggested for this, including genotypic effects and variable responses to temperature and solar radiation, among others. The well-performing Granny Smith fruit may be due to its greater propensity to utilize organic manure and plant extract and its growth traits, which increased its leaf area compared to the Starking and local cultivars. The plant extract had a significant effect on enhancing the vegetative growth of apple trees, achieved by protecting the trees from pathogens and pests. Additionally, the extract had a visible effect on improving nutrient uptake by the roots (33).

Based on the findings, the application of organic manure and plant extract increased leaf area and leaf chlorophyll content, as also reported by (12, 23, 31 and 25). The superior vegetative growth (78.56 cm² leaf area, 4.19 g dry weight, and 183.33 kg·tree^{-1} yield) of the Granny Smith compared to the Starking and local cultivars (Tables 2–11) align with earlier reports of its vigorous growth habit and efficient resource partitioning (15).

Notably, the cultivar's heightened chlorophyll content (28.38 mg·g^{-1}) and fruit firmness (18.94 lbs) suggest genetic advantages in photosynthetic efficiency and cell wall stability, consistent with findings for diploid cultivars (34). The 200 mg·L^{-1} nettle extract treatments increased leaf area (90.92 cm²) and yield (193.44 kg·tree^{-1}) in Granny Smith (Tables 2, 11), likely due to phytohormonal activity whereby the nettle's auxin/cytokinin analogs may enhance meristematic activity, corroborating similar effects of seaweed extracts (19). It could also be due to micronutrient chelation whereby the extract's high Mg (30–60 mg/100 g) and Fe (227.89 mg/kg) content (16) mitigate common orchard deficiencies, explaining improved chlorophyll synthesis (+23% vs. control). The 4 mL·L^{-1} organic manure + 200 mg·L^{-1} nettle extract combination maximized TSS (19.67%) and anthocyanins (98.82 mg.g^{-1} in Starking) (Tables 7, 4), supporting the hypothesis that in carbon partitioning, the organic amendments enhance sucrose transporter expression, increasing photoassimilate allocation to fruits.

It could also be due to stress mitigation where the nettle's phenolic compounds reduce oxidative stress, delaying ABA-mediated senescence (29 and 33), thus prolonging fruit maturation and sugar accumulation. Meanwhile, mineral fertilizers typically offer rapid N-P-K availability. In this study, the organic treatments improved fruit quality through higher TSS (+32%) and anthocyanins (+131% in Starking) (Tables 7, 4). It also reduced acidity, declining in the Granny Smith cultivar from 1.71% to 1.19% at the 4 mL·L^{-1} manure treatment (Table 9), likely due to pH-modulating microbiota (2). For Iraqi orchards, this suggests that short-term nettle extract foliar sprays (200 mg·L^{-1}) could bridge yield gaps while reducing chemical inputs.

Conclusion

The results of this study demonstrated that the Granny Smith apple cultivar significantly

outperformed the other tested cultivars in most of the evaluated traits, particularly leaf area, total chlorophyll content, total acidity, and total yield per tree. This superiority is attributed to its enhanced physiological capacity to respond favorably to environmental conditions and applied agricultural treatments, indicating its high efficiency in utilizing organic inputs and plant based extracts. Furthermore, the application of high concentrations of organic fertilizer (liquid biofoliar) led to clear improvements in both the physiological and chemical parameters of the plants, especially when compared with lower concentrations or untreated controls.

Foliar spraying with nettle (*Urtica dioica*) extract contributed significantly to enhancing vegetative growth and improving photosynthetic efficiency by increasing chlorophyll content, which ultimately reflected positively on tree growth and productivity. Notably, the interaction between organic manure and nettle extract proved to be more effective than either treatment alone, highlighting a synergistic effect between organic nutrients and the bioactive compounds present in the plant extract. The highest concentration (4 $ml.L^{-1}$) of the combined treatment yielded the most significant improvements in growth and quality-related traits.

This study recommends the use of integrated organic fertilization combined with plant extracts—particularly nettle extract—as part of a comprehensive nutrient management strategy for apple production, especially for the Granny Smith cultivar. Additional research could contribute to better assessments of the effects of these treatments on fruit quality attributes and in evaluating their performance in other apple cultivars under different environmental conditions.

Supplementary Materials
None.

Author Contributions
The authors collaborated to develop the technique, produce the first draft, and conducted the review and editing of this article. They have reviewed the completed text and approved it for publishing.

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None.

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None.

Conflicts of Interest
The authors declare that they have no conflict of interest.

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مقالة أصيلة

استجابة النمو والإنتاجية لأصناف التفاح للسماد العضوي و مستخلص نبات القريص

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الخلاصة

هدفت هذه الدراسة لمعرفة تأثير السماد العضوي (البيو–فولير بثلاثة تراكيز ٠ و٢ و٤ مل.لتر–١) و (مستخلص نبات القراص Urtica dioica بثلاثة تركيزات ٠ و١٠٠ و٢٠٠ ملجم.لتر–١) على الخصائص الخضرية والمحصولية لثلاثة أصناف من التفاح (ستاركينج وجراني سميث و الصنف المحلي) خلال موسم النمو لعام ٢٠٢٤ في بستان خاص في محافظة دهوك بالعراق. تم استخدام وقتين مختلفين للرش الورقي. تم الرش الأول في ٢٥ أبريل ٢٠٢٤ والثاني في ٢٥ مايو ٢٠٢٤. تم استخدام التجربة العاملية ضمن تصميم القطاع العشوائية بثلاثة مكررات. اجريت التحليل الإحصائي باستخدام برنامج SAS مع اختبار دنكان متعدد النطاق ($p \leq 0.05$) عن استجابات خاصة بالصنف. أظهر صنف "جراني سميث" أداءً متفوقًا في المعايير الخضرية، حيث زاد مساحة الأوراق بنسبة ٩٧.٦٪ (٩٠.٩٢ سم^2 مقابل ٤٧.٣٢–٤٧.٤٨ سم^2)، ومحتوى الكلوروفيل في الأوراق بنسبة ١٢.١٪ (٢٨.٣٨ ملغم/جم$^{-1}$)، وزاد المحصول بنسبة ٦٤.٥٪ (١٨٣.٣٣ كجم$^{-1}$ شجرة$^{-1}$) مقارنةً بصنفي "ستاركينج" و"لوكال". وقد أدت المعالجات المثلى (٤ مل/لتر$^{-1}$ سماد عضوي + ٢٠٠ ملغم/لتر$^{-1}$ مستخلص نبات القراص) إلى تحسين العديد من المعايير الفسيولوجية ومقياس المحصول بشكل ملحوظ: مساحة الأوراق (+٩٧.٦٪)، وكلوروفيل قشور الثمار (+٦٧.٢٪)، والمواد الصلبة الذائبة الكلية (١٩.٦٧٪)، ومحتوى الأنثوسيانين (٩٨.٨٢٪ في "ستاركينج")، مع خفض حموضة الثمار بنسبة ٣٠.٤٪ في "جراني سميث". تظهر هذه النتائج أن التعديلات العضوية المتكاملة يمكن أن تعمل بشكل فعال على تحسين إنتاجية التفاح وجودة الفاكهة، مع الاستجابات الخاصة بالصنف والتي تسلط الضوء على أهمية اختيار النمط الجيني في أنظمة إدارة البساتين المستدامة.

كلمات مفتاحية: تفاح، جراني سميث، ، سماد عضوي ، مستخلص نبات القريص

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