



RESEARCH ARTICLE

# Effect of poultry manure and spraying with urea on growth and yield parameters of local lettuce

Walaa Sameer Khalaf<sup>1</sup>, Ragheed M Hamza Alsultan<sup>2</sup>, Basim Mohammed Abed<sup>3</sup>, Idrees Hussein Mola Salih AL-Jaf<sup>3</sup> & Ahmed Fatkhan Zabar Al-Dulaimy<sup>3\*</sup>

<sup>1</sup>College of Dentistry, University of Anbar, Ramadi 31001, Iraq

<sup>2</sup>Department of Horticulture and Landscape Design, College of Agriculture and Forestry, University of Mosul, Nainawa 41001, Iraq

<sup>3</sup>Department of Horticulture and Landscape Gardening, College of Agriculture, University of Anbar, Ramadi 31001, Iraq

\*Correspondence email - [ag.ahmed.fatkhan@uoanbar.edu.iq](mailto:ag.ahmed.fatkhan@uoanbar.edu.iq)

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## Abstract

This study aims to study the effect of the interaction between poultry manure levels and foliar urea concentrations in improving the growth and productivity of the lettuce plant. A field experiment was undertaken during the 2024–2025 winter growing season to investigate the impact of varying poultry manure levels and urea foliar spray on local lettuce growth and productivity. The experiment was conducted in the College of Agriculture, University of Anbar, Iraq, at roughly 33.35° N latitude and 43.79° E longitude. Three poultry manure levels (0, 15 and 30 t ha<sup>-1</sup>) and 3 foliar urea concentrations (0, 0.5 and 1 %) were tested. The experiment employed 3 replications as a randomized complete block design (RBD). Application of 30 t ha<sup>-1</sup> poultry manure significantly increased plant height, total number of leaves, leaf area, plant weight and total yield, with the highest yield of 58.32 t ha<sup>-1</sup>. As for the effect of spraying with urea, the U2 treatment showed the best values for the studied traits including (plant height, total number of leaves, leaf thickness, leaves area, head diameter, total plant weight and total yield) which reached (42.03 cm, 64.17 leaf plant<sup>-1</sup>, 0.32 mm, 35.94 dm<sup>2</sup> plant<sup>-1</sup>, 20.54 cm, 1.68 kg and 55.69 t ha<sup>-1</sup>), respectively. On the other hand, the overlap of the 2 study factors revealed a significant effect on all examined parameters excluding leaf thickness and the best values for all traits appeared when W<sub>2</sub>U<sub>2</sub> was treated, while the treatment of no addition of poultry manure and spraying with urea W<sub>0</sub>U<sub>0</sub> showed the lowest values for all parameters. It is concluded from our study that the use of poultry manure and spraying with urea contributes significantly to boosting the growth traits of local lettuce, which is demonstrated positively in increasing the yield, so we recommend through the results of the study organic fertilisation with poultry manure and spraying with urea, as well as the interaction of the 2 study factors in order to give the best growth and yield to lettuce plants.

**Keywords:** foliar application; growth and yield traits; lettuce; organic fertiliser

## Introduction

Lettuce (*Lactuca sativa* L.) pertains to the family Asteraceae and due to its exceptional nutritional value, it is a vital winter vegetable crop globally, including Iraq (1). Iraq's local and foreign lettuce varieties primarily belong to the Cos or Romaine group, renowned for superior nutritional content. Lettuce latex contains lactucin and lactucopicrin, regulating the nervous system, enhancing sleep, appetite and digestion, reducing blood pressure and cholesterol levels and providing antioxidants (2, 3).

The crop's consumption relies heavily on fresh leaf intake, resulting in high nitrogen requirements. However, chemical fertilisers pose significant environmental and health risks due to their nitrogen content. Consequently, there is a growing trend towards reducing chemical fertiliser use and adopting sustainable, scientifically driven alternatives (4). Sustainable development is one of the most prominent global trends in modern agriculture, seeking to meet the needs of the present absent from compromising the

competence of future successive generations to meet their own needs (5, 6). In this context, lettuce is an important leafy crop with high nutritional value, which can be grown in sustainable ways that reduce resource consumption and preserve the environment. One modern approach gaining global traction is the utilisation of organic manures, which possess high nutritional content, enhance soil fertility and improve chemical and physical properties, including cation exchange capacity and water retention capacity, while releasing beneficial amino acids (7, 8). The lettuce plant is of great medical importance as it mainly contributes to weight loss, promoting heart health, lowering cholesterol, maintaining digestive health, treating sleep disorders, boosting immunity, preventing cancer and promoting and strengthening bone health (9). Poultry manure is rich in essential nutrients and improves soil fertility. This eco-friendly fertilizer provides plants with the necessary nutrients without harming human health or the environment (10). Macronutrients are crucial in plant organ growth and development, influencing metabolic processes. Nitrogen regulates plant hormone

activity, notably auxins, promoting cell division and increasing meristematic cell numbers. This, in turn, enhances shoot growth (11, 12). Foliar application is an effective fertilisation technique, enabling plants to absorb essential nutrients directly. Research has demonstrated the efficacy of foliar application in vegetable crops. Specifically, studies on lettuce have shown that foliar-applied urea enhances vegetative growth yield and reduces leaf nitrate levels (13, 14).

However, limited information is available on the combined effect of poultry waste and foliar urea application on lettuce growth and yield under Iraqi conditions. Consequently, this study was undertaken to evaluate the effect of poultry waste and foliar urea on yield and growth of lettuce. This research evaluates the effect of use of organic fertilisers (poultry waste), which contributes to improving soil fertility without causing pollution. Different poultry waste levels on lettuce growth and yield. Furthermore, it seeks to identify the optimal urea concentration for foliar application to maximize production. Our study hypothesises that the use of poultry fertiliser with spraying of urea at different levels will contribute to optimising vegetative growth and increasing the productivity of the native lettuce plant. It is expected that there will be a positive interaction between organic poultry manure and urea, which will enhance the growth of traits studied. It is also assumed that essential nutrients, when added in a balanced way, either directly to the soil or indirectly by spraying them on the leaves, will contribute to improving the qualities of lettuce and increase its resistance to various environmental stresses. The study aims to evaluate the effect of adding poultry fertilizer at different levels and spraying urea, as well as determining the best combination of both study factors that contribute to achieving the best growth of local lettuce plants and improving their productivity.

## Materials and Methods

A field experiment was conducted during the winter season 2024–2025 at the vegetable research field of the Department of Horticulture, College of Agriculture, University of Anbar, Iraq, to evaluate study the effect of poultry manure and foliar urea application on growth and yield of lettuce (*L. sativa*). The treatments consisted of three poultry manure levels (0, 15 and 30 t ha<sup>-1</sup>) and three foliar urea concentrations (0, 0.5 and 1 %). Poultry manure was incorporated into the soil before planting (15). The field soil designated for research was prepared by plowing it with a flip plow and then the area allocated for the experiment was divided into three equal blocks. Each block contained nine treatment plots, resulting in a total of 27 experimental units. The area of the experimental unit was 5 m<sup>2</sup> and its dimensions were (1 × 5 m). Each unit consisted of one row, 5 m long and 1 m wide and the distance

between one row and another is 0.80 m. Each row contains 17 plants. The distance between one plant and another is 0.30 m, so the plants number in the experimental unit is 17 plants. Basal N, P and K fertilisers were applied according to recommended rates (6 kg. N ha<sup>-1</sup>, 8 kg. P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>, 4 kg. K<sub>2</sub>O ha<sup>-1</sup>). Seeds were sown in a nursery on 15 October 2024 and seedlings were transplanted to the field on 30 October 2024 at the 2–3 leaf stage. Foliar urea was applied 6 weeks after transplanting by dissolving urea (46 % N) in distilled water to obtain concentrations of 0.5 % and 1 %. Distilled water was used as control. Spraying operations were executed until the plants were completely wet, with 3 sprays and 15 days apart from one another. The experiment was performed in RCBD and treatment means were compared using the LSD test at  $p \leq 0.05$  (16). The data were analysed using the Genstat software. Table 1 shows some of the characteristics of the field soil.

## Studied traits

Five plants were randomly chosen from every experimental unit to make the required measurements for all traits including:

1. Plant height (cm): The plant height (when harvested) was calculated using a metric tape measure from the soil surface level to the top of the head for the plants marked for each experimental unit and then calculated at their average.
2. Number of leaves (leaf plant<sup>-1</sup>): The total number of leaves for each of the five plants was calculated and the average for those plants was measured.
3. Leaf thickness (mm): This trait was measured for three outer leaves using a Vernier digital caliper for each of the plants studied in each experimental unit and the average for those plants was measured.
4. Leaves area (dm<sup>2</sup> plant<sup>-1</sup>): The leaf area of the plant was calculated in accordance with the method described by previous researchers (17). Then the total leaves area of the plant was found by the multiplied leaf area by the total of leaves number of the plant.
5. Head diameter (cm): The head diameter was assessed after removing the outer leaves and keeping only the curled leaves from each experimental unit with a measuring tape and the average was calculated for them.
6. Plant weight (g plant<sup>-1</sup>): The plant weight was calculated by dividing the weight of five plants by their number.
7. Total yield (t ha<sup>-1</sup>): Calculate the total yield of the experimental unit according to the following equation:

Experimental unit yield = yield of one plant × number of plants in the experimental unit (17 plants).

**Table 1.** Chemical and physical characteristics of experimental soil

pH	EC ds m <sup>-1</sup>	O.M %	Bulk density g cm <sup>-3</sup>	CaCO <sub>3</sub> g Kg <sup>-1</sup>	Total N %	P Av. mg Kg <sup>-1</sup>
7.61	2.93	2.78	1.52	124.40	0.29	1.73
Mg <sup>++</sup> meq L <sup>-1</sup>	Ca <sup>++</sup> meq L <sup>-1</sup>	Na <sup>+</sup> meq L <sup>-1</sup>	CO <sub>3</sub> <sup>=</sup> meq L <sup>-1</sup>	HCO <sub>3</sub> <sup>=</sup> meq L <sup>-1</sup>	Cl <sup>-</sup> meq L <sup>-1</sup>	SO <sub>4</sub> <sup>=</sup> meq L <sup>-1</sup>
48.31	82.46	33.94	0.86	Nil	4.59	35.13
Sand g Kg <sup>-1</sup>	Silt g Kg <sup>-1</sup>	Clay g Kg <sup>-1</sup>	Texture			
547.0	214.3	238.7	Sandy Clay Loam			

EC: Electrical conductivity; O.M: Organic matter; Bulk density; CaCO<sub>3</sub>: Calcium carbonate; Total N: Total nitrogen; P Av.: Available phosphorus.

## Results and Discussion

### Plant height (cm)

Poultry manure significantly affects plant height (Table 2). The highest plant height (42.64 cm) was recorded at 30 t ha<sup>-1</sup>, while the lowest (35.25 cm) was observed in control. Foliar urea significantly increased plant height, with maximum height (42.03 cm) at 1 % and minimum (36.92 cm) in control. The interaction effect was significant. The highest plant height (46.53 cm) was recorded at W<sub>2</sub>U<sub>2</sub>, while the lowest (33.03 cm) was recorded at W<sub>0</sub>U<sub>0</sub>.

**Table 2.** Effect of poultry waste and foliar urea on the plant height (cm).

Urea (%)	Poultry manure (t ha <sup>-1</sup> )			Mean
	W <sub>0</sub> 0 t ha <sup>-1</sup>	W <sub>1</sub> 15 t ha <sup>-1</sup>	W <sub>2</sub> 30 t ha <sup>-1</sup>	
U <sub>0</sub> 0 %	33.03	38.21	39.53	<b>36.92</b>
U <sub>1</sub> 0.5 %	35.53	41.26	41.86	<b>39.55</b>
U <sub>2</sub> 1 %	37.20	42.36	46.53	<b>42.03</b>
<b>Mean</b>	<b>35.25</b>	<b>40.61</b>	<b>42.64</b>	

LSD ( $p \leq 0.05$ ): Poultry manure = 0.98 Urea = 0.98 Interaction = 1.73

Values are mean  $\pm$  standard error of 3 replicates. LSD ( $p \leq 0.05$ ) indicates least significant difference for main effects and interaction.

### Number of leaves (leaf plant<sup>-1</sup>)

Poultry manure significantly affected number of leaves (Table 3). The number of leaves (70.32 leaf plant<sup>-1</sup>) was recorded at 30 t ha<sup>-1</sup>, while the lowest (44.69 leaf plant<sup>-1</sup>) was observed in control. Foliar urea significantly increased number of leaves, with maximum leaves number (64.17 leaf plant<sup>-1</sup>) at 1 % and minimum (50.49 leaf plant<sup>-1</sup>) in control. The interaction effect was significant. The highest leaves number (79.17 leaf plant<sup>-1</sup>) was documented at W<sub>2</sub>U<sub>2</sub>, while the lowest (39.83 leaf plant<sup>-1</sup>) was documented at W<sub>0</sub>U<sub>0</sub>.

**Table 3.** Effect of poultry waste and foliar urea on number of leaves (leaf plant<sup>-1</sup>).

Urea (%)	Poultry manure (t ha <sup>-1</sup> )			Mean
	W <sub>0</sub> 0 t ha <sup>-1</sup>	W <sub>1</sub> 15 t ha <sup>-1</sup>	W <sub>2</sub> 30 t ha <sup>-1</sup>	
U <sub>0</sub> 0 %	39.83	51.94	59.69	<b>50.49</b>
U <sub>1</sub> 0.5 %	45.57	62.10	72.10	<b>59.92</b>
U <sub>2</sub> 1 %	48.67	64.68	79.17	<b>64.17</b>
<b>Mean</b>	<b>44.69</b>	<b>59.57</b>	<b>70.32</b>	

LSD ( $p \leq 0.05$ ): Poultry manure = 0.98 Urea = 0.98 Interaction = 1.73

Values are mean  $\pm$  standard error of 3 replicates. LSD ( $p \leq 0.05$ ) indicates least significant difference for main effects and interaction.

### Leaf thickness (mm)

Poultry manure significantly affects leaf thickness (Table 4). The leaf thickness (0.32 mm) was recorded at 30 t ha<sup>-1</sup>, while the lowest (0.27 mm) was observed in control. Foliar urea significantly increased leaf thickness, with maximum leaf thickness (0.32 mm) at 1 % and minimum (0.28 mm) in control. Alternatively, the interaction between the two study factors exhibited no significant differences between treatments.

### Leaves area (dm<sup>2</sup> plant<sup>-1</sup>)

Poultry manure significantly affected leaves area (Table 5). The leaves area (38.42 dm<sup>2</sup> plant<sup>-1</sup>) was recorded at 30 t ha<sup>-1</sup>, while the lowest (31.50 dm<sup>2</sup> plant<sup>-1</sup>) was observed in control. Foliar urea significantly increased leaves area, with maximum leaves area

**Table 4.** Effect of poultry manure and foliar urea on leaf thickness (mm)

Urea (%)	Poultry manure (t ha <sup>-1</sup> )			Mean
	W <sub>0</sub> 0 t ha <sup>-1</sup>	W <sub>1</sub> 15 t ha <sup>-1</sup>	W <sub>2</sub> 30 t ha <sup>-1</sup>	
U <sub>0</sub> 0 %	0.24	0.29	0.30	<b>0.28</b>
U <sub>1</sub> 0.5 %	0.27	0.31	0.32	<b>0.30</b>
U <sub>2</sub> 1 %	0.29	0.33	0.35	<b>0.32</b>
<b>Mean</b>	<b>0.27</b>	<b>0.31</b>	<b>0.32</b>	

LSD ( $p \leq 0.05$ ): Poultry manure = 0.98 Urea = 0.98 Interaction = 1.73

Values are mean  $\pm$  standard error of 3 replicates. LSD ( $p \leq 0.05$ ) indicates least significant difference for main effects and interaction.

(35.94 dm<sup>2</sup> plant<sup>-1</sup>) at 1 % and minimum (30.63 dm<sup>2</sup> plant<sup>-1</sup>) in control. The interaction effect was significant. The highest area of leaves (38.42 dm<sup>2</sup> plant<sup>-1</sup>) was recorded at W<sub>2</sub>U<sub>2</sub>, while the lowest (27.85 dm<sup>2</sup> plant<sup>-1</sup>) was recorded at W<sub>0</sub>U<sub>0</sub>.

**Table 5.** Effect of poultry manure and foliar urea on leaves area (dm<sup>2</sup> plant<sup>-1</sup>)

Urea (%)	Poultry manure (t ha <sup>-1</sup> )			Mean
	W <sub>0</sub> 0 t ha <sup>-1</sup>	W <sub>1</sub> 15 t ha <sup>-1</sup>	W <sub>2</sub> 30 t ha <sup>-1</sup>	
U <sub>0</sub> 0 %	27.85	31.56	32.47	<b>30.63</b>
U <sub>1</sub> 0.5 %	32.40	34.61	36.69	<b>34.57</b>
U <sub>2</sub> 1 %	34.25	35.16	38.42	<b>35.94</b>
<b>Mean</b>	<b>31.50</b>	<b>35.16</b>	<b>38.42</b>	

LSD ( $p \leq 0.05$ ): Poultry manure = 0.98 Urea = 0.98 Interaction = 1.73

Values are mean  $\pm$  standard error of 3 replicates. LSD ( $p \leq 0.05$ ) indicates least significant difference for main effects and interaction.

### Head diameter (cm)

Poultry manure significantly affected head diameter (Table 6). The head diameter (22.11 cm) was recorded at 30 t ha<sup>-1</sup>, while the lowest (15.14 cm) was observed in control. Foliar urea significantly increased head diameter, with maximum head diameter (20.54 cm) at 1 % and minimum (16.87 cm) in control. The interaction effect was significant. The highest head diameter (24.67 cm) was recorded at W<sub>2</sub>U<sub>2</sub>, while the lowest (13.67 cm) was recorded at W<sub>0</sub>U<sub>0</sub>.

**Table 6.** Effect of poultry waste and foliar urea on head diameter (cm)

Urea (%)	Poultry manure (t ha <sup>-1</sup> )			Mean
	W <sub>0</sub> 0 t ha <sup>-1</sup>	W <sub>1</sub> 15 t ha <sup>-1</sup>	W <sub>2</sub> 30 t ha <sup>-1</sup>	
U <sub>0</sub> 0 %	13.67	17.65	19.28	<b>16.87</b>
U <sub>1</sub> 0.5 %	15.27	19.92	22.38	<b>19.19</b>
U <sub>2</sub> 1 %	16.47	20.47	24.67	<b>20.54</b>
<b>Mean</b>	<b>15.14</b>	<b>19.35</b>	<b>22.11</b>	

LSD ( $p \leq 0.05$ ): Poultry manure = 0.98 Urea = 0.98 Interaction = 1.73

Values are mean  $\pm$  standard error of 3 replicates. LSD ( $p \leq 0.05$ ) indicates least significant difference for main effects and interaction.

### Plant weight

Poultry manure significantly affected plant weight (Table 7). The plant weight (1.68 kg) was recorded at 30 t ha<sup>-1</sup>, while the lowest (1.32 kg) was observed in control. Foliar urea significantly increased plant weight, with maximum value (1.68 kg) at 1 % and minimum (1.38 kg) in control. The interaction effect was significant. The highest plant weight (1.85 kg) was recorded at W<sub>2</sub>U<sub>2</sub>, while the lowest (1.09 kg) was recorded at W<sub>0</sub>U<sub>0</sub>.

**Table 7.** Effect of poultry manure and foliar urea on plant weight (kg)

Urea (%)	Poultry manure (t ha <sup>-1</sup> )			Mean
	W <sub>0</sub> 0 t ha <sup>-1</sup>	W <sub>1</sub> 15 t ha <sup>-1</sup>	W <sub>2</sub> 30 t ha <sup>-1</sup>	
U <sub>0</sub> 0 %	1.09	1.48	1.58	<b>1.38</b>
U <sub>1</sub> 0.5 %	1.42	1.61	1.62	<b>1.55</b>
U <sub>2</sub> 1 %	1.44	1.76	1.85	<b>1.68</b>
<b>Mean</b>	<b>1.32</b>	<b>1.62</b>	<b>1.68</b>	

LSD ( $p \leq 0.05$ ): Poultry manure = 0.98 Urea = 0.98 Interaction = 1.73

Values are mean  $\pm$  standard error of 3 replicates. LSD ( $p \leq 0.05$ ) indicates least significant difference for main effects and interaction.

### Total yield

Poultry manure significantly affected yield (Table 8). The yield (58.32 t ha<sup>-1</sup>) was recorded at 30 t ha<sup>-1</sup>, while the lowest (44.76 t ha<sup>-1</sup>) was monitored in control. Foliar urea significantly increased yield, with maximum value (55.69 t ha<sup>-1</sup>) at 1 % and minimum (47.09 t ha<sup>-1</sup>) in control. The interaction effect was significant. The highest yield (62.42 t ha<sup>-1</sup>) was registered at W<sub>2</sub>U<sub>2</sub>, while the lowest (37.54 t ha<sup>-1</sup>) was registered at W<sub>0</sub>U<sub>0</sub>.

**Table 8.** Effect of poultry manure and foliar urea on total yield (t ha<sup>-1</sup>)

Urea (%)	Poultry manure (t ha <sup>-1</sup> )			Mean
	W <sub>0</sub> 0 t ha <sup>-1</sup>	W <sub>1</sub> 15 t ha <sup>-1</sup>	W <sub>2</sub> 30 t ha <sup>-1</sup>	
U <sub>0</sub> 0 %	37.54	49.97	53.76	<b>47.09</b>
U <sub>1</sub> 0.5 %	47.95	54.67	58.79	<b>53.80</b>
U <sub>2</sub> 1 %	48.79	55.86	62.42	<b>55.69</b>
<b>Mean</b>	<b>44.76</b>	<b>53.50</b>	<b>58.32</b>	

LSD ( $p \leq 0.05$ ): Poultry manure = 0.98 Urea = 0.98 Interaction = 1.73

Values are mean  $\pm$  standard error of 3 replicates. LSD ( $p \leq 0.05$ ) indicates least significant difference for main effects and interaction.

### Discussion

The improvement in yield and vegetative growth observed with poultry manure application may be attributed to increased availability of fundamental nutrients, particularly N, P and K, which assist cell division and plant development (17, 18). Poultry manure increases organic matter in the different soil, which enhances the number and activity of microorganisms and increases the function of enzymes, which in turn work to dismantle organic compounds and then liberate elements from them, rising plant growth rates (19, 20). The rise in the height of lettuce plants, their number of leaves and the total yield is caused by the large content of poultry waste, major and minor nutrients and organic matter that effectively contribute to boosting the physical, fertility and microbial traits of all soil. It helps raise aeration and improve soil granular structure, increasing the spread of roots in the soil and increasing their competence to absorb water and nutrients (21, 22). It also increases the cationic exchange capacity of the soil, which in turn contributes to reducing the loss of elements and making it ready for the plant for a longer period (23, 24). This, in turn, reflects positively on vegetative growth, including an increase in plant height and leaf count (25). On the other hand, urea spraying plays a major role in rapidly and directly preparing nitrogen for plants, especially at critical stages of plant growth where the roots cannot absorb enough nutrients from the soil (26). Urea is absorbed very efficiently by the leaves, which contributes to increasing the metabolic activity of the plant and promoting cell division and elongation, which leads to an increase in

vegetative growth of plants, which is positively reflected in the increase in yield (27).

It is observed that an increase in the studied traits coincided with an increase in urea concentrations when sprayed on plants and the reasons for this can be attributed to the effect of nitrogen in increasing the activity of the meristematic tissues which promote cell division and elongation as a result of the increased concentration of auxin or the readiness of the basic materials that the plant needs in construction processes, such as amino acids and some enzymatic companions such as NAD and NADP, which enter the nitrogen element in its composition (28, 29). The high concentrations of both 30 t ha<sup>-1</sup> poultry fertiliser and 1 % urea when interaction showed a significant effect on all studied traits except leaf thickness and the reasons for this may be due to the complementary effect of both study factors, which leads to high efficiency in the use of nutrients, as poultry fertiliser provides a suitable soil environment for plant root growth, while foliar spraying with urea prepares plants with the elements quickly and efficiently when needed (30–33). This balance between ground and foliar feeding plays a major role in achieving balanced and strong plant growth and thus contributes to achieving the best result. These findings agree with previous studies reporting increased lettuce growth and yield following organic manure and nitrogen application (34–38).

### Conclusion

Our study concludes that the addition of poultry fertiliser and spraying with urea both showed a significant positive effect in boosting the growth manifestations and rising the productivity of lettuce. It was found that the best treatment of organic fertilizer was 30 t ha<sup>-1</sup>, which improved soil properties such as increasing its fertility and equipping plants with major and minor nutrients necessary for vegetative growth and yield. In addition, compost increases soil aeration, improves its water retention and has a role in enhancing the microbial activity necessary in the decomposition of organic matter and the release of necessary nutrients for plants gradually and for a long time. As for urea spraying, the findings of the study demonstrated that the best concentration is 1 %, as the nitrogen element prepared the plants easily and quickly by absorbing it by the leaves, which greatly encourages the photosynthesis process and increases the growth rate and elongation of cells, which thus contributes to improving growth and increasing the rate of accumulation of carbohydrates in the plants, which was beneficially reflected in increasing the final product. When 30 t ha<sup>-1</sup> poultry fertiliser is applied with 1 % urea spraying, a marked improvement is observed in the studied qualities, as the balance of ground and foliar feed enhances the absorption efficiency of major and minor elements necessary for plant growth and also improves the physiological processes that take place inside the plant, including photosynthesis, respiration and nutrient transport, thus leading to balanced and vigorous growth.

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## Authors' contributions

WSK, RMHA, BMA, IHMSA and AFZA conducted the experimental study and collected the data. WSK performed the statistical analysis. All authors read and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflicts of interests to declare.

**Ethical issues:** None

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