

Interactive Effects of Ethephon and Salicylic Acid on Physiological Traits and Yield of Zucchini (*Cucurbita pepo* L.)

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Abstract

A field experiment was conducted at the Research Station of the Department of Horticulture and Landscape Engineering, College of Agriculture, University of Diyala, during the summer growing season of 2025 to evaluate the effects of Ethephon and salicylic acid foliar application on vegetative growth and yield of zucchini. The experiment comprised 12 treatments representing four Ethephon concentrations (0, 200, 400, and 600 mg L⁻¹) and three salicylic acid concentrations (0, 150, and 300 mg L⁻¹). Treatments were arranged in a factorial experiment according to a randomized complete block design (RCBD). Foliar application of Ethephon at 600 mg L⁻¹ significantly increased leaf nitrogen (2.822%), phosphorus (0.494%), potassium (2.707%), and chlorophyll content (1.823 mg L⁻¹), as well as number of fruits per plant (11.69 fruits plant⁻¹), average fruit weight (291.1 g), yield per plant (3.406 kg plant⁻¹), and total yield (56.71 t ha⁻¹). Similarly, salicylic acid at 300 mg L⁻¹ enhanced leaf nitrogen (2.800%), phosphorus (0.479%), potassium (2.699%), chlorophyll content (1.567 mg L⁻¹), fruit number (10.53 fruits plant⁻¹), mean fruit weight (264.7 g), yield per plant (2.814 kg plant⁻¹), and total yield (46.92 t ha⁻¹).

Keywords: zucchini, Ethylene, mineral nutrients, yield.

Introduction

Zucchini (*Cucurbita pepo* L.) belongs to the family *Cucurbitaceae* and is an economically important summer vegetable crop. It is an annual, herbaceous, monoecious plant bearing separate male and female flowers on the same plant (1). The crop is widely cultivated in tropical and subtropical regions and represents a valuable component of vegetable production systems due to its high nutritional and economic value. Fruits are rich in vitamins and antioxidant compounds, contributing to their dietary and medicinal importance. Zucchini exhibits considerable variability in fruit shape, size, and color among cultivars and local genotypes (2). Zucchini is regarded as one of the most important vegetable crops worldwide, serving as a commercial crop in both open-field and protected cultivation systems. The enhancement of leaf N, P, and K content by Ethephon is attributed to its role as a growth regulator that stimulates

protected cultivation systems. Summer squash represents a principal vegetable in many Mediterranean countries (3). Owing to its high productivity and nutritional value, summer squash has substantial potential to contribute to global food security, highlighting its importance for cultivation and utilization across diverse agroecological regions (4).

Ethephon is essential for flowering, pollen germination, and fertilization, playing a key role in sex expression and protein synthesis. In cucurbits, ethephon influences vegetative, floral, and fruit development, thereby affecting yield; foliar application at high concentrations has been reported to increase the number of female flowers (5).

ethylene release and modulates various physiological processes (6). Early-stage Ethephon application can also promote root

growth, which in turn improves leaf number and overall plant development, significantly affecting the plant's chemical composition (7) (5).

Salicylic acid, a phenolic compound, regulates plant growth and defense responses against reactive oxygen species. It promotes flowering, modulates thermal responses, and regulates stomatal activity (8). Additionally, salicylic acid influences physiological processes such as photosynthesis and respiration, enhancing plant tolerance under stress conditions (9).

Materials and Methods

Experiment was conducted during the summer season of 2025 at the Agricultural Research and Experiment Station, College of Agriculture, University of Diyala. Seeds of zucchini (*Cucurbita pepo* L.), F1 u-Turn Hybrid, obtained from local markets, were sown in the experimental field. Soil samples were collected randomly from a depth of 30 cm at multiple locations and analyzed at the Central Soil Laboratory, University of Baghdad, to determine key physical and chemical properties (Table 1). Study comprised 12 treatments, representing four Ethephon concentrations (0, 200, 400, and 600 mg L⁻¹) and three salicylic acid

It also increases leaf nutrient content (N, P, K) by facilitating nitrogen assimilation into amino acids and proteins (10) and acts as an antioxidant, scavenging free radicals and protecting cellular membranes, thereby improving nutrient uptake and translocation (11).

The present study aimed to evaluate the interactive effects of different concentrations of Ethephon and salicylic acid on leaf mineral nutrient content, chlorophyll concentration, and key yield components of *Cucurbita pepo* L.

concentrations (0, 150, and 300 mg L⁻¹). Foliar applications were performed in three sprays: the first at 30 days after sowing, followed by two sprays at 10-day intervals, distance between plants was 40 cm, with each experimental unit containing 8 plants and covering a total area of 4.8 m² per unit. Experiment was arranged as a factorial design within a randomized complete block design (RCBD) with three replicates. Data were statistically analyzed using SAS software, and treatment means were compared using Duncan's multiple range test at P ≤ 0.05.

Table 1. physical and chemical properties of the experimental field soil

Measured parameter	Value	Unit
pH	7.67	-
Electrical conductivity (EC)	7.80	Ds m ⁻¹
Nitrogen (N)	14.6	mg kg ⁻¹
Phosphorus (P)	32.35	mg kg ⁻¹
Potassium (K)	117.36	mg kg ⁻¹
Organic matter (OM)	1.38	%
Sand	543	g kg ⁻¹
Clay	221	g kg ⁻¹
Silt	236	g kg ⁻¹
Soil texture	Loamy-sandy	-

Studied traits

Five plants were randomly selected from each experimental unit, and the following measurements were recorded:

Nutrient content

- **Leaf nitrogen (%)** determined using Kjeldahl method (12).
- **Leaf phosphorus (%)** determined using spectrophotometry (13).
- **Leaf potassium (%)** – determined using flame photometry (12).
- **Chlorophyll content (mg L⁻¹)** – measured with spectrophotometer method (14)

Yield components

- **Number of fruits per plant (fruits plant⁻¹)**: counted at harvest

Total number of fruits in experimental unit ÷ Number of plants in experimental unit fruit weight (g)

- **fruit weight**
Total fruit weight per plant / Number of fruits per plant.

Yield per plant (kg) = Total yield of the experimental unit (kg) / number of plants in experimental unit.

Total yield per hectare (t ha⁻¹)

Total yield= Yield per plant × Number of plants per hectare /1000

Results and Discussion

Leaf nitrogen

Table(2) shows that foliar application of Ethephon and salicylic acid significantly enhanced leaf nitrogen content. Ethephon at E3 600 mg L⁻¹ produced the highest value (2.822%) compared to E0 control (2.565%). Salicylic acid at SA2 300 mg L⁻¹ gave 2.800%, not significantly different from 150 mg L⁻¹ (2.784%). The combined treatment of Ethephon E3 600 mg L⁻¹ and salicylic acid SA2 300 mg L⁻¹ resulted in highest leaf nitrogen (2.856%), whereas the control combination (E0SA0) had the lowest (2.193%).

Table (2). Effect of Ethephon salicylic acid on leaf nitrogen concentration (%) in zucchini .

Ethephon Concentrations	Salicylic Acid Concentrations			Ethephon Means
	SA0 mg L ⁻¹ 0	SA1 mg L ⁻¹ 150	SA2 mg L ⁻¹ 300	
E0 mg L ⁻¹ 0	2.193 d	2.750 c	2.753 c	2.565 D
E1 mg L ⁻¹ 200	2.750 c	2.766 c	2.770 c	2.762 C
E2 400 mg L ⁻¹	2.760 c	2.780 bc	2.820 ab	2.786 B
E3 600 mg L ⁻¹	2.770 c	2.840 a	2.856 a	2.822 A
Salicylic Acid Means	2.618 B	2.784 A	2.800 A	

Means sharing the same letters do not differ significantly according to Duncan’s multiple range test at P ≤ 0.05

- Leaf phosphorus (%)

Results of table 3 indicate a significant effect of Ethephon foliar treatments on leaf phosphorus content. Ethephon at E3 600 mg L⁻¹ produced the highest leaf phosphorus (0.494%) compared to control (0.433%). Foliar application of salicylic acid at SA2 300 mg L⁻¹ also significantly increased leaf phosphorus to 0.479%,

compared to the control (0.435%). Regarding the interaction treatments, the combination of Ethephon and salicylic acid resulted in the highest leaf phosphorus (0.520%), whereas the control combination showed the lowest value (0.406%).

Table (3). Effect of Ethephon salicylic acid on leaf phosphorus concentration (%) in zucchini.

Ethephon Concentrations	Salicylic Acid Concentrations			Ethephon Means
	SA0 mg L ⁻¹ 0	SA1 mg L ⁻¹ 150	SA2 mg L ⁻¹ 300	
E0 mg L ⁻¹ 0	0.406 g	0.443 e	0.450 e	0.433 D
E1 mg L ⁻¹ 200	0.430 f	0.450 e	0.456 e	0.445 C
E2 400 mg L ⁻¹	0.446 e	0.476 d	0.490 c	0.471 B
E3 600 mg L ⁻¹	0.456 e	0.506 b	0.520 a	0.494 A
Salicylic Acid Means	0.435 C	0.469 B	0.479 A	

Means sharing the same letters do not differ significantly according to Duncan's multiple range test at P ≤ 0.05

- Leaf potassium (%)

The results in Table 4 show that foliar application of Ethephon at E3 600 mg L⁻¹ significantly increased leaf potassium content to 2.707%, compared to E0 control (2.523%). Similarly, salicylic acid at SA2 300 mg L⁻¹ enhanced leaf potassium to 2.699%, while SA0 control recorded

2.560%. Regarding interaction treatments, the combination of Ethephon E3 600 mg L⁻¹ and salicylic acid 300 mg L⁻¹ resulted in highest leaf potassium content (2.726%), compared to the control combination, which had lowest value (2.250%).

Table (4). Effect of Ethephon and salicylic acid on leaf potassium concentration (%) in zucchini.

Ethephon Concentrations	Salicylic Acid Concentrations			Ethephon Means
	SA0 mg L ⁻¹ 10	SA1 mg L ⁻¹ 150	SA2 mg L ⁻¹ 300	
E0 mg L ⁻¹ 10	2.250 c	2.660 b	2.660 b	2.523 B
E1 mg L ⁻¹ 200	2.656 b	2.680 ab	2.700 ab	2.678 A
E2 400 mg L ⁻¹	2.660 b	2.696 ab	2.710 ab	2.688 A
E3 600 mg L ⁻¹	2.676 ab	2.720 a	2.726 a	2.707 A
Salicylic Acid Means	2.560 B	2.689 A	2.699 A	

Means sharing the same letters do not differ significantly according to Duncan's multiple range test at $P \leq 0.05$

- Chlorophyll content (mg L⁻¹)

Results in table 5 indicate that foliar application of Ethephon at E3 600 mg L⁻¹ significantly increased leaf chlorophyll E0 content to 1.823 mg L⁻¹, compared to the control (1.187 mg L⁻¹). Similarly, salicylic acid at SA2 300 mg L⁻¹ enhanced chlorophyll SA0 content to 1.567 mg L⁻¹,

compared to the control (1.431 mg L⁻¹). Regarding interaction treatments, the combination of Ethephon E3 600 mg L⁻¹ and salicylic acid SA2 300 mg L⁻¹ resulted in the highest chlorophyll content (1.888 mg L⁻¹), whereas the control combination recorded the lowest value (1.131 mg L⁻¹).

Table (5). Effect of Ethephon salicylic acid on leaf Chlorophyll content in zucchini.

Ethephon Concentrations	Salicylic Acid Concentrations			Ethephon Means
	SA0 mg L ⁻¹ 10	SA1 mg L ⁻¹ 150	SA2 mg L ⁻¹ 300	
E0 mg L ⁻¹ 10	1.131 f	1.172 f	1.258 ef	1.187 D
E1 mg L ⁻¹ 200	1.310 e	1.381 de	1.448 d	1.380 C
E2 400 mg L ⁻¹	1.509 d	1.637 c	1.676 bc	1.607 B
E3 600 mg L ⁻¹	1.773 ab	1.809 a	1.888 a	1.823 A
Salicylic Acid Means	1.431 C	1.499 B	1.567 A	

Means sharing the same letters do not differ significantly according to Duncan's multiple range test at $P \leq 0.05$

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- **Number of fruits per plant**

Table 6 shows that foliar application of Ethephon at E3 600 mg L⁻¹ significantly increased number of fruits per plant to 11.69, compared to the lowest value recorded in the control (8.677 fruits plant⁻¹). Salicylic acid at SA2 300 mg L⁻¹ also significantly enhanced fruit number to 10.78, compared to control SA0 (9.559

fruits plant⁻¹). Regarding interaction treatments, combination of Ethephon E3 600 mg L⁻¹ and salicylic acid SA2 300 mg L⁻¹ resulted in highest fruit number (12.63 fruits plant⁻¹), whereas control combination had lowest value (8.366 fruits plant⁻¹)

Table 6. Effect of Ethephon salicylic acid on number of fruits per zucchini plant (fruits plant⁻¹)

Ethephon Concentrations	Salicylic Acid Concentrations			Ethephon Means
	SA0 mg L ⁻¹ 0	SA1 mg L ⁻¹ 150	SA2 mg L ⁻¹ 300	
E0 mg L ⁻¹ 0	8.366 f	8.533 f	9.133 e	8.677 D
E1 mg L ⁻¹ 200	9.436 e	9.533 e	10.16 d	9.712 C
E2 400 mg L ⁻¹	9.583 e	10.51 cd	11.20 ab	10.43 B
E3 600 mg L ⁻¹	10.85 cb	11.58 a	12.63 a	11.69 A
Salicylic Acid Means	9.559 C	10.04 B	10.78 A	

Means sharing the same letters do not differ significantly according to Duncan's multiple range test at P ≤ 0.05

- **fruit weight (g)**

The results in Table 7 indicate that foliar application of Ethephon significantly increased fruit weight compared to control. Ethephon at E3 600 mg L⁻¹ produced the highest mean fruit weight (291.1 g), whereas E0 control recorded lowest value (222.1 g). Similarly, salicylic acid at SA2 300 mg L⁻¹ significantly enhanced fruit

weight to 264.7 g, compared to control SA0 (252.3 g). Regarding interaction treatments, the combination of Ethephon E3 600 mg L⁻¹ and salicylic acid SA2 300 mg L⁻¹ (E3SA2) resulted in the highest mean fruit weight (295.0g) , while the control combination had the lowest value (222.7 g).

Table 7. Effect of Ethephon salicylic acid on fruit weight of plant zucchini (g).

Ethephon Concentrations	Salicylic Acid Concentrations			Ethephon Means
	SA0 mg L ⁻¹ 0	SA1 mg L ⁻¹ 150	SA2 mg L ⁻¹ 300	
E0 mg L ⁻¹ 0	222.7 ef	216.0 f	227.7 e	222.1 D
E1 mg L ⁻¹ 200	235.3 d	250.0 c	252.0 c	245.8 C
E2 400 mg L ⁻¹	256.5 c	279.3 b	284.3 b	273.3 B
E3 600 mg L ⁻¹	294.8 a	283.6 b	295.0 a	291.1 A
Salicylic Acid Means	252.3 C	257.2 B	264.7 A	

Means sharing the same letters do not differ significantly according to Duncan's multiple range test at $P \leq 0.05$

- Yield per plant (kg)

Table 8 shows that foliar application of Ethephon at E3 600 mg L⁻¹ significantly increased single-plant yield to 3.406 kg plant⁻¹, compared to E0 control (1.928 kg plant⁻¹). Salicylic acid at SA2 300 mg L⁻¹ also enhanced yield to 2.890 kg plant⁻¹, compared to 2.434 kg plant⁻¹ in SA0

control. The combination of ethephon 600 mg L⁻¹ and salicylic acid 300 mg L⁻¹ resulted in the highest single-plant yield (3.735 kg plant⁻¹), whereas the lowest value was recorded in E0SA1 (1.843 kg plant⁻¹), which was not significantly different from the control.

Table 8. Effect of Ethephon salicylic acid on yield per plant (kg).

Ethephon Concentrations	Salicylic Acid Concentrations			Ethephon Means
	SA0 mg L ⁻¹ 0	SA1 mg L ⁻¹ 150	SA2 mg L ⁻¹ 300	
E0 mg L ⁻¹ 0	1.861 h	1.843 h	2.079 g	1.928 D
E1 mg L ⁻¹ 200	2.220 f	2.381 e	2.559 d	2.387 C
E2 400 mg L ⁻¹	2.457 de	2.905 c	3.184 b	2.849 B
E3 600 mg L ⁻¹	3.199 b	3.285 b	3.735 a	3.406 A
Salicylic Acid Means	2.434 C	2.603 B	2.890 A	

Means sharing the same letters do not differ significantly according to Duncan's multiple range test at $P \leq 0.05$

Total yield per hectare

Table 9 shows significant effects of foliar Ethephon and salicylic acid sprays on total yield. Ethephon at E3 600 mg L⁻¹ (E3) produced highest yield (56.71 t ha⁻¹) compared to control E0 (32.17 t ha⁻¹). Salicylic

acid at 300 mg L⁻¹ (SA2) increased yield to 48.19 t ha⁻¹, while SA0 recorded 40.52 t ha⁻¹. The interaction E3SA2 achieved the maximum yield of 62.25 t ha⁻¹, versus the lowest in E0SA1 (30.83 t ha⁻¹).

Table 9. Effect of Ethephon salicylic acid on total yield (t ha⁻¹) of zucchini plant.

Ethephon Concentrations	Salicylic Acid Concentrations			Ethephon Means
	SA0 mg L ⁻¹ 0	SA1 mg L ⁻¹ 150	SA2 mg L ⁻¹ 300	
E0 mg L ⁻¹ 0	31.02 h	30.83 h	34.66 g	32.17 D
E1 mg L ⁻¹ 200	37.00 f	39.69 e	42.66 d	39.78 C
E2 400 mg L ⁻¹	40.94 de	48.43 c	53.17 b	47.51 B
E3 600 mg L ⁻¹	53.12 b	54.75 b	62.25 a	56.71 A
Salicylic Acid Means	40.52 C	43.43 B	48.19 A	

Means sharing the same letters do not differ significantly according to Duncan’s multiple range test at P ≤ 0.05

Discussion

Foliar application of Ethephon at 600 mg L⁻¹ significantly increased leaf N, P, and K concentrations, likely due to its role as a growth regulator stimulating ethylene release and enhancing root and vegetative growth (6) (7) (5). Chlorophyll content also increased, reflecting improved nutrient uptake, particularly magnesium (15).

Similarly, salicylic acid at 300 mg L⁻¹ enhanced leaf nutrient levels and chlorophyll, possibly by promoting nitrogen assimilation, antioxidant protection, and overall nutrient absorption (10) (11) (16) (17). Ethephon and salicylic acid treatments significantly improved yield traits, including

fruit number, fruit weight, and total yield, through enhanced female flower formation, vegetative growth, and photosynthetic efficiency, which increased carbohydrate accumulation and assimilate production (18) (5).

Regarding salicylic acid, results from Tables 6–9 indicate that foliar application at 300 mgL⁻¹ significantly improved yield traits, including fruit number, fruit weight, single-plant yield, and total yield. This effect may be attributed to salicylic acid stimulating the synthesis of growth-promoting hormones such as auxins

and gibberellins, enhancing carbohydrate accumulation and reducing competition between vegetative and reproductive growth. Increased branching and leaf area under salicylic acid application likely improved

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photosynthetic efficiency, carbohydrate translocation, fruit set, and overall yield. These findings are consistent with (16) and (11), who reported similar effects in squash.

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