

International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(7): 646-654
www.biochemjournal.com
Received: 10-04-2026
Accepted: 15-05-2026

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Effect of different levels of ethephon on growth, sex expression, yield and quality of pumpkin (*Cucurbita maxima* L.) under summer temperature conditions

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i7Sh.9064>

Abstract

A field experiment was during the summer season of 2025 to study the effect of different levels of ethephon on growth, sex expression, yield, and quality of pumpkin (*Cucurbita maxima* L.) cv. Sadabahar under high temperature conditions. The experiment was laid out in a Randomized Block Design (RBD) with 11 treatments and 3 replications. Treatments consisted of Ethephon applications at various concentrations (150, 200, 250, 300, and 350 ppm) at the 2-leaf and 4-leaf stages, along with a control (water spray).

Results revealed significant variations among treatments. The treatment T₁₀ (Ethephon @350 ppm at 4-leaf stage) recorded the maximum vine length (3.5 m) and number of leaves (36). The highest number of nodes per plant (30) was observed in T₆ (Ethephon @150 ppm at 4-leaf stage). The highest yield (8.4 t/ha) was recorded in T₄ (Ethephon @300 ppm at 2-leaf stage). In quality parameters, T₆ showed the highest vitamin C content (11.0 mg/100 g), while T₈ (Ethephon @250 ppm at 4-leaf stage) recorded the highest TSS (4.42 °Brix). The maximum benefit-cost ratio (2.58) was achieved with T₄.

The combined effects demonstrated that Ethephon, an ethylene-releasing compound, effectively modified sex expression towards femaleness, improved earliness, and enhanced overall productivity under subtropical summer conditions.

Keywords: Pumpkin, *Cucurbita maxima*, ethephon, sex expression, TSS, femaleness

Introduction

Pumpkin (*Cucurbita maxima* L) is a monoecious plant. Pumpkin 2n = 40, is native to warm-temperate regions of South America. Plants are large, usually viney and branched, with branched tendrils & foliage is stiffly hairy.

Botanically, pumpkin is an annual, monoecious, tendril-bearing vine with a vigorous growth habit. The plant produces large, lobed leaves and extensive root systems that enable efficient nutrient uptake. Being monoecious, it bears staminate and pistillate flowers separately on the same plant, with male flowers usually appearing 7 to 10 days earlier and in greater numbers than female flowers. This skewed sex ratio, often ranging from 10:1 to 25:1, is one of the primary physiological constraints limiting fruit set and yield. Pollination is entomophilous and largely dependent on honeybees and other wild pollinators. The fruits are variable in size, shape, and skin colour, ranging from round to oblong and from green to orange at maturity. The fruit flesh is typically deep yellow to orange due to high β-carotene content.

Plant growth regulators, particularly ethylene-releasing compounds like ethephon (2-chloroethylphosphonic acid), have been shown to influence sex expression by promoting pistillate flowers and suppressing staminate ones. This study aimed to evaluate the optimal concentration and stage of Ethephon application to improve growth, flowering behavior, yield, and quality of pumpkin under summer conditions.

Ethephon, an ethylene-releasing chemical, promotes the development of pistillate flowers while delaying staminate flowers in monoecious cucurbits. Ethephon-treated pumpkin produced a significantly higher number of female flowers (4) compared to without treatment (2.5) (Li *et al.* 2021) Ethephon, 2-chloroethylphosphonic acid, is a synthetic plant growth regulator that releases ethylene upon metabolism within plant tissues ^[12].

Once absorbed, ethephon breaks down at cellular pH to liberate ethylene, phosphate, and chloride ions. The released ethylene mimics the physiological action of endogenous ethylene and influences multiple developmental processes including seedling growth, apical dominance, senescence, and sex expression. Thus this study aimed to study the effect of different levels of Ethephon at 2 and 4 leaves stage.

Materials and Methods

The experiment was conducted from March to June 2025 at the Vegetable Research Farm, SHUATS, Prayagraj. The soil was sandy loam with neutral pH. The local variety Sadabahar was used. The experiment followed a Randomized Block Design with 11 treatments and 3 replications.

Treatments Details

- To: Control (water spray at 2 & 4 leaf stages)
- T₁-T₅: Ethephon 150, 200, 250, 300, 350 ppm at 2-leaf stage
- T₆-T₁₀: Ethephon 150, 200, 250, 300, 350 ppm at 4-leaf stage

Standard cultural practices (FYM 25 t/ha, recommended NPK, irrigation, weeding) were followed. Observations on growth (vine length, leaves, nodes), flowering (days to first male/female flower, sex ratio), yield (fruit weight, yield/plant, yield/ha), quality (TSS, vitamin C, acidity, shelf life), and economics were recorded. Data were statistically analyzed using ANOVA.

Observations Recorded

A. Growth Parameters

Days to seed germination

Recorded as the number of days taken from sowing to the emergence of the first seedling (radicle emergence) under each treatment.

No. of leaves

The number of fully expanded leaves per plant was recorded at specific intervals (or at last harvest) by counting on randomly selected plants. The mean number of leaves was calculated and expressed as leaves per plant.

No. of Nodes/plant at Last Harvest

Number of nodes on the main vine or stem was counted at the final harvest stage on randomly selected plants.

Vine length at Last Harvest (m)

The total length of the vine from the base to the tip was measured using a measuring tape or scale at the final harvest and expressed in meters.

Plant Spread at Last Harvest (m)

Plant spread was measured in two directions (east-west and north-south) using a measuring scale. The average of both directions was calculated and expressed in meters.

B. Flowering Parameters

- **Days to opening of flowers:** Recorded by counting the number of days from transplanting/sowing to the appearance of the first open flower in each treatment.

- **No. of days to first male flower appearance:** Number of days taken from transplanting to the appearance of the first male flower.
- **No. of days to first female flower appearance:** Number of days taken from transplanting to the appearance of the first female flower.
- **No. of male flowers:** Total number of male flowers produced per plant was counted during the flowering period.
- **No. of female flowers:** Total number of female flowers produced per plant was counted during the flowering period.
- **Sex ratio:** Calculated as the ratio of male to female flowers (or vice versa) to understand the flowering behavior of the crop.

C. Yield Parameters

- **Days to first fruit set:** Recorded as the number of days from transplanting to the setting of the first fruit.
- **Days to first harvest:** Number of days taken from transplanting to the first harvest of mature fruits.
- **Fruit weight (kg):** Average weight of individual fruits or total fruit weight per plant/plot was recorded using a digital balance and expressed in kilograms.
- **Fruit diameter (cm):** Measured using a vernier caliper or measuring scale across the widest part of the fruit.
- **Fruit thickness (cm):** Measured as the thickness of the fruit (flesh or overall) using a measuring instrument.

D. Quality Parameters:

- **Total Soluble Solid (TSS °Brix):** Determined using a hand refractometer and expressed in °Brix.
- **Moisture content (%):** Determined by oven-drying method (weight loss on drying) and expressed as percentage.
- **Fibre content (%):** Estimated using standard laboratory procedures for crude fibre analysis.
- **Estimation of Acidity (%):** The acidity was determined using the standard titration method, as outlined by Ranganna (1986) [20]. The acidity was calculated and expressed as a percentage of citric acid equivalent using the following formula:

$$\text{Titrateable Acidity (\%)} = \frac{T \times N \times V_1 \times E \times 100}{V_2 \times W \times 1000}$$

Estimation of Vitamin C (Ascorbic Acid)

Vitamin C content was estimated by the 2,6-dichlorophenol indophenol dye titration method as described by A.O.A.C. (2000). The ascorbic acid content was expressed as mg per 100 g pulp using the following formula:

$$\text{Ascorbic Acid (mg/100 g pulp)} = \frac{T \times D \times V_1 \times 100}{V_2 \times W}$$

Shelf Life (Days)

The shelf life of fruits was assessed by storing harvested fruits at room temperature and tracking the number of days until they were no longer acceptable for consumption due to spoilage.

F. Insect Pest and Disease Incidence

The incidence of major insect pests and diseases was recorded at weekly intervals starting from 20 days after sowing until final harvest.

$$\text{Ascorbic Acid (mg/100 g pulp)} = \frac{T \times D \times V_1 \times 100}{V_2 \times W}$$

Result and Discussion

Growth Parameters

Days to Seed germination

The results pertaining on days to germinate of pumpkin are presented in Table 1. It was evident from analysis that days to germinate in plant was influenced by sowing time, temperature & depth of seed sown. There was non-significant difference present among the germination interval of the seeds. It was found that T₄- Ethephon @150ppm had taken minimum days to germinate (7.50 days).

The number of days to germination is an important character. Which indicate earliness or lateness of the crop in general. Better germination in this hybrid may be due to genetic potential or having the better permeability of seed coat to water and hence earlier initiation of germination. The early and late germination help in the occurrence of early/late flush of crop which is advantageous for market to fetch the higher price. The view was supported by Kumar R. *et al.* (2019) in bottle gourd [9].

No. of leaves

The results pertaining to number of leaves at last harvest of pumpkin (Kohra) are presented in Table 1. It was evident from the analysis that the number of leaves at last harvest was significantly influenced by the application of different concentrations of Ethephon. The F-test was found to be significant.

Among the different treatments, the maximum number of leaves (35.6) at last harvest was recorded with T₁₀ - Ethephon @350 ppm, followed by T₉ - Ethephon @300 ppm (35.0) and T₈ - Ethephon@ 250 ppm (34.5). The minimum number of leaves was recorded in T₃ - Ethephon@ 250 ppm (30.6), which was statistically at par with the control (T₀ - Water spray, 30.8).

The number of leaves at last harvest is an important growth character which directly contributes to the photosynthetic capacity and overall vigor of the plant. The significant improvement in leaf number due to higher concentrations of Ethephon (especially 300 and 350 ppm) may be attributed to the role of ethylene in regulating vegetative growth, delaying senescence and enhancing cell division and expansion in leaves.

These findings agree with earlier workers who reported significant enhancement in leaf number through plant growth regulators in cucurbitaceous crops. Similar results were recorded by Kumar R *et al.* (2019) [9].

No. of Nodes/Plant at Last Harvest

The results pertaining to number of nodes per plant at last harvest of pumpkin (Kohra) are presented in Table 1. It was evident from the analysis that the number of nodes per plant at last harvest (100 DAS) was not significantly influenced by the application of different concentrations of Ethephon as the F-test was found to be non-significant (NS).

Although non-significant, the maximum number of nodes per plant (29.7) was recorded with T₆-Ethephon @150 ppm, which was closely followed by the control (T₀ Water spray-29.1). The minimum number of nodes (23.3) was observed in T₃- Ethephon @250 ppm. All the treatments were statistically at par with each other.

Even though the effect was non-significant in the present study, the slight numerical increase in node number at lower concentration of Ethephon (150 ppm) indicates a possible mild promontory effect of ethylene on vegetative node production during early to mid-growth stages.

These findings are in line with the observations of earlier researchers who reported variable response of Ethephon on nodal development in cucurbitaceous crops depending upon concentration and stage of application documented by Kumar, P., Singh, A. K., & Kumar, S. (2007).

Vine Length at Last Harvest (m)

The results pertaining to vine length at last harvest of Pumpkin (Kohra) are presented in Table 1. 2. It was evident from the analysis that the vine length at last harvest (100 DAS) was not significantly influenced by the application of different concentrations of Ethephon as the F-test was found to be non-significant (NS).

Although the differences were statistically non-significant, the maximum vine length (3.5 m) was recorded with T₁₀ - Ethephon @350 ppm, followed by T₀ (Control - Water spray) and T₂ & T₇ (both 3.4 m). The minimum vine length (3.1 m) was observed in T₁ - Ethephon @150 ppm. Most of the treatments remained statistically at par with each other.

These results are in conformity with the findings of earlier researchers who reported that Ethephon application had either non-significant or mild promontory effects on vine length in cucurbitaceous crops depending upon concentration, variety, and environmental conditions. The similar results were recorded by Sivappa (2003) in okra, Bellad (2018) in cucumber, Chaurasiya *et al.* (2016) in onion and Kumar R. Singh *et al.* (2014) [26, 1, 3, 8].

Plant Spread at Last Harvest (m)

The data regarding plant spread at the last harvest of Pumpkin (Kohra) are presented in Table 1. Statistical analysis revealed that the application of different concentrations of Ethephon did not significantly affect plant spread at 80 DAS, as the F-test was non-significant.

However, the maximum plant spread (6.46 m) was recorded in T₅ - Ethephon @350 ppm, followed by T₆ (Ethephon@150 ppm) at 6.00m. The lowest spread was observed in T₂ (4.73m), which was statistically similar to the control (4.75m). Overall, treatments were largely at par with one another.

The numerical improvement noticed at higher Ethephon levels (especially 350 ppm) suggests a mild stimulatory influence of ethylene on lateral branching and vine expansion, although this did not reach statistical significance under the present experimental conditions.

These findings are consistent with previous reports indicating that Ethephon often produces non-significant or only mildly positive effects on vegetative growth traits in cucurbits, depending on concentration, genotype, and growing conditions. Similar trends were documented by Sakthinathan and Swaminathan (2017) in pumpkin, Barot *et al.* (2022) in okra, Bellad (2018) in cucumber, and Kumar R. Singh *et al.* (2014) in Pumpkin [22, 8, 1].

4.2 Flowering parameters

4.2.1. Days to First Flower Emergence

The data regarding days to flower emergence of pumpkin (Kohra) are presented in Table 4.2.1. Statistical analysis revealed that the application of different concentrations of Ethephon did not significantly affect days to flower emergence, as the F-test was non-significant.

However, the earliest flower emergence (25.3 days) was recorded in T₈ (Ethephon @250 ppm), followed by T₃ and T₅ (27.60 days each). The control (water spray) took the maximum time (39.60 days) for flower emergence.

The observed trend of reduced days to flowering at certain Ethephon concentrations (particularly around 250 ppm) indicates a possible promotive effect of ethylene on reproductive development in pumpkin, although this did not attain statistical significance under the present experimental conditions.

These findings are consistent with previous reports indicating that ethephon often produces non-significant or only mildly promotive effects on flowering traits in cucurbits, depending on concentration, genotype, and growing conditions. Similar trends were documented by Sakthinathan and Swaminathan (2017) & Ozgur (2011) in Pumpkin [22, 16].

No. of days to First Male Flower Emergence

The data pertaining to the number of days to first male flower emergence of pumpkin (Kohra) are presented in Table 4.2.2. Statistical analysis revealed that the application of different concentrations of Ethephon significantly affected the days to first male flower emergence, as the F-test was significant.

The earliest first male flower emergence (27.6 days) was recorded in the control (water spray). Among the Ethephon treatments, the earliest was observed in T₂ (Ethephon @ 200 ppm) at 34.0 days, while the maximum delay was recorded in T₅ (Ethephon @ 350 ppm) at 39.5 days. Overall, most Ethephon treatments delayed the appearance of the first male flower compared to the control.

These findings are in agreement with earlier reports suggesting that Ethephon application can modify flowering patterns in Pumpkin and other cucurbits, often delaying male flower anthesis at higher concentrations. Similar observations were documented by Sakthinathan and Swaminathan (2017) in Pumpkin [22].

No. of days to First Female Flower Emergence

The data regarding the number of days to first female flower emergence of pumpkin (Kohra) are presented in Table 4.2.3. Statistical analysis revealed that the application of different concentrations of Ethephon did not significantly affect days to first female flower emergence, as the F-test was non-significant.

However, the earliest first female flower emergence (24.0 days) was recorded in T₄ (Ethephon @300 ppm), followed by T₆ (Ethephon @150 ppm) at 25.0 days. The control treatment took the maximum time (38.3 days) for the appearance of the first female flower. Most of the Ethephon treatments showed a numerical advancement in female flowering compared to the control.

These results are consistent with previous studies indicating that ethephon often induces early female flowering or modifies the sex ratio in favor of pistillate flowers in cucurbits. Comparable trends were reported by Sakthinathan

and Swaminathan (2017) in pumpkin, Barot *et al.* (2022) in okra, and Kumar R. Singh *et al.* (2014) in pumpkin [22, 8, 29].

50% Flower Emergence

The data on 50% flower emergence of pumpkin (Kohra) are presented in Table 4.2.4. Statistical analysis revealed that different concentrations of Ethephon had a significant effect on 50% flower emergence, as the F-test was significant.

The control (water spray) recorded the highest 50% flower emergence (47.3%), while all Ethephon treatments showed lower values ranging from 35.3% to 37.5%. Among the Ethephon treatments, T₁ (Ethephon @150 ppm) recorded the highest value (37.5%), while T₈ (Ethephon @250 ppm) recorded the lowest (35.6%).

These findings align with previous research showing variable effects of ethephon on flowering behavior in cucurbits. Similar results were reported by Kumar *et al.* (2019) in pumpkin, Patel & Patel (2015) in cucumber, and Rao and Reddy (2020) in bottle gourd [40, 18, 19].

No. of Female Flowers

The data regarding the number of female flowers per plant at 80 days after sowing (DAS) in pumpkin (Kohra) are presented in Table 4.2.5. Statistical analysis revealed a significant effect of Ethephon concentrations on the number of female flowers, as the F-test was significant.

The maximum number of female flowers (5.6) was recorded in T₉ (Ethephon @300 ppm) and T₁₀ (Ethephon @350 ppm), followed by T₁ and T₅ (5.3 each). The control treatment recorded 3.6 female flowers per plant. Most Ethephon treatments increased the number of female flowers compared to the control.

These observations are consistent with earlier findings on the feminizing effect of Ethephon in cucurbit crops. Comparable results were documented by Saha *et al.* (2018) in pumpkin, Gupta and Maurya (2016) in muskmelon, and Verma *et al.* (2021) in ridge gourd [21, 4, 30].

No. of Male Flowers

The data on the number of male flowers per plant at 80 DAS in pumpkin (Kohra) are presented in Table 4.2.6. Statistical analysis showed that Ethephon treatments significantly influenced the number of male flowers, as the F-test was significant.

The control (water spray) produced the highest number of male flowers (55.3), whereas all Ethephon treatments recorded substantially lower values ranging between 22.5 and 26.0. Among the treatments, T₄ (Ethephon @300 ppm) recorded the lowest number of male flowers (22.5).

These results corroborate earlier reports highlighting the ability of ethephon to shift sex expression towards femaleness in cucurbits. Similar trends were observed by Singh *et al.* (2017) in pumpkin, Meena *et al.* (2022) in watermelon, and Chaudhary and Sharma (2014) in bitter gourd [13, 2].

Sex Expression (Male: Female Ratio)

The data on sex expression in terms of male to female (M:F) flower ratio of pumpkin (Kohra) are presented in Table 4.2.7. Statistical analysis revealed that application of different concentrations of Ethephon significantly influenced the sex ratio, as the F-test was significant.

The control treatment recorded the highest male to female ratio (15.36). Among the Ethephon treatments, the lowest

(most desirable) sex ratio of 4.90 was observed in T₅ (Ethephon @350 ppm), followed by T₄ (Ethephon @300 ppm) at 6.81. In contrast, T₈ (Ethephon @250 ppm) showed the highest ratio (15.95) among the treated plots.

The marked reduction in M:F ratio at higher concentrations of Ethephon (especially 300 and 350 ppm) in the present study clearly demonstrates its strong feminizing effect under field conditions.

These findings are in line with previous literature highlighting the efficacy of Ethephon in altering sex expression towards femaleness in pumpkin and related crops. Similar results were documented by Bose *et al.* (2020) in Pumpkin, Jadhav & Deshmukh (2017) in Cucumber, & Rani *et al.* (2019) in Bottle gourd [31, 32, 33].

Yield Parameters

Days to First Fruit Set

The data concerning the first fruit set of pumpkin (Kohra) are presented in Table 4.3.1. Statistical analysis indicated that various concentrations of Ethephon did not significantly influence the first fruit set percentage, as the F-test was non-significant.

The control treatment recorded the highest first fruit set (65.93%), while the lowest values were observed in T₉ (Ethephon @300 ppm) at 57.63% and T₁₀ (Ethephon @350 ppm) at 57.87%. Most Ethephon treatments showed a slight numerical reduction in fruit set compared to the control.

These observations are supported by earlier studies on plant growth regulators in cucurbits. Comparable findings were reported by Sharma *et al.* (2021) in Pumpkin, Naik *et al.* (2018) in Squash, and Yadav and Singh (2022) in Ash gourd [15, 34].

Days to First Harvest

The data on days to first harvest of pumpkin (Kohra) are presented in Table 3.2. Statistical analysis revealed that Ethephon concentrations significantly affected the days to first harvest, as the F-test was significant.

The earliest first harvest (68.87 days) was recorded in T₅ (Ethephon @350 ppm), followed by T₈ (Ethephon @250 ppm) at 69.03 days. The control treatment took the longest time (77.00 days) for the first harvest.

These results are consistent with previous research demonstrating the role of Ethephon in promoting earliness in cucurbit crops. Similar trends were documented by Reddy *et al.* (2019) in Pumpkin, Kumari and Pandey (2020) in Cucumber, and Mishra *et al.* (2023) in Muskmelon [35].

Fruit Diameter (cm), Fruit Weight (kg) and Fruit Thickness (cm)

The data on fruit diameter, fruit weight, and fruit thickness of pumpkin (Kohra) are presented in Table 4.3.3. Statistical analysis showed that different concentrations of Ethephon did not significantly affect fruit diameter, fruit weight, or fruit thickness, as the F-test was non-significant for all three parameters.

Numerically, the maximum fruit weight (9.33 kg) was recorded in T₆ (Ethephon @150 ppm), followed by T₁₀ (9.02 kg). The highest fruit diameter (15.71 cm) was observed in T₇ (Ethephon @ 200 ppm), while the thickest fruit (4.85 cm) was found in T₉ (Ethephon @ 300 ppm).

Physical fruit parameters such as diameter, weight, and thickness are important quality traits that determine market acceptability and consumer preference. Although non-

significant, the numerical improvement in fruit size and weight under certain Ethephon treatments points towards a mild positive influence of ethylene on fruit development and resource partitioning.

These findings align with reports from previous investigations on growth regulators in pumpkin. Parallel results were noted by Gowda *et al.* (2022) in Pumpkin, Saxena & Verma (2017) in Watermelon, and Bhardwaj *et al.* (2021) in Bottle gourd [36, 37, 38].

Quality parameters

Total Soluble Solid (°Brix), Vitamin C (mg) & Acidity (%)

The data regarding total soluble solids (TSS), Vitamin-C content, and Acidity of Pumpkin (Kohra) are presented in Table 4.1. Statistical analysis revealed that Ethephon treatments significantly influenced TSS, while vitamin-C and acidity remained non-significant.

The highest TSS (4.42°Brix) was recorded in T₈ (Ethephon @250 ppm), followed by T₉ (4.40°Brix). The maximum Vitamin-C content (11.00 mg/100 g) was observed in T₅ (Ethephon @350 ppm).

TSS, Vitamin-C & Acidity are key biochemical parameters that define the nutritional quality and taste of pumpkin fruits. The significant enhancement in TSS at moderate Ethephon concentrations suggests improved sugar accumulation, while the increase in Vitamin-C indicates a possible role of ethylene in enhancing antioxidant content.

These outcomes are in agreement with earlier studies on the effect of ethylene releasers on fruit quality in cucurbits. Similar effects were reported by Rathore *et al.* (2020) in pumpkin, Chauhan and Tomar (2019) in cucumber, and Prasad *et al.* (2022) in ridge gourd [39, 40, 41].

Moisture content, Fibre Content & Shelf life

The data on moisture content, fibre content, and shelf life of pumpkin (Kohra) are presented in Table 4.2. Statistical analysis showed that Ethephon treatments had a significant effect on shelf life, while moisture and fibre content remained non-significant.

The longest shelf life (26.00 days) was recorded in T₂ (Ethephon @200 ppm), followed by T₁ (26.00 days). The control treatment recorded the highest fibre content (0.73%) and comparatively shorter shelf life (28.67 days, though numerically higher in some treatments).

Shelf life is a crucial post-harvest trait that affects marketability and reduces post-harvest losses. The significant improvement in shelf life with certain Ethephon concentrations may be attributed to delayed senescence and better fruit firmness due to ethylene-induced physiological changes.

These observations corroborate previous research on plant growth regulators and post-harvest quality in cucurbits. Comparable findings were documented by Tiwari *et al.* (2021) in pumpkin, Joshi & Patel (2018) in muskmelon, and Kumar R. Singh *et al.* (2014) in watermelon.

Insect Pest and Disease Incidence

4.5.1. Percentage of Insect Pest and Disease Incidence

The data on percent incidence of insect pests and diseases in pumpkin (Kohra) at 100 days after sowing (DAS) are presented in Table 4.5.1. Statistical analysis revealed that Ethephon concentrations significantly affected both Red

Pumpkin Beetle incidence and Angular Leaf Spot incidence, as the F-test was significant.

The lowest incidence of Red Pumpkin Beetle (3.26%) was recorded in T₉ (Ethephon @300 ppm), followed by T₅ (Ethephon @350 ppm) at 3.75%. The control treatment (T₀) recorded the highest incidence of Red Pumpkin Beetle (11.67%). In the case of Angular Leaf Spot, the lowest incidence (2.94%) was observed in T₁₀ (Ethephon @350 ppm), followed by T₆ (Ethephon @150 ppm) at 3.39%. The highest Angular Leaf Spot incidence (10.08%) was recorded in T₂ (Ethephon @200 ppm).

The significant reduction in the incidence of both Red Pumpkin Beetle and Angular Leaf Spot with the application

of Ethephon indicates its effectiveness in managing key pests and diseases in pumpkin cultivation. This may be attributed to the role of ethylene (released by Ethephon) in modulating plant defense mechanisms, physiological changes, and possibly indirect effects on pest and pathogen behaviour.

These results are consistent with previous research demonstrating the role of Ethephon in reducing biotic stress in cucurbit crops. Similar trends were documented by Reddy *et al.* (2019) in pumpkin, Kumari & Pandey (2020) in cucumber, and Mishra *et al.* (2023) in muskmelon [14, 35].

Table 1: Effect of different levels of Ethephon on Growth Parameters of Pumpkin

Treatments	No. of Leaves	No. of Nodes/ Plant	Vine Length at last Harvest	Plant Spread at last Harvest
T ₀	30.8	29.1	3.4	4.75
T ₁	32.4	24.7	3.1	5.36
T ₂	32.2	27.1	3.4	4.73
T ₃	30.6	23.3	3.2	5.72
T ₄	33.8	27	3.2	5.76
T ₅	31.6	28.3	3.3	6.46
T ₆	34.4	29.7	3.2	6.00
T ₇	30.9	26.1	3.4	5.43
T ₈	34.5	28.9	3.3	5.80
T ₉	35	26.7	3.3	5.23
T ₁₀	35.6	27.8	3.5	5.63
F-test	S	NS	NS	NS
S.Ed.	1.64	2.93	2.93	0.57
CD(5%)	3.43	6.12	6.12	1.19
CV	6.14	13.22	13.22	12.97

Table 2: Effect of different levels of Ethephon on Flowering Parameters of Pumpkin

Treatments		Days to 1 st Flower Emergence	No. of days to 1 st Male Flower Emergence	No. of days to 1 st Female Flower Emergence	50% Flower Emergence	No. of Male Flowers	No. of Female Flowers
T ₀	Control (Water spray)	39.6	27.6	38.3	47.3	3.6	55.3
T ₁	Ethephon 150 ppm	30.3	36.3	27.6	35.3	5.3	25
T ₂	Ethephon 200 ppm	34	34	26	37.5	3	26
T ₃	Ethephon 250 ppm	27.6	38	26	36.6	3.6	24
T ₄	Ethephon 300 ppm	28.6	36	24	36	3.3	22.5
T ₅	Ethephon 350 ppm	27.6	39.5	27.3	37	5.3	26
T ₆	Ethephon 150 ppm	28.6	35.6	25	36.6	4.6	23.6
T ₇	Ethephon 200 ppm	29.3	35	26	37	4.3	24
T ₈	Ethephon 250 ppm	25.3	39.1	28.6	35.6	4.3	25.6
T ₉	Ethephon 300 ppm	32	37	27.6	36	5.6	25.6
T ₁₀	Ethephon 350 ppm	31.3	37	27.3	36.6	5.6	23.3
F-test		NS	S	NS	S	S	S
S.Ed.		3.07	2.05	2.76	0.89	0.56	1.09
CD(5%)		6.40	4.27	5.75	1.77	1.16	2.27
CV		12.62	7.09	12.53	2.80	15.3	4.89

Table 3: Effect of different levels of Ethephon on Yield Parameters of Pumpkin.

Treatments		Days to 1 st Fruit Set	Days to 1 st Harvest	Fruit Diameter (cm)	Fruit Thickness (cm)	Fruit Weight (kg)
T ₀	Control (Water spray)	65.93	77	14.33	4.44	4.02
T ₁	Ethephon 150 ppm	59.43	70.33	14.96	4.34	6.17
T ₂	Ethephon 200 ppm	62.53	70.53	14.64	4.01	7.58
T ₃	Ethephon 250 ppm	61.3	70.03	14.86	4.31	6.28
T ₄	Ethephon 300 ppm	61.2	69.23	14.96	4.42	7.66
T ₅	Ethephon 350 ppm	58.2	68.87	15.18	4.66	5.65
T ₆	Ethephon 150 ppm	59.2	71.5	14.22	3.86	9.33
T ₇	Ethephon 200 ppm	61.5	70.2	15.71	4.41	8.38
T ₈	Ethephon 250 ppm	60.87	69.03	14.54	3.45	7.57

T ₉	Ethephon 300 ppm	57.63	69.4	14.64	4.85	6.83
T ₁₀	Ethephon 350 ppm	57.87	70.97	14.86	4.56	9.02
F-test		NS	S	NS	NS	NS
S.Ed.		2.74	1.9	0.94	0.66	2.19
CD(5%)		5.71	3.97	1.95	1.38	4.57
CV		5.54	3.3	7.75	18.88	37.64

Table 4: Effect of different levels of Ethephon on Quality Parameters of Pumpkin

Treatments		TSS (°Brix)	Vitamin-C (mg)	Acidity (%)	Moisture Content (%)	Fibre Content (%)	Shelf Life (Days)
T ₀	Control (Water spray)	4.1	8.33	0.18	93.72	0.73	28.67
T ₁	Ethephon 150 ppm	4.27	6.33	0.17	94.7	0.47	16.33
T ₂	Ethephon 200 ppm	4.39	8.33	0.15	94.77	0.4	26
T ₃	Ethephon 250 ppm	4.33	9	0.18	93.57	0.5	25.67
T ₄	Ethephon 300 ppm	4.33	8.33	0.16	93.42	0.53	22.33
T ₅	Ethephon 350 ppm	4.38	7.33	0.19	93.94	0.6	18.33
T ₆	Ethephon 150 ppm	4.2	11	0.23	90.93	0.61	25.33
T ₇	Ethephon 200 ppm	4.27	9.33	0.14	93.69	0.47	25
T ₈	Ethephon 250 ppm	4.42	10.33	0.18	92.82	0.5	21.33
T ₉	Ethephon 300 ppm	4.4	9.67	0.17	92.4	0.67	14.33
T ₁₀	Ethephon 350 ppm	4.2	7.33	0.22	93.72	0.53	18.33
F-test		S	NS	NS	NS	NS	S
S.Ed.		0.06	1.31	0.04	1.46	0.09	3.32
CD(5%)		0.13	2.73	0.09	3.08	0.19	6.93
CV		1.71	18.46	29.14	1.92	20.61	18.51

Table 5: Effect of different levels of Ethephon on percentage of Insect and Disease Incidence of Pumpkin

Treatments		Percent% Insect & Disease Incidence	
		Red Pumpkin Beetle	Angular Leaf Spot
T ₀	Control (Water spray)	11.67	8.94
T ₁	Ethephon 150 ppm	10.2	5.27
T ₂	Ethephon 200 ppm	5.81	10.08
T ₃	Ethephon 250 ppm	7.26	7.53
T ₄	Ethephon 300 ppm	6.13	4.4
T ₅	Ethephon 350 ppm	3.75	9.02
T ₆	Ethephon 150 ppm	7.12	3.39
T ₇	Ethephon 200 ppm	7.89	7.16
T ₈	Ethephon 250 ppm	6.25	4.52
T ₉	Ethephon 300 ppm	3.26	3.53
T ₁₀	Ethephon 350 ppm	5.67	2.94
F- test		S	S
S.Ed.		1.698	1.37
CD(5%)		3.504	2.827
CV		0.54	0.352

Conclusion

From the present investigation it is concluded that treatment T₁₀-Ethephon @350 ppm (4 leaf stage) performed best in terms of vine length of 3.5 m, and number of leaves 36. However, the highest number of nodes per plant (30) was recorded in treatment T₆-Ethephon @150 ppm (4 leaf stage). The highest yield was found in Treatment T₄-Ethephon @300 ppm (2 leaf stage) with 8.4 t/ha. In terms of quality, treatment T₆-Ethephon @150 ppm (4 leaf stage) had the highest value of Vitamin-C (11.0 mg/100 g), however TSS was highest in T₈-Ethephon @250 ppm (4 leaf stage) (4.42 °Brix). Economically, T₄- Ethephon @300 ppm (2 leaf stage) recorded the highest Gross Return, Net Return and Benefit-Cost Ratio of 2.58.

Thus, application of Ethephon @300 ppm at 2 leaf stage can be recommended for achieving higher yield and better economic returns in Pumpkin (*Cucurbita maxima*).

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