Research Article

Influence of 4-CPA Growth Regulator for Enhancing Yield of Tomato During Low Night Temperature Stress

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Abstract | Flowering in *Solanum lycopersicum* L. is sensitive to low-temperature as it inhibits the fuit growth and causes poor fruit setting. The present experiment was conducted to improve the fruit growth and fruit set in tomato during low-temperature stress conditions by the use of growth regulator 4-chlorophenoxy acetic acid. Seven different 4-chlorophenoxy acetic acid levels along with two indeterminate tomato varieties saandal and sahel were tested in two minimum night temperature conditions 12.5-23°C and 2-7.5°C. Tomato yield per plant, yield per cluster, number of fruits per cluster, fruit weight and fruit diameter were significantly improved by the application of 4-chlorophenoxy acetic acid. Highest yield per plant 13.50 kg was recorded with the application of 75 ppm in 4- chlorophenoxy acetic acid twicely when the minimum temperature was ranged between 12.5-23°C. Likewise, maximum yield per plant 7.08 kg was also obtained with the same treatment when the minimum temperature was between 2-7.5°C. This gain was primarily due to increased yield per cluster, fruits per cluster, fruit weight and fruit diameter in both minimum night temperature conditions (12.5-23°C and 2-7.5°C). 87 % gain in yield per plant was observed with 75 ppm double sprayed treatment over control when minimum night temperature varied between 2-7.5°C. Successful yield increase per plant suggested that 4-CPA could be used as a tool for getting economical tomato yield when night temperature falls below 10°C.

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Introduction

At the flowering stage tomato (*Solanum lycopersicum* L.) is very prone to both high and low temperatures. Studies conducted to find the relationship between daily temperature and reproductive stage of tomato have found that day temperatures of 21–28°C and night temperatures of 15-20 °C are optimal for proper fruit setting and size development in tomato (Rahman et al., 2015). Any increase or decrease from optimum temperature results in premature drop of tomato fruit (Pramanik et al., 2017). Night temperature also plays an important role in the setting and development of the fruit, as night temperature below 10 °C significantly affects the fruit set in tomato (Karapanos et al., 2008). Adam et al. (2001) while evaluating the impact of temperature on growth and development of tomato fruit, reported that temperature below 14°C greatly reduces the tomato growth and causes the

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development of small and parthenocarpic tomatoes. Low temperature mainly reduces the pollen viability, pollen release and also delays germination of pollen on stigma, pollen tube development in style that leads to poor pollination and delays the fertilization process which are the prerequisite for proper fruit setting and development in tomato (Fernandez-munoz et al., 1995; Pressman et al., 2007).

Plant growth regulators are extensively being practiced in tomato for improving crop yield in temperature stress conditions. The impact of synthetic auxins and gibberellins to boost the production of tomatoes by setting parthenocarpic fruits has been acknowledged by many researchers (Tiwari et al., 2014; Pramanik et al., 2017). 4-Chlorophenoxy acetic acid is a synthetic auxin whose application has been reported to increase fruit set and size of tomato in temperature stress conditions (Picken and Grimmett, 1986; Ramin, 2003).

Many studies tested the growth hormones applications to improve tomato crop yield during high-temperature stress. There are few studies that check its effectiveness in low-temperature stress. However, investigations regarding 4-CPA test for low night temperature conditions are limited. In the present study effects of different 4-CPA levels were assessed in response to two minimum temperature conditions. In the first condition, different 4-CPA levels were tested during October to November when minimum night temperature was ranging between (12.5°C-23°C) and secondly the same levels of 4-CPA were tested in December- January when the minimum temperature at night was ranging between (2°C-7.5°C). The ultimate goal of the study was to find the best suitable level of 4-CPA growth regulator that could improve the fruit set and yield of the tomato crop during minimum nigh temperature conditions.

Materials and Methods

The experiment was conducted at the research area of Vegetable Research Institute Faisalabad, Pakistan, located at 31°23'52.8"N and 73°02'56.9"E during August 2017 to April 2018. Two indeterminate tomato hybrids Saandal and Sahel were used in this study. Both these varieties are being used commercially in normal planting season. Sandals give early production, but Sahel's fruit size is larger than sandals. During the last week of August 2017, seeds of both varieties were sown in vermicompost filled trays and seedlings of each variety were transplanted on both sides of the two beds in the last week of September in the high tunnel with the dimension of (100ft×30ft×15ft). Two-factor randomized complete block design with five replications was used to design the experiment and a flower cluster with 3 opened flowers was treated as an experimental unit. All the recommended cultural practices were followed during the conduction of this experiment.

The spray of 4-CPA treatments was performed five times with a one-week interval from October to November (18th Oct- 15th Nov) when minimum night temperature was ranging between (12.5°C-23°C). Secondly, the same experiment was repeated in December-January (28th Dec to 26th Jan) when the minimum night temperature was ranging between (2°C-7.5°C). Seven 4- chlorophenoxy acetic acid (4-CPA) levels i.e. T1= 00 ppm (control), T2 = 25 ppm single spray, T3= 50 ppm single spray, T4= 75 ppm single spray, T5= 25 ppm double spray, T6= 50 ppm double spray, T7=75 ppm double spray were used to access the effect of different levels of 4-CPA. In single spray treatments selected clusters were sprayed only one time while in double spray treatments, clusters were sprayed twice.

To collect data regarding tomato yield, all ripened fruits of each treatment were harvested separately. To collect data for fruit per cluster, all the marketable size ripened fruits were counted. On average five fruits from the center of the cluster of each treatment were used for data collection for fruit weight, fruit diameter, and the number of seed per fruit.

Analyses of variance for all the characters were performed using Statistix software. Means of all the treatments were calculated and the significance of differences between the pairs of means was tested by using the least significant difference test at 5 % level of significance. Percentage increase and decrease by the use of dose (double spray 75 ppm) that give more increase in traits over control was also calculated to get a more clear picture of the effect of 4-CPA.

Results and Discussion

Yield per plant

Yield per plant is a complex trait and is highly correlated with other traits such as fruit weight, fruit diameter and the number of fruit set per cluster. In the present study, yield per plant was significantly improved when minimum night temperature was between 2°C -7.5°C by the application of growth regulator 4-CPA. A comparison of means showed significant differences in response to the different levels of 4-CPA. During cooly nights when the temperature was between 2°C -7.5°C, highest yield per plant (7.08 kg) was recorded by the use of 75 ppm dose twice in a week (Table 3). 87 % more yield was recorded in double sprayed 75 ppm treatment than control (Table 1). In single spray treatment, 75 ppm produced the highest yield (5.91 kg) as compared to other treatments i.e 25ppm (4.18 kg) and 50 ppm (4.35 kg). Control treatment (0 ppm) showed the minimum yield (3.78 kg) as compared to other treatments (Table 3). Both varieties also showed significant differences regarding yield per plant. Saandal variety showed more yield per plant (4.74 kg) than the Sahel (4.30 kg) when night temperature was 2°C -7.5°C.

When the temperature was between 12.5-23°C, then again the application of growth regulator was found effective. Yield per plant was increased by the use of growth regulator 4-CPA in this condition. The interaction effects of variety into 4-CPA levels were found non-significant and indicated that the main effects of variety and 4-CPA levels are more important. Differences in varieties in respect of yield per plant were non-significant when minimum night temperature was 12.5-23°C. Significant differences in means of different 4-CPA levels indicated that to improve the yield of tomato use of 4-CPA is effective when night temperature was between 12.5-23°C. Highest yield per plant was recorded with 75 ppm double spray treatment and minimum was found in control. In single spray treatment, 75 ppm (10.51 kg) was found more effective than other treatments i.e. 25 ppm (7.53 kg), and 50 ppm (8.22 kg). Double spray treatment of 25 ppm (8.46 kg) and 50 ppm (9.69 kg) showed more yield than single spray treatment 25 ppm (7.53 kg) and 50 ppm (8.22 kg) (Table 3). Increase yield per plant was mainly due to the increase in fruit set and fruit growth of tomato. Picken and grimmett, 1986 found a small increase in yield by the application of 4-CPA at the rate of 0.02 gl^{-1} and β napthoxy acetic acid 0.0075 gl^{-1} in tomato. They found that β napthoxy acetic acid is effective at 16°C and 4-CPA at 13°C minimum night temperature. Further, the effect of both these growth regulators was questionable when minimum night temperature was 11°C. Our results varied from their findings as we recorded an increase of 87 % in yield when minimum night temperature was 2°C -7.5°C. This increase in yield was may be due to the use of higher concentration 75 ppm (0.075 gl^{-1}) and twice spray in a week.

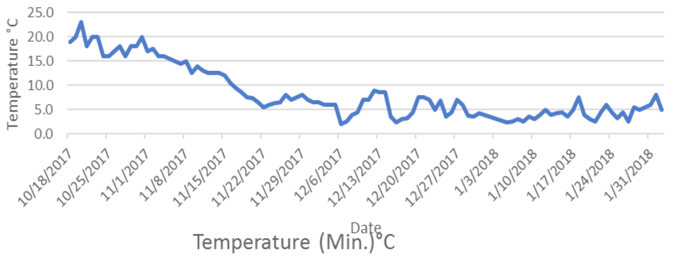

Figure 1: *Minimum night temperature recorded during the spraying period from Mid-October to January.*

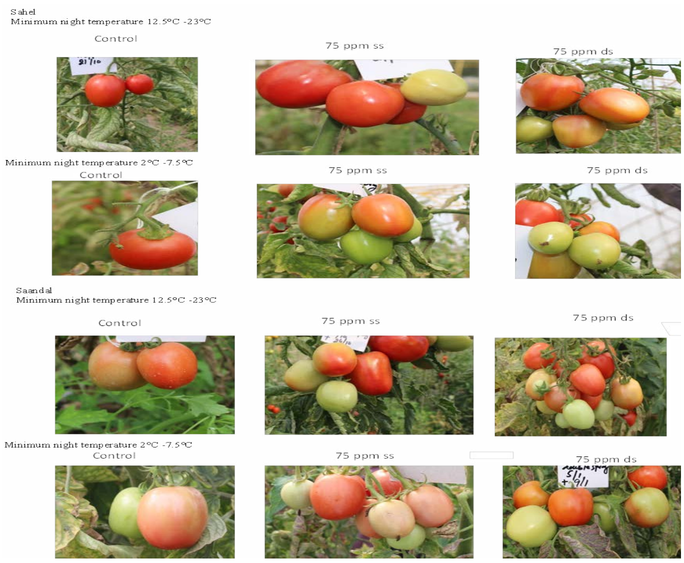

Figure 2: *Impact of 75 ppm single as well as double spray over control in both temperature conditions.*

Tomato yield per cluster

Tomato yield in both temperature conditions was significantly increased by the application of plant growth regulator 4-CPA. This increase in yield was mainly due to an increase in the number of fruits set on a cluster, fruit weight, and fruit diameter. 75 ppm double spray treatment in both temperature conditions 12.5°C -23°C and 2°C -7.5°C produced more yield per cluster as compared to control (0 ppm). An overall 163-300 % increase in yield was recorded in sprayed clusters over control in both temperature conditions (12.5°C -23°C and 2°C -7.5°C) (Table 1). The highest yield of 1.12 kg and 0.58 kg per cluster was recorded respectively, for both minimum night temperature conditions (12.5°C -23°C and 2°C -7.5°C) when the genotypes were sprayed with 75ppm twice while lowest yield was observed in control (0.42 kg, 0.14 kg) as presented in Table 3. In single spray treatment,

Table 1: *Percentage increase/decrease in 75 ppm double sprayed treatmetnt over control in respect of different studied parameters.*

Character	Min. temperature ranging between 12.5°C -23°C			Min. temperature ranging between 2°C -7.5°C		
	Control	Sprayed	Percentage increase/ Decrease	Control treatment	Sprayed treatment	Percentage increase/ Decrease
Yield per plant	6.49	12.00	85	3.78	7.08	87
Yield per cluster (kg)	0.428	1.124	163	0.147	0.589	300
Number of fruits per cluster	3.70	6.80	83	2.50	6.00	140
Fruit weight (g)	113.29	167.84	48	58.30	96.17	65
Fruit Diameter (mm)	52.38	67.46	29	45.71	61.29	34
No. of seeds/ fruit	57.05	20.70	63	49.10	9.50	8

Table 2: *Performance of different tomato varieties in low night temperature stress.*

Treatments	Minimum night temperature ranging between 12.5°C -23°C						Minimum night temperature ranging between 2°C -7.5°C					
	NF/C	FW (g)	FD (mm)	NS/F	Y/C (kg)	Y/P (kg)	NF/C	FW (g)	FD (mm)	NS/F	Y/C (kg)	Y/P (kg)
V1 (Sahel)	4.68b	151.89a	64.06a	33.72a	0.72a	8.72a	4.34b	77.27b	51.82b	19.25b	0.35b	4.30b
V2 (Saandal)	5.74a	129.80b	60.24b	33.45a	0.75a	9.02a	4.85a	79.27a	55.05a	27.74a	0.39a	4.74a
LSD	0.21	4.08	1.11	1.72	0.04	0.50	0.18	1.22	0.81	1.34	0.01	0.15
Level of significance (5%)	*	*	*	ns	ns	ns	*	*	*	*	*	*

NF/C: Number of fruit per cluster; FW: Fruit weight; FD: Fruit Diameter; NS/F: No. of seed/ fruit; Y/C: Yield per cluster; Y/P: yield per plant.

Table 3: *Impact of different 4-CPA levels on different yield contributing characters of tomato during low night temperature.*

Treatments	Minimum night temperature ranging between 12.5°C -23°C						Minimum night temperature ranging between 2°C -7.5°C					
	NF/C	FW (g)	FD (mm)	NS/F	Y/C (kg)	Y/P (Kg)	NF/C	FW (g)	FD (mm)	NS/F	Y/C (kg)	Y/P (kg)
T1 (0ppm)	3.70f	113.29e	52.38f	57.05a	0.42e	6.49e	2.50e	58.30g	45.71f	49.10a	0.14f	3.78f
T2 (25 ppm single spray)	4.50e	125.40d	59.20e	43.10b	0.54d	7.53d	3.80d	67.61f	50.24e	28.00b	0.26e	3.98e
T3 (50 ppm single spray)	5.30c	132.34d	61.59d	33.60c	0.68c	8.22c	4.70c	77.74d	53.043cd	22.40d	0.36d	4.35d
T4 (75 ppm single spray)	5.90b	147.02c	65.25b	26.20d	0.87b	10.51b	5.40b	89.97b	57.067b	16.20f	0.49b	5.91b
T5 (25 ppm double spray)	4.90d	145.26c	63.43c	28.70d	0.70c	8.46c	4.50c	74.71e	52.41d	20.40c	0.33d	4.08d
T6 (50 ppm double spray)	5.40c	154.77b	65.25b	25.80d	0.80b	9.69b	5.30b	83.30c	54.32c	18.90e	0.44c	5.31c
T7 (75 ppm double spray)	6.80a	167.84a	67.46a	20.70e	1.12a	12.00a	6.00a	96.17a	61.29a	9.50g	0.58a	7.08a
LSD	0.39	7.64	0.59	3.22	0.07	0.94	0.34	2.28	1.51	2.52	0.02	0.29
Level of significance (5%)	*	*	*	*	*	*	*	*	*	*	*	*

NF/C: Number of fruit per cluster; FW: Fruit weight; FD: Fruit Diameter; NS/F: No. of seed/ fruit; Y/C: Yield per cluster; Y/P: yield per plant.

75 ppm produced the highest yield (0.49 kg) as compared to other treatments i.e. 0 ppm (0.14 kg), 25ppm (0.26 kg), and 50 ppm (0.36 kg) when crop faced the temperature of 2°C -7.5°C at night time (Table 3). Control treatment (0 ppm) showed the minimum yield per cluster (0.14 kg) as compared to other treatments. Double sprayed treatments also showed more yield per cluster than single spray when minimum night temperature was between 2°C -7.5°C. Significant differences were also observed between varieties regarding yield per cluster. Saandal hybrid (0.35 kg) gave more yield per cluster than Sahel (0.35 kg). The performance of the varieties under different treatments showed that the variety Saandal is more responsive to the different levels of 4-CPA than Sahel (Table 4).

Table 4: *Comparison of interaction effects of 4-CPA levels and varieties in respect of different yield contributing characters of tomato during low night temperature stress.*

Treatments	Minimum night temperature ranging between 12.5°C -23°C						Minimum night temperature ranging between 2°C -7.5°C					
	NF/C	FW (g)	FD (mm)	NS/F	Y/C (kg)	Y/P (kg)	NF/C	FW (g)	FD (mm)	NS/F	Y/C (kg)	Y/P (kg)
V1T1 (Sahel, 0ppm)	3.20f	112.40i	52.95h	58.90a	0.37g	5.92g	2.00g	51.37i	43.46h	54.40a	0.11j	2.35j
V1T2 (Sahel, 25 ppm single spray)	4.20e	131.22fg	61.00f	42.80b	0.52f	6.36f	3.40f	65.36h	48.62g	21.60ef	0.22h	2.72h
V1T3 (Sahel, 50 ppm single spray)	5.00d	139.74ef	63.11d	32.40c	0.68e	8.16e	4.40e	78.48de	51.02f	18.80fg	0.34ef	4.14ef
V1T4 (Sahel, 75 ppm single spray)	5.60c	157.84cd	68.86ab	26.00de	0.88b	10.65b	5.20bc	88.58bc	54.90cde	7.40i	0.47c	5.67c
V1T5 (Sahel, 25 ppm double spray)	4.20e	159.35c	65.57c	32.80c	0.68e	8.18e	4.40e	74.15f	51.94f	16.20gh	0.31fg	3.82fg
V1T6 (Sahel, 50 ppm double spray)	4.80d	175.33b	67.58b	24.40de	0.81bc	9.82bc	5.00cd	86.19c	52.99def	13.40h	0.44cd	5.38cd
V1T7 (Sahel, 75 ppm double spray)	5.80bc	187.37a	69.32a	18.80f	1.11a	13.35a	5.70a	96.79a	59.79b	3.00j	0.58a	7.05a
V2T1 (Saandal, 0ppm)	4.20e	114.18hi	51.81h	55.20a	0.48fg	7.07fg	3.00f	65.22h	47.95g	43.80b	0.18i	3.19i
V2T2 (Saandal, 25 ppm single spray)	4.80d	119.58hi	57.39g	43.40b	0.55f	7.71f	4.20e	69.87g	51.86f	34.400c	0.30g	3.63g
V2T3 (Saandal, 50 ppm single spray)	5.60c	124.94gh	60.07f	34.80c	0.69de	8.28de	5.00cd	77.01ef	55.06cd	26.00d	0.37e	4.55e
V2T4 (Saandal, 75 ppm single spray)	6.20b	136.19f	62.63de	26.40de	0.86b	10.37b	5.60ab	91.36b	59.22b	25.00de	0.51b	6.14b
V2T5 (Saandal, 25 ppm double spray)	5.60c	131.18fg	61.29ef	24.60de	0.72cde	8.75cde	4.60de	75.28ef	52.88ef	24.60de	0.36e	4.33e
V2T6 (Saandal, 50 ppm double spray)	6.00bc	134.21fg	62.92d	27.20d	0.79bcd	9.57bcd	5.60ab	80.42d	55.66c	24.40de	0.43d	5.24d
V2T7 (Saandal, 75 ppm double spray)	7.80 a	148.31de	65.60c	22.60ef	1.13a	13.65a	6.30a	95.55a	62.74a	16.00gh	0.59a	7.11a
LSD	0.56	10.81	1.57	4.56	0.11	1.32	0.48	3.22	2.14	1.34	2.10	0.41
Level of significance (5%)	*	*	*	ns	ns	ns	ns	*	ns	*	*	*

NF/C: Number of fruit per cluster; FW: Fruit weight; FD: Fruit Diameter; NS/F: No. of seed/ fruit; Y/C: Yield per cluster; Y/P: yield per plant.

When minimum night temperature was 12.5°C-23°C then the double spray of 75 ppm caused more gain in yield per cluster (1.12 kg) than other treatments especially control (0.42). Double spray treatment of 25 ppm (0.70 kg) and 50 ppm (0.80 kg) showed more yield than the single spray treatment of 25 ppm (0.54 kg) and 50 ppm (0.68 kg). Single spray of 75 ppm (0.87 kg) was found more effective than other single spray treatments to increase yield per cluster i.e. 25 ppm (0.54 kg), and 50 ppm (0.68 kg). It was noted that in the sprayed cluster mostly fruits were formed by bypassing the regular fruit development process in which pollination and fertilization are the main requirements for fruit set. An increase in yield by the application of growth regulators under the cool season was also observed by Abad and Guardiola (1985). Gemici et al. (2006) and Ramin (2003) reported that parthenocarpic fruits development, increase in fruit weight and fruit size (fruit diameter) were the main reasons for more yield of plants that were treated with 4-CPA.

Number of fruits per cluster

The number of fruits per cluster is an important parameter that contributes to yield. As more the number of fruit sets per cluster more will be the yield of the plant. During cool nights when minimum night temperature was 2°C -7.5°C, the interaction effects of variety into 4-CPA levels were non-significant indicating that the main effects of variety and 4-CPA levels are more important in respect of the number of fruit per cluster. Double sprayed treatments set more number of fruits per cluster than single spray when minimum night temperature was between 2°C -7.5°C. More number of fruits (6.00) was set by applying double spray of 75 ppm (T7) while fewer fruits per cluster (2.5) were set in control clusters on which no chemical dose was sprayed (Table 3). In single spray treatment, by applying 75 ppm concentration more number of fruits (5.90) were sets as compared to other treatments i.e 25ppm (3.80), and 50 ppm (4.70) when crop faced the temperature of 2°C -7.5°C in the night (Table 3). Saandal variety was able to set 10.5% more fruits (4.85) per cluster as compared to Sahel (4.34) when night temperature was ranged between 2°C -7.5°C (Table 2).

When minimum night temperature was 12.5°C-23°C, double spray treatment of 75 ppm (6.80) showed more number of fruit per clusters than other double spray treatments i.e. 25 ppm (4.90) and 50 ppm (5.40). However, these double sprayed treatments did not show significant differences in comparison with single spray treatment 25 ppm (4.50) and 50 ppm (5.30). In single sprays, 75 ppm was found more effective than other treatments to increase the number of fruits per cluster i.e. 25 ppm (4.50), and 50 ppm (5.30). More number of fruits in treated clusters were mainly due to parthenocarpy that bypassed the process of natural pollination and fertilization which are two major processes required for proper fruit setting through sexual processes.

Fruit weight

In cooly nights when the temperature was 2°C -7.5°C at night time, Sahel hybrid (51.37 g) shows more reduction in fruit weight than Saandal (65.22) as compared to nights when the temperature was between 12.5°C-23°C in which Sahel fruit weight was 112.40g and Saandal was 114.18 g. An increase in fruit weight by the application of different doses of 4-CPA was observed in both temperature conditions. During cool nights when minimum night temperature was 2°C -7.5°C, interaction effects of variety into 4-CPA levels were significant indicating that the response of different 4-CPA levels was highly dependent on varieties. With a double spray of 75 ppm, Sahel hybrid (96.79) depicted more gain in fruit weight than Saandal (95.55). Overall 46.9% increase in Sahel (96.79 g) and 31.74% in Saandal fruit weight (95.55g) occurred with a double spray of 75 ppm (Table 4). Mean comparison of single and double sprayed treatments regarding fruit weight showed that double sprayed treatments were more effective in increasing fruit weight than single spray treatments in both varieties. An experiment performed by Gemici et al. (2006) also showed congruent results with our studies and reported an increase in fresh as well as dry fruit weight of the plants that were treated with 4-CPA.

Fruit diameter

An increase in fruit diameter by the application of 4-CPA over control in both temperature conditions was recorded. Highest fruit diameter (67.46 mm, 61.26 mm) was observed by the use of 75 ppm concentration two times in a week in both temperature conditions 12.5°C -23°C and 2°C -7.5°C, respectively. Similarly, minimum fruit diameter (52.38 mm, 45.71 mm) was found in control (0 ppm) in both temperature conditions 12.5°C -23°C and 2°C -7.5°C, respectively (Table 3). Both varieties showed different responses towards different 4-CPA levels but maximum fruit diameter was recorded in both varieties when treated with 75 ppm twice in a week (Table 2). The results of this study are in agreement with the findings of Halder et al. (2003) who reported the application of 4-CPA increased the fruit length as well as fruit diameter of summer tomato. Gemici et al. (2006) also observed an increase in fruit diameter by the application of 4-CPA and on the basis of hormonal assay he linked this increase with the increase in the internal hormone Indol-3-acetic acid IAA of the sprayed plants.

Number of seed per fruit

Parthenocarpic fruit development is the main reason for increase fruit set per cluster and yield. The decrease in seed per fruit was observed with the application of growth regulators. Less seed formation in sprayed fruits indicates the effectiveness of hormone in parthenocarpic fruit development. The highest number of seeds (57.05, 39.50) was observed in fruits of the control cluster in which no spray occurred and the minimum number of seeds (20.70, 9.50) was found in the fruits that were treated with 75 ppm concentration twice in a week (Table 3). Karapons et al. (2008) reported the parthenocarpic fruit development in the fruit clusters that were treated with 4-CPA. Gemici et al. (2006) found 80% parthenocarpic fruits in the plants that were treated with 4-CPA. Moreover, they reported that these seedless fruits were formed in control as well as treated clusters as ovaries of these flowers did not wait for pollination and form fruit bypassing the process of pollination and fertilization.

As in the case of hormonal application, the ovary has not waited for signal receipt on account of natural fertilization to develop into fruit and fewer seeds in these fruits may be due to delayed or disturbance in pollen tube growth on account of ovary enlargement. Whereas in case of control treatment, stigma as well as pollen tube development has remained active for the large time, thus allowing natural fertilization even after prolonged time and resulted in more seed formation as compared to sprayed one.

Conclusions and Recommendations

Based on this study it may be concluded that increase in yield of winter tomato planting is possible during low temperature stress when minimum night temperature was ranging between 12.5°C -23°C and 2°C -7.5°C, by the use of growth regulator 4-CPA at 75 ppm two times in a week. A positive influence of 4-CPA describes above on tomato yield could be a tool for getting economical tomato yield in the low night temperature stress conditions.

Authors Contributions

Saeed Ahmed Shah Chishti, Saba Aleem, executed the whole experiment, collected and analyzed the data and also wrote the whole manuscript. Kashif Nadeem helped in data collection. Nusrat Parveen and Iram Sharif helped in data, analyzing and write-up of the manuscript. Muhammad Najeebullah monitored the whole experiment and provided technical help in performing the experiment

Conflict of interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this article.

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