

Research Article

Influence of Calcium chloride and Gibberellic acid levels on the growth, yield and quality of tomato in the agro-climatic conditions of Mardan-Pakistan

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Citation

Wiqar Muhammad, Muhammad Noman Khan, Muhammad Ilyas*, Majid Hissam, Waqas Khan, Babar Ali, Muhammad Riaz Khan and Muhammad Hilal. Influence of Calcium chloride and Gibberellic acid levels on the growth, yield and quality of tomato in the agro-climatic conditions of Mardan-Pakistan. Pure and Applied Biology. Vol. 8, Issue 2, pp1191-1205. <http://dx.doi.org/10.19045/bspab.2019.80061>

Received: 26/01/2019

Revised: 01/04/2019

Accepted: 08/04/2019

Online First: 18/04/2019

Abstract

Tomato is an important vegetable commercialized in Pakistan, and the use of Gibberellic acid (GA_3) to cultivate it in the Peshawar valley may promote the production of high quality tomato. Therefore, A field experiment was conducted at the Agriculture Farm of Abdul Wali Khan University Mardan during summer 2017, to study the influence of calcium chloride and gibberellic acid levels on the growth yield and quality of tomato. (Cv. Ontario). There were four concentrations of calcium chloride i.e. 0, 3, 6, and 9% and four levels of GA_3 i.e. 0, 50, 75 and 90 ppm ha^{-1} . The experiment was laid out in randomized complete block design (RCBD) having three replication. Applications of calcium chloride and gibberellic acid levels have significant effect on the growth, yield and quality of tomato. The maximum number of branches $plant^{-1}$ (8.18), number of flower cluster $plant^{-1}$ (10), number of flower $plant^{-1}$ (45), number of fruit cluster $plant^{-1}$ (6), number of fruit $plant^{-1}$ (27), yield $plant^{-1}$ (2.0 kg), yield $plot^{-1}$ (8 kg) ha^{-1} (22 tons), weight of individual fruit (80.3 g), vitamin C content (69.63 mg $100 g^{-1}$), fruit firmness (14 N) and cost benefit ratio (1.8) was observed at 75 ppm of GA_3 , while the maximum plant height (88.93 cm) was found at 90 ppm of GA_3 . In case of calcium chloride the maximum number of branches $plant^{-1}$ (7.19), plant height (87.58 cm), number of flower cluster $plant^{-1}$ (10), number of flower $plant^{-1}$ (43), number of fruit cluster $plant^{-1}$ (5), number of fruit $plant^{-1}$ (23), yield $plant^{-1}$ (1.6 kg), yield $plot^{-1}$ (6.8 kg) ha^{-1} (18.8 tons), weight of individual fruit (74 g), Vitamin C content (70 mg $100 g^{-1}$) and cost benefit ratio (2.3) was found at 9% of $CaCl_2$, while the maximum fruit firmness (14.19 N) and minimum blossom end rot (4.82%) was noted at 6% of $CaCl_2$. It was concluded that $CaCl_2$ at the rate of 9% and GA_3 at the rate of 75 ppm has significant effect on enhancing growth and quality attributes of tomato. Therefore it is recommended that $CaCl_2$ at the rate of 9% and GA_3 at the rate of 75 ppm should be used for maximum growth, yield and quality of tomato in the agro-climatic conditions of District Mardan.

Keywords: Calcium chloride; Gibberellic acid; Mardan; Quality; Yield

Introduction

Tomato (*Lycopersicon esculentum*) belongs to family Solanacea and is locally called as Tamater. It is one of the most

important and commonly cultivated vegetable crops in the world. Tomato ranks 3rd position in the world in vegetables and is on the first place as processing crop in

vegetables tropical America is considered as its origin [1]. However, China, Iran, Egypt, Turkey, India, USA, Brazil, Italy, Indonesia and Mexico are the leading tomato producing parts of the world [2].

The major tomato crop is grown in summer; flowers and fruits during the months of May and July, when the temperature could be as high as 45°C. It grows well at the temperature ranged 25-30°C during the day and 21°C at night [3]. High temperature, at the flowering stage, results in poor pollens development, low fruit set and poor fruit yield [4, 5]. High temperature also inactivates Rubisco, the major photosynthetic enzyme that decreases the rate of photosynthesis [3]. The high summer temperature is also accompanied by extended high light intensity, which may aggravate other stresses [6]. In tomato plant, the optimum light duration is about 12 hours [7] and excessive light (17 hours) may cause leaf chlorosis [8].

The agro climate conditions of Pakistan are suitable for the cultivation of tomato, In Pakistan tomato has a great demand throughout the year due to its variety of uses in Pakistani dishes both traditional as well as modern foods.

It is very nutritious vegetable which can be used in salads, soups, ketchup, curry, sauce, juice and chutney etc. Tomato is highly nutritious because it contains calories energy (23), Protein (2 g), water (94%), Mg (7 mg), Ca (1 g), Vitamin "C" (31 mg), Vitamin "A" (1000 IU), Riboflavin (0.03 mg), Thiamin (0.1 mg), Niacin (0.8 mg).100 g⁻¹ of edible portion [9].

In Pakistan, the area and production of tomato in the year 2013-14 was 52300 ha¹ with 530,000 tones, respectively. Whereas, the average yield of tomato was about 10 tones ha⁻¹. However, in Khyber Pakhtunkhwa this crop was grown on 12.6 ha and produced 113.2 tons tomatoes. The average yield ha⁻¹ in Kpk is 8.98 tons [10]. GA₃ are growth promoter and can play a major role to improve plant growth, and development of vegetable crop. GA₃ is one

of the most important growth stimulating substance which help in cell division, and cell elongation, thus it can improve the plant growth and development of many crop [11]. [12] Reported that gibberellic acid (GA₃) can promote the fruit growth and development in pollinated ovaries which become dormant because of high temperature. It is also important for the better yield of tomato.

Calcium is an important secondary macro nutrient and can play a role in defense singling [13]. Calcium plays a major role in many physiological activity and plant development of bulbous flower [14] (Pan and Dong 1995). Direct applying of Calcium is the most effective method to increase the Calcium content in fruit [15]. Calcium increase vitamin C content as well as improves the quality of fruit and vegetable and also retains fruit firmness [16]. Calcium is an important nutrient for the growth development, quality and shelf life of tomato. Calcium application to the soil improves the growth of tomato, while applying as a foliar application during fruit growth period it can improve the quality of fruit [17]. Calcium deficiency can reduce the fruit quality and the disease like Blossom end rot and many other physiological disorders [18]. Calcium can play a major role in the cell membrane and cell wall stabilization [19].

In view of the above findings, it can be concluded that GA₃ and Calcium are the important sources for the improvement of yield and quality of fruit. Therefore, an experiment was designed to study the influence of Calcium and Gibberellic acid levels on the growth, yield and quality of tomato in the climatic conditions of Mardan; with the following Objective to investigate the optimum level of Calcium chloride for better growth, yield and quality of tomato. To explore the optimum level of GA₃ for growth, yield and quality of tomato. To determine the suitable interaction of Calcium chloride and GA₃ for the higher growth and yield of tomato.

Materials and methods

An experiment “Influence of Calcium chloride and Gibberellic acid levels on the growth, yield and quality of tomato in the climatic conditions of Mardan” was conducted at the Agriculture farm of Abdul Wali Khan University Mardan. The seedling of tomato was acquired from reliable source and was transplanted in the first week of April, 2017 with 50cm plant to plant distance and 60cm row to row distance. All the management activities were practiced according to the general recommendations.

Different concentration of Calcium chloride i.e., 0, 3, 6, 9% and GA₃ solution with concentration 0, 50, 75, 90 ppm was prepared and sprayed after 30 days of transplantation.

The experiment was laid out as two factors RCBD experiment.

Study parameters

The following parameters were studied.

Number of branches plant⁻¹

Number of branches were counted from the selected plants from the ground level to the top of the stem and means value were calculated.

Plant height (cm)

Plant height was measured from the selected plants from the ground surface to the top of the stem and means value was calculated.

Number of flower clusters plant⁻¹

The numbers of flower clusters were counted from the selected plants and the average numbers of flower clusters produced plant⁻¹ were calculated.

Number of flowers plant⁻¹

The total numbers of flower were counted from the selected plants. Each time the recorded clusters were marked with permanent marker and the average number of flower produced plant⁻¹ were calculated.

Number of fruit clusters plant⁻¹

The numbers of fruit cluster plant⁻¹ were counted from the selected plants and the average number of fruit clusters produced plant⁻¹ was recorded.

Number of fruits plant⁻¹

The total numbers of fruit were counted from the selected plants and the average numbers of fruit produced per plant were recorded.

Weight of individual fruit (g)

The weights of Ten (10) randomly selected fruits were taken in each treatment and mean was calculated.

Fruit yield plant⁻¹(kg)

The weight of fruit plant⁻¹ was measured by using weighing balance. It was determined by totalling of fruit yield from each plant during the period from first to final harvest and mean were calculated.

Fruit yield plot⁻¹ (kg)

The weights of fruit plot⁻¹ were measured by using weighing balance. It was determined by totaling of fruit yield from each plot during the period from first to final harvest and mean were calculated.

Fruit yield hectare⁻¹ (tons)

It was measured by the following formula:

Fruit yield per hectare (ton) = Fruit yield plot⁻¹ kg x10000 m²/ Area of plot (m²) x 1000 kg

Vitamin C (mg 100g⁻¹)

Vitamin C content of 10 randomly selected fruits was determined by analysing their sample in a lab. The average mean was calculated.

Procedure

10 ml of juice was taken from the extracted juice of tomato with the help of pipette. It was then poured into the graduated cylinder and after that the volume was raised to 100 ml with the help of 0.1N oxalic acid solution to make 10% solution. From that 10% solution, 10 ml was taken with help of pipette and poured into beaker, then it was titrated against the dye solution (2-6 dichloro phenol indo phenol + baking soda) from the burette and when the pink colour was attained titration was stopped and the reading was noted, Vitamin C contents was calculated using the following formula.

Vitamin C contents (mg 100 ml⁻¹) = $F \times T \times 100 / D \times S \times 100$

Where F = factor of standardization (ml of ascorbic acid used) / (ml of dye used)

T = ml of dye used for sample – ml of dye used for blank

D = ml of sample taken for titration

S = ml of dilute sample taken for titration

Fruit firmness (N)

The firmness of 10 randomly selected fruit were measure by using penetrometer. The mean was calculated.

Blossom end rot (%)

The blossom end rot was calculated as follow:

$BER (\%) = \frac{\text{No of ber fruit}}{\text{Total No of fruit}} \times 100$

Cost benefit ratio

The benefit cost ratio was calculated as follow:

$\text{Cost benefit ratio} = \frac{\text{Gross return ha}^{-1}}{\text{Total cost of production}}$

Statistical analysis of data

The data was statistically analyzed to determine the statistical significance. The means for all the treatments was calculated and the analysis of variance for all the characters was performed by “F” (variance ratio) test. The significance of the difference among the means was evaluated by Least Significance Difference (LSD) according to [20]Steel and Torrie, (1980) for interpretation of the result at 5% level of probability.

Results and discussion

This chapter includes the presentation and discussion of the results obtained from the influence of CaCl_2 and GA_3 on the growth yield and quality of tomato. The influence of different concentration of CaCl_2 and GA_3 and their interaction on the growth yield and quality of tomato contributing attributes. Yield and quality have been

presented in (Table 1 to 14). The results of each parameter in the experiment have been studied and discussed under below.

Number of Branches plant⁻¹

The mean data regarding number of branches plant⁻¹ is shown in (Table 1) shows that the influence of Calcium chloride and Gibberellic acid was significant, while their interaction was found non-significant. The mean data showed that the highest number of branches plant⁻¹ (8.18) was observed at 75ppm of GA_3 , followed by (7.277) at G_4 (90ppm) , while the lowest number of branches plant⁻¹ (5.77) was recorded in control. In case of Calcium chloride the maximum number of branches plant⁻¹ (8.08) were observed at C_4 (9%), followed by (7.19) at C_3 (6%), while minimum number of branches plant⁻¹ (5.84) were recorded in control.

The increase in number of branches may be due to the fact that GA_3 rapidly increases the cell division and cell elongation in meristematic region, this result was supported by [21, 22]. Similar results were found by [23] who reported that GA_3 significantly increased the number of branches plant⁻¹ as compare to control, [24] also reported the same result.

In case of calcium Increase in number of branches may be due to its key role in cell division, mitosis and carbohydrates metabolism [25]. Same result were shown by [26], who reported that Ca have a significant effect on the number of branches plant⁻¹, he reported that maximum number of branches plant⁻¹ (7) were recorded at 15 Mm CaCl_2 as compare to control. [27]also found similar results in Okra.

Table 1. Number of branches plant⁻¹ as affected by GA_3 and CaCl_2 in tomato

CaCl ₂ (%)	GA ₃ ppm				Mean
	0	50	75	90	
0	3.74	5.42	7.03	7.17	5.84c
3	5.60	7.50	8.12	6.48	6.93b
6	6.95	6.65	8.58	6.57	7.19b
9	6.78	7.67	9.00	8.85	8.08a
Mean	5.77c	6.81b	8.18a	7.27b	

Plant height (cm)

The mean data regarding plant height is shown in (Table2) shows that GA₃, CaCl₂ and their interaction significantly affected plant height.

The mean value shows that the maximum plant height (88.39cm) were recorded at 90ppm GA₃, followed by (83.53cm) at G₃ (75ppm) level, while the minimum plant height (80.20cm) were recorded in control. In case of Calcium chloride the maximum plant height (87.58cm) were recorded at C₄ (9%), followed by (84.50cm) at C₃ (6%), while minimum plant height (78.38cm) were observed at control. In case of interaction the maximum plant height (95.27cm) were observed at C₄ (9%) and G₄ (90ppm). Followed by (93.33cm) at G₄ (90ppm) and C₃ (6%), while the lowest

plant height (77.37cm) were observed at C₁G₁ (control).

The increase in plant height due to GA₃ application may be due to the reason that, GA₃ stimulate cell division, cell elongation and cell enlargement and ultimately lead to better plant growth, [28]. Same result was found by [29] they reported that GA₃ have positive effect on the plant height during vegetative growth [22, 30] also found the same results. Calcium applications significantly affect the plant height by activating enzyme for mitosis cell division and cell elongation and thus increase the plant height [31]. Same result was found by [32] they reported that maximum plant height (84.10cm) was observed at 6% Calcium. [26] Also found the similar results.

Table 2. Plant height (cm) as affected by GA₃ and CaCl₂ in tomato

CaCl ₂ (%)	GA ₃ ppm				Mean
	0	50	75	90	
0	77.37	78.30	81.53	78.33	78.88c
3	79.97	80.50	81.53	93.33	83.83b
6	84.57	83.10	81.70	88.63	84.50b
9	78.90	86.80	89.97	95.27	87.58a
Mean	80.20c	82.18bc	83.53b	88.39a	

Number of flower cluster plant⁻¹

The mean data regarding number of flower cluster plant⁻¹ as affected by CaCl₂ and GA₃ are given in (Table 3) shows that CaCl₂ and GA₃ significantly affected number of flower cluster plant⁻¹ while their interaction was found non-significant. The mean value shows that the maximum number of flower cluster plant⁻¹ (10.21) was found at G₃ (75ppm), Followed by (9.03) at G₄ (90ppm), while the minimum number of flower cluster plant⁻¹ (7.25) was found at control. In case of Calcium chloride, the highest number of flower cluster plant⁻¹ (10.17) was found at C₄ (9%), followed by (9.05) at C₃ (6%), which was statistically similar to C₄ (9%), while the lowest number of flower cluster plant⁻¹ (7.64) was observed in control.

The number of flower cluster plant⁻¹ mainly depends on number of branches plant⁻¹. As the GA₃ resulted in maximum number of branches per plant therefore number of flower cluster⁻¹ was also increased this result was confirmed by [21]. Same result was found by [22], who reported that GA₃ at 70 ppm can significantly increase number of flower cluster plant⁻¹ as compare to control. [33] Also found the similar result. Calcium has a vital role in photosynthesis, enzyme activation and carbohydrates metabolism, which will help to produce more flower cluster [34], same result was found by [35] they reported that the Calcium can significantly increase flower cluster, this result was confirmed by [36].

Table 3. Number flower cluster plant⁻¹ as affected by GA₃ and CaCl₂ in tomato

CaCl ₂ (%)	GA ₃ ppm				Mean
	0	50	75	90	
0	3.88	8.17	9.50	9.00	7.64c
3	7.17	8.58	10.57	7.53	8.51bc
6	8.87	8.67	9.83	8.83	9.05ab
9	9.08	10.08	10.75	10.75	10.17a
Mean	7.25c	8.88b	10.21a	9.03b	

Number of flower plant⁻¹

The mean data regarding number of flower plant⁻¹ is shown in (Table 4) shows GA₃ and CaCl₂ have significant effect on the number of flower plant⁻¹, while their interaction was found non-significant. The mean value shows that the maximum number of flower plant⁻¹ (45.10) was noted at G₃ (75ppm), followed by (41.57) at G₄ (90ppm), while the minimum number of flower plant⁻¹ (37.73) was observed in control. In case of Calcium chloride the maximum number of flowers plant⁻¹ (43.57) was found at C₄ (9%), followed by (42.10) at C₃ (6%). While the minimum number of flower plant⁻¹ (38.75) were recorded in control. Increase in number of flower may be due to the fact that GA₃ increase the levels of

endogenous Gibberellin and can play an important role in breaking the dormancy [57]. Same result was found by [29] who reported that GA₃ have significantly affected on number of flower plant⁻¹, they found the maximum number of flower plant⁻¹ (24.58) was noted at 50ppm of GA₃. [37] Swami (2013) also found the same result in strawberry. Calcium play a vital role in chlorophyll component cell wall and membrane integrity enhance pollen germination and growth, and activator of enzyme which help to increase number of flowers [38, 53]. Same result was found by [35] who stated that Calcium can significantly increase the number of flower as compare to control. [26] Also found the similar result.

Table 4. Number of flower plant⁻¹ as affected by GA₃ and CaCl₂ in tomato

CaCl ₂ (%)	GA ₃ ppm				Mean
	0	50	75	90	
0	31.25	36.82	44.80	42.12	38.75c
3	38.77	38.48	43.42	38.67	39.83bc
6	40.01	42.28	44.70	41.42	42.10ab
9	40.90	41.82	47.47	44.09	43.57a
Mean	37.73c	39.85bc	45.10a	41.57b	

Number of fruit cluster plant⁻¹

In (Table 5) shows the mean value regarding number of fruits cluster plant⁻¹ and 4.5a shows GA₃ and Calcium chloride significantly affected number of fruit cluster plant⁻¹, while their interaction was found non-significant. The mean value shows that the maximum number of fruit cluster per plant (6.27) was observed at G₃ (75ppm), followed by (5.35) at G₄ (90ppm), while the minimum number of fruit cluster plant⁻¹ (4.87) at control. In case of Calcium chloride the more number of

fruit cluster plant⁻¹ (5.91) was noted at C₄ (9%), followed by (5.67) at C₄ (6%) and C₃ (6%) level. While the less number of fruit cluster plant⁻¹ (4.74) was found at C₁ (control) level.

More number of fruit cluster per plant is due the maximum number of flower cluster. GA₃ help to increase number of flower cluster and fruit-set plant⁻¹ [30]. [12] Also found the similar results i.e., GA₃ increased number of fruit cluster, fruit set percentage as compare to control. Calcium reduces the abscission of flowers and fruit which results

increased number of fruit cluster [39] same result was found by [35] who reported that the Calcium can significantly increase the

number of fruit cluster plant⁻¹ as compare to control.

Table 5. Number of fruit cluster plant⁻¹ as affected by GA₃ and CaCl₂ in tomato

CaCl ₂ (%)	GA ₃ ppm				Mean
	0	50	75	90	
0	4.13	4.77	5.29	4.75	4.74c
3	4.63	5.48	6.46	4.88	5.37b
6	5.53	4.98	6.60	5.55	5.67ab
9	5.17	5.50	6.74	6.23	5.91a
Mean	4.87c	5.18bc	6.27a	5.35b	

Number of fruit plant⁻¹

The mean data regarding number of fruits plant⁻¹ is shown in (Table 6) shows that the influence of GA₃ and CaCl₂ on number of fruit plant⁻¹ were significant, while their interaction was found non-significant. The mean value shows that the maximum number of fruit plant⁻¹(27.13) was found at G₃ (75ppm), Followed by (21.88) at G₄ (90ppm), while the lowest number of fruit plant⁻¹ (16.83) was observed at control. In case of CaCl₂ the maximum number of fruit plant⁻¹(23.76) was found at C₄ (9%), Followed by (21.98) at C₃ (6%). While the minimum number of fruit plant⁻¹(19.53) was observed at control.

More number of fruit plant⁻¹ is due to the maximum number of fruit cluster. GA₃ promote the development of pollinated ovaries which become dormant due to high temperature which result increased number of fruit plant⁻¹[12]. [40] Reported if the concentration of GA₃ increases it will reduce both the number and size of fruit. Same result was found by [22]. [41] Reported that GA₃ increased number of fruit/plant as compare to control. Calcium reduce the flower drop and also increase the fruit retention [42], same result was found by [32] they stated that the Calcium have positive effect on number of fruit plant⁻¹ as compare to control. [35] Also found the similar result.

Table 6. Number of fruit plant⁻¹ as affected by GA₃ and CaCl₂ in tomato

CaCl ₂ (%)	GA ₃ ppm				Mean
	0	50	75	90	
0	14.90	20.48	24.50	18.25	19.53c
3	16.47	19.40	27.23	20.97	21.02b
6	17.17	20.10	28.50	22.17	21.98b
9	18.80	21.80	28.30	26.13	23.76a
Mean	16.83d	20.45c	27.13a	21.88b	

Weight of individual fruit (g)

The mean data regarding weight of individual fruit is shown in (Table 7) shows that the influence of Cacl₂ and GA₃ on weight of individual fruit was significant, while their interaction was found non-significant. The mean value shown that the maximum weight of individual fruit (80.3g) was found at G₃ (75ppm), followed by (71.1g) at G₄ (90ppm). While the minimum individual fruit weight (59.3 gm) was

observed at control. In case of CaCl₂ the maximum individual fruit weight (74.5 g) was found at C₄ (9%), followed by (72.23 g) at C₃ (6%). While the minimum individual fruit weight (63.8 g) was found at control.

The maximum individual fruit weight may be due to the fact that GA₃ increase the photosynthetic material and its efficient mobilization in plant giving rise to increased stimulation of fruit growth and

eventually lead to maximize the fruit weight [11, 43]. Same result was found by [29] who reported that GA₃ can significantly increase the fruit weight as compare to control. Calcium applications significantly maximize the plant by activating enzyme for cell mitosis,

carbohydrates metabolism and nutrient uptake increase the fruit weight [31]. Same result was found by [32]. They stated that the Calcium have positive effect on fruit weight. [62] Also reported that Calcium can increase the fruit weight as compare to control.

Table 7. Weight of individual fruit (g) as affected by GA₃ and CaCl₂ in tomato

CaCl ₂ (%)	GA ₃ ppm				Mean
	0	50	75	90	
0	58.17	62.17	70.67	64.47	63.87c
3	60.30	69.00	78.00	70.00	69.33b
6	59.47	70.77	85.87	72.83	72.23ab
9	59.53	74.53	86.87	77.17	74.53a
Mean	59.37c	69.12b	80.35a	71.12b	

Yield plant⁻¹(kg)

The mean data regarding yield plant⁻¹ is shown in (Table 8) revealed that CaCl₂ and GA₃ significantly affected yield plant⁻¹, while their interaction was found non-significant. The mean data shown that the highest yield plant⁻¹(2.09kg) was observed at G₃ (75ppm), followed by (1.3kg) at G₄ (90ppm). While the minimum yield/plant (0.99 kg) was noted at control. In case of CaCl₂ the maximum yield plant⁻¹(1.68kg) was found at C₄ (9%), Followed by (1.39 kg) at C₃ (6%). While the minimum yield plant⁻¹ (1.18 kg) was observed at control. The maximum yield plant⁻¹ is due to increased number of fruit and fruit weight by GA₃. GA₃ are growth stimulating

substance which help to improve the plant growth and development and also increase the fruit set in tomato [41], same result was found by [52] they reported that the application of GA₃ can significantly increase the yield plant⁻¹. [54] also reported that GA₃ can increase yield plant⁻¹ as compare to control. Calcium is important elements for the growth and yield of plant and act as an activator of enzyme [33], yield plant⁻¹ depend on nutrient uptake, and fruit weight, calcium increase these parameters and ultimately increases yield plant⁻¹ [67] same result was found by [26, 69] they reported that Calcium can significantly increase yield plant⁻¹ as compare to control.

Table 8. Yield plant⁻¹(kg) as affected by GA₃ and CaCl₂ in tomato

CaCl ₂ (%)	GA ₃ ppm				Mean
	0	50	75	90	
0	0.89	0.90	2.02	0.93	1.18c
3	0.81	1.21	2.07	1.36	1.36b
6	0.97	1.25	2.11	1.23	1.39b
9	1.29	1.55	2.14	1.73	1.68a
Mean	0.99c	1.23b	2.09a	1.31b	

Yield plot⁻¹(kg)

The data regarding yield plot⁻¹ is shown in (Table 9) showed that the influence of GA₃ and CaCl₂ on yield plot⁻¹ was significant, while their interactive effect was found non-significant. The mean value shows that

the more yield plot⁻¹(8.01kg) was found at G₃ (75ppm), followed by (5.62kg) at G₄ (90ppm). While the minimum yield plot⁻¹(3.95kg) was observed at control. In case of CaCl₂ the highest yield plot⁻¹(6.88kg) was observed at C₄ (9%), followed by

(5.94kg) at C₃ (6%) level. While the minimum yield plot⁻¹(4.16kg) was found at control.

GA₃ are growth motivating substance which improve the plant growth and development and also increase the fruit set in tomato as well as improve yield weight plant⁻¹ which ultimately increases yield plot⁻¹, [41]. Same result was found by [54] they stated that GA₃ have a significant

impact on yield/plant as compare to control. [56] Also found the similar result in mandarin. Increase in yield plot⁻¹ due to calcium application might be due to the fact that Calcium not only increase number of fruits but it also reduce fruit drop and increase fruit retention [42], same result was found by [35] they examined that Ca can increase the yield plant⁻¹ as compare to control This result was supported by [6, 48].

Table 9. Yield plot⁻¹(kg) as affected by GA₃ and CaCl₂ in tomato

CaCl ₂ (%)	GA ₃ ppm				Mean
	0	50	75	90	
0	1.83	3.22	7.10	4.50	4.16c
3	3.70	4.52	8.03	5.70	5.49b
6	5.23	5.17	8.13	5.23	5.94b
9	5.03	6.67	8.77	7.04	6.88a
Mean	3.95d	4.89bc	8.01a	5.62b	

Yield hac⁻¹(tons)

The data regarding yield ha⁻¹ was affected by CaCl₂ and GA₃ is given in (Table 10) showed that the effect of CaCl₂ and GA₃ was significant, while their interaction effect were found non-significant. The mean value showed that the highest yield ha⁻¹(22 tons) was found at G₃ (75ppm) followed by (16.36 tons) at G₄ (90ppm). While the lowest yield ha⁻¹ (10.5 tons) was observed at G₁ control level. In case of CaCl₂ the maximum yield ha⁻¹(18.83 tons) was obtained at C₄ (9%), followed by (16.97 tons) at C₃ (6%) level. While the minimum yield ha⁻¹(11.tons) was found at control level.

GA₃ increase yield ha⁻¹ which may be due to formation of more metabolites resulting in increased flowering, fruit set, fruit weight, and number of fruit [55] GA₃ are phytohormone which help to increase these parameters and reduce the fruit drop [50]. Same result was found by [79] they reported that GA₃ can significantly increase yield ha⁻¹ as compare to control. [80] also found the similar result. Calcium acts as an activator of enzymes and also important in the process of photosynthesis which increases the production. Same result was found by [32, 35] who stated that Calcium increased yield ha⁻¹ as compare to control.

Table 10. Yield ha⁻¹(tons) as affected by GA₃ and CaCl₂ in tomato

CaCl ₂ (%)	GA ₃ ppm				Mean
	0	50	75	90	
0	6.43	10.80	14.87	12.17	11.07c
3	11.50	10.83	22.77	18.17	15.82b
6	11.83	15.23	24.50	16.30	16.97b
9	12.40	18.13	25.90	18.80	18.83a
Mean	10.56d	13.75c	22.01a	16.36b	

Vitamin C content (mg 100 g⁻¹)

The data regarding vitamin C content is shown in (Table 11). The effect of Calcium chloride and Gibberellic acid was

significant, while their interactive effect was found non-significant.

The mean value showed that the highest vitamin C content (69.63 mg 100g⁻¹) was observed at G₃(75ppm), Followed by

(65.48mg 100g⁻¹) at G₄ (90ppm). While the lowest vitamin C content (57.69mg 100 g⁻¹) was observed at control. In case of CaCl₂ the maximum Vitamin C content (70.15 mg 100g⁻¹) was found at C₄ (9%), followed by (63.37 mg 100g⁻¹) at C₃ (6%), while the lowest Vitamin C content (59.53 mg 100g⁻¹) was found at control. The increase in vitamin C content may be due to the fact that GA₃ increase the mobilization of nutrient, carbohydrates and photosynthetic material which improve the fruit quality

[11, 43]. [51] Found the similar result in strawberry. Who reported that GA₃ at 90 ppm increased Vitamin C content as compare to control. [49] Also found the similar result in apple. Calcium can increase the Calcium content in fruit [15] increase vitamin C content as well as improves the quality of fruits [16], same result was found by [26] who reported that Ca at 10mM can increased vitamin C content as compare to control. [35] Also found the similar results.

Table 11. Vitamin C content (mg 100g⁻¹) as affected by GA₃ and CaCl₂ in Tomato

CaCl ₂ (%)	GA ₃ ppm				Mean
	0	50	75	90	
0	50.57	57.00	64.95	65.58	59.53c
3	57.23	63.37	67.67	63.83	63.03bc
6	54.36	63.59	68.66	66.87	63.37b
9	68.58	69.13	77.23	65.65	70.15a
Mean	57.69c	63.27b	69.63a	65.48b	

Fruit firmness (N)

Fruit firmness is affected by different levels of CaCl₂ and GA₃, (Table 12) shown the mean value shows that the effects of CaCl₂ and GA₃ were significant, while their interaction was found non-significant. The mean value shows that the maximum fruit firmness (14.01 N) was found at G₃ (75 ppm), followed by (11.97 N) at G₄ (90 ppm), while the minimum fruit firmness (9.87 N) was observed at untreated control level. In case of CaCl₂ the maximum fruit firmness (14.19 N) was observed at C₃ (6%), Followed by (12.86 N) at C₄ (9%).

While the minimum fruit firmness (9.40 N) was observed at control.

GA₃ significantly increase the fruit firmness as compare to control, same result was found by [26] who reported that GA₃ increase the fruit firmness as compare to control. [44] Also reported that GA₃ increase the fruit size and firmness of cherry fruit. Calcium plays a major role in the cell membrane and cell wall stabilization [19], Calcium improve the quality of fruit and also retain fruit firmness [16], same result was found by [26] who reported that Calcium at 10mM increase fruit firmness as compare to control.

Table 12. Fruit firmness (N) as affected by GA₃ and CaCl₂ in tomato

CaCl ₂ (%)	GA ₃ ppm				Mean
	0	50	75	90	
0	7.57	9.25	12.40	8.37	9.40d
3	8.83	11.23	13.20	11.27	11.13c
6	12.50	12.93	15.55	15.77	14.19a
9	10.57	13.27	15.13	12.47	12.86b
Mean	9.87c	11.67b	14.01a	11.97b	

Blossom-end-rot (%)

The data regarding Blossom end rot is given in (Table 13) showed that the influence of

CaCl₂ was significant, while the effect of GA₃ as well as their interaction was found non-significant. The mean value showed

that the maximum blossom end rot fruit (11.68%) was observed at control. Followed by (10.68%) at C₂ (3%) which was statistically similar to C₁ (control) While the minimum blossom end rot fruit (4.8 %) was found at C₃ (6%).

Calcium can play a significant role in the stabilization of membrane system and the formation of Calcium-pectates which increase the rigidity of the cell wall and

middle portion of the fruit [45, 46]. Calcium inhibit the degradation of the middle portion and cell wall [47]. And also play a role in defense signaling, and reduce the Blossom end rot [13], same result was found by [38] they reported that Ca reduce the Blossom end rot up to 8% as compare to control. [26] Also reported that Calcium reduce blossom end-rot up to 4 % as compare to control.

Table 13. Blossom end rot (%) as affected by GA₃ and CaCl₂ in tomato

CaCl ₂ (%)	GA ₃ ppm				Mean
	0	50	75	90	
0	11.57	11.67	12.47	11.00	11.68a
3	8.97	9.87	10.67	13.20	10.68a
6	5.13	4.97	4.57	4.60	4.82c
9	6.00	5.50	7.90	6.93	6.58b
Mean	7.92	8.00	8.90	8.93	

Economic analysis

Input cost for land preparation, seed cost, fertilizer and manure cost and man power required for all the operations from transplanting of seedling to harvesting of tomato were recorded for unit plot and converted into cost per hectare. Prices of tomato were considered in market rate basis. The economic analysis was carried out to find the gross and net return and the benefit cost ratio in the current research work and presented under following headings.

Gross return

CaCl₂ showed different gross return under the trial. The maximum gross return (RS 187900ha⁻¹) was obtained from C₄ (9%), and the minimum gross return (RS 11000 ha⁻¹) was calculated from C₁ (0 % Ca) in case of GA₃ the maximum gross return (RS 220000 ha⁻¹) was obtained from G₃ (75ppm), while the minimum Gross return (RS 105000 ha⁻¹) at control level.

Net return

In case of net return, CaCl₂ showed different results. The highest net return (RS107300 ha⁻¹) were obtained from C₄ (9%), while the lowest net return (RS 45500 /ha) was obtained from C₁ (control). GA₃ showed the highest net return (RS 100000 ha⁻¹) were obtained from G₃ (75ppm) level, while the lowest net return (RS 31000 ha⁻¹) was obtained from control level.

Cost benefit ratio (CBR)

Highest cost benefit ratio (2.3) was obtained from C₄ (9%) and the lowest cost benefit ratio (1.8) was obtained from C₁ (control). In case of GA₃ the highest cost benefit ratio (1.8) was obtained from G₃ (75ppm), whereas the lowest (1.2) was found at G₄ (90 ppm). From the economic point of view, it is apparent that CaCl₂ at (9%) and GA₃ (75ppm) was the most profitable than rest of the treatments under the study (Table 14).

Table 14. Cost and return of tomato cultivation as influenced by GA₃ and CaCl₂

Treatments	Cost of production ha ⁻¹	Yield of tomato (t/ha)	Gross return (Rs/ha)	Net return (Rs./ha)	Benefit cost ratio
C1(Control)	64500	11	110000	45500	1.8
C2	69900	15.82	158200	88300	2.2
C3	75300	16.9	169000	93700	2.2
C4	80700	18.8	187900	107300	2.3
G1(CONTROL)	64500	10.5	105000	40500	1.6
G2	102000	13.75	137500	35500	1.3
G3	120000	22	220000	100000	1.8
G4	132000	16.36	163000	31000	1.2

Cost of tomato @Rs.10000/ton

1 gm of GA₃@Rs. 3000/gm

Conclusion

The overall results obtained from the study facilitated to draw the following conclusions; GA₃ at a rate 75ppm was produced the maximum number of branches plant⁻¹, number of flower cluster plant⁻¹, number of flower plant⁻¹, number of fruit cluster plant⁻¹ number of fruit plant⁻¹, weight of individual fruit, yield plant⁻¹, yield plot⁻¹, yield ha⁻¹, vitamin C content, and also increase cost benefit ratio. CaCl₂ at rate of 9% was found best as it increase the number of branches, plant height, number of flower cluster plant⁻¹, number of flower plant⁻¹, number of fruit cluster plant⁻¹, number of fruit plant⁻¹, weight of individual fruit, yield plant⁻¹, yield plot⁻¹, yield ha⁻¹, Vitamin C content, as well as cost benefit ratio, whereas 6 % of CaCl₂ was consider best for increasing the fruit firmness and reduce blossom end rot. Therefore it is recommended that GA₃ at 75ppm and CaCl₂ 9 % was most effective for the better growth yield and quality of tomato.

Authors' contributions

Conceived and designed the experiments: MN Khan & M Ilyas, Performed the experiments: W Muhammad, Analyzed the data: W Muhammad, Contributed materials/analysis/ tools: M Hissam, W Khan, B Ali & M Hilal, Wrote the paper: M Ilyas.

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