INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 14, No. 3, p. 335-345, 2019

RESEARCH PAPER OPEN ACCESS

Cumulative effect of zinc and gibberellic acid on yield and quality of tomato

Md. Saidur Rahman[1*], Md. Junaid Saki[1], Md. Tofail Hosain[1], Sonia Rashid[2]

[1]Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh

[2]Senior Executive, Golden Barn Kingdom Pvt. Limited, Dhaka, Bangladesh

Key words: Gibberellic acid, Quality, Tomato, Yield, Zinc.

http://dx.doi.org/10.12692/ijb/14.3.335-345 Article published on March 27, 2019

Abstract

The study was aim to find out the effect of different levels of zinc and GA_3 on yield attributes and quality of tomato. The experiment included three levels of Zinc i.e. Foliar application of Zinc Z_0= control, Z_1 = 0.5 kg ha^{-1}, Z_2= 1 kg ha^{-1} and four levels of Gibberellic acid (GA_3) i.e. G_0 = control, G_1= 50 ppm GA_3, G_2 = 75 ppm GA_3, G_3= 100 ppm GA_3 respectively, was outlined in Randomized Complete Block Design (RCBD) with three replications. The results indicated that Zinc and GA_3 influenced significantly on all observed parameters. In case of combined effect, Z_1G_2 (Z_1 @ 0.5 kg ha^{-1} + G_2 @ 75 ppm) gave the highest flower clusters plant^{-1} (14.67), flowers cluster^{-1} (13.00), fruit cluster^{-1} (11.00), fruit plant^{-1}(83.33), fruit weight plant^{-1} (3.027 kg), fruit weight plot^{-1} (33.31 kg), fruit yield (92.54 t ha^{-1}), TSS (8.00%), β-Carotene (0.3967 mg per 100g), vitamin-C (114.1 mg per 100g). So, it can be concluded that Z_1G_2 (Z_1 @ 0.5 kg ha^{-1} + G_2 @ 75 ppm) is the best for yield and quality of tomato and can be tested further under different field conditions.

* **Corresponding Author:** Md. Saidur Rahman ✉ saidur34@sau.edu.bd

Introduction

Tomato (*Solanum lycopersicum*) is a solanaceous self-pollinated vegetable crop. Tomato is one of the most popular, important and widely used vegetable crops as ranked second number vegetable of the world after potato (Olaniyi *et al.,* 2010). It is one of the important, popular and nutritious vegetables grown in Bangladesh in both winter and summer season around all parts of the country (Haque *et al.,* 1999). Tomato is very rich in nutrients, especially potassium, folic acid, vitamin C and contains a mixture of different carotenoids, including vitamin A, effective β-carotene as well as lycopene (Bose and Som, 1990; Wilcox *et al.,* 2003). It contains Calories 97, Iron 2.7 mg, Protein 4.5 g, Riboflavin 0.15 mg, Calcium 50 mg, Niacin 3.2 mg, Phosphorus 123 mg and Ascorbic acid 102 mg per 1 pound edible portion (Lester, 2006). Uddain *et al.* (2009) reported that tomato adds flavor to the foods and it is also rich in medicinal value. The consumption of tomatoes rich in lycopene leads directly to a decreased incidence of cancer in mouth, pharynx, esophagus, stomach, large intestine and rectum (Franceschi *et al.,* 1994).

Production of tomato depends on many factors, such as quality of seed, plant spacing, planting time, manure, fertilizer, salinity, pruning and management practices etc. The yield of tomato in our country is not satisfactory in comparison to its requirement (Aditya *et al.,* 1999).

There are generally various constraints resulting in low production of tomato which includes poor soil fertility, water scarcity, poor cultivation skills, attack of pest and disease, poor availability of inputs and harsh climate (Baliyan and Kgathi, 2009).

Adequate supply of micronutrients also plays an important role in tomato production. Zinc plays an important role in chlorophyll formation, cell division, meristematic activity of tissue expansion of cell and formation of cell wall (Salam *et al.,* 2010). Among the micronutrients, zinc play an important role in improving the yield and quality of tomato in addition to checking various diseases and physiological disorders (Magalhaes *et al.,* 1980). Zn is known to have an important role either as a metal component of enzymes or as a functional, structural or regulatory cofactor of a large number of enzymes (Grotz and Guerinot, 2006).

Use of PGR had improved the production of tomato including other vegetables in respect of better growth and quality (Saha, 2009). GA_3 is one of the most important growth stimulating substances used in agriculture since long. It may promote cell elongation, cell division and thus helps in growth and development of tomato plant. GA_3 applications help in improvement in number of fruits per cluster, fruit set, and marketable fruit number per plant and extended maturity time and harvest (Gelmesa *et al.,* 2012; Hasanuzzaman *et al.,* 2015). GA_3 increased proteins, soluble carbohydrates, ascorbic acid, total soluble solid (TSS), starch and β-carotene in the tomato (Graham and Ballesteros, 2006; Kumar *et al.,* 2014).

Although, tomato is the second major crop of the world after potato, but there is lack of research, particularly under field conditions, to show interactive effects of zinc and Gibberellic acid on tomato. Keeping the above point of view, the present study was undertaken to evaluate the effect of different levels of zinc and GA_3 on yield attributes and quality of tomato.

Materials and methods

Experiment site

The field experiment was conducted in the experimental farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from October, 2017 to March, 2018. The location of the experimental site was at $23^{o}74^{/}$ N latitude and $90^{o}35^{/}$ E longitude with an elevation of 8.45 meter from the sea level.

Climate and soil

The climate of the experimental site is sub-tropical, wet and humid. Heavy rainfall occurs in the monsoon (mid-April to mid-August) and scanty during rest of the year. The soil of the experimental area was silty clay in texture. Soil pH was 6.7 and has organic carbon 0.45%.

Experimental treatment and design

Tomato variety "BARI Tomato-14" was used as the test crop in this experiment. The experiment comprised two factors. Factor A: Foliar application of three levels of Zinc i.e. Z_0= control, Z_1 = 0.5 kg ha^{-1}, Z_2= 1 kg ha^{-1} and four levels of GA_3 i.e. G_0 = control, G_1= 50 ppm GA_3, G_2 = 75 ppm GA_3, G_3= 100 ppm GA_3. The experiment was laid out in a randomized complete block design (RCBD) with three replications. There were 12 plots of 4 m^2 in size in each of 3 replications resulting 36 plots in total. The distance maintained between two blocks and two plots were 0.5 m and 0.5 m, respectively.

Preparation of GA_3 and application of Zinc

The stock solution of 1000 ppm of GA3 with small amount of ethanol to dilute and then mixed in 1 liter of water turn as per requirement of 50 ppm, 75 ppm and 100 ppm solution of GA3. 50, 75 and 100 ml of stock solution were mixed with 1 liter of water. Application of Zinc was done at 15, 35, 50 days after transplanting as per treatment.

Crop husbandry

The seeds were sown in the seedbed on 15 October, 2016 and after sowing, seeds were covered with light soil to a depth of about 0.6 cm. Necessary shading, weeding, mulching and irrigation were done from time to time as and when required and no chemical fertilizer was used in the seedbed. The fertilizers i.e. urea, TSP, MoP and manures i.e. cowdung were applied @ 100 kg, 200 kg, 175 kg and 20 tons ha^{-1} (BARI, 2015). The entire amounts of TSP, MP and cowdung were applied during the final land preparation. Urea was applied in three equal installments at 20, 30 and 40 days after seedling transplanting. Healthy and uniform 35 days old seedlings were transplanted in the experimental plots maintaining a spacing of 60 cm x 50 cm between the rows and plants, respectively. Intercultural operations were done to ensure normal growth of the crop. Plant protection measures were followed as and when necessary.

Data collection

Ten pre-selected hills per plot from which different data were collected. Data on the following parameters were recorded during the course of the experiment such as - number of flower clusters $plant^{-1}$, flowers $cluster^{-1}$, fruit $cluster^{-1}$, fruit $plant^{-1}$, fruit weight $plant^{-1}$, fruit weight $plot^{-1}$, fruit yield, TSS%, β-Carotene, vitamin-C. Fruits were harvested at 3 days interval during early ripe stage when they developed slightly red color.

Measurement of Total Soluble Sugar (TSS), β-carotene and Vitamin C

a) One drop ripens tomato juice was used to take the TSS reading in a digital brix meter (ATOGA, JAPAN).

b) β- carotene was calculated by the following formula: β- carotene (mg)= 0.216 (reading of 664nm) + 0.452 (reading of 453nm)-1.22 (reading of 645nm)-0.304 (reading of 505nm)

c) Vitamin C and titratable acidity of green and dry fruits were determined according to the method described by the A.O.A.C. (1990).

Statistical package

All the collected data were tabulated and analyzed statistically using analysis of variance technique and subsequently, Least Significance Difference (LSD at 5%) for comparing the treatment means, by MSTAT-C software (Gomezm and Gomez, 1984).

Results and discussion

Number of flower clusters $plant^{-1}$

The effect of different levels of zinc in respect of flower clusters $plant^{-1}$ was statistically significant (Table 01). The maximum number of flower clusters $plant^{-1}$ (12.67) was found from Z_1 (0.5 kg Zn ha^{-1}) and the minimum (8.750) was found from Z_0 (control). Number of flowers cluster $plant^{-1}$ significantly increased with the foliar application of Zn (Ullah *et al.,* 2015). The result corroborated with the finding of Singh and Tiwari (2013).

Table 1. Effect of Zinc on yield and yield contributing characters of tomato. The treatment means with the same letter are not significantly different using LSD at 5%.

Treatment	Flower clusters plant^{-1} (no.)	Flowers cluster^{-1} (no.)	Fruit cluster^{-1} (no.)	Fruit plant^{-1} (no.)	Fruit weight plant^{-1} (kg)	Fruit weight plot^{-1} (kg)	Fruit yield (t ha^{-1})
Z_0 (control)	8.750 b	7.417 b	6.083 b	40.75 c	2.018 b	19.41 b	53.90 b
Z_1 (0.5 kg ha^{-1})	12.67 a	10.33 a	8.417 a	62.75 a	2.519 a	26.35 a	73.19 a
Z_2 (1 kg ha^{-1})	10.25 b	8.417 b	6.167 b	47.08 b	1.677 c	14.85 c	41.26 c
$Lsd_{0.05}$	1.522	1.691	1.316	3.536	0.1693	1.534	4.264
CV (%)	8.52	11.45	11.28	4.16	4.89	4.48	4.49

The number of flower clusters plant^{-1} was significantly influenced by GA_3 (Table 02). The highest number of flower clusters plant^{-1} (11.44) was found from G_2 (75 ppm GA_3), whereas the lowest number of flowers clusters plant^{-1} (9.778) was found from G_0 (control). Uddain *et al.* (2009) observed that GA_3 gives the highest number of flowers cluster plant^{-1} than other plant growth regulators. Sultana (2013) concluded that application of GA_3 50 ppm in tomato increases the number of flower clusters plant^{-1}. There was statistically significant difference among the treatment combinations in respect of number of flower clusters plant^{-1}(Table 03). It was evident that the treatment combination of Z_1G_2 (0.5 kg Zn ha^{-1} and 75 ppm GA_3) gave the maximum number of flower clusters plant^{-1} (14.67) and the minimum number of flower cluster plant^{-1} (6.667) was recorded from the treatment combination of Z_0G_0 (control).

Table 2. Effect of GA3 on yield and yield contributing characters of tomato. The treatment means with the same letter are not significantly different using LSD at 5%.

Treatment	Flower clusters plant^{-1} (no.)	Flowers cluster^{-1} (no.)	Fruit cluster^{-1} (no.)	Fruit plant^{-1} (no.)	Fruit weight plant^{-1} (kg)	Fruit weight plot^{-1} (kg)	Fruit yield (t ha^{-1})
G_0 (control)	9.778 b	7.889 a	6.667 a	43.00 d	2.003 a	18.71 b	51.98 b
G_1 (50 ppm GA_3)	10.56 ab	8.556 a	6.556 a	51.11 b	2.042 a	20.00 b	55.54 b
G_2 (75 ppm GA_3)	11.44 a	9.667 a	7.778 a	59.56 a	2.161 a	22.62 a	62.84 a
G_3 (100 ppm GA_3)	10.44 ab	8.778 a	6.556 a	47.11 c	2.079 a	19.47 b	54.09 b
$Lsd_{0.05}$	1.522	NS	NS	3.536	NS	1.534	4.264
CV (%)	8.52	11.45	11.28	4.16	4.89	4.48	4.49

Number of flowers cluster^{-1}

A significant variation in the number of flowers cluster^{-1} was observed due to effect of different levels of zinc (Table 01).

The highest number of flowers cluster^{-1} (10.33) was found from Z_1 (0.5 kg Zn ha^{-1}) and the minimum (7.417) was produced at Z_0 (control). Suganiya and Kumuthini (2015) reported that zinc increased the number of flowers cluster^{-1} than control treatment in brinjal plant.

The variation in number of flowers per cluster at different GA_3 levels was not statistically significant (Table 02). The highest number of flowers cluster^{-1} (9.667) was produced in G_2 (75 ppm GA_3) and the lowest number (7.889) was obtained from G_0 (control). Sultana (2013) concluded that application of GA_3 50 ppm increases the number of flowers cluster^{-1} of tomato plant. Uddain *et al.* (2009) observed that GA_3 gives the highest number of flower cluster plant^{-1} than other plant growth regulators.

Combined effect or different levels of zinc and GA_3 on number of flowers cluster^{-1} were found to be significant (Table 03). The maximum number of flowers cluster^{-1} (13.00) was observed in the treatment combination of Z_1G_2 (0.5 kg Zn ha^{-1} and 75 ppm GA_3) and the minimum (6.000) from Z_0G_0 (control).

Table 3. Combined effect of Zinc and GA_3 on yield and yield contributing characters of tomato. The treatment means with the same letter are not significantly different using LSD at 5%. Z_1=control, Z_2=0.5 kg ha^{-1} and Z_3=1 kg ha^{-1} and G0=control, G_1=50 ppm GA_3, G_2=75 ppm GA_3, and G_3=100ppm GA_3

Treatment	Flower clusters plant^{-1} (no.)	Flowers cluster^{-1} (no.)	Fruit cluster^{-1} (no.)	Fruit plant^{-1} (no.)	Fruit weight plant^{-1} (kg)	Fruit weight plot^{-1} (kg)	Fruit Yield (t ha^{-1})
Z_0G_0	6.667 e	6.000 f	5.000 g	30.33 j	1.727 e	16.15 f	44.86 f
Z_0G1	8.667 d	7.333 def	6.000 def	35.67 i	1.983 d	17.86 e	49.60 e
Z_0G_2	9.667 cd	8.000 cde	6.667 cde	46.33 g	2.117 cd	21.16 d	58.78 d
Z_0G_3	10.00 cd	8.333 cde	7.000 bcde	50.67 ef	2.247 bc	22.46 cd	62.38 cd
Z_1G_0	11.33 bc	8.000 cde	7.000 bcde	42.00 h	2.297 b	22.14 cd	61.50 cd
Z_1G_1	12.00 b	9.333 bc	7.333 bcd	64.67 b	2.413 b	26.55 b	73.74 b
Z_1G_2	14.67 a	13.00 a	11.00 a	83.33 a	3.027 a	33.31 a	92.54 a
Z_1G_3	12.67 b	11.00 b	8.333 b	61.00 c	2.340 b	23.39 c	64.96 c
Z_2G_0	11.33 bc	9.667 bc	8.000 bc	56.67 d	1.987 d	17.85 e	49.59 e
Z_2G_1	11.00 bcd	9.000 cd	6.333 def	53.00 e	1.730 e	15.59 f	43.29 f
Z_2G_2	10.00 cd	8.000 cde	5.667 efg	49.00 fg	1.340 f	13.40 g	37.21 g
Z_2G_3	8.667 d	7.000 ef	5.333 fg	30.47 j	1.650 e	12.58 g	34.94 g
$Lsd_{0.05}$	1.522	1.691	1.316	3.536	0.1693	1.534	4.264
CV (%)	8.52	11.45	11.28	4.16	4.89	4.48	4.49

Number of fruit cluster^{-1}

The number of fruit per cluster at different levels of zinc was found to be significant (Table 01). The maximum number of fruit clusters^{-1} (8.417) was produced by Z_1 (0.5 kg Zn ha^{-1}) and the control treatment Z_0 produced the minimum number of fruit clusters^{-1} (6.083). Haque (2007) also found higher number of fruits cluster^{-1} with the application of boron than control in tomato plant. The application of boron and zinc enhances fruit set by delaying abscission of flowers (Smit and Combrink, 2004).

There was no significant difference among the different GA_3 levels on the number of fruit clusters^{-1} (Table 02). The highest number of fruit cluster^{-1} (7.778) was produced in G_2 (75 ppm GA_3) and the lowest number (6.556) was obtained from G_1 and G_3 (50 ppm and 100 ppm GA_3, respectively). Gelmesa *et al.* (2012) showed similar results i.e., GA_3 increased fruit number cluster^{-1} over the control. Hasanuzzaman *et al.* (2015) revealed that application of GA_3 @ 125 ppm showed an increased number of fruit clusters^{-1}.

Table 4. Effect of Zinc on quality characters of tomato. The treatment means with the same letter are not significantly different using LSD at 5%.

Treatment	TSS (%)	β-Carotene (mg/100g)	Vitamin C (mg/100g)
Z_0 (control)	7.350 b	0.2908 c	86.86 c
Z_1 (0.5 kg ha^{-1})	7.683 a	0.3600 a	104.8 a
Z_2 (1 kg ha^{-1})	6.958 c	0.3150 b	91.67 b
$Lsd_{0.05}$	0.1855	0.0005	4.451
CV (%)	1.47	1.70	2.78

Significant interaction effect was found between different Zinc levels and GA_3 in case of number of fruit cluster^{-1}(Table 03). The maximum number of fruit cluster^{-1} (11.00) was observed in the treatment combination of Z_1G_2 (0.5 kg Zn ha^{-1} and 75 ppm GA_3) and the minimum (5.00) from Z_0G_0 (control).

Number of fruit plant^{-1}

A significant variation in the number of fruit plant^{-1} was observed due to the effect of different levels of zinc (Table 01). The highest number of fruit plant^{-1} (62.75) was found from Z_1 (0.5 kg Zn ha^{-1}) and the minimum (40.75) was produced from Z_0 (control).

Ejaz *et al.* (2011) also reported that application of zinc provide better results in number of fruits plant^{-1} of tomato as compared to control.The variation in number of fruit plant^{-1} at different GA_3 levels was significant (Table 02). The highest number of fruit plant^{-1} (59.56) was produced in G_2 (75 ppm GA_3) and the lowest number (43.00) was obtained from G_0 (control). Naeem *et al.* (2001) revealed GA_3 spray on tomato plant reduces fruit drop and contributes better number of fruits plant^{-1}. Application of GA_3 at 50 ppm increases number of fruits in tomato (Uddain *et al.,* 2009).

Table 5. Effect of GA_3 on quality characters of tomato. The treatment means with the same letter are not significantly different using LSD at 5%.

Treatment	TSS (%)	β-Carotene (mg/100g)	Vitamin C (mg/100g)
G_0 (control)	7.244 b	0.3067 d	91.45 b
G_1 (50 ppm GA_3)	7.378 ab	0.3267 b	94.44 ab
G_2 (75 ppm GA_3)	7.500 a	0.3344 a	97.44 a
G_3 (100 ppm GA_3)	7.200 b	0.3200 c	94.45 ab
$Lsd_{0.05}$	0.1855	0.0005	4.451
CV (%)	1.47	1.70	2.78

Combined effect or different levels or Zinc and GA3 on number of fruit plant^{-1} were found to be significant (Table 03). The maximum number of fruit plant^{-1} (83.33) was observed in the treatment combination of Z_1G_2 (0.5 kg Zn ha^{-1} and 75 ppm GA_3) and the minimum (30.33) from Z_0G_0 (control).

Weight of fruits plant^{-1}

It was noticed that different levels of zinc exhibited significant effect on the weight of fruits plant^{-1} (Table 01). The maximum fruits weight (2.519 kg) was found from Z_1 (0.5 kg Zn ha^{-1}) and the minimum weight (1.677 kg) was obtained from Z_2 (1kg Zn ha $^{-1}$).

Similar effects of different boron levels in respect of fruit weight plant^{-1} have been reported by Singh and Gangwar (1991). According to Mallick and Muthukrishnan (1980) increase in size of tomato fruit might be attributed to the catalytic role of zinc and boron by increasing the weight of the fruits plant^{-1}.

Table 6. Combined effect of Zinc and GA_3 on quality characters of tomato. The treatment means with the same letter are not significantly different using LSD at 5%. Z_1=control, Z_2=0.5 kg ha^{-1} and Z_3=1 kg ha^{-1} and Go=control, G_1=50 ppm GA_3, G_2=75 ppm GA_3, and G_3=100ppm GA_3.

Treatment	TSS%	β-Carotene (mg/100g)	Vitamin C (mg/100g)
Z_0G_0	6.800 fg	0.2633 k	80.77 i
Z_0G1	7.633 bcd	0.2900 i	85.90 gh
Z_0G_2	7.733 b	0.3033 h	89.75 fg
Z_0G_3	7.233 e	0.3067 g	91.03 ef
Z_1G_0	7.433 d	0.3167 f	94.87 de
Z_1G_1	7.600 bcd	0.3600 c	102.6 c
Z_1G_2	8.000 a	0.3967 a	114.1 a
Z_1G_3	7.700 bc	0.3667 b	107.7 b
Z_2G_0	7.500 cd	0.3400 d	98.72 cd
Z_2G_1	6.900 f	0.3300 e	94.87 de
Z_2G_2	6.767 fg	0.3033 h	88.46 fgh
Z_2G_3	6.667 g	0.2867 j	84.62 hi
$Lsd_{0.05}$	0.1855	0.0005	4.451
CV(%)	1.47	1.70	2.78

The weight of fruits plant^{-1} was not significantly influenced by different levels of GA_3 (Table 02). The highest value (2.161 kg) was found from G_2 treatment (75 ppm GA_3) and the lowest value (2.003 kg) was found from G_0 (control) treatment. Sultana (2013) concluded that application of GA_3 50 ppm increases the weight of fruits plant^{-1} of tomato. Kazemi (2014) which revealed an increase in fruit weight of tomato by using different GA_3.

There was significant combined effect of different levels of zinc and GA_3 on the weight of fruits plant^{-1} (Table 03). The maximum fruit weight plant^{-1} (3.027 kg) was obtained from the treatment combination of Z_1G_2 (0.5 kg Zn ha^{-1} and 75 ppm GA_3) and the lowest fruit weight (1.340 kg) was found from the treatment combination of Z_2G_2 (1 kg Zn ha^{-1} and 75 ppm GA_3).

Weight of fruits plot^{-1}

Statistically significant variation was recorded on fruit weight plot^{-1} due to the application of different levels of zinc (Table 01).

The highest fruit weight plot^{-1} (26.35 kg) was obtained from Z_1 (0.5 kg Zn ha^{-1}), whereas the lowest (14.85 kg) was observed in Z_2 (1kg Zn ha^{-1}) treatment. According to Mallick and Muthukrishnan (1980) increase in size of tomato fruit might be attributed to the catalytic role of zinc and boron by increasing the weight of the fruits.

Statistically significant variation was recorded on fruit weight plot^{-1} due to the application of different levels of GA_3 (Table 02). The highest fruit weight plot^{-1} (22.62 kg) was obtained from G_2 (75 ppm), whereas the lowest (18.71 kg) was observed in G_0 (control) treatment. Kazemi (2014) which revealed an increase in fruit weight of tomato by using different GA_3.

Combined effect of different levels of zinc and GA_3 showed statistically significant variation on fruit weight plot^{-1} (Table 03). The highest fruit weight plot^{-1} (33.31 kg) was found from Z_1G_2 (0.5 kg Zn ha^{-1} and 75 ppm GA_3), while the lowest fruit weight plot^{-1} (12.58) was recorded from Z_2G_3 (1 kg Zn ha^{-1} and 100 ppm GA_3).

Fruit yield

The fruit yield was significantly influenced by different levels of Zinc (Table 01). The highest fruit yield (73.19 t ha^{-1}) was produced from Z_1 treatment (0.5 kg Zn ha^{-1}) and the lowest yield (41.26 t ha^{-1}) was produced from Z_2 treatment (1kg Zn ha^{-1}). Islam (2006) observed the same result in case of Zinc treatment on tomato. Ullah *et al.* (2015) also showed that application of zinc gave higher yield ha^{-1} than untreated control in tomato.

Different levels of GA_3 significantly influenced on the fruit yield (Table 02). The highest fruit yield (62.84 t ha^{-1}) was recorded from G_2 (75ppm GA_3) and the lowest yield was (51.98 t ha^{-1}) from G_0 (control) treatment. Sultana (2013) concluded that application of GA_3 50 ppm increases the yield of tomato. Hasanuzzaman *et al.* (2015) revealed that application of GA_3 @ 125 ppm showed an increased fruit yield ha^{-1}. Verma *et al.* (2014) revealed that GA_3 plays role on increasing fruit yield and extending shelf life in tomato. Prasad *et al.* (2013) reported that fruit yield ha^{-1} significantly increased with the application of GA_3 compared to control.

Interaction effect of different levels of Zinc and GA_3 performed significant effect on the fruit yield (Table 03). The treatment combination of Z_1G_2 (0.5 kg Zn ha^{-1} and 75 ppm GA_3) gave the maximum fruit yield (92.54 t ha^{-1}) and the minimum yield (34.94 t ha^{-1}) was found from the treatment combination on Z_2G_3 (1 kg Zn ha^{-1} and 100 ppm GA_3).

Total soluble solid (TSS) content

Different levels of zinc exhibited significant effect on total soluble solid (%) content of tomato fruit (Table 04). The maximum TSS (7.683%) of fruits was found from Z_1 (0.5 kg Zn ha^{-1}) and the minimum TSS (6.958%) was obtained from Z_2 (1kg Zn ha^{-1}) treatment. Singh and Tiwari (2013) reported that maximum T.S.S. was found with the application of boric acid+zinc sulphate+copper sulphate @ 250 ppm each. Varied levels of boron and zinc had profound influence on TSS (%) content of fruit. It ranged from 4.02 to 4.47 (Salam *et al.,* 2011).

Different levels of GA_3 significantly influenced on total soluble solid (%) content of tomato fruit (Table 05). The highest TSS (7.500%) was recorded from G_2 (75 ppm GA_3) and the lowest TSS (7.200%) was recorded from G_3 (100 ppm GA_3) treatment.

Application of GA_3 at 50 ppm increases TSS in tomato (Gelmesa *et al.,* 2012). Kumar *et al.* (2014) observed the highest total soluble solid (TSS) treated with GA_3 at 50 ppm.

Combination effect of different levels of Zinc and GA_3 showed statistically significant variation on the total soluble solid (%) content of tomato fruit (Table 06). The highest TSS (8.00%) was found from Z_1G_2 (0.5 kg Zn ha^{-1} and 75 ppm GA_3), while the lowest TSS (6.667%) was recorded from Z_2G_3 (1 kg Zn ha^{-1} and 100 ppm GA_3).

β-Carotene content

Statistically significant variation was recorded on β-Carotene in different sample due to application of different levels of zinc (Table 04). The highest β-Carotene (0.3600 mg/100g) was obtained from Z_1 (0.5 kg Zn ha^{-1}), whereas the lowest (0.2908 mg/100g) was observed in Z_0 (control) treatment.

Different levels of GA_3 significantly influenced on the β-Carotene amount (Table 05). The highest β-Carotene (0.3344 mg/100g) was recorded from G_2 (75 ppm GA_3) and the lowest β-Carotene was (0.3067 mg/100g) from G_0 (control) treatment. Graham and Ballesteros (1980) reported that GA_3 increased β-carotene in the tomato.

Combination effect of different levels of Zinc and GA_3 showed statistically significant variation on the β-Carotene amount (Table 06). The highest β-Carotene (0.3967 mg/100g) was found from Z_1G_2 (0.5 kg Zn ha^{-1} and 75 ppm GA_3), while the lowest β-Carotene (0.2633 mg/100g) was recorded from Z_0G_0 (control) treatment.

Vitamin C content

The application of different level of zinc showed significant variation in case of Vitamin C content of tomato fruit (Table 04).

The higher amount of Vitamin C (104.8 mg/100 g) was found from Z_1 (0.5 kg Zn ha^{-1}) treatment and lower amount Vitamin C (86.86 mg/100 g) was found from Z_0 (control) treatment. Singh and Tiwari (2013) reported that maximum ascorbic acid were found with the application of boric acid+zinc sulphate+copper sulphate @ 250 ppm each. Dube *et al.* (2004) recorded the highest ascorbic acid content with the soil application of zinc sulphate and borax @ 10 and 20 kg ha^{-1}, respectively in tomato.

The significant variation was observed on Vitamin C content of tomato fruit due to the different level of GA_3 (Table 05). The higher amount of Vitamin C (97.44 mg/100 g) found from G_2 (75 ppm GA_3) treatment and lower amount of Vitamin C (91.45 mg/100 g) found from G_0 (control) treatment.

Application of GA_3 at 50 ppm increases ascorbic acid (Ouzounidou *et al.,* 2010). Kumar *et al.* (2014) observed the highest ascorbic acid treated with GA_3 at 50 ppm.

Combined effect of different levels of Zinc and GA_3 performed significant effect on Vitamin C content of tomato fruit (Table 06). The treatment combination of Z_1G_2 (0.5 kg Zn ha^{-1} and 75 ppm GA_3) was gave the maximum Vitamin C content (114.1 mg/100 g) and the minimum Vitamin C content (80.77 mg/100 g) was found from the treatment combination of Z_0G_0 (control).

Conclusion

In conclusion, foliar application of Zn and GA_3 in the appropriate combination at optimal concentration, particularly Z_1G_2, may be an effective strategy to maximize the yield and quality of tomato. This combination can be tested further under field conditions and can be recommended to farmers after proper confirmation.

References

A.O.A.C. 1990. Official methods of analysis of the association of official agriculture chemists. Published by association of official agriculture chemists, 13th Ed. Washington, D.C., USA.

Aditya TL, Rahman L, Shah-E-Alam M, Ghosh AK. 1999. Correlation and path coefficient analysis in tomato. Bangladesh Agricultural Science Journal **26,** 119- 122.

Baliyan SP, Kghati DL. 2009. Production and marketing problems in small scale horticultural farming in Botswana. Acta Horticulture **831,** 31- 40. http://dx.doi.org/10.17660/ActaHortic.2009.831.3

BARI (Bangladesh Agricultural Research Institute). 2015. Krishi Projokti Hath Boi. Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh.

Bose TK, Som MG. 1990. Vegetable crops in India. Naya Prakash, Calcutta, India, 687- 691.

Dube BK, Pratima S, Chatterjee C. 2004. Effects of boron and zinc on the yield and quality of tomato. Indian Journal of Horticulture **61,** 48- 52.

Ejaz M, Rahman S, Waqas R, Manan A, Imran M, Bukhari, MA. 2011. Combined efficacy of macro-nutrients and micro-nutrients as foliar application on growth and yield of tomato. International Journal of Agro Veterinary and Medicine Science **5,** 327- 335.

Franceschi SE, Bidoli C, La Vacchia R, Talamini B, Avanzo D, Negri E. 1994. Tomatoes and risk of digestive-tract cancers. International Journal of Cancer **59,** 181- 184. https://doi.org/10.1002/ijc.2910590207

Gelmesa D, Abebie B, Lemma D. 2012. Regulation of tomato (*Lycopersicon esculentum* Mill.) fruit setting and earliness by gibberellic acid and 2,4-dichlorophenoxy acetic acid application. African Journal of Biotechnology **11,** 11200- 11206. http://dx.doi.org/10.5897/AJB11.2928

Gomez KA, Gomez AA. 1984. Statistical procedures for agricultural research. John wlley and Sons. Inc. New York, 67-215.

Graham HD, Ballesteros M. 1980. Effect of plant growth regulators on plant nutrients. Journal of Food Science **45,** 502- 505. https://doi.org/10.1111/j.1365-2621.1980.tb04086.x

Grotz N, Guerinot ML. 2006. Molecular aspects of Cu, Fe and Zn homeostasis in plants. Biochim. Biochimica et Biophysica Acta (BBA)-Molecular Cell Research **1763,** 595–608. https://doi.org/10.1016/j.bbamcr.2006.05.014

Haque MS, Islam MT, Rahman M. 1999. Studies on the presentation of semi-concentrated tomato juice. Bangladesh Journal of Agricultural Science **26,** 37-43.

Haque ME. 2007. Effect of nitrogen and boron on the growth and yield of tomato. MS thesis, Department of Soil Science, Sher-E-Bangla Agricultural University, Dhaka-1207.

Hasanuzzaman A, Md-Mazed HEM, Ashraful I, Md P, Chowdhury MSN, Moonmoon JF. 2015. Role of gibberellic acid on growth, yield and quality of tomato. International Journal of Applied Research **1,** 71- 74.

Islam ATMR. 2006. Effect of S, Zn and Boron on yield and quality of BINA moog-5. M.S. thesis. Department of Agricultural Chemestry, BAU, Mymensingh.

Kazemi M. 2014. Effect of gibberellic acid and potas-sium nitrate spray on vegetative growth and reproductive characteristics of tomato. Journal of Biology and Environmental Science **8,** 1- 9.

Kumar A, Biswas TK, Singh N, Lal EP. 2014. Effect of gibberellic acid on growth, quality and yield of tomato (Lycopersicon esculentum Mill.). Journal of Agricultural Veterinary Science **7**, 28- 30. http://dx.doi.org/10.9790/2380-07742830

Lester GE. 2006. Environmental regulation of human health nutrients (ascorbic acid, β-carotene and folic acid) in fruits and vegetables. Horticulture Science **41,** 59- 64. https://doi.org/10.21273/HORTSCI.41.1.59

Magalhaes JR, Solwa CEWL, Monnerat PH. 1980. Levels and methods of boron application in tomatoes. Pesquisa Agropecuria Brasilesia **10,** 153-157.

Mallick MFR, Muthukrishnan CR. 1980. Effect of micronutrients on growth and development of tomato. South Indian Horticulture **27**, 121- 124.

Naeem N, Ishtiaq M, Khan P, Mohammad N, Khan J, Jamiher B. 2001. Effect of gibberellic acid on growth and yield of tomato Cv. Roma. Journal of Biological Science **1,** 448- 450. http://dx.doi.org/10.3923/jbs.2001.448.450

Olaniyi JO, Akanbi WB, Adejumo TA, Akande OG. 2010. Growth, fruit yield and nutritional quality of tomato varieties. African Journal of Food Science **4,** 398-402.

Ouzounidou G, Ilias I, Giannakoula A, Papadopoulou P. 2010. Comparative study on the effects of various plant growth regulators on growth, quality and physiology of *Capsicum annuum* L. Pakistan Journal of Botany **42,** 805- 814.

Prasad RN, Singh SK, Yadava RB, Chaurasia SNS. 2013. Effect of GA_3 and NAA on growth and yield of tomato. Vegetable Science **40,** 195-197.

Saha P. 2009. Effect of NAA and GA_3 on yield and quality of tomato (*Lycopersicon esculentum* Mill). Environmental Ecology **27,** 1048-1050.

Salam MA, Siddique MA, Rahim MA, Rahman MA, Goffar MA. 2011. Quality of tomato as influenced by boron and zinc in presence of different doses of cowdung. Bangladesh Journal of Agricultural Research **36,** 151- 163. https://doi.org/10.3329/bjar.v36i1.9239

Salam MA, Siddique MA, Rahim MA, Rahman MA, Saha MG. 2010. Quality of tomato (*Lycopersicon esculentum* Mill.) as influenced by boron and zinc under different levels of NPK fertilizers. Bangladesh J. Agriculture Research **35,** 475-488. https://doi.org/10.3329/bjar.v35i3.6454

Singh D, Gangwar R. 1991. Management practices for higher productivity in India a review. Agriculture Research **12,** 15-21.

Singh HM, Tiwari JK. 2013. Impact of micronutrient spray on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill.). Horticultural Flora and Research Spectrum **2,** 87- 89.

Smit JN, Combrink NJJ. 2004. Pollination and yield of winter-grown greenhouse tomatoes as affected by boron nutrition, cluster vibration and relative humidity. South African Journal Plant and Soil **22,** 110-115. https://doi.org/10.1080/02571862.2005.10634691

Suganiya S, Kumuthini DH. 2015. Effect of Boron on flower and fruit set and yield of ratoon Brinjal crop. International Journal of Scientific Research and Innovative Technology **2,** 135- 141.

Sultana M. 2013. Effect of nitrogen and gibberellic acid on growth and yield of tomato, M. S. Thesis, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.

Uddain J, Hossain KMA, Mostafa MG, Rahman MJ. 2009. Effect of different plant growth regulators on growth and yield of tomato. International Journal of Sustainable Agriculture**1,** 58-63.

Ullah R, Ayub G, Ilyas M, Ahmad M, Umar M, Mukhtar S, Farooq S. 2015. Growth and yield of tomato (*Lycopersicon esculentum* L.) as influenced by different levels of zinc and boron as foliar application. American-Eurasian Journal of Agriculture and Environmental Science **15,** 2495-2498.
http://dx.doi.org/10.5829/idosi.aejaes.2015.15.12.12820

Verma PS, Meena ML, Meena SK. 2014. Influence of plant growth regulators on growth, flowering and quality of tomato (*Lycopersicon esculentum* Mill), cv. H-86. Indian Journalof Hill Farming **27,** 19-22.

Wilcox JK, Catignani GL, Lazarus C. 2003. Tomatoes and cardiovascular health. Food Science and Nutrition **43,** 1-18.
https://doi.org/10.1080/10408690390826437