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Acceleration of growth in tomato seedlings grown with growth retardant

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Abstract: In vegetable growing, seedling is the foundation of a successful growing. Use of commercial seedlings have become more popular in recent years due to effective use of labour and land and economic concerns. It is aimed to produce small vigorous seedlings with sufficient roots and free of diseases and pests in the commercial seedling enterprises. Although certain cultural applications are used for production of small-sized seedlings, growth retarding chemicals are generally preferred due to their effective results. There are some concerns regarding on-going retarding effects of such chemicals under field conditions. In this study, it is aimed to remove the possible retarding effects provided by paclobutrazol in dosages of 0, 25, 50 and 100 ppm applied on tomato seeds in a short period of time by applying gibberellic acid (GA3) in dosages of 0, 50, and 100 ppm by spraying it on the leaves. In this study, the plant height (cm), stem diameter (mm) height to stem diameter ratio, number of blooming cluster and dry matter ratio of stem (%) were determined in the different stages of growth. Paclobutrazol ensured a height control of 26.45%–40.85% on the height of plants in the seedling period depending on the dosage, and this ratio varied by 19.51 to 45.86% under field conditions. It has been found out that effects of paclobutrazol diminished in time, and these effects were removed faster by GA3 applications. Paclobutrazol, as opposed to GA3, decreased the height to stem diameter ratio and induced formation of a stronger seedling. Paclobutrazol increased the number of blooming clusters, whereas GA3 had no significant observable effect on the number of blooming cluster. It has been concluded that 50 ppm paclobutrazol can be used for height control of the seedling in terms of growth and flowering, and 100 ppm GA3 should be applied for quality plant growth and to remove possible retarding effects.

Key words: Diameter, dry weight, height, PP 333

1. Introduction

Tomato is an indispensable vegetable for our lives due to its ingredients, bioactive compounds, and different forms of consumption. Tomatoes are consumed raw in the salads or sandwiches or in gravies, sauces, peeled and sliced form, juices, soups, dry form and by being processed in different products (Beckles, 2012). Tomato, which ranks first in terms of production of plants of which fruit is eaten, ranks second following the potato in the list of cultured vegetables (Costa and Heuvelink, 2018). Nowadays, tomato is grown around the entire globe for different purposes in greenhouses or fields. China, India, USA, and Turkey form the four largest tomato producers of the world. Global tomato production gradually increases. In the last ten years, USA's tomato production shrank, whereas India, China, and Turkey recorded increase in tomato production by 88%, 54%, and 10%, respectively (FAO, 2020).

Although traditional methods are still used in tomato growing, shift to high technology production systems has been accelerated. Tomato production by directly sowing is limited, and it is generally grown by seedlings. The production period varies by ecologies and market tendencies, and the production plans are formed accordingly. In the traditional production procedures, losses of seedlings occur due to reasons such as climate conditions, uncontrollable environmental conditions, lack of knowledge, and equipment and deficiency in frequency of culturing practices (Demir, 2007). On the other hand, tomato seedlings are produced by commercial enterprises in the countries where advanced agricultural techniques are used. In these enterprises, all stages of seedling production are conducted under controlled conditions, and quality seedlings are produced. Being free of diseases and pests, root/stem balance, nonovergrowing, short internodes, strong root growth, strain-special leaf, and stem color are the specialties desired in a quality seedling. Thus, homogenous seedlings are produced in commercial growing and production of tiny seedlings with small root volume is preferred to achieve maximum output from the

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area of production. Seedling growth caused by genetic structure and special to strains and even varieties and ecological conditions such as low light exposure, low and high temperatures, excessively dry or humid temperature, etc. limit production of seedlings with the aforesaid qualities. In order to grow nonovergrowing seedlings with desired qualities, physical practices such as reducing irrigation volume, use of cold water, pruning, copper applications, brushing, sweeping, etc. as well as mechanical stress, growth retarding chemicals, and redirecting cultivation containers are utilized (Latimer, 1998; Uğur and Eser, 2000; Brigard et al., 2006; Uğur and Kavak, 2007; Bozokalfa, 2008). Paclobutrazol has been preferred in commercial seedling production in recent years due to its practicality and effective results. Paclobutrazol is effective in the synthesis of gibberellin by preventing the conversion of ent-kaurene to ent-kaurenoic acid (Rademacher, 2000). With the application of paclobutrazol, gibberellin synthesis is inhibited, and shorter seedlings are obtained. However, there are some concerns on excessively scrub appearance emerging on seedling especially depending on the application dosage and frequency. On the other hand, continuance of scrub appearance under field conditions depending on decomposition time of the chemical raise concerns for its use in commercial seedlings. In this study, it has been aimed to control the growth of seedlings by applying paclobutrazol to tomato seeds in varying dosages and remove the retarding effects on the plants faster under field conditions by applying gibberellic acid on the leaves prior to planting.

2. Materials and methods

2.1. Material

H 2274 standard tomato variety seeds (*Solanum lycopersicum* L.) of Bursa Seed Company, which is compatible with field growing, were used in the study.

Paclobutrazol of triazole class with the commercial title of ‘’Bonzi” was applied on the seeds as growth retardant (4 g/L active ingredient, Syngenta Crop Protection Canada, Inc.), and gibberellic acid (Megafil tablet, Natural Chemicals Agrochemical Company, Antalya) was applied on the seedlings before planting.

2.2. Methods

2.2.1. Applying paclobutrazol on the seeds

The tomato seeds were treated with four different paclobutrazol (PP 333) doses [0 (pure water), 25, 50, and 100 ppm] in the study. The seeds were kept in paclobutrazol solutions for 2 h at room temperature (20±1 °C). The seeds were maintained under room temperature till sowing.

2.2.2. Growing the seedlings

Tomato seedlings and plants were grown in an unheated plastic greenhouse with maximum/minimum indoor temperatures of 32/12 °C in the 2017-2018 growing season. For seedling growing, a mixture of peat: perlite prepared in a ratio of 3: 1 was prepared and filled into 70-cell viols (root volume 42 ml). The seeds were sown on 15/03/2018, and the seedlings were cared till they achieve a size suitable for planting (Vural et al., 2000). The tomato seedlings were sprayed with 150 ppm NPK fertilizer solution twice on April 20 and May 5, once on April 28. 1.8 ppm NPK fertilizer per plant was applied from the soil.

2.2.3. GA3 applications on seedlings

0 (control-water), 50, and 100 ppm dosages of GA3 were tested on the 40-days-old seedlings. A total of 50 mL GA3 solution per viol was sprayed on the leaves of the seedlings on 25/04/2018.

2.2.4. Planting of seedlings

The tomato seedlings were planted on pots of 75×16×14 cm (volume of 12 liters) filled with 3:1 turf/perlite mixture with 5 seedlings on each pot, on 04/05/2018. All cultural procedures were performed in a timely manner following the planting. After planting, on the 10th and 25th days, 15-15-15 NPK fertilizer was applied twice at a dose of 5 kg/da.

2.2.5. Measurements performed

The observation periods of tomato seedlings and plants following planting on the pots are indicated in the Table 1. The height of seedlings was determined by measuring the ten tomato seedlings from the soil level to the growth tip by a ruler on the 25th and 40th days following seed sowing. The stem diameters of the seedlings were measured from 1 cm above the root collar by a digital caliper in millimeter (mm) on the 40th day. Measurements were performed on 5 plants following the planting within the scope of the study. Those following were determined in these measurements: plant height (from the soil level to the growing tip), stem diameter (1 cm above the root collar), plant height to stem diameter ratio, number of blooming cluster, and dry weight of plants (stem and leaf mixtures) (70 °C for 72 h).

2.2.6. Analysis of the data

The data were statistically analyzed through JUMP packaged software. The meaningful differences between applications were determined to have a $p < 0.05$ level of significance in LSD multiple comparison test. In the tables, different letters on the column indicate significant differences at $p < 0.05$ according to LSD Test.

3. Results and discussion

3.1. Effect of paclobutrazol application on the height of seedlings

The effect of paclobutrazol on height of the tomato seedlings are shown in the Table 2. It was found out that paclobutrazol applied on seeds in varying dosages had retarding effects on the height of seedlings in both observation periods, and the tiniest seedlings were identified to be the ones on which

Table 1. Observation period of seedlings and plants.

Observation period	Measurement dates	Plant age (days)	Growing place
Observation 1	09/04/2018	25	Viol
Observation 2	24/04/2018	40	Viol
Observation 3	04/05/2018	50	Plant pot
Observation 4	14/05/2018	60	Plant pot
Observation 5	21/05/2018	67	Plant pot
Observation 6	28/05/2018	74	Plant pot
Observation 7	04/06/2018	81	Plant pot

Table 2. Height of tomato seedlings in the seedbed (cm).

Seedling height (cm)		
Treatment	**25th day**	**40th day**
Control (water)	2.57 a	4.74 a
25 PP	1.89 b	2.91 b
50 PP	1.83 b	2.76 b
100 PP	1.52 c	2.52 c
LSD:	0.22***	0.23***

ns.: $p > 0.05$; *:$p < 0.05$; **:$p < 0.01$; ***:$p < 0.001$

Table 3. Stem diameter of the tomato seedlings in the seedbed (mm).

Stem diameter (mm)	
Treatment	**40th day**
Control (water)	3.01 a
25 PP	2.79 ab
50 PP	2.76 b
100 PP	2.60 b
LSD:	0.23*

ns.: $p > 0.05$; *:$p < 0.05$; **:$p < 0.01$; ***:$p < 0.001$

100 ppm paclobutrazol was applied in both observation periods. Application of 100 ppm paclobutrazol on the tomato seedlings provided a height control of 59.15% on the 25th day, and it was measured to be 53.17% on the 40th day. Compared to control seedlings, the decrease in seedling heights is due to the inhibition of gibberellic acid reactions by paclobutrazol applications (Rademacher, 2000). Increasing the dose of paclobutrazol made the effect more pronounced. Uğur and Kavak (2007) stated that by increasing the dose of paclobutrazol applied to tomato seeds, shorter seedling heights were obtained.

3.2. Effect of paclobutrazol application on the stem diameter of seedlings

The effect of paclobutrazol on the stem diameter of the tomato seedlings are shown in the Table 3. It was found out that paclobutrazol downsized stem diameters of the seedlings and the lowest stem diameter values were obtained in the case of 50 ppm and 100 ppm paclobutrazol. Contrary to the findings of some researchers that there was an increase in stem diameters with paclobutrazol applications, in our study, seedling diameter values decreased with paclobutrazol application (Berova and Zlatev, 2000; Mahesaniya, 2003; Zandstra et al., 2007; Akdemir, 2018). Reductions in seedling stem diameters were observed with paclobutrazol not only as a suppression of plant height, but also a general regression tendency in the whole plant. Application from seed is likely to increase the effectiveness of paclobutrazol on seedling diameter values.

3.3. Effects of gibberellic acid on the height of tomato plants

The changes in the height of tomato seedlings, on which paclobutrazol was applied in varying dosages, following GA3 applications are indicated in the Table 4. It was identified that GA3 applied on the seedlings treated with paclobutrazol previously brought along statistically significant changes in the height of the plants in all observation periods, and its interactions effects were concluded to be insignificant excluding the height values on the 74th day (Table 4). It was found out that the effects of paclobutrazol applied on the seeds of tomato plants were maintained. In the first two observation periods, paclobutrazol dosages were found out to have a similar effect on the height of the plants, but retarding effects of 100 ppm paclobutrazol were identified to be higher compared to the dosages of 25 and 50 ppm in the following periods. The rate of formation of tiny plants reached up

Table 4. Effects of gibberellic acid on the height of tomato plants (cm).

Treatments		Plant height (cm)				
Seed	**Seedling**	**50th day**	**60th day**	**67th day**	**74th day**	**81st day**
0 PP (Control)	**GA_3 0**	8.00	12.81	23.73	32.55 de	36.74
	GA_3 50	11.33	19.63	29.18	38.48 b	43.63
	GA_3 100	11.53	20.76	33.75	44.76 a	49.99
	GA_3 0	3.99	6.62	14.31	22.33 ij	26.63
25 PP	**GA_3 50**	6.36	12.91	21.13	29.55 fg	35.21
	GA_3 100	6.53	14.65	25.80	36.37 bc	43.07
	GA_3 0	3.61	6.76	14.81	24.43 hi	29.60
50 PP	**GA_3 50**	6.87	14.35	22.41	30.23 ef	34.93
	GA_3 100	6.87	15.61	24.43	33.63 cd	37.96
	GA_3 0	4.17	6.69	13.19	21.33 j	24.95
100 PP	**GA_3 50**	6.16	13.38	20.44	27.08 gh	30.70
	GA_3 100	6.37	15.67	21.41	28.36 fg	34.71
GA_3	***GA_3 0***	*4.94 B*	*8.22 C*	*16.51 C*	*25.16 C*	*29.48 C*
	GA_3 50	*7.68 A*	*15.07 B*	*23.29 B*	*31.34 B*	*36.12 B*
	GA_3 100	*7.82 A*	*16.67 A*	*26.35 A*	*35.78 A*	*41.43 A*
PP 333	**Control**	10.29 A	17.73 A	28.89 A	38.60 A	43.45 A
	25 PP	5.62 B	11.39 B	20.41 B	29.42 B	34.97 B
	50 PP	5.79 B	12.24 B	20.55 B	29.43 B	34.16 B
	100 PP	5.57 B	11.92 B	18.35 C	25.59 C	30.12 C
	LSD_{PP}:	0.60***	0.96***	1.43***	1.73***	2.22***
	LSD_{GA3}:	0.52***	0.83***	1.24***	1.49***	1.92***
	LSD_{PP*GA3}:	ns.	ns.	ns.	2.99*	ns.

ns.: $p > 0.05$; *:$p < 0.05$; **:$p < 0.01$; ***:$p < 0.001$

to 45.87 on the 50th day by application of paclobutrazol, but this retarding effect was reduced to 30.67% on 81st day. In this study, we observed the growth promoting effects of GA3 on tomato plants whose growth was retarded by paclobutrazol. When the plant height values are examined, it is known that paclobutrazol applied on the leaf or seed of tomato has retarding effects on the height of seedlings. In this regard, we can mention Uğur and Kavak (2007) who state that the height of seedlings was reduced by up to 25% by application of 250 and 500 ppm paclobutrazol and Pasian and Bennett (2001) who state that applying 1000 ppm paclobutrazol on the tomato seeds for 24 h reduce the height of seedlings by 40% as the examples of this suggestion. Geboloğlu et al. (2015) achieved the best quality seedlings by applying 100 and 200 ppm paclobutrazol on the seeds of eggplant seedlings. The height-reducing effect may be caused by prevention of gibberellin synthesis or convection in the plants by paclobutrazol (Ross et al., 1983; Cramer and Bridgen, 1998). By remedying the retarding effect in the height of seedlings obtained by paclobutrazol by applying GA3, the height of the plants increased in all observation periods by varying rates depending on the application. Whereas, GA3 dosages were all included in the same statistical group in the first observation period in terms of the height of plants, higher dosages of GA3 applications brought a more evident effect on the height of plants in time. By GA3 applications, a fast increase in the height of plants was observed, and it was increased approximately by up to 102.80% on the 60th day. This effect, albeit continuing compared to the control group, gradually decreased by 81st day and dipped to 40.53%. While the height of plants was 29.48 cm for the control group on 81st day, it reached up to 41.43 cm by application of 100 ppm GA3. Application of gibberellin, known as growth hormone, induced growth in the tomato plants. Ujjwal et al. (2018) state that different dosages of GA3 applied on tomato plants twice provided an increase in the height of plants by 15 to 33% on 60th day. Akand et al. (2016) applied GA3 on the tomato plants three times (50th, 65th and 80th day) and identified that applying 40 ppm GA3 increased the height of plants approximately by 62% compared to the control group. Another interesting point in our study is that the retarding effects diminished in time. For 100 ppm paclobutrazol, the rate of change in the height of seedlings in between 50th and 60th day was 114%, whereas it was 72.30% for the control plants. This variation in the height of seedlings gradually reduced throughout the observation periods, and it was measured to be 17.70% and 12.56% in between the 81st day and the 74th day, respectively. This firstly emerged as a reduction in the effects of paclobutrazol by application of GA3 and then as an increase in the height of plants. However, the limited growth rate of the control plants compared to those on which GA3 applied indicates that mostly the genetic factors came into play in the scrub tomato variety with limited growth. This may be caused by the fact that gibberellic acid is a more active substance compared to paclobutrazol. Patidar (2015) achieved an increase in the height of plants in all GA3 dosages (10, 15, and 20 ppm) applied to the tomato plants. He found out that the effect of GA3 diminished in time and the rate of increase in height, which was approximately 17% on the 30th day, was reduced to 8.5% on the 90th day. This result supports our findings. Interaction of paclobutrazol and GA3 application in the height of plants was found out to be statistically significant only on the 74th day, and the height of plants varied 21.33 to 44.76 cm.

3.4. Stem diameter of tomato plants

The change in the stem diameters of the plants, heights of which were brought under control by paclobutrazol, caused by GA3 applications is shown in Table 5. Paclobutrazol applied on seeds brought along statistically significant variations in the stem diameters of the plants in the first and last observation periods. Although the control plants had the thickest stem of 3.74 mm in the first observation period, stem diameters of the plants were included in the same statistical group and varied from 3.47 to 3.55 mm in paclobutrazol. The increase in stem diameters of the plants on which paclobutrazol was applied as from the first observation period was measured to be relatively higher than the increase in the stem diameters of the control plants. In the last observation period, the stem diameters of the plants on which 50 and 100 ppm paclobutrazol was applied were measured to be higher than the stem diameters of the control plants. In this period, the stem diameters increased up to 6.23% compared to the control group. It was revealed by examining stem diameters of the tomato seedlings that the stem diameters decreased compared to the control group due to suppression of growth of plant in paclobutrazol applications. This decrease continued until observation values of the 50th day in the field stage and then stem diameters of the paclobutrazol-applied tomato seedlings increased to a certain degree. This situation continued for a long time in the field, and, in the last observation period, the stem diameters of the plants applied with high dose paclobutrazol were found to be thicker. These results are similar to the findings of Teto et al. (2016) and Uğur and Eser (2000). Similarly, Zandstra et al. (2007) states that 5 ppm paclobutrazol applied on the tomato seedlings increased the stem diameter by 53%; Berova and Zlatev (2000) states that it increased the stem diameter by 18% and 26; Akdemir (2018) states that 100 ppm paclobutrazol applied on the leaves of lettuce seedlings in autumn and spring increased the stem diameter by 70.93% and 50.22% respectively and Mahesaniya (2003) states that the stem diameter was increased by 16% by applying paclobutrazol on tomato. However, factors such as application type of paclobutrazol, plant species, application period, and dosage can affect effectiveness of the application (Uğur and Kavak, 2007; Bhattarai, 2017).

The effect of GA3 applications on the stem diameters of plants were found out to be statistically significant on 50th, 67th and 74th days. It was observed by examining the stem diameters of the plants that application of 50 and 100 ppm GA3 caused an increase approximately up to 7.92% in stem thickness of the plants compared to the control plants. However, the increase in the stem diameters associated with the increase in height provided by GA3 was limited compared to the control plants. The stem diameters were found out to be similar on the 81st day in terms of GA3 applications and varied between 7.74 and 8.15 mm. Regarding the effects of GA3 on stem diameters, Latimer (1998) indicates that the stem diameter values were similar at the end of 7th week when GA3 was applied on the tomato seedlings of two weeks. In contrast with the apparent increase in the height of seedlings by GA3 applications, their effect on the stem diameters of the seedlings may vary by the application dose and observation period. Since the direction of the change in stem diameter values to the application dose differs between the observation periods, it is a bit difficult to explain the change in the stem diameters with existing data considering it along with genetic differences among the species and effect of ecologic factors. In the Table 5, interaction of the paclobutrazol with the GA3 applications with regards to stem diameters seem to be statistically insignificant except for the 60th day. It was observed that effects of application of paclobutrazol and GA3 were independent of each other in terms of the stem diameters of the plants. The stem diameters varied between 7.51 and 8.82 mm on the 81st day.

3.5. Height to stem diameter ratio of the tomato plants

The effects of GA3 applications on the seedlings of which height were kept under control by paclobutrazol

Table 5. Effects of gibberellic acid on the stem diameters of tomato plants (mm).

Treatments		**Stem diameter (mm)**				
Seed	**Seedling**	**50th day**	**60th day**	**67th day**	**74th day**	**81st day**
0 PP (Control)	**GA_3 0**	3.71	4.75 a	6.91	7.59	7.97
	GA_3 50	3.69	4.22 bc	6.29	7.12	7.74
	GA_3 100	3.83	4.22 bc	6.50	7.38	7.86
	GA_3 0	3.29	4.09 c	6.78	7.56	7.99
25 PP	**GA_3 50**	3.51	4.31 bc	6.50	7.20	7.51
	GA_3 100	3.61	4.21 bc	6.20	7.03	7.53
	GA_3 0	3.18	4.17 bc	6.89	7.61	8.19
50 PP	**GA_3 50**	3.68	4.33 bc	6.39	6.92	7.57
	GA_3 100	3.59	4.42 abc	6.67	7.59	8.41
	GA_3 0	3.47	4.28 bc	6.79	7.57	8.11
100 PP	**GA_3 50**	3.50	4.37 bc	6.66	7.32	8.12
	GA_3 100	3.68	4.50 ab	7.34	8.02	8.82
GA_3	***GA_3 0***	*3.41 B*	*4.32*	*6.84 A*	*7.58 A*	*8.07*
	GA_3 50	*3.59 A*	*4.31*	*6.46 B*	*7.14 B*	*7.74*
	GA_3 100	*3.68 A*	*4.34*	*6.68 AB*	*7.50 A*	*8.15*
PP 333	**Control**	3.74 A	4.39	6.56	7.36	7.86 B
	25 PP	3.47 B	4.20	6.49	7.26	7.68 B
	50 PP	3.48 B	4.30	6.65	7.37	8.05 AB
	100 PP	3.55 B	4.38	6.93	7.64	8.35 A
	LSD_{PP}:	0.13**	ns.	ns.	ns.	0.47*
	LSD_{GA3}:	0.12***	ns.	0.28*	0.30*	ns.
	LSD_{PP*GA3}:	ns.	0.36*	ns.	ns.	ns.

ns.: $p > 0.05$; *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$

are given in the Table 6. The change obtained in the height to stem diameter ratio by GA3 applications on the seedlings on which paclobutrazol was applied was measured to be statistically significant in all observation periods. In all observation periods, the paclobutrazol dosages were in different groups than the control plants, and this made effects of all application dosages clear in the last observation period. Similar effects were also observed for GA3 applications and variation in the effects of application depending on the paclobutrazol dosages emerged on the 60th day. Although the height to stem diameter ratio was 36.61 for the control plants with regards to GA3 applications, it was measured to be 51.39 for the plants on which 100 ppm GA3 was applied. The height to stem diameter ratio of the plants, for which the said ratio was measured to be 55.41 for a GA3 dosage of 0 ppm in the last observation period varied between 36.00 and 45.84 depending on application dosages of paclobutrazol. It was observed that stem diameters of the plants increased in the first observation period but did not change in the following periods and increased in the last observation period according to application dosages of paclobutrazol. It was identified by examining the height to stem diameter ratios that paclobutrazol reduced the height to stem diameter ratio of the plants in all periods and led to formation of stronger plants. This effect diminished to a certain degree as the observation period progressed. Haase (2008) defines height to stem diameter ratio as strength ratio of the seedling and states that stronger and steadier seedlings will be obtained as this ratio decreases. In our study, stronger plants were obtained by the paclobutrazol, and GA3 applications suppressed these effects to a certain degree. Interaction of the applications for height to stem diameter ratio of the plants was found out to be statistically insignificant in the first two periods and significant in the following ones. It varied between 30.75 and 63.61 on the 81st day for the tomato plants (Table 6).

Table 6. Effects of gibberellic acid on the height/stem diameters rates of tomato plants.

Treatments		**Height/stem diameters rate**				
Seed	**Seedling**	**50th day**	**60th day**	**67th day**	**74th day**	**81st day**
0 PP (Control)	**GA_3 0**	21.57	27.02	34.30 def	42.98 c	46.22 c
	GA_3 50	30.72	46.55	46.43 b	54.04 b	56.40 b
	GA_3 100	30.15	49.23	51.95 a	60.67 a	63.61 a
	GA_3 0	12.12	16.19	21.08 h	32.12 f	33.30 ef
25 PP	**GA_3 50**	18.10	30.00	32.60 efg	41.19 cd	47.06 c
	GA_3 100	18.03	34.77	41.61 c	51.74 b	57.17 b
	GA_3 0	11.36	16.23	21.48 h	32.12 ef	36.16 def
50 PP	**GA_3 50**	18.72	33.15	35.11 de	41.19 c	46.37 c
	GA_3 100	19.12	35.36	36.64 d	44.35 c	45.29 c
	GA_3 0	11.97	15.71	19.43 h	28.15 f	30.75 f
100 PP	**GA_3 50**	17.63	30.63	30.70 fg	36.93 de	37.77 de
	GA_3 100	17.31	34.80	29.30 g	35.58 e	39.48 d
GA_3	***GA_3 0***	*14.26 B*	*18.79 C*	*24.07 C*	*33.19 C*	*36.61 C*
	GA_3 50	*21.29 A*	*35.08 B*	*36.21 B*	*43.98 B*	*46.90 B*
	GA_3 100	*21.15 A*	*38.54 A*	*39.88 A*	*48.09 A*	*51.39 A*
PP 333	**Control**	27.48 A	40.93 A	44.23 A	52.57 A	55.41 A
	25 PP	16.08 B	26.98 B	31.76 B	40.82 B	45.84 B
	50 PP	16.40 B	28.25 B	31.08 B	40.08 B	42.61 C
	100 PP	15.64 B	27.04 B	26.48 C	33.55 C	36.00 D
	LSD_{PP}:	1.39***	1.81***	21.01***	2.78***	31.78***
	LSD_{GA3}:	1.21***	1.57***	1.82***	2.41***	2.75***
	LSD_{PP*GA3}:	ns.	ns.	3.64**	4.82**	5.51**

ns.: $p > 0.05$; *:$p < 0.05$; **:$p < 0.01$; ***:$p < 0.001$

3.6. Dry matter ratio in the stems of tomato plants

The effects of GA3 applications on dry matter ratio of stems of the plants, the height of which were kept under control by paclobutrazol, are given in Table 7. Dry matter ratio of the stems of tomatoes was measured in two different periods, namely on the 50th and 81st day. Although the effects of GA3 and paclobutrazol on the dry matter ratio of the stems were found out to be statistically significant, interaction of paclobutrazol and gibberellic acid application was measured to be statistically insignificant (Table 7). The dry matter ratio of the stems displayed a decrease compared to the control group by 25 and 50 ppm paclobutrazol on the 50th day, and the values for 100 ppm paclobutrazol were in between these two groups. The stem weights were measured to be higher for the control group on the 81st day. By GA3 applications, the dry matter ratio of the stems decreased in the first period and increased in the last observation period. In terms of plant stem dry weight ratios, Latimer (1998) suggests that the paclobutrazol dosages (0, 14, 30, 60 and 90 ppm) sprayed on the leaves of the tomato seedlings increased dry weight of the stems by 37 to 52% compared to the control plants. Berova and Zlatev (2000) found out that paclobutrazol (1 and 25 ppm) applied on the soil and leaves of the tomato seedlings decreased dry weight of the plants by 7% and 6%, respectively. On the other hand, Thakur et al. (2006) states that dry weight of the plants was increased to a significant degree by paclobutrazol applied on lily grown in aquaculture. By applying paclobutrazol for vegetable and other plant species, dry matter ratio of the plants generally decreased. The changes in dry matter ratio of the plants are caused by retardation in growth occurring due to paclobutrazol effects on gibberellic acid synthesis and transfer (Ross et al., 1983; Cramer and Bridgen, 1998). A fast water ingestion occurs in the body of the plants by GA3 applied on the tomatoes in the seedling stage. Following the water ingestion, cell growth and division activities accelerate (Cosgrove and Sovonick-Dunford,

Table 7. Effects of gibberellic acid on the dry matter ratio of the stems (%).

Treatments		**Dry matter ratio of the stems**	
Seed	**Seedling**	**50th day**	**81st day**
0 PP (Control)	**GA_3 0**	18.93	16.20
	GA_3 50	15.89	16.46
	GA_3 100	15.82	17.73
25 PP	**GA_3 0**	18.29	12.29
	GA_3 50	15.45	15.01
	GA_3 100	15.22	15.48
50 PP	**GA_3 0**	18.10	13.12
	GA_3 50	15.31	13.86
	GA_3 100	15.67	16.17
100 PP	**GA_3 0**	19.10	13.27
	GA_3 50	15.50	13.67
	GA_3 100	14.99	15.81
GA_3	***GA_3 0***	*18.60 A*	*13.72 C*
	GA_3 50	*15.54 B*	*14.75 B*
	GA_3 100	*15.43 B*	*16.30 A*
PP 333	**Control**	16.88 A	16.79 A
	25 PP	16.32 B	14.26 B
	50 PP	16.36 B	14.39 B
	100 PP	16.53 AB	14.25 B
	LSD_{PP}:	0.42*	1.03***
	LSD_{GA3}:	0.36***	0.89***
	LSD_{PP*GA3}:	ns.	ns.

ns.: $p > 0.05$; *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$

1989). As the sampling was performed in a period when water ingestion of the seedlings increased and thus dry weight of the stems were affected ten days after external GA3 application, the dry weight values were measured to be lower than the control group. However, dry weight values were measured to be higher than the control group as the effects of GA3 became more apparent in the plant stage. Interaction effects of paclobutrazol and GA3 on dry ratio matter of the stems of tomato were found out to be statistically insignificant (Table 7).

3.7. Number of blooming clusters of tomato plants

The effects of GA3 applications on number of blooming clusters in the tomato plants, of which heights were brought under control by paclobutrazol, are shown in the Table 8. Number of blooming clusters in the tomato plants was counted in three observation periods. Paclobutrazol were found out to be statistically effective in the second and last observation periods, but GA3 applications and interaction effects were determined to be statistically insignificant in all observation periods. In the last observation periods, number of blooming clusters in the plants on which paclobutrazol of 50 ppm was applied increased by 28.81%. Albeit being lower compared to the control group, application dosage of 100 ppm paclobutrazol also had an increasing effect on the number of blooming clusters. The effects of GA3 dosages on number of blooming cluster in tomato plants were identified to be statistically insignificant in all three observation periods. In the last observation period, number of blooming clusters per plant was measured to be 2.58, 2.64, and 2.79 for control, 50 ppm and 100 ppm dosages of GA3, respectively. The main purpose of tomato cultivation is to obtain tomato fruit. In tomatoes, fruit consists of flowers on a cluster. The presence of a healthy number of flowers is seen largely as a sign of high yield. In our study, the number of blooming clusters was determined to evaluate this situation. When the applications are evaluated in this respect, especially paclobutrazol is observed to have positive effects. Similarly, Berova and Zlatev (2000) identified that paclobutrazol applied through soil and leaves (1 and 25 ppm) increased number of blooming clusters by 83% and 89% in tomato. Giovinazzo and Souza-Machado (2001) state that increases of 6% and 13% were obtained in industrial tomato species with seeds treated by 50 ppm paclobutrazol in terms of early productivity and total productivity. Moraes et al. (2005) identified that 0, 2, 4, 8, 16, and 32 ppm paclobutrazol applied on ornamental tomato from the soil led to decrease in fruit diameter and increase in number of blooming clusters depending on the application dosage. Zandstra et al. (2007) state that 5 ppm paclobutrazol applied in 2-leaf stage increased the number of clusters per plant from 0.3 to 2.5 on the 31st day following the planting. It was found out by examining these studies that different application methods and dosages of paclobutrazol had positive effects on blossoming. It is believed that these effects are caused by three behaviors of the plants. Firstly, the plants tend to form more cluster as the internodes shrink. Secondly, the plants tend to form more cluster/blossoms due to acceleration in transition to generative phase caused by stress effects of paclobutrazol. Another factor is that paclobutrazol reduces the effects of gibberellic acid and directs assimilation materials to the generative phase as a result of suppressing vegetative growth in plants (Yuniastuti et al., 2001). In our study, the number of blooming clusters were found out to be consistent with the values indicated in the literature.

Ujjwal et al. (2018) applied different dosages of GA3 (20, 30, 40, and 50 ppm) on tomato plants on 15th and 35th days following the planting. The number of blossoming, which was 40.73 per plant in the control plants, increased

Table 8. Effects of gibberellic acid on the number of blooming clusters of tomato plants.

Treatments		Number of blooming clusters		
Seed	**Seedling**	**67th day**	**74th day**	**81st day**
0 PP (Control)	**GA_3 0**	1.20	2.20	2.47
	GA_3 50	1.13	1.50	2.20
	GA_3 100	1.00	1.69	2.42
	GA_3 0	1.07	2.00	2.40
25 PP	**GA_3 50**	1.00	1.80	2.57
	GA_3 100	1.00	1.87	2.80
	GA_3 0	1.27	2.40	3.07
50 PP	**GA_3 50**	1.08	2.07	3.00
	GA_3 100	1.00	2.07	3.06
	GA_3 0	1.00	1.60	2.40
100 PP	**GA_3 50**	1.11	1.87	2.80
	GA_3 100	1.00	1.73	2.87
GA_3	***GA_3 0***	*1.13*	*2.05*	*2.58*
	GA_3 50	*1.08*	*1.81*	*2.64*
	GA_3 100	*1.00*	*1.84*	*2.79*
PP 333	**Control**	1.11	1.80 B	2.36 B
	25 PP	1.02	1.89 B	2.59 B
	50 PP	1.12	2.18 A	3.04 A
	100 PP	1.04	1.73 B	2.69 AB
	LSD_{PP}:	ns.	0.27*	0.39*
	LSD_{GA3}:	ns.	ns.	ns.
	LSD_{PP*GA3}:	ns.	ns.	ns.

ns.: $p > 0.05$; *:$p < 0.05$; **:$p < 0.01$; ***:$p < 0.001$

by GA3 applications, and it was measured to be 50.13 cluster per plant by application of 50 ppm GA3. Baby et al. (2018) mention that GA3 dosages (0, 15, 30, 45, 60, and 75 ppm) applied on the leaves of cherry tomato increased the number of blossoms per cluster, and the number of blossoms per cluster, which was 20.36 for the control plants, increased up to 62.52 for 75 ppm GA3 application. Akand et al. (2016) applied different GA3 dosages on the tomato plants three times and identified that the number of blooming clusters increased from 7.5 to 10.6 for 40 ppm GA3. However, GA3 dosages had an increasing effect on number of blooming clusters of tomato plants in our study, but this effect is statistically insignificant. In terms of number of blooming clusters, interaction effects of paclobutrazol and GA3 were also found out to be statistically insignificant. We believe that further data are needed to have a definite judgement regarding the number of blooming clusters (Table 8).

4. Conclusion

With the application of paclobutrazol to tomato seeds, the seedling height decreased compared to the control. Applying gibberellic acid to these seedlings removed the regressive effects on the seedlings after planting, and the plants grew faster. While gibberellic acid applications did not have a negative effect on flowering, 50 ppm paclobutrazol application had an effect on increasing the number of bloomed clusters. In the study, the dosages of paclobutrazol applied on the seeds did not lead to a decrease in germination under convenient climate conditions. On the other hand, radicles of the seeds on which paclobutrazol was applied got brownish under field conditions and the radicles were observed to be weaker compared to the control plants. This effect became apparent under uncontrolled conditions and germination and emergence got better as the temperatures rose. Paclobutrazol being applied on the seed is a practical method to keep height of seedlings under control. Less chemicals are used compared to application through leaves, and possible toxic effects on the leaves are prevented. For seed applications, lower dosages of paclobutrazol may be tried. Hypocotyls of the tomato seedlings got shorter and darker by paclobutrazol. Use of paclobutrazol is significant for the seedling sector to adjust rootstock and scion growth rate and obtain ripe seedling for inoculation in the inoculated seedling growing. During the seedling period, the retarding effects of paclobutrazol were slowed down with GA3 applications and the growth of the seedlings accelerated. The use of GA3 is seen as a good alternative to eliminate postplanting regressive effects in field and greenhouse conditions in seedlings treated with paclobutrazol for height control. Lower dosages of both paclobutrazol and GA3 may be tried to better understand the effects of application effects. Applying GA3 subsequent to planting on the field should be considered in terms of adaptation of the plant.

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