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Research Paper

Effect of Chlormequat chloride on cultivation of capsicum (*Capsicum annuum* L.)

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Abstract: Yield reduction in Capsicum (*Capsicum annuum* L.), which occurs due to physiological and hormonal imbalances in the plants, particularly under unfavourable environments, is one of the main problems in Sri Lanka. Plant growth regulator has the potential to reduce fruit and flower drops. A preliminary experiment was conducted at the Horticultural Crop Research and Development Institute at Gannoruwa to determine the effect of plant growth regulators on capsicum cultivation. Chlormequat chloride was used as plant growth regulator and sprayed as foliar spray at one (T2), two (T3), and five (T4) weeks after transplanting and one, two and five weeks after transplanting (T5), respectively. The plants sprayed with water served as the control (T1). Treatments were arranged in a Randomized Complete Block design. There was no significant difference (P>0.05) among tested treatments in plant height, chlorophyll content, number of days taken to 50% flowering, number of days taken to first fruit and the number of flowers per branch, average canopy width and number of fruits per plant. All treatments had the first flower at 34 days after transplanting. Further, marketable, non-marketable, and total capsicum yields were statistically the same in all tested treatments. Therefore, the present study concluded that applying chlormequat chloride at different time intervals in different growth stages did not positively impact the growth and yield of capsicum.

Keywords: Capsicum, chlormequat chloride, foliar spray, yield

Introduction

Capsicum (*Capsicum annuum* L.) is an important vegetable in several dishes. It is a vital source of nutrients, carotenoids, phenols, vitamin C and folates (Phillips *et al*., 2006), and capsicum is used to treat several diseases. Due to its benefits, interest and demand for capsicum has increased dramatically in recent years. Even though the demand for capsicum is high in Sri Lanka, the production of capsicum is low due to unfavourable environmental conditions. High temperatures adversely affect capsicum fruit set (Dorland and Went, 1947). The loss of flowers and fruits can result in a severe yield decrease and constitutes a significant risk factor in capsicum production. Poor fruit set was believed to be one of the significant barriers in capsicum (Saha *et al*., 2010). Flower and fruit drops can be minimized by applying plant growth regulators in most crops (Chattopadhyay and Sen, 1974) by spraying various growth regulators on foliage (Ramesh and Thirumurugan, 2001).

Plant growth regulators (PGRs) are organic compounds that, in small amounts, promote, inhibit or modify specific physiological processes in plants (Tukey *et al*., 1954). Specific plant growth regulators are used to modify crop growth rates and growth patterns during various stages of plant development. The regulators have been intensively and extensively applied for agriculture production and have played a vital role in the growth and development of plants. The varying responses of capsicum to plant growth regulators have been reported by Chaudhary *et al*. (2006). Applications of plant growth regulators have been assessed by many researchers in areas of plant physiology and nutriology (Amarjit, 2000). Chlormequat chloride is highly mobile in both xylem and phloem tissue (Kust, 1986) and rapidly absorbed and translocated. It is highly water soluble (Cathey and Stuart, 1961) and passively absorbed by all plant tissues, allowing it to be effectively applied as a spray or drench (Tolbert, 1960). It also improves the photosynthetic capacity by increasing the chlorophyll content of the leaf (Wang *et al*., 2010). However, more information is needed regarding the effectiveness of plant growth regulators on growth and other physiological parameters of commercial capsicum cultivars. Therefore, this attempt aimed to find the impact of plant growth regulators on capsicum cultivation by using chlormequat chloride.

Materials and Methods

A preliminary study was conducted at the experimental fields of the Horticultural Crop Research and Development Institute at Gannoruwa from October 2015 to February 2016 to study the impact of Chloromequat chloride on capsicum cultivation. The site was located at an elevation of 500-1000 m from Mean Sea Level, belongs to WM 2b (mid-country wet zone) and consists of Red Yellow Podzolic Soil. The experiment was laid out as a Randomized Complete Block Design. *Capsicum annuum var* CA-8 was the test crop and chlormequat chloride was used as the plant growth regulator. Chlormequat chloride was sprayed at different times from transplanting capsicum plants at the rate of 14 ml /16 L water as a foliar spray. Treatments were water spray (control) (T1), the spray of plant growth regulator at one (T2), two (T3), and five (T4) weeks after transplanting (WAT) and one, two and five WAT (T5). All the agronomic practices were followed as per the Department of Agriculture recommendations, Sri Lanka, except treatments. Plant growth and yield parameters were recorded, leaf chlorophyll content was measured using the SPAD meter, and the collected data were analyzed using statistical software.

Results and Discussion

<u>Plant height:</u>

Plant growth regulators modify crop growth rates and growth patterns during various stages of plant development. Therefore, plant height was taken as a parameter during vegetative and reproductive stages to determine the effect of chlormequat chloride on capsicum. There was no significant (P>0.05) difference among treatments on average plant height measured at weekly intervals, as shown in Table 1. This finding is agreeable with Songvut (1992), that chlormequat chloride does not affect the plant height in Dahlia.

Table 1. Average plant height measured at weekly intervals

Treatment	At 1st week	At 2nd week	At 3rd week	At 4th week	At 5th week	At 6th week	At 7th week	At 8th week
T_1	11.75	14.50	17.10	19.25	24.97	31.52	35.44	35.89
T_2	12.66	15.08	17.33	19.75	26.47	35.30	38.69	39.08
T_3	11.49	13.83	17.69	21.61	28.52	35.55	37.46	38.72
T_4	11.72	14.30	17.32	19.94	25.58	34.78	37.22	37.99
T_5	10.64	14.16	16.72	20.19	27.30	37.64	41.21	41.47
F test	ns	ns	ns	ns	ns	ns	ns	ns

Values represent mean ∓ standard error of four replicates. F test: - ns: not significant at P=0.05. T_1 = control, T_2 = spray of the growth regulator at one week after transplanting (TAP), T_3 = spray of the growth regulator at two WAT, T_4 = spray of the growth regulator at five WAT, T_5 = spray of growth regulator at one, two and five WAT.

The regression equations that depict the relationship between plant height and time are shown in Table 2. Adjusted R^2 for models range from 91.1% (T1) to 81.7% (T2). All fitted models are significant (P<0.000) to predict the values in the interpolation area. The slope of the equation provides the plant growth rate, which is high in T5 (4.82) followed by T3 (4.36). It may suggest that applying chlormequat chloride at 1, 2 and 5 WAT increases the plant growth rate. This finding agrees with Clark and Fedak (1977) that applying plant growth regulators causes stem elongation. However, in contrast to these findings, Thanopoulos *et al.* (2013) noted that chlormequat chloride reduced the okra height, while Hou *et al.* (2013) reported reduced plant height of *Angelica dahurica* after application of chlormequat chloride. Gibson and Whipker (2003) found that daminozide at 5000 mg L^{-1} applied with chlormequat chloride was effective. However, a single foliar application of daminozide at concentrations up to 10,000 mg L^{-1} was ineffective in controlling the height of Osteospermum plants.

Table 2. Plant growth rate in different treatments

Treatments	Regression equation	R^2	*P* value
T_1	Plant height = 6.50 + 3.84 Week	91.1	0.000
T_2	Plant height = 6.41 + 4.21 Week	81.7	0.000
T_3	Plant height = 6.03 + 4.36 Week	85.8	0.000
T_4	Plant height = 5.82 + 4.25 Week	86.2	0.000
T_5	Plant height = 4.20 + 4.82 Week	91.0	0.000

T_1 = control, T_2 = spray of the growth regulator at one week after transplanting (TAP), T_3 = spray of the growth regulator at two WAT, T_4 = spray of the growth regulator at five WAT, T_5 = spray of growth regulator at one, two and five WAT.

<u>Chlorophyll Content:</u>

After the fourth week, chlorophyll content increased in all treatments compared with previous weeks, as shown in Figure 1. It may suggest that the application of chlormequat chloride has resulted in a higher chlorophyll content during the reproductive stage of capsicum. This finding agrees with Rajesh *et al.* (2014), who stated that applying chlormequat chloride resulted in higher chlorophyll content during the reproductive stage in green gram. Davis (1991)found that chlormequat chloride would enhance photosynthesis in plants. However, no significant (P>0.05) difference in chlorophyll content measured weekly among the treatments, as illustrated in Figure 1.

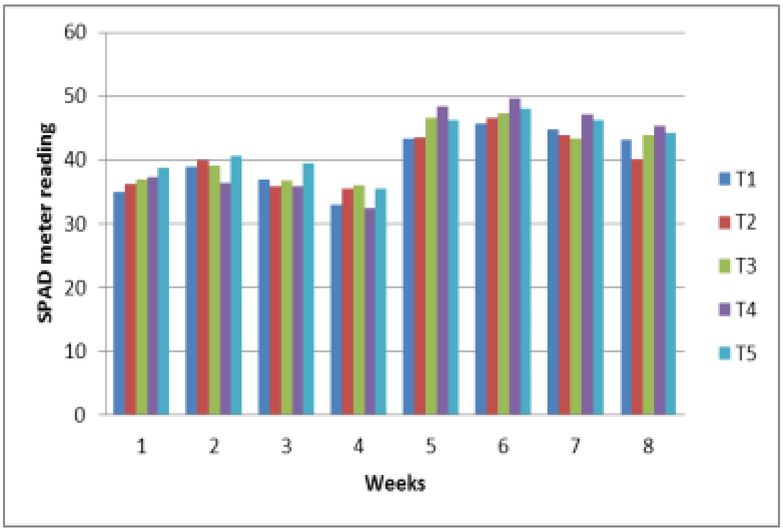

Figure 1. Average chlorophyll content. T_1 = control, T_2 = spray of the growth regulator at one week after transplanting (TAP), T_3 = spray of the growth regulator at two WAT, T_4 = spray of the growth regulator at five WAT, T_5 = spray of growth regulator at one, two and five WAT.

The canopy width and chlorophyll in the 8th week after transplanting had a significant positive correlation with a coefficient of 0.645 ($P<0.05$; Table 3). Mustafa *et al*. (2012) found that the plant canopy, leaf density and leaf area have consequently increased with the chlorophyll contents of the orange plants. Further, they stated that chlormequat chloride had increased the canopy width at the harvesting stage.

Table 3. Correlation between chlorophyll content and canopy width in capsicum plant

Correlation	**Coefficient**	**P value**
Chlorophyll content and canopy width at the 8th week	0.645	0.009

<u>Number of days to first flowering and 50% flowering:</u>

All tested treatments produced the flowers 34 days after transplanting (DAT), and there was no variation in treatments due to chlormequat chloride compared with the control treatment. It is agreeable with Georgia *et al*. (2010) that there were no variations in delay in the flowering of green pepper by chlormequat chloride. A χ^2 of 3.0 (P = 0.558 indicates no significant difference among treatments in the number of days to 50% flowering (Table 4). However, Resmi and Gopalakrishnan (2004) stated that chlormequat chloride leads to early flowering on Yard long bean. Passam (2008) reported that lettuce produced shorter and thicker flower stalks after applying chlormequat chloride.

Table 4. Number of days to 50% flowering

Treatments	**Median**
T_1	36
T_2	34
T_3	38
T_4	36
T_5	35
P value	0.558
χ^2	3.0

T_1 = control, T_2 = spray of the growth regulator at one week after transplanting (TAP), T_3 = spray of the growth regulator at two WAT, T_4 = spray of the growth regulator at five WAT, T_5 = spray of growth regulator at one, two and five WAT.

<u>Number of days taken to fruit initiation after transplanting:</u>

The number of days taken for fruit initiation is important for higher plant yields. For plants treated with chlormequat chloride at the 5th WAT (T4) and one, two and five WAT (T5), the number of days to fruit initiation was five days earlier than in other tested treatments. However, the χ^2value of 3.0 ($P=0.558$) confirms that there was no significant difference among the tested treatments ($P>0.05$) in the number of days taken to fruit initiation (Table 5).

Table 5. Number of days taken to fruit initiation after transplanting

Treatments	**Median**
T_1	42
T_2	42
T_3	42
T_4	37
T_5	37
P value	0.051
χ^2	9.44

T_1 = control, T_2 = spray of the growth regulator at one week after transplanting (TAP), T_3 = spray of the growth regulator at two WAT, T_4 = spray of the growth regulator at five WAT, T_5 = spray of growth regulator at one, two and five WAT.

The number of flowers per branch:
There was no significant difference (P>0.05) in the number of flowers per branch at 6th (P=0.80), 7th (P=0.421) and 8th (P=1.11) WAT with Ӽ2 values of 1.61, 3.89 and 1.11, respectively, is shown in Table 6. Ashraf *et al.* (1987) also found that chlormequat chloride did not affect the number of flowers per branch in *Brassica junica* L.

Table 6. Number of flowers per branch at different weeks

Treatments	**At 6 week**	**At 7th week**	**At 8th week**
T_1	5	11	4
T_2	7	10	5
T_3	7	8	2
T_4	4	15	4
T_5	4	9	2
P value	0.80	0.421	0.893
$Ӽ^2$	1.61	3.89	1.11

T_1 = control, T_2 = spray of the growth regulator at one week after transplanting (TAP), T_3 = spray of the growth regulator at two WAT, T_4 = spray of the growth regulator at five WAT, T_5 = spray of growth regulator at one, two and five WAT.

Average canopy width:
Colwell (1974) stated that ground cover percentage can provide information regarding crop growth and health of the crop. Therefore, canopy width was considered a parameter in this study (Table 7). At the 1st harvest, plants in T2 showed the maximum canopy width (22.44 cm per plant), followed by T1 (21.72 cm per plant). The minimum canopy width of 18.94 cm per plant was reported in T3 (application in 2 WAT). However, at the 1st harvest, there was no significant difference (P>0.05) in plant canopy width among the tested treatments. The average canopy width increased from the 1st to 2nd harvest in each treatment, including the control. Plants in T3 showed a higher increase in canopy width from 1st to 2nd harvest, compared with other treatments. However, there was no significant difference (P>0.05) in the average canopy width among treatments at the 2nd harvest.

Table 7. The average canopy width (cm per plant)

Treatments	**At 1st harvest**	**At 2nd harvest**
T_1	21.72 ± 3.66	25.86 ± 3.46
T_2	22.44 ± 2.50	24.19 ± 4.05
T_3	18.94 ± 0.32	25.27 ± 1.13
T_4	21.16 ± 4.18	24.94 ± 3.80
T_5	20.72 ± 3.01	23.63 ± 2.13
F test	ns	ns
CV	15.45	14.03

Values presented as mean ± standard error of four replicates. F test: - ns: not significant; CV = coefficient of variation. T_1 = control, T_2 = spray of the growth regulator at one week after transplanting (TAP), T_3 = spray of the growth regulator at two WAT, T_4 = spray of the growth regulator at five WAT, T_5 = spray of growth regulator at one, two and five WAT.

Number of fruits per plant:
Gowda and Gowda (1983) stated that chlormequat chloride increased the number of fruits per plant in okra. Rathod and Patel (1996) also reported that chlormequat treatments resulted in the highest number of fruits per plant in okra. However, Rathod *et al.* (2015) found that chlormequat chloride has reduced the number of fruits per plant in French beans. In the present study, there was no significant difference (P>0.05) among tested treatments in fruits per plant ($Ӽ^2$ = 1.61, P = 0.808; Table 8).

Table 8. Number of fruits per plant

Treatments	Number of fruits per plant
T_1	2
T_2	2
T_3	4
T_4	3
T_5	1
P value	0.808
Chi Square	1.61

T_1 = control, T_2 = spray of the growth regulator at one week after transplanting (TAP), T_3 = spray of the growth regulator at two WAT, T_4 = spray of the growth regulator at five WAT, T_5 = spray of growth regulator at one, two and five WAT.

Average length, width and thickness of fruits:
The fruit length was high in T5, which received the chlormequat chloride in the vegetative and reproductive stages. T2 showed the maximum width of the fruit among the treatments, and T3 showed the maximum thickness (Table 9). However, there was no significant difference (P>0.05) in the length, width, and thickness of fruits among the treatments. The shortest green fruits harvest received 200 ppm of chlormequat chloride, while no difference was observed in fruit diameter in French beans (Rathod *et al*., 2015).

Table 9. Average length, width and thickness of fruits

Treatments	Fruit Length (cm)	Fruit Width (cm)	Fruit Thickness (mm)
T_1	10.79	6.82	0.19
T_2	10.23	6.96	0.22
T_3	10.58	6.94	0.34
T_4	10.84	5.94	0.17
T_5	10.85	6.71	0.19
F test	ns	ns	ns
CV	3.98	4.24	1.57

Values presented as mean ± standard error of four replicates. F test: - ns: not significant. CV= Co-efficient variation. T_1 = control, T_2 = spray of the growth regulator at one week after transplanting (TAP), T_3 = spray of the growth regulator at two WAT, T_4 = spray of the growth regulator at five WAT, T_5 = spray of growth regulator at one, two and five WAT.

Yield per plant:
There were no significant differences (P>0.05) among tested treatments in marketable, non-marketable, and total yield per plant (Table 10). The highest total yield was observed in the T4 (49.52 g/plant), while the lowest was reported in T1 (31.49 g/plant). However, the total yield of T4 and T1 are statistically similar. The results agree with those of Resmi and Gopalakrishnan (2004), who reported that chlormequat chloride had enhanced the yield of yard-long beans. Gillaspy *et al.* (1993) stated that ear formation and yield of barley increased with treatment using chlormequat chloride. In contrast, Rathod *et al.* (2015) reported that chlormequat had reduced the yield of French beans. Shulgina and Ledovskii (1978) suggested that chlormequat significantly increased the yield of tomatoes. In the present study, there was no significant difference (P>0.05) in yield in tons per ha.

Correlation between canopy width and marketable yield:
A positive relationship between the canopy width at the 8th week and yield at the 1st harvest of capsicum (Table 11).

Table 10. Yield of capsicum after four picks

Treatment	Marketable yield (g/plant)	Non-marketable yield (g/plant)	Total yield (g/plant)	Total yield (tons/ha)
T_1	20.47	11.01	31.49	1.259
T_2	18.30	13.87	32.19	1.287
T_3	20.65	12.61	33.27	1.330
T_4	33.30	16.22	49.52	1.980
T_5	15.27	17.54	32.81	1.312
F test	ns	ns	ns	ns

Values represent mean ∓ standard error of four replicates. F test: - ns: not significant. T_1 = control, T_2 = spray of the growth regulator at one week after transplanting (TAP), T_3 = spray of the growth regulator at two WAT, T_4 = spray of the growth regulator at five WAT, T_5 = spray of growth regulator at one, two and five WAT.

Table 11. Correlation between yield at the 1st harvest and canopy width at 8th week

Correlation	Coefficient	P value
Canopy width at 8th week and marketable yield at the 1st harvest	0.631	0.012

Conclusion

Chlorophyll content (SPAD meter reading), though there was no significant difference among treatments, increased in all treatments after the 4th WAT compared to previous weeks. All tested treatments produced flowers at 34 DAT, and there was no variation in treatments due to the application of chlormequat chloride compared with the control. However, the days to 50% flowering and days to fruit initiation in T4 and T5 were five days earlier than the rest of the treatments. However, the time taken to fruit initiation was not statistically significant among treatments. The number of flowers per branch and the average canopy width were similar among the treatments. Further, the treatments resulted in similar effects in the number of fruits per plant, the length, width, and thickness of fruits, and marketable, non-marketable, and total yield. Therefore, the present study concluded that applying chlormequat chloride at different time intervals in different growth stages did not positively impact the growth and yield of capsicum grown in the open fields. Further studies with higher treatment concentrations at the correct time are warranted to establish the impact of the chemical on the capsicum crop.

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