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Full Length Research Paper

Effects of prohexadione-calcium with three rates of phosphorus and chlormequat chloride on vegetative and generative growth of tomato

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The aim of this study was to analyze the effects of prohexadione-calcium [(Regalis®)(100 mg L^{-1})] and chlormequat chloride (2000 mg L^{-1}) on vegetative and generative growth of tomato plant. An underlying aim was to evaluate the growth of plants treated with pro-Ca with three phosphorus rates (40, 80 and 120 mg L^{-1}). Pro-Ca was applied to plants either as a spray or medium drench, while chlormequat chloride was applied only as a spray. Results show that inhibiting effect of pro-Ca and chlormequat chloride applications on seedling height were significant and these two chemicals produced smaller seedlings compared to the control. Height reduction with chlormequat chloride was 56%, while with pro-Ca treatments it varied from 46 to 55%. Effects of chemicals on total weight of two trusses were not significant, although spray of pro-Ca together with the 40 mg L^{-1} phosphorus rate was promising in relation to chlormequat chloride and control plants. Based on the results of this study, it seems likely that pro-Ca, having an inhibiting effect on stem elongation without a negative effect on total weight of two trusses would be sufficient to control stem elongation. However, further researches are needed to suggest a strong opinion whether the pro-Ca treated tomato plants give same responses in every independent application of this chemical.

Key Words: Prohexadione-calcium, chlormequat chloride, growth rate, seedling height, tomato.

INTRODUCTION

Early interests in the control of stem elongation centred on growth retardants. Growth retardants to control height have been widely used in seedling industry. Ancymidol, daminozide, paclobutrazol, chlormequat chloride and uniconazole are among the most commonly used growth retardants to control plant height (Pasian and Bennett, 2001; Ilias and Rajapakse, 2005). Generally, highly effective chemicals on reduction of plant height also might be highly persistent, which is important because residual effects can influence field growth. Also, the use of growth regulating chemicals has disadvantages of causing excessive height reduction, delayed flowering, slow growth after transplanting and health risk (Ilias and Rajapakse, 2005). Moreover, alternative methods such as photoselective films, wind, vibrations, touching, brushing, clipping, higher light intensity, negative or equal DIF (difference between the day and night temperature), roll-out benches, scheduling and water stress, salts and nutrient stress which regulate osmotic potential of the root zone are also used to control seedling height (Schnelle et al., 1993; Rajapakse and Li, 2004; Rideout, 2004; Rideout and Overstreet, 2003; Duman and Düzyaman, 2003; Latimer et al., 1991).

Chlormequat chloride, which is effective on growth control, fruit set and yield, and also has rapid action on the reduction of shoot growth rate (Asín et al., 2007), is among the most used plant growth retardants. In addition, prohexadione-Ca, a new generation horticultural plant growth regulator, has low toxicity on plants and consumers. It inhibits stem elongation acting as a structural mimic of 2-oxoglutorale, thereby inhibiting dioxygenases

Abbreviation: pro-Ca, Prohexadione-calcium; **CCC,** chlormequat chloride.

that catalyze distinct steps in GA biosynthesis (Rademacher, 2000). It has been registered in the U.S.A (trade name Apogee®) and in Europe (trade name Regalis®) for use on reducing shoot growth on apple (Ilias and Rajapakse, 2005). It has also been classified by The United States Environmental Protection Agency as a reduced risk compound. Because of not being persistent in the environment and degraded in higher plants with a half-life of few weeks and in the soil with a half-life of less than a week (Ilias and Rajapakse, 2005), pro-Ca might be a good alternative for regulating growth in vegetables. The aim of this study therefore was to analyze the effects of pro-Ca on reducing plant height, vegetative and generative growth of tomato plant. An underlying aim was to evaluate the growth of plants treated with pro-Ca with three phosphorus rates and a relatively high potassium rate.

MATERIALS AND METHODS

Plant material, treatments and culture

The study was carried out from March to July growing period in 2011, in Tekirdag, Türkiye, in a cold glasshouse. Seeds of Maya F_1 (MayAgro Co.), an indeterminate type of tomato were used. These seeds were sown in a multicellular tray filled with peat (Klasmann Potgrond H, Germany) on March 31st.

Chlormequat chloride (CCC) (40%, w/v) and prohexadione-calcium (Regalis®) (BAS 125 10 W, BASF Corp) treatments were performed at three-leaf stage. CCC (2000 mg L^{-1}) was applied to leaves and stems with a sprayer, while prohexadione-calcium (pro-Ca, 100 mg L^{-1}) applied either as a spray (S) or medium drench (D). Spray treatments were performed to leaves and stems, while drench treatments were given to root medium as a solution. Pro-Ca solution contained AcidoWett as a surfactant (Tayosis) to adjust the pH to 5.2-5.5 and water.

Plants were divided into 8 groups: One for CCC application, one for control and six for pro-Ca applications with a set of 72 plants in each group. While three of six pro-Ca groups plants were sprayed, the other three of six pro-Ca groups plants were drenched with pro-Ca solution. Due to the fact that uniform drench is critical for uniform height control, drench applications were limited to 15 ml for each pot (Ø 3,5 cm). Spray applications were performed under shading cloth in order to avoid leaf and stem damage. When leaves were dry, shading cloth was removed. Furthermore, starting from two-leaf stage plant fertilized regularly with liquid fertilizers. In each three pro-Ca groups, plants were fertilized with three different rates of phosphorus containing fertilizer. In CCC and control treatment, 40 mg L^{-1} P containing (P1) liquid fertilizer was used thorough the experiment. Liquid fertilizers used in experiment with three phosphorus rates were (mg L^{-1}): P1: 120 N (30% NH_4-N), 40 P, 237 K, 40 Mg and 22 S; P2: 120 N (30% NH_4-N), 80 P, 237 K, 40 Mg and 52 S; P3: 120 N (30% NH_4-N), 120 P, 237 K,40 Mg and 34 S.

Treatments evaluated included pro-Ca with two application methods and three P rates and with one CCC treatment and with one control were: SP1:100 mg L^{-1} pro-Ca as spray + P1 fertilizer; SP2: 100 mg L^{-1} pro-Ca as spray + P2 fertilizer; SP3:100 mg L^{-1} pro-Ca as spray + P3 fertilizer; DP1:100 mg L^{-1} pro-Ca as drench + P1 fertilizer; DP2:100 mg L^{-1} pro-Ca as drench + P2 fertilizer; DP3:100 mg L^{-1} pro-Ca as drench + P3 fertilizer; CCC: 2000 mg L^{-1} CCC as spray + P1 fertilizer; control: no growth retardant application + P1 fertilizer. Forty-eight days after sowing, plants were transferred to pots filled with peat at a plant density of 2.0 plants m^{-2}. Side shoots were removed regularly. No pesticides application or any kind was carried out during the experiment. The plants were stopped after the 2nd truss leaving 5 leaves after the truss. Finally, 102 days after sowing (DAS) [69 days after chemical application (DAA)], research was concluded.

Vegetative growth measurements

Measurement of plant height (measured from medium surface to the apical meristem), stem diameter (just below the first true leaf), leaf area (m^2), number of leaves, and plant, leaf, stem and root fresh and dry weight (ventilated oven, 105°C) were carried out from 33 days after sowing till transplanting, 48 days after sowing. First measurements were performed just before application of pro-Ca and CCC, afterwhich it was repeated every third day till 48 days after sowing. Following transplanting, measurements of plant height, stem diameter and number of leaves were performed one week apart to the end of the experiment. All measurements were performed separately for 4 plants per replication for all treatments. Plant extension rate (mm day^{-1}), and stem expansion rate (mm day^{-1}) were calculated using differences between measurements. Seedling weight/seedling height ratio was expressed as milligram dry matter per cm plant (mg cm^{-1}). Specific leaf area (SLA, m^2 g^{-1}) was calculated according to the following equation (Hunt et al., 2002):

$$SLA = \frac{LA}{LW} \tag{1}$$

Where, LW is the total leaf dry weight per plant (g) and LA is the total leaf area per plant (m^2).

Flower and fruit development measurements

Measurements of flower and fruit number of each plant, as well as fruit length and diameter were performed once a week to the end of the experiment. Fruit diameters were recorded for first fruit of each truss in all treatments during the period between 34 DAA (days after application) and 69 DAA (102 DAS). Fruit expansion rate (cm^3 day^{-1}), as increase in fruit volume, was calculated using by differences between masurements. Fruit volume was calculated according to the following equation (Guichard et al., 2005):

$$\text{Fruit volume } (cm^3) = 0.55\ [\text{fruit diameter } (cm)]^{2.93} \tag{2}$$

At the end of the experiment, measurements of fresh and dry weight of first fruit of each truss, total fresh weight of each truss, total fruit fresh weight of each plant and percentage fruit set of each truss were performed.

Statistical analysis

The experiment was laid out in a completely randomized block design with each treatment comprising three replications. Treatment effects were compared by Duncan's multiple range test. Statistical analysis was performed with the aid of the SPSS statistical package (18.0 for Windows).

RESULTS

Vegetative growth of plant

Results show that pro-Ca and CCC applications affected seedling height (Table 1 and Figure 1). While inhibiting effect of pro-Ca, especially spray applications on seedling height was apparently 6 days after the application and lasted till 12 DAA; inhibiting effect of CCC on seedling height was evident 3 DAA and lasted till 9 DAA. After this period, between 9 and 12 DAA in CCC treatment, seedling height was higher than pro-Ca treatment. Following this period, however, seedling height was always lower than control and pro-Ca applied plants (Figures 1 and 2a). Additionally, 15 DAA heights of control plants was taller than all pro-Ca and CCC applied plants. Control plants were 4.21 times taller, while CCC plants were 2.0. In addition, SP1 applied plants were 1.09, while DP2 applied plants were 1.96 than they were at the time of applications (33 DAS) (Figures 1 and 2a). However, at first week following transplanting with pro-Ca treatment, plant height remained smaller than control plants, but it was taller than CCC treatment. Starting from two weeks after transplanting (34 DAA) in all pro-Ca application, plant height was higher than CCC applied plants and even than control plants to the end of the experiment (Table 2).

All chemical applications decreased stem diameter related to the control starting from 3 DAA, but during the period between transplanting and harvest, effects of chemicals on stem diameter were different for each recording date. Although, stem growth rate with CCC was faster between 27 and 34 DAA, it slowed after this period (Figure 2b and c). Plant and leaf fresh weights were also significantly reduced by Pro-Ca and CCC related to the control (Table 1). Measurements made between 3 DAA and 15 DAA showed a significant effects of the chemicals on number of leaves and specific leaf area. Plant dry weight and number of leaves were lower compared to the control plants (Table 1). In all pro-Ca treatments between 3 and 9 DAA, SLA was higher than the control and CCC treatment. Following this period, however, it was lower than control. For pro-Ca and CCC applications, at the 9 DAA SLA of CCC, plants were higher while they were lower at 12 and 15 DAA than pro-Ca applied plants (Table 1). Pro-Ca application decreased leaf number related to the control. From 9 DAA to the end of the seedling period, CCC treated plants had more leaves than pro-Ca treated plants. Decreasing effects of pro-Ca on leaf number was seen clearly following the application of the chemical to the 15 DAA (Table 1).

Moreover, seedling weight/seedling height (mg cm^{-1}) ratio (SW/SH) was not statistically significant. And exception of applications SP1 and SP2 pro-Ca, it was higher than control plants (Table 1). The highest ratios were observed with DP3 and CCC treatments respectively. Additionally, with spray application of pro-Ca treatments, SW/SH ratios were lower than those of with drench application in all P rates. The analysis took into account at the harvest that the effects of chemicals on plant height and stem diameter were significant (Table 2). The highest lenght (79.33 cm) was from DP3, while the shortest lenght (62.5 cm) was from the CCC treatment. Stem diameter from control plants was statistically lower than from CCC and pro-Ca treatments. No significance differences in leaf number were observed, although, pro-Ca applied plants produced more leaves compared to the CCC application and control.

Flower and fruit development

The effects of pro-Ca and CCC treatments on flower and fruit numbers and fruit set rates were not significant, even though SP1, SP2, DP1, DP2 and control plants produced maximum number of flowers. DP1, SP2 and control also had maximum number of fruits. Regarding fruit set, best results were obtained from DP1 and SP3 treatments and control respectively (Table 2, Figure 4a and b).

Measurements of weight of first fruit of first truss fresh weight of first fruit of second truss and total fresh weight of first truss did show significant differences among treatments (Table 2). Weight of first fruit of first truss was greater for CCC treatment compared to pro-Ca treated and control plants. Control and SP2 and SP3 treatments were in the second ranking group following CCC treatment. Moreover, total weight of first truss in SP2 treatment was statistically the highest. total weight of two trusses were also higher with SP2 and SP1 treatments compared to the CCC and control. Considering of the weight of two trusses as an early yield, it can be speculated that early yield of SP2 and SP1 plants were higher than of CCC treatment and control.

DISCUSSION

It is apparent from the study presented here that being as effective as CCC, pro-Ca reduced the seedling height related to the control. In contrast with the study of Rideout and Overstreet (2003), however, P rates did not affect the seedling height. Moreover, seedling heights were similar from all P rates and control plants fed with the fertilizer containing lowest rate of P produced the highest seedlings. Althought, P rates used in this study was not less than the one third of the N rate, nevertheless higher rates of P produced shorter seedlings related to the control. But for supporting the findings of presented experiment, it should be mentioned that authors also reported that greatest control was obtained with a combination of other practices.

The specific inhibitory effect of pro-Ca on seedling height and shoot lenght is supported by other reporters for several species such as apple (Ratiba Medjdoub and Blanco, 2004), pear (Smit et al., 2005), okra (Ilias et al., 2007), cabbage (Hamano et al., 2002), cucumber (Ergun et al., 2007) and petunia and impatiens (Ilias and Rajapakse, 2005). In contrast with the report of Ergun et

Table 1. Effects of pro-Ca and CCC[1] applications and application method and P rates on seedlings growth.

Parameter	pro-Ca application						control	CCC	Level of significance
	P1		P2		P3				
	S	D	S	D	S	D			
3 Days after application									
Number of leaves	3.00^{b}	3.25^{b}	3.00^{b}	3.00^{b}	3.00^{b}	3.00^{b}	4.0^{a}	3.25^{b}	P<0.01
Plant dry weight (g)	0.11^{bc}	0.14^{bc}	0.08^{c}	0.16^{b}	0.12^{bc}	0.16^{b}	0.26^{a}	0.22^{a}	P<0.01
SLA (m^2 g^{-1})	0.0364^{a}	0.0367^{a}	0.0354^{a}	0.0305^{a}	0.0372^{a}	0.0323^{a}	0.0198^{b}	0.0193^{b}	P<0.01
6 Days after application									
Number of leaves	4.00^{ab}	4.00^{ab}	4.00^{ab}	4.00^{ab}	4.00^{ab}	4.00^{ab}	4.25^{a}	3.75^{b}	P<0.01
Plant dry weight (g)	0.25^{ab}	0.22^{ab}	0.17^{b}	0.21^{b}	0.26^{ab}	0.28^{ab}	0.32^{a}	0.25^{ab}	P<0.01
SLA (m^2 g^{-1})	0.0221	0.0260	0.0250	0.0269	0.0257	0.0225	0.0214	0.0199	ns
9 Days after application									
Number of leaves	4.25^{b}	4.25^{b}	4.00^{b}	4.00^{b}	4.00^{b}	4.00^{b}	5.50^{a}	4.50^{b}	P<0.01
Plant dry weight (g)	0.25^{d}	0.30^{bcd}	0.25^{d}	0.29^{bcd}	0.33^{bc}	0.35^{b}	0.59^{a}	0.28^{cd}	P<0.01
SLA (m^2 g^{-1})	0.0221^{ab}	0.0208^{ab}	0.0208^{ab}	0.0208^{ab}	0.0213^{ab}	0.0193^{b}	0.0225^{a}	0.0218^{ab}	P<0.01
12 Days after application									
Number of leaves	4.25^{cd}	4.50^{cd}	4.50^{cd}	4.00^{d}	4.75^{cd}	5.00^{c}	7.00^{a}	6.00^{b}	P<0.01
Plant dry weight (g)	0.38^{c}	0.48^{bc}	0.39^{bc}	0.40^{bc}	0.44^{bc}	0.47^{bc}	1.04^{a}	0.56^{b}	P<0.01
SLA (m^2 g^{-1})	0.0181^{ab}	0.0190^{ab}	0.0191^{ab}	0.0177^{ab}	0.0200^{ab}	0.0181^{ab}	0.0205^{a}	0.0170^{b}	P<0.01
15 Days after application									
Seedling height (cm)	10.16^{b}	8.99^{b}	10.82^{b}	9.58^{b}	$9.,58^{b}$	8.97^{b}	19.88^{a}	8.82^{b}	P<0.01
Number of leaves	5.25^{bc}	5.25^{bc}	5.50^{bc}	4.75^{c}	5.00^{c}	5.25^{bc}	7.00^{a}	6.00^{b}	P<0.01
Stem diameter (cm)	3.14^{c}	3.73^{bc}	3.25^{bc}	3.53^{bc}	3.60^{bc}	3.60^{bc}	4.49^{a}	3.84^{b}	P<0.05
Plant fresh weight (g)	3.42^{b}	3.48^{b}	3.44^{b}	3.13^{b}	3.30^{b}	3.64^{b}	7.13^{a}	3.74^{b}	P<0.01
Leaf fresh weight (g)	2.44^{b}	2.56^{b}	2.43^{b}	2.26^{b}	2.37^{b}	2.70^{b}	4.49^{a}	2.80^{b}	P<0.01
Seedling weight/Seedling height ratio (mg cm^{-1})	49.2	57.8	45.3	52.8	53.2	65.8	51.8	63.5	ns
Plant dry weight (g)	0.50^{b}	0.52^{b}	0.49^{b}	0.51^{b}	0.51^{b}	0.59^{b}	1.03^{a}	0.56^{b}	P<0.01
SLA (m^2 g^{-1})	0.0194^{ab}	0.0195^{ab}	0.0186^{ab}	0.0181^{ab}	0.0185^{ab}	0.0175^{b}	0.0206^{a}	0.0170^{b}	P<0.01

[1]Mean separation by Duncan's multiple range test (P<0.05), ns; non-significant. Means within the same row with different letters are significantly different. D; medium drench application, S; spray application. P1, P2 and P3 represents three rates of phosphorus, 40, 80 and 120 mg L^{-1} respectively. Values are mean of three replicates. SLA, Specific leaf area.

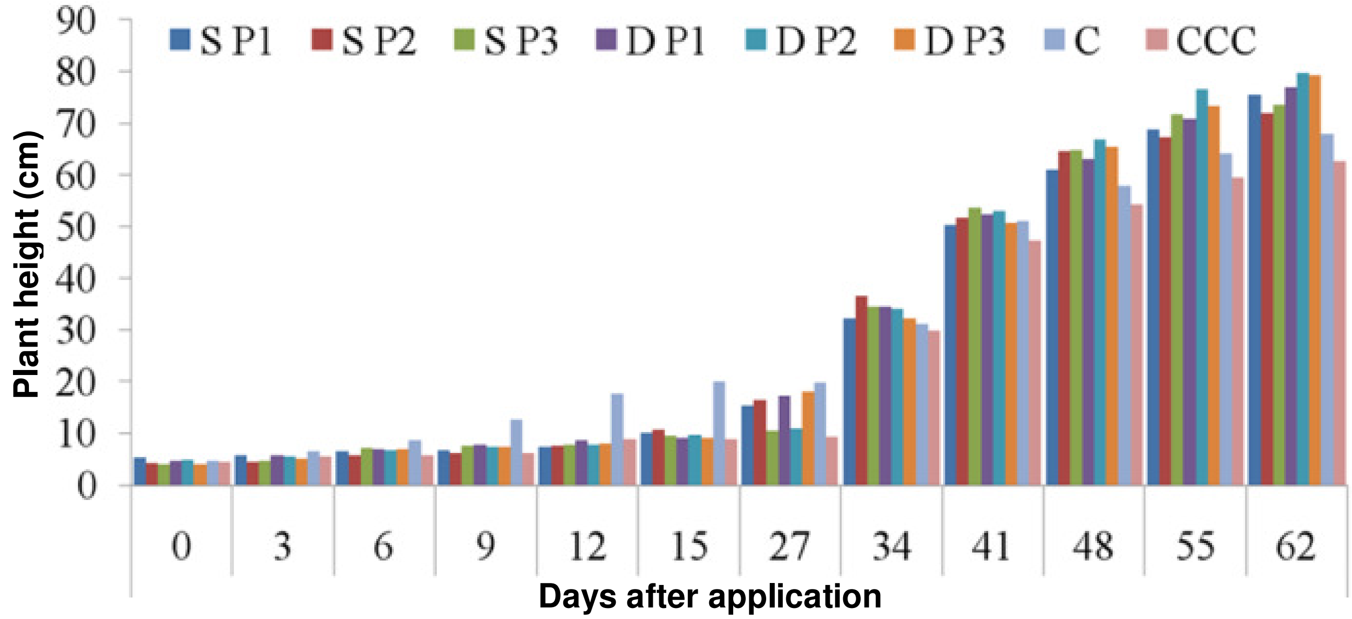

Figure 1. Effects of pro-Ca and CCC applications, application methods and P rates on plant height. S; spray application of pro-Ca and D; drench application of pro-Ca. P1, P2 and P3 represents three rates of phosphorus, 40, 80 and 120 mg L^{-1} respectively. Values are mean of three replicates.

al. (2007), pro-Ca reduced the stem diameter. Plant dry weight and number of leaves in seedling stage were also reduced by pro-Ca and CCC. Alternatively, however, most pro-Ca treatments gave favourable results during the main growing period related to control. Starting from two weeks after transplanting (34 DAA) in all pro-Ca applications, plant height was higher than CCC applied plants and even than control plants to the end of the experiment. More also, pro-Ca applied plants had more leaves and larger stems related to the control. This indicated that reducing plant height control with pro-Ca treatment did not affect vegetative growth of tomato in the field.

SW/SH ratio, as a weight of per unit length, may be a factor when determining seedling quality. A high ratio may indicate a stocky seedling (Rideout and Overstreet, 2003), which is important because long seedlings with weaker diameters might be damaged when planting in the field using by planting machines. They need more frequent irrigation, especially with bare-root transplants, than stocky ones after transplanting. Effects of pro-Ca and CCC treatments on SW/SH ratio were not significant. While plants with DP3 and CCC treatments produced the highest ratio, the lowest ratio was observed with SP1 and SP2 treatments related to the control. Interestingly, however, plants with SP1 and SP2 treatments produced higher yields than plants with DP3 and CCC treatments. Additionally, yields from these two treatments were even lower than from the control plants. It is apparent from these results that an increase in dry matter production for plants with DP3 and CCC treatments could not have resulted from an icrease in light interception as Heuvelink and Buiskool (1995) pointed out, since these two treatments also had lower leaf area (data not shown). It may be considered that an increase in dry matter production resulted from, at least partly, a low sink/source ratio.

Moreover, SP1, SP2, DP1, DP2 and control plants produced maximum number of flowers. DP1, SP2 and control also have maximum number of fruits. Regarding fruit set ratio, the best results were obtained from DP1 and SP3 treatments and control, respectively. Although, the main factors determining the number of flowers initiated are temperature and light, other environmental factors such as nutrition and growth regulators directly or indirectly can influnce flower initiation (Heuvelink, 2005). Flower development on the other hand is primarily influenced by temperature (Heuvelink, 2005). In the present study, plants were grown in a cold greenhouse and it was found that the number of flowers and fruits were not affected significantly by the treatments and the relation between the temperature and flower and fruit numbers here remains to be tested. However, pro-Ca applications produced similar number of flowers to control and even some treatments produced more fruit; this may be considered as a proof that the pro-Ca applications have a positive or at least not negative effect on flower and fruit numbers.

Although, main effects of phosphorus rates and pro-Ca application methods (data not presented) were not significant on the percentage of fruit set, differences between pro-Ca treatments might indicate that fruit set

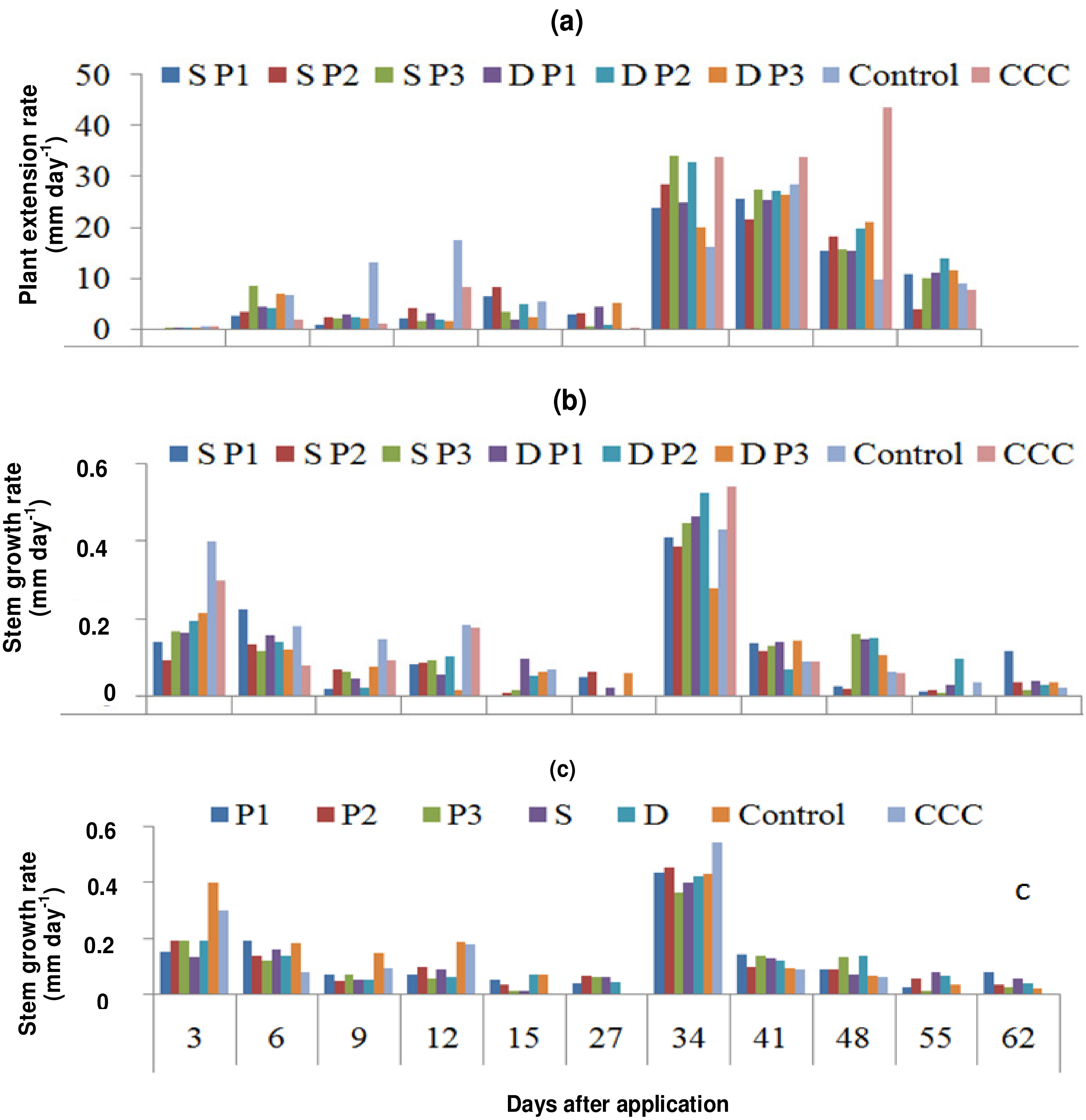

Figure 2. Effects of pro-Ca and CCC applications, application methods and P rates on plant extension (a) and stem growth rates (b and c) between 3 and 62 days after application. S; spray application of pro-Ca and D; drench application of pro-Ca. P1, P2 and P3 represents three rates of phosphorus, 40, 80 and 120 mg L^{-1} respectively. Values are mean of three replicates.

was influenced, at least partly, by the application method and phosphorus combinations.

Improving effect of pro-Ca on yield, fruit set and quality of crops such as pear and strawberry is revealed by several researches (Smit et al., 2005; Duval, 2002). On the other hand, there are reports that this chemical have no effect on fruit quality and on flower initiation of apple (Ratiba Medjdoub and Blanco, 2004; Asín et al., 2007). However, in contrast with the results of this study, it should be mentioned that Zandstra et al.

Table 2. Effects of pro-Ca and CCC[1] applications and application method and P rates on vegetative and reproductive growth of tomato plants.

Parameter	pro-Ca application						Control	CCC	Level of significance
	P1		P2		P3				
	S	D	S	D	S	D			
Plant Height (cm)	75.5^{ab}	77.0^{ab}	72.0^{ab}	79.0^{a}	72.83^{ab}	79.33^{a}	68.00^{bc}	62.5^{c}	P<0.05
Stem Diameter (mm)	8.74^{bc}	9.69^{a}	9.15^{abc}	8.75^{bc}	8.75^{bc}	8.61^{bc}	8.34^{c}	9.48^{ab}	P<0.05
Number of Leaves	16.3	16.6	16.0	17.3	15.6	16.6	15.0	14.6	ns
Fresh Weight of First Fruit of First Truss (g)	71.4^{b}	71.2^{b}	74.1^{ab}	72.3^{b}	74.2^{ab}	46.9^{c}	82.5^{ab}	93.8^{a}	P<0.05
% Dry Weight of First Fruit of First Truss	6.49	6.79	7.07	6.93	6.79	7.13	7.19	6.70	ns
Fresh Weight of First Fruit of Second Truss (g)	25.1^{b}	18.8^{b}	20.1^{b}	30.8^{b}	38.5^{ab}	54.0^{a}	22.5^{b}	37.7^{ab}	P<0.05
% Dry Weight of First Fruit of Second Truss	7.2	7.5	7.6	7.1	7.5	7.2	8.6	7.3	ns
Fruit Number of First Truss	6.3	6.0	7.3	4.3	4.6	4.6	7.3	4.6	ns
Total Fresh Weight of First Truss (g)	165^{ab}	137^{ab}	184^{a}	104^{b}	129^{ab}	108^{ab}	169^{ab}	137^{ab}	P<0.05
Fruit Number of Second Truss	4.6	6.0	5.0	5.3	5.0	3.6	4.6	4.3	ns
Total Fresh Weight of Second Truss (g)	32	40	18	42	36	55	10	25	ns
% Fruit Set in First Truss	61.3	85.8	62.8	40	93.4	48.5	53.9	77.8	ns
% Fruit Set in Second Truss	46.6	43.9	41.4	48.4	60.1	50.0	42.4	52.0	ns
Total Fresh Weight of Fruit (g)	197	177	202	146	166	163	179	163	ns
Total Fruit Number of Plant	10.9	12.0	12.3	7.6	9.6	8.2	11.9	8.9	ns

[1]Mean separation by Duncan's multiple range test (P<0.05), ns; non-significant. Means within the same row with different letters are significantly different. D; medium drench application, S; spray application. P1, P2 and P3 represents three rates of phosphorus, 40, 80 and 120 mg L^{-1} respectively. Values are mean of three replicates.

(2006) reported that pro-Ca, being in the same statistical group with the control, was not effective at increasing plant growth and yield in tomato. This may be because of relatively high dose of chemical or selected cultivar. In fact, cultivar, physiological stage of development, water quality and rates of plant growth regulators can influence the response of plant (Smit et al., 2005; Ilias and Rajapakse, 2005). Duval (2002) demon-strated that 62.5 ppm pro-Ca treatment resulted in significantly higher marketable yield than control in strawberry.

Fruit growth of tomato presents a sigmoud curve: Following anthesis displays a slow growth about 2 weeks and a 3 to 5 weeks period of rapid growth and again a slow growth for about a 2 weeks, in which increase in fruit mass is little (Heuvelink, 2005). Fruit expansion rates of CCC treatment, drench applications of pro-Ca and control plants were faster than spray applications of pro-Ca during the first 2 to 3 weeks of fast growing period, but slowed afterwards, while fruit expansion rates of spray applications of pro-Ca remained relatively high (Figure 3). This may be a indication of high yield.

The flower appearences and fruit set in the first truss of CCC treated plants began early, hence it may be postulated that first trusses of CCC treated plants have a shorter fast growing period related to all other treatmets as suggested by Heuvelink and Dorais (2005). However, these suggestions do not represent an explanation for control plants and drench applica tions of pro-Ca

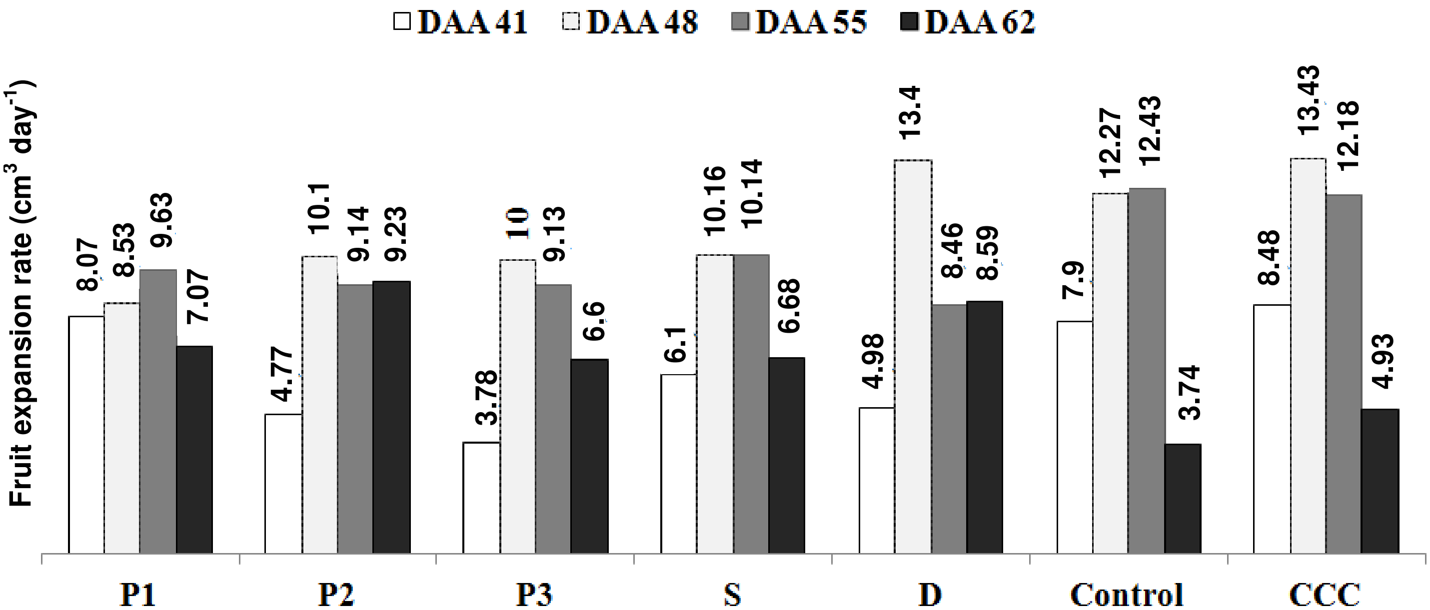

Figure 3. Effects of pro-Ca and CCC applications, application methods and P rates on fruit expansion rates between 41 and 62 DAA (days after application). S, Spray application of pro-Ca; D, drench application of pro-Ca. P1, P2 and P3 represents three rates of phosphorus, 40, 80 and 120 mg L^{-1} respectively. Values are mean of three replicates.

also having slower fruit expansion rates. In addition, due to the fact that DP2 and DP3 had the same fruit number in the first truss as CCC and that SP2 treatment had the same fruit number in the first truss as control plants, it can be spaculated that fruit number did not influence the total yield of first trussess. These results might be derived from fruit development process and dry matter partioning. As it has been pointed out by Heuvelink and Dorais (2005) in tomato, biomass allocation has a direct impact on crop production. And biomass allocation is determined by the sink/source ratio or assimilate demand. Also, assimilate demand primarily depends on temperature. Additionally, cultivar, sources, the transport path and sinks may have influence the allocation (Heuvelink and Dorais, 2005).

Since researches conducted on the effect of pro-Ca on vegetative and generative performance of plant mainly concentrated on orchard plants especially apples, and pot flowers and grains, there is limited work related to vegetable crops. Hence, it is difficult to state a strong opinion as to this chemical's effect on tomato plant. However, due to the fact that pro-Ca is a gibberellin inhibitor likewise CCC, it can be suggested that it inhibited the seedling elongation, and not the expense of growth of plants since the productive period was not negatively affected in this research, although responses to pro-Ca varied with P rates and application method. As to the phosphorus rates and application methods, it can be realized that spray applications combined with P2 and P1 rates indicate the promising results both pre-in pre-transplanting and post-transplanting period of tomato growing.

Conclusion

Seedling height is important in vegetable growing. Seedlings with longer internodes and weaker stems can be challenging. Seedlings might be damaged when establishing a field using planting machines. They also need more frequent irrigation, especially with bare-root transplants, than sturdy ones. All of these dis-advantages result in delayed yield and decreased total yield, which is important for conventional production. From the viewpoint of the results of this experiment, and of establishing and cultivation cost of a field, it seems likely that pro-Ca having an inhibiting effect on stem elongation with no negative effect on yield of first two trusses, would be sufficient to control stem elongation.

Regarding the cost of fertilizers and difficulty of drench application in mass production, it can be concluded that spray application of pro-Ca combined with 40 mg L^{-1} phosphorus rate would be sufficient to cope with the challenges in seedling production. However, further researches are needed to provide a strong opinion whether the Pro-Ca treated tomato plants give the same responses in every independent application of this chemical.

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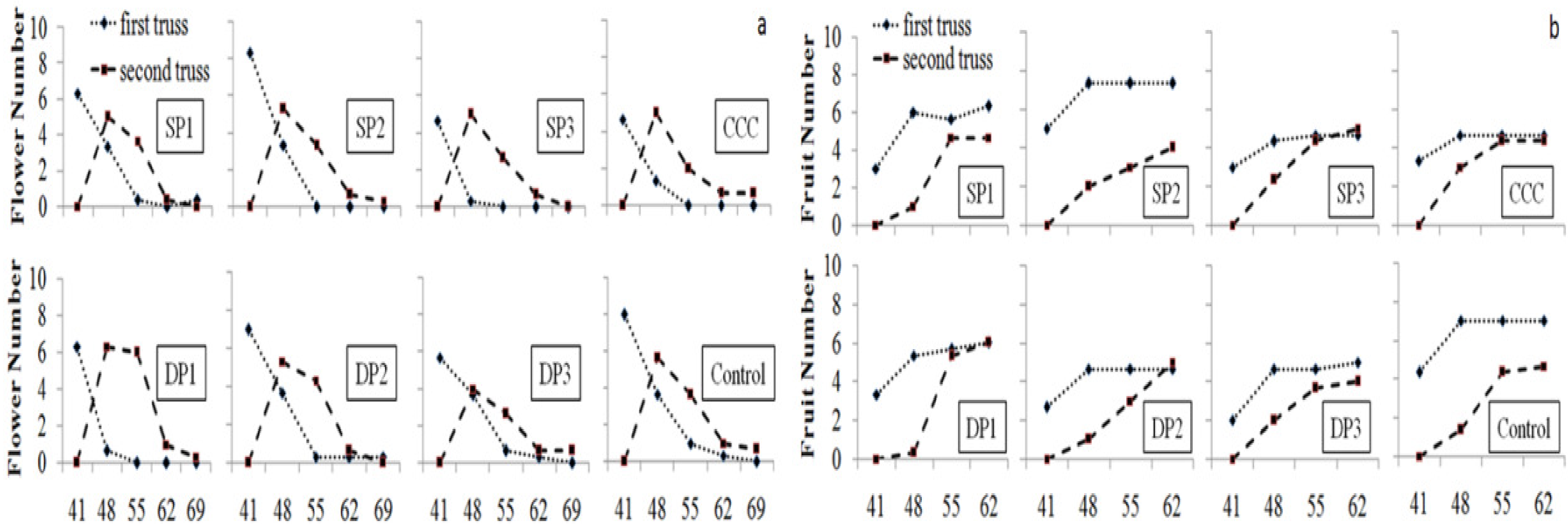

Figure 4. Effects of pro-Ca and CCC applications, application methods and P rates on flower (a) and fruit numbers (b) between 41 and 69 DAA (days after application). S, Spray application of pro-Ca; D, drench application of pro-Ca. P1, P2 and P3 represents three rates of phosphorus, 40, 80 and 120 mg L^{-1} respectively. Values are mean of three replicates.

REFERENCES

Asín L, Alegre S, Montserrat R (2007). Effects of paclobutrazol, prohexadione-Ca, deficit irrigation, summer pruning and root pruning on shoot growth, yield and return bloom, in a 'Blanquilla' pear orchard. Sci. Hort. 113(2): 142-148.

Duman I, Düzyaman E (2003). Growth control in processing tomato seedlings. Acta Hort.. 613: 95-102.

Duval JR (2002). Use of prohexadione-Ca to increase early yield and reduce establishment irrigation of strawberry (*Fragaria xananassa*). Proc. Fla. State Hort. Soc. 115: 220-222.

Ergun N, Çağlar G, Özbay N, Ergun M (2007). Hıyar fide kalitesi ve bitki gelişimi üzerine prohexadione-calcium uygulamalarının etkileri. Bahçe. 36(1-2): 49-52.

Guichard S, Gary C, Leonardi C, Bertin N (2005). Analysis of growth and water relations of tomato fruits in relation to air vapor pressure deficit and plant fruit load. J. Plant Growth Regul. 24: 201-213.

Hamano M, Yamato Y, Amazaki H, Miura H (2002). Endogenous gibberellins and their effects on flowering and stem elongation in cabbage (*Brassica oleracea* var. *capitata*) J. Hort. Sci. Biotechnol., 77(2): 220-225.

Heuvelink E (2005). Developmental process. Chapter 3, In Tomatoes, Edit. Heuvelik, E. Cabi Publishing Cromwell Press, Trowbridge, UK. ISBN: 0 85199 396 6. pp. 53-85.

Heuvelink E, Dorais M (2005). Crop growth and yield. Chapter 4, p: 85-145. In Tomatoes, Edit. Heuvelik, E. Cabi Publishing Cromwell Press, Trowbridge, UK. ISBN: 0 85199 396 6.

Heuvelink E, Buiskool RPM (1995). Influence of sink-source interaction on dry matter production in tomato. Ann. Bot. 75: 381-389.

Hunt R, Causton DR, Shipley B, Askew AP (2002). A modern tool for classical plant growth analysis. Ann. Bot., 90: 485-488.

Ilias FI, Rajapakse N (2005). Prohexadione-calcium affects growth and flowering of petunia and impatiens grown under photoselective films. Sci. Hort. 106(2): 190-202.

Ilias I, Ouzounidou G, Giannakoula A, Papadopoulou P (2007). Effects of gibberellic acid and prohexadione-calcium on growth, chlorophyll flourescence and quality of okra plant. Biologicia Plantarum, 51(3): 575-578.

Latimer JG, Johjima T, Fukuyama Y (1991). The effect of brushing on the growth and quality of field-grown root crops. Hort. Sci. 26: 1771-1773

Pasian CC, Bennett MA (2001). Paclobutrazol soaked marigold, geranium, and tomato seeds produce short seedlings. Hort. Sci. 36: 645-814.

Rademacher W (2000). Effects on gibberellin biosynthesis and other metabolic pathways. Ann. Rev. Plant Physiol. Plant Mol. Biol. 51: 501-531.

Rajapakse NC, Li S (2004). Exclusion of far red light by photoselective greenhouse films reduces height of vegetable seedlings. Acta Hortic. 631: 193-199.

Ratiba Medjdoub JV, Blanco A (2004). Prohexadione-Ca inhibits vegetative growth of 'Smoothee Golden Delicious' apple trees. Sci. Hortic. 101(3): 243-253.

Rideout JM, Overstreet LF (2003). Phosphorus rate in combination with cultural practices reduces excessive growth of tomato seedlings in the float system. Hort. Sci. 38(4): 524-528.

Rideout JW (2004). Field growth and yield of tomato transplants grown in the float system using low phosphorus fertilizer and height restricting cultural practices. Hort. Sci. 39(1): 23-27.

Schnelle MA, McCraw BD, Dole JM (1993) Height control of flowering crops and vegetable transplants. Oklahoma Coop. Ext. Serv. OSU Extension Facts, F 6714.

Smit M, Meintjes JJ, Jacobs G, Stassen PJC, Theron KI (2005). Shoot growth control of pear trees (*Pyrus communis* L.) with prohexadione-calcium. Sci. Hortic. 106(4): 515-529.

Zandstra JW, Dick J, Lang J (2006). Evaluation of growth regulators for transplant size control and earlier maturity of processing tomato. Technical Report. University of Guelph Ridgetown College. CA.