To the Graduate Council:

I am submitting herewith a thesis written by Priyavadan A. Joshi entitled "Interaction of Temperature and Growth Retardants on Pimiento Pepper." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant and Soil Science.

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INTERACTION OF TEMPERATURE AND GROWTH RETARDANTS ON PIMIENTO PEPPER

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Priyavadan A. Joshi

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ABSTRACT

The effects of temperature and growth retardants were studied on pimiento pepper. Seedlings were subjected to night temperatures of 12°-13°C or 20°-21°C for 21 days after the appearance of first true leaves. Drench and foliar application of the growth retardants (2-chloroethyl) trimethylammonium chloride (CCC) and N-dimethylamino succinamic acid (SADH) at concentrations of 10^{-2}M, 10^{-3}M and 10^{-4}M were made at the 2, 4-6 and 6-8 leaf stages of growth.

In the greenhouse, interaction of temperature and growth retardants resulted in an increase in number of flower buds and fruits set and subsequently enhanced flower and fruit development and fruit ripening. Treated plants were shorter, greener and had more extensive root systems than untreated plants. Control of plant growth occurred during the early stages by the retardation of internodal elongation in the sub-apical region. Morphological and anatomical observations indicated that the increased stem diameter of treated plants resulted from an increased amount of conducting tissue and enlarged pith region.

Under field conditions, interaction of temperature and growth retardants resulted in significantly higher early yield of ripe fruits. Plants that had been exposed to cool temperature in the seedling stage yielded slightly less than

those which had been exposed to warmer temperature. Application of growth retardants to plants which had been exposed to the cooler temperature in the seedling stage resulted in higher total yield. CCC seemed to be more effective than SADH in this regard.

Results indicated that pimiento seedlings were more sensitive to the interaction at the higher concentrations and early leaf stages. Since these interactions did not result in a phytotoxic effect on plant growth and ultimate yield, commercial use of CCC could be an advantage in growing pimiento transplants. Transplants with better developed root systems, shorter and thicker internodes could be grown in cooler areas where night temperatures go down to 12°-13°C. This would help to overcome the problem of over-sized transplants which impair mechanical transplanting and also possibly lower the cost of transplant production. The early application of CCC (at the 2-leaf stage) may produce a significantly higher early marketable yield by 10-12 days, which would bring a higher price for the pimiento growers.

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CHAPTER I

INTRODUCTION

Pimiento peppers (*Capsicum frutescens* L.) are produced largely in west Tennessee and are grown exclusively for the processing market. Processors located in Tennessee, Alabama and Georgia, buy both mature green and red fruits from Tennessee growers. Varieties recommended for Tennessee have been Truhart Perfection type (2). The pimiento pepper has been utilized in cookery chiefly as a condiment, for its color, adding an attractive and appetizing appearance to many food preparations. The chemical composition has been determined (1) and the Vitamin C content of the canned product found to be equivalent to that of fresh grapefruit. In addition, the Perfection pimiento pepper is high in carotene and Vitamin A (1).

One of the greatest difficulties in pepper growing is obtaining good uniform size and stout transplants sufficiently early in the season. At present, most of the pimiento acreage is established with transplants by the use of mechanical transplanters. Plants are produced by the open-field method in the central part of Florida and in south Georgia, and pimiento processors each year transport several million transplants to their respective areas of production. Unfavorable weather in areas of production may delay the transplanting operation and cause problems in transplanting by mechanical transplanters due to an increase in the size of the transplants. Hand labor for transplanting is difficult to obtain and problems in establishing this crop have discouraged pimiento pepper production.

Uniform and adequate plant stands are of major importance in mechanized production of pimientos. The efficiency of once-over mechanical harvest of pimiento will depend on concentrated and uniform maturity of the fruits.

An experiment was designed to study the interaction effect of two different temperatures (13°C and 21°C) and growth retardants, (2-chloroethyl) trimethylammonium chloride (CCC, cyocel) and N-dimethylamino succinamic acid (SADH, B-Nine), on pimiento pepper (cv. Perfection) applied at the seedling stage. The present research interest was on uniform ripening of fruit, height of transplants, flowering, fruit-setting and subsequent marketable yield.

An interaction effect of two temperatures and two growth retardants was also studied for the following characters, such as, the development of roots, degree of branching, number of basal shoots, diameter of stem and diameter, length and weight of marketable fruits. Observations were made regarding whether an interaction of temperatures and growth retardants resulted in phytotoxic effects on pimiento seedlings which would ultimately be reflected in yield.

CHAPTER II

LITERATURE REVIEW

The development of the plant body is a complex process where ultimate shape, size, form and degree of complexity are the result of the interaction between its genetic composition and environment.

Deoxyribonucleic acid (DNA) is the primary genetic substance that conveys hereditary information from generation to generation, while the major physical environmental factors such as light, temperature, soil and atmosphere modify the growth and development of the plant.

Although for an entire plant, vegetative and reproductive development may proceed concurrently, at each shoot apical meristem a transition occurs from leaf production to bract or sepal production at the time of flower initiation. Flowering provides the plant with the mechanism for genetic outcrossing. The physiology of flowering is therefore mainly the study of how synchrony is achieved through environmental cues and internal regulatory devices. The most conspicuous devices for achieving synchrony in flowering include the internal programming of earliness and the external cueing of flowering by such environmental features as light, photoperiod and temperature. Many species are induced or promoted to flower by low temperature, especially many biennials and perennials. The promotive effect of low temperature on flowering is termed vernalization. Unlike the photoperiodic stimulus to flowering, the vernalization stimulus is perceived ordinarily in the apical meristem (more specifically, dividing cells) where the low temperature alters the morphological expression of growth for a protracted period of time.

The presence of natural growth substances which regulate the quantity and quality of growth, also offers interesting possibilities of explaining such developmental events as flowering. Growth substances have been found to play important roles in the endogenous control of flowering. The idea of the programming of flowering through repression and derepression of genetic information has led to an understanding that the flowering processes can be interfered with by inhibitors of protein synthesis. It has also been shown that the locus of nucleic acid involvement in flowering is at the apical bud. It is presumed that the onset of flowering involves an alteration in the genetic instruction being translated into RNA and then protein synthesis. This involves the synthesis of specific mRNA, but regulation could be achieved through other RNA components, too.

Recently, new types of organic chemicals which retard stem elongation, increase green color of leaves, and indirectly affect flowering without causing malformation of the plants, have been studied on varieties of plants. These chemicals slow down cell division and cell elongation in shoot tissues and regulate plant height physiologically without formative effects.

I. HISTORY OF GROWTH RETARDANTS

In 1949, Mitchell, Wirwille and Weil (28) reported that a new class of chemicals, the nicotiniums, retarded stem elongation of bean plants without any formative changes. They also showed that picolinium, pyridinium and quaternary ammonium compounds of coal tar derivation were active on bean plants.

Later, Wirwille and Mitchell (42) reported similar effects of quaternary ammonium carbamates on growth of snap beans under greenhouse conditions without phytotoxic effects on plants. The compounds such as morpholinium, quinaldinium, quinolinium, piperidinium and substituted hydrazine, were shown to be growth retardants on snap beans and cucumbers (5). The major effects of these compounds were on retardation of stem growth without affecting terminal growing points.

In 1955, Gowing and Leeper (16) reported that β-hydroxyethylhydrazine-BOH induced flowering in pineapple. The primary action of this chemical was to retard stem elongation. During the same period the growth-retarding effect of phosphonium was first reported on cucumber plants where treated plants developed much shorter internodes than untreated plants (5).

In 1960, a new group of quaternary ammonium compounds was reported by Tolbert (38). He showed that the most active compound (2-chloroethyl) trimethylammonium chloride, was an analogue of choline, in that the hydroxy group in choline was replaced with a chlorine substituent. The compound was designated as chlorocholine chloride (CCC) and it retarded the growth of a larger number of species than any of the earlier compounds.

In 1962, Riddel et al. (29) showed that application of foliar sprays of substituted maleamic and succinamic acid retarded the growth of legumes, vine crops, potatoes, and ornamental plants. The most active compounds were N-dimethylamino maleamic acid (CO11) and N-dimethylamino succinamic acid (B995).

In 1960, Tolbert (38) reported the existence of a series of quaternary ammonium compounds. The most active of these was CCC and it was considered as an analogue of choline with the general formula of the cation $CH_2X\text{-}CH_2\text{-}N\text{-}(CH_3)_3$. In this compound the trimethyl quaternary ammonium cation was necessary for activity. Compounds were active when the substituents at "X" position were small, nucleophilic and nonionizable. The bromide and chloride salts are active compounds.

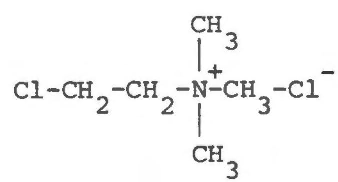
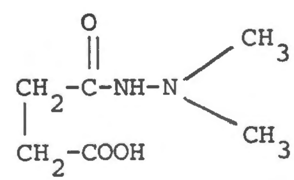
N-dimethylamino succinamic acid, designated B995, is unique in its chemical structure as a growth retardant. It does not contain a benzene ring, quaternary ammonium or phosphonium cation or substituents that are of small size, nucleophilic and nonionizable (29). It is a free, ionizable acid with the C-C-N-N system found in maleic hydrazine. Table 1 includes the chemical structure and activity of both CCC and SADH.

II. EFFECT OF GROWTH RETARDANTS ON PLANTS

Pith parenchyma cells in Pharbitis seedlings treated with CCC had a larger diameter than those in untreated plants (5). Several reports indicated that there was an increase in the stem diameter of the treated plants. Scherff (34) showed that in the bean stem, this increase was due to the stimulation of cell production in the cambium, accompanied by a delay in cell differentiation and to an increase in cell volume of the parenchymatous cortical cells.

It has been reported by several workers that as a result of treatment with growth retardants the stems were shorter because of the inhibition of cell division and elongation of the sub-apical meristem (5, 6, 32, 38). It has been noticed primarily that internode elongation was retarded by the application of CCC on wheat, rice, potato and tobacco plants.

Table 1. Chemical Structure and Activity of CCC and SADH.

Characteristic	CCC	SADH
Molecular weight	158	160
Solubility	Complete	5% by weight
Hygroscopicity	High	Slight
Persistance in soil	3-4 weeks	3-4 weeks
Response to concentration	High requirement; ranges from no response to toxicity symptoms	High requirement; response to a plateau over wide dosage range; no toxicity
Use in solution culture	Safe	Safe
Chemical name	(2-chloroethyl) trimethylammonium chloride	N-dimethylamino succinamic acid
General name	CCC	SADH
Trade name	Cycocel	Alar, B-9, B-995
Chemical structure		

On certain woody plants, the time of flower initiation was greatly accelerated from treatment with growth retardants. Stuart (35) first demonstrated that application of the growth retardants CCC and B995 (SADH) caused suppression of vegetative growth and promoted initiation of flower buds in Rhododendron. These responses did not depend on minimum age or size of plant, specific photoperiod or temperature.

Acceleration of flowering was also reported in herbaceous plants. Tomato seedlings treated in the cotyledon stage flowered earlier and produced a larger number of flowers in the first inflorescence than untreated plants (43, 44). According to Cathey (5), Jaffee and Isenberg reported that sweet corn produced more ears per plant with increasing dosages of B995 (SADH).

Tiessen (37) treated tomatoes and peppers at the seedling stage with CCC and found that foliar application of CCC increased total yield of peppers started at the warmer (64°-68°F) temperature, while it did not affect the yield of plants grown at the cooler (55°-56°F) temperature.

The leaves of all plants grown in soil treated with growth retardants were much darker than those of untreated plants. It was shown that color was directly related to the action of the growth retardants and not to mineral nutrition (5). In connection with this, Wittwer and Tolbert (43) observed that all the known types of tomato cultivars (dwarf, determinate, indeterminate, greenhouse forcing, early market and processing types) responded in having more compact growth and deepening of green color when treated with CCC.

Halevy and Kessler (18) found that bean plants treated with phosfon and CCC were less susceptible to water stress than untreated ones.

Lindstrom and Tolbert (24) reported that early applications of CCC and phosfon to soil were essential for the most effective response of the plant.

III. ROLE OF GROWTH RETARDANTS

Growth retardants and phytochrome exhibited no direct interaction. The germination of light-promoted seed of lettuce and *Lepidium virginicum* L. was retarded depending upon concentration. Phosfon, Amo-1618, and CCC did not alter the dormancy of nonpromoted seeds held in darkness (5, 44). Growth-retarding substances apparently in no way entered into the processes initiating germination but were operative only when growth was started by light or gibberellins. The competitive effect of growth-retarding chemicals, light, and temperature were studied on many garden plants. Cathey (5) reported that B995 applied as a foliar spray limited internode elongation of china aster, marigold, petunia, salvia and zinnia at any daylength without delaying flowering appreciably.

According to Cathey (5), the relation between the flower-inducing substance produced in the leaves and translocated to the apical meristem was studied by Zeevaart on seedlings of Pharbitis nil Choisy, strain Violet. He suggested that the suppression of flowering by massive dosage of growth retardants was the result of inhibition of cell division in the plumule during the period when the floral stimulus was present. This prevented the expression of the stimulus in flower primordia.

Growth retardants were found to be active primarily on intact plants. The classical bio-assay for growth, such as Avena curvature test (19) using plant parts, often slanted the response toward an auxin interaction or a gibberellin antagonism. Kuraishi and Muir (19) and Wittwer and Tolbert (44) observed that CCC suppressed the growth of Avena coleoptile sections both in the presence or absence of indole-3-acetic acid (IAA). Gibberellin had little effect on the inhibitory action of CCC on Avena sections.

Lockhart reported that the growth retardants act as antigibberellins in a biological sense (25) and on the basis of his kinetic studies, in a biochemical sense (26).

According to Lockhart, they exerted their influence by reducing the activity of gibberellin in the growth system. He proposed that growth retardants should be considered as antimetabolites rather than as antigibberellins or antiauxins. Tolbert reported that the growth retardants were not analogues of any known substance, but they apparently showed competitive interaction that was distinguishable from independent effects with the naturally occurring growth substances.

IV. TEMPERATURE AND FLOWERING

Temperature provides another salient climatic cue for plants, a ready signal of seasonal changes. Several species are promoted or induced to flower by low temperature, especially many biennials and perennials. The initiation of flower formation by subjecting seeds, seedlings or bulbs to low temperature, is known as vernalization. Floral initiation, like other physiological processes, is determined by genotype. Once the plant reaches the physiological stage of readiness for flower initiation, the first noticeable morphological change indicating the transition of a vegetative meristem to a reproductive one is enhanced cell division in the central zone immediately below the apical part of the vegetative meristem. The ability of temperature treatment to shift earliness was noted long ago by Sachs (1972) and by Gassner in 1918 (23).

Cochran (10) studied the temperature effect on growth and fruit-setting in the pepper. Temperature had a marked effect on height of plants, bud formation, anthesis and development of fruit. It also had an effect on the number of blossoms formed as well as on the number and percentage of blossoms that set fruits. At the higher temperature (90°-100°F) the root system was smaller and the roots were shorter and less branched, than at the lower temperature (60°-70°F).

Went (41) reported that the size of the inflorescence varied very much with the night temperature; the warmer the night, the smaller the inflorescence and the flowers. Flower clusters were much larger at night temperatures of 8°, 13° or 16°C than at temperatures of 22°, 26.5° or 30°C.

A series of reports from the John Innes Horticultural Institution (England) (20, 21, 22), and a report of Verkerk (40) from the Horticultural laboratory of the Agricultural University in Wageningen (the Netherlands), have suggested that intervals of cold (13°C) exposure of tomato seedlings subsequent to cotyledon expansion as favorable to differentiation of greater number of flowers on the first cluster.

Wittwer and Teubner in 1955 (45) studied the importance of temperature during early stages of tomato seedlings development in the formation of a greater number of flowers as well as a fewer number of leaves preceding the first flower cluster.

Tiessen (37) reported that pepper plants exposed to cold treatment for 3 weeks at a night temperature of 12°-13°C produced more flowers than those grown at a night temperature of 19°-20°C.

Temperature influences fruit size in various crops. At a night temperature of 14°C, Went (41) obtained tomato fruit 3 times the size obtained at 26°C.

Carllson (4) found a high correlation between leaf and fruit size in different cultivars of pepper.

V. PIMIENTO INDUSTRY

The first true Spanish pimiento pepper in America was that raised by S. D. Riegel and Sons of Experiment, Spalding County, Georgia. Peppers belong to the same family (Solanaceae) as the egg plant and tomatoes, and are very sensitive to cold and require a long season to mature their fruit. A temperature of 24°-27°C should be maintained for 4-6 weeks after planting the seeds. At present, most of the pimiento acreage is established with transplants. Estimate of harvested acreage, production and grower value for peppers in the United States in 1976 by Marshall (27) indicates that Tennessee ranks second in the production of pimiento pepper (Table 2).

In Tennessee, pimiento peppers are largely concentrated in West Tennessee and are grown exclusively for the processing market. It is a high value crop which returns about $200 per ton. It was reported by Brooker in 1975 (3) that for many years, the canners of pimiento peppers purchasing in Tennessee have obtained 100 percent of their annual pepper

Table 2. Estimates of Harvested Acreage, Production and Grower Value of Pimiento, 1976.

	Pimiento (Processed)		
State	Harvested Acreage	Production (Tons)	Value ($1000)
Alabama	2,500	6,250	1,250
California	750	6,000	1,140
Georgia	5,000	14,690	3,500
Kentucky	250	1,000	180
Mississippi	2,200	6,630	1,325
Tennessee	2,200	7,700	1,540
U.S. Total	12,900	42,270	8,935

supply under contractual arrangements with growers. In 1968, the number of Tennessee and Kentucky growers was approximately 2,000; however, the percentage of Tennessee growers was estimated to be 60 percent of the total. Approximately 2,400 growers in Tennessee and Kentucky produced peppers for canners in 1974, and it was estimated that 15 percent of these growers were located in Tennessee. Therefore, the number of contracting pimiento pepper growers in Tennessee has decreased in both absolute and relative terms from 1968 to 1974.

CHAPTER III

MATERIALS AND METHODS

The objective of the experiment was to determine the influence of different temperatures and growth retardants on morphological characters and marketable yield at different stages of growth of plants. The experiment was conducted in the greenhouse as well as in the field. This approach consisted of two temperatures (i.e., 12°-13°C and 20°- 21°C), different concentrations of CCC and SADH, different modes of application and different stages of seedling growth at the time of treatment (Table 3).

Fifty seeds were planted in 17.8 cm azalea pots containing a soil mixture and kept under greenhouse conditions for germination. The pots were watered as required.

Seedlings were subjected to two different night temperatures immediately after the appearance of the first two true leaves for 3 weeks. A cool night temperature treatment of 13°C was maintained in the growth changer while a warm night temperature treatment of 21°C was set in the greenhouse. The first chemical treatment was applied when the first true leaf was 2.5 to 4.0 cm long. The second treatment was at the 4-6 leaf stage, and the third at the 6-8 leaf stage. CCC and SADH were applied at concentrations of 10^{-2} molar, 10^{-3} molar and 10^{-4} molar at 2, 4-6 and 6-8 leaf stages by

Table 3. Experimental Design for the Greenhouse Study Treatment.*

Treatment Number		Sub Plots
1	Control	
2	CCC	10^{-2} molar applied at 2 leaf stage
3	CCC	10^{-2} molar applied at 4-6 leaf stage
4	CCC	10^{-2} molar applied at 6-8 leaf stage
5	CCC	10^{-3} molar applied at 2 leaf stage
6	CCC	10^{-3} molar applied at 4-6 leaf stage
7	CCC	10^{-3} molar applied at 6-8 leaf stage
8	CCC	10^{-4} molar applied at 2 leaf stage
9	CCC	10^{-4} molar applied at 4-6 leaf stage
10	CCC	10^{-4} molar applied at 6-8 leaf stage
11	SADH	10^{-2} molar applied at 2 leaf stage
12	SADH	10^{-2} molar applied at 4-6 leaf stage
13	SADH	10^{-2} molar applied at 6-8 leaf stage
14	SADH	10^{-3} molar applied at 2 leaf stage
15	SADH	10^{-3} molar applied at 4-6 leaf stage
16	SADH	10^{-3} molar applied at 6-8 leaf stage
17	SADH	10^{-4} molar applied at 2 leaf stage
18	SADH	10^{-4} molar applied at 4-6 leaf stage
19	SADH	10^{-4} molar applied at 6-8 leaf stage
20	CCC	10^{-3} molar drench at 2 leaf stage
21	CCC	10^{-3} molar drench at 4-6 leaf stage
22	CCC	10^{-3} molar drench at 6-8 leaf stage

*Main plots: X-seedlings grown in growth chamber; night temperature 12°-13°C.

Y-seedlings grown in greenhouse; night temperature 20°-21°C.

a foliar spray to the point of the run-off stage, using a portable hand sprayer. In addition to these, 240 ml of 10^{-3} molar concentration of CCC was also applied at the 3-leaf stages as a soil drench. Different levels of concentrations were made immediately prior to application using water as a carrier and 0.5 percent Tween-20 as a surfactant.

After the temperature and chemical treatment was over and when plants were ready to transplant, they were transplanted into individual pots of 15.2 cm, using a recommended soil mixture and were arranged into 4 replications under controlled conditions in the greenhouse. Other plants from certain treatments were taken to the field (Table 4).

The field experiment was arranged in a split-plots design, with 4 replications. Main plot consisted of temperatures and subplot consisted of times and levels of application of retardants. The plot size was of one row 4.6 meters long. The distance between two rows was 106.7 cm apart and plants 45.7 cm apart in the row. Fertilizer rate and pesticide control were carried out as recommended for commercial production. Fertilization consisted of a granular application of 449 kg/ha. of 6-12-12 analysis fertilizer broadcast preplant as recommended by soil tests. Additional application of 13.6 kg/ha. nitrogen was made at the fruit-set stage. Supplemental irrigation was provided whenever necessary.

Table 4. Experimental Design for the Field Treatment.*

Treatment Number		Sub Plots
1	Control	
2	CCC	10^{-2} molar applied at 2 leaf stage
3	CCC	10^{-2} molar applied at 4-6 leaf stage
4	CCC	10^{-2} molar applied at 6-8 leaf stage
5	CCC	10^{-3} molar applied at 2 leaf stage
6	CCC	10^{-3} molar applied at 4-6 leaf stage
7	CCC	10^{-3} molar applied at 6-8 leaf stage
8	SADH	10^{-2} molar applied at 2 leaf stage
9	SADH	10^{-2} molar applied at 4-6 leaf stage
10	SADH	10^{-2} molar applied at 6-8 leaf stage
11	SADH	10^{-3} molar applied at 2 leaf stage
12	SADH	10^{-3} molar applied at 4-6 leaf stage
13	SADH	10^{-3} molar applied at 6-8 leaf stage
14	CCC	10^{-3} molar drench at 2 leaf stage

*Main plots: X-seedlings grown in growth chamber; night temperature 12°-13°C.

Y-seedlings grown in greenhouse; night temperature 20°-21°C.

I. DATA COLLECTION

Greenhouse and field data were collected separately.

Greenhouse Experiment

Height of plant. Plant heights were recorded at different intervals; the transplanting stage and 10 and 21 days after transplanting, respectively. Height of the plant was measured from the first lowermost true leaf to apical bud region.

Flowering and fruit set. At the time of the appearance of the first bud, i.e., 18 days, the total number of flower buds was recorded. One month later, the total number of fruit-set was counted for each plant.

Stem diameter. This was measured at the basal and the apical regions with a caliper. Base diameter was recorded between the first and second internode. Top diameter was recorded about 3.8 cm below the apical bud region.

Branches. Primary and secondary branches were recorded 21 days after transplanting.

Fruit count. Data for the total number of fruit and total number of ripe fruits were collected after 70 days (i.e., before first harvest) and again after 80 days.

At each harvest, ripe fruits were weighed and measured for length and diameter for each treatment. In addition to these, specific data were recorded regarding date of anthesis, date of fruit-set, and date of first sign of maturity or ripening of fruit.

<u>Field Experiment</u>

Field data collection consisted of measurement of total number of plants per plot, number of branches, number of basal shoots and number of fruit-set. Four plants selected at random were sampled for each measurement. Harvesting was done 80, 90 and 97 days after transplanting. Fruit diameter, length and weight were recorded at each harvest. Two fruits were selected for diameter and length measurement for each treatment.

II. STATISTICAL ANALYSIS

Analysis of variance was performed on all data and means were separated by Duncan's test. All statistical analyses were performed by the University of Tennessee computer and statistical analysis system (SAS).

CHAPTER IV

RESULTS AND DISCUSSION

Because of the many treatments (i.e., 22), results are usually presented and discussed, which are significantly different at the 5 percent level according to Duncan's Multiple Range Test. However, a few results are also presented which are not statistically different, but appear to be of special interest.

I. GREENHOUSE EXPERIMENT

As a result of treatment with growth retardants, internodal elongation in the sub-apical region was decreased (Figures 1, 2, 3). Development was not inhibited at the apical region, indicating no phytotoxic effect of the treatments. The treated plants appeared about half the size of control plants (Figures 2, 3). Treated plants showed more extensive development of root systems than untreated plants. Plants treated with CCC had larger root systems than those treated with SADH (Figures 3, 4, 5). The most extensive root system resulted from drench treatment with CCC (Figures 3, 4). The interaction of temperature with growth retardants CCC and SADH resulted in dark green-colored leaves (Figure 3). The leaves were thicker than those of control plants (34). Chemically treated plants appeared to show more resistance to

Figure 1. Retardation of growth from an application of CCC.

Figure 2. Major effect of growth retardants on internodal elongation.

Figure 3. Effect of growth retardants on the development of root system and chlorophyll.

Figure 4. Effect of CCC on the development of root system.

Figure 5. Effect of SADH on the development of root system.

water stress. Cathey (5) showed similar kinds of results and reported that color was directly related to the action of the growth retardants and not to mineral nutrition. Foliar application of all growth retardants at all concentrations enhanced the green color of foliage. The soil drench treatment gave the same response.

Table 5 shows the plant height at transplanting (i.e., 21 days), and 10 days later. Table 6 also presents the height of plants at transplanting, and 21 days later. The mode of collecting data differs between Tables 5 and 6. Data presented in Table 6 are the results of duplication of certain treatments to confirm the retardant effects of CCC and SADH on pimiento pepper. It was determined that the mode of collecting data for plant height in Table 6 was more accurate than for Table 5. Foliar application of 10^{-3}M CC at the 2-leaf stage was significantly more effective than the drench treatment in controlling the plant height (Table 6). Concentration of 10^{-3}M CCC has stronger effects than 10^{-3}M SADH at 2-leaf stage, but the reverse was true at 4-6 leaf stage. It was observed that application of these growth-retarding chemicals was more effective at the early stage of a plant's growth, i.e., 2-leaf stage (Table 6, Treatments Nos. 3, 4, 11). In general, nearly all the chemical treatments, foliar as well as drench, were effective in limiting plant height. The action of these growth-retarding substances was specific on internodal elongation

Table 5. Effect of CCC and SADH on Pimiento Plant Height from Lowermost True Leaf to Apical Bud Region.

Treatment	Concentration	Leaf Stage	Height at Transplant Stage cm	Height after 10 Days cm
1	Control	-	8.0 bcd[z]	12.0 abcd
2	10^{-2}M CCC	2	6.1 ef	11.0 cde
3	10^{-2}M CCC	4-6	5.5 f	9.7 e
11	10^{-2}M SADH	2	7.1 de	12.2 abcd
12	10^{-2}M SADH	4-6	5.9 ef	9.5 e
20	10^{-3}M CCC-D	2	6.7 de	11.5 bcde
21	10^{-3}M CCC-D	4-6	7.1 de	11.0 cde
22	10^{-3}M CCC-D	6-8	9.9 a	13.0 abc

[z]Means separated by Duncan's Multiple Range Test, 5 percent level.

D = Drench.

Table 6. Effect of CCC and SADH on Pimiento Plant Height from Cotyledon Leaf to Apical Bud Region.

Treatment	Concentration	Leaf Stage	Height at Transplant Stage cm	Height after 21 Days cm
1	Control	-	22.2 a[z]	29.7 a
2	10^{-2}M SADH	2	14.5 ef	23.0 ef
3	10^{-3}M SADH	2	15.5 de	25.9 cd
4	10^{-4}M SADH	2	12.5 g	23.9 def
5	10^{-2}M SADH	4-6	15.7 de	24.8 def
6	10^{-3}M SADH	4-6	15.9 de	27.5 bc
9	10^{-3}M SADH	6-8	14.8 e	23.4 ef
11	10^{-3}M CCC	2	13.0 fg	23.6 ef
13	10^{-3}M CCC	4-6	18.0 c	27.7 bc
14	10^{-4}M CCC	4-6	20.1 b	28.6 ab
16	10^{-3}M CCC-D	2	17.0 cd	25.0 de

[z]Means separated by Duncan's Multiple Range Test, 5 percent level

D = Drench.

since the other parts of the plants were not noticeably affected (Figures 1, 2, 3).

Tolbert reported similar results working with the effect of CCC on wheat plants (38). Similar types of results were also presented by Yadava while working with B995 on tobacco plants (46). He reported that effectiveness of B995 differed according to the concentration of the solution applied. Stem length and total height of the tobacco shoots showed significant differences as compared to untreated plants. Application of CCC and SADH appear useful in the mechanical transplanting. The possibility exists that application of CCC and SADH at the seedling stage to pimiento plants would overcome the problem of oversized transplants, which often develops during an unfavorable season. A related type of research was conducted by Dempsey(1972) on pimiento transplant performance after topping at the Georgia Experiment Station. His primary research interest was to determine the subsequent effects upon growth and yield of topping oversized pimiento transplants. He found that oversized pimiento transplants (20 inches), after topping to 12 or 16 inches in height, produced higher yields of marketable red ripe fruits than transplants not topped or topped to 8 inches in height.

Growth retardants apparently promote flowering by modifying activity in the cambium. This causes the production of abnormal types of cells in the xylem and the disappearance of schlerenchymatous cells next to the cortex. The limitation on growth of vegetative parts alters the metabolism and creates conditions favorable to flower initiation (5). Table 7 shows the data for the flowering and fruiting behavior for different treatments. As expected (35, 43, 44, 46), there was a significant increase in the number of flower buds (21 days) with both foliar and drench applications of these growth retardants. The highest number of flower buds was recorded by treatment number 3 (i.e., 10^{-2}M CCC at the 4-6 leaf stage). Treatments 2, 3, 11, and 22 gave significantly higher numbers of flower buds than control plants. Foliar application of CCC was more effective than SADH and drench applications in inducing higher numbers of flower buds. The first sign of appearance of flower buds was recorded 11 days from transplanting (Figure 6). Promotion of earlier flowering was noticed by the following treatments: (2) 10^{-2}M CCC at the 2-leaf stage (13°C), (b) 10^{-2}M CCC at the 2-leaf stage (21°C), (c) 10^{-3}M CCC drench at the 4-6 leaf stage (13°C), and (d) 10^{-3}M CCC drench at the 4-6 leaf stage (21°C). Control plants showed no sign of flower buds at this time (Figure 7). These results indicate the promotive effect of CCC on the earlier development of flower buds of treated pimiento pepper plants. It can also be seen that growth retardants did not inhibit or affect the growing point, i.e., the apical region, but their major influence was on sub-apical regions. Earlier

Table 7. Effect of CCC and SADH on Average Number of Flower Buds, Number of Blossoms and Fruit Set of Pimiento Plants after 21 Days and 30 Days.

Treatment	Concentration	Leaf Stage	Flower Buds 21 Days	Number of Blossoms	Fruit Set 30 Days
1	Control	-	15.2 c[z]	1.6 cd	0.2 e
2	10^{-2}M CCC	2	21.7 ab	3.0 abc	1.1 bcde
3	10^{-2}M CCC	4-6	23.9 a	2.8 abc	2.5 a
11	10^{-2}M SADH	2	22.1 a	3.3 ab	1.5 abcd
12	10^{-2}M SADH	4-6	19.0 bc	3.4 a	0.4 de
20	10^{-3}M CCC-D	2	17.7 bc	2.8 abc	0.6 cde
21	10^{-3}M CCC-D	4-6	18.2 bc	1.8 bcd	1.9 ab
22	10^{-3}M CCC-D	6-8	21.6 ab	2.6 abc	1.7 abc

[z]Means separated by Duncan's Multiple Range Test, 5 percent level.

D = Drench.

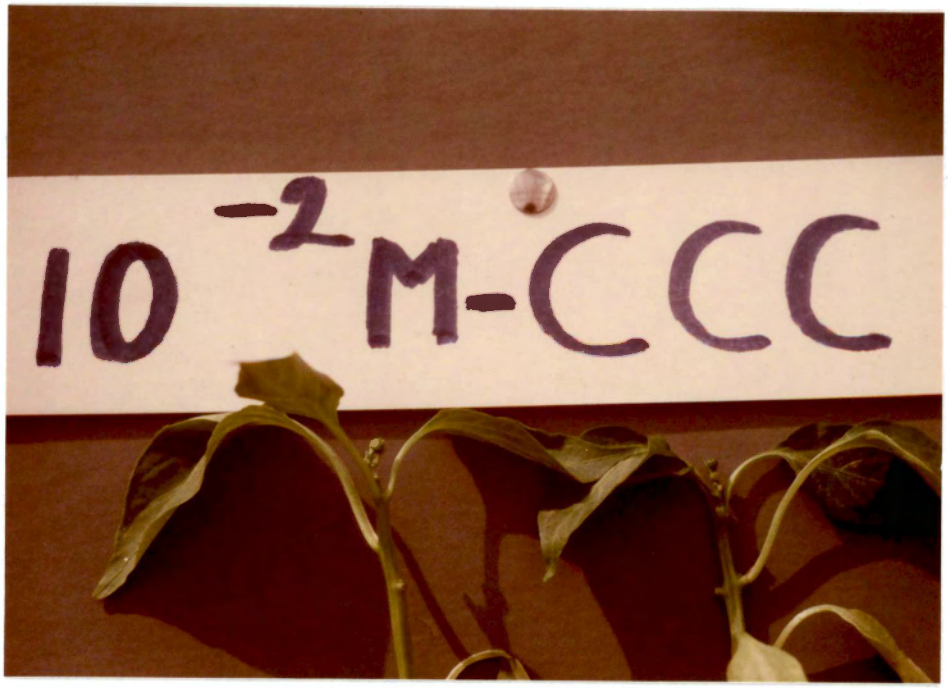


Figure 6. Effect of CCC on the development of early flower bud.

Figure 7. A control plant showing apical region with no response to the development of flower bud.

application (i.e., 2-leaf or 4-6 leaf) of these growth retardants was an important factor as differentiation of flower primordia in pimiento under normal day length (9) takes place about 23 days after the seedling emerges.

Besides an increase in the number of flower buds, a marked effect on the flowering and fruiting was also noticed. The first sign of blossom was recorded 18 days after transplanting. The following treatments showed the first blossom in greenhouse tests: (a) treatment 20 (13°C), (b) treatment 21 (13°C and 21°C), (c) treatment 22 (13°C and 21°C). These were followed by (a) treatment 8 (13°C) and (b) treatments 5, 6, 9, and 10 (21°C).

Table 7 indicates that the highest number of blossoms were found in treatments 2, 11, and 12, which were significantly higher than in the control plants. The indication of first fruit set was noticed by petal fall after 22 days after transplanting. Temperature as well as temperature-retardant interaction effect did not show any significant difference in fruit set. The highest number of fruit set was recorded with the application of 10^{-2}M CCC at the 4-6 leaf stage which was significantly different from the control plants (Table 7). As compared to control plants, application of CCC seemed to be more effective than SADH in increasing fruit set.

Several researchers have shown that there was an increase in the stem diameter of chemically treated plants. Data presented in Table 8 can be supported by Scherff's investigation with bean stem (34), where he showed that increase in stem diameter was due to the stimulation of cell production in cambium which was followed by a delay in cell differentiation and an increase in cell volume of the parenchymatous cells.

During the present investigations, transverse sections of chemically treated plants showed an increase in the volume of parenchymatous pith cells and an increase in the number of conducting tissues (data not presented). Plants treated with CCC showed about 6-7 more rows of conducting tissues than control plants. The data presented in Table 8 show the significant differences between treated and untreated plants (base diameter) and it can be seen that CCC was more effective than SADH in increasing the diameter of the stem. Treated pimiento pepper plants with increased diameter, reduced height and well-developed root systems should have better stands in the field during unfavorable environmental conditions. In addition, an increase in 6-7 rows of conducting tissues might increase the area for absorption of nutrients from the soil. Several researches have suggested that growth retardants may influence the uptake, translocation and concentration of mineral nutrients in plants (30, 46).

Table 8. Increase in Diameter of Pimiento Stem with the Application of CCC and SADH.

Treatment	Concentration	Leaf Stage	Diameter of Stem Base (cm)	Diameter of Stem Top (cm)
1	Control	-	0.59 ef[z]	0.85 abc
2	10^{-2}M CCC	2	0.71 a	0.85 abc
3	10^{-2}M CCC	4-6	0.71 a	0.86 ab
11	10^{-2}M SADH	2	0.69 ab	0.87 a
12	10^{-2}M SADH	4-6	0.66 abc	0.82 abc
20	10^{-3}M CCC-D	2	0.63 cde	0.73 d

[z]Means separated by Duncan's Multiple Range Test, 5 percent level.

D = Drench.

The first sign of fruit maturity or ripening was noticed on June 26 by the 10^{-3}M CCC drench treatment. Table 9 shows the percentage of ripe fruits at the time of first harvest in the greenhouse. The highest percentage of ripe fruits at the time of first harvest was recorded by later application of the 10^{-3}M CCC drench treatment. In general, later applications of growth retardants was more favorable in ripening of fruit (Figure 8).

Table 10 shows the interaction effect of temperature and retardants on percentage ripening of fruit in the greenhouse. Fruits from seedlings grown at 13°C did not ripen as rapidly as fruits from seedlings grown at 21°C. Retardant-treated plants at both cool and warm temperatures showed a higher percentage of ripe fruit than control plants. In general, interaction of cool (13°C) temperature with CCC was more effective than with warm temperature.

II. FIELD EXPERIMENT

Early effects of temperature at the seedling stage seemed to have no significant effect on fruit set in the field, but chemical treatments with CCC and SADH significantly increased the number of fruit set (Table 11). Foliar application of CCC and SADH resulted in a significantly higher number of fruit set than drench treatment with CCC. Higher concentrations of CCC and SADH gave better results than the lower concentrations.

Table 9. Effect of CCC and SADH on Percentage Ripening of Pimiento Fruit at First Harvest in Greenhouse (i.e., 70 Days).

Treatment	Concentration	Leaf Stage	Total Fruits Per Plant	Total Ripe Fruits Per Plant	Ripened Fruits %
1	Control	-	4.7	0.1	2.1
2	10^{-2}M CCC	2	5.6	0.9	16.1
3	10^{-2}M CCC	4-6	4.9	0.9	18.4
9	10^{-4}M CCC	4-6	5.2	0.6	11.5
11	10^{-2}M SADH	2	4.7	0.9	19.1
12	10^{-2}M SADH	4-6	5.2	0.2	3.8
16	10^{-3}M SADH	6-8	4.4	0.9	20.4
20	10^{-3}M CCC-D	2	4.5	0.5	11.1
21	10^{-3}M CCC-D	4-6	5.5	0.7	12.7
22	10^{-3}M CCC-D	6-8	4.2	1.0	23.8

D = Drench.

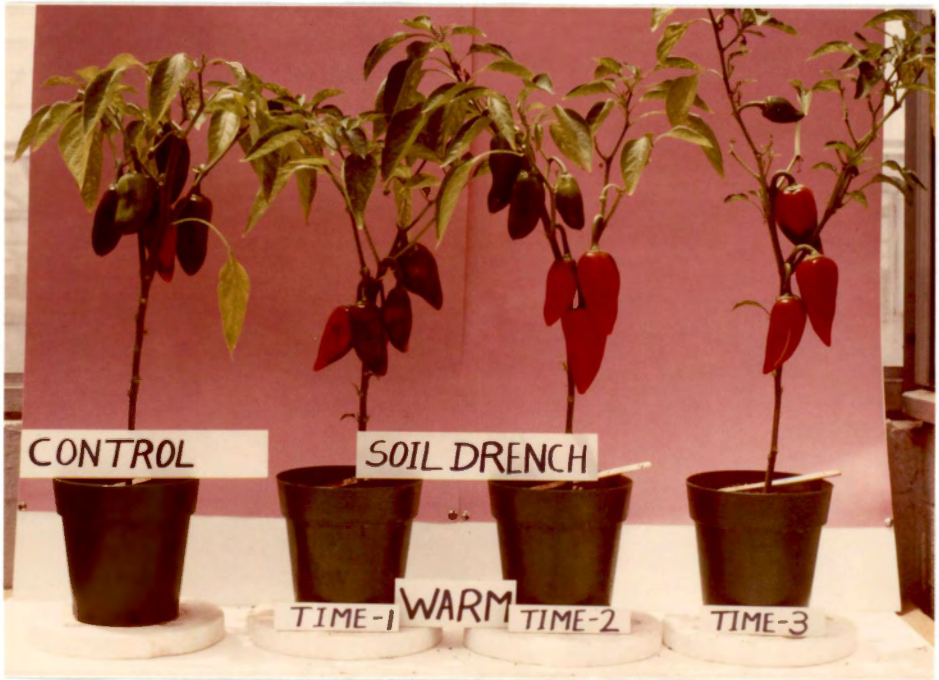


Figure 8. Earlier fruit ripening with the application of growth retardant.

Table 10. Interactive Effect of Temperature and CCC and SADH on Percentage Ripening of Pimiento Fruit at First Harvest in Greenhouse (i.e., 70 Days).

Treatment	Concentration	Leaf Stage	Total Fruits		Ripe Fruits		% Ripe Fruits	
			Cool	Warm	Cool	Warm	Cool	Warm
1	Control	-	4.7	4.7	0.0	0.2	0.0	4.2
2	10^{-2}M CCC	2	5.0	6.2	1.0	0.7	20.0	11.3
3	10^{-2}M CCC	4-6	5.0	4.7	1.2	0.5	24.0	10.8
9	10^{-4}M CCC	4-6	5.0	5.5	0.2	1.0	4.0	18.2
11	10^{-2}M SADH	2	5.0	4.5	0.5	1.2	10.0	26.7
12	10^{-2}M SADH	4-6	5.2	5.2	0.5	0.0	9.6	0.0
16	10^{-3}M SADH	6-8	4.5	4.2	0.5	1.2	11.1	28.6
20	10^{-3}M CCC-D	2	4.7	4.2	1.0	0.0	21.3	0.0
21	10^{-3}M CCC-D	4-6	5.7	5.2	0.7	0.7	12.3	13.5
22	10^{-3}M CCC-D	6-8	4.7	3.7	1.2	0.7	25.5	18.9

D = Drench.

Table 11. Fruiting Responses of Pimiento Pepper with CCC and SADH in Field.

Treatment	Concentration	Time of Application	Fruit Set
1	Control	-	2.6 bc[z]
2	10^{-2}M CCC	2 leaf	3.5 ab
3	10^{-2}M CCC	4-6 leaf	3.2 abc
6	10^{-3}M CCC	4-6 leaf	3.3 ab
9	10^{-2}M SADH	4-6 leaf	3.5 ab
10	10^{-2}M SADH	6-8 leaf	4.0 a
14	10^{-3}M CCC-D	2 leaf	2.2 c

[z]Means separated by Duncan's Multiple Range Test, 5 percent level.

D = Drench.

Table 12 shows fruit diameters at the time of first harvest (i.e., after 80 days). Foliar, as well as drench, applications of CCC and SADH showed no significant effect on diameter of fruits. Diameter is one of the important grading criteria for pimiento pepper, with 4 cm being about the minimum acceptable for processing markets. Therefore, at harvest, specific attention was given to diameter of fruits. Fruits less than 3.8 cm were rejected in considering marketable yield. Temperature showed significant differences on fruit diameter in the field. Cool temperature (13°C) at the seedling stage and also interaction with retardants resulted in fruits with smaller diameter (Table 12). It might be pointed out that cool temperature (13°C) did not effect or decrease the diameter of fruit to such an extent that it would effect commercial grading of marketable pimiento fruits.

There was no significant effect of temperature and growth retardants on length of marketable fruit. Apparently, fruits obtained as a result of interaction of cool temperature (13°C) and CCC and SADH had slightly more length than those obtained with seedlings grown at a warmer temperature (21°C) (Table 13). The effect of the growth retardants CCC and SADH on maturation of early marketable yield are presented in Table 14. Normally, pimiento pepper fruits ripen about 90 days after transplanting. In the present investigations, it

Table 12. Interactive Effect of Temperature and CCC and SADH on Diameter of Marketable Fruit of Pimiento Pepper.

			Diameter of Fruit (cm) Temperature	
Treatment	Concentration	Time of Application	Cool (13°C)	Warm (21°C)
1	Control	-	4.7	5.2
2	10^{-2}M CCC	2 leaf	4.8	5.0
3	10^{-2}M CCC	4-6 leaf	4.9	5.1
8	10^{-2}M SADH	2 leaf	4.7	5.1
11	10^{-3}M SADH	2 leaf	4.9	4.6
12	10^{-3}M SADH	4-6 leaf	4.8	5.0
14	10^{-3}M CCC-D	2 leaf	4.8	4.9

D = Drench.

Table 13. Interactive Effect of Temperature and Growth Retardants CCC and SADH on Average Length of Marketable Fruit of Pimiento Pepper.

Treatment	Concentration	Time of Application	Average Length of Fruit (cm) Temperature	
			Cool (13 C)	Warm (21 C)
1	Control	-	9.0	9.1
2	10^{-2}M CCC	2 leaf	9.7	8.6
3	10^{-2}M CCC	4-6 leaf	9.0	8.7
4	10^{-2}M CCC	6-8 leaf	9.4	8.7
7	10^{-3}M CCC	6-8 leaf	9.9	9.1
8	10^{-2}M SADH	2 leaf	9.6	8.9
11	10^{-3}M SADH	2 leaf	9.3	9.2
12	10^{-3}M SADH	4-6 leaf	9.6	9.0
14	10^{-3}M CCC-D	2 leaf	9.5	8.7

D = Drench.

Table 14. Effect of CCC and SADH on Early Marketable Yield of Pimiento Pepper (80 Days).

Treatment	Concentration	Time of Application	Total Number Ripe Fruits per Plot	Weight of Ripe Fruits per Plot kg.	Early Marketable Yield MT/ha
1	Control	-	6.5 c	0.4 b[z]	0.7
2	10^{-2}M CCC	2	14.6 a	0.8 a	1.8
3	10^{-2}M CCC	4-6	13.6 ab	0.8 a	1.6
8	10^{-2}M SADH	2	11.7 abc	0.7 ab	1.3
11	10^{-3}M SADH	2	8.5 bc	0.4 b	0.9
12	10^{-3}M SADH	4-6	9.0 bc	0.6 ab	1.1
14	10^{-3}M CCC-D	2	12.0 ab	0.7 ab	1.3

[z]Means separated by Duncan's Multiple Range Test, 5 percent level.

D = Drench.

was observed that fruits from treated plants started ripening about 15-16 days earlier than normal ones. The first harvest was on the eightieth day after transplanting. Treated plants showed significantly higher early yield as compared to control plants (Table 14). This correlates with the results obtained in greenhouse trials where treated plants resulted in earlier ripening and a greater number of flower buds and fruits set. Highest numbers of ripe fruits were recorded from treatments 2 and 3 (Table 14). Temperatures experienced at the seedling stage seemed to have no significant effect on early fruit yield.

From the data presented in Table 15, it can be seen that the application of retardants at the seedling stage (2-leaf) resulted in a higher total yield of pimiento pepper (treatments 2, 3, 11). Average marketable weight of fruit and total yield were not significantly affected by different temperatures or growth retardants. Temperature had a slight effect in reducing the total yield (Table 16). Warmer temperature plots (21°C) had a greater yield (13.9 MT/ha) as compared to cooler temperature plots (10.5 MT/ha), but the interaction of cool temperature with retardants at the seedling stage slightly increased the total marketable yield as compared to plants grown at warmer temperature (Table 16).

Table 15. Effect of CCC and SADH on Average Weight of Marketable Fruit, and Total Marketable Yield of Pimiento Pepper.

Treatment	Concentration	Time of Application	Average Marketable Weight of Fruit per Plant gm	Total Marketable Yield of Ripe Fruit MT/ha	Grand Total Marketable Yield MT/ha
1	Control	-	45	7.4	12.1
2	10^{-2}M CCC	2 leaf	46	8.3	13.0
3	10^{-2}M CCC	4-6 leaf	49	8.5	13.0
8	10^{-2}M SADH	2 leaf	48	7.6	11.9
11	10^{-3}M SADH	2 leaf	47	7.6	13.2
12	10^{-3}M SADH	4-6 leaf	49	6.7	11.4
14	10^{-3}M CCC-D	2 leaf	49	7.8	13.0

D = Drench.

Table 16. Interactive Effect of Temperature and Growth Retardant on Total Yield of Pimiento Pepper.

Treatment	Concentration	Time of Application	Total Marketable Yield of Ripe Fruit MT/ha		Grand Total Marketable Yield MT/ha	
			Cool	Warm	Cool	Warm
1	Control	-	5.8	9.0	10.5	13.9
2	10^{-2}M CCC	2 leaf	8.7	8.3	13.0	12.8
3	10^{-2}M CCC	4-6 leaf	8.7	8.5	13.4	12.5
8	10^{-2}M SADH	2 leaf	8.1	6.9	12.5	11.2
11	10^{-3}M SADH	2 leaf	6.9	8.1	13.2	13.2
12	10^{-3}M SADH	4-6 leaf	6.3	6.9	9.8	12.5
14	10^{-3}M CCC-D	2 leaf	7.4	8.3	13.0	12.8

D = Drench.

CHAPTER V

SUMMARY AND CONCLUSIONS

The present investigation consisted of a study of night temperatures, 13°C or 21°C, and rate and times of application of the growth retardants, CCC and SADH, on pimiento pepper seedlings to determine at what physiological stage they are most sensitive, and if these factors influence flowering, fruit set, fruit ripening, yield and subsequent growth of the pimiento plant.

Night temperatures of 13°C and 21°C seemed to have no significant effect on pimiento seedlings, but the interaction of temperature with growth retardants showed significant effects on height of transplants, number of flower buds, blossoms and fruit set, stem diameter and early yield in the field.

One of the first differences noted relative to the effect of these chemicals on the pimiento plants was an enhancement of green coloration of foliage. Chemically treated plants were shorter and stockier, with a more extensive root system than found with untreated plants. The highest concentration of roots was shown by plants treated with CCC at the higher concentration. Early application (i.e., 2-leaf stage) of CCC or SADH was most effective in controlling the height of transplants. The major retardant effects of CCC and SADH were noticed in the sub-apical region where internodal elongation was retarded without having any apparent phytotoxic effect on further growth of pimiento seedlings.

Control of vegetative growth by the interaction of temperatures and growth retardants mainly during the early stages of plant growth had significant influence on the subsequent development of earlier and increased number of flower buds and fruits set. Foliar application of 10^{-2}M CCC resulted in the highest number of flower buds and fruits set.

An increase in stem diameter was confirmed by the anatomical observation which showed that the chemically treated plants had an increase in number of xylem tissues and an enlarged pith region, as compared to control plants. The greatest stem diameter was observed with the foliar application of CCC at an earlier stage of pimiento seedling growth (i.e., 2-leaf stage) and was more effective than drench treatment with 10^{-3}M CCC.

In the greenhouse study, a higher percentage of ripe fruits was obtained from treated plants. A drench treatment of 10^{-3}M CCC resulted in earlier ripening and a higher percentage of ripe fruits, as compared to the control plants. An interaction of cool temperature with CCC as a foliar and drench application was more favorable in producing a higher percentage of ripe fruits. Interaction of night temperature (13°C or 21°C) and growth retardants (CCC and SADH) did not show significant influence on the diameter and length of fruit.

Foliar, as well as drench, applications of CCC and SADH resulted in earlier fruit ripening and a significantly higher yield in the field. A foliar application of 10^{-2}M CCC at the 2-leaf stage gave the highest early yield among all the treatments. Seedlings grown under warm temperature gave a higher total yield than seedlings grown under cool temperatures. Plants having an interaction effect of cool temperature with CCC or SADH resulted in higher total yield in the field. Application of CCC was more effective than SADH.

From this investigation, it could be possible to produce transplants with thicker leaves and stems, shorter internodes and darker green foliage, which would flower earlier than normal. This might overcome the problem of oversized pimiento transplants which develop during unfavorable seasons. Transplants with increased conducting tissue and more extensively developed root systems would probably result in a better crop stand in the field. Since they would be able to better transport nutrients and other growth materials, this might result in a higher nutritive value of pimiento fruits. Since interaction of cool temperatures and the growth retardants, CCC or SADH, did not result in any phytotoxic effects on the pimiento plant growth and ultimate yield, it may be possible to grow pimiento seedlings in a cooler area than they are currently grown. This might overcome the problem of importing the transplants from the warmer areas and possibly lower the cost of transplant production. The early application of CCC (at the 2-leaf stage) may produce a significantly higher early marketable yield by 10-12 days.

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