To the Graduate Council:

I am submitting herewith a thesis written by John Oscar Best entitled "Effects of Ethephon on Sex Expression and Yields of Summer Squash." 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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EFFECTS OF ETHEPHON ON SEX EXPRESSION AND YIELDS OF SUMMER SQUASH

A Thesis

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ABSTRACT

The plant growth regulator 2-chloroethylphosphonic acid (ethephon) was applied to four summer squash cultivars to determine its effects on yield and flowering habits. Four ethephon rates, three application regimes, and two locations were used in field studies. Flowering patterns were examined for two cultivars under early fall greenhouse growth conditions. Four ethephon rates and four stages of plant growth for ethephon application were utilized in the greenhouse study.

Ethephon levels of 150, 300, and 600 ppm were tested in field studies. The 150 ppm level resulted in the highest yields with the least amount of quality reduction as defined by percentage of fruit marketable. The 600 ppm level resulted in the highest percentage of unmarketable fruit, especially for Zucchini cultivars. Fruit quality was lowered by inadequate pollination, and supplemental pollen sources planted near ethephon treated plants helped alleviate the problem. Average fruit weight was lowered by ethephon for about two weeks after treatment.

In field studies, ethephon at the 150 ppm rate applied at the three-leaf stage resulted in higher early yields than did the control in all cultivars. 'Early Prolific' (a yellow open-pollinated cultivar), 'Dixie' (a yellow hybrid cultivar), 'Aristocrat' and 'Senator' (Zucchini cultivars) exhibited early yield increases of 540, 58, 51, and 150 percent respectively with the 150 ppm, three-leaf stage ethephon treatment. Only Senator exhibited a season total yield increase (32 percent)

resultant from ethephon treatment. Ethephon treatment resulted in an increase in total fruit number but not total yield for Early Prolific.

Split application of 150 or 300 ppm ethephon were no more successful in increasing yields than were single, three-leaf stage applications of these treatments. Plants treated with split applications tended to distribute yields throughout the season rather than concentrating them at the early part of the harvest period, thereby exhibiting a yield pattern similar to that of control plants.

Ethephon levels of 75, 150, and 300 ppm resulted in about the same total numbers of pistillate flowers as did the control for either Early Prolific or Dixie plants grown under early fall greenhouse conditions. However, due to a shortage of staminate flowers, all ethephon treated plants had significantly fewer pollinated pistillate flowers than did control plants. Numbers of pistillate primordia which formed on plants but aborted prior to reaching the flowering stage were 307 to 382 percent higher for Early Prolific plants treated with 75 and 300 ppm ethephon respectively than for control plants. Plants treated with ethephon at the first flower stage had more fruit formed parthenocarpically than did control plants or those treated at the seed stage (seeds were soaked in ethephon for 30 minutes prior to planting) or first fruit stage.

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CHAPTER I

INTRODUCTION

Agricultural scientists are confronted with the formidable task of feeding a hungry world with constantly shrinking acreages of available cropland. In their search for ways to meet this goal, they have begun to intensively investigate a group of chemicals collectively known as "plant growth regulators." The term arises from the ability of these compounds to affect plant growth and development in some way. They are distinguished from plant hormones in that they do not normally occur in plants. One such growth regulator is 2-chloroethylphosphonic acid (ethephon). The compound was developed by AM-CHEM Products, Inc. and was released for investigative use under the trade name "Ethrel." To date, many plant processes have been found to be affected by ethephon. These include fruit ripening, senescence, abcission, and sex regulation. The effects of ethephon on sex regulation will be the subject of this investigation.

Since 1968, considerable research has been conducted concerning the use of ethephon on various crops of the family Cucurbitaceae. Researchers have found that the chemical shifts sex expression balance toward femaleness. This characteristic has already been capitalized upon in the production of hybrid seed. There has been some success in increasing cucumber yields. However, most of the yield increases have been only for the early part of the season. Total yield increases have

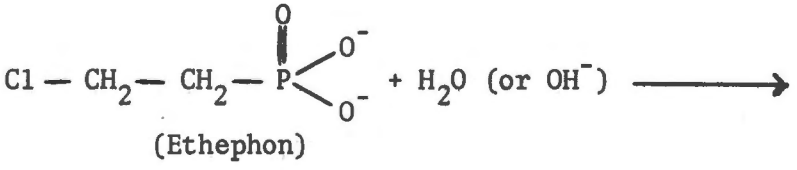
been marginal in most instances. Little information is available concerning the use of ethephon on squash, especially with respect to effects on yield. The objective of this research was to investigate the effects of ethephon on summer squash flowering habits and yield. The study utilized various ethephon rates, ethephon application regimes, and summer squash cultivars. The influence of ethephon on summer squash sex expression was studied under both field and greenhouse conditions.

CHAPTER II

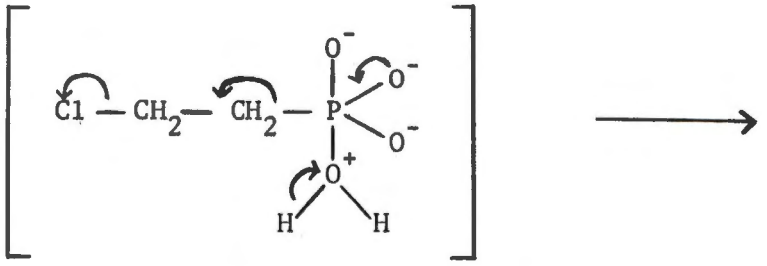
LITERATURE REVIEW

The Chemical Nature of Ethephon

Ethephon is a synthetic chemical first marketed in 1967 by AM-CHEM Products, Inc., Ambler, Penn. It exerts its effect by gradually releasing ethylene as a decomposition product in living plant tissue (30,33). The mechanism for ethylene evolution has been debated and various theories have been proposed (30,33). There appears to remain some question as to the actual mechanism, but the theory proposed by Yang has been accepted in a recent text on plant growth regulators (31). This theory is briefly outlined by the following equation and involves a nucleophilic attack by H_2O or OH^-.



(Ethephon)



$$Cl^- + CH_2{=}CH_2 + H_2PO_4^- \text{ (or } HPO_4^{=})$$

Yamaguchi et al. (32) studied the fate of ethephon when applied to summer squash, cucumber, and tomato plants. In squash, ethephon was injected into the petioles. The rate of production of total ethylene reached a peak during the first day, then rapidly declined to a low level after three days. Over 20 percent of the applied ^{14}C-ethephon was converted to ethylene the first day and slightly less than 15 percent the second day. One day after the petiole injection, radioactivity in the squash plant was mainly ethephon. After two days, the presence of an unknown metabolite was noted. After six days, the radioactivity of the unknown metabolite at the injection site was greater than that of ethephon. All translocated radioactivity was in the form of the unknown metabolite. It is not known whether ethephon is converted to the unknown metabolite before, or after translocation. The presence of the unknown metabolite was not detected in either the cucumber or the tomato. Small, but measurable amounts of translocated radioactivity remained even after 14 days in tomato fruit and squash leaves and after 25 days in portions of the cucumber plant.

Ethylene, one of the final end products of ethephon decomposition, is now generally accepted as a plant hormone which affects many plant processes (31). These processes are involved in abcission, growth regulation, and fruit ripening. Burg et al. (4) studied many of the plant interactions in which ethylene appears to be involved. Some of their findings link ethylene to participation in the transcription and translation of the genetic code from DNA to RNA to protein. The compound also plays an integral part in cell growth and division through

association with auxins. These findings are constantly being supplemented with new research. They indicate, however, the many possibilities for involvement in the aforementioned plant processes.

Crops Affected by Ethephon

The myriad of crops affected by ethephon is large and continues to grow as results from new research are reported. The compound has already been labeled by the Environmental Protection Agency for use in promotion of early red coloring of apples, loosening of cherries for early harvest, hastening of filbert maturity, and acceleration of tomato ripening (2).

Ethephon Expression on Cucurbits

Since 1968, much research has been conducted concerning the use of ethephon in altering the sex expression of the many species of the family Cucurbitaceae. This portion of the literature review will be concerned with two of these species, Cucumis sativus (cucumber) and Cucurbita pepo (summer squash).

The investigation of ethephon as it influences sex expression was initiated at North Carolina State University in 1968. McMurray and Miller (14) applied ethephon to monoecious cucumbers (commonly exhibiting both pistillate and staminate flowers) and found that treated plants exhibited gynoecious characteristics (possessing only female flowers) for as many as 19 nodes. Ethephon appeared to have an additive effect since lower rates with multiple applications had the same effect as higher rates with single applications. Other investigators have since reported similar findings (6,7,11,13,19,20,22,25,27).

Lower et al. (13) studied the effects of ethephon applications at various stages of cucumber plant development. The chemical was applied as a 120 ppm foliar spray at either the 1, 2, 3, 4, 6, 8, 10, or 12 leaf stage. All treatments significantly reduced the number of staminate flowers. Treatments at the 2, 4, 6, 8, and 10 leaf stages significantly increased the number of pistillate flowers. Plants treated at the 1, 2, 3, 4, and 6 leaf stages exhibited only slight growth depression, while those treated at the 8, 10, and 12 leaf stages were severely stunted for about a week and suffered abortion of developing pistillate primordia. However, all of these latter treatments recovered and resumed flowering 15 to 18 days after treatment. This study produced no fruit yield information since flowers were counted but were not pollinated.

Some success has been achieved using ethephon as a soil treatment. Cantliffe and Robinson (5) applied the chemical to direct seeded cucumber plants at concentrations of 10, 25, and 50 ppm as a soil treatment. The 10 and 25 ppm rates showed no differences from the control. However, the 50 ppm rate significantly increased the number of pistillate flowers while significantly decreasing the number of staminate flowers. It is possible that the results would have been even more dramatic had higher concentrations been used. The researchers also applied ethephon to the soil in which plants at the two-leaf stage were transplanted. Rates of 125, 250, and 500 ppm all yielded higher numbers and higher percentages of pistillate flowers than did either the control plants of plants receiving foliar treatments of the same magnitude.

Ethephon has not been as extensively investigated for use on squash as it has for use on cucumbers, but there is considerable evidence to indicate that effects are quite similar for the two crops. Abdel-Gawad and Ketellapper (1) found that concentrations of 50, 100, and 250 ppm as foliar applications at the one-week-old stage caused formation of the first pistillate flower at node 1 compared to node 9 on the controls. They found also that a soil drench of 100, 250, or 500 ppm had a slight effect. Thompkins and Smay (28) treated two cultivars of summer yellow squash with ethephon at rates of 75, 150, and 300 ppm at the two to four-leaf stage (depending upon the cultivar) as a foliar spray. Flower counts conducted one week prior to the first harvest showed that the 300 ppm treatment had 170 to 194 percent more pistillate flowers than did untreated plants. This large increase in female flowers resulted in 25 to 63 percent higher early yields than were harvested from the control plants. Similar results with squash have been achieved by others (20). Responses to ethephon by both cucumbers and squash have been many and varied. Such responses indicate that expression of ethephon influence on these plants is largely affected by the genetic system in the plant which controls female tendencies (8).

Relationships Between Ethephon and Other Growth Substances

Ethephon has been investigated for use in combination with other chemicals. Gibberellins are plant hormones which control a number of plant growth characteristics. These include stimulation of growth, internode elongation (31) and occurrence of male flowers (18). These

characteristics appear to be basically opposite of those promoted by ethephon. There exists, therefore, the question as to whether ethephon acts to suppress GA (gibberellin) or whether the two compounds act independently. Rodriquez and Lambeth (21) found that ethephon enhanced growth stimulation by GA_3. This would suggest a synergistic relationship. Robinson et al. (19), however, found an apparent antagonistic relationship between the two compounds with respect to effects on flowering. Iwahori et al. (11) proposed that the relationship was actually not antagonistic but that the two compounds had different sites of action. This theory was supported by Abdel-Gawad and Ketellapper (1) who found that ethephon did not lower GA content. They suggested that ethephon did not act by inhibiting GA synthesis. All of these findings seem to indicate that there does, indeed, exist a relationship. The relationship, however, appears to be complex and will require much further investigation before it is thoroughly understood.

Freytag et al. (7) found that 2,3,5-triiodobenzoic acid (TIBA) applied to monoecious cucumbers at the first true-leaf stage resulted in predominantly staminate flowers. Ethephon yielded predominantly pistillate flowers. When applied together, the chemical produced the same results as did ethephon alone.

Rodriquez and Lambeth (21) found that 100 ppm ethephon in combination with 2000 ppm succinic acid-2,2 dimethyl hydrazide (SADH) produced plants as compact as those treated only with SADH and as female as those treated only with ethephon. The SADH retards stem elongation by preventing cell division in the subapical meristem, usually without affecting the apical meristem (31).

The growth regulator, 2-chloro-9-hydroxyfluorene-9-carboxylic acid (chlorflurenol), belongs to a group of compounds collectively called "morphactins" because of their ability to produce striking morphological changes (31). Cantliffe et al. (6) found that ethephon alone increased set of pistillate flowers in cucumbers but did not increase total yield over the control. However, ethephon combined with 50 ppm chlorflurenol significantly increased fruit set over the control because of parthenocarpic development promoted by the chlorflurenol.

Promising Uses of Ethephon on Cucurbits

A realization of the regulatory effects of ethephon on cucurbits arouses a desire to capitalize on these effects in enhancing crop yields and minimizing production costs. In the following paragraphs, some of the efforts exerted in achieving these goals will be examined.

The most promising use of ethephon on cucurbits to date is in the production of hybrid seed. Lower and Miller (12) applied ethephon at rates of 240, 480, and 960 ppm to eight cucurbit cultivars (including three Cucurbita pepo cultivars). These rates resulted in increases in both numbers and earliness of pistillate flowers. Pollinated flowers from the treated plants (using pollen from untreated plants) germinated readily and resultant seedlings appeared normal. The obvious advantage of using ethephon in seed production is the elimination of hand emasculation, thus lowering labor costs. Rudich et al. (22) found that staminate flower formation could be inhibited for three weeks using ethephon. This would be ample time for cross pollination to occur.

A rate of 250 ppm applied at the one-leaf stage and again at the three-leaf stage resulted in the most favorable results.

Robinson et al. (20) obtained results similar to those previously mentioned with cultivated cultivars, but found that ethephon was ineffective in inducing flowering in wild species of Cucurbita that were vegetative under the environmental conditions of the experiment. This, of course, would limit the use of ethephon in backcrossing and various other breeding techniques.

Ethephon has also been used in attempts to increase yields but with varied success. Cantliffe et al. (6) noted that ethephon alone did not increase total cucumber yields. Tompkins and Smay (28) found that ethephon did not increase total yields of summer squash but that early yields were significantly increased. Apparent advantages exist where early markets are superior. McMurray and Miller (15) found increased dollar per acre values for both early and total yields in three of four ethephon-treated cucumber cultivars. This increase was attributed both to increased numbers of fruit and to a higher percentage of optimum size fruit. With more fruit on the plants, maturity appeared to be slower and the fruit could be harvested at a more optimum stage of growth.

Effects of Ethephon on Quality

Ethephon does not appear to affect quality of cucurbit fruit to any significant extent. Miller et al. (16) evaluated pickles from cucumber plants treated with ethephon and found no differences in appearance, flavor, texture, firmness, bloater formation, or acceptability

of the product. The only difference noted was that fruit were shorter from treated plants than from untreated plants. Tompkins and Shulteis (27) similarly found no effects of ethephon on cucumber fruit quality and also noted a decrease in fruit size. This difference actually proves to be advantageous in that smaller fruit grade higher than larger ones.

Thompkins and Smay (28), in experiments with summer squash, found no differences in soluble solids, total solids, shear press readings, or color between fruit from plants treated with ethephon and fruit from untreated plants.

Flowering and Fruiting Habits of Summer Squash

"Summer squash" is a collective term used to identify several related cultivars in the botanical classification Cucurbita pepo. The summer squash are usually eaten in the very immature stage. Although most cultivars included in the category are yellow squash, Zucchini (an Italian vegetable marrow cultivar) will be included for convenience in the remainder of this study. Indeed, Zucchini is often referred to as a summer squash since it is popular in gardens in many sections of this country (29).

Squash flowers are yellow, imperfect, and normally occur singly in the axils of the leaves. The flowers are open for several hours and stigmas are receptive throughout this period (24). Placement of hives of bees near squash fields is recommended since squash flowers are exclusively insect pollinated (29). In many bushy types of squash,

pistillate flowers occur on the lower nodes of the plants (24). With hybrid cultivars, pistillate flowers often appear as many as eight to ten days before staminate flowers (17). Pollination difficulties are obvious since no source of pollen is present. Parthenocarpic development may compensate for lack of pollen in some instances. Globerson (9) found that Zucchini squash grown in greenhouses during the winter months developed parthenocarpically, but that such development did not occur in the summer months. Partial pollination caused ovary abortion in some fruit and a reduced growth rate in others. Other signs of inadequate pollination are fruit deformities and blossom-end rot. Ovary enlargement often occurs in unfertilized fruit, but the quality of these fruit is generally unacceptable (17).

CHAPTER III

MATERIALS AND METHODS

Since the primary objective of the experiment was to determine the general suitability of ethephon for enhancing summer squash yields, a rather broad approach was utilized. This approach involved using different types of summer squash, different ethephon concentrations, different stages of plant growth for ethephon application, and different application regimes. The experiment spanned two summers in the field and a period of three months of greenhouse study in the fall. The bulk of the experiment was conducted at the University of Tennessee Plant Sciences Farm at Knoxville. In addition, portions of the study were duplicated, with minor variations, at the Plateau Experiment Station at Crossville.

Cultivar Study

This part of the experiment was conducted at Knoxville in 1973 and at Crossville in 1974. Cultivars were selected which represented a crosssection of the major types of summer squash grown both commercially and in home gardens in Tennessee. At Knoxville these cultivars were: 'Dixie,' a summer yellow crookneck hybrid; 'Early Prolific,' an open-pollinated summer yellow straight-neck; and 'Aristocrat,' a Zucchini squash. The cultivars grown at Crossville were the same except for 'Aristocrat,' which was replaced by 'Senator,' another Zucchini cultivar.

Ethephon, formulation 68-240, was applied at rates of 0, 150, 300 and 600 ppm as a foliar spray to the point of runoff at the two-leaf stage. Applications were made with a portable hand sprayer. Solutions were mixed immediately prior to application using water as a carrier and "Tween 20" at a concentration of 0.05 percent as a surfactant.

Experimental design at both locations consisted of a split-plot arrangement with four replications. Main treatments were cultivars and subtreatments were ethephon rates. Each subplot consisted of one row 20 x 3.5 feet with plants spaced 18 inches apart in the row.

Application Regime Study

This study was conducted at Knoxville during the summer of 1974. Only one cultivar, Dixie, was used. This cultivar was selected because of the current trend toward using hybrids in commercial production (17). To compensate for the lack of early pollen in hybrid cultivars, a tendency compounded by ethephon, pollinator rows receiving no ethephon were planted adjacent to each treatment row. These pollinator rows were planted ten days prior to planting of the treatment rows to insure that pollen availability would not be a limiting factor.

Experimental design consisted of a split-split-plot arrangement with four replications. Main treatments were ethephon rates. Subtreatments were stages of application of the increments involved in each application regime. Sub-subtreatments were application regimes. Each sub-subplot consisted of a 10 x 4 foot section of row with plants

spaced 18 inches apart in the row. Data were recorded from the center five plants of the seven plant sub-subplots.

Three ethephon concentrations of 0, 150, and 300 ppm were used. Three different application regimes were used, consisting of a single ethephon application, application split into two equal parts, and application split into three equal parts. The split applications were spread in increments over the growing season. The single application treatment was applied at the three-leaf stage as was the initial increment for each of the split application treatments. Each of the remaining increments for the latter was applied at each of two different stages of plant growth. One of the stages occurred at the time fruit set resulting from the previous ethephon application was relatively complete. The other stage occurred at the time the majority of fruit resulting from the previous ethephon application had been harvested. In other words, the second split of the two-way treatment was applied to each of the aforementioned plant stages, and both the second and third splits of the three-way treatment were applied to each of these plant growth stages. Experimental design is explained diagrammatically in Figure 1.

Greenhouse Study

Two cultivars of summer squash were used, Dixie and Early Prolific. Ethephon rates of 0, 75, 150, and 300 ppm were used. The ethephon was applied to different groups of plants at various stages in their development. These applications consisted of a 30-minute seed soak

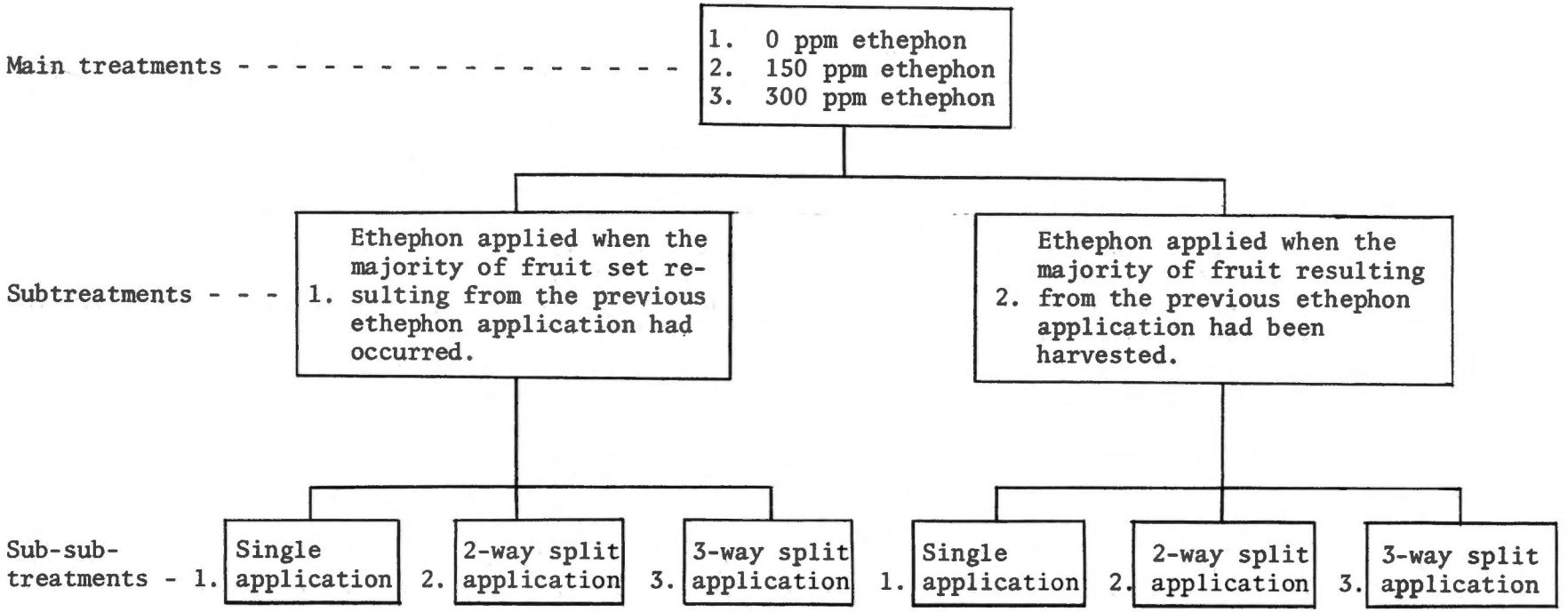


Figure 1. Experimental design for the 1974 application regime study.

prior to planting, a foliar spray at the three-leaf stage, a foliar spray at the time of first flower set, and a foliar spray at first fruit harvest.

The experimental design was a split-split-plot arrangement with two replications. Cultivars were main treatments, times of application were subtreatments, and levels of ethephon were sub-subtreatments. Each sub-subtreatment consisted of a single plant.

Cultural Practices

Cultural practices for all field studies were uniform throughout the experiment. Mechanical cultivation was used for weed control. Disease and insect control consisted of the use of recommended pesticides (3,10) as needed. Insecticides were used only when necessitated by large insect populations. Fertilization consisted of a granular application of 400 pounds 6-12-12 analysis fertilizer broadcast preplant as recommended by soil tests. Supplemental irrigation was provided for the application regime study at Knoxville in 1974.

Cultural practices for the greenhouse study were the same as for the field studies for disease and insect control. Plants were grown individually in 6-inch pots using soil as the growth medium and were trellised to facilitate the most efficient use of space. The growth period extended from September 27 to December 1. Plants were watered automatically using a tensiometer to monitor soil moisture conditions and an automatic timing device set to deliver a predetermined volume of water when soil water potential reached 0.5 atmospheres. All

flowers were hand pollinated using only pollen sources (staminate flowers) from the same plant as the pollen recipient (pistillate flowers) or from plants receiving identical ethephon treatments as the pollen recipient. This practice was designed to simulate a field situation where all plants in a location received identical treatment. This meant, of course, that many pistillate flowers received no pollen, especially those on some of the earlier ethephon treatments.

Data Collection

Field data collection consisted entirely of measurements of various yield components. These components included weight of marketable fruit, total number of fruit, and marketable number of fruit. At Crossville, time and labor which could be allocated to the experiment were limited, so data collection was confined to total yield and total number of fruit. Squash fruit in all field studies were harvested three times per week. Marketable fruit were limited to those which were between four and six inches in length (yellow cultivars) or six to ten inches in length (Zucchini cultivars), were physically sound, and exhibited, at most, only minor abnormal growth characteristics.

Greenhouse data collected were: number of marketable size fruit developed from pollinated flowers; number of fruit developed parthenocarpically; number of female flowers not pollinated; number of female flowers pollinated; number of days male flowers were available without females to receive pollen; number of days female flowers were available but had no males for pollen sources; total number of female flowers; and number of pistillate primordia not flowering.

Statistical Analysis

Analysis of variance was performed on all data, and means were separated by Duncan's New Multiple Range Test. All statistical analysis was performed by the University of Tennessee computer and Statistical Analysis System (SAS) developed by Anthony J. Barr and James H. Goodnight (23). In addition to field data mentioned in the section on data collection, values were also derived for and statistical analysis performed on percentage of fruit marketable and average weight per fruit. Because of some missing data in the Knoxville cultivar study, the SAS procedure would not give a valid analysis for average fruit weight for the season using the analysis of variance procedure. Consequently, this analysis was performed using the method of least squares (26).

CHAPTER IV

RESULTS AND DISCUSSION

Results of each of the areas of investigation described in the preceding chapter will be discussed. Special emphasis will be placed on the various yield components, and an attempt will be made to relate ethephon response as exhibited by these components to fruit quality as determined by percentage of fruit marketable and average fruit weight. Some aspects of pollination and fruit development will be discussed in the greenhouse study section. To expedite discussion of the field studies, weight of fruit harvested will be referred to as either "total yield" or "marketable yield" as the case may be.

Cultivar Study

Knoxville - 1973. Yields were high despite some periods when moisture stress was encountered. Total yields ranged from 17.4 tons per acre for Early Prolific to 23.5 tons per acre for Aristocrat (Table 1). Yield response to ethephon was highly significant in week 1, when all ethephon treated plants gave 75 to 88 percent higher yields than did control plants. There were no yield differences in week 2, but in week 3, plants treated with the 600 ppm ethephon rate yielded less than did either the controls or those plants receiving the 150 ppm rate. In week 4, yield of all ethephon treated plants fell below that of the controls. All ethephon treated plants except

TABLE 1

TOTAL WEIGHT OF SQUASH FOR 1973 KNOXVILLE CULTIVAR STUDY

Cultivar	Ethephon Level	Harvest Period					
		Week 1	Week 2	Week 3	Week 4	Week 5	Total
	ppm	----------Tons per acre----------					
Aristocrat	0	1.1 d*	6.7 bc	5.0 a	5.0 ab	6.5 a	24.3 a
	150	0.6 d	10.1 a	3.2 cde	4.4 ab	6.6 a	24.7 a
	300	1.0 d	10.6 a	2.4 e	5.7 a	4.5 b	24.2 a
	600	0.7 d	8.7 ab	2.5 e	4.9 ab	4.0 b	20.7 ab
Dixie	0	3.3 c	4.3 cde	4.7 a	4.1 bc	6.9 a	23.3 a
	150	5.2 a	2.4 ef	4.5 a	3.0 cd	5.7 ab	20.8 ab
	300	4.0 bc	1.9 ef	4.0 abcd	3.0 cd	5.4 ab	18.3 b
	600	4.7 ab	1.4 f	4.3 abc	2.3 de	5.2 ab	17.9 b
Early Prolific	0	0.5 d	5.4 cd	2.8 de	3.8 bc	4.7 b	17.2 b
	150	3.2 c	2.7 def	4.6 a	1.6 e	5.7 ab	17.8 b
	300	3.4 c	3.0 def	4.4 ab	2.0 de	5.4 ab	18.2 b
	600	3.5 c	3.1 def	3.3 bcde	2.4 de	4.1 b	16.4 b
Ethephon Level Mean							
	0	1.6 b	5.5 a	4.2 a	4.3 a	6.0 a	21.6 a
	150	3.0 a	5.1 a	4.1 a	3.0 b	6.0 a	21.1 ab
	300	2.8 a	5.2 a	3.6 ab	3.5 b	5.1 ab	20.2 ab
	600	2.9 a	4.4 a	3.4 b	3.2 b	4.5 b	18.4 b
Cultivar Mean							
Aristocrat		0.8 c	9.0 a	3.3 a	5.0 a	5.4 a	23.5 a
Dixie		4.3 a	2.5 b	4.4 a	3.1 b	5.8 a	20.1 a
Early Prolific		2.7 b	3.6 b	3.8 a	2.4 b	5.0 a	17.4 a

*Values in individual column segments separated by solid lines and followed by the same letters are not significantly different at the .05 level of probability.

those receiving the 600 ppm rate recovered to the level of the controls in week 5. Season totals reveal no differences among any of the treatments except for a slightly lower yield for the 600 ppm treated plants than for control plants. Aristocrat was slower in fruiting than the other cultivars, therefore ethephon response was delayed until the second week of harvest. In a commercial situation, the first week of harvest for Aristocrat would probably have been omitted so that ethephon response would have, indeed, occurred in the first harvest week. Otherwise, treatment response was relatively consistent among all cultivars (as is evidenced by the absence of cultivar x ethephon rate interactions). A significant cultivar x ethephon rate interaction in week 3 is attributed to a more rapid recovery from ethephon treatments by Early Prolific than by the other cultivars. In this case, plants treated at the 150 and 300 ppm ethephon levels again produced higher yields than did the controls in week 3, a response not exhibited by either of the other cultivars.

Total number of fruit in week 1 from all ethephon treated plants was significantly higher than from the controls (Table 2). There were no fruit number differences in week 2, but in week 3, plants treated at the 150 and 300 ppm rates were again higher in total fruit number than were the control plants or those receiving the 600 ppm rate. However, in week 4, all ethephon treatments resulted in a lower total fruit number than did the control. In week 5, only the 600 ppm treatment resulted in a lower fruit number than did the control. For the season total, 150 ppm ethephon treated plants were significantly

TABLE 2

TOTAL NUMBER OF SQUASH FOR 1973 KNOXVILLE CULTIVAR STUDY

Cultivar	Ethephon Level	Harvest Period					
		Week 1	Week 2	Week 3	Week 4	Week 5	Total
	ppm	Number per subtreatment					
Aristocrat	0	9 c*	29 bc	23 cd	18 d	27 e	105 e
	150	6 c	49 ab	18 cd	19 d	25 e	117 e
	300	8 c	53 a	18 cd	23 d	19 e	121 e
	600	5 c	43 abc	16 d	17 d	16 e	97 e
Dixie	0	45 b	49 ab	57 a	49 a	69 a	269 ab
	150	74 a	34 abc	63 a	36 bc	71 ab	277 a
	300	62 a	33 abc	61 a	35 bc	61 abc	251 abc
	600	68 a	25 c	58 a	28 cd	59 bc	237 bc
Early Prolific	0	8 c	50 ab	27 c	42 ab	47 d	172 d
	150	45 b	52 a	53 a	21 d	51 cd	222 c
	300	48 b	54 a	58 a	25 cd	51 cd	236 bc
	600	44 b	52 a	43 b	26 cd	46 d	211 c
Ethephon Level Mean							
	0	20 b	43 a	35 b	36 a	47 a	182 b
	150	41 a	45 a	45 a	25 b	49 a	205 a
	300	39 a	47 a	46 a	28 b	44 ab	203 ab
	600	39 a	40 a	39 b	23 b	40 b	181 b
Cultivar Mean							
Aristocrat		7 c	44 a	18 c	19 c	22 c	109 c
Dixie		62 a	35 a	60 a	37 a	65 a	258 a
Early Prolific		36 b	52 a	45 b	28 b	49 b	210 b

*Values in individual column segments separated by solid lines and followed by the same letters are not significantly different at the .05 level of probability.

higher in total number than either 600 ppm ethephon treated plants or the controls. All season total yield relationships (cultivar x ethephon level values) were essentially the same as for overall ethephon level values.

Marketable number of fruit (Table 3, Figure 2) was similar to both yield and total number of fruit for week 1. However, in week 2, all ethephon treated plants fell sharply below the control plants in marketable fruit number, a decline not present in the other yield components. Weeks 3, 4, and 5 showed marketable fruit number responses similar to those of total fruit number, but season total response was similar to that of total yield - only the 600 ppm ethephon rate depressed total marketable number.

Some of the differential responses of yield, total fruit number, and marketable fruit number to treatments can be reconciled by examining the percentage of total fruit which were marketable (Table 4). In week 1, when all yield components responded similarly, no differences existed in percentage of fruit marketable. In week 2, however, total number of fruit (Table 2) was the same for all ethephon treated plants, but marketable number of fruit (Table 3) was lower for this same group of plants. During this period, percentage of fruit marketable was much lower for plants receiving ethephon, especially for Early Prolific and Aristocrat cultivars. Harvest records for week 2 reveal that many Dixie and Early Prolific fruit harvested during this period were immature and rotting, and that many Aristocrat fruit were pointed and some of these were rotting. These characteristics are indications that

TABLE 3

MARKETABLE NUMBER OF SQUASH FOR 1973 KNOXVILLE CULTIVAR STUDY

Cultivar	Ethephon Level	Harvest Period					
		Week 1	Week 2	Week 3	Week 4	Week 5	Total
	ppm	Number per subtreatment					
Aristocrat	0	8.8 d*	28.8 cd	22.0 d	15.8 ef	23.8 d	99.0 f
	150	5.5 d	40.5 ab	12.5 e	13.5 f	22.3 d	94.3 f
	300	8.3 d	40.5 ab	10.5 e	17.8 def	17.8 d	94.8 f
	600	5.3 d	32.0 bc	5.8 e	13.8 f	13.5 d	70.3 f
Dixie	0	42.0 c	48.3 a	54.0 ab	48.3 a	66.3 a	258.8 a
	150	71.5 a	25.5 cd	59.3 a	34.5 bc	66.5 a	257.3 a
	300	59.0 b	23.5 cd	55.8 a	34.5 bc	59.0 ab	231.8 ab
	600	66.0 ab	17.3 d	55.5 a	26.8 cd	56.8 abc	222.3 bc
Early Prolific	0	5.5 d	46.0 a	24.0 d	40.0 ab	45.3 c	160.8 e
	150	40.0 c	28.5 cd	46.8 bc	20.8 def	47.5 bc	183.5 de
	300	43.3 c	30.5 bc	50.8 ab	24.8 cde	49.3 bc	198.5 cd
	600	38.3 c	31.8 bc	40.0 c	24.3 de	44.8 c	179.0 de
	Ethephon Level Mean						
	0	18.8 b	41.0 a	33.3 b	34.7 a	45.1 a	172.8 a
	150	39.0 a	31.5 b	39.5 a	22.9 b	45.4 a	178.3 a
	300	36.8 a	31.5 b	39.0 a	25.7 b	42.0 ab	175.0 a
	600	36.5 a	27.0 b	33.8 b	21.6 b	38.3 b	157.2 b
Cultivar Mean							
Aristocrat		6.9 c	35.4 a	12.7 c	15.2 c	19.3 c	89.6 c
Dixie		59.6 a	28.6 a	56.1 a	36.0 a	62.1 a	242.5 a
Early Prolific		31.8 b	34.2 a	40.4 b	27.4 b	46.7 b	180.4 b

*Values in individual column segments separated by solid lines and followed by the same letters are not significantly different at the .05 level of probability.

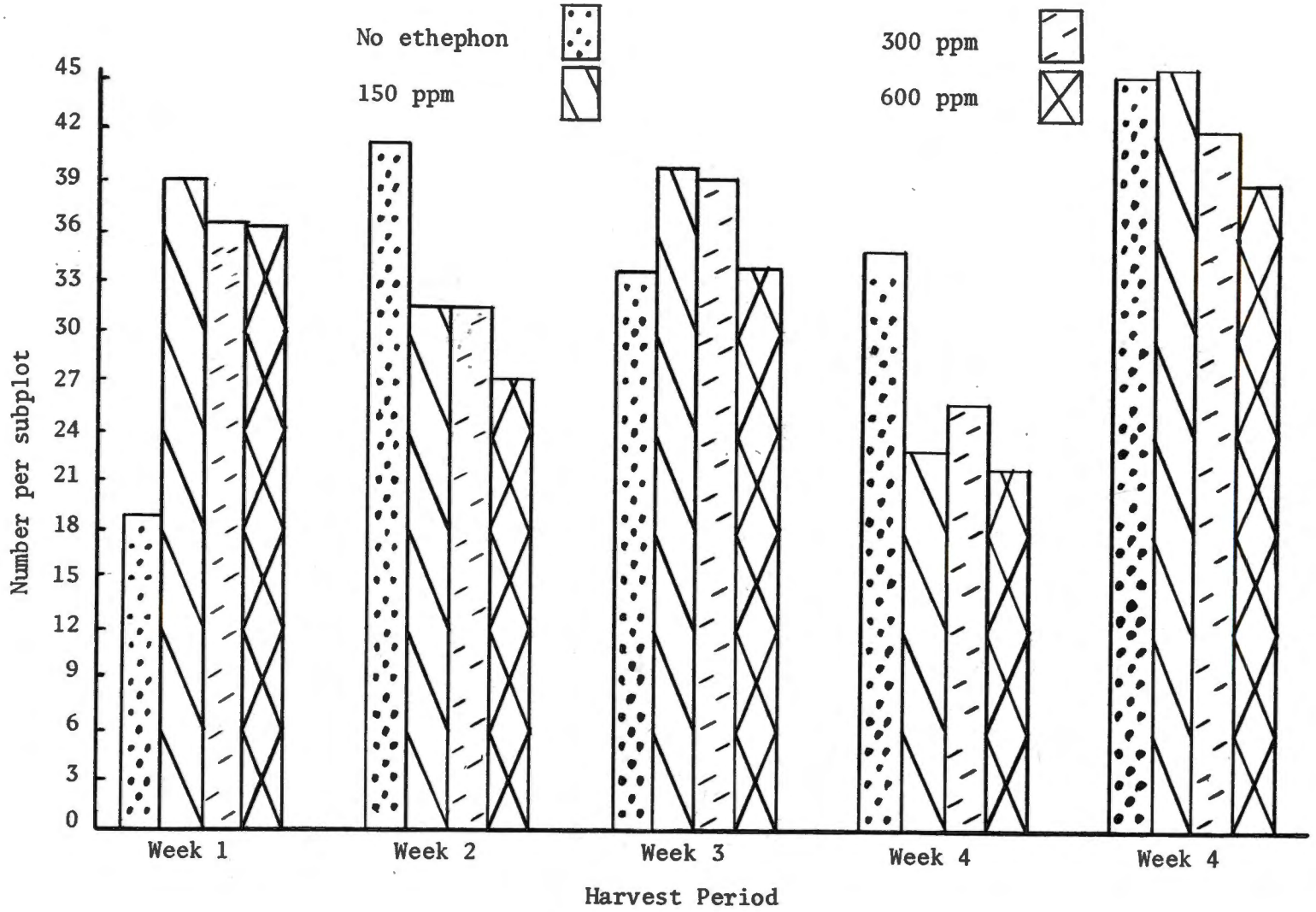


Figure 2. Marketable number of squash for 1973 Knoxville cultivar study.

TABLE 4

PERCENTAGE OF SQUASH MARKETABLE IN 1973 KNOXVILLE CULTIVAR STUDY

Cultivar	Ethephon Level	Harvest Period					
		Week 1	Week 2	Week 3	Week 4	Week 5	Total
	ppm	percent					
Aristocrat	0	100.0 a*	99.1 a	97.6 a	87.8 ab	89.2 a	94.5 ab
	150	100.0 a	84.9 ab	77.2 a	70.0 cd	86.6 a	79.8 bc
	300	100.0 a	79.9 abc	72.0 a	77.4 bc	92.8 a	77.7 c
	600	75.0 ab	59.8 cd	39.7 b	61.2 d	65.3 b	54.5 d
Dixie	0	94.5 a	98.1 a	94.9 a	98.1 a	96.1 a	96.1 a
	150	97.4 a	81.3 abc	93.5 a	97.1 a	93.2 a	93.1 ab
	300	95.7 a	76.1 abcd	91.1 a	99.1 a	96.9 a	92.3 abc
	600	97.8 a	78.8 abc	96.0 a	96.6 a	96.7 a	94.0 ab
Early Prolific	0	67.6 b	91.9 a	90.5 a	96.6 a	97.3 a	93.2 ab
	150	89.4 ab	55.4 d	87.9 a	97.3 a	94.2 a	82.5 abc
	300	90.8 ab	64.2 bcd	87.6 a	98.9 a	96.0 a	84.6 abc
	600	86.6 ab	66.2 bcd	93.1 a	95.1 a	97.3 a	85.0 abc
Ethephon Level Mean							
	0	87.4 a	96.4 a	94.4 a	94.2 a	94.2 a	94.6 a
	150	95.6 a	73.9 b	86.2 ab	88.1 ab	91.3 a	85.1 b
	300	95.5 a	73.4 b	83.6 ab	91.8 ab	95.2 a	84.8 b
	600	86.5 a	68.3 b	76.2 c	84.3 b	86.4 a	77.8 b
Cultivar Mean							
Aristocrat		93.8 a	80.9 ab	71.6 b	74.1 b	83.4 a	76.6 b
Dixie		96.4 a	83.6 a	93.9 a	97.7 a	95.7 a	93.9 a
Early Prolific		83.6 a	69.4 b	89.8 a	97.0 a	96.2 a	86.3 ab

*Values in individual column segments separated by solid lines and followed by the same letters are not significantly different at the .05 level of probability.

pollination was not adequate for proper fruit development (17). Inadequate pollination is attributed directly to the absence of sufficient numbers of staminate flowers on the ethephon treated plants. Flower counts taken one week prior to the first harvest show higher numbers of pistillate flowers on the ethephon treated plants than on control plants (Table 5). Though actual staminate flower counts were not conducted, visual observations revealed that ethephon treated plants had no staminate flowers at the time pistillate flower counts were taken. There are two possible explanations as to why percentage of fruit marketable differences did not show up in harvest week 1. The first explanation concerns harvesting inconsistencies. Immature fruit were not harvested as closely during week 1 as in week 2 - that is, many were left to rot on the vines. The significance of these immature fruit (with respect to their relation to inadequate pollination) was not immediately recognized. As a result, they were not included in harvest records until the second week of harvest. Another explanation is that a sufficient quantity of pollen was not available even for the control. This explanation is supported by data in Table 4 where it is evidenced that control plants had a lower percentage of fruit marketable in week 1 than in week 2 except for Aristocrat, where number of fruit harvested from all treatments in week 1 was very low.

Dixie and Early Prolific appeared to be recovered from insufficient pollination by week 3. However, Aristocrat exhibited difficulties throughout the harvest period, and season totals revealed a stepwise

TABLE 5

PISTILLATE FLOWER COUNTS FOR 1973 KNOXVILLE CULTIVAR STUDY

Cultivar	Ethephon Level	Female Flowers**
	ppm	Number per plant
Aristocrat	0	2.6 f*
	150	5.4 e
	300	6.2 de
	600	7.1 cde
Dixie	0	4.4 ef
	150	8.6 bcd
	300	9.7 bc
	600	8.8 bcd
Early Prolific	0	2.5 f
	150	10.5 ab
	300	12.8 a
	600	12.8 a
	Ethephon Level Mean	
	0	3.1 c
	150	8.1 b
	300	9.5 ab
	600	9.8 a
Cultivar Mean		
Aristocrat		5.2 c
Dixie		7.8 b
Early Prolific		9.6 a

* Values in column segments separated by solid lines and followed by the same letters are not significantly different at the .05 level of probability.

**Flower counts were taken one week prior to the first harvest date and represent means of five plants counted per plot.

decrease in percentage of fruit marketable from the controls to plants treated with 600 ppm ethephon. Many of the fruit from Aristocrat ethephon treated plants showed lack of sufficient pollination throughout the season by their bottleneck appearance.

Other differential responses of yield components to ethephon treatments are results of differences in average fruit weights (Table 6). Yield and fruit number were in agreement in weeks 1, 2, 4, and 5 (Tables 1, page 21, and 2, page 23). In week 3, however, total yield was slightly lowered by ethephon treatments while total fruit number was increased by the 150 and 300 ppm ethephon rates. During this period, all ethephon treated plants exhibited a lower average fruit weight than did the controls. This lower average fruit weight is attributed to higher numbers of fruit on ethephon treated plants than on control plants. The lower average fruit weight in week 2 is attributed to the large number of immature fruit harvested. In contrast to week 3, however, differential response between total yield and total fruit number was not significant in week 2 due to greater experimental error. Season total average fruit weight was lower for ethephon treated plants than for the controls. This weight difference coincides with the differential response between total yield and total fruit number. Though ethephon treated plants produced a higher total fruit number than did controls (Table 2), total yield was the same for all treatments due to the smaller size of fruit from ethephon treated plants.

TABLE 6

AVERAGE FRUIT WEIGHT FOR 1973 KNOXVILLE CULTIVAR STUDY

Cultivar	Ethephon Level	Harvest Period					
		Week 1	Week 2	Week 3	Week 4	Week 5	Total
	ppm	pounds					
Aristocrat	0	0.40 a*	0.75 a	0.73 a	0.89 a	0.79 a	0.75 a
	150	0.27 bc	0.68 a	0.56 b	0.79 b	0.80 a	0.68 bc
	300	0.35 ab	0.67 a	0.44 c	0.81 b	0.76 a	0.64 c
	600	0.42 a	0.68 a	0.50 bc	0.95 a	0.84 a	0.70 ab
Dixie	0	0.24 cd	0.38 bc	0.27 de	0.27 c	0.32 b	0.28 de
	150	0.23 cd	0.24 bc	0.23 e	0.27 c	0.26 b	0.24 e
	300	0.21 cd	0.20 c	0.21 e	0.28 c	0.29 b	0.23 e
	600	0.22 cd	0.21 c	0.24 e	0.27 c	0.29 b	0.24 e
Early Prolific	0	0.18 d	0.34 b	0.34 d	0.30 c	0.33 b	0.32 d
	150	0.23 cd	0.17 c	0.28 de	0.24 c	0.36 b	0.26 e
	300	0.23 cd	0.19 c	0.25 e	0.25 c	0.34 b	0.25 e
	600	0.26 cd	0.20 c	0.25 e	0.30 c	0.29 b	0.25 e
	Ethephon Level Mean						
	0	0.27 a	0.46 a	0.44 a	0.49 a	0.48 a	0.45 a
	150	0.24 a	0.37 b	0.36 b	0.43 b	0.47 a	0.39 b
	300	0.26 a	0.35 b	0.30 c	0.45 b	0.46 a	0.38 b
	600	0.29 a	0.34 b	0.31 c	0.47 ab	0.44 a	0.37 b
Cultivar Mean							
Aristocrat		0.36 a	0.70 a	0.56 a	0.85 a	0.79 a	0.69 a
Dixie		0.22 b	0.23 b	0.24 c	0.27 b	0.29 b	0.25 b
Early Prolific		0.22 b	0.23 b	0.28 b	0.27 b	0.33 b	0.27 b

*Values in individual column segments separated by solid lines and followed by the same letters are not significantly different at the .05 level of probability.

Crossville - 1974. Yield from plants treated with 150 ppm ethephon was considerably higher than that from plants receiving any other treatment. Early yield (week 1) was increased by all ethephon treatments (Table 7). The 150 ppm rate produced a highly significant yield increase of 169 percent over the control while the 300 and 600 ppm rates gave increases of 62 and 78 percent, respectively. Plants treated with the higher ethephon rates (300 and 600 ppm) were lower in yield than were control plants in week 2, but those receiving the 150 ppm rate yielded the same as did the control during this period. In fact, at no time during the harvest period did plants receiving the 150 ppm ethephon treatment fall below the yield level of the control plants. For the season total, the 150 ppm rate produced essentially the same yield as did the control, but resulted in a significantly higher yield than did either of the other ethephon treatments.

Total number of fruit (Table 8) followed a pattern very similar to total yield. The primary exception was for the season total where the 150 ppm rate resulted in a significantly higher total number than did any of the other treatments including the control. Here, as at Knoxville, the differential response between total fruit weight and total fruit number can be associated with a lower average weight per fruit for the ethephon treatments than for the control.

Most of the observed difference in yield response to ethephon at Crossville is attributed to Senator. Though statistical analysis produced no highly significant cultivar x ethephon rate interaction, many of the differences among treatments, especially for the season

TABLE 7

TOTAL WEIGHT OF SQUASH FOR 1974 CROSSVILLE CULTIVAR STUDY

Cultivar	Ethephon Level	Harvest Period					
		Week 1	Week 2	Week 3	Week 4	Week 5	Total
	ppm	Tons per acre					
Senator	0	1.80 bcd*	5.01 ab	4.98 ab	7.03 ab	0.11 b	18.93 b
	150	4.54 a	5.38 a	6.75 a	7.71 a	0.60 a	24.98 a
	300	2.60 bc	3.46 c	4.58 bc	6.09 b	0.16 b	16.89 b
	600	3.24 ab	3.95 bc	5.36 ab	6.93 ab	0.34 ab	19.82 b
Dixie	0	1.03 cde	1.86 d	2.60 cde	3.15 c	0.20 ab	8.84 cd
	150	2.27 bc	1.57 d	3.40 bcd	3.23 c	0.35 ab	10.83 c
	300	1.71 bcd	0.94 d	2.46 cde	2.91 cd	0.22 ab	8.25 cd
	600	1.69 bcd	1.03 d	2.04 de	2.56 cd	0.40 ab	7.73 cd
Early Prolific	0	0.08 e	1.26 d	2.31 de	3.54 c	0.37 ab	7.55 cd
	150	1.03 cde	1.66 d	1.57 de	2.76 cd	0.16 b	7.17 cd
	300	0.40 de	1.48 d	0.93 e	2.91 cd	0.11 b	5.83 cd
	600	0.26 de	0.78 d	0.59 e	1.58 d	0.31 ab	3.52 d
	Ethephon Level Mean						
	0	0.97 b	2.71 a	3.30 ab	4.57 a	0.22 a	11.78 ab
	150	2.61 a	2.87 a	3.91 a	4.57 a	0.37 a	14.33 a
	300	1.57 b	1.96 b	2.66 b	3.97 ab	0.16 a	10.32 b
	600	1.73 b	1.92 b	2.67 b	3.69 b	0.35 a	10.35 b
Cultivar Mean							
Senator		3.05 a	4.45 a	5.42 a	6.94 a	0.30 a	20.16 a
Dixie		1.68 ab	1.35 b	2.63 b	2.96 b	0.29 a	8.91 b
Early Prolific		0.44 b	1.29 b	1.35 b	2.70 b	0.24 a	6.02 b

*Values in individual column segments separated by solid lines and followed by the same letters are not significantly different at the .05 level of probability.

TABLE 8

TOTAL NUMBER OF SQUASH FOR 1974 CROSSVILLE CULTIVAR STUDY

Cultivar	Ethephon Level	Harvest Period					
		Week 1	Week 2	Week 3	Week 4	Week 5	Total
	ppm	Number per subplot					
Senator	0	15.8 bc*	29.0 ab	27.5 abc	35.0 ab	7.3 abcd	114.5 bc
	150	43.5 a	30.8 a	37.0 a	41.0 a	12.0 a	164.3 a
	300	27.0 ab	20.8 bc	25.5 bcd	35.3 ab	7.3 abcd	115.8 bc
	600	33.8 ab	20.0 bc	28.3 abc	34.0 abc	7.8 abcd	123.8 b
Dixie	0	15.8 bc	17.5 cd	23.3 bcd	28.0 bcd	9.5 ab	94.0 bcde
	150	42.3 a	13.5 cd	32.3 ab	26.8 bcd	12.3 a	127.0 b
	300	32.8 ab	11.5 cd	24.3 bcd	25.3 cd	9.0 ab	102.8 bcd
	600	32.0 ab	11.3 cd	18.5 cde	20.5 de	10.5 a	92.8 bcde
Early Prolific	0	1.5 c	11.0 cd	20.8 bcde	26.8 bcd	8.8 abc	68.8 def
	150	15.3 bc	16.3 cd	15.5 def	23.0 de	5.0 bcd	75.0 cdef
	300	6.3 c	15.8 cd	10.0 ef	22.8 de	2.8 d	57.5 ef
	600	4.3 c	9.3 d	6.3 f	14.5 e	3.8 cd	38.0 f
	Ethephon Level Mean						
	0	11.0 c	19.2 a	23.8 ab	29.9 a	8.5 ab	92.4 b
	150	33.7 a	20.2 a	28.3 a	30.3 a	9.8 a	122.1 a
	300	22.0 b	16.0 ab	19.9 b	27.8 ab	6.3 b	92.0 b
	600	23.3 b	13.5 b	17.7 b	23.0 b	7.3 ab	84.8 b
Cultivar Mean							
Senator		30.0 a	25.1 a	29.6 a	36.3 a	8.6 ab	129.6 a
Dixie		30.7 a	13.4 b	24.6 a	25.1 b	10.3 a	104.1 ab
Early Prolific		6.8 b	13.1 b	13.1 b	21.8 b	5.1 b	59.8 b

*Values in individual column segments separated by solid lines and followed by the same letters are not significantly different at the .05 level of probability.

total, clearly arose from Senator treatment differences (Tables 7 and 8).

Other than yields being lower, response to ethephon treatment by Dixie and Early Prolific at Crossville was little different from that observed at Knoxville. Response to the 150 ppm rate was somewhat more pronounced at Crossville while response to the higher ethephon rates was slightly higher at Knoxville.

Application Regime Study

Early yields (week 1) were enhanced by both the 150 and 300 ppm ethephon rates (Tables 9, 10, and 11). Both of these rates also increased total marketable number of fruit in week 3. However, the 300 ppm rate depressed all yield components (marketable yield, marketable number, and total number) in week 4. For the season total, only total fruit number was significantly increased by any ethephon treatment. The 300 ppm rate gave a 10 percent higher total fruit number than did the control while the 150 ppm rate resulted in intermediate response (not significantly different from either the control or the 300 ppm rate).

Little difference in yield existed among any of the different application regimes. Tables 9, 10, and 11 indicate that the two-way split application treatment tended to increase all yield components more than either the single application of the three-way split application in all weeks after week 1. However, only week 2 showed a statistically significant increase at the 0.05 level of probability.

TABLE 9

MARKETABLE WEIGHT OF SQUASH FOR 1974 APPLICATION REGIME STUDY

Ethephon Level	Application Regime	Harvest Period					
		Week 1	Week 2	Week 3	Week 4	Week 5	Total
ppm		Tons per acre					
0	Single application	1.03 c*	1.70 ab	3.47 a	2.74 ab	3.79 ab	12.72 ab
	Two-way split	1.20 bc	1.94 a	3.33 a	3.00 a	3.44 ab	12.92 ab
	Three-way split	1.35 bc	1.95 a	3.48 a	3.02 a	3.16 b	12.96 ab
150	Single application	2.07 a	1.35 ab	3.73 a	2.49 ab	3.71 ab	13.36 ab
	Two-way split	1.68 ab	1.81 a	3.94 a	3.04 a	3.79 ab	14.25 a
	Three-way split	1.34 bc	1.72 ab	3.31 a	2.55 ab	3.52 ab	12.43 ab
300	Single application	2.06 a	1.24 c	3.43 a	2.25 ab	3.29 ab	12.26 b
	Two-way split	1.96 a	1.26 c	3.65 a	2.73 ab	3.68 ab	13.28 ab
	Three-way split	1.60 ab	1.30 c	3.54 a	1.85 b	4.11 a	12.40 ab
Ethephon Level Mean							
0		1.19 b	1.86 a	3.43 a	2.92 a	3.46 a	12.87 a
150		1.70 a	1.62 a	3.66 a	2.69 ab	3.67 a	13.35 a
300		1.87 a	1.27 a	3.54 a	2.28 b	3.69 a	12.65 a
	Application Regime Mean						
	Single application	1.72 a	1.43 b	3.54 a	2.49 a	3.60 a	12.78 a
	Two-way split	1.61 ab	1.67 a	3.64 a	2.92 a	3.64 a	13.49 a
	Three-way split	1.43 b	1.66 a	3.44 a	2.47 a	3.60 a	12.59 a

*Values in individual column segments separated by solid lines and followed by the same letters are not significantly different at the .05 level of probability.

TABLE 10

TOTAL NUMBER OF SQUASH FOR 1974 APPLICATION REGIME STUDY

Ethephon Level	Application Regime	Harvest Period					
		Week 1	Week 2	Week 3	Week 4	Week 5	Total
ppm		Number per sub-subplot					
0	Single application	7.6 e*	11.0 abc	20.1 b	15.9 ab	18.4 bc	73.0 b
	Two-way split	8.0 e	13.0 a	21.0 ab	16.8 a	17.1 bc	75.9 ab
	Three-way split	9.3 de	12.0 ab	20.1 b	16.6 a	15.3 c	73.3 b
150	Single application	15.4 bc	7.6 d	23.3 ab	13.4 ab	17.8 bc	77.4 ab
	Two-way split	13.5 c	9.9 bcd	24.1 a	15.4 ab	19.0 bc	81.9 ab
	Three-way split	12.3 cd	11.8 ab	21.4 ab	15.4 ab	18.5 bc	79.3 ab
300	Single application	18.0 ab	8.6 cd	21.9 ab	13.4 ab	17.5 bc	79.4 ab
	Two-way split	19.3 a	7.5 d	23.4 ab	14.0 ab	19.5 ab	83.6 a
	Three-way split	14.9 bc	8.6 cd	23.8 ab	11.3 b	22.8 a	81.3 ab
Ethephon Level Mean							
0		8.3 b	12.0 a	20.4 b	16.4 a	16.9 a	74.0 b
150		13.7 a	9.8 ab	22.9 a	14.7 ab	18.4 a	79.5 ab
300		17.4 a	8.3 b	23.0 a	12.9 b	19.9 a	81.4 a
	Application Regime Mean						
	Single application	13.7 a	9.1 b	21.8 a	14.2 a	17.9 a	76.6 a
	Two-way split	13.6 a	10.1 ab	22.8 a	15.4 a	18.5 a	80.5 a
	Three-way split	12.1 a	10.8 a	21.8 a	14.4 a	18.8 a	77.9 a

*Values in individual column segments separated by solid lines and followed by the same letters are not significantly different at the .05 level of probability.

TABLE 11

MARKETABLE NUMBER OF SQUASH FOR 1974 APPLICATION REGIME STUDY

Ethephon Level	Application Regime	Harvest Period					
		Week 1	Week 2	Week 3	Week 4	Week 5	Total
ppm		Number per sub-subplot					
0	Single application	7.5 e*	10.9 abc	19.5 b	15.0 ab	17.1 ab	70.0 b
	Two-way split	8.0 e	12.6 a	20.0 ab	16.3 a	15.9 b	72.8 ab
	Three-way split	9.3 de	11.9 ab	19.6 b	16.4 a	14.4 b	71.5 ab
150	Single application	15.1 ab	7.3 e	22.4 ab	12.9 ab	16.1 b	73.8 ab
	Two-way split	13.5 bc	10.0 bcd	23.4 a	15.3 ab	17.6 ab	79.8 a
	Three-way split	11.6 cd	10.8 abc	20.8 ab	14.9 ab	17.3 ab	75.3 ab
300	Single application	16.6 a	8.1 de	21.4 ab	13.3 ab	16.6 ab	76.0 ab
	Two-way split	15.6 ab	7.4 e	22.3 ab	13.6 ab	18.1 ab	77.0 ab
	Three-way split	14.0 abc	8.5 cde	22.8 ab	10.8 b	20.0 a	76.0 ab
Ethephon Level Mean							
0		8.3 b	11.8 a	19.7 b	15.9 a	15.8 a	71.4 a
150		13.4 a	9.3 ab	22.2 a	14.3 ab	17.0 a	76.3 a
300		15.4 a	8.0 b	22.1 a	12.5 b	18.3 a	76.3 a
	Application Regime Mean						
	Single application	13.1 a	8.8 b	21.1 a	13.7 a	16.6 a	73.3 a
	Two-way split	12.4 a	10.0 ab	21.9 a	15.0 a	17.2 a	76.5 a
	Three-way split	11.6 a	10.4 a	21.0 a	14.0 a	17.2 a	74.3 a

*Values in individual column segments separated by solid lines and followed by the same letters are not significantly different at the .05 level of probability.

This yield increase is attributed to the lower initial ethephon rates which were applied to the split treatments at the first application time. These lower rates resulted in a smaller week 2 yield depression than did the higher rate applied as the single application treatment (Figure 3). A similar yield depression, which followed a period of very high yield, was exhibited in week 2 of the 1973 cultivar study (Tables 1, 2, and 3, pages 21, 23, and 25, respectively).

There is no statistically valid way to evaluate the effects of the pollinator rows on yield and quality. However, 68 percent of the fruit from the first harvest of the pollinator rows were unpollinated. There were no unpollinated fruit in the first harvest of treatment rows. This difference is attributed to the absence of early staminate flowers in the pollinator rows and a consequential lack of adequate pollination. The ten-day lag in planting between the pollinator and treatment rows allowed sufficient time for development of staminate flowers in numbers high enough to insure adequate pollen levels for the treatment rows.

There were few treatment differences in percentage of fruit marketable (Table 12). Plants receiving the two-way split application of the 300 ppm rate were lower in percentage of fruit marketable for both week 1 and for the season total than were plants receiving either the single application or the three-way split application. There is no apparent explanation for these differences since they were not exhibited by plants treated with the 150 ppm ethephon rate. A difference in percentage of fruit marketable also existed for the overall ethephon effect in week 1. Plants receiving the 300 ppm rate

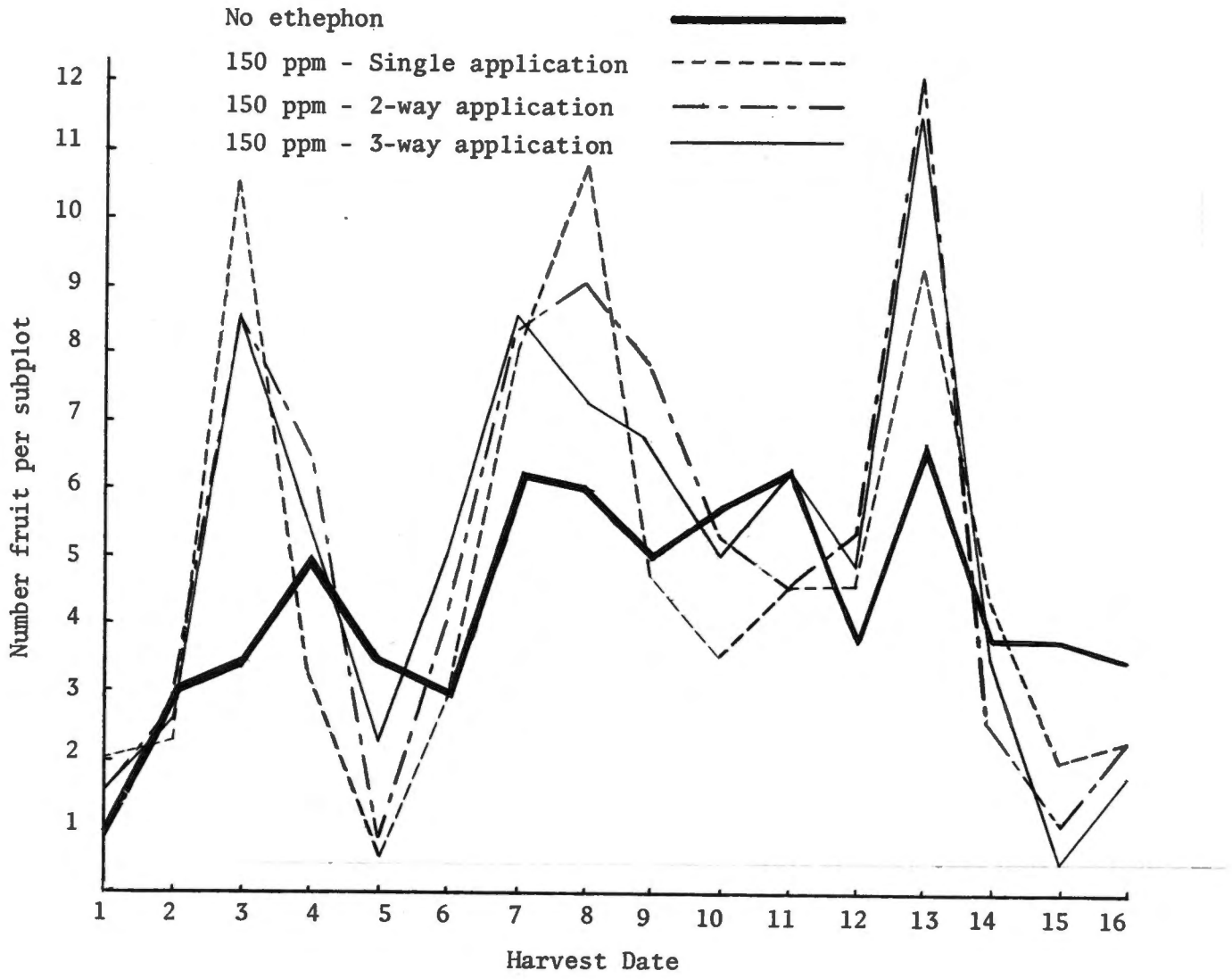


Figure 3. Marketable number of squash for 1974 application regime study.

TABLE 12

PERCENTAGE OF SQUASH MARKETABLE IN 1974 APPLICATION REGIME STUDY

Ethephon Level	Application Regime	Harvest Period					
		Week 1	Week 2	Week 3	Week 4	Week 5	Total
ppm		percent					
0	Single application	98.8 a*	99.0 ab	96.2 a	94.1 a	93.9 a	95.9 ab
	Two-way split	100.0 a	97.2 ab	95.3 a	97.2 a	93.8 a	96.0 ab
	Three-way split	100.0 a	99.2 ab	97.3 a	98.4 a	94.0 a	97.6 a
150	Single application	98.4 a	95.8 ab	96.4 a	96.3 a	91.3 a	95.3 abc
	Two-way split	100.0 a	100.0 a	96.7 a	99.1 a	93.3 a	97.4 a
	Three-way split	96.5 a	91.8 b	97.1 a	97.1 a	94.0 a	95.0 abc
300	Single application	94.9 a	93.6 ab	98.1 a	99.4 a	95.0 a	96.0 ab
	Two-way split	85.9 b	98.4 ab	95.2 a	97.9 a	93.3 a	92.4 c
	Three-way split	94.6 a	99.3 ab	96.0 a	93.6 a	88.1 a	93.5 bc
Ethephon Level Mean							
0		99.6 a	98.5 a	96.3 a	96.6 a	93.9 a	96.5 a
150		98.3 a	96.1 a	96.7 a	97.5 a	92.9 a	95.9 a
300		91.8 b	97.1 a	96.5 a	97.0 a	92.1 a	94.0 a
	Application Regime Mean						
	Single application	97.4 a	96.1 a	96.9 a	96.6 a	93.4 a	95.7 a
	Two-way split	95.3 a	98.8 a	95.7 a	98.1 a	93.5 a	95.3 a
	Three-way split	97.1 a	96.8 a	96.8 a	96.4 a	92.0 a	95.4 a

*Values in individual column segments separated by solid lines and followed by the same letters are not significantly different at the .05 level of probability.

were lower in percentage of fruit marketable than either of the other two rates. There are at least two possible explanations for this difference. First, the 300 ppm ethephon rate response was lowered considerably by the low percentage marketable previously mentioned for the two-way split application treatment. Secondly, indications are that there may be a higher tendency for parthenocarpic fruit development with higher ethephon rates even when pollen supply is adequate. However, this proposal arises purely from visual observations and has not yet been supported with statistical data.

Differences in average weight per fruit existed only for overall ethephon rate effects in week 1 (Table 13). Here, fruit from plants receiving either the 150 or 300 ppm ethephon rates were lower in average weight than those from the controls. These differences are attributed to the larger numbers of fruit per vine, resulting in a slower fruit growth rate.

Yields were considerably lower for this study than for the cultivar study at the same location in 1973 (Table 1, page 21, and Table 9, page 36). Various factors helped contribute to the yield depression. Planting was delayed by wet soil conditions and by the necessity of having pollinator rows planted at least a week prior to the planting of treatment rows. The plants were exposed to considerable moisture deficit stress at about the time the first flower buds were being initiated. Before supplemental irrigation was provided, considerable stunting of plant growth occurred. Insect problems were more severe than in 1973, a result of the less vigorous plant growth and higher

TABLE 13

AVERAGE FRUIT WEIGHT FOR 1974 APPLICATION REGIME STUDY

Ethephon Level	Application Regime	Harvest Period					
		Week 1	Week 2	Week 3	Week 4	Week 5	Total
ppm		pounds					
0	Single application	0.18 abc*	0.20 b	0.23 a	0.25 a	0.29 a	0.24 a
	Two-way split	0.20 a	0.20 b	0.22 a	0.24 a	0.29 a	0.23 ab
	Three-way split	0.19 ab	0.22 ab	0.23 a	0.24 a	0.29 a	0.24 a
150	Single application	0.18 abc	0.24 a	0.22 a	0.26 a	0.31 a	0.24 a
	Two-way split	0.16 cd	0.23 ab	0.22 a	0.26 a	0.29 a	0.23 ab
	Three-way split	0.15 cd	0.21 ab	0.21 a	0.23 a	0.28 a	0.22 ab
300	Single application	0.16 cd	0.20 b	0.21 a	0.23 a	0.26 a	0.21 b
	Two-way split	0.17 bcd	0.23 ab	0.22 a	0.26 a	0.26 a	0.22 ab
	Three-way split	0.15 cd	0.20 b	0.20 a	0.23 a	0.27 a	0.21 b
Ethephon Level Mean							
0		0.19 a	0.21 a	0.23 a	0.24 a	0.29 a	0.24 a
150		0.16 b	0.23 a	0.22 a	0.25 a	0.29 a	0.23 a
300		0.16 b	0.21 a	0.21 a	0.24 a	0.26 a	0.22 a
	Application Regime Mean						
	Single application	0.17 a	0.22 a	0.22 a	0.24 a	0.29 a	0.23 a
	Two-way split	0.18 a	0.22 a	0.22 a	0.25 a	0.28 a	0.23 a
	Three-way split	0.16 a	0.21 a	0.21 a	0.23 a	0.28 a	0.22 a

*Values in individual column segments separated by solid lines and followed by the same letters are not significantly different at the .05 level of probability.

insect populations. Insect control problems were further complicated by the necessity for a minimal spray schedule. Since chemicals employed to control cucumber beetles (the dominant pest problem) also discouraged honeybees, a delicate balance was required to give effective insect control and also allow sufficient bee populations for proper pollination. Considerable plant damage occurred during the slow growth period before this balance was achieved.

Greenhouse Study

The term "marketable yield" will carry a somewhat different connotation in the greenhouse study discussion than in previous discussions. Here, the term will refer to those fruit which reached harvest size and were developed from fertilized pistillate flowers. No total marketable yield differences existed among any of the ethephon treated plants or between either of the cultivars used (Table 14). However, ethephon applied at the first flower stage resulted in a lower overall marketable yield than did application as a seed soak. Ethephon applied to flowering plants resulted in abortion of pistillate flowers present at the time of application. Though pistillate flower development later resumed, these abortions appeared to be sufficient to cause an overall yield depression.

Many of the female flowers which were not pollinated developed fruit parthenocarpically. Ethephon application at the first flower stage resulted in more parthenocarpic fruit than did application at the first fruit stage (Table 14). The other application times resulted

TABLE 14

MARKETABLE NUMBER OF FRUIT, NUMBER OF PARTHENOCARPIC FRUIT, AND TOTAL NUMBER OF FEMALE FLOWERS FOR GREENHOUSE STUDY

Treatment	Variable		
	Marketable Number Fruit	Parthenocarpic Fruit	Female Flowers
	Number per plant		
Ethephon Level (ppm)			
0	0.75 a*	0.46 a	4.67 a
75	0.67 a	0.58 a	5.46 a
150	0.50 a	0.75 a	4.50 a
300	0.50 a	0.67 a	4.75 a
Time of Ethephon Application			
Seed soak	0.88 a	0.46 bc	5.00 ab
Three-leaf stage	0.58 ab	0.75 ab	5.83 a
First flower stage	0.33 b	0.83 a	4.38 b
First fruit stage	0.63 ab	0.42 c	4.17 b
Cultivar			
Dixie	0.56 a	1.17 a	6.54 a
Early Prolific	0.65 a	0.06 b	3.15 b

*Values in individual column segments separated by solid lines and followed by the same letters are not significantly different at the .05 level of probability.

in intermediate numbers of parthenocarpic fruit. Dixie exhibited considerably more parthenocarpic fruit development than did Early Prolific.

Fruit yield is strongly influenced by the number of female flowers which have no pollen source available when pollen is needed for fertilization. All ethephon treatments had more pistillate flowers in this situation than did the control (Table 15). This is explained, of course, by the tendency for ethephon to reduce or eliminate male flower development for some time after application (22). Dixie had four times as many female flowers with no pollen available as did Early Prolific. This is a natural tendency for many hybrids (17), and normally, under field conditions, the pollen shortage occurs exclusively at the beginning of the season. In this study, however, a rather strange turn of events occurred. Flowering in the Dixie cultivar began on October 25 with both male and female flowers appearing on some plants. By October 27, male flowers were plentiful on all treatments except for those where ethephon had been applied at the three-leaf stage. Flowering progressed for several days with both males and females present. Occasionally, a treatment exhibited a female with no male present for pollination, but such occurrences were relatively rare. Then on November 12, almost all of the Dixie plants began to exhibit accelerated vegetative growth. After this date no further males were formed on any plants even though females continued to flower until November 30 when the experiment was terminated. No such cessation of male flower formation occurred with Early Prolific, where staminate

TABLE 15

STAMINATE AND PISTILLATE FLOWER DISTRIBUTIONS FOR GREENHOUSE STUDY

Treatment	Variable** FNPA	TPOL	DMNF	DFNM
	--------Season totals per plant--------			
Ethephon Level (ppm)				
0	2.38 b*	2.92 a	15.17 a	1.88 b
75	3.92 a	1.58 b	11.71 b	3.04 a
150	3.46 a	1.04 b	9.83 c	3.04 a
300	3.88 a	1.04 b	7.54 d	2.92 a
Time of Ethephon Application				
Seed soak	3.25 ab	1.79 a	14.71 a	2.71 ab
Three-leaf stage	4.13 a	1.71 a	8.54 c	3.71 a
First flower stage	3.67 ab	0.88 b	8.83 c	2.92 a
First fruit stage	2.58 b	1.58 a	12.17 b	1.54 b
Cultivar				
Dixie	5.46 a	1.08 b	6.77 b	4.40 a
Early Prolific	1.35 b	1.90 a	15.35 a	1.04 b

* Values in individual column segments separated by solid lines and followed by the same letters are not significantly different at the .05 level of probability.

**Variable titles are defined as follows:

FNPA - Number of female flowers with no pollen source available.

TPOL - Total number of female flowers receiving pollen.

DMNF - Days in which male flowers were present but had no pollen recipient.

DFNM - Days in which female flowers were present but had no pollen source.

flowers were still being formed at the termination of the study. At this time, the only explanation which can be offered is that Dixie responds more to either daylength or light intensity, or perhaps both, than does Early Prolific. It is possible that one of the plant hormones linked to sex expression was triggered by the environmental conditions present on the date that staminate flower production ceased.

Total number of pistillate flowers receiving pollen is a good indicator of yield potential. All ethephon treated plants were lower in this category than were control plants (Table 15). Since female flowers were pollinated only with pollen from males receiving an identical treatment, the ethephon treated plants naturally suffered pollen shortages. Plants treated with ethephon at the first flower stage were lower in total number of female flowers receiving pollen than were plants receiving the other ethephon treatments. This difference resulted not only because of a shortage of male flowers, but because (as was previously mentioned) many of the females present at the time ethephon was applied aborted prior to flowering. Early Prolific had more pollinated female flowers than did Dixie even though Dixie had more total pistillate flowers. This reversal resulted from the complete absence of pollen sources in the Dixie cultivar for the latter part of the growing season.

Seasonal flower distribution for the two cultivars and possible pollination difficulties which may arise as a result of this distribution warrants some examination. Table 15 shows the number of days over the growth period in which males were available for pollination

but had no flowering females as pollen recipients (DMNF). Table 15 also shows the number of days in which flowering females were present but had no flowering males for pollen sources (DFNM). The DMNF exhibited a stepwise decline with increasing ethephon concentrations. At the same time, DFNM tended to be lower for the controls than for plants receiving the ethephon treatments. Once again, these trends point out the effects of ethephon in depressing numbers of male flowers. The seed soak treatment resulted in more DMNF than did any of the other ethephon treatments. The reason lies in the fact that the seed soak was ineffective as an ethephon treatment and, consequently, produced response similar to that shown by the controls in all the other time of application treatments (Table 16). The first fruit application was intermediate in DMNF response, apparently because the ethephon treatments were applied too late to effectively lower numbers of male flowers. This same reasoning explains the lower DFNM value for the first fruit application - fewer females were without pollen sources because males were not effectively suppressed by the treatment. Early Prolific was higher than Dixie in number of days when males were without females, but was lower in the number of days when females were without males. This trend is attributed, at least in part, to the period when Dixie was completely barren of males. The trend also appears to be characteristic of open-pollinated versus hybrid cultivars.

There were no statistically significant differences in the total number of female flowers for any of the ethephon rates or for any of the treatment times (Table 14, page 45). However, ethephon application

TABLE 16

EARLY FLOWER COUNTS FOR GREENHOUSE STUDY

Ethephon Application		Cultivar			
		Dixie*		Early Prolific**	
Stage of Plant	Rate	Males	Females	Males	Females
	ppm	----------Number per plant----------			
Seed Soak	0	14.0	1.7	26.3	3.0
	75	13.3	2.0	24.3	4.0
	150	15.0	1.7	25.3	2.0
	300	14.7	1.7	27.3	3.7
Three-Leaf	0	17.0	1.0	29.0	2.7
	75	1.0	4.3	11.3	10.7
	150	0.0	4.3	6.3	14.3
	300	0.0	6.0	2.7	18.7
First Flower	0	16.3	1.3	29.0	2.7
	75	16.0	1.3	24.7	2.0
	150	16.7	1.0	26.0	3.7
	300	15.0	2.7	22.3	2.0
First Fruit	0	14.0	1.3	25.3	2.0
	75	15.0	1.3	26.7	2.7
	150	14.3	2.0	28.7	3.3
	300	13.3	2.3	27.3	3.7

* Flower counts were taken at the 8-leaf stage.

**Flower counts were taken at the 14-leaf stage.

at the two-leaf stage tended to be higher than any of the other application times in total female flowers. Dixie had twice as many total female flowers as did Early Prolific.

It has been proposed that yield response to ethephon would be much greater if some way could be found to lower the number of pistillate primordia which abort before reaching the flowering stage (28). This proposal is supported by this study. Numbers of female primordia which formed on the plants but did not reach the flowering stage are shown for the three-leaf application stage in Table 17. Differences among ethephon treatments were highly significant for the three-leaf application stage, and were striking for Early Prolific. Aborted females in Early Prolific ranged from 307 to 382 percent higher for the 75 and 300 ppm rates, respectively, than for the control. The yield increase would be phenomenal should these primordia reach maturity. However, it may very well be that a plant could not support a fruit load of such magnitude.

TABLE 17

PISTILLATE PRIMORDIA NOT REACHING FLOWERING STAGE ON ETHEPHON TREATMENTS APPLIED AT THE THREE-LEAF STAGE - GREENHOUSE STUDY

Cultivar	Ethephon Level	Primordia Not Flowering
	ppm	Number per plant
Dixie	0	5.3 cd*
	75	3.3 d
	150	5.7 cd
	300	8.7 ab
Early Prolific	0	2.7 d
	75	11.0 a
	150	13.0 a
	300	13.0 a

*Values followed by the same letters are not significantly different at the .05 level of probability.

CHAPTER V

SUMMARY AND CONCLUSIONS

Results of squash cultivar studies indicate that Early Prolific yields are enhanced more by ethephon treatments than are Dixie yields. Early marketable yields (harvest week 1) for Early Prolific were enhanced by as much as 540 percent while early yields for Dixie were increased by 58 percent. Season total marketable yields for Dixie were not increased by any ethephon treatment. Season total Early Prolific fruit number was as much as 23 percent higher for ethephon treated plants than for control plants, but yields were not significantly increased by any ethephon treatment. The Zucchini cultivars, Aristocrat and Senator, behaved differently in their responses to ethephon. However, since different locations were involved, statistical comparisons between the two cultivars were not possible. Aristocrat responded to ethephon treatment at Knoxville in about the same manner as did Dixie. Early marketable yields (week 2) were increased by 41 percent by ethephon treatments, but season total marketable yields were the same for treated plants as for control plants. Senator exhibited early yield increases from ethephon treatment similar to those of Aristocrat. In contrast to Aristocrat, however, Senator showed a season total yield increase of 32 percent.

The 150 ppm ethephon rate resulted in the highest summer squash yields, both early and season total, of any of the ethephon rates

tested at Crossville. At Knoxville, yields were about the same for plants treated with either the 150 or 300 ppm rates. There were some indications that a rate slightly lower than 150 ppm might be sufficient to increase early yields. In week 1 of the application regime study, there was an opportunity to examine rates of 50, 75, and 100 ppm before the remaining portions of the split applications involved could affect plant growth. Here, the 50 ppm rate resulted in essentially the same yield as did the control, while plants treated with the 75 and 100 ppm rates approached the yield levels of those treated with the higher rates (150 and 300 ppm). These lower rates would certainly warrant examination in future rate studies. Ethephon levels in excess of 300 ppm appear to be ineffective in increasing squash yields beyond those attained with levels below 300 ppm, and results from this study indicate that these higher levels lower quality, especially in Zucchini cultivars.

Results from the application regime study indicate that split applications of an ethephon treatment are no more successful in increasing yields than a single, three-leaf stage application of the treatment. These results are by no means conclusive since many regimes other than those which were tested are possible. However, additional expense and time involved in using split applications would certainly constitute major factors in any consideration of ethephon treatments. As plant size increases, the volume of spray material required for complete coverage increases proportionally as does the risk of plant damage from mechanical injury during application. Further examination

of application regimes will be necessary before solid conclusions can be formed.

Pollination difficulties which accompany ethephon applications were reflected in all studies. Although some untreated plants were present in all field studies, fruit quality was lowered by inadequate pollination in the 1973 cultivar study. Quality reduction was especially severe for Aristocrat plants receiving the high ethephon rate. Though fruit quality data were not recorded for Senator, it appears that Zucchini cultivars suffer more severe adverse effects from inadequate pollination than do the yellow cultivars. Pollination difficulties were minor in the 1974 application regime study, presumably because untreated pollinator rows were planted adjacent to each treatment row. In the greenhouse study, statistical evidence was produced to substantiate observations on pollination difficulties. All ethephon levels produced about the same total number of female flowers as did the control. However, all ethephon treatments had significantly fewer female flowers receiving pollen than did the control.

In conclusion, it appears that ethephon is very effective in increasing early summer squash yields where supplementary pollen sources are supplied. Optimum levels for these supplementary sources remain yet to be established and appear to vary with cultivars used. Ethephon offers little promise for increasing season total yields with any of the cultivars, rates, or application regimes tested in this study.

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