SUMMER GARDEN PERFORMANCE OF SEED AND CUTTING-PROPAGATED GERANIUM CULTIVARS AS INFLUENCED BY CHLORMEQUAT APPLIED DURING GREENHOUSE PRODUCTION AND SUMMER LIGHT INTENSITY

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CHAPTER I

INTRODUCTION

Geraniums are one of the most popular commercially grown greenhouse flowering crops. They are used mainly as bedding or patio container plants to supply color during the frost-free season. They are occasionally used as flowering pot plants indoors, and frequently for Memorial day decorations. In 1981, 52.6 million pots were sold at an estimated wholesale value of 49.5 million dollars (18, 24).

Voight (26) stated in a 1981 national survey, that 13% of 216 growers surveyed reported that cutting-propagated geraniums were one of their four best selling bedding plants, while 4% said that seed-propagated cultivars were among their four best sellers. To propagate plants from cuttings is time consuming and expensive, but has been enhanced by the cultured-cutting procedure for freedom from disease, and the attractiveness of the double-petalled flowers of the cutting-propagated cultivars (4, 14, 23).

In recent years, much work has been done to develop seed-produced cultivars. This type of production allows the grower to produce a large, uniform crop with less initial investment and on a predictable schedule (3). Except for the 'Marathon' geraniums, seed-propagated cultivars produce flowers with single petalage that tend to shatter easily (3, 20).

It has been a common commercial practice to treat geranium plants with a chemical growth retardant during greenhouse forcing to produce compact plants with dark green foliage, good basal branching, and often earlier flowering (3, 15). Chlormequat or Cycocel (2-Chloroethyl) trimethylammonium chloride and ancymidol or A-Rest, a-cyclproplya-(4-methoxyphenol)-5-pyramidine-methanol are the most commonly used products. These may be applied either as foliar sprays or soil drenches (16). Other than one study in France (7) and some observations by Miranda and Carlson (15), very little research information can be found relative to whether there are carry-over or residual effects of growth retardants into the summer growing season, such as earlier or more flowering, reduced vegetative growth or other effects.

There are no known critical research studies on the flowering performance of geraniums outdoors in Oklahoma. With the extreme heat and dryness encountered here, it would be beneficial to know more about how the seedling and cutting-produced cultivars perform in sun and shade.

The specific objectives of this study were to use one seed-propagated cultivar and one cutting-propagated cultivar to:

1. Determine the effects of chlormequat (Cycocel) foliar sprays on growth and flowering during the greenhouse production period; and
2. Determine whether the chemical retardant (Cycocel) had any carry-over effects on vegetative growth or flowering performance of plants grown outdoors in the summer at three light intensity levels.

3. Learn more about summer growth and flowering characteristics of seed and cutting-propagated geranium cultivars under Oklahoma conditions.

CHAPTER II

REVIEW OF LITERATURE

Background

The common zonal geranium (*Pelargonium* X *hortorum* Bailey) is a popular crop among consumers. It ranks as the sixth most important flowering crop, probably due to its versatility. It can withstand a wide range of soil and weather conditions and still perform (4). Between 60-70% of the present demand is for red cultivars, 30-35% for pink and 5% for white types (3, 25).

This member of the Geraniaceae family is native to South Africa. Because of the extensive fibrous root system and lush foliage, it is a desirable bedding plant. The leaves and new shoots are often covered with a pubescense that gives it an unusual appearance (14).

There are several hundred cultivars available, however only 25-35 of these are of commercial importance (14). Most are sold in 10 cm (4 in.) pots in the spring time with major production occurring in the Midwest and Northeast (13). Geraniums will perform well provided they have a properly drained media and adequate moisture (4, 14). Since there are two major production methods, seeds and cuttings, (13) a separate discussion will be given on each.

Seedling Production

The flowers of the geranium are perfect flowers producing viable

seed in 32-35 days (14). The seed has a hard seed coat but seed dealers scarify them to insure rapid germination (18). Most scarified seeds will germinate within 5-7 days with a soil temperature of 21-24°C (70-75°F) (3, 4, 13, 14). Since germination is uniform, a large crop can be planted and uniform flowering dates can be predicted (3). These seedling-produced plants are vigorous and result in superior performance outdoors (3, 4, 14). There are a few drawbacks with seedlings. Most of the seed available is for single petalage flowers and these tend to shatter easily (3, 13, 20), and seedling geraniums are susceptible to the same diseases as cutting-propagated geraniums (13, 14, 23). Systemic fungal organisms are not usually a problem during propagation, but such organisms as Pythium and Fusarium can attack later. The usual symptom is a blackening of the stem at or near the soil line. This problem can be prevented by using sterile soil and monthly drenches of proper fungicides (3, 14, 23).

As seed-cultivars are continually improved and growers become familiar with production techniques, plus the lower initial costs (no stock plants or cuttings required), seedling-produced plants should have a good market potential (3, 4).

Cutting Propagation

Years ago growers would save their own stock plants to produce next years cuttings (14), but today's modern grower has turned to specialists who produce disease-free cultured cuttings (23). These cuttings can be ordered either callused or rooted and are guaranteed to be disease-free upon arrival. Presently, rooted cultured cuttings cost about 45¢ each (18). They are then potted, pinched, and grown to produce several

cuttings. Strict sanitation must be maintained to keep these plants disease-free (4, 14). When propagation time approaches, the grower takes cuttings from these plants and produces a saleable 10 cm (4 inch) pot in 7-9 weeks (13, 18). Although production time is shorter than for seed cultivars, growers must take cuttings in flushes as they are produced. Therefore, one does not get a large quantity of uniform flowering plants (4); in addition there is the extra expense of maintaining a greenhouse for the stock plants (3).

The risk of disease problems is greater with cuttings than seed. Many times the stock plant is infected with bacterial stem rot and leaf blight (Xanthomonas pelargonii) and shows no symptoms. When cuttings are taken bacteria are transmitted which can destroy all the cuttings in a few weeks (14). Cuttings are also susceptible to Pythium (blackleg) and Rhizoctonia (root rot). A sterile medium and drenches with fungicides will help prevent these diseases (14, 23).

Chemical Growth Retardants

A good quality seed geranium is a multiple-branched plant that is 20-25 cm (8-10 inches) tall (10). Since excessive height is a problem with both seed and cutting produced geraniums, (21, 23) chemical growth retardants are used to produce a desirable plant (10, 23).

These chemicals will control the height by reducing internode elongation. Other benefits are compact, well-branched plants that are darker green and often slightly earlier flowering (2, 7, 10, 15, 16, 17, 21, 22, 23, 28). Some cultivars treated with retardants flowered 7-10 days earlier, (3, 11, 15, 28) but Holcomb and others (11, 16, 21) showed that flowering of some cultivars was not affected by the treatments.

A-Rest and Cycocel work equally well on height control, basal branching and increased flowering, depending on the rates used. Tests have determined that a 200 ppm spray of A-Rest or a double application of 1500 ppm Cycocel produces optimum results. Some articles have indicated that Cycocel is less expensive, 1.5¢ per plant compared to A-Rest which is 3.25¢ per plant (3, 15).

The mechanism involved in height control by use of Cycocel is inhibition of the biosynthesis of gibberellin in the plant (15, 27).

In respect to retardant effects on flowering there are two theories: Retardants may offset a juvenility factor that permits early development of reproductive primordia (12, 28). Flower initation was found to occur 56-63 days after seed-sowing in control plants, and 42-56 days in retardant-treated plants. A-Rest and Cycocel were used and no difference was found between these two chemicals (15).

Craig and Walker (8) found cumulative solar energy to be a major environmental factor controlling flowering. Their plants required a certain amount of solar energy to flower, regardless of the sowing date. Work at Michigan State University (9) confirmed the importance of photosynthetically active radiation (PAR). Vegetative height and the number of branches was also positively correlated to PAR. Plants receiving the greatest amount of light flowered in significantly fewer days than plants under lower light levels (1, 9). It is thought that PAR is only critical until the flowers have been initiated and after that it does not play a major role (9). Since retardants are applied before flower initiation, they may reduce the light requirements for flowering. A-Rest and Cycocel were tested, and A-Rest was more effective on early sowings. In later sowings, A-Rest and Cycocel were equally effective (15).

Miranda and Carlson (15) carried their treated plants outdoors and observed that A-Rest was more persistent than Cycocel. No data were presented for the garden portion of the experiment. In France (7), 48 seed cultivars were sprayed with Cycocel, 4.5 cc/liter (about 530 ppm), 8 and 10 weeks after sowing. This was a low rate of application compared to most studies in the U.S. (3, 15). These plants were evaluated in the greenhouse and placed outdoors. Of these 48 cultivars only eight showed significantly lower height and only two cultivars showed increased flowering.

Specific Leaf Weight

Researchers have been looking for a useful tool to measure net photosynthesis. They have used techniques such as determining chlorophyll content, internal leaf structure, dry weight accumulation, and now specific leaf weight (SLW). SLW is a good indication of net photosynthetic potential (6). Propiglia and Barden (19) found SLW to be a useful tool in dealing with light environments and shading. SLW is measured as dry weight (in mg) per unit leaf area (in cm^2).

CHAPTER III

MATERIALS AND METHODS

Experimental Treatments

There were two phases of the research: (A) the greenhouse production phase in which the only variable was growth retardant (control and treated), and (B) the outdoor garden phase. The control and treated plants from the greenhouse were planted outdoors under either full sun, 30% shade, or 63% shade (hereafter referred to as 60%), to determine carry-over effects of the growth retardant, as well as determining summer performance (flowering and vegetative growth) under these three light intensity environments. The seed-propagated cultivar used was 'Sooner Red' and the cutting-propagated cultivar was 'Yours Truly'. Separate experiments were conducted for each cultivar. Treatments (for each cultivar) were:

(A) Greenhouse Phase

1. Control - No chlormequat [1/] (hereafter referred to as Cycocel).
2. Cycocel applied twice (foliar spray) at 1500 ppm.

(B) Outdoor Garden Phase

1. No Cycocel, full sun.

[1/] (2-Chloroethyl) trimethylammonium chloride, Cycocel, an 11.8% American Cyanamid liquid formulation.

2. No Cycocel, 30% shade.
3. No Cycocel, 60% shade.
4. Cycocel-treated, full sun.
5. Cycocel-treated, 30% shade.
6. Cycocel-treated, 60% shade.

A randomized complete block design was used, with six single plant replications per treatment.

Data Recorded

Greenhouse Phase

1. Date first flower opened (a flower was considered open when 8 florets of the inflorescence were expanded) and subsequent flowering dates.
2. Vegetative plant height (cm) above the pot rim on May 15.
3. Total leaf area (cm^2) on May 15 of the two leaves at the third node down from the terminal growing tip, measured with a LI-COR portable area meter, Model LI-3000.
4. Total dry weight (g) of these two leaves, May 15.
5. Specific leaf weight (mg dry wt. per cm^2 leaf area) derived from 3. and 4., May 15.

Outdoor Garden Phase

1. A complete flowering record for each plant was maintained from May 15 through September 18 (each flower was tagged when it was judged as open). When a flower reached a stage of deterioration considered to be "no longer usable or attractive", it was removed from the plant.

2. Leaf area, dry weight, and specific leaf weight of the two leaves at the third node down from the terminal tip were derived June 25, August 4, and September 17.
3. Vegetative and flowering plant heights were obtained on those same three dates.
4. Light intensity comparisons (microeinsteins per sec per m^2) between full sun,

   30% shade, and 60% shade were made at 1:30 p.m. on sunny days, June 24, August 5, and September 18. Six randomly selected plants from each of the shade treatments were used to derive averages for each treatment. (The LI-190SB quantum sensor of the LI-COR LI-188B integrating/radiometer/photometer was placed horizontally under the shade cloth at the top of the plant for each reading).
5. Temperature comparisons (°C) were made utilizing the same plants as in 4., measured at 1:30 p.m. on sunny days, June 24, August 5, and September 18:
   a. ambient air temperature (within shade chamber)
   b. leaf temperature (within shade chamber)
   c. soil temperature (within shade chamber) 2.54 cm (1 inch) deep 20.3 cm (8 inches) from the base of the plant.

   These measurements were made with a Cole-Parmer 8519-00-SA thermometer with the appropriate air, leaf, or soil probe.
6. Above-ground plant dry weight (g) was obtained for each plant at the termination of the experiment September 18.

Propagation and Greenhouse Culture

Seeds of 'Sooner Red' were sown January 26, 1981 in flats of a commercial peat-vermiculite mixture (Redi-earth) and placed under intermittent mist with 21°C (70°F) bottom heat. On February 9, the seedlings were transplanted to 11.4 cm (4½ inch) plastic pots.

Stem cuttings of 'Yours Truly' were propagated March 10, 1981. A 0.1% Indole butyric acid-talc rooting hormone treatment was used. The cuttings were stuck directly into 11.4 cm (4½ inch) pots, one per pot, and placed under intermittent mist at a minimum air temperature of 18.3°C (65°F). By March 27, the plants had well-established roots, and misting was terminated.

Both cultivars, 'Sooner Red' and 'Yours Truly', were grown in a medium of three parts sphagnum peat, one part perlite, and one part vermiculite, plus 4.5 kg dolomite, 1.13 kg superphosphate, 680 g potassium nitrate and 85 g fritted trace elements per cubic meter of medium.

A night temperature range of 15.5 - 17.5°C (60-63°F) was maintained in a fiberglass greenhouse. Plants were liquid-fertilized weekly with 500 ppm N, 220 ppm P, and 415 ppm K using 20-8.8-16.6 fertilizer until April 24, when the program was changed to a constant liquid fertilizer program using 230 ppm N, 105 ppm P, and 209 ppm K from 15-7-14 fertilizer, including trace elements.

Growth Retardant Applications

Cycocel was applied as a foliar spray to thoroughly wet the foliage, to the point of runoff.

For 'Sooner Red', the first 1500 ppm spray was applied March 9, four weeks after the seedlings were transplanted to 11.4 cm (4½ inch) pots. The second 1500 ppm spray was applied March 18.

For 'Yours Truly', the first 1500 ppm spray was applied March 30, about 3 weeks after propagation. The second 1500 ppm spray was applied April 6.

Outdoor Garden Planting and Culture

Plants were planted outdoors May 15, 1981 in a clay loam soil amended with a 5 cm (2 inch) layer of moist sphagnum peat moss and 10-8.8-8.3 fertilizer applied at 680 g per 9 sq. meters (1½ lbs. per 100 sq. ft.), all incorporated thoroughly into the top 12.5 cm (5 inches) of soil. Thereafter, 500 ppm N, 220 ppm P, and 415 ppm K were applied monthly through a trickle irrigation system, using 20-8.8-16.6 fertilizer.

The shade chambers for the 30 and 60% shade treatments were constructed of 15 x 15 cm (6 x 6 inch) box wire. Each chamber consisted of a wire cylinder 61 cm (24 inch) in diameter and 61 cm tall, covered with Chicopee style 5187109 30% actual shade, or style 5184009 63% actual shade regular polypropylene shade fabric.

Wire cylinders without shade fabric covers were used for the full sun treatments.

For ease of establishing a randomized complete block design, a shade chamber (or wire cylinder only for full sun) was used for each plant in the experiments. The plants were planted 152 cm (5 ft) apart in the row, with rows 152 cm apart so that no shade was cast from one chamber to another. In this way, guard rows were not needed, and each plant had approximately equal environmental conditions.

CHAPTER IV

RESULTS AND DISCUSSION

Greenhouse Phase

Since 'Sooner Red' and 'Yours Truly' were handled in separate experiments, formal statistical comparisons between the two cultivars will usually not be made in the results and discussion. However, certain informal statements about differences in the two cultivars will be presented.

Flowering Record

Cycocel treatment had no significant effect on the number of flowers produced by May 15 on either cultivar. Cycocel-treated 'Sooner Red' plants produced 12 flowers whereas the control plants produced seven. 'Yours Truly' had 20 flowers for each treatment (Table I, Figure 1).

'Sooner Red' seeds were sown January 26. The time from sowing seeds to May 15 is 15.5 weeks. The seed company supplying the 'Sooner Red' seeds predicted 15 weeks to flowering (5).

'Yours Truly' cuttings were propagated March 10. Only 9.5 weeks were required for production of 20 flowers by May 15.

Vegetative Height

Cycocel caused significant height reduction in both cultivars (Tables II and III). There is stronger evidence of a retardant effect on 'Sooner

TABLE I

SIGNIFICANCE OF MAIN EFFECTS DURING THE GREENHOUSE PHASE

Source of Variation	Number of Flowers	Vegetative Height	Total Leaf Area	Specific Leaf Weight
'Sooner Red' retardant (Cycocel)	NS[X]	0.01	0.01	0.01
'Yours Truly' retardant (Cycocel)	NS	0.01	0.01	NS

[X] Non significant (above 0.05)

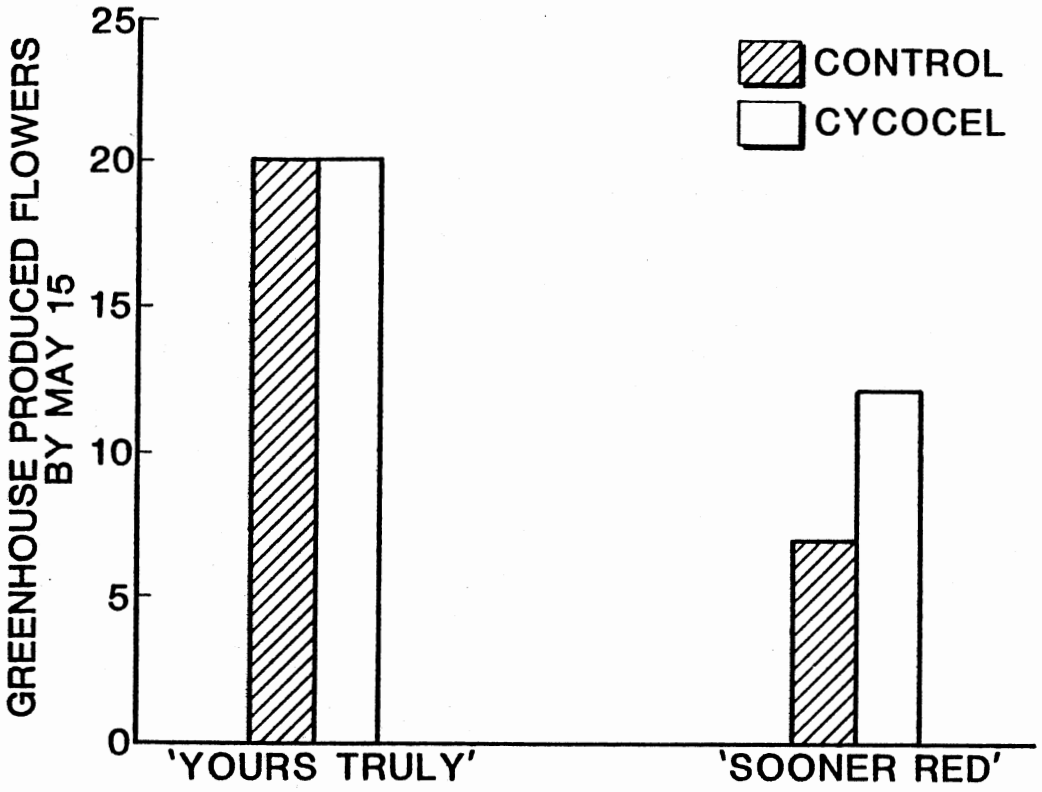

Figure 1. Effect of Cycocel Application on Number of Greenhouse Produced Flowers per 18 Plants

Red' than for 'Yours Truly'.

Total Leaf Area

Cycocel caused a significantly reduced total leaf area on both cultivars (leaves at third node from tip) (Tables II and III).

Specific Leaf Weight

Cycocel application caused a significantly lower SLW for 'Sooner Red' (Table II), but not for 'Yours Truly' (Table III).

The results on vegetative height and SLW suggest that the physical morphology of the leaves on 'Yours Truly', especially the heavy pubescence, may have caused a lower absorption rate of foliar sprayed Cycocel than for the 'Sooner Red' cultivar, although leaf area was significantly reduced by Cycocel application in 'Yours Truly'. Why leaf area would be affected, but not SLW is not clear.

Outdoor Garden Phase

Flowering Record

The statistical analysis for flowering for the total season (Table IV) was run using retardant (Cycocel), shade and retardant x shade (interaction) as variables. Since there was no significant interaction between retardant and shade, these parameters were examined separately.

The flowering periods were grouped into two-week intervals for ease of analysis and presentation.

'Sooner Red' peaked in flowering July 16-31 regardless of the treatment (Table V). Local weather bureau data showed that there were seven days of 38°C (100°F) temperatures or above during this period (Figure 2).

TABLE II

EFFECTS OF CYCOCEL APPLICATION ON HEIGHT, SPECIFIC LEAF WEIGHT AND LEAF AREA[X], 'SOONER RED' IN THE GREENHOUSE

TREATMENT	VEGETATIVE HEIGHT (cm)	SLW (mg/cm^2)	TOTAL LEAF AREA (cm^2)
CONTROL	$22.81^{Y}{}_{B}{}^{Z}$	5.35_{B}	77.17_{B}
CYCOCEL	10.73_{A}	4.65_{A}	48.97_{A}

X Leaves at third node from terminal growing tip.

Y Each figure is the mean of 18 plants.

Z Means within columns followed by different letters are significantly different at the 5% level, using the T-test.

TABLE III

EFFECTS OF CYCOCEL APPLICATION ON HEIGHT, SPECIFIC LEAF WEIGHT AND LEAF AREA[X], 'YOURS TRULY' IN THE GREENHOUSE

TREATMENT	VEGETATIVE HEIGHT (cm)	SLW (mg/cm²)	TOTAL LEAF AREA (cm²)
CONTROL	$20.91^{Y}{}_{B}{}^{z}$	5.44_{A}	127.75_{B}
CYCOCEL	17.82_{A}	5.47_{A}	100.19_{A}

X Leaves at third node from terminal growing tip.

Y Each figure is the mean of 18 plants.

Z Means within columns followed by different letters are significantly different at the 5% level, using the T-test.

TABLE IV

SIGNIFICANCE OF MAIN EFFECTS AND INTERACTIONS OF CYCOCEL AND SHADE ON FLOWERING OF 'SOONER RED' AND 'YOURS TRULY' OUTDOORS

SOURCE OF VARIATION	TOTAL FLOWERING RECORD	
	'SOONER RED'	'YOURS TRULY'
Retardant (Cycocel)	NS[X]	NS
Shade	0.01	0.01
Retardant X Shade	NS	NS

[X] Non significant (above 0.05)

TABLE V

NUMBER OF FLOWERS PRODUCED BY 'SOONER RED' AS INFLUENCED BY SHADE AND CYCOCEL DURING THE GARDEN PHASE

RETARDANT	PERCENT SHADE	MAY 16-31	JUNE 1-15	JUNE 16-30	JULY 1-15	JULY 16-31	AUG 1-15	AUG 16-31	SEPT 1-18	TOTAL
None	0	6[Z]	9	26	98	194	114	125	136	708
	30	10	14	35	93	172	108	107	134	673
	60	9	12	25	34	115	66	42	63	366
Cycocel	0	10	19	47	96	167	82	115	139	675
	30	11	28	46	87	121	56	89	90	528
	60	8	29	21	54	85	40	56	69	362
Total		54	111	200	462	854	466	534	631	3312

Z Each figure is the total of 6 plants.

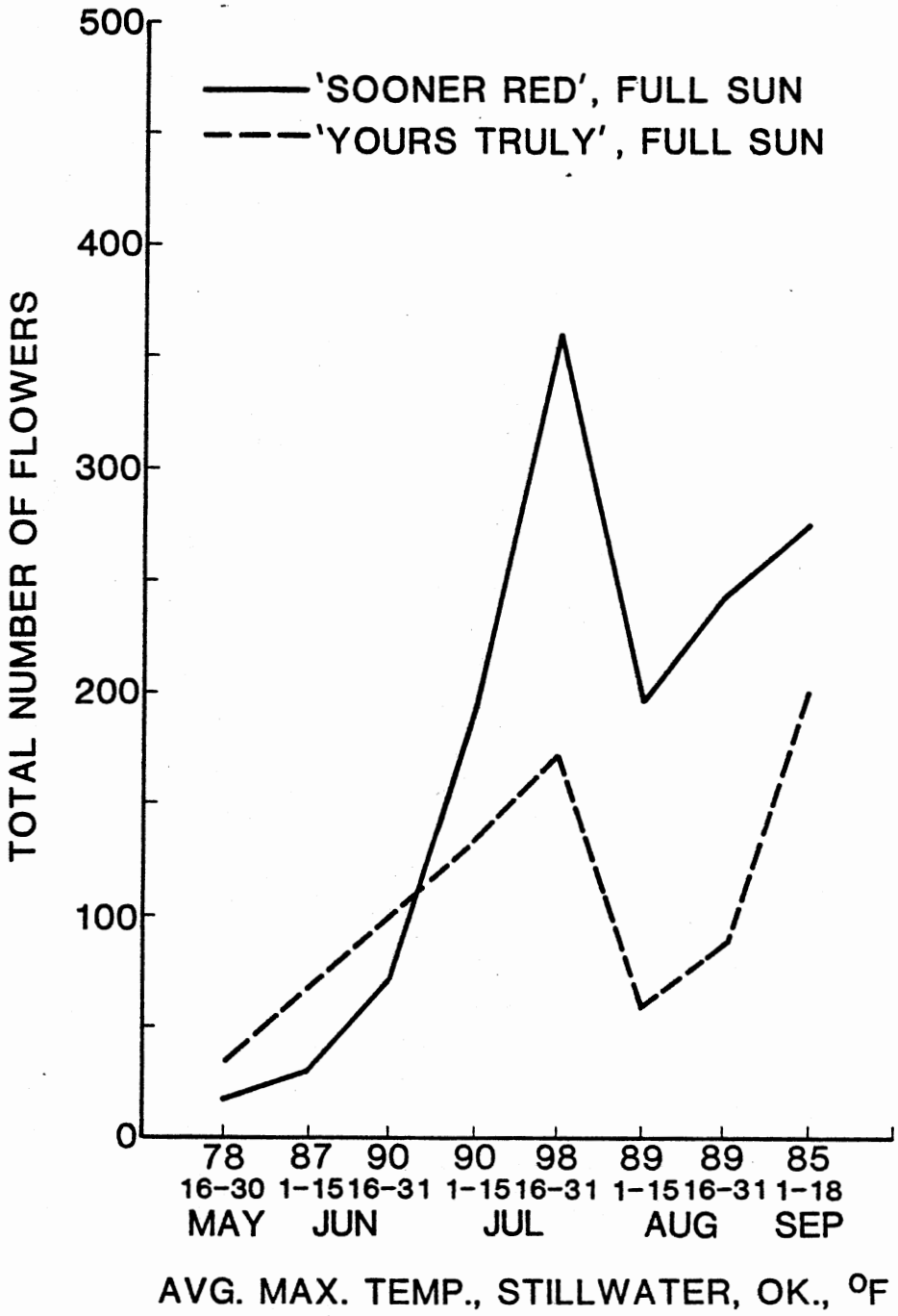

Figure 2. Number of Flowers as Affected by the Average Maximum Temperature for the Various Flowering Periods During the Garden Phase

After July 31, flowering declined and by September 1-18 was increasing toward a second peak. It appears that every 8 to 10 weeks during the summer a flowering peak occurs, followed by a decline and then an increase toward another peak. It would be interesting to study flower bud initiation and development in relation to these cycles or flushes of flower production. The 36 plants in the 'Sooner Red' experiment produced a total of 3312 flowers from May 16-September 18. Not shown in the data, however, is the fact that many of the flowers, especially in hot weather, had few florets and were showy for only a short period of time.

One of the principal objectives of this study was to determine the residual or carry-over effects of the Cycocel treatment. Cycocel caused a significant increase in 'Sooner Red' flowering for the June 1-15 period only (Table VI, Figures 3 and 4). The number of flowers produced by the Cycocel-treated plants was more than double the number produced by the control plants during this period. Although not statistically significant, Cycocel-treated plants continued to produce more flowers than the control plants through July 15. Later in the season, July 16-August 15, the control plants produced more flowers than the treated plants. From August 16-September 18, this trend continued but was not significant. Apparently, the Cycocel treatment does stimulate an early summer flowering increase that could be commercially important, but some later flowering is sacrificed due to the cyclic pattern of flower production (peaks followed by declines).

The amount of shade had significant effects on flowering of 'Sooner Red' (Tables IV and VII, Figure 5). As shade increased, a lower number of flowers were produced, especially when shade was increased from 30 to 60 percent.

TABLE VI

EFFECTS OF CYCOCEL APPLICATION ON THE NUMBER OF GARDEN PRODUCED FLOWERS BY 'SOONER RED' FOR EACH PERIOD

	Number of Flowers								
RETARDANT	MAY 15-31	JUNE 1-15	JUNE 16-30	JULY 1-15	JULY 16-31	AUG 1-15	AUG 16-31	SEPT 1-18	TOTAL
None	25_A [X,Y]	35A	86_A	225_A	481_B	288_B	274_A	333_A	1747
Cycocel	29_A	76_B	114_A	237_A	373_A	178_A	260_A	298_A	1565

X Each figure is the total number of flowers for 18 plants.

Y Means within columns followed by different letters are significantly different at the 5% level, using the T-test.

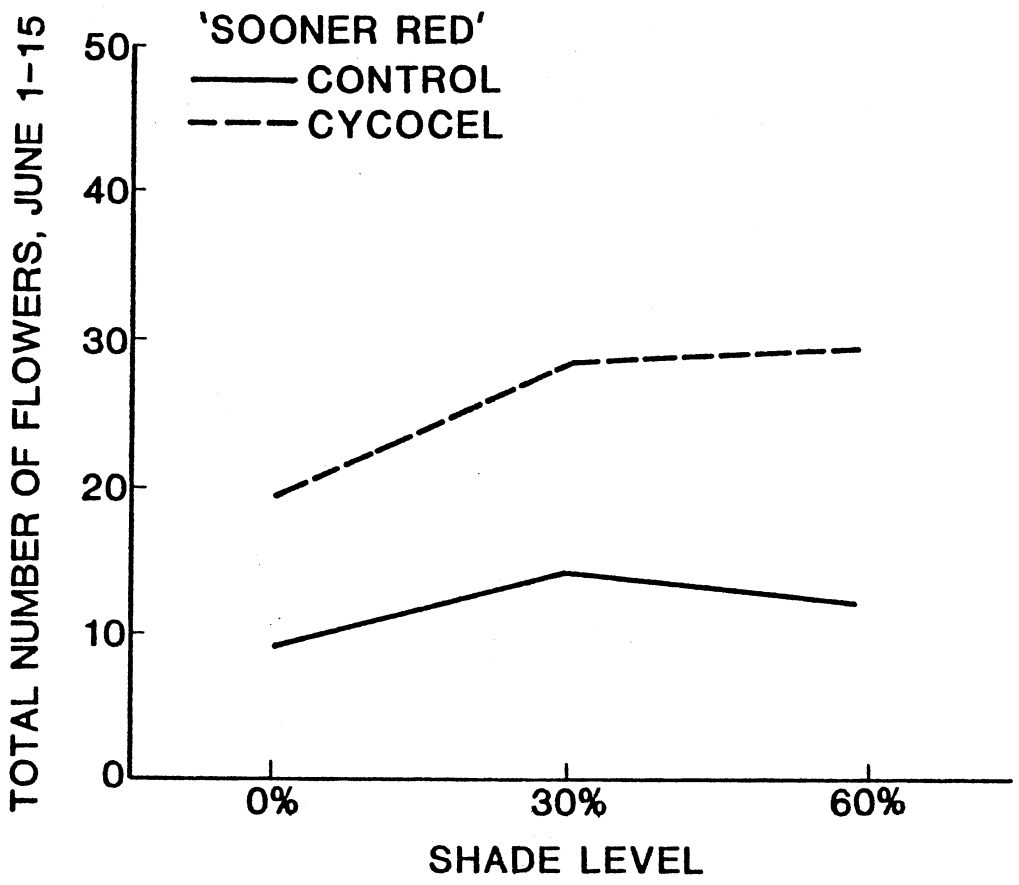

Figure 3. Effect of Cycocel Application on the Number of Garden-Produced 'Sooner Red' Flowers, June 1-15

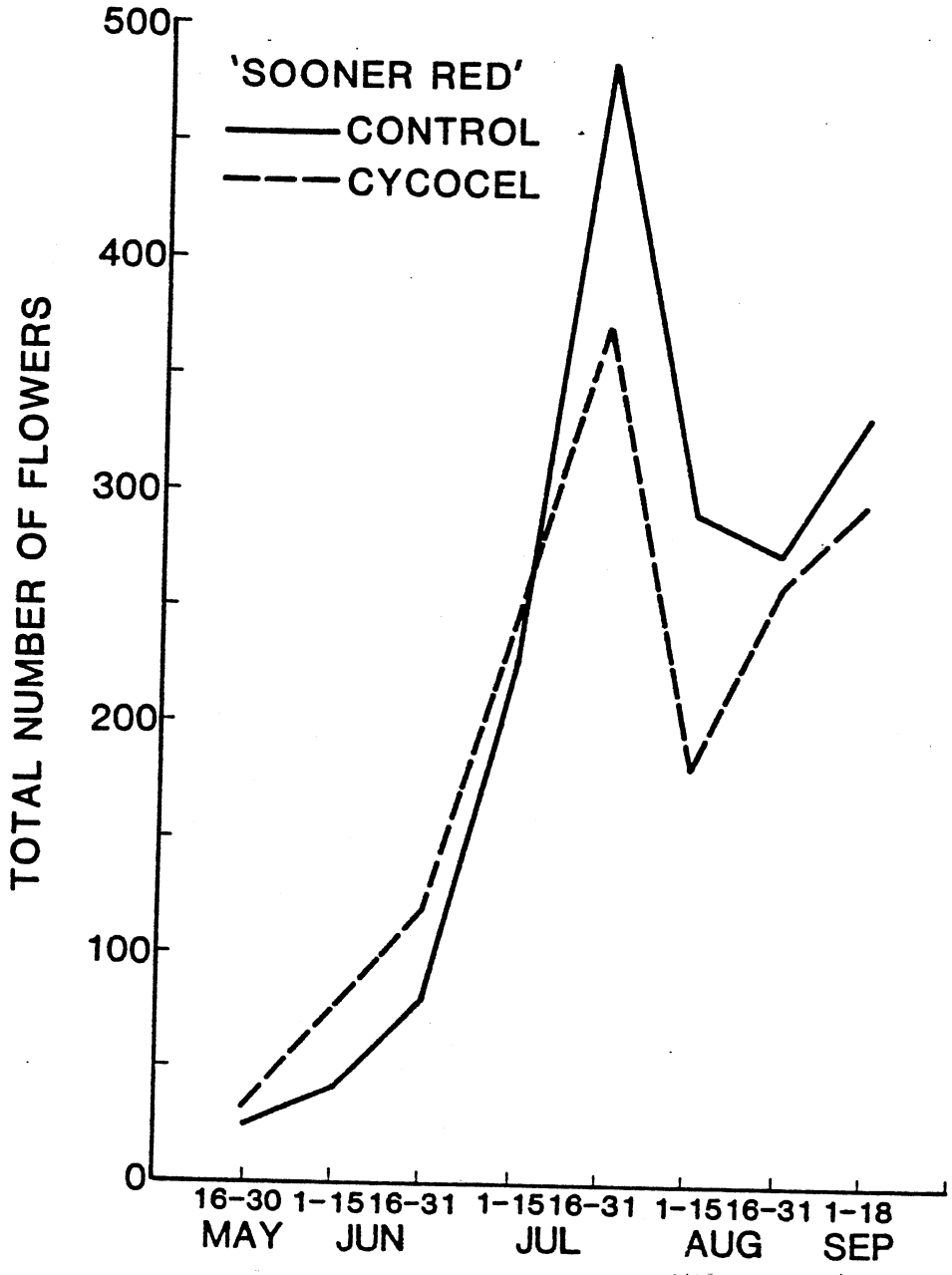

Figure 4. Effect of Cycocel Application on the Over-All Garden Flowering Performance of 'Sooner Red'

TABLE VII

EFFECT OF THREE LIGHT INTENSITIES ON TOTAL NUMBER OF FLOWERS PRODUCED FOR 'SOONER RED'

Shade Level	Average Number Flowers[Y]
Full Sun	115.6_{a}[Z]
30% Shade	100.6_{b}
60% Shade	61.3_{c}

Y Each figure is the mean number of flowers per plant, May 16-September 18.

Z Means within columns followed by different letters are significantly different at the 5% level, using Duncan's Multiple Range Test.

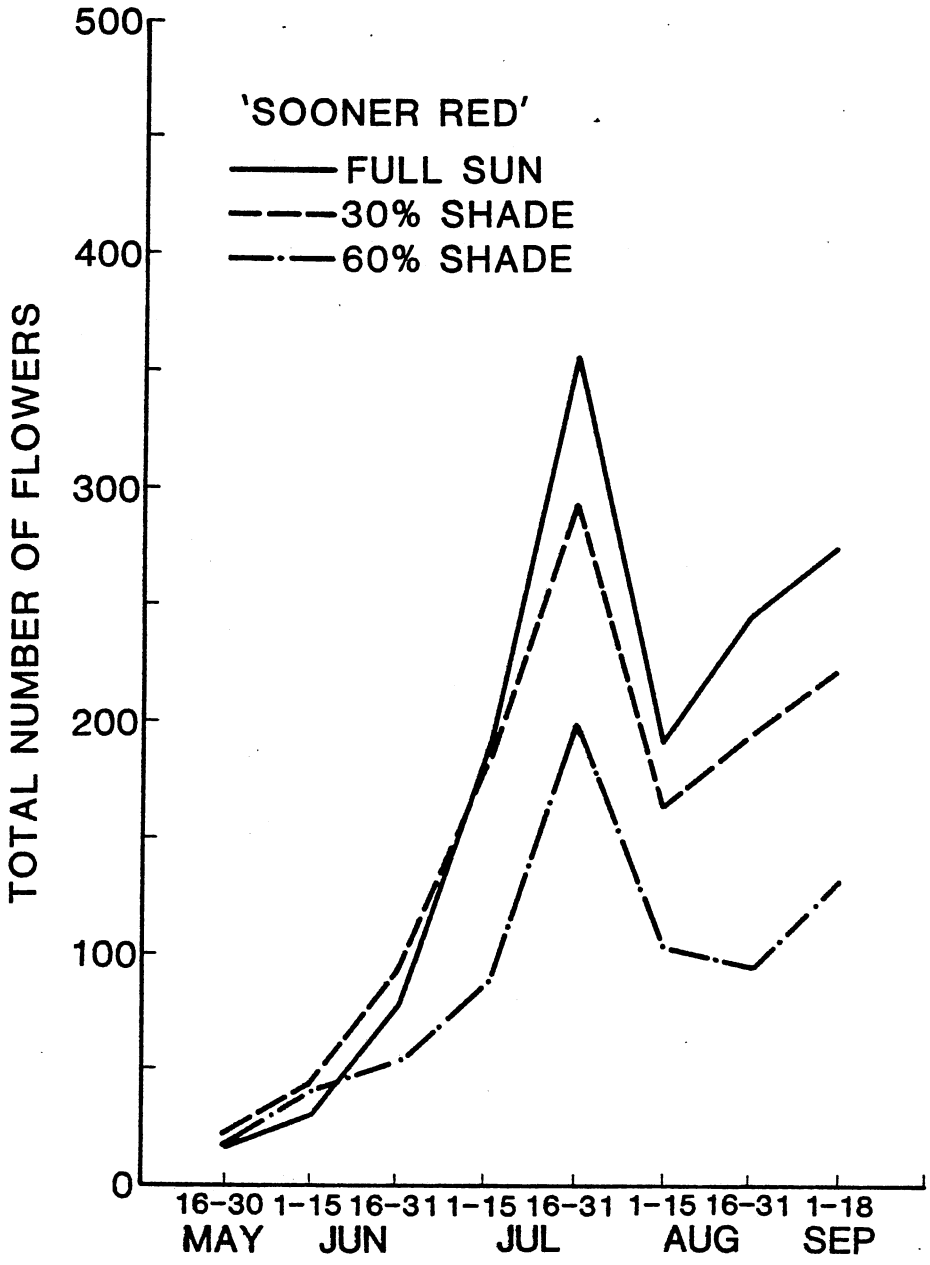

Figure 5. The Effect of Shade on the Over-All Flowering Performance of 'Sooner Red' During the Garden Phase

For 'Yours Truly', an initial flowering peak was reached July 16-31, but the highest flowering peak was September 1-18 (Table VIII and Figure 6). The late peak in September after a rapid August 1-31 decline may indicate that this cultivar responds well to cooler temperatures relative to flower development, although more detailed research would be required in this area to draw a definite conclusion. Cycles of flowering of 'Yours Truly' were very similar to those of 'Sooner Red', although 'Yours Truly' produced 1101 fewer flowers than 'Sooner Red' from May 16 to September 18 (Tables V and VIII). Individual flowers on 'Yours Truly' with double petalage were usually more showy than flowers of 'Sooner Red', especially when viewed from a close distance.

Cycocel treatment had no significant effect on flowering throughout the season for 'Yours Truly' (Table IX). This is shown graphically in Figure 6. This again may indicate that the Cycocel was not absorbed in sufficient quantity by 'Yours Truly' plants to cause as great an effect on early flowering as occured with 'Sooner Red', or that there are simply cultivar differences in sensitivity to Cycocel treatment.

There was no significant difference in flower production between 'Yours Truly' plants grown in full sun and under 30% shade. Plants under 60% shade produced significantly fewer flowers than those in full sun or 30% shade (Table X and Figure 7). Since 30% shade didn't reduce flowering, partial shade would probably be a favorable environment for this cultivar in very hot summer weather.

Vegetative Height

Plant heights were recorded June 25, August 4, and September 18. Cyocel-treated 'Sooner Red' plants were significantly shorter than

TABLE VIII

NUMBER OF FLOWERS PRODUCED BY 'YOURS TRULY' AS INFLUENCED BY SHADE AND CYCOCEL DURING THE GARDEN PHASE

		Number of Flowers								
RETARDANT	PERCENT SHADE	MAY 16-31	JUNE 1-15	JUNE 16-30	JULY 1-15	JULY 16-31	AUG 1-15	AUG 16-31	SEPT 1-18	TOTAL
None	0	17[Z]	34	51	67	78	22	47	93	409
	30	15	28	38	59	80	68	46	111	445
	60	14	21	19	33	65	31	25	76	284
Cycocel	0	17	31	48	66	95	29	40	107	433
	30	20	31	44	51	75	43	28	128	420
	60	11	23	14	22	51	27	11	61	220
Total		94	168	214	298	444	220	197	576	2211

Z Each figure is the total for 6 plants.

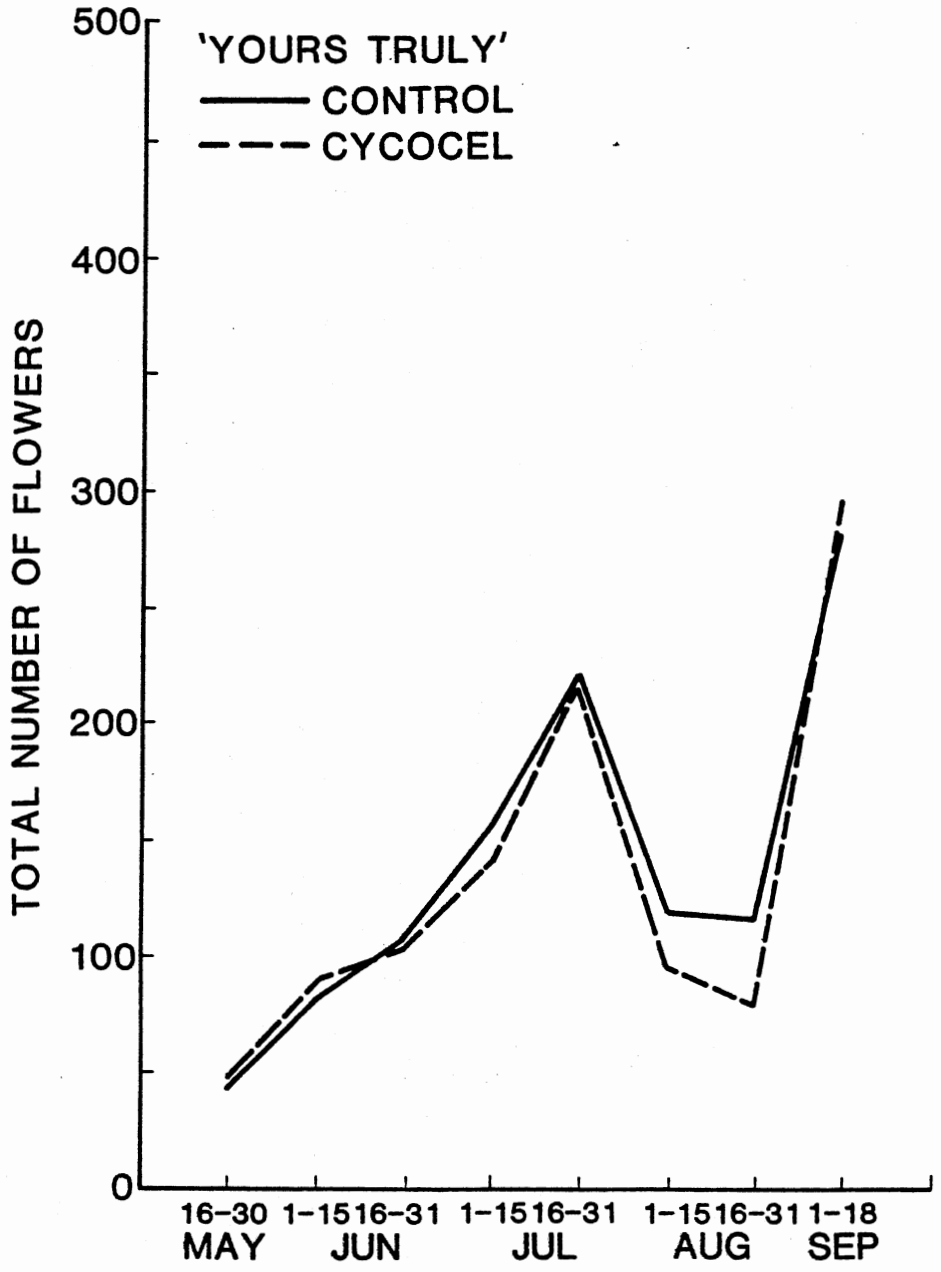

Figure 6. Effect of Cycocel Application on the Over-All Garden Flowering Performance of 'Yours Truly'

TABLE IX

EFFECTS OF CYCOCEL APPLICATION ON THE NUMBER OF GARDEN-PRODUCED FLOWERS BY 'YOURS TRULY' FOR EACH PERIOD

	Number of Flowers								
RETARDANT	MAY 16-31	JUNE 1-15	JUNE 16-30	JULY 1-15	JULY 16-31	AUG 1-15	AUG 16-31	SEPT 1-18	TOTAL
None	46^{X}_{A} Y	83_{A}	108_{A}	159_{A}	223_{A}	121_{A}	118_{A}	280_{A}	1138
Cycocel	48_{A}	85_{A}	106_{A}	139_{A}	221_{A}	99_{A}	79_{A}	296_{A}	1073

X Each figure is the total flowers for 18 plants.

Y Means within columns followed by different letters are significantly different at the 5% level, using the T-test.

TABLE X

EFFECT OF THREE LIGHT INTENSITIES ON TOTAL NUMBER OF FLOWERS PRODUCED BY 'YOURS TRULY'

Shade Level	Average Number of Flowers[Y]
Full Sun	71.3_{a}[Z]
30% Shade	73.0_{a}
60% Shade	41.1_{b}

Y Each figure is the mean number of flowers per plant, May 16-September 18.

Z Means within columns followed by different letters are significantly different at the 5% level, using Duncan's Multiple Range Test.

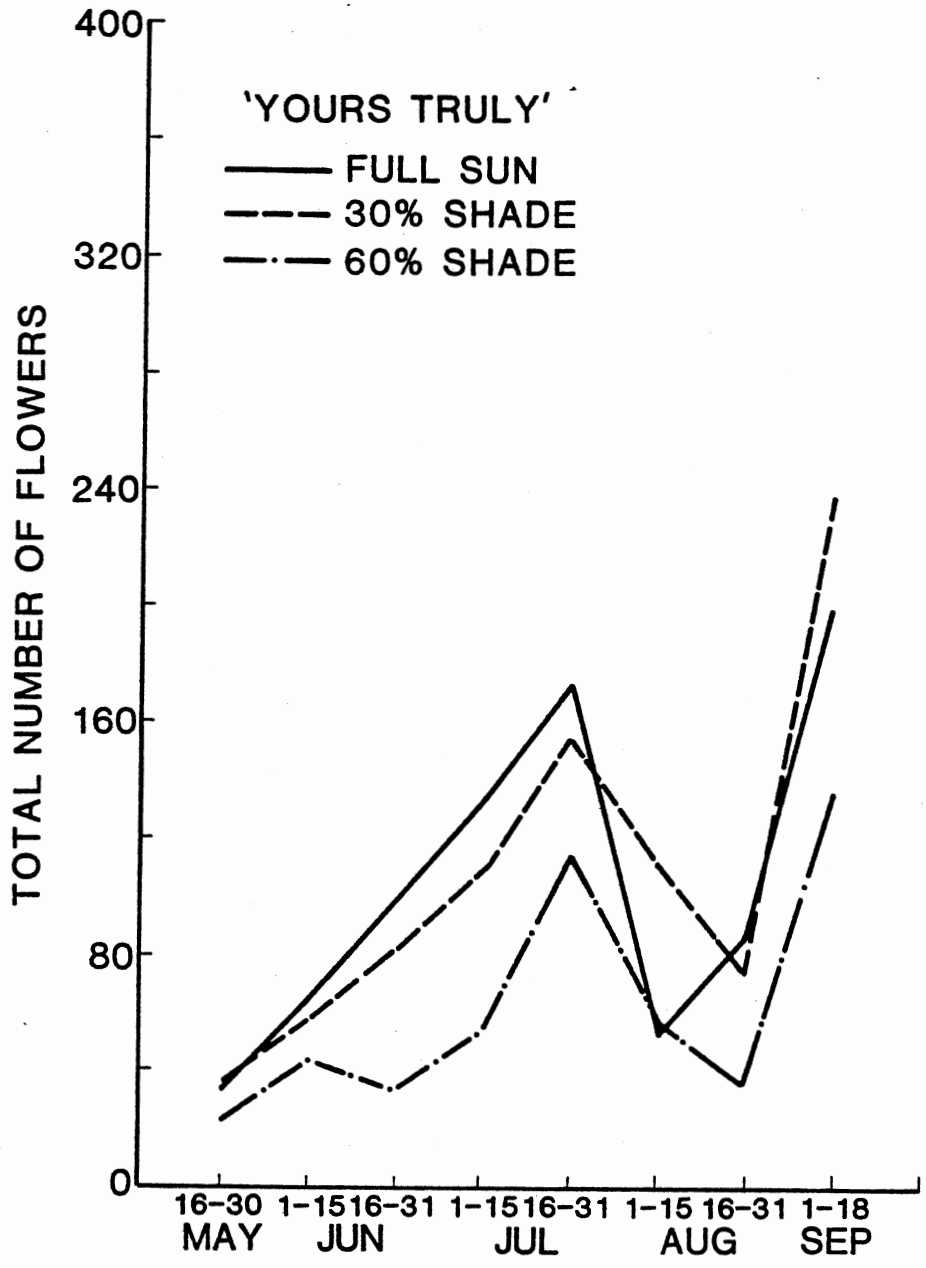

Figure 7. The Effect of Shade on the Over-All Flowering Performance of 'Yours Truly' During the Garden Phase

non-treated plants at all three dates (Table XI and Figure 8). 'Yours Truly' Cycocel-treated plants were shorter than controls on August 4 only (Table XI and Figure 9).

The effect of shade on plant height was similar for both cultivars (Tables XII and XIII). Early in the season (June 25) there were no significant height differences. On August 4 and September 18, there were no significant differences in height between full sun plants and those in 30% shade, but in all cases, plants in 60% shade were significantly taller than those in full sun. The plants in 60% shade were also significantly taller than plants in 30% shade except for 'Sooner Red' on August 4.

Specific Leaf Weight

Cycocel treatment caused a significantly lower SLW for 'Sooner Red' on June 25, but later in the season no significant differences were noted between control and Cycocel-treated plants (Tables XIV and XV). This is similar to the flower production results discussed earlier which showed that there was a definite flowering increase due to Cycocel early, but this did not continue later in the season (Table VI, Figure 3). For 'Sooner Red', the only all season carry-over effect of Cycocel was on plant height (Table XI and Figure 8).

For 'Yours Truly', there were no significant SLW differences due to Cycocel throughout the season (Table XIV and XVI). This again indicates the lesser effect of the foliar spray application of Cycocel on this cultivar.

The effects of shading on SLW of 'Sooner Red' are shown in Table XVII. By June 25, no significant differences had developed, but a trend

TABLE XI

SIGNIFICANCE OF GROWTH RETARDANT ON THE VEGETATIVE HEIGHT DURING THE GARDEN PHASE

Source of Variation	June 25	August 4	September 18
'Sooner Red' Retardant (Cycocel)	0.01	0.01	0.01
'Yours Truly' Retardant (Cycocel)	NS[X]	0.02	NS

[X] Non significant (above 0.05)

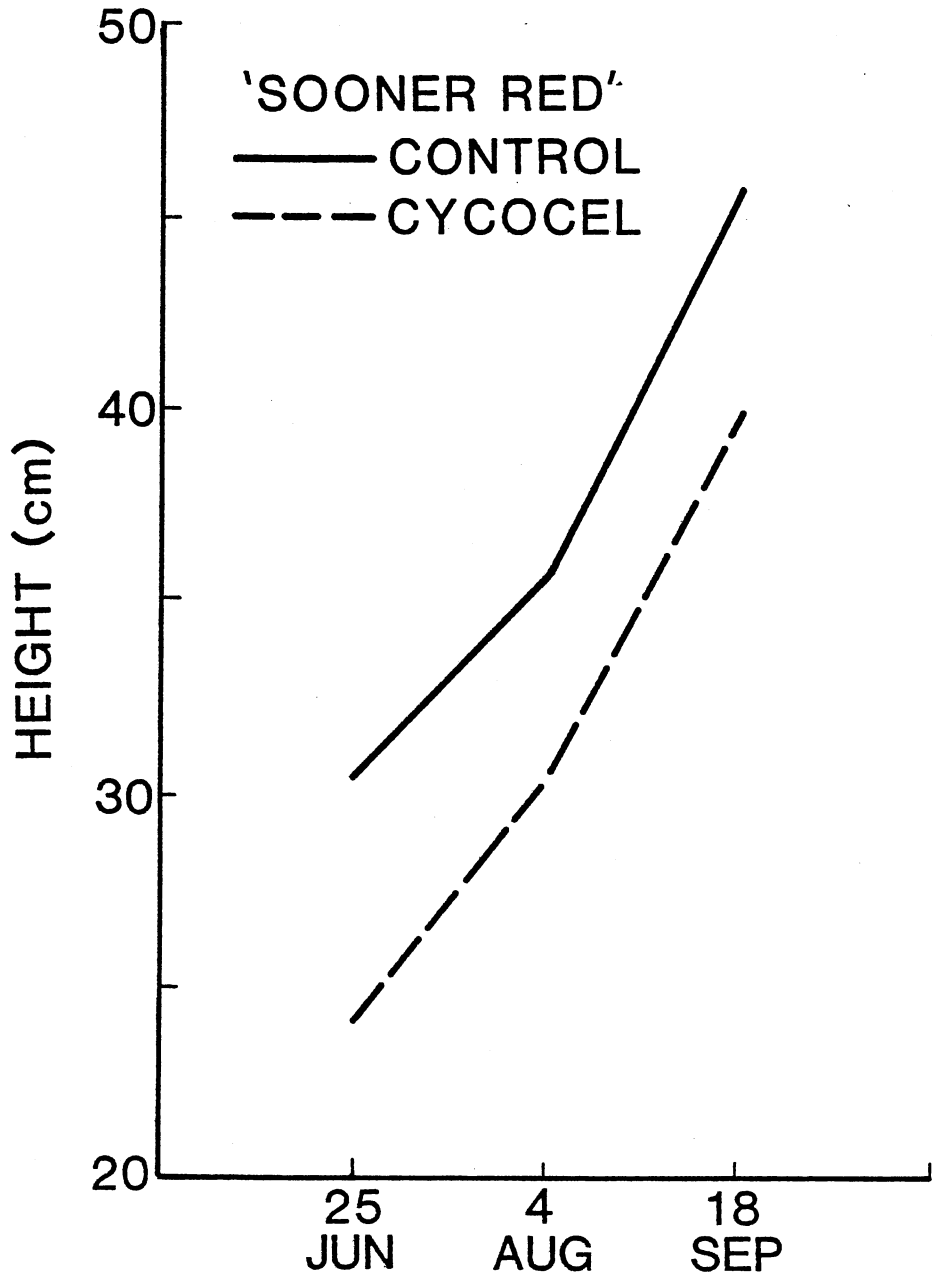

Figure 8. The Effect of Cycocel on the Vegetative Height of 'Sooner Red' During the Garden Phase

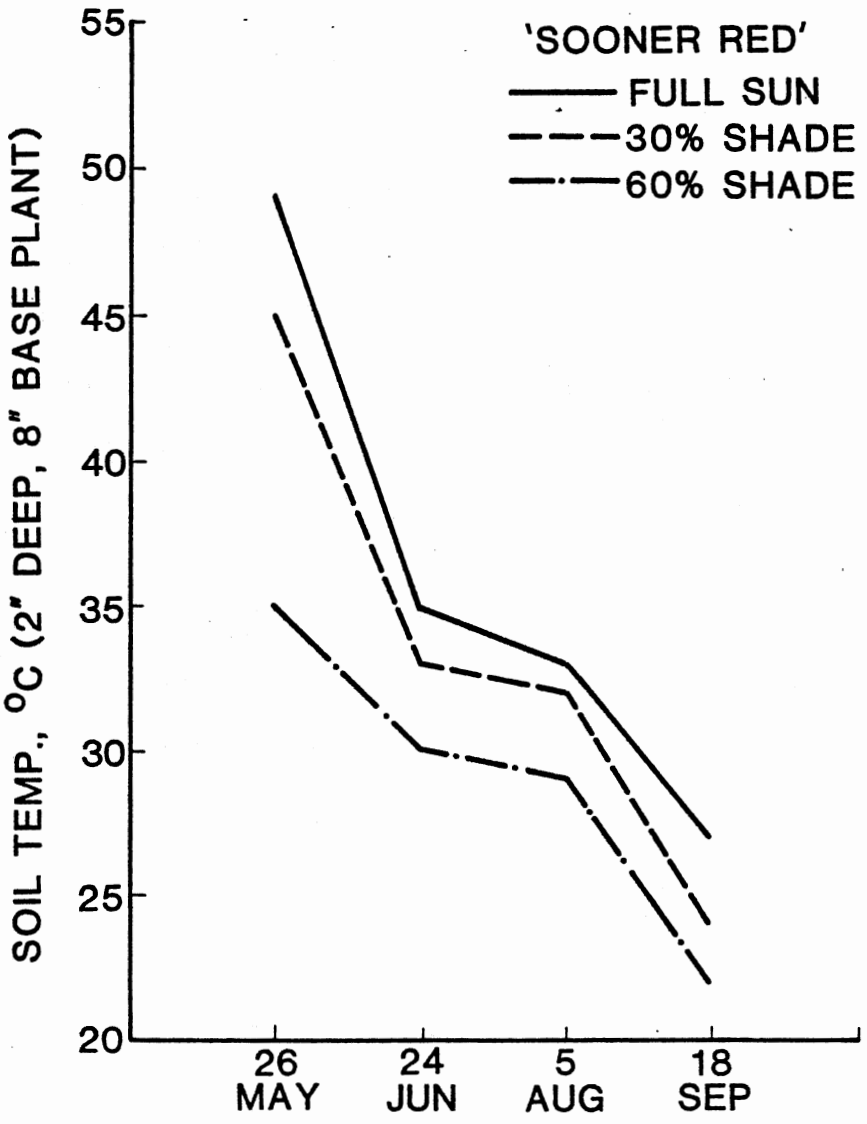

Figure 9. The Effect of Cycocel on the Vegetative Height of 'Yours Truly' During the Garden Phase

TABLE XII

EFFECT OF LIGHT INTENSITY ON THE VEGETATIVE HEIGHT[X] OF 'SOONER RED' DURING THE GARDEN PHASE

	Height (cm)		
SHADE LEVEL	JUNE 25	AUGUST 4	SEPTEMBER 18
Full Sun	$26.45^{Y}{}_{A}{}^{Z}$	33.06_{A}	39.92_{A}
30%	26.65_{A}	30.62_{AB}	41.43_{A}
60%	27.78_{A}	35.28_{B}	47.17_{B}

X Height measured in cm from soil line to top of plant.

Y Each figure is the mean of 12 plants.

Z Means within columns followed by different letters are significantly different at the 5% level, using Duncan's Multiple Range Test.

TABLE XIII

EFFECT OF LIGHT INTENSITY ON THE VEGETATIVE HEIGHT[X] OF 'YOURS TRULY' DURING THE GARDEN PHASE

SHADE LEVEL	Height(cm) JUNE 25	AUGUST 4	SEPTEMBER 18
Full Sun	$25.68^{Y}{}_{A}{}^{Z}$	29.00_{A}	32.02_{A}
30%	28.92_{A}	28.63_{A}	36.04_{A}
60%	28.38_{A}	40.48_{B}	52.83_{B}

X Height measured in cm from soil line to top of plant.

Y Each figure is the mean of 12 plants.

Z Means within columns followed by different letters are significantly different at the 5% level, using Duncan's Multiple Range Test.

TABLE XIV

SIGNIFICANCE OF MAIN EFFECTS AND INTERACTIONS
DURING THE OUTDOOR GARDEN PHASE

SOURCE OF VARIATION	MEAN SLW (mg/cm^2) JUNE 25	AUGUST 4	SEPTEMBER 18
'Sooner Red'			
Retardant (Cycocel)	0.01	NS[X]	NS
Shade	0.01	0.01	0.01
Retardant X Shade	NS	NS	NS
'Yours Truly'			
Retardant (Cycocel)	NS	NS	NS
Shade	0.01	0.01	0.01
Retardant X Shade	NS	NS	NS

[X] Non significant (above 0.05)

TABLE XV

EFFECTS OF CYCOCEL ON SPECIFIC LEAF WEIGHT FOR 'SOONER RED'

TREATMENT	MEAN SLW (mg/cm^2)		
	JUNE 25	AUGUST 4	SEPTEMBER 18
Control	$6.50^{Y}{}_{a}{}^{Z}$	6.10_{a}	6.06_{a}
Cycocel	5.10_{b}	5.97_{a}	6.34_{a}

Y Each figure is the mean of 18 plants.

Z Means within columns followed by different letters are significantly different at the 5% level, using the T-test.

TABLE XVI

EFFECTS OF CYCOCEL ON SPECIFIC LEAF WEIGHT FOR 'YOURS TRULY'

TREATMENT	MEAN SLW (mg/cm^2)		
	JUNE 25	AUGUST 4	SEPTEMBER 18
Control	$6.87^{Y}{}_{a}{}^{Z}$	7.72_{a}	7.27_{a}
Cycocel	6.78_{a}	7.36_{a}	6.77_{a}

Y Each figure is the mean of 18 plants.

Z Means within columns followed by different letters are significantly different at the 5% level, using the T-test.

TABLE XVII

EFFECTS OF LIGHT INTENSITY ON SPECIFIC LEAF WEIGHT FOR 'SOONER RED'

TREATMENT	MEAN SLW (mg/cm²)		
	JUNE 25	AUGUST 4	SEPTEMBER 18
Full Sun	6.65[Y]aZ	7.55a	7.09a
30% Shade	5.80a	5.77b	6.55b
60% Shade	4.89a	4.76c	4.97c

Y Each figure is the mean of 12 plants.

Z Means within columns followed by different letters are significantly different at the 5% level, using Duncan's Multiple Range Test.

had started which was evident on August 4 and September 18. It showed that as shade increased, SLW decreased. This agrees with work of Barden (6) who found that SLW was lower on internal leaves compared to the peripheral leaves of apple trees.

Results were similar but not as consistent for 'Yours Truly' (Table XVIII). The shade effect became evident by June 25 when 30% and 60% shade resulted in significantly lower SLW than for full sun. On August 4, as shade increased, SLW decreased, and on September 18 only 60% shade plants had a lower SLW.

Final Dry Weight

At the end of the experiment, plants were harvested individually by cutting the stem at the soil line. They were dried in a 50°C (122°F) oven to obtain dry weight.

Cycocel application had no significant effect on final dry weight of either 'Sooner Red' or 'Yours Truly' (Table XIX). There appeared to be a trend for the Cycocel-treated plants to have lower dry weight, but the differences were not significant (Table XX). This generally agrees with the June, August, and September SLW data discussed earlier (Tables XV and XVI).

For 'Sooner Red', shade had a significant effect on final plant dry weight (Tables XIX and XX). As shade increased, final dry weights significantly decreased. This agrees closely with SLW data for August and September (Table XVII), again seeming to indicate that SLW may be as good a measure of photosynthetic potential as plant dry weight.

However, with 'Yours Truly', there were no significant differences in final plant dry weight due to shade (Table XXII), and the trend was

TABLE XVIII

EFFECTS OF LIGHT INTENSITY ON SPECIFIC LEAF WEIGHT FOR 'YOURS TRULY'

TREATMENT	MEAN SLW (mg/cm^2)		
	JUNE 25	AUGUST 4	SEPTEMBER 18
Full Sun	$7.75^{Y}{}_{a}Z$	8.95_{a}	7.94_{a}
30% Shade	6.70_{b}	7.71_{b}	7.28_{a}
60% Shade	6.02_{b}	5.96_{c}	5.83_{b}

Y Each figure is the mean of 12 plants.

Z Means within columns followed by different letters are significantly different at the 5% level, using Duncan's Multiple Range Test.

TABLE XIX

SIGNIFICANCE OF MAIN EFFECTS AND INTERACTIONS OF CYCOCEL AND SHADE ON FINAL DRY WEIGHT DURING THE OUTDOOR GARDEN PHASE

Source of Variation	Final Dry Weight	
	'Sooner Red'	'Yours Truly'
Retardant (Cycocel)	NS[X]	NS
Shade	0.01	NS
Retardant X Shade	NS	NS

[X] Non significant (above 0.05)

TABLE XX

EFFECTS OF CYCOCEL APPLICATION ON
FINAL DRY WEIGHTS

Treatment	Mean Final Dry Weight (g)	
	'Sooner Red'	'Yours Truly'
Control	$161.85^{X}{}_{a}{}^{Y}$	107.29_{a}
Cycocel	150.98_{a}	106.81_{a}

X Each figure is the mean of 18 plants.

Y Means within columns followed by different letters are significantly different at the 5% level, using the T-test.

TABLE XXI

EFFECTS OF LIGHT INTENSITY ON THE FINAL DRY WEIGHT OF 'SOONER RED'

Treatment	Mean Final Dry Weight (g)
Full Sun	210.12^{X}_{a} Y
30% Shade	150.12_{b}
60% Shade	109.00_{c}

X Each figure is the mean of 12 plants.

Y Means within columns followed by different letters are significantly different at the 5% level, using Duncan's Multiple Range Test.

TABLE XXII

EFFECTS OF LIGHT INTENSITY ON THE FINAL DRY WEIGHT OF 'YOURS TRULY'

Treatment	Mean Final Dry Weight (g)
Full Sun	104.24^{X}_{a} Y
30% Shade	105.90_{a}
60% Shade	111.01_{a}

X Each figure is the mean of 12 plants.

Y Means within columns followed by different letters are significantly different at the 5% level, using Duncan's Multiple Range Test.

TABLE XXIII

ACTUAL LIGHT INTENSITIES OBSERVED DURING
THE GARDEN PHASE

SHADE LEVEL	Mean Microeinsteins $sec^{-1}m^2$					MEAN % LIGHT REDUCTION
	MAY 26	JUNE 24	AUG. 4	SEPT. 18	MEAN	
FULL SUN	1875	2083	2012	1908	1970	
30%	1188	1463	1397	1232	1320	33
60%	554	662	639	549	618	69

for an increase in dry weight as shade increased (difference not statistically significant). This does not agree with SLW data for 'Yours Truly' (Table XVIII) and more research would be required to determine why SLW and dry weight results differed for this cultivar. There was not total disagreement, since by September 18, there was no significant difference in SLW between plants in full sun and 30% shade (Table XVIII).

It appears that 'Yours Truly' is more shade-tolerant than 'Sooner Red' and that 30% shade is actually a satisfactory light environment for 'Yours Truly', but 60% shade is too great for best growth and flowering (Tables X and XVIII).

Light Intensity Measurements

Light intensity measurements, all recorded on sunny days, revealed that the "30% shade" plants received a mean 33% light reduction and the "60% shade" plants received a mean 69% light reduction (Table XXIII).

Temperature Measurements

Soil temperature measurements, all recorded on sunny days, were found to be significantly affected by shade at the 0.01 level. As the shade level increased the soil temperature significantly decreased. It was also determined that as the summer progressed the soil temperatures became cooler (Figures 10 and 11), probably due to the plant expanding in width and providing shade to the soil.

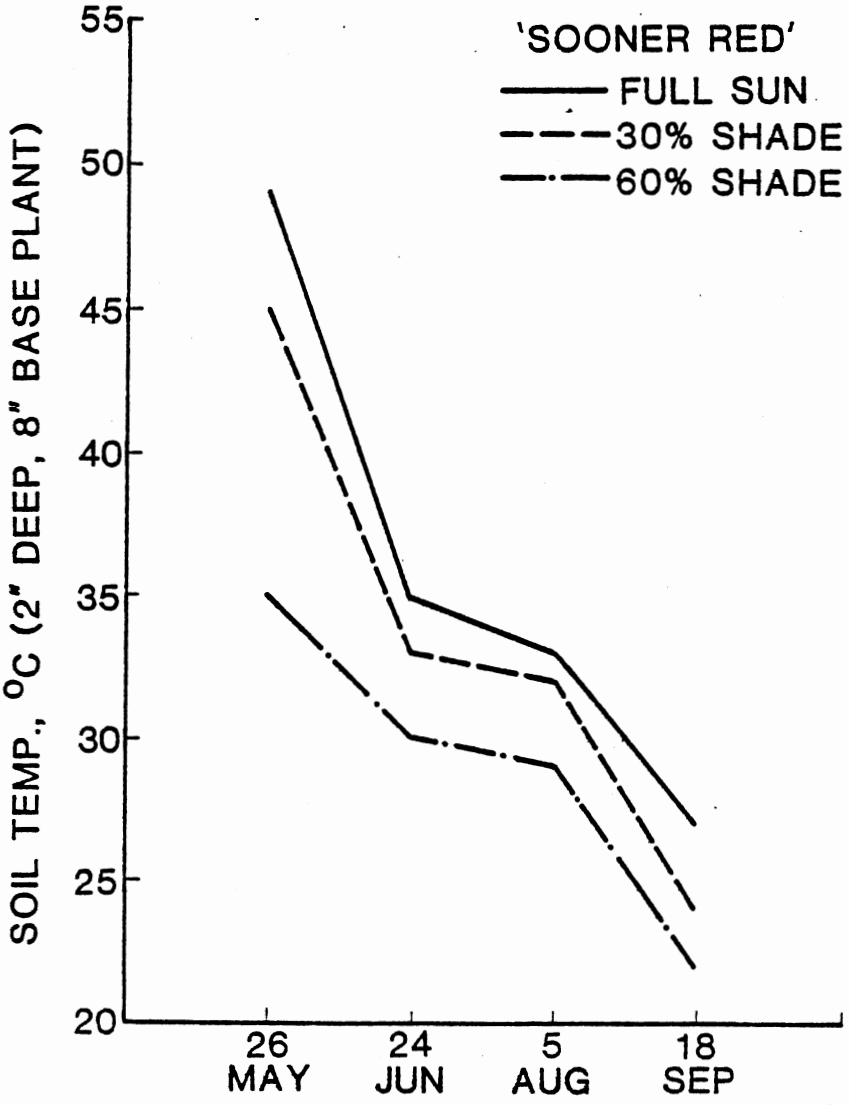

Figure 10. The Effect of Shade on the Soil Temperature of 'Sooner Red' During the Garden Phase

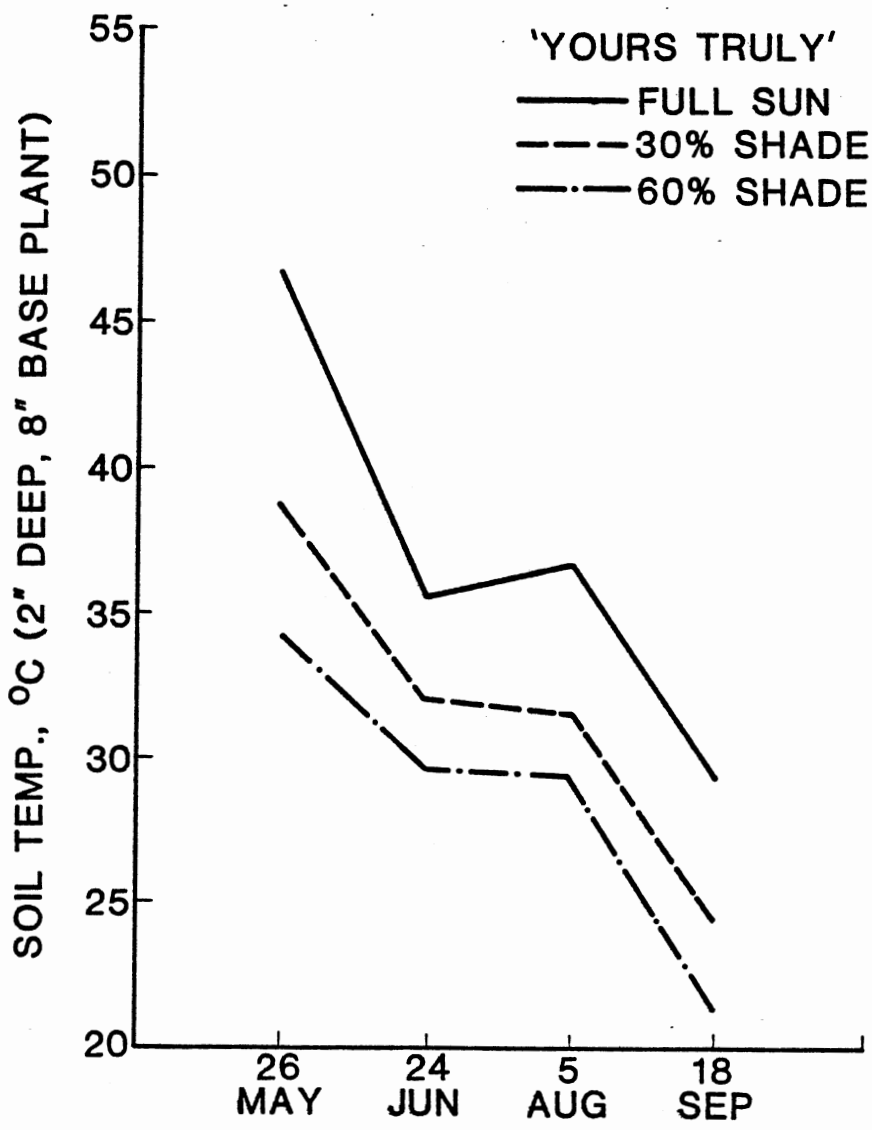

Figure 11. The Effect of Shade on the Soil Temperature of 'Yours Truly' During the Garden Phase

CHAPTER V

PRINCIPAL CONCLUSIONS

Chemical growth retardant (Cycocel) applied during the greenhouse production period resulted in significantly shorter plants in both 'Sooner Red' and 'Yours Truly'. By May 15, the last day in the greenhouse, there were no significant differences in number of flowers produced by control plants and Cycocel-treated plants for either cultivar.

The Cycocel treated plants also had significantly less leaf area of third-node leaves than did control plants of either cultivar. Likewise, the Cycocel-treated plants had significantly lower SLW compared to the control plants of 'Sooner Red', but 'Yours Truly' was unaffected.

During the outdoor phase of the experiment, Cycocel-treated 'Sooner Red' plants remained significantly shorter than untreated plants throughout the entire season, May 15-September 18; however, 'Yours Truly' was unaffected.

In general the control plants of both cultivars produced more flowers than the Cycocel-treated plants. 'Sooner Red' Cycocel-treated plants did produce more than double the number of flowers compared to the control plants June 1-15, although this trend reversed later in the season. Flowering of 'Yours Truly' was unaffected by the Cycocel treatment.

Shade had a very significant effect on flowering. With 'Sooner Red', as the shade level increased there were significantly fewer flowers.

'Yours Truly' was affected, but not as strongly. There was no significant difference in the number of flowers produced in full sun or 30% shade; however, 60% shade resulted in plants producing significantly fewer flowers.

The Cycocel-treated plants produced a significantly lower SLW during the June reading for 'Sooner Red' but after that there was no statistical difference. There was no significant difference between the treated and untreated 'Yours Truly' plants throughout the entire garden experiment.

The shade treatments also resulted in significantly lower SLW for both 'Sooner Red' and 'Yours Truly'. As each shade level increased the SLW significantly dropped, with 60% shade plants having the lowest SLW.

Vegetative height for 'Sooner Red' and 'Yours Truly' was not affected by the light intensities early in the season; however, the trend was toward the heavy shade plants being taller. By the end of the experiment 60% shade plants were significantly taller for both cultivars, and there was no statistical difference between full sun and 30% shade.

In summary, Cycocel-treated 'Sooner Red' plants doubled flower production from June 1-15, showing that there is a residual effect of retardant applied earlier during greenhouse production, but this effect did not hold throughout the summer.

The residual effect of Cycocel on plant height lasted all season on 'Sooner Red'.

Apparently, the foliar application of Cycocel was not as effective on 'Yours Truly' as on 'Sooner Red' since effects were less significant.

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VITA

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Master of Science

Thesis: SUMMER GARDEN PERFORMANCE OF SEED AND CUTTING-PROPAGATED GERANIUM CULTIVARS AS INFLUENCED BY CHLORMEQUAT APPLIED DURING GREENHOUSE PRODUCTION AND SUMMER LIGHT INTENSITY

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