THESIS

ENVIRONMENTAL FACTORS AFFECTING GROWTH OF CARNATION STOCK PLANTS AND CUTTINGS

Submitted by

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In partial fulfillment of the requirements

for the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

August, 1964

COLORADO STATE UNIVERSITY

AUGUST 196 4

WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY RALPH ALLEN ALTSTADT ENTITLED ENVIRONMENTAL FACTORS AFFECTING GROWTH OF CARNATION STOCK PLANTS AND CUTTINGS BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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ACKNOWLEDGEMENTS

Acknowledgements are expressed to the following of Colorado State University for their assistance in the course of this investigation:

Mr. W. D. Holley, Professor of Horticulture, without whose advice and encouragement this study would not have been possible, Miss Susan M. Felton for her assistance in preparing this manuscript, Mr. Kenneth L. Goldsberry, Assistant Professor of Horticulture, for his advice on mechanical systems, and Dr. Richard L. Foskett, Professor of Horticulture, and Dr. Ralph Baker, Professor of Botany and Plant Pathology, for their help in reviewing this manuscript.

The author also acknowledges the financial support of Colorado Flower Growers' Association, Inc., Denver, Colorado.

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INTRODUCTION

Three basic phases are involved in the culture of carnations: (1) production of cuttings from stock plants, (2) rooting of cuttings in a propagation medium, and (3) subsequent growth of cuttings when planted for flower production. Considerable research has been devoted to refining methods of all three phases; however, few studies, relating the effects of stock plant environment to the growth of cuttings before and after removal, have been performed.

At present the majority of cuttings are produced by the mother block system. Stock plants are grown from disease-free plants and increased by vegetative propagation for the sole purpose of producing cuttings. The alternate system involves the use of lateral shoots taken from flowering plants.

The mother block system allows better disease control, greater control of cultural procedures, more uniformity in size and quality of cuttings, and greater versatility in storing and marketing of cuttings than can be had with the alternate system. The ensuing studies are concerned with the mother block system.

The growth of a young crop of carnation cuttings is often variable. Undoubtedly a certain portion of this variability can be traced to fluctuating environmental conditions affecting plants in their flower production phase; however various factors involved in the stock plant environment can play a considerable role in the eventual performance of a cutting. A study of cultural methods and environmental conditions affecting stock plants, as related to subsequent performance of the derived cuttings, is necessary before quality in a cutting can be defined.

Problem

What factors involved in the production of cuttings from stock plants most significantly affect their performance as measured by the quantity and quality of the flowers produced? What ways can be devised in evaluating quality of cuttings, as they are removed from stock plants, which could be applicable to a system of grading? And finally, would a grading system be beneficial to growers?

Problem analysis

Experiment I - Stock plant environment. Obviously many factors are involved in the environmental complex. It is essential to select factors which (1) appear to have the greatest effect on plant growth and (2) can be controlled by the experimenter and producer.

In this experiment the effects of temperature and nutrition on stock plants were studied. Two aspects of these effects are considered:

1. The fresh weight, per cent dry matter, dry weight and number of cuttings taken from stock plants.
2. The performance of cuttings taken from these stock plants as measured by the production and quality of the first crop of flowers and the amount of potential, subsequent second-crop production.

Experiment II - Juvenility. The effect of age of stock plants on the subsequent performance of cuttings produced from these plants was studied.

Experiment III - Grading of cuttings. Attempts are made to evaluate the following factors pertaining to the cutting in terms of its eventual performance when planted for crop production: (1) fresh weight, (2) dry weight, (3) per cent dry matter, (4) number of expanded leaves, and (5) morphological stage of apical meristem.

One or more of the above criteria will be utilized to develop a system of grading cuttings.

Definition of Terms

1. Preharvest environment of cuttings - all environmental factors affecting stock plants before removal of cuttings.
2. Postharvest performance of cuttings - the rooting and subsequent growth of cuttings in producing benches after they are removed from stock plants.
3. Stock plant - any plant grown for production of cuttings.
4. Mother block plant - a synonym of stock plant.
5. Mother block system - a series of propagation procedures whereby large numbers of stock plants are produced from a single plant that is selected for desirable variety characteristics and is disease-free.
6. Cutting - terminal vegetative or reproductive shoot which is detached from the parent plant for the purpose of regenerating roots.

7. Single pinch - removal of a terminal portion of a caulescent plant to stimulate production of lateral shoots.
8. Disbudding - standard procedure in all experiments whereby all reproductive lateral shoots plus the uppermost vegetative lateral shoot are removed from each flower stem.
9. Blind wood - basal portion of a stock-plant shoot which contains only residual meristems.
10. Expanded leaves of cuttings - all expanded leaf pairs including the uppermost pair which is separated at least 0.25 inch.

Definition of Measurements

1. Midpoint of flower production - In any comparative study, when the first flower was produced in any treatment the period of time designated the harvest period was begun for all treatments. The end of the harvest period for all treatments was arbitrarily determined by judging the time when first-crop flowers were cut from a majority of treatments. The midpoint of flower production for a given treatment occurred when half the total flowers were cut.
2. Average pinching date - the time required for half the plants within a given treatment to reach an arbitrary stage of growth so plants could be pinched.
3. Vegetative shoots remaining on plants after pinching - all vegetative, axillary shoots 0.5 inch or longer counted on plants directly after pinching.
4. Mean grade of cut flowers - system used to evaluate quality of flowers as follows:

flower grade	points allotted
design	2
short	3
standard	4
fancy	5

5. Rooting percentage - system used to evaluate the quantity of roots formed during propagation as follows:

vertical length of root ball (inches)	points allotted
0	0
0 to 1.0	0.5
1.0 or more	1.0

Delimitations

No attempt was made to analyze chemical constituents in plants. Dry weights were determined to give an indication of quality in cuttings.

Chapter II

REVIEW OF LITERATURE

Carnations, as well as several other major flower crops, are propagated asexually by terminal stem cuttings. The growth of cuttings before they are removed from stock plants can be considered the preharvest period. Factors affecting size, form, and physiological constitution of cuttings during the preharvest period have a considerable effect on their postharvest performance. The effect of preharvest factors is independent from, but modified by, subsequent cultural procedures. The present discussion will deal with factors affecting: (1) the production of cuttings from stock plants and (2) the subsequent performance of these cuttings after propogation.

Light

Plants respond to light intensity, quality, and duration. Seasonal changes produce considerable variation in light (42). The different ways in which plants respond to light would be too numerous to mention here. Only a discussion of the effects of light intensity, quality, and duration on stock plants will be presented.

Light intensity

In a given plant photosynthetic rate increases with light intensity, when all other growth factors are at their optimum, until the point where light saturation occurs (33). Korns and Holley (21) showed that carnation growth, as measured by dry matter accumulation, followed quite closely with solar energy. Odom (26) demonstrated similar results with carnation cuttings grown from stock plants. Daily decreases in dry matter of cuttings were related to similar decreases in light intensity.

Dry matter is a reliable means of measuring accumulated photosynthate in plants (4,24,25). Since plant dry matter, as an indication of stored photosynthate, can be correlated with light intensity, it follows that the amount of stored food in cuttings varies with the light intensity received.

A high energy light process is essential before flower initiation can occur; however, plants must reach a certain minimal age, termed "ripeness to flower," before high energy light can be effective. The minimal time required for ripeness to flower differs greatly between plant species. Given proper environmental conditions, _Chenopodium rubrum_ will flower in the seedling stage whereas a period of 5 to 50 years or longer is required for certain bamboo species (33). Hanzel _et al._ (14) found that flower initiation in the carnation variety Northland occurred between 10 and 18 weeks after shoots originate. This fact was in agreement with Wagner (19) who stated that bud initiation in carnation cuttings varied with the season of the year, the position of the shoot on the plant, and the variety.

Time required for ripeness to flower in carnation, a facultative long-day plant (2), can be only partially modified by environmental conditions. A minimum number of nodes subtending a flower are required (14). Certain tomato varieties flower after production of 13 nodes, regardless of environmental conditions (4). Conversely, with Chrysanthemum, an inductive short-day plant, time required for ripeness to flower is highly dependent upon environmental conditions (6,23).

Light duration

Light intensity occurs concomitant with the effects of daylength on plant growth. However very low light intensity is required in photoperiodic responses. A minimum of 0.3 foot-candles is required to keep Xanthium in the vegetative condition. Similarly, flower induction in long-day plants can be brought about by extending the daylength with low intensity light (4).

Plants that have a critical daylength requirement respond qualitatively to photoperiod. Many other plants not having a critical daylength requirement can be quantitatively promoted by daylength and many other environmental factors. Salisbury (33) has presented an excellent classification and enumeration of various plant responses to environment.

Before the work of Harris and Griffin (15), daylength responses in carnation were thought to be a function of total radiation received by the plant. Attempts have been made to separate the effects of photoperiod and total incident light energy on flower initiation in carnation. Harris and Griffin (15) from studies with White Sim Carnation maintain that time of flower initiation in carnation is affected by photoperiod and that this effect can occur independently of the total radiation received by the plant. Blake (2) found that carnation varieties Puritan and Maytime, grown in short days, had more pairs of leaves below the flower than plants grown in long days; the greater leaf number was associated with delayed appearance of the flower bud. Her statement is based on experiments which showed that buds were initiated on plants given 2 hours of light in the middle of the night; whereas those given extended daylength or an 8-hour night did not form buds. Harris and Harris (16) showed that low light intensities delayed flower initiation in White Sim Carnation. An associated reduction in growth, reduced rates of leaf initiation and increased leaves formed below the flower were observed. They further state that flower primordia were present in the long-day treatment and absent in the short-day treatment when numbers of leaves initiated below the flower were about the same.

Pokorny and Kamp (30) subjected stock plants of Sidney Littlefield to 8 and 16-hour photoperiods. Cuttings from these plants were propagated under 8 and 16-hour photoperiods and finally grown to flowering under 8 and 16-hour photoperiods. They found that cuttings from short-day stock plants grown to flowering under long days flowered the earliest and produced the most salable flowers per unit area. Cuttings propagated under long days rooted better than those under short days. The most rapid development was by cuttings derived from short-day stock, rooted under long days, and finally grown under long days.

Van Drunnen and Kamp (39) investigated the effects of photoperiod on the rooting of cuttings of different plant species. In the 5 plant species studied, including chrysanthemum varieties Illini Wigwam and Illini Formal, a 9-hour photoperiod provided better rooting than one of 17 hours. This response does not compare with that of the long-day plant, carnation. It is interesting to note that most of the species tested by Van Drunnen and Kamp were shade plants, except chrysanthemum, a short-day plant.

Light quality

The effects of various spectral qualities of light on plant growth can be considered exothermic. These wavelengths of light ultimately activate, or direct, an amount of stored energy which may be larger than the energy content of the light responsible for the stimulus (42). It is possible that various wavelengths of light can trigger pigment systems which bring about gross reactions in plants (33).

Some generalizations can be made about the effects of light quality on plants. The blue-violet end of the solar spectrum is required for sturdy growth and for flat expansion of leaves. If radiation above 529 mu is given, plants are spindly, elongated, and the leaves are epinastically curved. Radiation above 472 mu produces effects intermediate between that obtained with the full daylight spectrum and that obtained in the region above 529 mu. These reactions occur independently from light intensity. Evidence has recently been presented that certain spectral regions of light during the high-intensity light period are essential for specific plant responses, namely flowering, so that a long day plant may fail to flower for extended periods if certain spectral regions of light are lacking (42).

Stolwijk (36) demonstrated increased dry weight production in plant stems as wavelength of light increased. This was considered due to increased quantum content of equal energies toward the longer wavelengths. Leaves and roots showed smaller differences, indicating a relative promotion of these organs in the blue-violet region (36).

Stoutemyer and Close (37) reported that exposure of stock plants to light of different spectral qualities exerted a striking influence on both root and callus formation of <u>Gordonia axillaris</u> cuttings. Blue light on stock plants produced the best rooting of cuttings when compared with daylight tubes or natural daylight.

Light quality affects the flowering process and many other responses of plants. Discussion of these numerous processes would not be pertinent to the subject at hand and will not be discussed in this review.

Temperature

Temperature is among the most important factors in the environmental complex, and is probably the most important climatic factor affecting natural plant distribution. Temperature requirements vary considerably during the ontogeny of a plant. Temperature requirements for reproductive development may not coincide with those optimal for vegetative growth. Other growth processes such as germination and vernalization may have temperature requirements still different from those mentioned above (4).

A general discussion of temperature will not be presented here. Only the effects of temperature on vegetative and reproductive growth of some major horticultural crops will be reviewed, with special emphasis on stock plants.

Mason and Vince (23) stated that the pattern of vegetative growth in chrysanthemum can be interpreted on the basis that chilling (below 16°C.), high temperature, long days and high light intensity are the environmental factors favoring internode extension. Absence of chilling, low temperature, short days and low light intensities cause reduced internode length. There is some correlation between internode extension and flower initiation. When rosettes are produced, flowering is delayed and if initiation occurs extension is immediately resumed.

Cathey (8) showed that temperature altered the critical photoperiod necessary for initiation and development of a flower in all varieties of chrysanthemum tested. He concluded that the photoperiod required for initiation of the inflorescence was shortened by lowering temperature from 80 to 50°F. Conversely, the photoperiod required for development of the inflorescence was shortened by raising the temperature from 50 to 80°F. Cathey, in a previous study with chrysanthemum (7), demonstrated three distinctly different responses of stock plants to night temperatures of 50, 60, and 80°F. His classification of these responses is as follows: (1) Thermozero -- temperature at which stock plants were grown made only slight differences in time to flower. (2) Thermopositive -- continuous low temperature inhibited the flowering of these varieties. (3) Thermonegative -- continuous high temperature inhibited flowering. Cathey (6) found that chrysanthemum stock plants grown at temperatures of 50 and 55°F., produced cuttings which were larger in diameter, had shorter internodes and rooted in a shorter time than cuttings produced at 60 to 70°F. Day temperature averaged 5 to 10 degrees higher. Cuttings from the lower temperature treatment always grew faster and produced taller plants with heavier stems at flowering.

From a study of day temperatures on 3 varieties of carnation, Hanan (13) concluded that 65°F. was near optimum. He further postulated that optimum day temperatures drop with increasing age and decreasing light intensity.

Tayama (38) showed similarly that optimum night temperatures decrease with age of chrysanthemum plants from 0 to 10 weeks of age.

Blake and Spencer (3) stated that, while day temperatures of 50 and 60°F. had little effect, night temperatures of 50 and 60°F. had a considerable effect on growth of White Sim Carnations. Flower initiation was delayed at the 60 night temperature. They concluded that any treatment accelerating flower initiation in carnations tends both to decrease the node number and increase the mean internode length for the whole plant.

Critical studies of temperature on carnation stock plants have not been apparent to the writer up to this time.

Nutrition

Mineral nutrition of stock plants has been shown to effect rooting of cuttings and their subsequent growth; however generalizations cannot be made between species concerning optimum nutritional requirements.

Haun and Cornell (17) studied combinations of low, medium, and high levels of each of the elements nitrogen, potassium, and phosphorus on geranium stock plants. Their experiments indicated that treatments combining high phosphorus with low nitrogen, and high potassium with medium or low nitrogen resulted in the highest percentage of rooted cuttings. They concluded that, although fewer cuttings from high nitrogen treatments rooted, those that did root developed more and longer roots than those from low nitrogen treatments.

Preston, Shanks, and Cornell (31) studied effects of nitrogen, potassium, and phosphorus on azalea stocks, and found that the various levels of nitrogen had the greatest effect on cutting production and rooting. Succulent cuttings from plants receiving the low level of nitrogen had a greater degree of rooting than those from plants receiving the high level; the opposite trend occurred with mature cuttings.

Shanks and Link (34) studied all combinations of low, medium, and high levels of nitrogen, potassium, and phosphorus on poinsettia stock plants. They found that the high level of nitrogen produced the most desirable response while medium levels of phosphorus and potassium were adequate in most instances.

Von Hentig (41) found that high levels of nitrogen and potassium, when applied jointly to chrysanthemum and fushsia stock plants, resulted in greater production of cuttings, less time required for root formation, and more adventitious roots than could be had with low levels. Changes in the levels of nitrogen and potassium had a greater effect on the results than changes in phosphorus.

Odom (27) studied the effects of various levels of nitrogen, potassium, and phosphorus on carnation stock plants. He found that a high level of nitrogen, applied at 1.5 pounds of ammonium nitrate per 100 square feet of bench area, resulted in more cuttings of higher fresh weight. These cuttings rooted faster and subsequently produced more growth than those from stock plants receiving lower levels of nitrogen. Phosphorus and potassium had little effect on number of cuttings produced or their subsequent performance.

Carbon Dioxide

It has been established that carnations grown in atmospheres of high carbon dioxide produce more growth and mature sooner than those grown in normal atmospheres (11,20).

Goldsberry (11) found that total flower production and per cent dry matter of carnation increased 37.0 per cent and 4.2 per cent, respectively, in an atmosphere containing 500 ppm carbon dioxide when compared to a 200 ppm atmosphere.

Korns (20) tested the effects of increasing carbon dioxide and temperature on carnations whenever light intensity increased. He found that increasing temperature with light intensity resulted in less ventilating time thus allowing more hours for carbon dioxide injection. The injection of carbon dioxide during daylight hours when ventilation was off increased growth of young plants 12 per cent over the automated chamber without CO_2 injection.

Juvenility

The juvenile condition of plants when compared to the adult condition is marked by the production of more anthocyanin, retention of leaves during winter, greater ease of rooting of cuttings, more thorniness, and lack of flowering (32). Optimum temperature requirements of some plants decrease as plants age (38). It is possible that lower temperatures are required for translocation of sugars in old plants.

Furuta and Kiplinger (9) found that chronological age of cuttings influenced the flower formation of pompon chrysanthemums. All stock plant shoots that had grown 8 weeks from the time of origination contained initiated flower buds. Those grown for 5 weeks or less remained vegetative. Furthermore, they observed that as age of stock plant shoots increased the height of the crown bud of the resulting unpinched plants decreased.

The ability of cuttings to form roots is affected by the age of the propagative material from which it is taken. O'Rourke (28) studied the rooting ability of hardwood cuttings taken from different positions on blueberry shoots. He noted that cuttings containing vegetative buds rooted better than those containing flower buds. He also noted that per cent of rooting and growth of the cutting thereafter were both inversely related to the position on the shoot from which the cutting was taken. Cuttings taken from the base of the shoot were the most desirable in terms of rooting and subsequent growth.

Gardner (10) observed that one-year-old cuttings from a number of different hardwood species outperformed cuttings from trees 2 years old, or older. When one-year-old seedlings were cut back to the ground, the resultant sprouts were equal or superior in rooting ability.

O'Rourke (29) has reviewed the literature on juvenility of various hardwood and evergreen species. He concludes that cuttings taken from juvenile plants, or juvenile portions of plants, consistently root better and grow better after planting than those from adult plant material. He points out that the processes which take place in the transformation from the juvenile to the adult form are closely associated with development, but not growth, and that these processes are not chronological, but purely physiological.

Quality in Cuttings

Various measurements have been made on plant size and chemical composition to give an indication of growth (4,24,25). Carbohydrate-nitrogen ratio and total food supply, as indicated by size of cutting, are probably the most important measurements of rooting ability and growth potential of cuttings. Calma and Richey (5) found that cuttings of Concord grape containing a high percentage of carbohydrate produced more roots as well as earlier top growth than cuttings containing low carbohydrate.

In general, the younger the tissue the lower is the C/N ratio. The C/N ratio increases from the seedling stage until enough carbohydrate is accumulated to allow flowering (35). Probably factors other than C/N ratio or total carbohydrates are involved in ripeness to flower.

Dry weight as an indication of growth and quality has been used in various experiments with carnation (11,13,20). It may also be possible to indirectly correlate dry weight of cuttings with their rooting and subsequent performance.

Holley (18) has shown that size of cutting measured by fresh weight has an effect on its growth. He showed that more flowers were produced in a shorter period of time from large cuttings of 10 grams and above when compared to smaller cuttings.

The growth stage of the apical meristem in a cutting is considered to exert an effect on its subsequent performance. Furuta and Kiplinger (9) showed that initiated chrysanthemum cuttings developed crown buds on much shorter stems than did vegetative cuttings.

After a terminal bud is removed, apical dominance is lost. Vqn Overbeck (1938) observed that auxin content increased in the stem after the terminal bud had been removed. He postulated that auxin blocks the passage of nutrients to the lateral buds which have a poor connection with the main cylinder. When the amount of auxin is reduced a better connection is established. Nutrients can then pass into the axillary buds thus allowing their development.

Another postulated mechanism is that auxin, moving in its usual downward direction through the stem, is considered to cause synthesis of a growth inhibitor which, upon movement into lateral buds, prevents their growth (24).

It is probable that, when flower initiation occurs, growth of axillary meristems is accelerated in the same manner as when the apical bud is mechanically removed. It is implied that an initiated apical meristem does not produce sufficient quantities of auxin to effect inhibition of axillary meristems.

Summary

From the results of various workers, it is apparent that environmental conditions and cultural methods given stock plants significantly affect the size and quality of cuttings produced from these plants. Furthermore, the type of cutting taken from stock plants has been shown to exert a considerable effect on the performance of the cutting after planting. A study of environmental conditions affecting carnation stock plants with special emphasis on the performance of the derived cuttings, may prove valuable to basic science and commercial interests.

Chapter III

METHODS AND MATERIALS

Experiment I

Part I - The effects of temperature, carbon dioxide, and nutrition on stock plants

This experiment was designed to show the effects of temperature and nutrition on the growth and production of carnation stock plants grown in higher carbon dioxide atmospheres. Samples of cuttings from each stock plant treatment were planted in greenhouse benches and grown until the first crop of flowers had been cut. In this manner environmental conditions in which stock plants were grown could be tested.

Four growth chambers described by Goldsberry (11) were used in the study. These chambers were covered with polyvinyl plastic. Cooling in each chamber was maintained by a two-hp compressor containing a two-ton evaporative coil charged with freon refrigerant. Heat was supplied when needed by electric heaters placed in the air circulation ducts. Temperature could be controlled to plus or minus 1 degree of the set point. Day temperatures in chambers 1, 2, 3, and 4 were regulated at 65, 70, 75, and 80°F., respectively. Night temperature in all chambers was 55°F. The light source was sunlight as it passed through the greenhouse glass and the plastic walls of the control chambers. On bright sunny days the light levels were equal to approximately 80 per cent of the light outside the greenhouse range. On cloudy days only 55 to 60 per cent of outside light was attained (11). No attempt was made to control humidity. Daily variations were large. Average relative humidity readings on sunny days from July 20 to July 25, 1963 were: chamber 1 - 70 per cent, chamber 2 - 70 per cent, chamber 3 - 65 per cent, and chamber 4 - 60 per cent. One cloudy day in this period produced relative humidity readings that varied between 80 and 100 per cent in each chamber. Carbon dioxide within the chambers was measured by a model LB 15A Bechman Infrared gas analyzer. Atmospheric carbon dioxide in all chambers was held as close as possible to 600 ppm.

Uniformly sized cuttings of the carnation variety Pink Mamie were planted in 10-inch pots of steamed volcanic scoria on November 12, 1962. Thirty-six pots were placed in each chamber. Each of three nutrient levels was applied to 12 pots arranged in a latin square design. The nutrient levels were established at 1.5, 2.0, and 2.5 times the standard greenhouse feeding rate and were designated low, medium, and high, respectively. Boron and iron were held constant in all nutrient treatments. The major and minor elements in the standard ratio were as follows:

Element	Source	Parts per million
nitrogen	calcium nitrate	125.0
phosphorus	phosphoric acid	100.0
potassium	potassium chloride	140.0
magnesium	magnesium sulfate	12.0
sodium	sodium nitrate	8.0
iron	iron sequestrene	3.0
boron	borax	1.5

It was found that phosphoric acid caused excessive acidity in the nutrient solution. A ratio of 1 part phosphoric acid applied in the nutrient solution, to 5 parts treble super phosphate applied as a top dressing to each pot, was substituted for straight phosphoric acid in the nutrient mixture, thus providing 100 ppm phosphorus. The parts per million of total nitrogen from calcium nitrate and sodium nitrate was 125 as given in the top line of the list of concentrations.

Dissolved nutrients were injected in the water lines with a model PR portable Fertoject. Plants were watered every third and fourth day in winter and every second day in summer. Plants in all chambers were watered within one hour of each other on the days that watering was required.

The shoot tips of cuttings in all treatments were removed to five remaining nodes as soon as lateral shoots were visible. Each week, from January 17, 1963, to November 5, 1963, cuttings were harvested from the stock plants. All cuttings were taken from stock plant shoots containing 8 pairs of expanded leaves. Each cutting contained 5 pairs of expanded leaves with 3 pairs of leaves being left on the shoot from which it was taken. The total weight and number of cuttings from each treatment were recorded each week until the experiment was terminated. Dry weights were calculated on the treatments at various times. Before fresh and dry weights were determined, cuttings were allowed to absorb water from their basal ends to remove variation between treatments due to wilting.

Part II - Flowering trials

Once a month, starting on April 16, 1963, and ending on October 1, 1963, cuttings were selected from each stock plant treatment, weighed, and placed in perlite for rooting. Dry weight determinations were made on duplicate samples in each case. After sufficient roots were formed, cuttings of each treatment were planted in a flowering trial containing 2 randomized blocks of 5 plants, spaced evenly across a greenhouse bench, per treatment. Plants were spaced 6 x 8 inches within the blocks. A total of 6 flowering trials were used in the experiment. A control from untreated stock plants was included in the last four flowering trials.

Separate benches were used for each flowering trial, resulting in considerable variation in soil type and environment between plantings. By growing each flowering trial in different environmental conditions and at different times of the year, more accurate, all-around performance of the initial stock-plant treatments could be measured. In general, each planting was subjected to day and night temperatures of 70 and 53°F., respectively. The plants were watered with nutrient solution at the first sign of wilting.

After approximately 3 weeks of growth, the shoot tips of all plants were removed in such a manner to allow growth of all possible vegetative, lateral shoots. Production and grade of first-crop flowers were determined for all treatments in each flowering trial. After all first-crop flowers were removed, fresh weight, total number of lateral shoots and total number of buds greater than 0.25 inch in size were recorded for all trials except the first. Plants were removed at the soil line for fresh weight determinations. The measurements of fresh weight and number of buds on residual plants were designed to give an estimate of second-crop production.

Experiment II

Part I - Cuttings sized evenly by number of expanded leaves

Three clones each of the varieties White Pikes Peak and Red Gayety were selected for juvenility studies. An equal number of cuttings from old and young stock plants of each clone were selected. Old and young stock plants were 4 and 18 months of age, respectively. The cuttings were removed at a position allowing 3 pairs of leaves to remain on the stock plant shoots from which they were taken. Each cutting contained 6 pairs of expanded leaves. On July 25, 1963, the cuttings were placed in perlite for rooting. On August 17, 1963, all treatments were planted in twice replicated blocks, each containing the same arrangement of clones. Each treatment was an individual clone containing 5 plants spaced evenly in a row across a greenhouse bench, giving a plant spacing of 6 x 8 inches throughout a block. A total of 60 plants each from young and old stock plants were compared in the experiment. Methods of handling the young plants and measurements of first and second-crop production were the same as in the production trials of Experiment I. Growing procedures and temperature settings were the same as outlined in Part II, Experiment I.

Part II - Cuttings sized evenly by fresh weight

From the results of Part I, it was thought that the performance of a plant was due more to the weight of the cutting than to the age of stock plants. The following experiment was designed to more adequately test the effect of juvenility.

Cuttings were selected from two clones each of Red Gayety and White Pikes Peak. Cuttings from 7 and 21-month-old stock plants of each clone were sized evenly by weight and placed in perlite on October 22, 1963. On November 12, 1963, the rooted cuttings were planted. Due to space limitations, a total of only 28 cuttings from young stock plants of each clone were planted side by side for comparison. Each row contained 7 plants, giving a plant spacing of 6 x 6 inches throughout the block. Methods of handling the young plants and measurements of first and second-crop production were done as in the production trials of Experiment I. Growing procedures and temperature settings were the same as outlined in Part II of Experiment III.

Experiment III

Part I - Effect of cutting size on performance in producing benches

Different sized cuttings were selected from White Pikes Peak stock plants. Each cutting was removed at a position allowing 3 pairs of leaves to remain on the stock plant shoot. The cuttings were arbitrarily graded into categories of 4, 5, 6, 7, and 8 pairs of expanded leaves. Within each leaf-pair category, cuttings were further divided into light and heavy groups by weighing on a triple-beam balance. This constituted a 5 x 2 factorial study containing 10 treatments. Dry weight determinations were made on a duplicate sample of cuttings from each treatment. On September 21, 1963, 2 blocks of 5 rooted cuttings per treatment, were planted in a greenhouse bench.

Plants were spaced 6 x 8 inches throughout. Leaf-pair plots were planted in numerical sequence with the 2 weight treatments arranged identically within each plot. Methods of handling young plants and measurements of first and second-crop production were given in Experiment I.

Part II - Second planting (two pinching methods)

On November 7, 1963, 6 blocks of rooted cuttings—containing treatments and design identical to that described in Part I—were planted in a greenhouse bench. Both the September and November plantings were located in the same greenhouse. Day and night temperatures were regulated at 70 and 53°F., respectively. Plants were watered with nutrient solution at the first sign of wilting. Exceptions from Part I in the experimental procedure were as follows: (1) Initial dry weight determinations on duplicate treatments of cuttings were not made due to insufficient supply. (2) Three blocks were pinched to 5 remaining shoots, the other 3 blocks being handled as in Part I. (3) Plants were allowed to remain in production after first-crop flowers were cut. Total number of buds 0.25 inch or greater were counted per treatment in each block to give an estimate of second-crop production. (4) Plants were spaced 6 x 6 inches in the producing bench, giving a total of 7 plants per individual treatment.

Part III

Miscellaneous experiments were conducted to give additional information about quality in a cutting. Methods of these experiments are explained briefly along with the results.

A. Attempts were made to correlate various measurements of a cutting with the morphological stage of its apical meristem.

Cuttings were taken from Pink Sim stock plants at various times during the period from October 3, to November 26, 1963. All cuttings were taken at a position which allowed 3 pairs of leaves to remain on the shoots from which they were taken. The following measurements were recorded: fresh weight, total length of cutting (measured from base to extended leaf tip), total number of nodes subtending the apical meristem, height of apical meristem (measured from the base of the first visible pair of nodes to the top of the meristem), and the arbitrary stage of development of the apical meristem. In another study (1), it had been shown that height of the apical meristem, as measured with a binocular microscope containing a micrometer, was a reliable way to determine the transition between the vegetative and reproductive stage of the apex. With this in mind attempts were made to correlate the measurements of the cutting with the morphological stage of the apical meristem.

B. The effects of cutting size at the time of removal from stock plants was compared to subsequent performance of cuttings planted at different times of the year. Data was taken from various experiments to provide a final evaluation of cuttings.

C. The results from Part B above were used to establish a system of growing stock plants and grading cuttings to effect maximum performance of cuttings when planted in producing benches.

Chapter IV

RESULTS

The results in this section are discussed separately by experiments in the order listed in chapter 3. Analysis of variance was used in all major experiments to determine homogeneous variance. Regression analysis was used when cause and effect relationships were suspected. Duncan's New Multiple-Range Test was used to determine significant differences between treatments. Significant differences 5 and 1 per cent are shown by single and double asterisks, respectively. All analysis of variance tables appear in the Appendix.

Experiment I

Part I - Stock plant environment

Temperature had a great effect on the performance of Pink Mamie stock plants; whereas the effects of nutrition were varied and inconsistent. Table 1 summarizes the effects of temperature and nutrition on the growth of stock plants as well as the size and quality of the cuttings produced. Data for individual treatments is given in Table A of the Appendix. For total fresh weight production, significant decreases were observed for each increment of temperature increase. Most of these differences were due to size of cuttings. When the total number of cuttings was considered, very small differences could be discerned between cuttings produced at 65, 70, and 75°F.; however, a significant decrease was observed at 80.

TABLE 1.--EFFECTS OF TEMPERATURE AND NUTRITION ON PRODUCTION OF PINK MAMIE CARNATION STOCK PLANTS. DATA TAKEN FROM PART I, EXPERIMENT I. DUNCAN'S NEW MULTIPLE-RANGE TEST USED FOR ANALYSIS.

	MEASUREMENT				
Treatment	Total fresh weight of cuttings1/ (grams)	Total number of cuttings1/	Average fresh weight per cutting2/	Average per cent dry matter2/	Average dry weight per cutting2/
Temperature (°F.)					
65	10,827a3/	1,316abc	9.63a	13.81cd	1.29ab
70	9,919b	1,323ab	8.63b	14.38c	1.21b
75	8,709c	1,325a	7.51c	15.28b	1.11c
80	7,359d	1,192d	6.89cd	15.82ab	1.05d
Nutrient level					
1½ x standard	8,946	1,250	8.33	14.79	1.19
2 x standard	9,350	1,296	8.04	14.82	1.15
2½ x standard	9,314	1,321	8.12	14.86	1.16
	N.S.4/	N.S.	N.S.	N.S.	N.S.

1/Mean values for temperature and nutrient level were derived from full experimental data and computed from total production over 41 weeks from January 14, 1963, through November 5, 1963.

2/Mean values were derived from 10 monthly samples taken from January through October, 1963.

3/Means followed by the same letter are not significantly different, at the 1 per cent level. Means followed by different letters are significantly different at the 1 per cent level.

4/N.S. - not significantly different at the 1 or 5 per cent level.

In the first 4 weeks of growth from January to February, 1963, more fresh weight and quantity of cuttings were produced at the higher temperatures (Figures 1 and 2). This increase was due to faster development and a higher percentage of shoots produced on blind wood of plants in the first sampling period (Table 2).

TABLE 2.—SUMMARY OF SHOOT DEVELOPMENT FROM PINK MAMIE CARNATION STOCK PLANTS GROWN AT FOUR TEMPERATURES. DATA TAKEN FROM PART I, EXPERIMENT I.

Sampling period	Number of days required for development of cuttings, containing five pairs of expanded leaves, from blind wood				
	Temperature (°F.)				
	65	70	75	80	Average
January through March, 1963	51	50	50	48	49.8
July through August, 1963	39	35	34	34	37.3
	Percentage of blind wood developing shoots				
	Temperature (°F.)				
	65	70	75	80	Average
January through March, 1963	66.6	100.0	100.0	100.0	91.7
July through August, 1963	66.7	88.9	83.4	77.8	79.2

With samples taken from July to August, 1963, the trend was duplicated; cool-grown plants required more time to develop standard-sized cuttings than those grown at the high temperatures. In comparing both sampling dates, the percentage of shoots developing from blind wood was constant at 65°F. and at the 3 higher temperatures decreases were observed in the summer. The most noticeable decrease was at 80°F. which could account, in part, for the decrease in total production of cuttings at the end of the experiment.

Increases in nutrition resulted in slight increases in total fresh weight of cuttings. At all temperatures except 65°F. more fresh

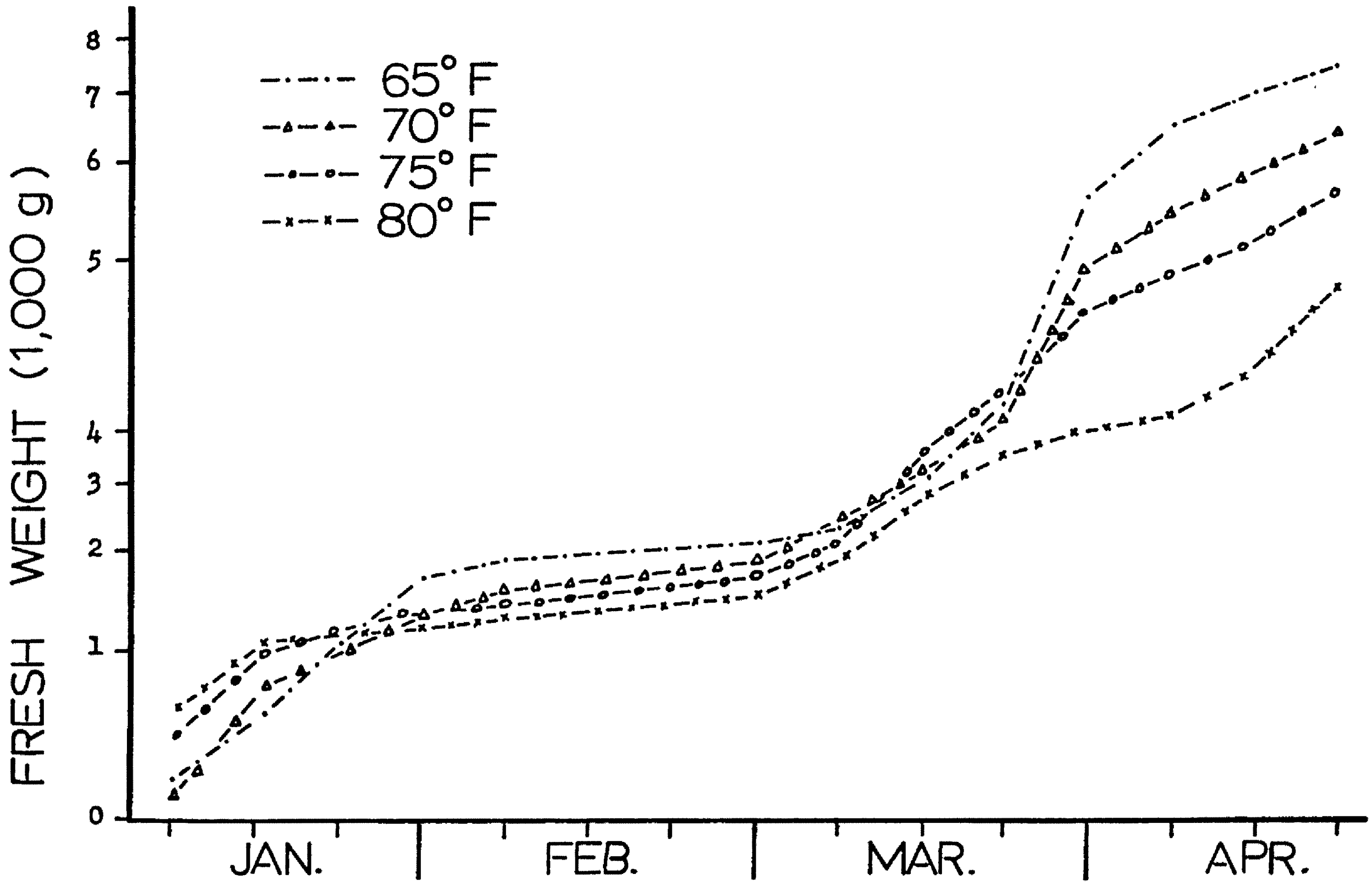

Figure 1 - Accumulated fresh weight of cuttings produced from Pink Mamie stock plants grown at four temperatures in the first four months of 1963. Part I, Experiment I.

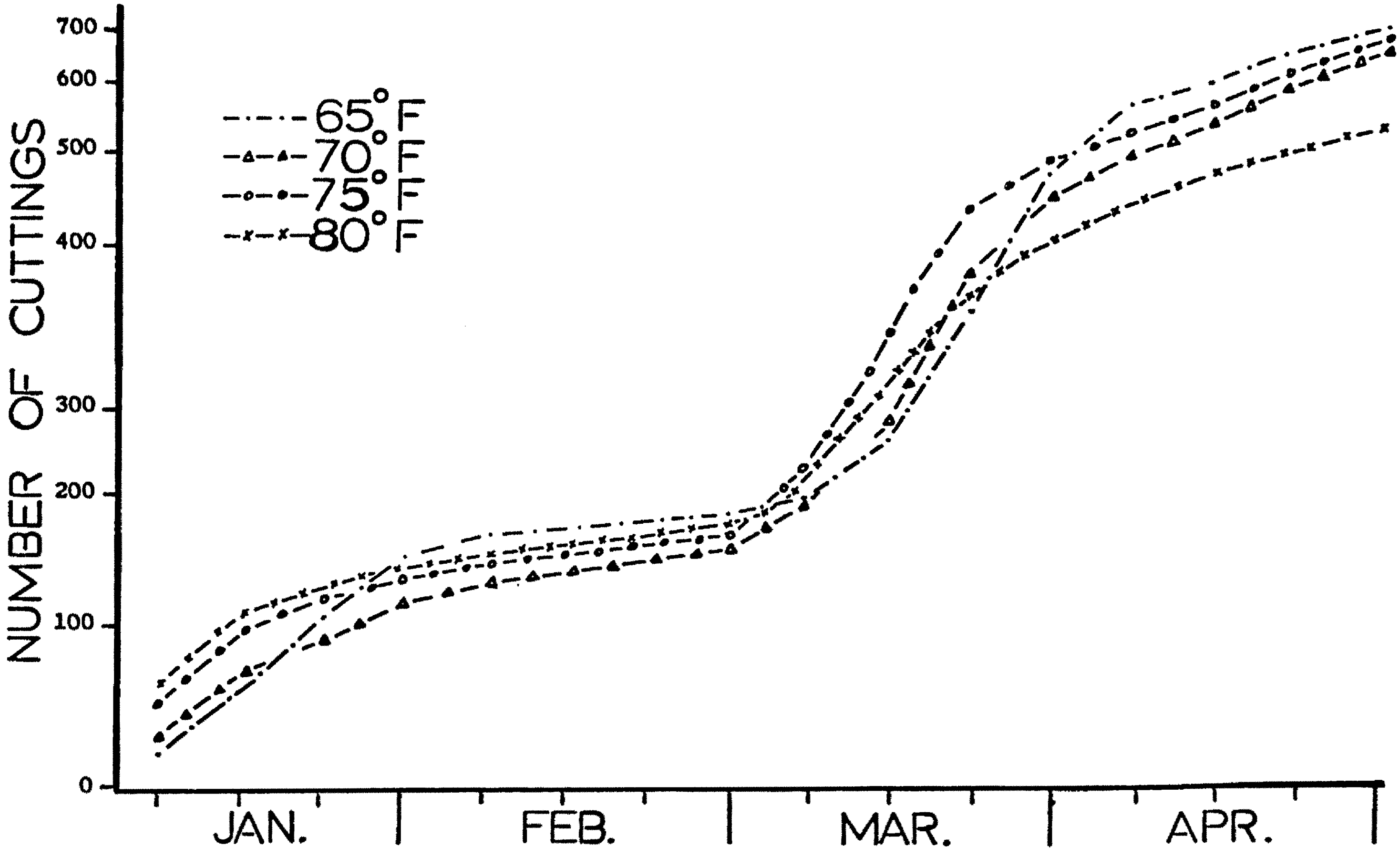

Figure 2 — Accumulated numbers of cuttings produced from Pink Mamie stock plants grown at four temperatures in the first four months of 1963. Part I, Experiment I.

weight was produced at each of the 2 highest nutrient levels (Table 1). When total quantity of cuttings was considered, proportional increases were observed with increasing nutrition at 75 and 80°F. and indiscernable differences at 65 and 70. At all temperatures, a higher fresh weight per cutting was observed at the lowest nutrient level. No consistent differences in per cent dry matter or dry weight per cutting occurred between any of the nutrient levels. In any of the growth measurements, nutrition produced no significant differences.

The effects of seasonal solar energy on the size and quality of cuttings appeared to have occurred concomitant with progressing age of plants. Figures 3,4, and 5 show the effects of solar energy and time of year on the per cent dry matter, fresh weight, and dry weight of cuttings taken from stock plants grown at different temperatures. Each monthly value for solar energy represents a mean, daily reading of total solar energy for the week preceeding the time when cuttings were harvested. In the first 2 months of production, per cent dry matter, fresh weight per cutting and dry weight per cutting all increased with a comparable increase in solar energy. As time progressed, the latter two measurements followed a general decrease with increasing solar energy. Per cent dry matter, on the other hand, followed closely with solar energy throughout the year. This trend has been observed by others working with carnations grown for flower production (13,21). The relationships between fresh weight, dry weight, and per cent dry matter at various times of the year are given in Figure 6. The overall length of cuttings as measured in July, 1963, was similar at all temperatures, but a slight decrease was observed at 65°F. On this

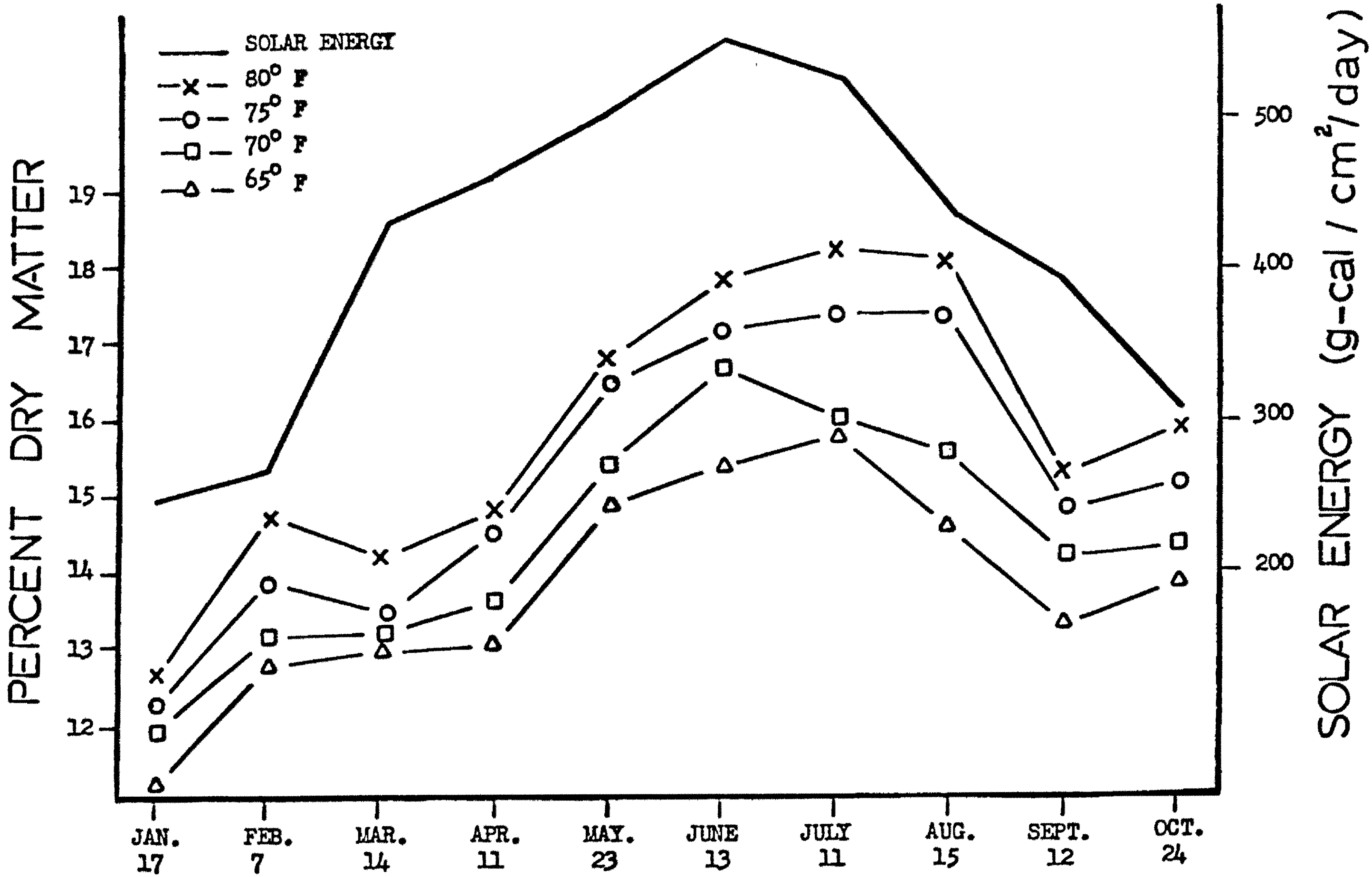

Figure 3 -- Comparison of solar energy in 1963 with per cent dry matter of cuttings taken from Pink Mamie stock plants grown at four temperatures. Part I, Experiment I.

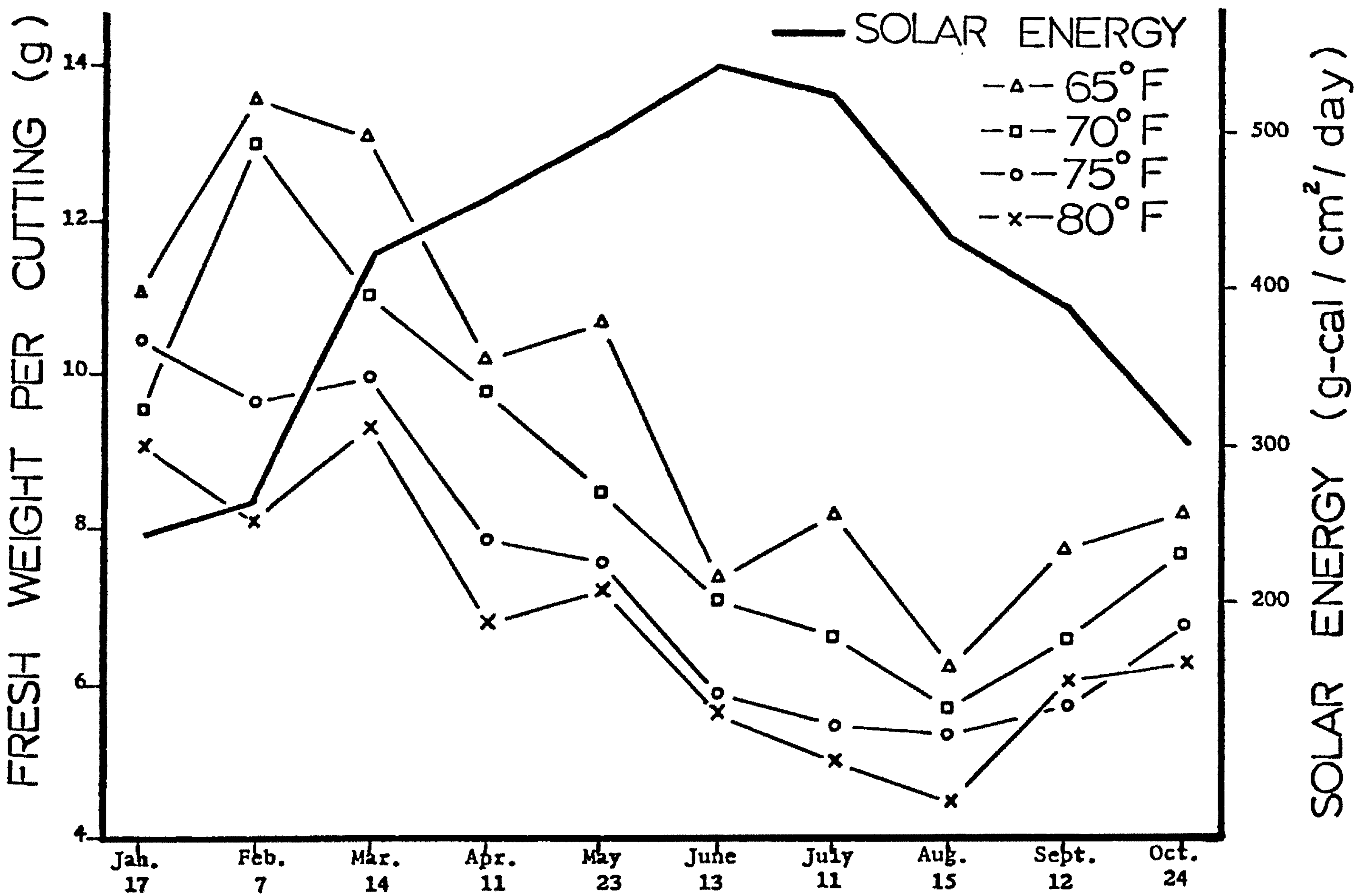

Figure 4 —Comparison of solar energy in 1963 with fresh weight of cuttings taken from Pink Mamie stock plants grown at four temperatures. Part I, Experiment I.

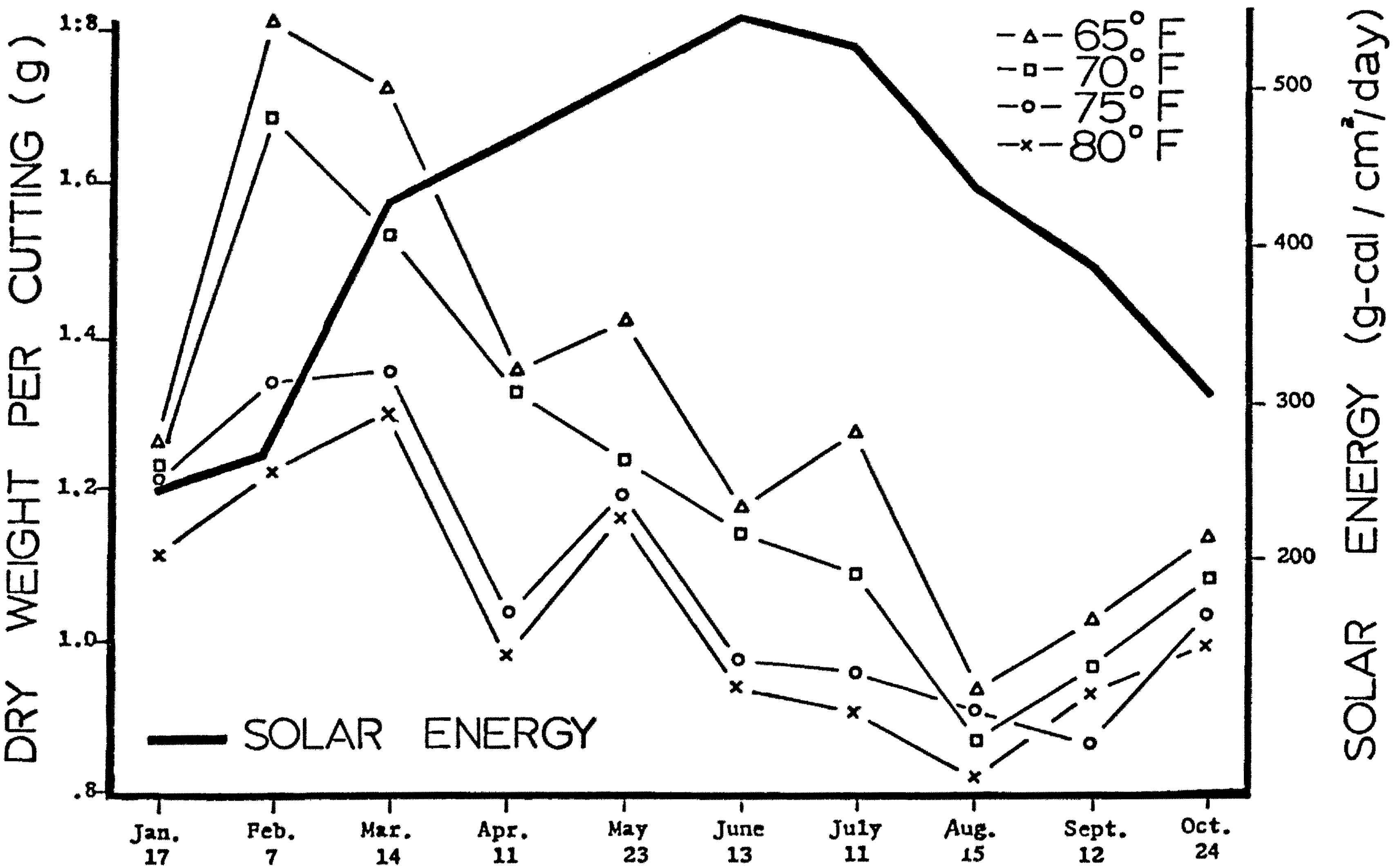

Figure 5 — Comparison of solar energy in 1963 with dry weight of cuttings taken from Pink Mamie stock plants grown at four temperatures. Part I, Experiment I.

sampling date fresh weight per unit length was considerably higher at 65°F. with slight decreases occurring at temperatures from 70 to 80°F. (Table 3).

TABLE 3.--AVERAGE LENGTH, WEIGHT, AND WEIGHT PER UNIT LENGTH OF PINK MAMIE CUTTINGS TAKEN FROM STOCK PLANTS GROWN AT FOUR DIFFERENT TEMPERATURES ON JULY 11, 1963.[1]

Measurement	Temperature (°F.) 65	70	75	80
Length per cutting (inches)	7.41	7.80	7.58	7.55
Fresh weight per cutting (grams)	7.66	6.81	6.44	6.28
Fresh weight per cutting per inch	1.03	.88	.85	.83

[1] Each value represents a mean of 45 cuttings.

The appearance of cuttings grown at the 4 temperatures is shown in Figures 7 and 8. In general, as temperature increased fresh weight per cutting and dry weight per cutting decreased with a commensurate increase in per cent dry matter. Similarly the diameter of stems and the number of visible axillary shoots decreased with each increment of temperature. Cool-grown cuttings (65 and 70°F.) had a greater amount of leaf curling than those grown at higher temperatures (75 and 80°F.).

<u>Part II - Flowering trials</u>

The growth of cuttings taken from stock plants produced under different environments was tested by observing their performance in flowering trials. The temperatures given stock plants had a consistent

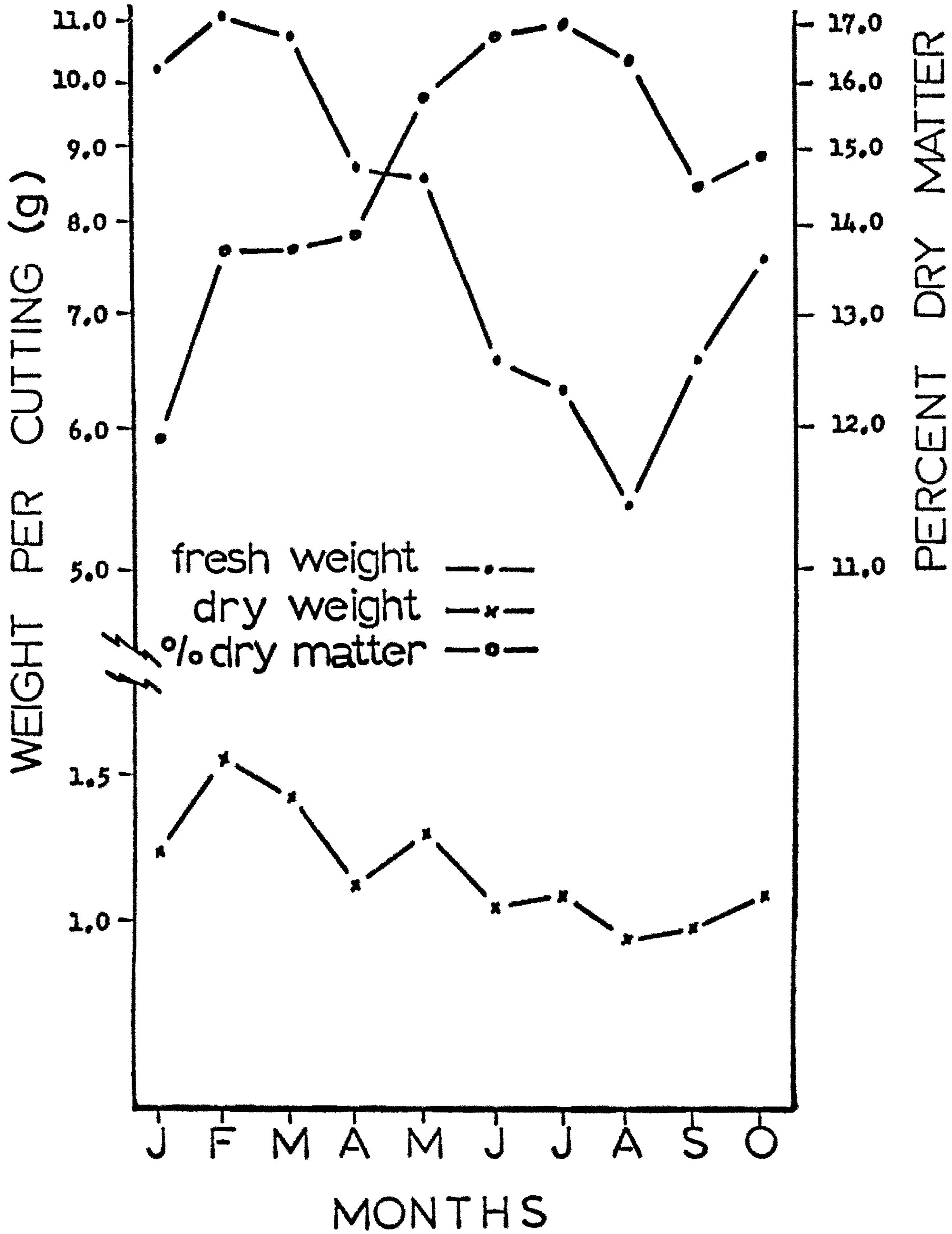

Figure 6--Comparison between samples of fresh and dry weight and percent dry matter of Pink Mamie cuttings grown from January to October, 1963. Values for each month represent means of combined treatment sums of Part I, Experiment I.

Figure 7--Samples of Pink Mamie stock plants grown at 4 temperatures. Note compressed growth and increased branching of plant on left. Picture taken on October 14, 1963

Figure 8--Samples of cuttings taken from plants in the order as shown in Figure 7. Note the increased axillary growth and increased width of stem, and decreased internode length of the two cuttings on the left (65 and 70°F.).


65°F
70°F
75°F
80°F


65°F
70°F
75°F
80°F

effect on the performance of the derived cuttings within the period from planting through the end of the first harvest. Few differences were observed due to the level of nutrition given stock plants.

A resume of planting dates and other cultural information concerning the different flowering trials is given in Table 4. The seasonal changes in environment, to which the growth of cuttings were subjected, ranged from the first planting date in April, 1963, to the last harvest date in May, 1964. The early growth of plants in the 6 flowering trials was observed during the period from spring to fall; whereas the production of first-crop flowers occurred from fall to the following spring. In this way it was possible to simulate the shortest cropping times of the year (April and May plantings) and the longest (September and October plantings) as well as two intermediate ones (July and August).

TABLE 4.—CULTURAL DATA FOR FLOWERING TRIALS. PART II, EXPERIMENT I.

Flowering trial	Planting date	Number of days from planting to pinching	Number of days in harvest period	Number of days from planting to final harvest date
1	4/16/63	15	56	136
2	5/17/63	16	84	146
3	7/ 3/63	21	98	196
4	8/ 1/63	27	77	209
5	9/ 5/63	25	63	224
6	10/ 1/63	26	70	219

Temperature effects A summary of data representing averages of the entire experiment is given in Table 5. Highly significant differences due to stock plant temperature occurred with the number of vegetative shoots contained by the plants after pinching and the number of axillary shoots contained by plants after all first-crop flowers were cut. Apparently a greater number of initial shoots was followed by a comparably greater number of shoots in the second growth. Cuttings from low temperature stock plants (65 and 70°F.) contained more lateral shoots at planting time and developed these shoots faster than those from high temperature stock plants (75 and 80°F.). No significant differences occurred from the number of flowers cut, the number of buds remaining after harvest, or the fresh weight of the residual plants; however consistently higher values occurred at 65 and 70°F. (Figures 9 and 10). First-crop flowers were produced in slightly less time by cuttings from low temperature stock plants. Differences in mean grade of cut flowers were small but significant due to the uniformity in the data. Cuttings from stock plants grown at the two higher temperatures produced better first-crop flowers.

Nutrient effects Very small differences were observed due to nutrient levels, as in Part I of this experiment. In general cuttings from stock plants grown under high nutrition produced more growth and cropped faster than those from the medium or low treatments. No reason can be given for the significant differences in number of buds counted after the harvest period (Table 5). The writer feels that differences due to nutrition were so small that further discussion is not warranted.

Flowering trials Significant differences occurred in production due to time of planting. These differences were due to the total time required at different seasons of the year for production of first-crop flowers. The numbers of first-crop flowers produced

TABLE 5.--SUMMARY OF RESULTS FROM PART II, EXPERIMENT I SPEED, QUANTITY, AND QUALITY OF FIRST-CROP FLOWER PRODUCTION AND ESTIMATED SECOND-CROP POTENTIAL FROM PINK MAMIE CUTTINGS TAKEN FROM STOCK PLANTS GROWN AT 4 TEMPERATURES AND 3 NUTRIENT LEVELS.

	1	2	3	4	5	6	7	8	9
Source of variance	Number of plants in average	Initial fresh weight of cuttings	Number of axillary shoots after pinching	Number of flowers produced	Midpoint of crop in days	Mean grade of flowers	Number of axillary shoots per residual plant	Number of buds per residual plant	Fresh weight per residual plant (grams)
Temperature (°F.)									
65	180	8.73	6.05a **	5.32	39.1	4.20ac *	12.34a **	3.48	341.5
70	180	8.17	6.23ab	5.36	39.1	4.20ab	12.77ab	3.09	338.3
75	180	6.65	5.83cb	5.23	40.5	4.26bc	11.95c	3.03	324.9
80	180	6.24	5.77cd	5.04	40.8	4.28cd	10.92d	3.00	311.7
Nutrient									
1½ x standard	240	7.48	5.94	5.24	40.4	4.21	11.71	2.93a *	319.9
2 x standard	240	7.36	5.94	5.14	39.7	4.25	12.03	3.09ab	333.4
2½ x standard	240	7.36	6.03	5.33	39.4	4.24	12.25	3.42bc	334.1
Flowering trial									
1	120		5.06 **	4.36 **	26.3 **	4.15 **	9.77 **	-- **	217.9 **
2	120		4.68	4.53	46.0	3.44	12.77	2.17	329.2
3	120		6.26	5.75	43.4	4.19	15.03	4.78	408.7
4	120		6.57	5.12	44.4	4.61	13.23	4.50	358.7
5	120		6.38	5.71	40.2	4.48	10.28	2.37	339.8
6	120		6.83	5.92	38.7	4.48	10.82	1.92	317.8

In columns 2, 3, and 4 all figures represent averages per plant. Column 5 represents the midpoint of total production as measured by the total number of days during the harvest period. Means followed by the same letter are not significantly different at the 5 or 1 per cent level.

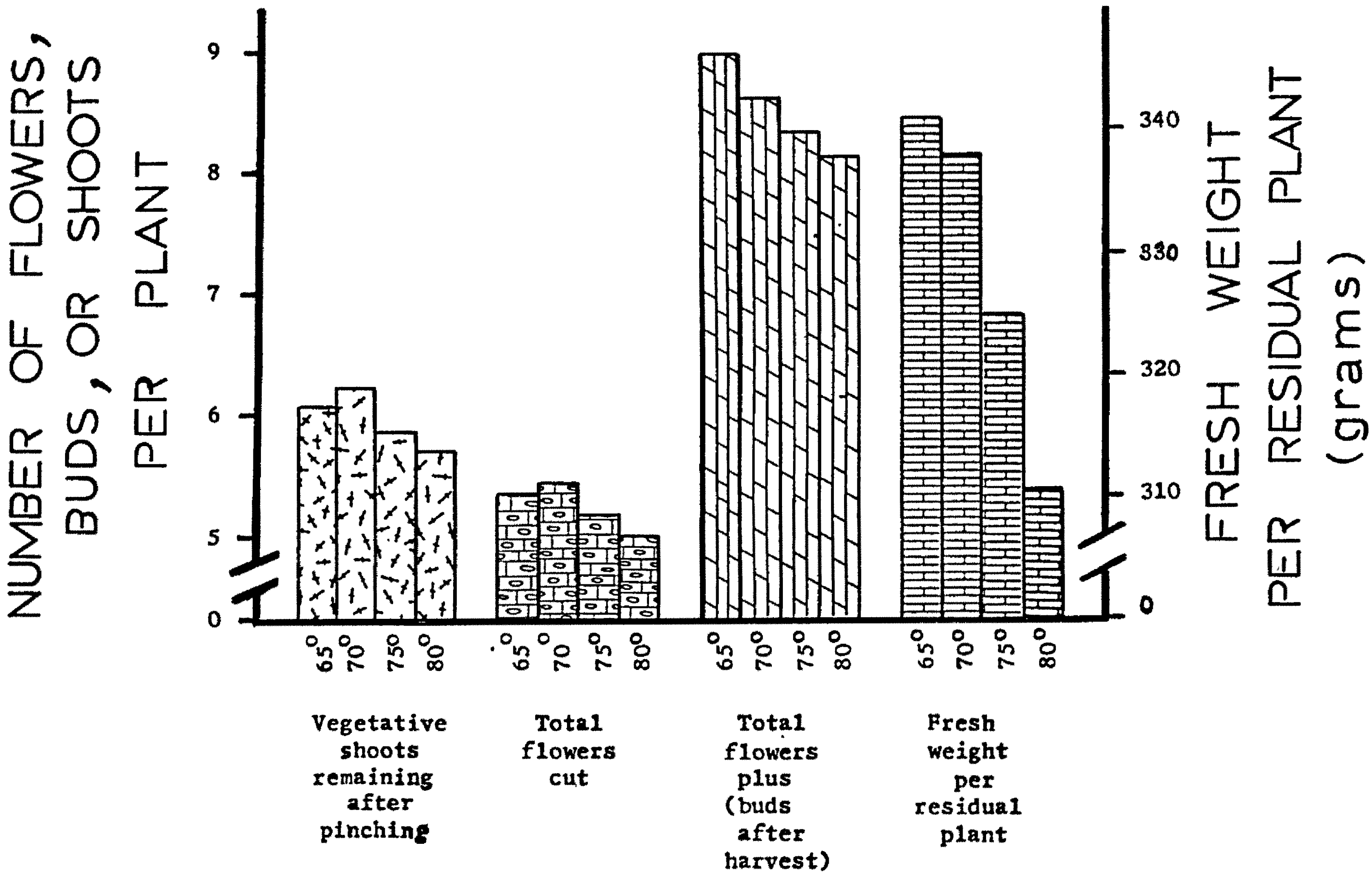

Figure 9--Comparison between different growth measurements of Pink Mamie cuttings taken from stock plants grown at four temperatures. Part II, Experiment I.

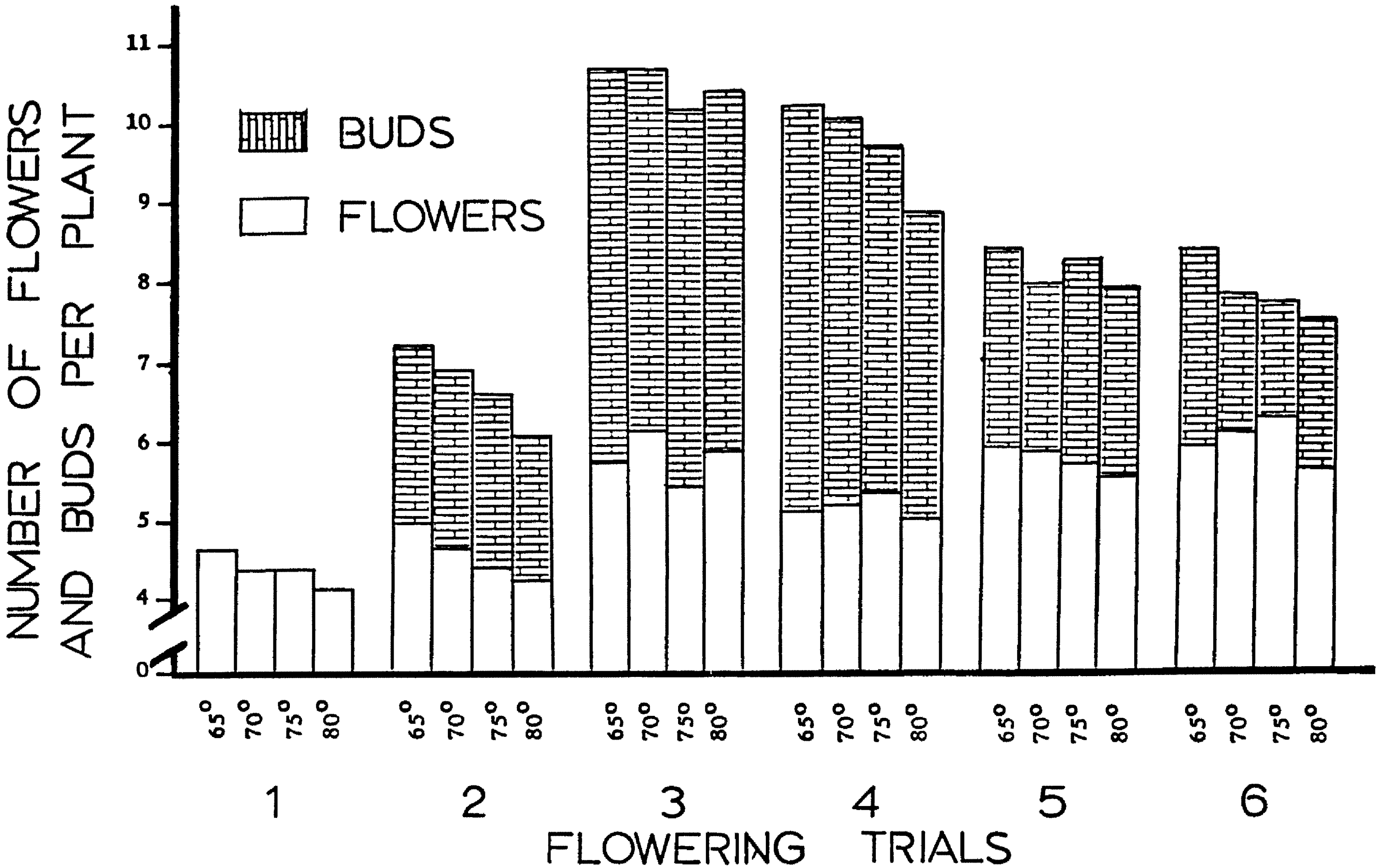

Figure 10--Total flowers and (buds remaining after harvest) produced from Pink Mamie cuttings taken from stock plants grown at four temperatures. Part II, Experiment I.

and buds remaining after the harvest period are given in Figure 10 for each flowering trial. Inverse relationships existed between flower production and stock plant temperature (Table 6) in the trials which matured earliest. When the number of buds is added to the number of

TABLE 6.—TOTAL FLOWER PRODUCTION PER PLANT OF PINK MAMIE CARNATIONS FOR SIX DIFFERENT FLOWERING TRIALS. PART II, EXPERIMENT I.[1]

Stock plant treatment	Number of plants in average	Flowering trial						Average
		1	2	3	4	5	6	
Temperature (°F.)								
65	30	4.60	4.90	5.66	5.03	5.83	5.86	5.32
70	30	4.36	4.60	6.09	5.16	5.83	6.06	5.36
75	30	4.36	4.33	5.39	5.29	5.69	6.23	5.23
80	30	4.10	4.20	5.83	5.00	5.46	5.53	5.03
Nutrient level								
1½ x standard	40	4.38	4.65	5.90	4.85	5.98	5.70	5.24
2 x standard	40	4.05	4.73	5.33	5.10	5.63	6.00	5.14
2½ x standard	40	4.70	4.23	6.03	5.43	5.53	6.08	5.33
Check	10	—	—	5.80	3.90	4.80	5.60	5.03

[1] Results grouped by temperature, nutrient level and check.

cut flowers, it can be seen that a more distinct, inverse relationship exists between crop production and stock plant temperature (Table 7). In all cases, higher production occurred in the treatments than in the check. The mean carbon dioxide level for the entire period was approximately 525 ppm, which was below the desired 600 ppm. It is well to note that cuttings were taken in the summer for comparison with the treatments when growing temperatures for check stock plants were in the vicinity of 80°F. Average production over all flowering trials (above) for the check was lower than the highest temperature treatment (80°F.). Nearly significant differences occurred in cut flower production, due to temperature, in the second flowering trial, and also when the first and second flowering trials were averaged

TABLE 7.--TOTAL FLOWERS PRODUCED PLUS BUDS REMAINING AFTER HARVEST OF PINK MAMIE CARNATIONS FOR 5 DIFFERENT FLOWERING TRIALS. PART II, EXPERIMENT I.[1]

Stock plant treatment	Number of plants in average	Flowering trial					Average
		2	3	4	5	6	
Temperature (°F.)							
65	30	7.17	10.60	10.20	8.37	8.37	8.94
70	30	6.87	10.83	10.03	7.90	7.80	8.65
75	30	8.83	10.07	9.57	8.20	7.70	8.43
80	30	6.13	10.83	8.73	7.87	7.53	8.22
Nutrient level							
1½ x standard	40	7.00	10.33	8.78	7.98	7.65	8.45
2 x standard	40	6.25	10.00	9.80	8.08	8.08	8.45
2½ x standard	40	6.83	11.28	10.30	8.20	7.83	8.89
Check	10	--	9.70	7.90	7.20	7.30	8.03

[1] Results grouped by temperature, nutrient level and check.

together (Table E, Appendix). Furthermore when the estimated daily production of flowers and fresh weight of residual plants was computed on a daily basis, it was found that the highest production occurred with the May planting (Table 8). Thus it is indicated that the normal planting time for carnations in commercial practice (May to June) also provides the greatest daily return for the first crop.

TABLE 8--EVALUATION OF DIFFERENT PLANTING DATES BY COMPUTED DAILY PRODUCTION OF FLOWERS AND FRESH WEIGHT OF PINK MAMIE CARNATIONS WITHIN THE PERIOD FROM PLANTING TO THE END OF HARVEST. PART II, EXPERIMENT I.

Flowering trial	Days from planting to end of harvest period	Number of flowers per plant per day	Fresh weight per residual plant per day (grams)
1	136	.032	1.60
2	146	.031	2.26
3	196	.029	2.08
4	209	.024	1.71
5	224	.025	1.52
6	219	.027	1.45

<u>Summary of Experiment I</u> Growing temperatures for Pink Mamie stock plants significantly effected size and quality of cutting (Part D). The subsequent growth of these cuttings in producing benches depended upon their size at planting time. A summary of the effects of size and quality on subsequent performance of cuttings in producing benches is given in Table 10. Regression analyses (Table 9) show significant relationships between size of cuttings and (1) number of shoots per plant after pinching, (2) mean grade of cut flowers, and (3) number of axillary shoots per residual plant. The sum of F values computed from regression analysis of the independent variable (cutting size) and the dependent variable (subsequent production) indicated fresh weight per cutting was the most reliable measurement of growth potential.

When all treatment means are compared with the check means, (Table 10) it can be seen that initial size of check cuttings was higher than those treated. The number of axillary shoots after pinching was the same in the check as in the treatment; however lower cut flower production, mean grade of cut flowers, and fresh weight per residual plant was observed in the check. The writer feels that the latter 3 differences, not attributable to size of cutting alone, were due to higher carbon dioxide and nutrient levels applied to the treatments.

TABLE 9.—SUMMARY OF F VALUES COMPUTED FROM REGRESSION ANALYSIS OF PHYSICAL MEASUREMENTS OF CUTTINGS AT THE TIME OF REMOVAL FROM STOCK PLANTS ON THEIR SUBSEQUENT PERFORMANCE WHEN PLANTED IN PRODUCING BENCHES. DATA TAKEN FROM PART II, EXPERIMENT I.

	Independent variable		
Dependent variable	Fresh weight per cutting (grams)	Dry weight per cutting (grams)	Per cent dry matter
Number of shoots per plant after pinching	(-) 7.69*	(-) 6.99*	(+) 4.88
Number of flowers produced per plant	(-) 3.73	(-) 2.29	(+) 2.03
Midpoint of crop in days	(+) 2.98	(+) 1.51	(-) 2.35
Mean grade of cut flowers	(+) 8.90*	(+) 7.89*	(-) 10.41*
Number of auxillary shoots per residual plant	(-) 10.92*	(-) 10.09*	(+) 10.35*
Number of buds per residual plant	(-) 2.44	(-) 2.64	(+) 2.40
Fresh weight per residual plant (grams)	(-) 5.49	(-) 3.96	(+) 4.48
Total F values	42.15	35.37	36.90

Significant at 5 per cent level.
Tabular F (5 per cent level) = 5.99.
Plus or minus signs signify positive or negative relationships.

TABLE 10.—COMPARISON BETWEEN MEASUREMENTS OF PINK MAMIE CUTTINGS AT THE TIME OF REMOVAL FROM STOCK PLANTS AND THEIR SUBSEQUENT PERFORMANCE WHEN PLANTED IN PRODUCING BENCHES. PARTS I AND II, EXPERIMENT I.

	Measurements of cuttings prior to propagation and planting in flowering trials				Performance of cuttings after planting in producing benches			
Preharvest treatment	Number of plants or cuttings in average	Fresh weight per cutting (grams)	Mean per cent dry matter	Dry weight per cutting (grams)	Number of axillary shoots per plant after pinching	Number of cut flowers per plant	Mean grade of cut flowers	Fresh weight per residual plant
Temperature (^{o}F.)								
65	180	8.73	14.3	1.26	6.05	5.32	4.20	341.5
70	180	8.17	15.1	1.18	6.23	5.36	4.20	338.3
75	180	6.65	15.9	1.06	5.83	5.23	4.26	324.9
80	180	6.65	16.6	1.04	5.77	5.04	4.28	311.7
Nutrient level								
1.5 x standard	240	7.48	15.5	1.16	5.94	5.24	4.21	319.9
2.0 x standard	240	7.36	15.4	1.11	5.94	5.14	4.25	333.4
2.5 x standard	240	7.50	15.5	1.15	6.03	5.33	4.25	331.1
Treatment mean[2/]	480	6.12	16.2	.98	6.50	5.62	4.44	356.4
Check mean	40	6.38	16.7	1.06	6.50	5.03	4.32	308.5

[1/]First seven lines represent means of temperature and nutrient treatments for six flowering trials.

[2/]Values represent means over all treatments from the last four flowering trials which contained check plots.

Experiment II

Part I - Cuttings containing equal numbers of expanded leaves

In this experiment, cuttings containing 6 pairs of expanded leaves were selected from stock plants 4 and 18 months of age. The juvenile cuttings had higher fresh weight per cutting, higher dry weight per cutting, and lower per cent dry matter than cuttings from old stock plants (Table 11).

TABLE 11.--FRESH WEIGHT, DRY WEIGHT, AND PER CENT DRY MATTER OF CARNATION CUTTINGS, CONTAINING 6 PAIRS OF EXPANDED LEAVES, TAKEN FROM STOCK PLANTS OF DIFFERENT AGE. PART I, EXPERIMENT II.[1/]

Age of stock plants	Fresh weight per cutting(g)	Dry weight per cutting(g)	Per cent dry matter
4 months	9.22	1.51	16.3
18 months	6.73	1.23	18.3

[1/]Each group represents a mean of 60 cuttings containing equal numbers of Red Gayety and White Pikes Peak.

Highly significant differences were observed in growth and performance of cuttings due to age of stock plants. Cuttings from young stock plants produced (1) more lateral shoots in a shorter period of time (Figure 14), (2) more cut flowers plus remaining buds after harvest, (3) higher mean grade of flowers, (4) greater number of axillary shoots in the second growth, (5) more fresh weight per residual plant, and (6) required less time for maturation of first-crop flowers than cuttings from old stock plants (Table 12). Similar differences were observed between varieties. Red Gayety consistently out performed

TABLE 12.—EFFECTS OF STOCK PLANT AGE ON SPEED, QUALITY, AND QUANTITY OF GROWTH OF CARNATION CUTTINGS. PLANTING DATE, AUGUST 17, 1963, FINAL HARVEST DATE, MARCH 29, 1964. PART I, EXPERIMENT II.[1]

Age of stock plants	Number of plants in average	Number of days from planting to pinching	Number of axillary shoots per plant after pinching	Number of cut flowers per plant	Mean grade of cut flowers	Fresh weight per residual plant (g)
4 months	60	27.3**	6.47	5.91**	4.38	458.8**
18 months	60	34.8	6.37	4.95	4.23	340.4

Treatment	Number of plants in average	Number of buds per plant	Number of cut flowers plus buds per plant	Number of days to midpoint of crop	Number of axillary shoots per residual plant
Age of stock plants[2]					
4 months	60	5.58**	11.50**	32.5**	15.30**
18 months	60	2.97	7.91	44.0	11.67
Varieties[3]					
Red Gayety	60	5.28**	10.77**	38.8	13.67
White Pikes Peak	60	3.27	8.64	37.8	13.35

**Significant at the 1 per cent level, analyses of variance used.

[1] Each value represents combined means of Red Gayety and White Pikes Peak for 2 blocks.

[2] Combined means of Red Gayety and White Pikes Peak for 2 blocks.

[3] Combined means of cuttings from 4 and 18 month-old stock plants.

White Pikes Peak; moreover stock plant age appeared to affect the growth of cuttings of both varieties in the same way.

The appearance of young and old stock plants and cuttings from these stock plants is shown in Figures 11 and 12. Cuttings from young stock plants were larger in diameter and contained more advanced axillary shoot development than cuttings from the older stock plants.

Such large differences in performance developed from the two groups of cuttings that it was difficult to attribute these effects to age of stock plants alone. Cuttings from young stock plants weighed considerably more than those from old stock plants. The following experiment was designed to eliminate the effect of differences in fresh weight of cuttings and to more accurately test the effects of juvenility.

Part II - Cuttings sized evenly by weight

In this experiment, cuttings were selected so that fresh weight of cuttings from young and old stock plants were equal (Figure 13). With this method of sizing, cuttings from old stock plants had higher dry weight per cutting and a greater number of expanded leaves than those from young stock plants (Table 13).

Sample size was too small for statistical analysis; however cuttings from young stock plants matured earlier and produced more first-crop flowers of higher quality than cuttings from old stock plants (Table 13). By the end of the first crop, performance of cuttings from old stock plants surpassed that of juvenile cuttings (indicated by the greater number of buds and axillary shoots remaining after first-crop flowers were cut, and fresh weight per residual plant). This was due to the fact that all first-crop flowers from juvenile cuttings were removed at the arbitrary point when first-crop flower production was considered finished: whereas, at this time, cuttings from old stock plants were only partially harvested. Probably the most accurate, single measurement of growth, that occurred up to the time the first crop of flowers was cut, was the number of flowers cut during the harvest period plus the number of buds remaining after harvest. It is apparent from Table 13 that, although cuttings from old stock plants had higher dry weight and per cent dry matter, there was a 7.1 per cent decrease in the number of buds and flowers when compared to juvenile cuttings.

Varietal differences found in this part of the study were similar to those observed in Part I. Again juvenile cuttings from either variety outperformed those obtained from old stock plants, with Red Gayety surpassing White Pikes Peak with both types of cuttings (Table 13). Red Gayety grew faster, even though initial fresh weight and number of expanded leaves were greater for White Pikes Peak cuttings, indicating differences in growth potential between the two varieties.

Experiment III

Part I - Size of cutting study (first planting)

The growth of cuttings in this experiment occurred during the winter months and required 225 days for maturation of the first crop of flowers. Cuttings planted September 21, 1963, required an average of 40 days to pinching, 63 days to beginning of harvest period, and completed harvest on May 3, 1964.

TABLE 13.—EFFECTS OF STOCK PLANT AGE ON SIZE OF CUTTINGS AND PERFORMANCE OF THESE CUTTINGS AFTER PLANTING. PLANTING DATE, NOVEMBER 12, 1963, FINAL HARVEST DATE, JUNE 7, 1964. PART II, EXPERIMENT II.

	Age of stock plants		Varieties	
	7 months	21 months	Red Gayety	White Pikes Peak
Measurements on cuttings				
Fresh weight per cutting (grams)	7.20	7.12	6.96	7.35
Dry weight per cutting (grams)	1.18	1.29	----	----
Per cent dry matter	16.40	18.10	----	----
Number of expanded leaves per cutting	5.04	6.78	5.76	6.06
Growth of cuttings after planting				
Number of cut flowers per plant	4.28	3.28	4.32	3.25
Mean grade of cut flowers	4.55	4.48	4.47	4.56
Number of buds per residual plant	2.75	3.25	3.24	2.75
Number of flowers produced plus buds after harvest	7.03	6.53	7.56	6.00
Number of days to midpoint of crop	27.50	31.30	26.80	32.00
Number of axillary shoots per residual plant	6.78	7.64	6.68	6.74
Fresh weight per residual plant (grams)	259.20	266.10	279.20	245.10

Figure 11--Typical old (left) and young stock plants on October 24, 1963. Part I, Experiment II.

Figure 12--From left to right, cuttings containing 6 pairs of expanded leaves taken from young and old stock plants. Part I, Experiment II.

Figure 13--From left to right, cuttings of the same fresh weight taken from young and old stock plants. Part II, Experiment II.

Figure 14--Growth of cuttings from young and old stock plants 9 weeks after planting. Plants on outside rows are from young stock plants. Part I, Experiment II.

The sequence of experimental plots within a block in the greenhouse bench appears in Table 14. Two blocks were planted.

TABLE 14.—OUTLINE FOR EXPERIMENTAL DESIGN FOR PART I, EXPERIMENT III.

Number of expanded leaves per cutting	4	5	6	7	8
Weight L = light, H = heavy	L H	L H	L H	L H	L H
Number of planted cuttings per plot	5 5	5 5	5 5	5 5	5 5

Measurements of cuttings at the time of harvest from stock plants are given in Table 15 grouped by number of expanded leaves and weight. Fresh weight per cutting of individual plots is given in Table B of the Appendix. Relative sizes of cuttings containing different numbers of expanded leaves are shown in (Figure 15).

TABLE 15.—MEASUREMENTS OF WHITE PIKES PEAK CUTTINGS AT THE TIME OF REMOVAL FROM STOCK PLANTS. PART I, EXPERIMENT III.

Treatment	Number of cuttings in average	Fresh weight per cutting	Dry weight per cutting	Per cent dry matter
Leaf pair				
4	24	5.06	.78	15.42
5	24	7.34	1.09	14.89
6	24	10.29	1.58	15.38
7	24	11.52	1.74	15.09
8	24	14.58	2.28	15.62
Weight				
light	60	8.47	1.29	15.28
heavy	60	10.61	1.63	15.38

Figure 15—From left to right, cuttings removed from stock plants at 4, 5, 6, 7, and 8 pairs of expanded leaves. Note increased length of stems and axillary shoot growth as size increases (stripped cuttings below).

The size of cuttings before planting, as measured by the number of expanded leaves, significantly affected their performance after planting. The speed of growth of cuttings until pinching time increased with size of cuttings (Table 16). This trend was similar for the number of axillary shoots contained by plants after pinching, except for cuttings containing 8 leaf-pairs. The decrease in the latter was attributed to the removal of a large number of reproductive shoots from cuttings at pinching time. Reproductive shoots are always removed from young, producing carnations. In any leaf-pair category, heavy cuttings produced more axillary shoots in a shorter length of time than light cuttings. At the end of the first-crop flower

TABLE 16.--SPEED AND QUANTITY OF VEGETATIVE GROWTH FROM CUTTINGS OF DIFFERENT SIZES. PART I, EXPERIMENT III.

Treatment	Number of plants in average	Number of weeks from planting to pinching	Number of axillary shoots per plant after pinching	Number of axillary shoots per plant after harvest of first flower crop	Fresh weight per residual plant (grams)
Leaf pair					
4	20	7.20a *	5.65e **	12.00	346.7
5	20	6.15b	7.05abc	11.10	383.0
6	20	5.85bc	7.10ab	12.90	439.6
7	20	4.75d	7.30a	11.50	405.1
8	20	4.60de	6.50abcd	11.10	428.0
Weight					
light	50	6.08 *	6.44	11.08	379.6
heavy	50	5.14	6.88	12.34	421.3

Single and double asterisks mean significance at the 5 and 1 per cent levels using analysis of variance. Means followed by the same letter are not significantly different. Means followed by different letters are significantly different.

production, cuttings containing 4 and 5 leaf-pairs contained as many return, vegetative shoots as the heavier cuttings; however fresh weight per residual plant at this time was considerably less for small cuttings (4 and 5 leaf-pairs). Within any leaf-pair category, heavy cuttings produced more fresh weight per residual plant.

Speed, quantity and quality of first-crop flower production were greatly affected by cutting size (Table 17). As with the number of initial axillary shoots, production of cut flowers was directly related to size of cuttings up to 6 leaf pairs. Increasing the number to 7 resulted in no increase in production. A decrease in production

TABLE 17.—SPEED, QUANTITY AND QUALITY OF FIRST-CROP FLOWER PRODUCTION FROM CUTTINGS OF DIFFERENT SIZES. PART I, EXPERIMENT III.

Treatment	Number of plants in average	Number of first-crop flowers per plant	Number of buds per residual plant	Number of flowers produced plus buds after harvest	Mean grade of cut flowers	Number of days to midpoint of crop
Leaf pair						
4	20	4.45a **	2.60	7.05	4.31ab **	31.8
5	20	5.40bc	2.60	8.00	4.28a	31.5
6	20	5.90bcd	2.95	8.85	4.56c	28.0
7	20	5.90bcd	2.30	8.20	4.58cd	29.0
8	20	5.20b	3.55	8.75	4.63cde	26.0
Weight						
light	50	5.02*	2.84	7.86	4.44	31.3
heavy	50	5.72	2.76	8.48	4.49	27.2

Single and double asterisks mean significance at the 5 and 1 per cent levels using analysis of variance. Means followed by the same letter are not significantly different. Means followed by different letters are significantly different.

was noted when the cuttings contained 8 leaf pairs. This decrease was undoubtedly due to fewer shoots per plant after pinching. The number of buds remaining after the first-crop flowers were cut was proportionately higher with small cuttings (4 and 5 leaf-pairs), this being due to a portion of late, first-crop flowers being included in the bud count after the harvest period. When considering the number of flowers plus buds, it can be seen (Figure 16) that production increased with size of cutting with those groups containing 4, 5, and 6 leaf-pairs and decreased at 7 and 8. Flowering was accelerated with each increase in cutting size, except with cuttings containing 7 leaf-pairs. Mean grade of flowers was directly related to cutting size, this being due partially to small flowers and weak stems produced from small cuttings.

Within any leaf-pair category, heavy cuttings produced (1) more flowers (Figure 17) and buds in a shorter period of time, (2) more total shoots at the start of the second crop, and (3) higher mean grade of cut flowers.

Part II - Size of cutting study (two pinching treatments)

The growth of cuttings in this experiment occurred from late fall to late spring, requiring 212 days for maturation of the first crop of flowers. Cuttings planted November 7, 1963, required an average of 46 days to pinching, 63 days to beginning of harvest period, and completed harvest on June 7, 1964.

The experimental design of this study was the same within blocks as in Part I. The block design, filling one greenhouse bench, appears in Table 18.

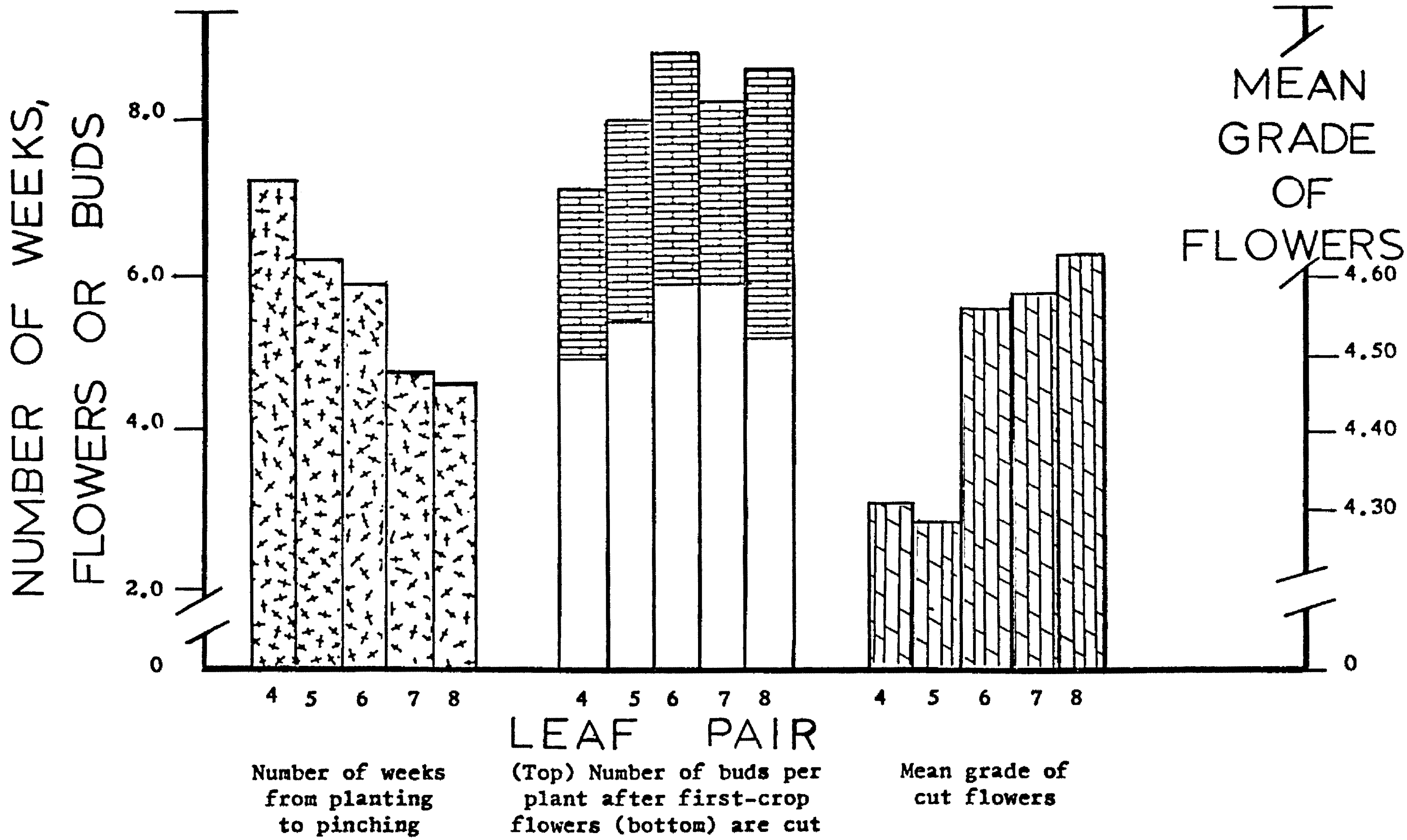

Figure 16--Speed, quality and quantity of growth from White Pikes Peak cuttings containing different numbers of expanded leaves. Part I, Experiment III.

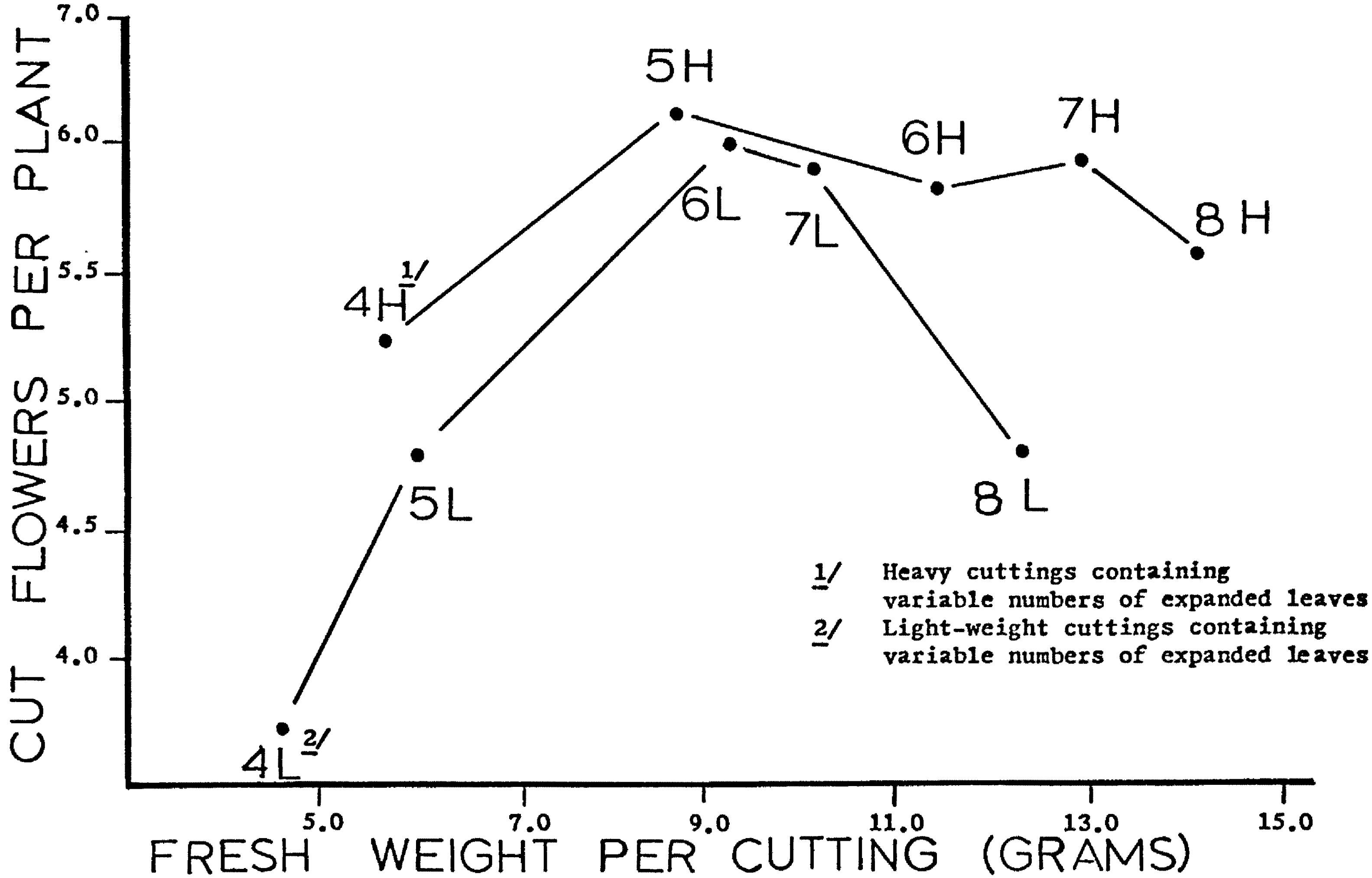

Figure 17--Effect of fresh weight per cutting at the time of removal from White Pikes Peak stock plants on the number of flowers produced in the first crop. Part I, Experiment III.

TABLE 18.—BLOCK DESIGN FOR PART II, EXPERIMENT III.

Type of pinching treatment	fan end		Blocks[1/]			pad end
Plants pinched to 5 vegetative shoots	1		2		3	
Plants pinched to allow growth of all possible vegetative shoots		1		2		3

[1/]Pinching treatments were linearly adjacent in the greenhouse bench.

Determination of dry weight of cuttings was not accomplished due to insufficient supply of cuttings at that time. Fresh weight per cutting along with performance results, grouped by individual treatments, appears in Table C of the Appendix.

The same trends concerning (1) pinching time, (2) mean grade of cut flowers, and (3) speed of flower production were observed as in Part I of this section. Of all the measurements of performance, numbers 1 and 3 above were the only ones that were significant effects, and were inversely related to size of cuttings. Mean grade was directly related to size of cuttings.

Plants given a late pinch developed approximately 2 more vegetative shoots per plant (Table 19) which resulted in a similar increase in the number of cut flowers produced in the first crop. Opposite results occurred with the number of buds counted after first-crop flowers were cut. At the time bud counts were made, a greater number of second-growth shoots were developed on plants initially pinched to 5 shoots than on plants given a late pinch. This was due to faster flower production for the latter, allowing more time for development of second growth (Table 20). In general, plants pinched to 5 breaks produced (1) fewer flowers, but in a shorter period of time, (2) more buds at the beginning of the second crop, (3) more flowers plus buds (Figure 18), and (4) higher mean grade of cut flowers than plants pinched to allow growth of all possible vegetative shoots.

TABLE 19.—SPEED AND QUANTITY OF VEGETATIVE GROWTH FROM WHITE PIKES PEAK CUTTINGS OF DIFFERENT SIZES WHEN GIVEN TWO PINCHING TREATMENTS. PART II, EXPERIMENT III.

Treatment	Number of plants in mean	Fresh weight per cutting (grams)	Weeks from planting to pinching: Pinching[1] method 5	5+	Mean	Number of axillary shoots per plant after pinching: Pinching method 5	5+	Mean
Leaf pair								
4	42	3.95	8.0a**[2]	9.2a**	8.60	5.27	7.81	6.54
5	42	5.93	6.7ab	7.4b	7.05	5.40	7.27	6.34
6	42	7.82	6.0bc	6.4bc	6.20	5.17	7.18	6.18
7	42	9.41	5.7bcd	6.0cd	5.85	4.97	7.33	6.15
8	42	11.08	5.0cde	5.9cde	5.45	5.00	7.31	6.16
Weight								
light	105	6.52	6.5	7.4*	6.95	5.17	7.09	6.13**
heavy	105	8.94	6.0	6.5	6.25	5.15	7.69	6.42

[1] 5 = plants pinched to 5 axillary, vegetative shoots.
5+ = plants pinched to allow growth of all axillary, vegetative shoots.

[2] Single and double asterisks mean significance at 5 and 1 per cent levels using analysis of variance. Duncan's New Multiple-Range Test used to describe least significant differences between treatments. Means followed by the same letter are not significantly different at the 1 per cent level. Means followed by different letters are significantly different at the 1 per cent level.

TABLE 20.--SPEED, QUANTITY, AND QUALITY OF FIRST-CROP FLOWER PRODUCTION FROM WHITE PIKES PEAK CUTTINGS OF DIFFERENT SIZES WHEN GIVEN 2 DIFFERENT PINCHING TREATMENTS. PART II, EXPERIMENT II. DUNCAN'S NEW MULTIPLE-RANGE TEST USED FOR ANALYSIS.

		Treatment							
	Pinching[1/] method	Leaf pair					Weight		
Measurements		4	5	6	7	8	L	H	Mean
Initial fresh weight per cutting (g)		3.95	5.93	7.82	9.41	11.08	6.52	8.94	3.93
Number of plants in mean		42	42	42	42	42	105	105	210
Number of flowers per plant	5	3.84	4.03	4.07	3.81	3.91	3.98	3.88	3.93
	5+	4.91	4.34	4.41	4.27	4.40	4.30	4.61	4.46
Average		4.38	4.19	4.24	4.04	4.16	4.14	4.25	
Number of buds per residual plant	5	2.25	2.38	2.22	2.52	2.75	2.21	2.64	2.43
	5+	1.65	2.15	2.20	2.10	2.72	2.28	2.12	2.20
Average		1.95	2.27	2.21	2.31	2.29	2.25	2.38	
Number of flowers plus buds	5	6.06	6.41	6.16	6.19	6.33	6.08	6.58	6.36
	5+	6.56	6.49	6.78	6.47	6.98	6.63	6.68	6.66
Average		6.31	6.45	6.47	6.33	6.66	6.36	6.63	
Mean grade of flowers	5	4.21	4.16	4.21	4.25	4.18	4.17	4.24	4.21
	5+	4.08	4.24	4.23	4.28	4.39	4.23	4.25	4.24
Average		4.15	4.20	4.22	4.27	4.29	4.20	4.25	
Days to midpoint of crop	5	38.7	35.5	38.0	38.8	34.9	38.3	35.7	37.0*
	5+	45.0	42.2	37.3	38.5	26.0	40.1	39.5	39.8
Average	**	41.9 a	38.9 ab	37.7 abcd	38.7 abc	35.5 bcde	39.2	37.6	

1/5 = plants pinched to 5 axillary vegetative shoots.
5+ = plants pinched to allow growth of all axillary, vegetative shoots.

Single and double asterisks mean significance at 5 and 1 per cent levels using analysis of variance. Means followed by the same letter are not significantly different at the 1 per cent level. Means followed by different letters are significantly different.

With either pinching treatment, trends concerning production of flowers and buds from cuttings of different sizes were not exactly comparable to those observed in Part I of this section (Table 20). Due to a greater number of initial shoots after pinching, cuttings containing 4 leaf-pairs produced more first-crop flowers, but in a longer period of time than larger cuttings. When the number of buds is added to the number of flowers, it can be seen that a general increase occurred with cutting size, except for cuttings containing 7 leaf-pairs. It is well to mention that less space was allowed between plants in this experiment than was allowed in Part I of this section. Even though spacing was equal between plants, a proportionately greater amount of light and nutrients was available to small cuttings than large cuttings, which could partially account for the differences. When the sum of light-weight cuttings for all leaf-pair categories is compared to heavy cuttings, it can be seen that heavy cuttings produced more vegetative shoots after pinching, resulting in more cut flowers produced in a shorter period of time, (2) more flowers plus buds at the end of harvest time, and (3) a slightly higher mean grade of cut flowers.

Summary of Experiment III

During the time that performance studies of different sized cuttings were established, it was thought that the rooting percentage of cuttings of different sizes might have an effect on the performance of cuttings after planting. In September, during the time when cuttings were planted for Part I of this section, cuttings were selected and grouped in the same categories as described for performance tests. Two replications of rooting studies were made. A summary of the

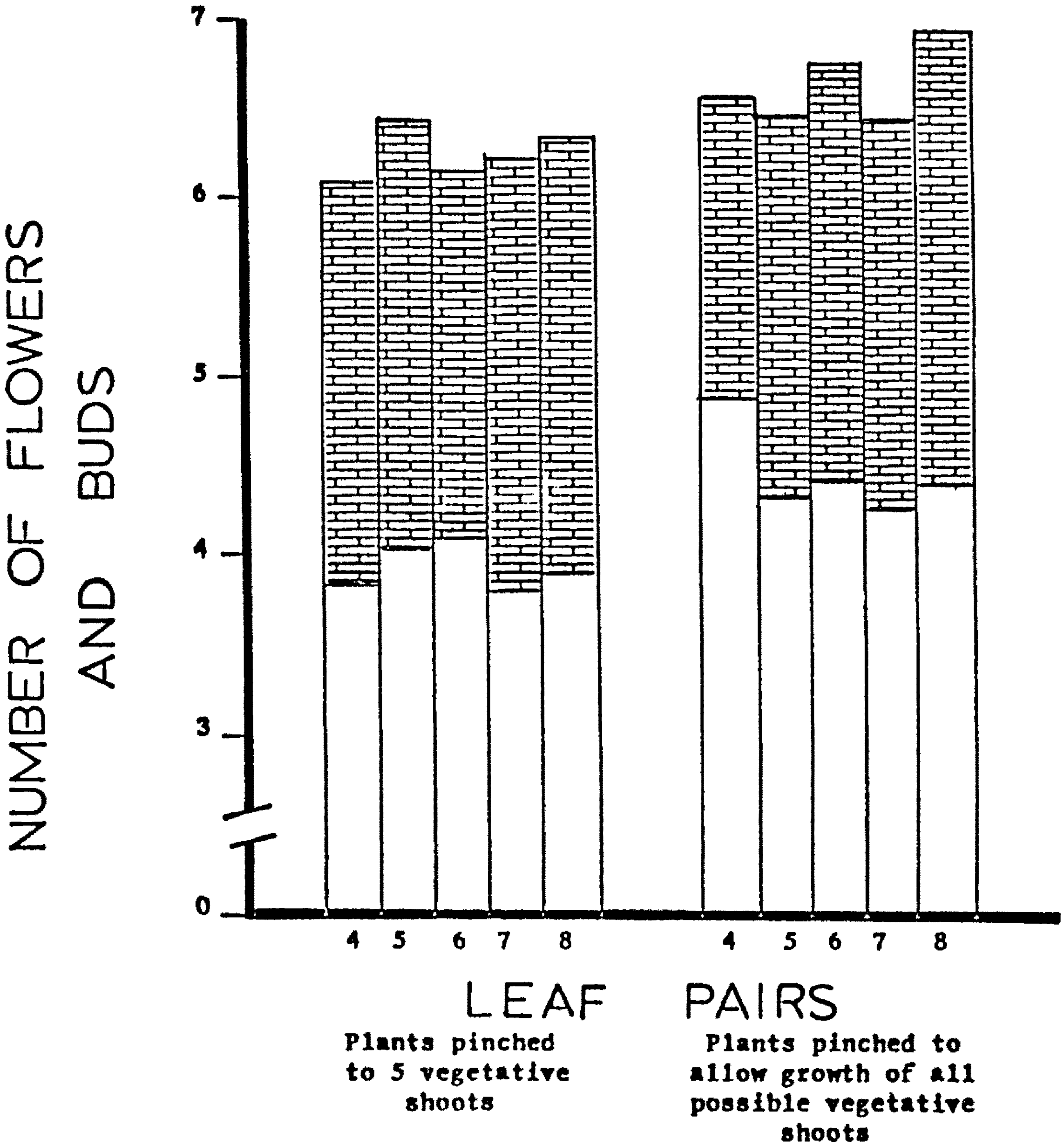

Figure 18--Effects of two different pinching treatments on the total production of flowers and buds from White Pikes Peak cuttings of different sizes. Data represents average per plant. Part II, Experiment III.

effects of cutting size on the rooting percentage and growth of cuttings, as indicated by the number of expanded leaf-pairs during propagation, is presented in Table 21.

TABLE 21.—COMPARISON BETWEEN MEASUREMENTS OF WHITE PIKES PEAK CUTTINGS OF DIFFERENT SIZES BEFORE PROPAGATION, AND PER CENT ROOTING AND GROWTH DURING PROPAGATION. MEAN VALUES FOR TWO REPLICATIONS TAKEN IN SEPTEMBER, 1963.

		Measurements of cuttings at time of removal from stock plants			Evaluation of cuttings after propagation	
Treatment	Number of cuttings in average	Fresh weight per cutting (grams)	Dry weight per cutting (grams)	Mean[1/] per cent dry matter	Mean rooting percentage	Number[2/] of expanded leaf-pairs
Leaf pair						
4	48	4.70	0.72	15.30	80.3	0.38
5	48	6.84	1.02	14.95	94.8	0.55
6	48	8.42	1.28	15.24	90.1	0.50
7	48	11.13	1.68	15.07	85.5	0.50
8	48	12.53	1.98	15.81	81.3	0.39
Weight						
light	120	8.47	1.30	15.28	87.5	0.40
heavy	120	10.41	1.60	15.38	85.4	0.49

[1/] Indirect measurement from duplicate samples used to calculate dry weight per cutting.
[2/] Average number of leaves expanded during propagation.

Although rooting percentages were not significantly different, it can be seen that a higher rooting percentage occurred with cuttings containing 5, 6, and 7 pairs of expanded leaves. This was accompanied by slightly more growth during propagation.

Due to the similarity between replications, the effects of cutting size on either quantity of roots formed during propagation or growth and performance after planting can be considered reliable. Table 22 summarizes the mean effects (from Parts I and II of this experiment) of cutting size before planting on subsequent performance. It can be seen (Table 22 and Figures 19 and 20) that speed, quantity, and quality of growth of White Pikes Peak cuttings increased with initial cutting size during the period between planting and the end of the first crop. No explanation can be given for the fact that cuttings containing 7 leaf-pairs in either Parts I or II did not conform to the linear trends. In general, within any leaf-pair category, heavy cuttings produced faster growth, more total flowers plus buds (Figure 21), and higher quality cut flowers than light-weight cuttings.

It is doubtful whether the quantity of roots formed on cuttings during propagation had any consistent effects on their subsequent performance.

Part III A - Comparison of cutting size to the growth stage of the apical meristem

It had been suspected by the writer that the amount of axillary shoot growth of cuttings was related to flower initiation. To study this theory, cuttings were taken at 4 through 10 pairs of expanded leaves, leaving 3 pairs of leaves on the stock-plant shoots from which they were taken. Cuttings were then stripped of all leaves, the number of nodes from the base of the cutting to the apical meristem were counted, and the meristem was examined under the bionocular microscope to determine its height and stage of development. It was

TABLE 22.--EFFECTS OF SIZE AND QUALITY OF WHITE PIKES PEAK CUTTINGS ON PERFORMANCE AFTER PLANTING.[1]

	Measurements of cuttings at time of removal from stock plants				Performance of cuttings after planting				
Treatment	Number of cuttings in average	Fresh weight per cutting (grams)	Dry weight per cutting (grams)	Per cent dry matter	Number of weeks from planting to pinching	Axillary shoots per plant after pinching	Number of flowers produced plus buds after harvest	Days to midpoint of crop	Mean grade of flowers
Leaf pair									
4	62	4.51	.69	15.30	8.20	6.73	6.81	38.4	4.20
5	62	6.64	.99	14.95	6.78	7.16	7.25	36.9	4.26
6	62	9.06	1.38	15.24	6.13	7.14	7.82	32.7	4.40
7	62	10.47	1.58	15.07	5.38	7.32	7.32	33.8	4.43
8	62	12.83	2.03	15.81	5.25	6.91	7.87	31.0	4.51
Weight									
light	155	7.50	1.15	15.28	6.74	6.77	7.25	35.7	4.34
heavy	155	9.78	1.50	15.38	5.82	7.29	7.58	33.4	4.37

[1] Mean values of Part I plus Part II, Experiment III.

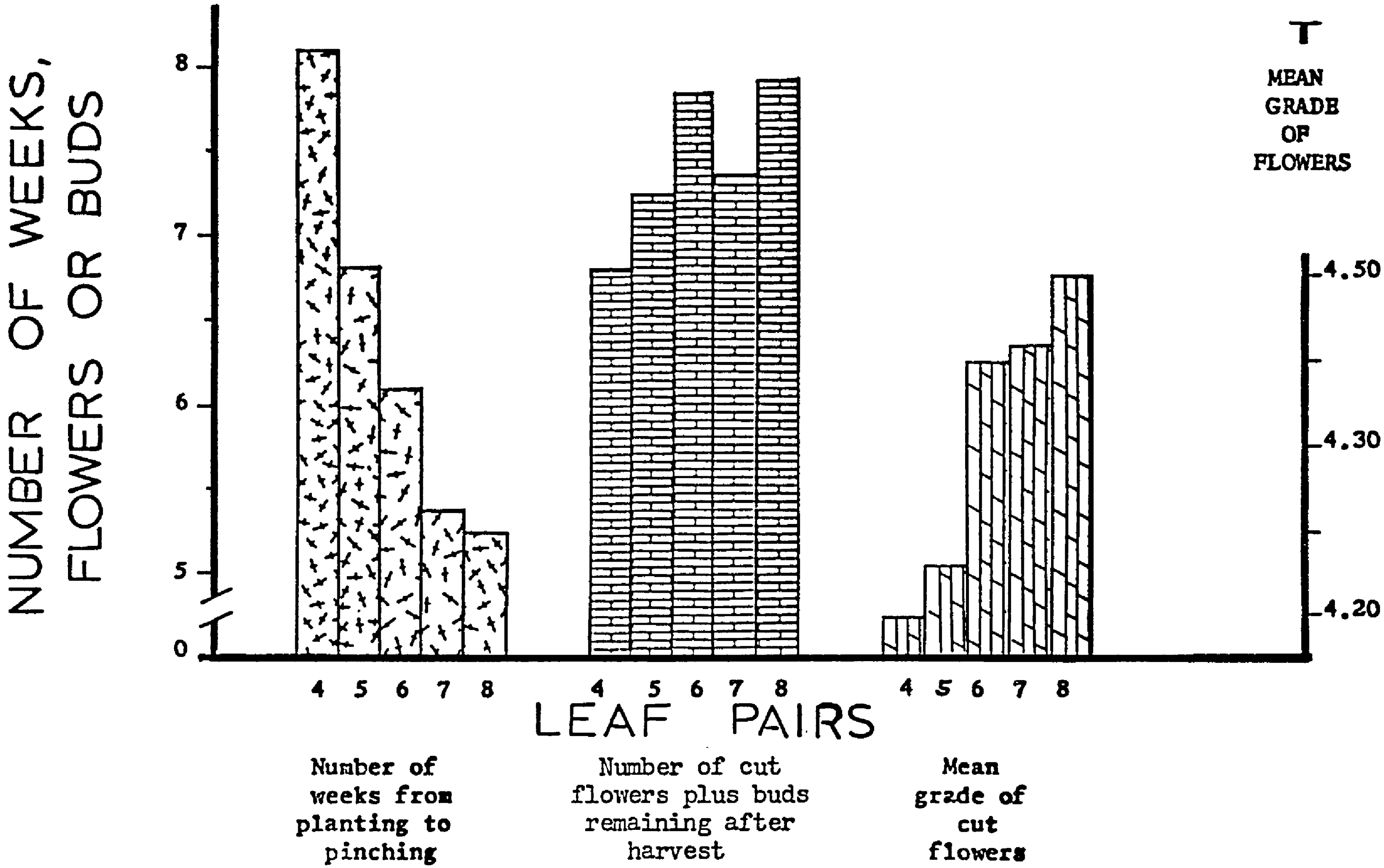

Figure 19--Comparisons among speed, quantity, and quality of growth from White Pikes Peak cuttings containing different numbers of expanded leaves. Mean values for Part I plus Part II, Experiment III.

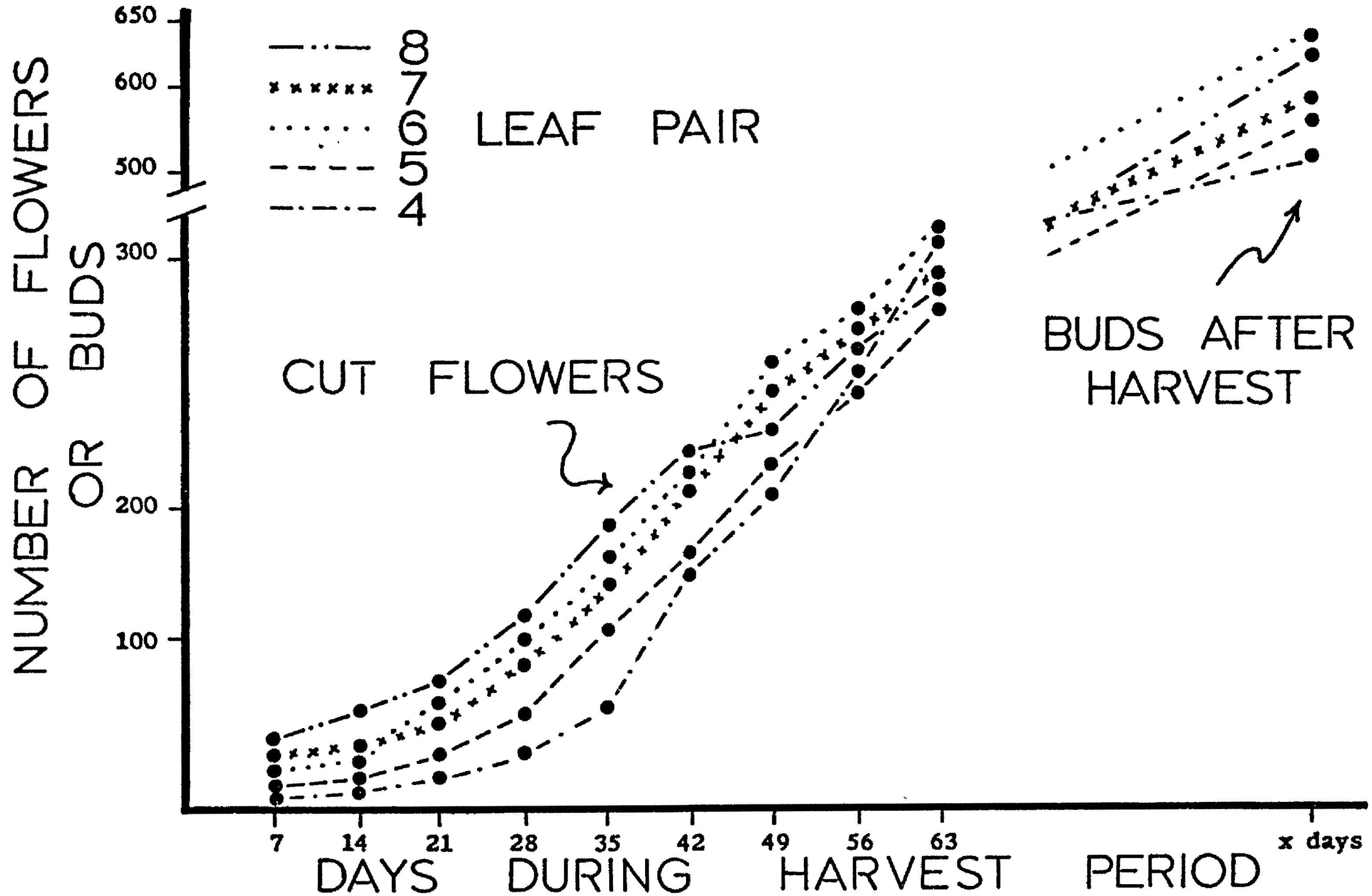

Figure 20--Accumulated weekly production of cut flowers produced from White Pikes Peak cuttings containing different numbers of expanded leaves. Early second-crop production estimated by number of buds remaining after flowers were cut. Mean values for Part I plus Part II, Experiment III.

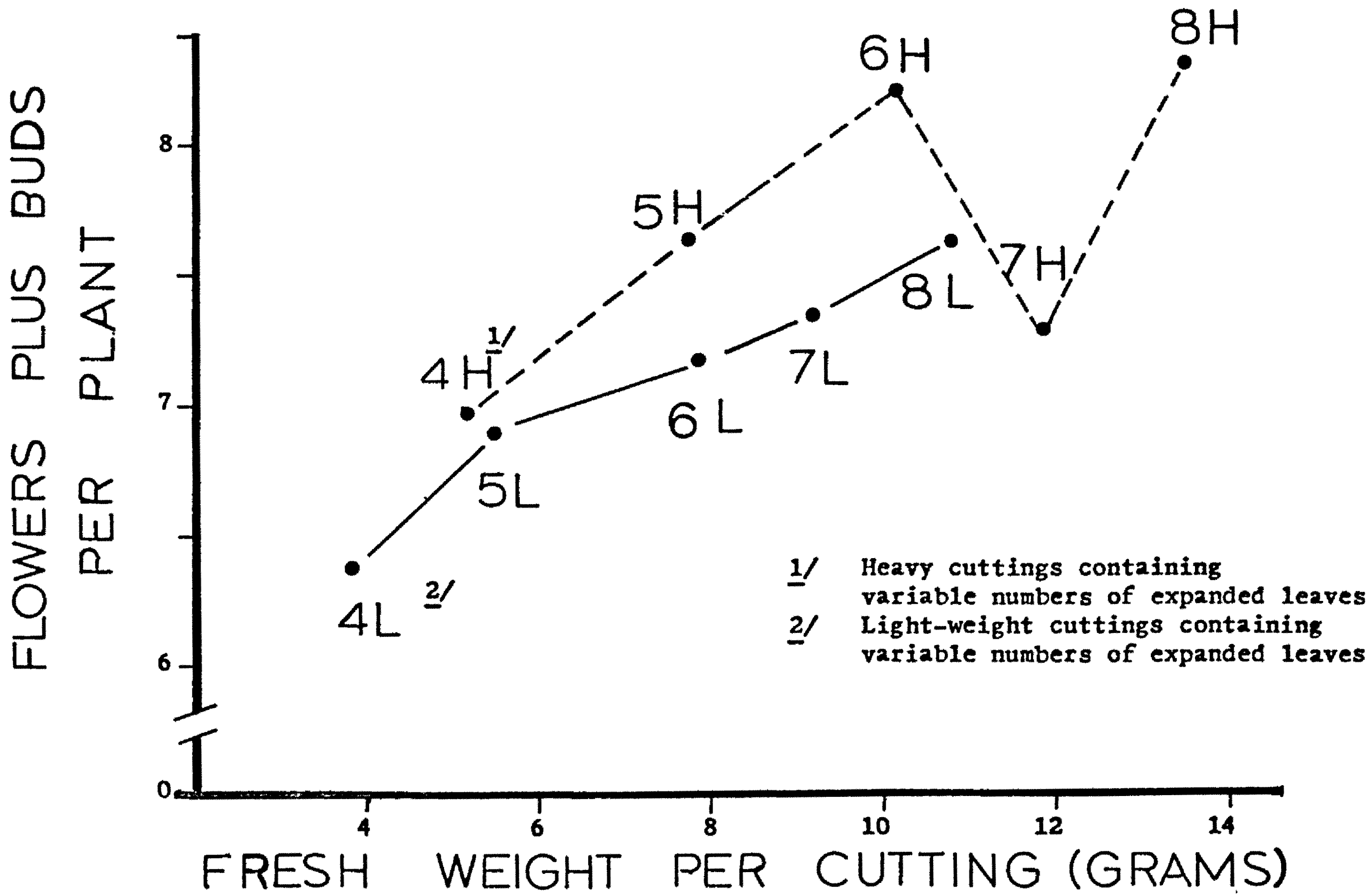

Figure 21--Effect of fresh weight per cutting at the time of removal from White Pikes Peak stock plants on the number of flowers produced plus buds counted after harvest of the first flower crop. Mean values of Part I plus Part II, Experiment III.

found that, as the height of the apical meristem increased from 185 to 476 microns, there occurred a gradual transition from completely vegetative meristems to those that had formed a majority of primordial floral organs. Furthermore, this transition occurred as cuttings increased in size from 6 to 10 pairs of expanded leaves and an associate increase in fresh weight from 8.66 to 13.80 grams (Table 23). As cutting size increased from 6 to 10 leaf-pairs, the number of nodes subtending the apex increased from 11.9 to 15.0.

During the time the above study was made, the average number of leaf-pairs subtending the flowers on Pink Sim producing plants was counted to determine the maximum number of leaf nodes contained by mature flower stems. Of 150 counts of flower stems arising from different positions on the plant, the average number of leaf nodes subtending the flower was 15.6, with the range from 13 to 18, depending upon the position of the plant from which the flower stem grew. It was noted, in accordance with Hanzel et al. (14), that the higher the position of the flower stem on the plant the fewer the number of leaf nodes subtending the flower. Measurements of this type were not made on stock plants, thus direct findings concerning positional effects on the number of nodes subtending the flower could not be made. However a reasonable estimate can be made from the counts made on flowering plants. With these points in mind, it can be seen from Table 23 that, when the number of leaf nodes left on stock plants is added to the number of nodes subtending the apex on cuttings of different sizes, the range is from 13.3 for cuttings containing 4 pairs of expanded leaves to 18.0 for cuttings containing 10 leaf-pairs.

The maximum number of leaf nodes, from the counts on flowering plants (15.6), were observed on cuttings containing 6 and 7 leaf-pairs, when the number of leaves left on stock plants are added to those counted on cuttings. It can also be seen that the apical meristems of cuttings in the latter two groups were changing from the vegetative to the reproductive stage. Relative axillary shoot growth of cuttings of different sizes is shown in Figure 15. It can be seen from the photograph, and was observed throughout the study, that cuttings containing 4 and 5 leaf-pairs have very little stem development and only a small amount of axillary shoot development; whereas a considerable increase in development of stems and axillary growth occurred with larger cuttings. When apical meristems of cuttings were changing from the vegetative to the reproductive stage, an associate, rapid increase in axillary shoot growth occurred.

The fresh weight, per cent dry matter, and dry weight of cuttings ranging from 3 to 9 leaf-pairs in size are shown in Table 24. As size of cuttings increased, per cent dry matter was initially high at 3 leaf-pairs, decreased at 5, and increased gradually thereafter. These tables are presented together for the purpose of making comparisons between all macroscopic measurements of cuttings and the developmental stage of their apical meristems.

Part III B - Final evaluation of cutting size in terms of performance after planting

This final summary of results is presented in Tables 25 and 26. In general, the size and quality (as indicated by dry weight per cutting) of cuttings had a considerable effect on their performance after planting. The date when cuttings were planted also had a great

TABLE 23.—COMPARISONS BETWEEN THE DEVELOPMENTAL STAGE OF THE APICAL MERISTEM AND SIZE OF CUTTINGS. PART III A, EXPERIMENT III. (5 SAMPLING DATES FROM OCTOBER TO NOVEMBER, VARIETY PINK SIM USED).

Leaf pairs	Fresh weight (grams)	Total length (inches)	Number of nodes from base of cutting to apex	Height of apex (microns)	Growth[1/] stage of apex	Length of stripped cutting (inches)
4	5.43	7.13	10.3	148.9	1.00	1.02
5	6.50	7.32	11.1	144.9	1.00	1.72
6	8.66	10.07	11.9	185.0	1.27	2.24
7	10.02	9.87	13.1	194.7	1.45	3.53
8	11.71	10.52	13.5	214.6	2.30	3.58
9	11.23	11.30	14.3	428.0	2.75	—
10	13.80	12.00	15.0	476.0	3.20	--

[1/]Mean stage of development determined by the following system:

Points allotted	Stage	
1	1	vegetative
2	2	elongation and floral initiation
3	3	early floral development, calyx visible
4	4	advanced floral development, calyx and corrolla visible

TABLE 24.—FRESH WEIGHT, PER CENT DRY MATTER, AND DRY WEIGHT OF CUTTINGS OF TWO SIM VARIETIES CONTAINING DIFFERENT NUMBERS OF EXPANDED LEAVES. JULY SAMPLE - PINK SIM; SEPTEMBER SAMPLE - WHITE PIKES PEAK.

Measurement	Sampling date	Number of expanded leaves: 3	4	5	6	7	8	9
Fresh weight per cutting	July 16, 1963	3.33	3.60	5.88	7.66	8.78	10.73	13.95
	September 12, 1963		5.06	7.34	10.29	11.52	14.58	
Per cent dry matter	July 16, 1963	17.2	16.7	16.6	16.9	17.0	17.1	17.3
	September 12, 1963		15.4	14.9	15.4	15.1	15.6	
Dry weight per cutting	July 16, 1963	.38	.60	.98	1.39	1.50	1.83	2.41
	September 12, 1963		.78	1.09	1.58	1.74	2.28	

TABLE 25--EVALUATION OF THE EFFECTS OF CUTTING SIZE AT DIFFERENT PLANTING DATES ON THE QUALITY AND QUANTITY OF THE FIRST CROP OF FLOWERS. DATA TAKEN FROM EXPERIMENTS I, II, AND III. SECOND-CROP POTENTIAL PRODUCTION ESTIMATED BY FRESH WEIGHT OF RESIDUAL PLANTS PER SQUARE FOOT.

Comparative sample		Number of cuttings in average	Number of expanded leaves per cutting	Fresh weight per cutting grams	Per cent dry matter	Dry weight per cutting (grams)	Planting date	Number of weeks from planting to final harvest	Number of flowers per square foot per week 2/	Mean grade of flowers	Fresh weight of residual plants per square foot
Mean values for	1	120	5	9.21	13.60	1.21	4/16/63	19	.78	4.15	741
flowering trials	2	120	5	8.82	14.50	1.28	5/16/63	21	.73	3.44	1,119
(Variety Pink Mamie,	3	120	5	7.14	16.90	1.21	7/16/63	28	.70	4.19	1,391
Average temperature 72.5 F	4	120	5	6.65	16.90	1.12	8/16/63	30	.58	4.61	1,217
Average nutrient level	5	120	5	5.71	15.15	.87	9/ 5/63	32	.61	4.48	1,153
2x standard	6	120	5	6.30	14.15	.89	10/ 1/63	31	.65	4.48	1,081
Average carbon dioxide	check 1/	40	5	6.38	16.70	1.06		30	.57	4.32	1,050
525 ppm)											
Juvenility study	young	60	6	9.22	16.30	1.51	8/17/63	32	.63	4.38	1,557
(age of stock plants)	old	60	6	6.73	18.30	1.23			.53	4.23	1,156
(Varieties Red Gayety											
and White Pikes Peak,	young	28	5	7.20	15.00	1.08	11/12/63	30	.57	4.55	1,036
Standard growing	old	28	6	7.12	15.50	1.10			.44	4.48	1,064
conditions)											
		20	4	5.06	15.42	.78	9/12/63	32	.47	4.31	1,176
Size of cutting study	first	20	5	7.34	14.89	1.09			.57	4.28	1,302
(Variety White Pikes	planting	20	6	10.29	15.38	1.58			.63	4.56	1,493
Peak,		20	7	11.52	15.09	1.74			.63	4.58	1,377
Standard growing		20	8	14.58	15.62	2.28			.55	4.63	1,455
conditions)											
		42	4	3.95			11/7/63	32	.58	4.15	
	pinching	42	5	5.93					.56	4.20	
	study	42	6	7.82					.57	4.22	
		42	7	9.41					.54	4.27	
		42	8	11.08					.55	4.29	

1/ Mean values for the last 4 flowering trials
2/ Weekly values figured for the period of time from planting to the end of the first crop

TABLE 26.—COMPARISON BETWEEN FRESH WEIGHT, PER CENT DRY MATTER, AND DRY WEIGHT OF CUTTINGS CONTAINING 5 LEAF-PAIRS AND PERFORMANCE AT DIFFERENT PLANTING DATES AND GROWING CONDITIONS.

Source of sample	Number of cuttings in average	Fresh weight per cutting (grams)	Per cent dry matter	Dry weight per cutting (grams)	Number of expanded leaves per cutting	Number of[1] flowers per square foot per week	Mean grade of flowers	Fresh weight of residual plants per square foot
Stock plant study (Variety Pink Mamie, Average temperature 72.5°F. Average nutrient level 2 x standard) Carbon dioxide 525 ppm	120	5.71	15.15	.87	5	.61	4.48	1,153
Juvenility study (age of stock plants) (Varieties Red Gayety and White Pikes Peak Standard growing conditions)	60	6.73	14.90	1.00	5	.51	4.38	1,159
Size of cutting study (Variety White Pikes Peak Standard growing conditions)	20	7.34	14.89	1.09	5	.57	4.28	1,302

[1] Refer to footnote 2 of Table 25.

effect on the performance of the crop, no matter what size of cutting was initially planted; however, when considering any single planting date, the effect of initial cutting size was still apparent. Cuttings from young stock plants consistently outproduced those from old stock plants, even when the two groups were of equal sizes. When all performance measurements are considered, it is concluded that cuttings weighing 10 to 15 grams and having 6 to 8 pairs of expanded leaves performed significantly better than smaller cuttings. Cuttings grown from stock plants that were given high carbon dioxide and nutritional levels, and an average temperature of 72.5°F., outperformed those which received standard cultural methods (Table 26).

Part III C - Proposed grading system for cuttings

The following recommendations are advocated for the maximum performance of cuttings:

1. Grow stock plants at 65 to 70°F. If possible, increase atmospheric carbon dioxide levels to 500 to 600 ppm, and apply nutrients at 1.5 times the standard rate used for flowering plants.

2. Take cuttings that weigh no less than 10 grams each and contain 6 pairs of expanded leaves.

3. At certain times of the year (summer and winter months), when cuttings containing 6 leaf-pairs do not weigh at least 10 grams, take cuttings that contain 7 and 8 pairs of leaves.

A combination of fresh weight and number of expanded leaf-pairs is indicated as the best criteria on which to base a grading system for carnation cuttings.

Chapter V

DISCUSSION AND CONCLUSIONS

Preharvest Environment of Cuttings

The effects of environmental conditions on stock plants were demonstrated by the size and quality of cuttings produced. The effects of temperature appeared to be great; however, a portion of these effects could have been attributed to water stress in the 2 highest temperatures (75 and 80°F.). As was pointed out in Chapter III, plants in all treatments were watered on the same days; thus, due to evaporation and transpiration, plants grown at high temperatures lost more water in a given period of time. No method was devised to determine moisture stress, but since plants showed no signs of wilting it was decided that adequate moisture was provided.

Probably respiration played a dominant role in the growth of stock plants at different temperatures. Temperatures of 65 and 70°F. produced larger cuttings of higher quality, as measured by dry weight, indicating that at the 2 lower temperatures more photosynthates were stored in cuttings due to decreased respiration rates. The optimum day temperatures for carnations grown for flower production in Colorado have been established to be about 65°F. (13); this was verified in the present study with stock plants. As temperature increased the extent of axillary shoot growth of cuttings decreased, again indicating more growth at lower temperatures.

At any given temperature, seasonal solar energy was of major importance in the growth of stock plants. As light increased, per cent dry matter increased and fresh or dry weight decreased, except for the first few weeks of production. In this initial period, plant load was at a minimum, allowing more stored photosynthate in the cuttings. As plant load and solar energy increased, size of cuttings decreased. Maximum plant load was reached approximately 6 months after planting (May, 1963). Size of cuttings decreased to a low in August, then increased with decreasing light intensity until October, 1963. A possible explanation for this phenomenon could be that as light increased above the range of 400 g cal/cm^2, leaf temperature and thus respiration were sufficiently greater than at lower light intensities, resulting in a reduction in size of cuttings. The reduction of internode length of carnation flowers due to high light intensities has been reported by various workers (13,16,20). A reduction of leaf width of carnation in July was reported by Manring (22). The general reduction in plant size reported by other workers is possibly due to reduced cell elongation throughout tissues of the plant, which could account for the noticeable effects of light intensity in the present study. Reduction in cell size due to high light intensity would logically mean a higher ratio of cell wall components (cellulose and lignins) to aqueous materials, thus resulting in smaller cuttings containing a higher percentage of dry matter. High night temperatures in the summer could also have contributed to increased respiration rates.

Postharvest Performance of Cuttings

The results of performance tests of cuttings grown on stock plants in controlled environments and later planted in flowering trials indicate that the amount of either fresh or dry weight of cuttings determines the speed, quality, and quantity of first-crop flower production. In general as size of cuttings increased, speed and quantity of first-crop production increased. The increase in number of flowers and buds produced in the first crop is directly related to the advanced rate of axillary shoot development of cuttings at planting time. Higher production appeared to occur at the sacrifice of quality, as mean grade of cut flowers was inversely related to cutting size. These opposing factors are difficult to evaluate unless economic factors are considered. The writer feels at this point that the slight reduction in mean grade (1.9 per cent) does not compensate for the increase in first-crop flower production (5.2 per cent) and the decrease in production time (4.1 per cent) of cuttings produced at 65°F. when compared to those produced at 80°F. Within the confines of this study, it is concluded that stock plants grown at 65 or 70°F. produce higher-quality and larger-sized cuttings which perform significantly better than those grown at 75 and 80°F.

Effects of Stock Plant Age

It is difficult to accurately relate plant age to its effects on growth. Plants, as opposed to higher animals, have the ability to rejuvenate tissues from residual meristems, almost regardless of their chronologic age. Most writers feel that physiological age of plants, caused by environmental conditions, is the only appropriate way to describe juvenility or senility (29). Aside from morphological considerations, plants perform differently with the onset of age. In general, residual tissues of older plants do not resume active growth as rapidly as juvenile tissues (10,29,32). These findings were verified in both experiments of the present study. When cuttings were sized equally by the number of expanded leaves, highly significant increases were found in speed, quantity, and quality of first-crop flower production of cuttings from juvenile plants. Some of these effects were due to the greater size of cuttings from juvenile stock plants; however, when initial fresh weights were equal in the two groups of cuttings of the second experiment, dry weight of cuttings from old stock plants was 8.5 per cent higher and first-crop flower production was 23.4 per cent lower than that of juvenile cuttings. Furthermore, a decrease in quality of cut flowers was observed with cuttings from old stock plants.

It is concluded that the main effects of juvenility in this study were (1) the presence of a greater number of axillary shoots contained by cuttings at planting time and (2) faster rates of development of these shoots.

It is well to note that, even though a difference of 12 months existed between young and old stock plants, the large differences in performance of cuttings were due partly to plant load. Old stock plants had a considerably larger number of shoots than young stock plants, resulting in reduced size and higher dry weight in cuttings of the former. Had the old stock plants been removed of cuttings so that the same number of cuttings was contained by plants of both groups, the large differences in performance might not have occurred.

In view of the opposing considerations, one must make a compromise between plant load and size of cuttings. It is not possible to consistently take large cuttings from heavily-loaded stock plants.

Effect of Cutting Size on Performance

As was observed in the previous two studies, cutting size was directly related to performance after planting in producing benches. It was observed in the second experiment that cuttings containing 4 leaf-pairs produced more vegetative shoots after the pinch, but in a much longer period of time than larger cuttings. The fact that small cuttings were more juvenile did not compensate for the increased fresh or dry weight contained by larger cuttings. Performance increased greatly as cuttings increased in size from 4 through 6 pairs of leaves, and increases thereafter were small. It is concluded that, when all practical and commercial aspects are considered, cuttings containing 6 leaf-pairs and weighing at least 10 grams provide the most desirable results in the producing bench. A cutting of this size is at a stage where the apical meristem is transforming from the vegetative to the reproductive stage, and growth from lateral meristems is increasing at a rapid rate.

Plants Grown Under High Carbon Dioxide Versus Check Plants

Table 26 shows the performance of cuttings grown from stock plants receiving high levels of carbon dioxide and nutrition, when compared to those grown from stock plants receiving standard environmental conditions. From all other work in this paper, it has been shown that fresh or dry weight per cutting is indicative of performance of cuttings. However, when comparing high carbon dioxide and nutrient treatments to "checks," it is apparent that higher performance occurred with the former, even though it contained lower fresh or dry weight per cutting than the check. It is possible that energy factors other than components of dry weight contributed to the higher production observed with cuttings produced under high carbon dioxide and nutrition.

Goldsberry (12) reported higher production of cuttings from stock plants receiving high levels of carbon dioxide, but no significant differences in the subsequent performance of cuttings. In this particular study, increased nutritional levels were not applied, probably resulting in a limiting factor accounting for the lack of differences in growth of cuttings.

The writer feels that increasing stock-plant nutrient levels to 1.5 to 2.0 times the standard feeding rate, and increasing carbon dioxide at least to the level applied in this study (525 ppm) will significantly increase yield of first-crop flowers produced from the derived cuttings. Additional increases in both carbon dioxide and nutrients could possibly produce even greater results than reported in this paper.

Suggestions for Further Study

1. An experiment should be designed to determine differences in: (1) growth of stock plants, when given high nutrition and carbon dioxide, under glass and plastic coverings, (2) rooting of

cuttings under glass and plastic, and (3) the growth of cuttings taken from combinations of the former two treatments, under glass and plastic.

2. Work should be done to determine the chemical composition of cuttings grown from stock plants receiving high levels of carbon dioxide. In the work reported here, any measurements of fresh weight, dry weight, or per cent dry matter were not reliable means to compare performance of cuttings taken from stock plants grown in carbon dioxide versus standard environments.

Chapter VI

SUMMARY

Three major experiments concerning carnation stock plants were designed to determine the highest possible quality of cuttings measured by their performance in terms of the speed, quantity, and quality of first-crop flower production.

Experiment I

Pink Mamie stock plants were grown in 4 environmental control chambers set at temperatures of 65, 70, 75 and 80°F., each containing 3 levels of nutrition (1.5, 2.0, and 2.5 times the standard feeding rate). All chambers were given approximately 525 ppm carbon dioxide. A check was included for comparison.

Nutrition produced no significant differences in stock plant growth or subsequent performance of cuttings. Each decrease in temperature produced an increase in total fresh weight of cuttings, fresh weight per cutting, and dry weight per cutting, while the opposite trend was noted for per cent dry matter. Yield of cuttings was approximately the same for 65, 70 and 75°F., but a decrease was observed at 80. As plants aged and solar energy increased, the size of cuttings decreased in any given temperature.

Cuttings taken from stocks grown at 65 and 70°F. produced more first-crop flowers in a shorter period of time and more second crop potential than those grown at 75 and 80^{o}F. Mean grade was slightly higher for the latter two groups.

Experiment II

Two studies of stock-plant age were established. The first tested the growth of cuttings taken from stock plants 4 and 18 months of age, with cuttings sized equally by number of expanded leaves. The second tested the growth of cuttings from stock plants 7 and 21 months of age, when cuttings were sized equally by fresh weight.

Cuttings from young stock plants in the first study contained more shoots after pinching, grew faster after planting, produced more first-crop flowers of higher mean grade, and had more second-crop potential growth. When cuttings contained equal fresh weights, similar trends were observed as formerly, except second-crop potential was equal for both groups. The differences in the first study were due primarily to higher fresh weight contained by cuttings from young stock plants. Differences in the second study were largely due to stock-plant age, with effects occurring in the period terminated by the first crop of flowers.

Experiment III

The growth of cuttings containing 4, 5, 6, 7, and 8 leaf-pairs was determined, along with the effects of 2 weight groups within each leaf-pair category. In one study, plants were pinched to allow growth of all possible vegetative shoots, and spaced 6 x 8 inches. In a second study, the above pinching treatment was compared to the method of pinching plants to 5 vegetative shoots and spacing plants 6 x 6 inches.

As cutting size increased from 4 through 8 pairs of expanded leaves, less time was required for development of young plants and quality of first-crop flowers increased. In the first study higher production of cut flowers occurred in a shorter period of time as size of cuttings increased from 4 through 6 leaf-pairs and decreased slightly at 7 and 8. In the second study, first-crop production was higher with cuttings containing 4 leaf-pairs but longer time was required for flowering. Considering the sum of first-crop flowers and buds after harvest of both experiments, increases were observed as cutting size increased to 6 leaf-pairs, decreased at 7 and reached a high at 8. Within any leaf-pair category, heavy cuttings outperformed light cuttings. The largest difference in total cut flowers was 39.3 per cent, observed between light cuttings containing 4 leaf-pairs and heavy cuttings containing 5 leaf-pairs (original fresh weights of 4.67 and 8.63g respectively). Plants pinched to allow growth of all possible vegetative shoots slightly outperformed those pinched to 5 shoots.

In a separate experiment, cutting size was compared to the stage of development of the apical meristem. Cuttings containing 4 and 5 leaf-pairs were vegetative, those containing 6 leaf-pairs were in the transitional stage, and from 7 through 10 leaf-pairs, rapid development of floral organs occurred.

Considering data from all experiments, maximum all-around performance was achieved with cuttings containing at least 6 pairs of expanded leaves and weighing at least 10 grams. Stock plants receiving high levels of nutrition and carbon dioxide and grown at temperatures of 65 and 70°F. produced the highest quality and quantity of cuttings.

When per cent dry matter was relatively constant, the most accurate measurement of cutting quality was fresh weight. Either fresh weight or dry weight per cutting was more reliable than per cent dry matter in estimating performance of cuttings.

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A P P E N D I X

TABLE A.--EFFECTS OF TEMPERATURE AND NUTRITION ON PRODUCTION OF PINK MAMIE CARNATION STOCK PLANTS. DATA TAKEN FROM PART I, EXPERIMENT I.

Nutrient	Measurement[3]	TEMPERATURE (°F.) 65	70	75	80	Nutrient means
Low	Total fresh weight[1]	10,785.00	9,662.00	8,091.00	7,246.00	8,946.00
	Total number of cuttings[1]	1,330.00	1,287.00	1,239.00	1,145.00	1,250.00
	Average fresh weight/cutting[2]	9.84	8.81	7.67	7.01	8.33
	Average per cent dry matter[2]	13.95	14.22	15.14	15.85	14.79
	Average dry weight/cutting[2]	1.34	1.21	1.11	1.08	1.19
Medium	Total fresh weight	10,981.00	10,120.00	9,051.00	7,248.00	9,350.00
	Total number of cuttings	1,308.00	1,349.00	1,333.00	1,193.00	1,296.00
	Average fresh weight/cutting	9.49	8.51	7.45	6.71	8.04
	Average per cent dry matter	13.69	14.22	15.34	16.01	14.82
	Average dry weight/cutting	1.25	1.20	1.11	1.04	1.15
High	Total fresh weight	10,714.00	9,974.00	8,984.00	7,584.00	9.314.00
	Total number of cuttings	1,310.00	1,334.00	1,402.00	1,237.00	1,321.00
	Average fresh weight/cutting	9.56	8.58	7.40	6.95	8.12
	Average per cent dry matter	13.78	14.69	15.35	15.61	14.86
	Average dry weight/cutting	1.27	1.22	1.11	1.03	1.16
	TEMPERATURE MEANS					
	Total fresh weight	10,827.00	9,919.00	8,709.00	7,359.00	-----
	Total number of cuttings	1,316.00	1,323.00	1,325.00	1,192.00	-----
	Average fresh weight/cutting	9.63	8.63	7.51	6.89	-----
	Average per cent dry matter	13.81	14.38	15.28	15.82	-----
	Average dry weight/cutting	1.29	1.21	1.11	1.05	-----

[1] Total production for the entire experiment.
[2] Mean values for 10 monthly samples.
[3] All fresh and dry weights are in grams.

TABLE B.—QUANTITY, QUALITY AND SPEED OF GROWTH FROM CUTTINGS OF DIFFERENT SIZES TAKEN FROM WHITE PIKES PEAK STOCK PLANTS AUGUST 30, 1963, AND PLANTED SEPTEMBER 21, 1963. DATA WAS TAKEN FROM PART I, EXPERIMENT III.[1]

Number of expanded leaves	Size of cutting at time of removal from stock plants 4		5		6		7		8	
Weight category[2]	L	H	L	H	L	H	L	H	L	H
Initial fresh weight of cuttings (grams)	4.67	5.60	6.04	8.63	9.19	11.38	10.17	12.87	12.29	14.58
Weeks from planting to pinching	7.7	6.7	6.3	6.0	6.0	4.7	5.7	3.8	4.7	4.5
Number of axillary shoots per plant after pinching	5.1	6.2	6.7	7.4	7.1	7.1	7.4	7.2	6.5	6.5
Number of first-crop flowers per plant	3.7	5.2	4.7	6.1	6.0	5.8	5.9	5.9	4.8	5.6
Mean grade of cut flowers	4.26	4.35	4.14	4.42	4.44	4.67	4.57	4.58	4.81	4.44
Days to midpoint of flower production	35.5	33.0	34.0	28.5	31.5	24.5	33.0	25.0	22.0	30.0
Fresh weight per plant after flowering period (grams)	162.0	184.0	173.0	210.0	207.0	232.0	190.0	215.0	217.0	211.0

[1] Each value represents a mean for 10 plants

[2] L = light cuttings
H = heavy cuttings

TABLE C.—QUANTITY, QUALITY AND SPEED OF GROWTH FROM CUTTINGS OF DIFFERENT SIZES TAKEN FROM WHITE PIKES PEAK STOCK PLANTS ON OCTOBER 2, 1963, AND PLANTED NOVEMBER 7, 1963. PART II, EXPERIMENT III.[1]

Number of expanded leaves	Size of cutting at time of removal from stock plants: 4		5		6		7		8	
Weight category[2]	L	H	L	H	L	H	L	H	L	H
Average weight per cutting (grams)	3.19	4.70	4.91	6.94	6.65	8.98	8.25	10.57	9.60	12.55
Weeks from planting to pinching	8.5	8.1	7.5	6.5	6.1	6.1	6.3	5.3	5.7	5.1
Number of axillary shoots per plant after pinching	6.35	6.76	6.31	6.38	5.83	6.55	6.23	6.10	5.96	6.38
Number of first-crop flowers and buds per plant[3]	5.76	6.85	6.52	6.40	6.42	6.50	6.05	6.67	6.71	6.60
Mean grade of cut flowers	4.11	4.19	4.22	4.20	4.20	4.26	4.27	4.27	4.25	4.35
Days to midpoint of flower production	43.3	40.6	40.1	37.0	37.6	37.9	39.2	37.2	36.1	34.9

[1] Each value is a mean of 42 plants

[2] L = light cuttings
H = heavy cuttings

[3] Flowers were cut weekly until June 7, 1963. Number of buds ¼" or greater were counted directly after flowers were cut.

TABLE D.--ANALYSIS OF VARIANCE OF PRODUCTION MEASUREMENTS OF PINK MAMIE STOCK PLANTS GROWN AT 4 TEMPERATURES, EACH CONTAINING 3 NUTRIENT LEVELS. PART I, EXPERIMENT I.

F 2,6 (05) = 5.14 (01) = 10.92 F 3,6 (05) = 4.76 (01) = 9.78

Sources of variance	d.f.	m.s.	f.
Total number of cuttings			
Temperature	3	12,654	7.750*
Nutrient level	2	5,111	3.130
Error	6	1,632	
Total fresh weight			
Temperature	3	6,791,951	10.240*
Nutrient level	2	199,968	3.010
Error	6	66,336	
Fresh weight per cutting			
Temperature	3	4.424	90.262**
Nutrient level	2	.091	1.856
Error	6	.049	
Per cent dry matter			
Temperature	3	2.439	51.312**
Nutrient level	2	.0047	< 1.000
Error	6	.0470	
Dry weight per cutting			
Temperature	3	.0032	47.285**
Nutrient level	2	.0009	1.286
Error	6	.0007	

TABLE E.--FLOWER PRODUCTION FROM CUTTINGS TAKEN FROM PINK MAMIE STOCK PLANTS GROWN AT 4 TEMPERATURES. DUNCAN S NEW MULTIPLE-RANGE TEST USED FOR ANALYSIS. PART II, EXPERIMENT I.

Flowering trial	Number of plants in average	Temperature (°F) 65	70	75	80	Least significant difference between highest and lowest mean at the 5% level
2	30	4.90	4.60	4.33	4.20	.73
Average of 1 and 2	60	4.73	4.48	4.37	4.22	.54

TABLE F.--ANALYSIS OF VARIANCE OF PERFORMANCE OF CUTTINGS TAKEN FROM STOCK PLANTS GROWN AT 4 TEMPERATURES, EACH CONTAINING 3 NUTRIENT LEVELS. PART II, EXPERIMENT I.

F (05) = 3.32   F (05) = 2.92   F (05) = 2.53
2,30 (01) = 5.39   3,30 (01) = 4.51   5,30 (01) = 3.70

Source of variances	d.f.	m.s.	f.
Number of shoots per plant after pinching			
Temperature	3	.790	7.383*
Nutrient level	2	.070	.654
Flowering trials	5	9.208	86.056**
Error	30	.107	
Total first-crop flower production per plant			
Temperature	3	.693	2.240
Nutrient level	2	.220	< 1.000
Flowering trials	5	5.372	17.390**
Error	30	.309	

TABLE F.—continued.

Source of variances	d.f.	m.s.	f.
Mean grade of cut flowers			
Temperature	3	.033	4.120*
Nutrient level	2	.010	1.250
Flowering trials	5	2.164	270.500**
Error	30	.008	
Number of days to the midpoint of crop			
Temperature	3	14.350	1.288
Nutrient level	2	6.350	$<$ 1.000
Flowering trials	5	612.980	55.025**
Error	30	11.140	
Number of cut flowers plus buds per plant after harvest period			
Temperature	3	1.426	1.410
Nutrient level	2	1.630	1.630
Flowering trials	5	27.658	27.350**
Error	30	1.011	
Number of buds counted on residual plants			
Temperature	3	.750	1.388
Nutrient level	2	1.305	2.414
Flowering trials	5	22.675	41.949**
Error	30	.541	
Number of axillary shoots per residual plant			
Temperature	3	11.273	6.294**
Nutrient level	2	1.815	1.013
Flowering trials	5	49.440	27.605**
Error	30	1.791	

TABLE F.--continued.

Source of variances	d.f.	m.s.	f.
Fresh weight per residual plant			
Temperature	3	3,344.970	2.761
Nutrient level	2	1,531.600	1.264
Flowering trials	5	47,625.280	39.310**
Error	30	1,211.540	

TABLE G.--ANALYSIS OF VARIANCE OF PERFORMANCE OF CARNATION CUTTINGS TAKEN FROM 3 CLONES EACH OF RED GAYETY AND WHITE PIKES PEAK STOCK PLANTS 4 AND 18 MONTHS OF AGE. PART I, EXPERIMENT II.

$F_{1,5}$ (05) = 6.61 (01) = 16.26 $F_{5,5}$ (05) = 5.05 (01) = 10.97

Source of variances	d.f.	m.s.	f.
Number of shoots per plant after pinching			
Stock plant age	1	0.040	0.244
Varieties	5	0.266	1.622
Error	5	0.164	
Total first-crop flower production per plant			
Stock plant age	1	5.600	23.530**
Varieties	5	0.190	< 1.000
Error	5	0.238	
Mean grade of cut flowers			
Stock plant age	1	0.148	1.339
Varieties	5	0.040	0.356
Error	5	0.900	

TABLE G.—continued

Source of variances	d.f.	m.s.	f.
Number of days to midpoint of crop			
Stock plant age	1	793.510	48.771**
Varieties	5	59.500	3.657
Error	5	16.270	
Number of cut flowers plus buds per plant after harvest period			
Stock plant age	1	77.400	47.369**
Varieties	5	8.872	5.430*
Error	5	1.634	
Number of buds counted on residual plants			
Stock plant age	1	41.1082	64.390**
Varieties	5	8.003	12.540*
Error	5	0.638	
Number of axillary shoots per residual plant			
Stock plant age	1	81.401	7.160*
Varieties	5	7.594	< 1.000
Error	5	11.361	
Fresh weight per residual plant			
Stock plant age	1	84.158.730	59.300**
Varieties	5	9.377.250	6.610*
Error	5	1.419.170	

TABLE H.—ANALYSIS OF VARIANCE OF PERFORMANCE OF WHITE PIKES PEAK CUTTINGS TAKEN FROM STOCK PLANTS AT DIFFERENT NUMBERS OF EXPANDED LEAVES, EACH LEAF-PAIR CATEGORY BEING DIVIDED INTO TWO GROUPS ACCORDING TO FRESH WEIGHT. PART I, EXPERIMENT III.

$F_{1,4}$ (05) = 7.71 $F_{4,4}$ (05) = 6.39
(01) = 21.20 (01) = 15.98

TABLE H.--continued.

Source of variances	d.f.	m.s.	f.
Number of shoots per plant after pinching			
Fresh weight	1	0.578	4.551
Leaf pairs	4	1.727	13.598*
Error	4	0.127	
Total first-crop flower production per plant			
Fresh weight	1	2.450	20.082*
Leaf pairs	4	1.438	11.787*
Error	4	0.122	
Mean grade of cut flowers			
Fresh weight	1	0.013	2.741
Leaf pairs	4	0.105	22.982**
Error	4	0.005	
Number of days to midpoint of crop			
Fresh weight	1	84.050	1.268
Leaf pairs	4	18.050	< 1.000
Error	4	66.295	
Number of cut flowers plus buds per plant after harvest period			
Fresh weight	1	1.922	1.820
Leaf pairs	4	2.083	1.970
Error	4	1.057	
Number of buds counted on residual plants			
Fresh weight	1	0.003	< 1.000
Leaf pairs	4	0.092	< 1.000
Error	4	0.126	

TABLE H.--contined.

Source of variances	d.f.	m.s.	f.
Number of axillary shoots per residual plant			
Fresh weight	1	7.940	1.722
Leaf pairs	4	2.353	< 1.000
Error	4	4.610	
Fresh weight per residual plant			
Fresh weight	1	8,694.770	1.255
Leaf pairs	4	5,503.080	< 1.000
Error	4	6,926.460	

TABLE I.--ANALYSIS OF VARIANCE OF PERFORMANCE OF WHITE PIKES PEAK CUTTINGS TAKEN FROM STOCK PLANTS AT DIFFERENT NUMBERS OF EXPANDED LEAVES, EACH LEAF-PAIR CATEGORY BEING DIVIDED ACCORDING TO FRESH WEIGHT. PART II, EXPERIMENT III.

	F 1,8	(05) = 5.32 (01) = 11.26	F 4,8	(05) = 3.84 (01) = 7.01
Pinching treatments	F 1,4	(05) = 7.71 (01) = 21.20	F 4,4	(05) = 6.39 (01) = 15.98

Source of variances	d.f.	m.s.	f.
Plants pinched to 5 shoots			
Weeks from planting to pinching			
Fresh weight	1	0.670	4.757
Leaf pairs	4	2.600	18.460**
Error	4	0.240	

TABLE I.—continued.

Source of variances	d.f.	m.s.	f.
Plants pinched to allow growth of all possible shoots			
Weeks from planting to pinching			
Fresh weight	1	1.682	46.960**
Leaf pairs	4	3.849	20.520**
Error	4	0.082	
Number of shoots per plant after pinching			
Fresh weight	1	1.320	13.122**
Leaf pairs	4	0.341	3.391
Pinching method	1	74.151	737.170**
Error	8	0.101	
Total first-crop flower production per plant			
Fresh weight	1	0.197	< 1.000
Leaf pairs	4	0.186	< 1.000
Pinching method	1	4.117	16.969**
Error	8	0.243	
Mean grade of cut flowers			
Fresh weight	1	0.034	1.439
Leaf pairs	4	0.039	1.662
Pinching method	1	0.025	1.063
Error	8	0.024	
Number of days to midpoint of crop			
Fresh weight	1	36.817	5.707*
Leaf pairs	4	64.406	9.984**
Pinching method	1	120.417	18.667**
Error	8	6.451	

TABLE I.—continued.

Source of variances	d.f.	m.s.	f.
Number of cut flowers plus buds per plant after harvest period			
Fresh weight	1	1.485	2.258
Leaf pairs	4	0.226	< 1.000
Pinching method	1	2.696	4.099
Error	8	0.658	
Number of buds counted on residual plants			
Fresh weight	1	0.216	< 1.000
Leaf pairs	4	0.959	< 1.704
Pinching method	1	1.014	1.802
Error	1	0.563	

A B S T R A C T

O F

T H E S I S

Abstract of Thesis

ENVIRONMENTAL FACTORS AFFECTING GROWTH OF CARNATION STOCK PLANTS AND CUTTINGS

Three major experiments concerning carnation stock plants were designed to determine the highest possible quality of cuttings measured by their performance in terms of the speed, quantity, and quality of first-crop flower production.

In experiment I, Pink Mamie stock plants were grown in 4 environmental control chambers set at temperatures of 65, 70, 75, and 80^{o}F, each containing 3 levels of nutrition (1.5, 2.0, and 2.5 times the standard feeding rate). All chambers received approximately 525 ppm CO_2.

Nutrition produced no significant differences in stock plant growth or subsequent performance of cuttings. Each decrease in temperature produced an increase in total fresh weight of cuttings, fresh weight per cutting, and dry weight per cutting, while the opposite trend was noted for per cent dry matter. Yield of cuttings was approximately the same for 65, 70, and 75^{o}F, but a decrease was observed at 80. As plants aged and solar energy increased, the size of cuttings decreased in any given temperature.

Cuttings taken from stocks grown at 65 and 70^{o}F produced more first-crop flowers in a shorter period of time and more second-crop potential than those grown at 75 and 80^{o}F. Mean grade was slightly higher for the latter two temperatures.

In the second experiment, two studies of stock-plant age were established. The first tested the growth of cuttings taken from stock plants 4 and 18 months of age, with cuttings sized equally by number of

expanded leaves. The second tested the growth of cuttings from stock plants 7 and 21 months of age, when cuttings were sized equally by fresh weight.

Cuttings from young stock plants in the first study contained more shoots after pinching, grew faster after planting, produced more first-crop flowers of higher mean grade, and had more second-crop potential growth. When cuttings contained equal fresh weights, similar trends were observed as formerly, except second-crop potential was equal for both age groups.

In experiment III, the growth of cuttings containing 4, 5, 6, 7, and 8 leaf-pairs was determined, along with the effects of 2 weight groups within each leaf-pair category.

As cutting size increased from 4 through 8 pairs of expanded leaves, less time was required for development of young plants and quality of first-crop flowers increased. Considering the sum of first-crop flowers and buds after harvest, increases were observed as cutting size increased to 6 leaf-pairs, decreased at 7 and reached a high at 8.

Generalizations from the entire study are as follows: (1) stocks receiving high levels of nutrition and carbon dioxide, along with cool temperatures, produced the highest quality and quantity of cuttings, (2) the most accurate measurement of cutting quality was fresh weight, and (3) maximum all-around performance was achieved with cuttings containing at least 6 pairs of expanded leaves and weighing at least 10 grams.

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August, 1964

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