1-1-1981

The relationships between vegetative and reproductive growth in pepper.

William Montgomery Clapham
University of Massachusetts Amherst

Recommended Citation

Clapham, William Montgomery, "The relationships between vegetative and reproductive growth in pepper." (1981). *Doctoral Dissertations 1896 - February 2014*. 5990.
https://scholarworks.umass.edu/dissertations_1/5990

The Relationships between Vegetative and Reproductive Growth in Pepper

A Dissertation Presented

By

William Montgomery Clapham

Submitted to the Graduate School of the
University of Massachusetts in partial fulfillment
of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 1981

Department of Plant and Soil Science

Supported by the
Massachusetts Agricultural Experiment Station

The Relationships between Vegetative and Reproductive Growth in Pepper

A Dissertation Presented

By

William Montgomery Clapham

Approved as to style and content by:

Herbert V. Marsh, Jr.

Herbert V. Marsh, Chairperson of Committee

William Bramlage

William J. Bramlage, Member

R A Damon Jr.

R. A. Damon, Jr., Member

Paul H Jennings

Paul H. Jennings, Member

James A Lockhart

James A. Lockhart, Member

Allen V Barker

Allen V. Barker, Department Head
Department of Plant and Soil Science

ACKNOWLEDGMENTS

I wish to express my sincere appreciation to Dr. Herbert V. Marsh for his guidance and assistance, and who from the beginning encouraged my graduate study. My debt extends to Drs. Paul H. Jennings and James A. Lockhart who served on my dissertation committee, and whose help was indispensible in this project.

Special appreciation is given to Dr. William J. Bramlage for his careful scrutiny in the preparation of this manuscript and for his priceless advice.

I am also grateful to Dr. R. A. Damon Jr. for his assistance with the statistical analysis and for the many hours of enjoyable conversation.

In addition I would like to extend my thanks to Stephanie Digby, John Begg, Paul Syphers, and Stanley Kopinto for their technical assistance.

DEDICATION

I would like to dedicate this dissertation to David W. Bierhorst who set the example, and to Otto L. Stein who showed me the way.

TABLE OF CONTENTS

Chapter

....

LIST OF TABLES

ILLUSTRATIONS

LIST OF APPENDICES

Appendix

ABSTRACT

The Relationships
between Vegetative and Reproductive Growth
in Pepper

May 1981

William M. Clapham, B.A., Illinois Wesleyan University
Ph.D., University of Massachusetts
Directed by: Professor Herbert V. Marsh

Fruit yields, root dry weights, total plant dry weights of two cultivars of bell peppers (*Capsicum annuum* L., cvs. Keystone Resistant Giant and Ladybell) increased linearly as a consequence of extending the duration of vegetative growth by defloration. The dry weight fractions of fruit/total increased and root/total remained the same, whereas shoot/total and leaf/total decreased.

The responses to three container volumes (31, 66 and 147 cm^3) and three seeding dates (3/30, 4/10, 4/20) were evaluated with these cultivars. Seedling root and shoot masses decreased with later seeding dates and increased with larger container volumes. The number of days from seeding to opening of the first flower decreased with later seeding dates in container volumes of 31 and 66 cm^3, but were the same in the 147 cm^3 container. The number of days from transplanting to the opening of the first flower increased with later seeding dates and smaller container volumes and was least with the 3/30 seeding date and the 147 cm^3 container. Early yields were maximum with the 147 cm^3 container. Residual effects of container volume and seeding date disappeared in the later harvests.

The effects of different mulch treatments were compared to a bare soil control. Clear plastic resulted in the highest soil temperatures followed by black plastic, the bare soil control, and finally aluminum-coated kraft paper. The warmest soils produced greater vegetative and reproductive growth. More of the total plant dry weight was partitioned into fruit with warmer soil temperatures.

Treatments which resulted in increased vegetative growth also resulted in increased fruit production. Larger plants were produced, and more of the total dry weight was partitioned to fruit.

CHAPTER I

Introduction

The problem of variable yields in bell peppers (_Capsicum annuum_, L.) is interesting and important to horticulturists and vegetable growers. Market prices make this crop an attractive vegetable to produce. However, production costs are relatively high for this crop, consequently yield variability can reduce profit margins significantly.

Following germination of the seed, the pepper plant grows vegetatively for a predetermined number of nodes depending upon the cultivar. The shoot then terminates in a flower, and two subtending axillary buds subsequently "break" and grow, also terminating in flowers. The plant continues this sympodial fashion of growth for the rest of its life, producing a leaf, a flower, and two axillary branches at each node. The number of flowers produced by this pattern during the season can be described by the equation: number of potential flowers = (2^n-1), where n = the number of flowering nodes. Axillary buds of nodes prior to the first flowering node "break" later in the season and also produce flowers in the same sympodial fashion. Even though several hundred potential flowering sites are produced during a season, good fruit set is regarded to be between ten and twenty peppers per plant per season, a fraction of the total number of flowers.

Reduction of fruit set due to flower bud abscission can be attributed to two basic phenomena:

1. Abscission of flowers once they have reached anthesis, due presumably to problems encountered in pollination or fertilization of the flowers.
2. Abscission of flowers prior to anthesis.

A preliminary greenhouse study of the first four flowering nodes of Keystone Resistant Giant showed that while the first floral node set fruit, all flowers of the three subsequent flowering nodes abscised. The flowers of the second node abscised following anthesis, whereas the flowers of the third and fourth nodes abscised prior to anthesis. This suggested that yield reductions due to flower abscission were due to preanthesis abscissions and not related to pollination and fertilization problems.

Hall (28) compared the differences between vegetative growth rates in fruiting and deflorated plants. Vegetative growth rates, particularly those of the stem and roots, were inhibited by a developing fruit. However, leaf growth rates and total plant growth rates were roughly the same in fruiting and deflorated plants. In addition, flower bud growth rates were severely inhibited by a developing fruit. When fruit matured and their absolute growth rates approached zero, vegetative growth rates of the stem and roots increased sharply, as did the growth rates of flower buds (28).

Hall's work suggests a pattern of cycling between vegetative and fruit growth rates. However, the distinction between vegetative, floral and fruiting growth rates is only relative because vegetative growth rates are not zero during the maximum growth rate of a developing fruit. The hypothesis formulated from this cycling nature of pepper plant growth was that the duration and/or amplitude of the fruit growth rates is a function of the duration and/or amplitude of prior vegetative growth.

Since peppers are grown exclusively from transplants in commercial plantings in New England, the growth of the pepper plant for commercial production can be arbitrarily divided into three periods:

Stages of Development	Site
1. Germination of Seed to Vegetative Transplant	Greenhouse
2. Vegetative Transplant to Flowering Transplant	Field
3. Flowering Transplant to Fruiting Plant	Field

The present investigation was conducted with the following objectives:

1. To quantify the relationship between vegetative growth and the ability to set fruit by generating different vegetative masses:
    1. during stage 1 by generating an array of seedlings through the manipulation of seeding date and container size;
    2. during stage 2 directly by manipulating duration of vegetative growth;
    3. during stage 3, indirectly by providing the plants with different root environments using mulches which resulted in differential root growth.
2. To quantify the effects of early reproductive growth on subsequent vegetative and reproductive growth.
3. To examine partitioning of dry matter within the pepper plant as a function of defloration.

CHAPTER II

Review of Literature

Studies of blossom drop have been made on many different fruit-bearing crops. Floral abscission with resulting decreased yields has been recognized as a general phenomenon and has been attributed primarily to a variety of genetic, environmental, or pathological factors (16). The effects of temperature on fruit set and growth have been well studied in the pepper (15,16,17). In a greenhouse study Cochran found the greatest growth with conditions of high soil moisture, very high soil fertility and temperatures of 21 C - 27 C. Fruit setting was also maximum under these conditions (16). Another study showed that more pepper flowers were produced at a night temperature of 12 C than at 18 C (24). Dorland and Went (25) showed that as chili plants got older, vegetative growth increased with decreasing night temperatures. In general these studies suggest that the greatest vegetative growth and maximum fruit set are under conditions which favor maximum net CO_2 assimilation.

Flower abscission can occur following anthesis as a result of either poor pollination or failure of syngamy. Due to these problems, poor fruit set is most common in cross pollinated crops which either rely on some pollen vector and/or have a high degree of self-incompatibility. This is generally not the case in the

Solanaceae as they are self-pollinating. Morphological factors such as abnormal elongation of tomato styles, due to high temperatures, can reduce the probability of pollination (72,73). However, extreme temperature conditions can decrease the viability of pollen grains. Tomato fruit set is not reduced by low temperatures (50 F) during or after pollination, though fruit set is reduced when low temperatures occur during microsporogenesis (12,68). Apple pollen can withstand much lower temperatures than pistils without injury. In fact, pollen from blossoms in which the pistils have been killed by moderately low temperatures will still germinate given a suitable medium (3). Auchter concluded that the source of developing apple pollen greatly influences pollination results (3).

Although environmental extremes can hinder pollination or fertilization in many crops, preanthesis abscissions are responsible for low yields in others. The majority of floral abscissions in tomatoes occur while the blossoms are immature (63). Cochran noted the same phenomenon in peppers (16). Developmental studies in tomato have shown that microsporogenesis is the most sensitive floral stage. Howlett showed that microsporogenesis in tomatoes was very sensitive to carbohydrate deficiencies (33). In tomatoes pollen from the same plant can differ greatly in viability between winter and summer, and variation in pollen viability is presumably due to differences in light intensities and duration (56).

Several studies have shown that soil temperatures affect plant growth and development (66,89). Optimum soil temperature for normal pepper seedling growth is 17 C, and temperatures less than 10 C or greater than 30 C can retard growth (66). Phosphorus deficiencies have been associated with low soil temperatures (44). Phosphorus deficiences during the early growth of Epilobium montana resulted in decreased total yields, despite the addition of phosphorus in attempts to correct this deficiency (2). The same response has been demonstrated in barley (9). The influence of phosphorus nutrition on growth is dependent to some extent upon soil temperature (44). Starter solutions provide high concentrations of soluble phosphorus to seedlings and increase early yields of peppers (41) and tomatoes (6).

Soil temperatures are commonly raised with various mulches, particularly black and clear plastic mulches (18,32,39,48,60,77). Accompanying increased soil temperatures are increased vegetative growth, early yield and total fruit yield. Warm season crops benefit most from mulches which raise the soil temperature. This has been shown in pepper (66), cantaloup (14,27,48,83), tomato, summer squash (83), and bean (18). On the other hand, cool season crops such as cabbage or beet show decreased yields under plastic mulches (83). In addition to increased soil temperatures, plastic mulches increase the retention of soil moisture in comparison to unmulched controls (30,32,45,83,86). Thompson and Platenius (83) showed that mulched soils had higher levels of nitrate and concluded that increased nitrification was a result of higher soil temperatures and moisture levels.

The effects of the general nutrition on growth and fruiting in peppers have been well documented (39,52,54,55,69,70,82) and therefore will not be discussed in this text. However, the effects of nitrogen on carbohydrates and growth are germain to this discussion. Differential growth due to nitrogen nutrition was shown in irrigated cotton, with the suppression of root growth correlated with carbohydrate deficiency presumably caused by stimulated shoot growth (21). The inverse relationship between nitrogen nutrition and carbohydrates was also shown by Wadleigh in cotton (85) and by Nightingale, _et al_. in tomato (59). Kraus and Kraybill (40), cited by Singh (69), postulated that high nitrogen levels altered the carbohydrate/nitrogen balance within the tomato plant and had dire effects on fruit set. Carbohydrate deficiency has been related to problems in microsporogenesis in tomato (33). Rosa reported that soils rich in nitrogenous matter resulted in excessive blossom drop in tomato; the same response was observed when the water table (due to subirrigation) was too high. High nitrogen has been shown to surpress root growth, and a high water table also might have restricted root growth (64). Deflorated pepper plants contained more total non-structural carbohydrates in the stem than did an intact control. This condition was also associated with increased secondary development in the stem below the fruit site (29).

The effect of developing fruit on subsequent growth, flowering, and yields has been studied in many crops. There was much research activity in this area during the 1920's with the problem of biennial bearing in apples. Crow suggested that during the "off year", vegetative growth could be stimulated by either "heading off" the small branches or with the application of nitrate of soda (20). Mack showed that there was a relationship between spur vigor, number of spurs and bearing habit (50). Other approaches involved deblossoming trees or pruning. Flower buds in biennial trees were sometimes killed with an iron sulfate spray (26). This cycling pattern of fruit production has also been observed in vegetable crops and small fruit crops.

Vegetative inhibition in vegetables by developing fruit is a well-recognized phenomenon (43,57). The inhibitory effect of a fruit upon vegetative growth has been shown in cucumber (53), cantaloup (65), watermelon (24), tomato (58), pepper (16), okra (62), and grape (11). Inhibition by a developing fruit is generally accepted to be the result of the production of growth regulators which inhibit vegetative growth (49) and/or by photosynthate sink demand (28,51). Abscisic acid has been implicated in the abortion of younger fruit by its production in older fruit in Phaseolus vulgaris (78). In tomato the greatest effect of fruits on vegetative growth is reduction of root growth (34). Hall showed the same relationship in a study comparing fruiting and deflorated pepper plants (28).

Murneek observed exceptionally large numbers of root primordia initiated in the basal region of new growth as a result of tomato fruit removal (58). Singh (69) cited Taranovsky (79) as having observed that when fruits and seeds were not permitted to develop on the plant, there was:

1. increased development of all vegetative parts, including roots;
2. increased osmotic pressure of the cell sap;
3. increased CO_2 accumulation;
4. increased absorption of minerals;
5. higher production of dry matter; and
6. better utilization of the environment.

Deflorated McIntosh apple trees showed a 35% increase in leaf area of apple spurs in the early season, though following six weeks later, increases were smaller (76,80). Thies (81) suggested that if apple trees blossom heavily, there is failure to store sufficiently high carbohydrate reserves to insure a set of flower buds for the next year. Fruit thinning increased the accumulation of certain carbohydrates, formation of flower buds and the percent flowers set in apple trees (1). Removal of flower buds in biennial flowering apple trees increased the annual bearing habit (5). The sugar prune, which also bears biennially, could be forced out of phase by defloration; however, heavy set was always followed by a "barren" year (23).

Similar responses have been observed in vegetable crops. Removal of developing fruit increased the number of fruit set on cantaloup (7) and tomato plants (84). Slack and Calvert (71) also observed increases in the mean weights of individual tomato fruit. The pattern and magnitude of fruiting in indeterminate tomato was influenced by the size of the vegetative organs at fruiting, and conversely, further vegetative and reproductive growth was influenced by a developing fruit. The same response was observed in bell peppers by Singh and Nettles (70). Murneek (57) pointed out that the "morphological expression of a plant is determined not only by its genetic constitution and the nature and intensity of environmental factors, but likewise by the effects of correlation of its organs."

Removal of flowers or pods in soybean led to reduced dry matter accumulation but increased leaf area and delayed senescence of the plant. These differences became more pronounced with increased duration of removal (80). Hicks, et al. (31), showed that when 1/3 of all flowers were removed, seed weight increased such that yields did not decrease. When 2/3 of the flowers were removed, seed weight increases were not great enough to prevent yield decreases. Deflorated soybeans accumulated more carbohydrates than non-deforated plants (4). A delay in senescence was also observed in pigeonpeas as a result of defloration. Thus, it seems that defloration will increase fruit yields in perennial crops, whereas in annuals (often photoperiodic) yield increases will be realized as long as seed increases can compensate for pod loss. Defloration results in an increase in vegetative material prior to reproductive growth.

The relationship between vegetative growth and subsequent fruit yields can be observed in studies of the effects of hardening on early yields. Hardening is a cultural practice which slows or checks growth in seedlings. A result of this practice is believed to be increased resistance to chilling injury by sensitive plants (87). Hardening of tomato plants appears to affect differentiation and maturation of stem tissue (19). Hardening is achieved by withholding nutrients and/or water and by providing cold treatments (47). Once hardened, the process cannot be reversed with the application of nutrient salts prior to setting the plants out (19). Early yields are reduced in hardened as compared with "tender" or unhardened seedlings (8).

It is very possible that seedlings may be inadvertently hardened by the early seeding of tomato plants in small containers. It has been reported that early seeding can result in lower early yields than from plants seeded later (13,67). Container sizes which are large enough not to constrict growth also result in greater early yields (10,39,41,46,61). The larger containers result in larger seedlings. Thus, increased vegetative growth was followed by increased early reproductive growth. However, these same authors report no increase in total yields.

CHAPTER III

Materials and Methods

For all experiments Keystone Resistant Giant and/or Ladybell were grown. Keystone Resistant Giant is an open-pollinated pureline which produces high quality fruit tending to be four-lobed, thick-fleshed, and blocky. Ladybell is an F_1 hybrid which is currently widely grown in New England producing high yields of three-to four-lobed fruit. Both cultivars were obtained from Harris Seed Company (Rochester, New York).

Experiments were conducted in both 1978 and 1979 at the University of Massachusett's experimental farm in Deerfield, Massachusetts in Hadley silty-loam. Methods were generally the same for both years and will be described below, however specific differences will be detailed subsequently.

Flats were seeded in 100% Jiffy Mix (JPA, West Chicago, Ill.) such that all transplants were 6 to 10 weeks of age when they were set in the field. The flats were kept in the greenhouse at ambient temperatures which averaged 21 C days and 16 C nights prior to transplanting. No supplemental lighting was provided. Flats were randomized twice weekly to minimize any bench effects. Seedlings were saturated with a full-strength Hoagland's solution weekly (Hoagland and Arnon, 1938).

The plants were set in the field during the first week of June without prior hardening in both years. Prior to transplanting the seedlings to the plots, the field was plowed and harrowed. One-half ton of 10-10-10 fertilizer per acre was spread and harrowed in. No starter solution was used in 1978, however in 1979 the seedlings were given 237 mls of Peter's Special Formula (W. R. Grace and Co., Allentown, Pa.) starter solution (9-45-15) per plant once set in the ground.

All experiments were completely randomized block designs with 7 blocks and 5 or 3 plants per treatment per block. Experiments where plants were deflorated had the flowers pinched off when they reached anthesis. The defloration treatments each differed by 1 week. In each treatment all flowers at anthesis were removed daily up to a specific date. Thus, increasing defloration increased the duration of vegetative growth by weekly increments. Other experiments utilized different plastic mulches or transplanting depths specified below. The following data were collected for each plant in all Experiments.

1. The number of days from seeding to opening of the first flower.
2. The total number of fruit.
3. Fresh and dry weights of the fruit per harvest.

Fruit were harvested in the following manner. On any given harvest date or period (Table 1) all plants were harvested; however only marketable-sized fruit were picked. For plants with no fruit of marketable size, a "0" was recorded for number of fruit, fruit fresh weight, and fruit dry weight for that date. Total fruit dry weight was calculated by summing the dry weights of the harvests.

At the end of each growing season the vegetative portions of the plants in Experiments 1, 2 (1978) and 4 (1979) were harvested in the following fashion. (Vegetative fractions could not be determined accurately in Experiments 3 and 5 (1979) due to partial defoliation from a Bacterial Leaf Spot infection).

1. Two plants were randomly selected for each treatment per block and defoliated. The stems were separated from the roots at the cotyledonary node. Leaves and stems (which when summed equal the total shoot) were bagged separately and dried.

2. The shoots of all remaining plants were separated at the cotyledonary node from the roots and were bagged.

3. The roots were harvested with a spading fork by placing the fork 24 cm from the base of the plant, inserting it vertically down to the top of its head, and then pushing the handle to the ground. This lifted the plants up and obtained the bulk of the roots, however the fine feeding roots were not recovered. A root ball was then shaken free of soil, and bagged. Following oven drying, the root samples were rolled over a screen to remove any additional soil.

All vegetative and fruit samples were dried in a forced air oven at 60 C for at least 1 week. Dry weights were then determined for all samples. Total fruit dry weight was calculated by summing the

Table 1. Harvest schedule for experiments 1 - 5, 1978 - 1979.

1978		1979			
Harvest Period	Dates Exps. 1 and 2	Harvest Number	Exp. 3	Dates Exp 4	Exp 5
1	6/24 - 7/3	1	7/17	8/2	7/24
2	7/4 - 7/13	2	7/24	8/9	7/31
3	7/14 - 7/23	3	7/31	8/15	8/8
4	7/24 - 8/2	4	8/7	8/23	8/15
5	8/3 - 8/12	5	8/17	8/30	8/22
6	8/13 - 8/22	6	8/21	9/5	8/30
7	8/23 - 9/1	7	8/28	9/13	9/5
8	9/2 - 9/11	8	8/28	9/13	9/5
9	9/12 - 9/21				

harvests. Partitioning of the dry matter was calculated by dividing the dry weight of a particular fraction into the total dry weight of the plant.

The data were analyzed and models developed by Analysis of Variance, Covariance, or Polynomial Regression as outlined by Steel and Torrey (75) or by Multiple Regression techniques outlined by Johnston (36).

Experiment 1, 1978: Defloration Experiment

This experiment tested the effects of deflorating the pepper plants on subsequent reproductive and vegetative growth. Ladybell and Keystone Resistant Giant were used in this experiment. Keystone was seeded in wooden flats in 100% Jiffy Mix on March 22, 1978, and Ladybell was seeded in like manner on March 31, 1978. Keystone seedlings were transplanted to 3" Jiffy pots in a greenhouse soil mix (soil/sand/peat, 1:1:1) on April 19th and the same was done for Ladybell on the April 24. All seedlings had 2 to 3 primary leaves at this time. Seedlings were transplanted to the field on June 7. Five defloration treatments were imposed upon the plants: defloration until June 8, June 15, June 22, June 29, and July 6.

Experiment 2,1978: Mulch Experiment

This experiment examined the effects of various mulches upon vegetative and reproductive yields and how dry matter was partitioned within the pepper plant. Keystone was the only cultivar used. Seedlings came from the same population as in experiment 1 and were also planted in the field on June 7, 1978. Treatments consisted of aluminum-coated kraft paper, as used in house siding, and black and clear plastic. The aluminum-kraft paper was purchased as a 3 ft roll, and the black and clear plastics (3 ft x 1.5 mil) were obtained from Deerfield Plastics, (Deerfield, Mass.). Beds were prepared prior to laying the mulch and were 3 ft (center to center). Seedlings were spaced 3 ft apart. Fruits were harvested during periods outlined in Table 1.

Experiment 3, 1979: Container Size and Seeding Date Experiment

The effects of container size, seeding date, and variety on seedling root and shoot dry weights and subsequent fruit yields were examined in this experiment. Treatments were set up in a factorial design.

Ladybell and Keystone were seeded (Table 2) in Todd Planters, Models 150-2, 200, and 300 (Speedling, Inc., Sun City, Florida) on 3 different dates: 3/30, 4/10, 4/21. The transplants were set out on June 4 in beds 4 ft apart under black polyethylene mulch (Polyagro

Table 2. Container sizes and seeding dates, Experiment 3, 1979.

Container Size	Todd Model Number	Size (in.)	Volume (cm^3)
1	150-2	1.5	31
2	200	2.0	66
3	300	3.0	147

Seeding Number	Date	Number of Days from Seeding to Transplanting
1	3/30	65
2	4/10	54
3	4/21	44

Inc., Bridgeport, Pa.), 3 ft x 1.5 mil. Plants were spaced 2 ft apart. Fruit were harvested as shown in Table 1.

Experiment 4, 1979: Combined Defloration and Mulch Experiment

This experiment combined treatments from Experiments 1 and 2 (1978), defloration and mulches, in a factorial design. However, there were significant changes in methods.

Ladybell was seeded on April 17th in 100% Jiffy Mix into Model 200 Todd planters. Seedlings were set out in beds under various mulches on June 4. The mulch treatments consisted of: 3 ft x 1.5 mil black polyethylene plastic; 3 ft x 1.5 mil aluminum-coated black polyethylene plastic (Polyagro); 3 ft x 1.5 mil clear polyethylene plastic (Deerfield Plastics); and a bare soil control.

Defloration methods were the same as in 1978 except that there were 6 durations of treatment: defloration until 7/2, 7/9, 7/16, 7/23, 7/30, and a control of no defloration.

In 1979 to avoid cutworm damage, the plants were sprayed on 7/16 with Sevin at 2 lb/acre. The aisles between the beds were sprayed with Enide (50W) at 9 lb/acre for weed control. During the fourth week of August, Bacterial Leaf Spot disease appeared. Disease control was attempted by spraying the plants with 1.5 lbs/acre Kocide.

CHAPTER IV

Results

The effects of prolonged vegetative growth on subsequent fruiting were examined in Keystone and Ladybell peppers by removing the flowers from the plants for increasing periods of time during the growing season. During the summer both Keystone and Ladybell showed varying trends in fruit production that were influenced by the extent of defloration (Figs. 1 and 2). Those plants which were allowed to fruit first (deflorated until 6/8) produced an early peak of fruit production (7/20) followed by a decline, and then a second peak of production (8/19). Keystone plants which were deflorated until 6/22 yielded 1 peak and two shoulders of fruit production (7/20, 8/19, 9/8). Ladybell deflorated until 6/22 yielded 1 shoulder (7/19) and 1 peak (8/28) of fruit production. With both cultivars the peaks of greatest magnitude were produced on those plants deflorated the longest. These results show a clear trend in fruit production as a function of defloration: as defloration increased, the amplitude of early fruit production decreased while that of later production periods increased.

Defloration had a great effect on the total dry weight of the plant. In both Keystone and Ladybell, total plant dry weight increased linearly with increasing defloration (Fig. 3). The only

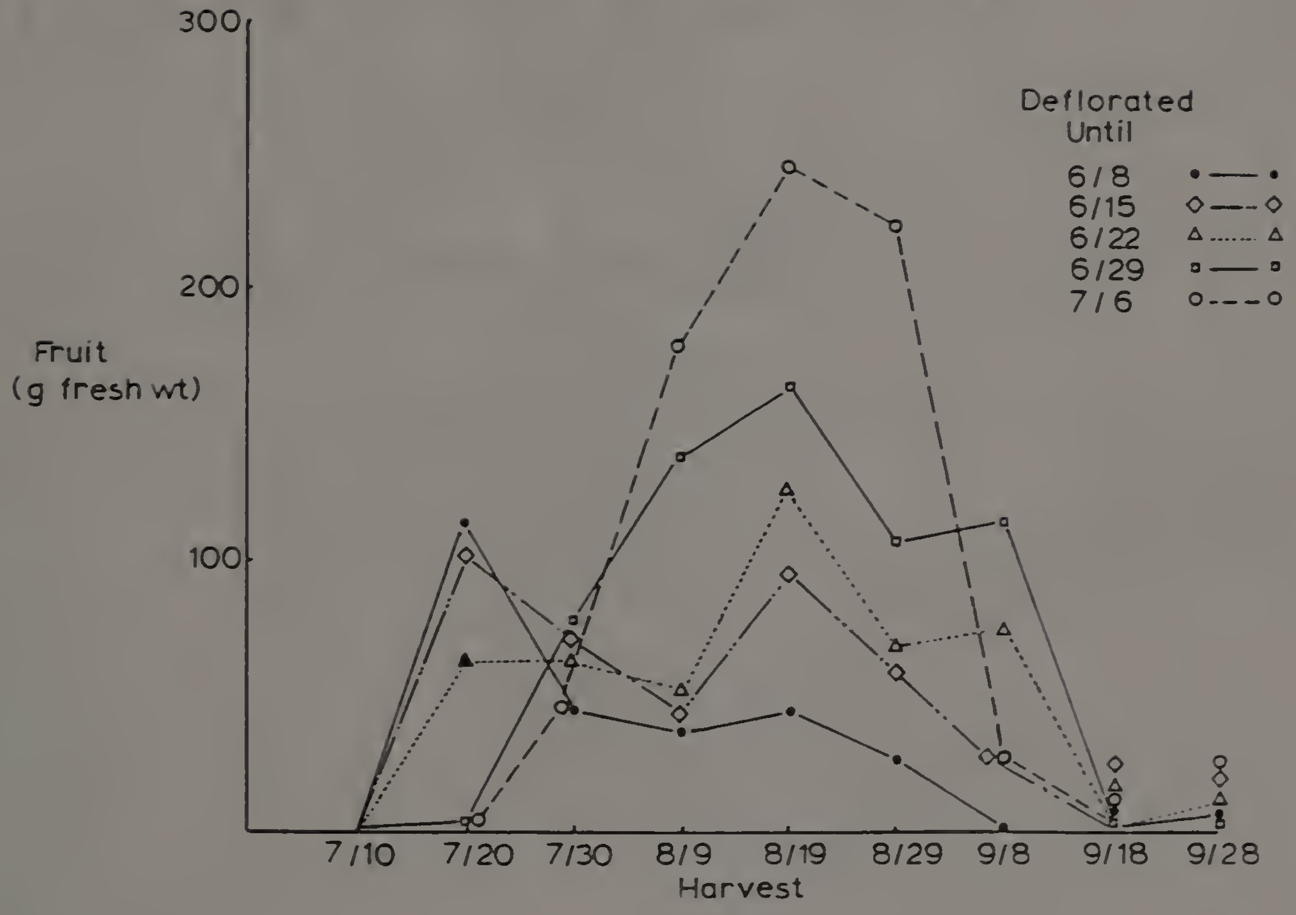

Fig. 1. Fruit fresh wt per plant per harvest: Keystone. Experiment 1, 1978.

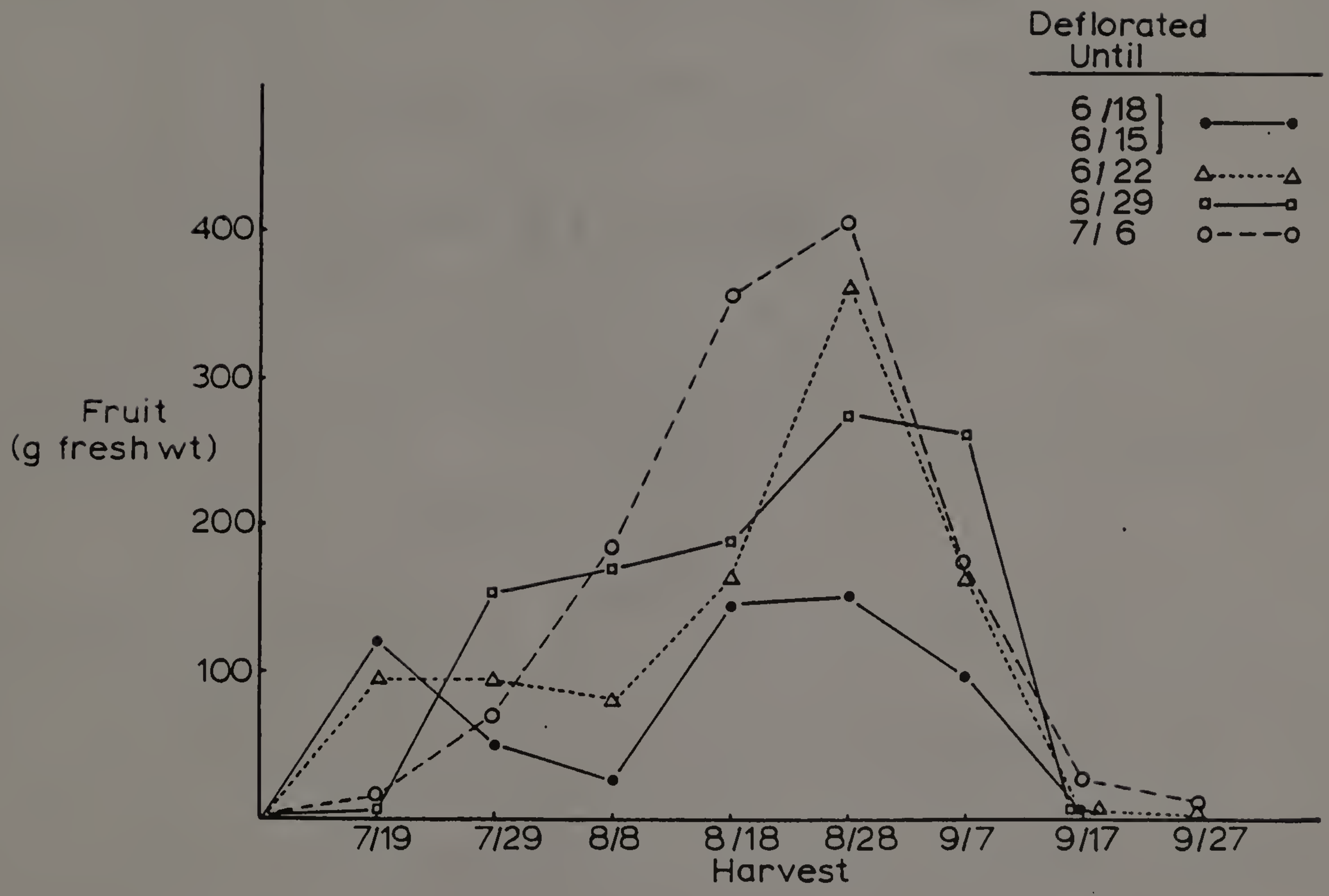

Fig. 2. Fruit fresh wt per plant per harvest: Ladybell. Experiment 1, 1978.

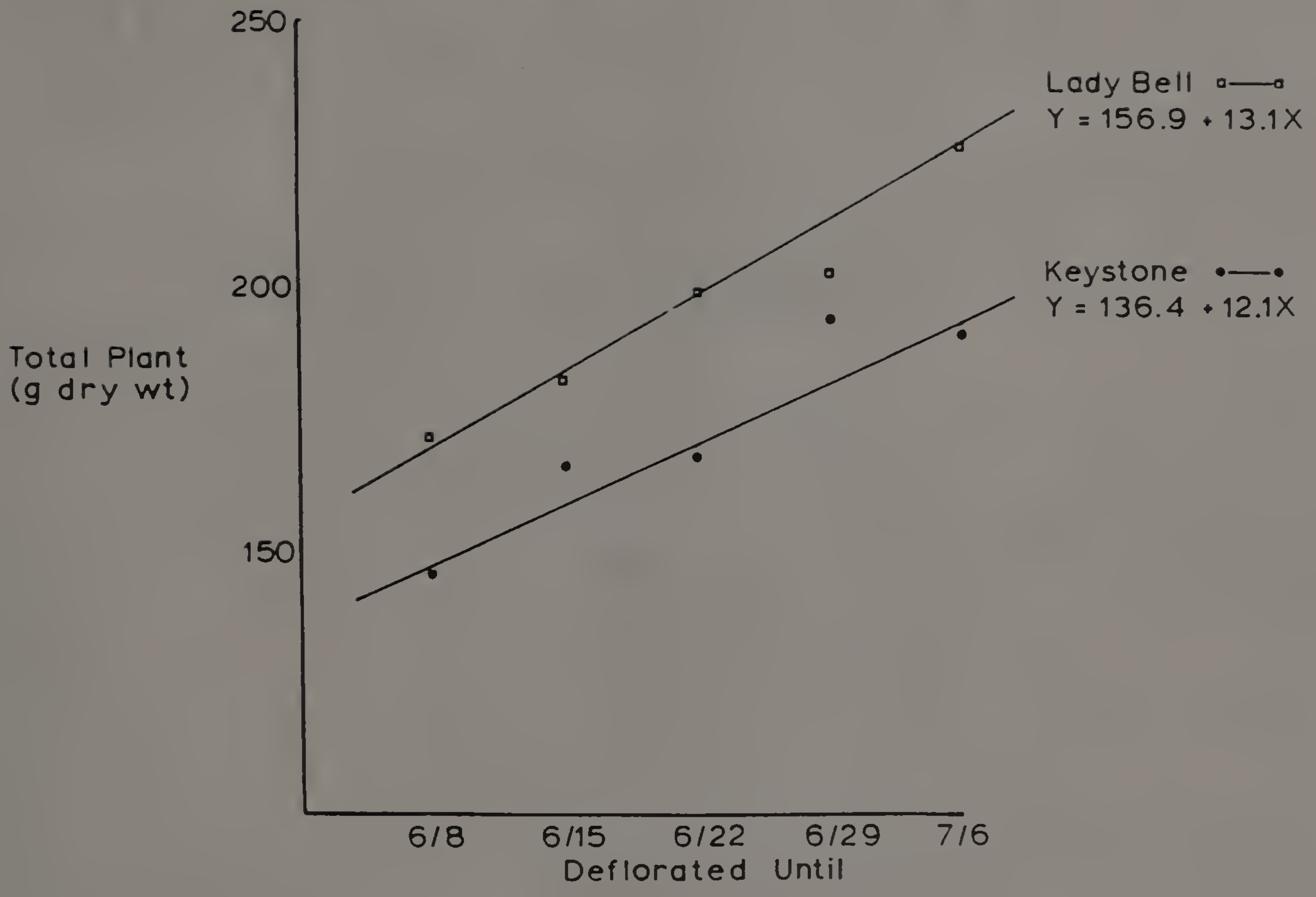

Fig. 3. Effect of defloration on total plant dry wt. Experiment 1, 1978.

real difference between the 2 cultivars was that Ladybell was approximately 20 grams heavier at every level of defloration than Keystone. Although the Y intercepts differed by 20 grams, the slopes were essentially the same for the two cultivars.

The increased total dry weight associated with defloration was not due to an effect on shoot (leaf + stem) dry weight for either cultivar (Fig. 4). However, defloration did have a positive effect on root dry weights with root dry weight increasing with increasing duration of defloration for both cultivars (Fig. 5). The response to defloration was essentially the same for both cultivars, with the Y intercepts and regression coefficients being the same.

The greatest effect that defloration had was upon total fruit production (Fig. 6). Fruit dry weight production showed a linear increase with increasing durations of defloration. Ladybell and Keystone differed in both the Y intercept and in slope, with slope and intercept being twice as great for Ladybell as for Keystone.

The partitioning of dry matter, that is, a given fraction's dry weight as a percent of that of the whole plant, indicates how the resources of a plant were allocated during a season. The partitioning data in Keystone (Fig. 7) shows that with increasing length of defloration, the dry weight ratios of fruit/total increased, whereas shoot/total decreased, due to a decrease in leaf/total. Virtually the same response occurred for both Ladybell

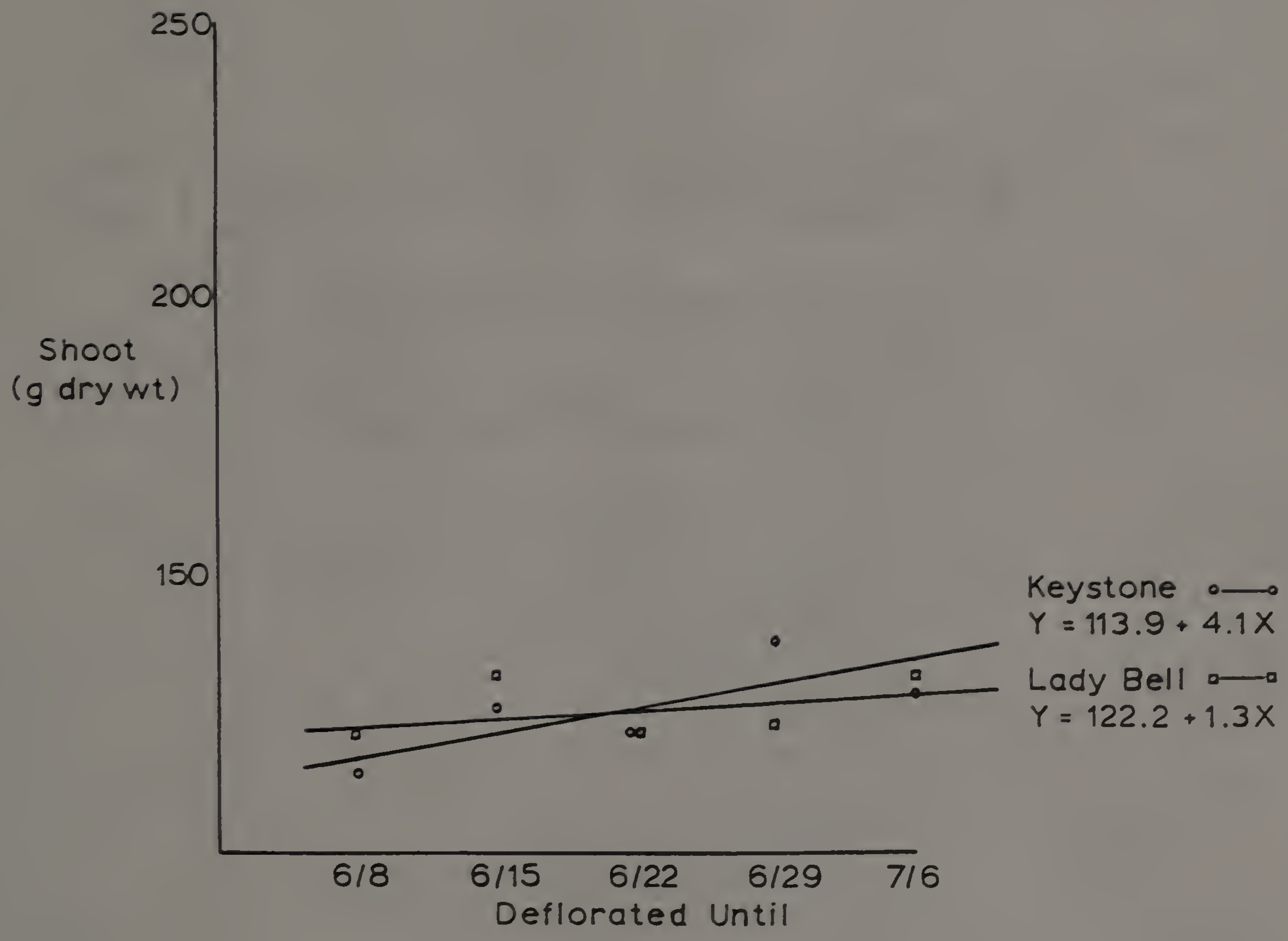

Fig. 4. Effect of defloration on shoot dry wt. Experiment 1, 1978.

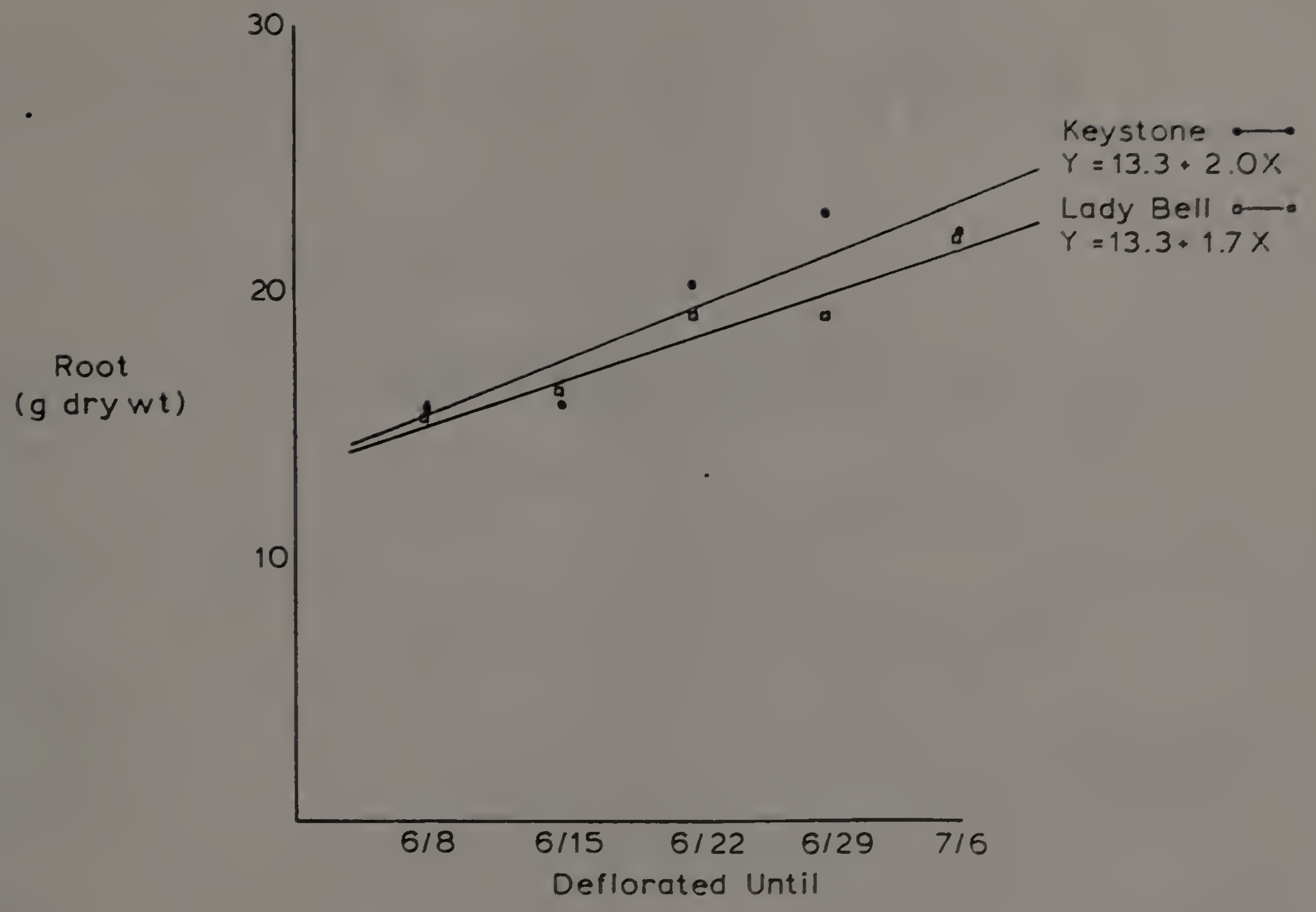

Fig. 5. Effect of defloration on root dry wt. Experiment 1, 1978.

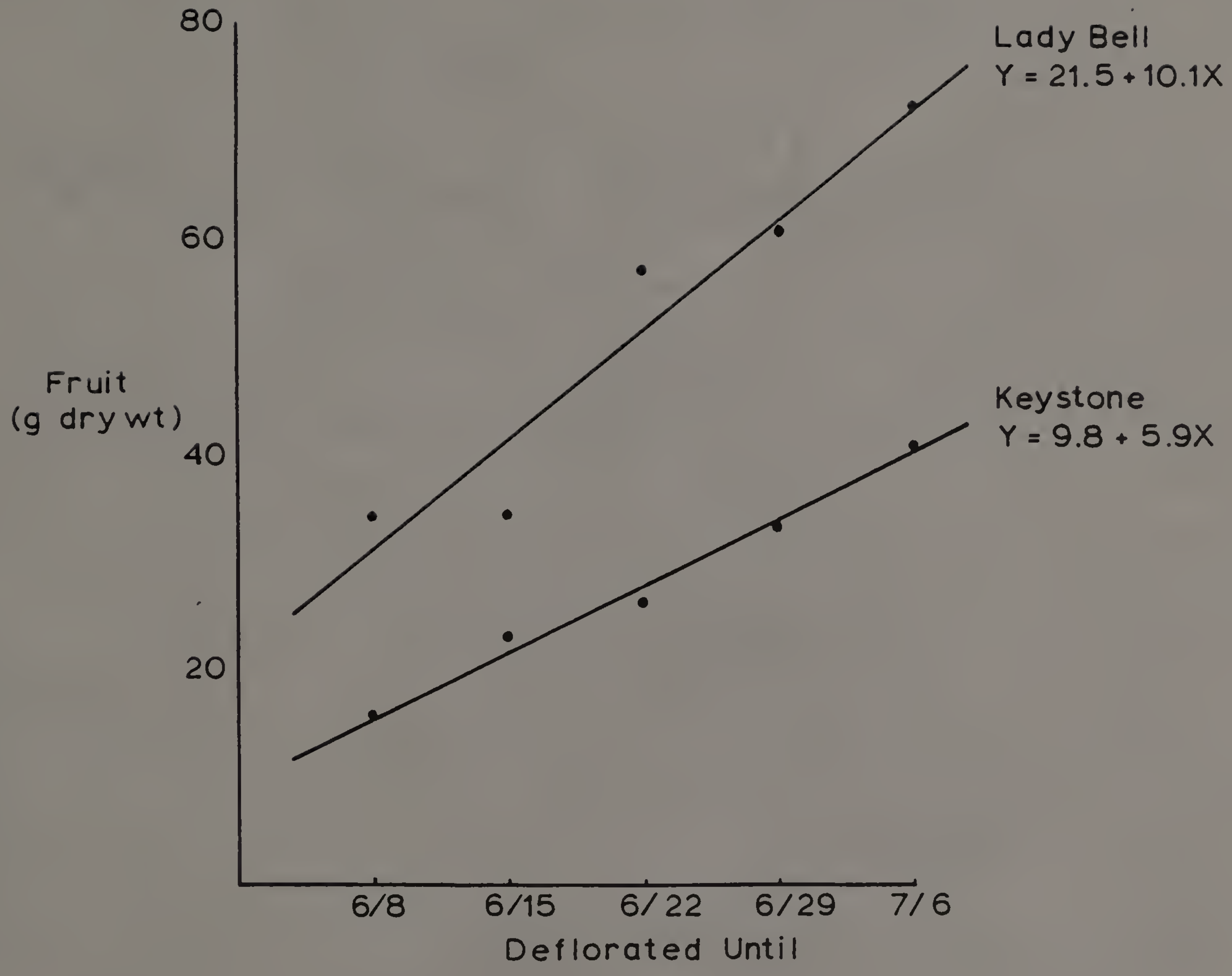

Fig. 6. Effect of defloration on total plant dry wt. Experiment 1, 1978.

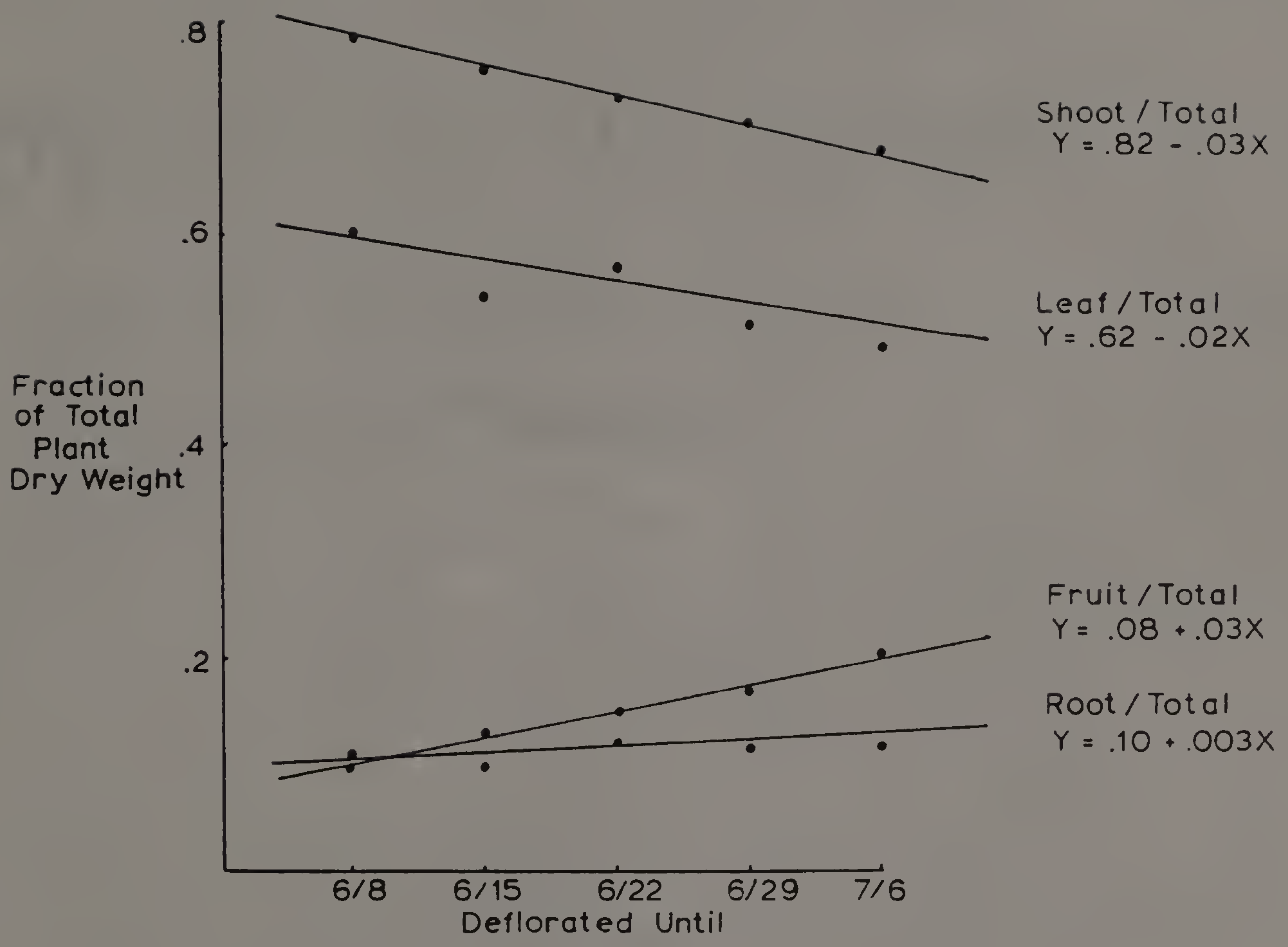

Fig. 7. Fractions of total plant dry wt: Keystone. Experiment 1, 1978.

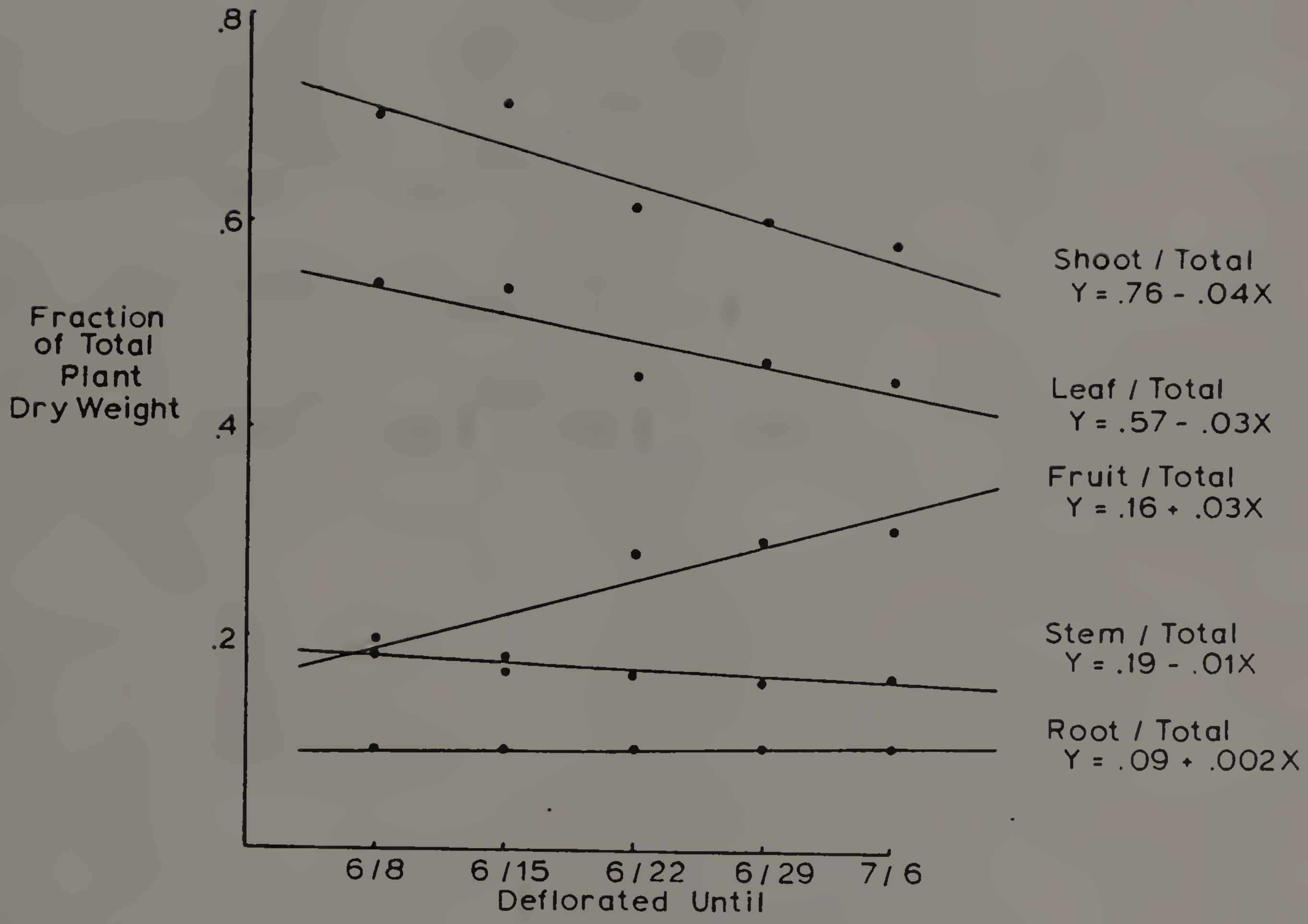

Fig. 8. Fractions of total plant dry wt: Ladybell. Experiment 1, 1978.

and Keystone (Fig. 8). The dry wt ratio of root/total showed no change with defloration.

The effects of different mulches on fruit and vegetative production in Keystone Resistant Giant pepper was examined in Experiment 2, 1978. Three mulches plus a bare soil control were compared. The data presented in Fig. 9 show soil temperatures in 2 cm increments to a depth of 16 cm as a function of mulch treatment. These observations were made during the middle of a hot, sunny day in early July when temperature differences among the mulches would presumably be greatest. Differences in temperature were greatest at the surface of the soil, with the clear plastic producing a temperature of 45 C. The soil surface below the black plastic was 10 C cooler than under clear plastic, but the soil under both plastics was warmer than bare soil. Soil under aluminum-coated kraft paper was cooler than the bare soil. At 16 cm the temperatures of the control and aluminum mulch were the same (21 C), whereas the black and clear mulches produced temperatures of 25 C and 27 C, respectively at this depth.

Fruit production under these conditions showed a cyclical pattern (Fig. 10) with approximately the same peaks (on 7/20, 8/19, 9/18) in all treatments. The greatest difference among the treatments was in the 8/19 peak where the clear plastic produced the greatest yield, followed by the black plastic. The aluminum-coated

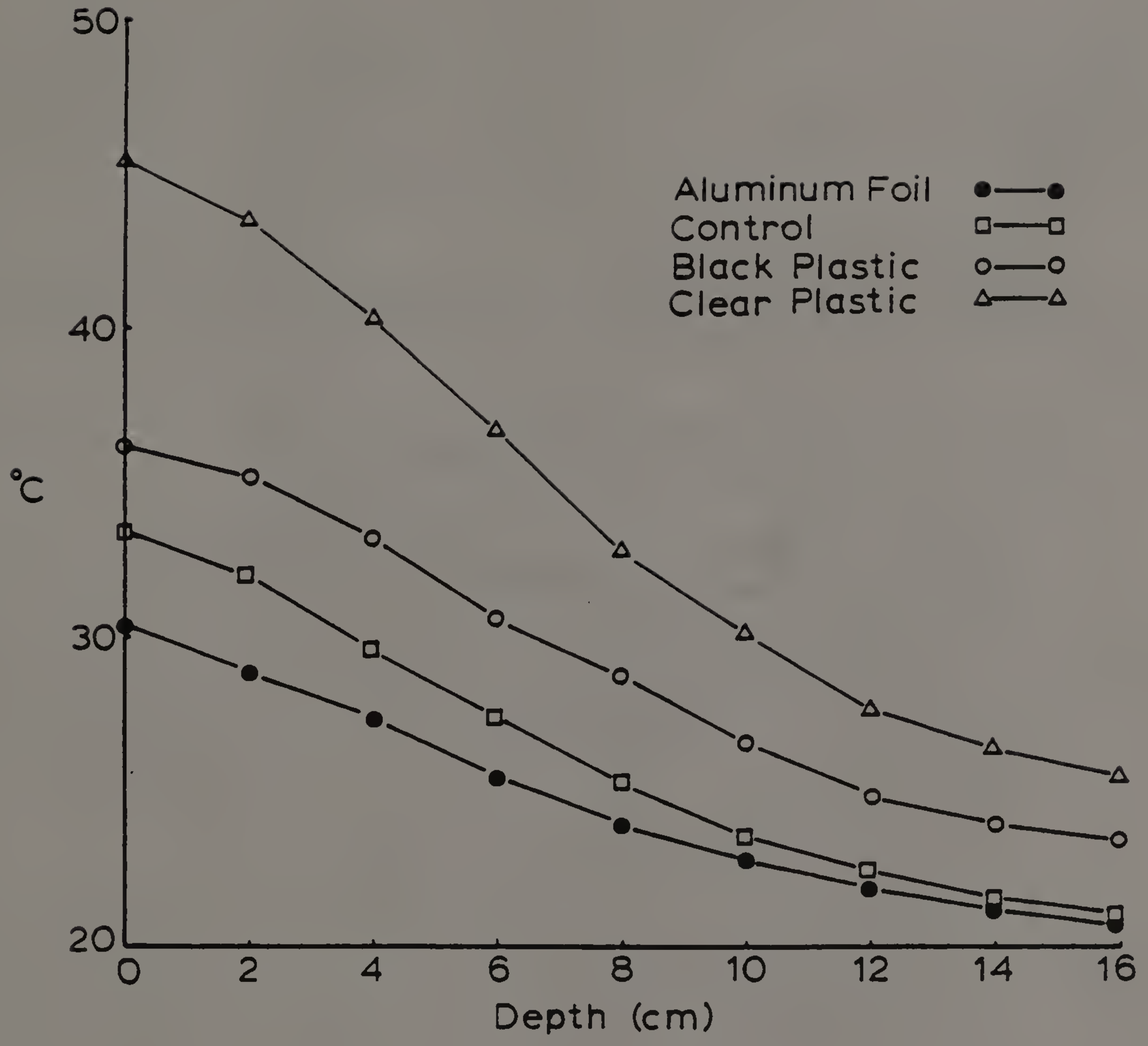

Fig. 9. Soil temperatures under mulches (11 am - 3 pm, 7/8/78, 34 C Air Temp) Experiment 2, 1978.

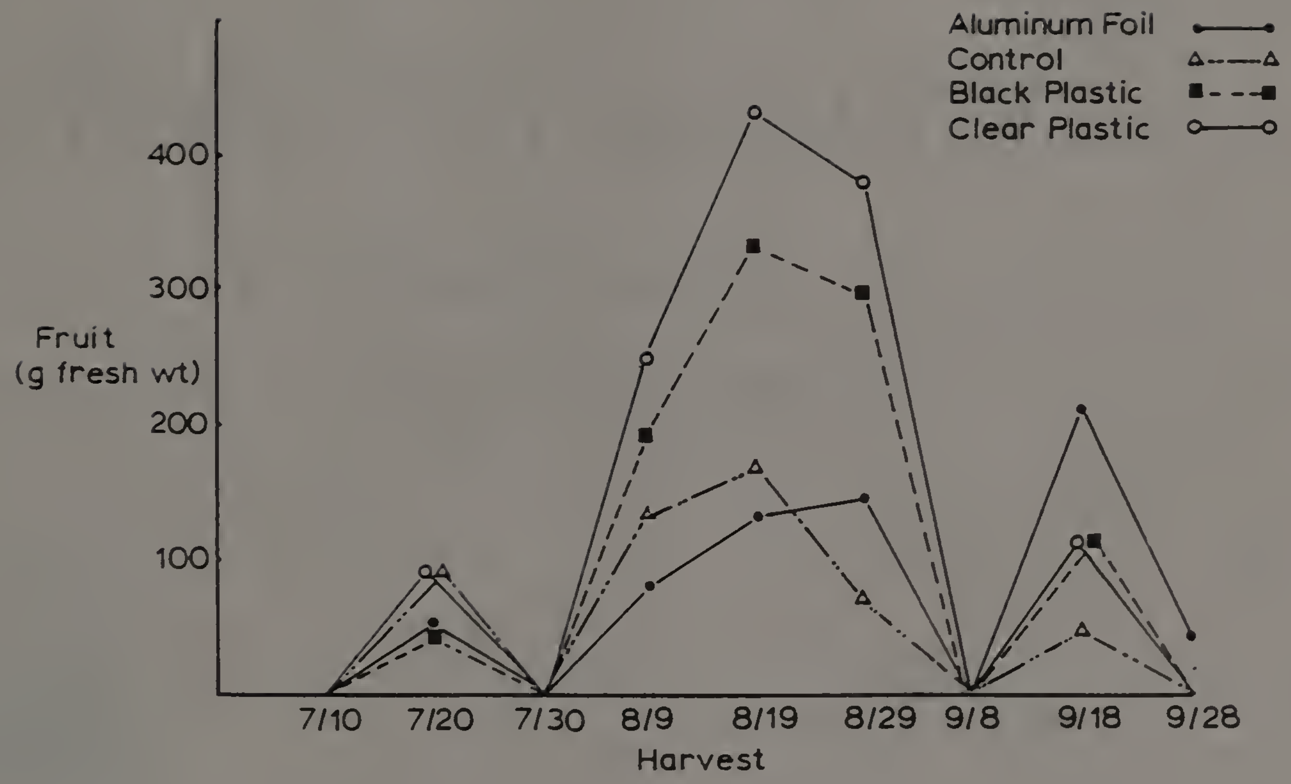

Fig. 10. Mulch effect on fruit fresh wt per plant per harvest. Experiment 2, 1978.

kraft paper and control produced equivalent fruit yields during this period. In the 9/18 peak the greatest yield was produced by the aluminum-coated kraft paper. The black and clear plastic produced about half as much fruit, and the control produced only about 25% as much fruit as the plants with aluminum-coated kraft paper mulch.

Total dry weight yield of fruit (Fig. 11) was greatest with the clear plastic, followed by those of the black plastic, control, and aluminum-coated kraft paper, respectively. Dry wt yields from black and clear plastic mulches were significantly different from each other, and both were significantly higher than either the aluminum and the control. There was no significant yield difference between aluminum and the control (Table 3).

Mulch treatments resulted in differences in root dry weights and stem dry weights (Fig. 11). Black and clear plastic produced greater masses of roots than either the control or the kraft paper. Stem dry wts responded in the same way (Fig. 11). The mass of the stems was greater with clear and black plastic than with the aluminum-coated kraft paper.

The partitioning of dry matter is shown in Fig. 12. The dry wt ratio of fruit/total was greatest with clear and black plastic followed by the aluminum-coated kraft paper which was the same as the control. Conversely, the shoot/total dry wt ratio was the same for the aluminum mulch and the control and decreased for black and clear plastic. Therefore, those conditions which increased soil

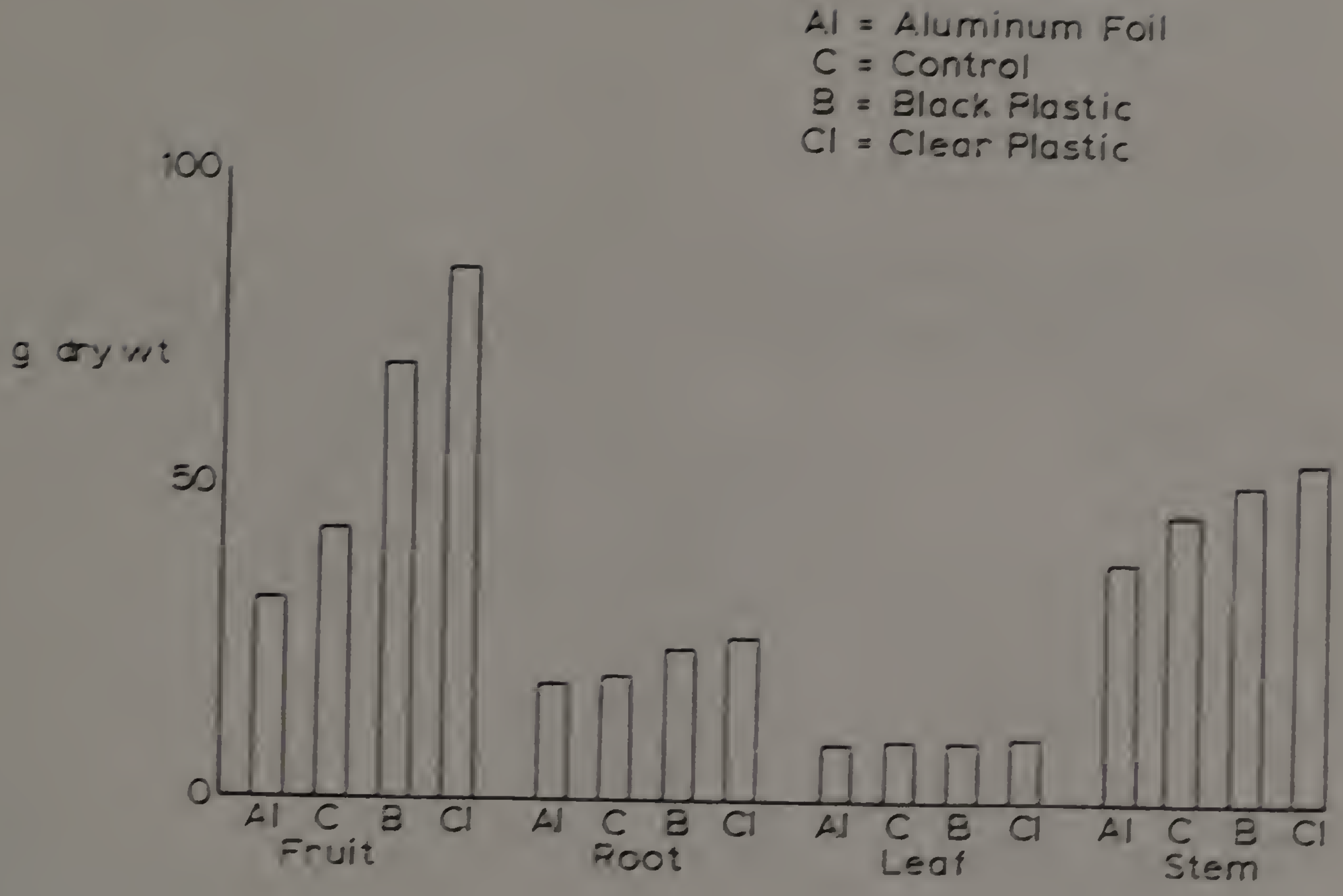

Fig. 11. Mulch effect on plant fraction dry wts. Experiment 2, 1978.

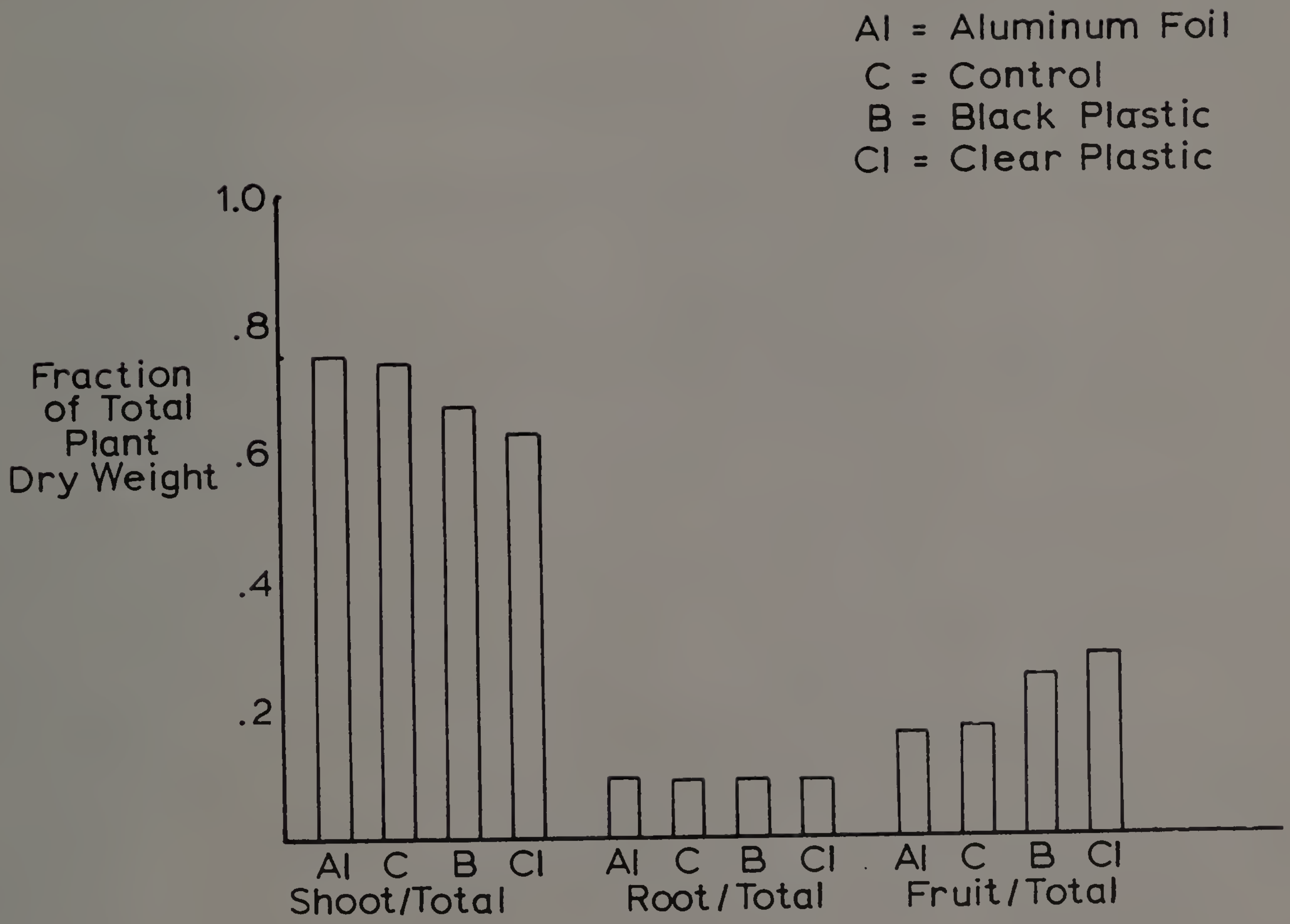

Fig. 12. Mulch effect on dry matter partitioning in pepper. Experiment 2, 1978.

Table 3. ANOVA of Total Fruit Fresh Weight, Experiment 2, 1978.

Source of Variation	df	Sum of Squares	Mean Square	F
Blocks	6	5056.43	842.74	0.71
Mulch	3	61042.55	20347.52	17.04***
Aluminum and Control vs. Black and Clear	1	54917.28	54917.28	72.83***
Aluminum vs. Control	1	2091.18	2091.18	2.77
Black vs. Clear	1	4034.09	4034.09	5.35*
Block x Mulch	18	21489.09	1193.84	1.58
Plant(Block x Mulch)	112	84455.80	754.07	

***p<.001

temperatures increased growth in the roots, increased total fruit yields, and resulted in a greater proportion of the entire plant being partitioned to fruit.

The relationship of variety, container volume, and seeding date to seedling dry weights, partitioning of dry matter in the seedling, the number of days from seeding to the opening of the first flower, and the subsequent yields, (measured by fruit per harvest, fresh weight of fruit per harvest, total fruit per season, and total fresh fruit weight per season) was examined in Experiment 3, 1979. The conditions imposed upon the seedlings resulted in dramatic differences in the size of the seedlings (Figs. 13 and 14). Seedling shoot and root dry weights of both varieties, showed the same trend: the later the seeding date, the less dry weight was produced in either root or shoot. Container volume had the opposite effect: as container volume increased, the dry weights of both root and shoot increased.

Multiple regressions of seedling shoot and root dry weights with variety, container size, and seeding date (Tables 4 and 5) showed that the variables container size, seeding date, and the interaction between container size and seeding date were all highly significant. Variety was highly significant in the seedling shoot dry wt, but was only significant at the .05% level in the root dry wt.

In addition to the shoot and root dry weight, the number of days from seeding to opening of the first flower also varied with variety,

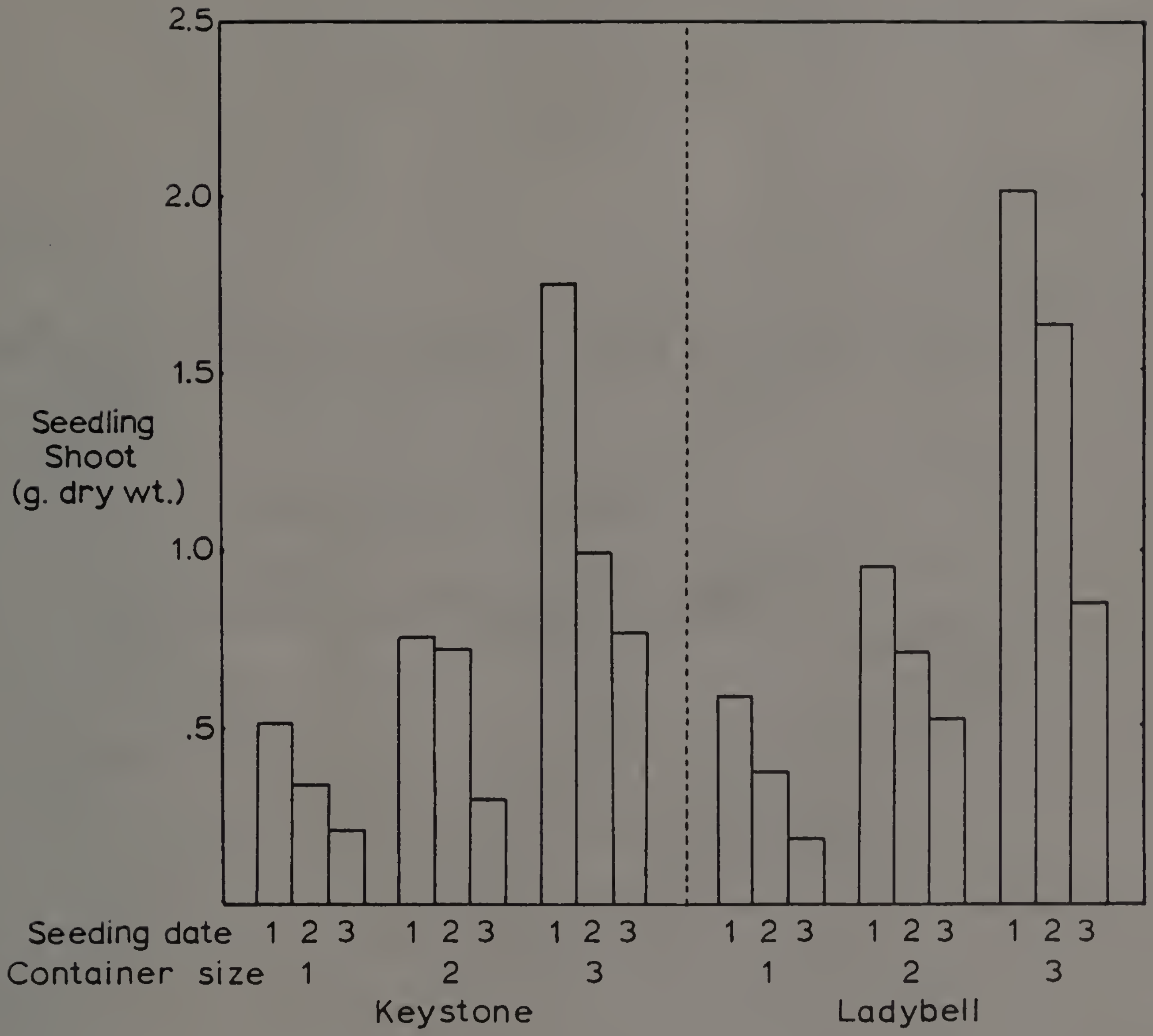

Fig. 13. Effects of variety, container size and seeding date on seedling shoot dry wt. Experiment 3, 1979. (Seeding Date 1 = 3/30, 2 = 4/10, 3 = 4/21; Container Size (cm^3) 1 = 31, 2 = 66, 3 = 147).

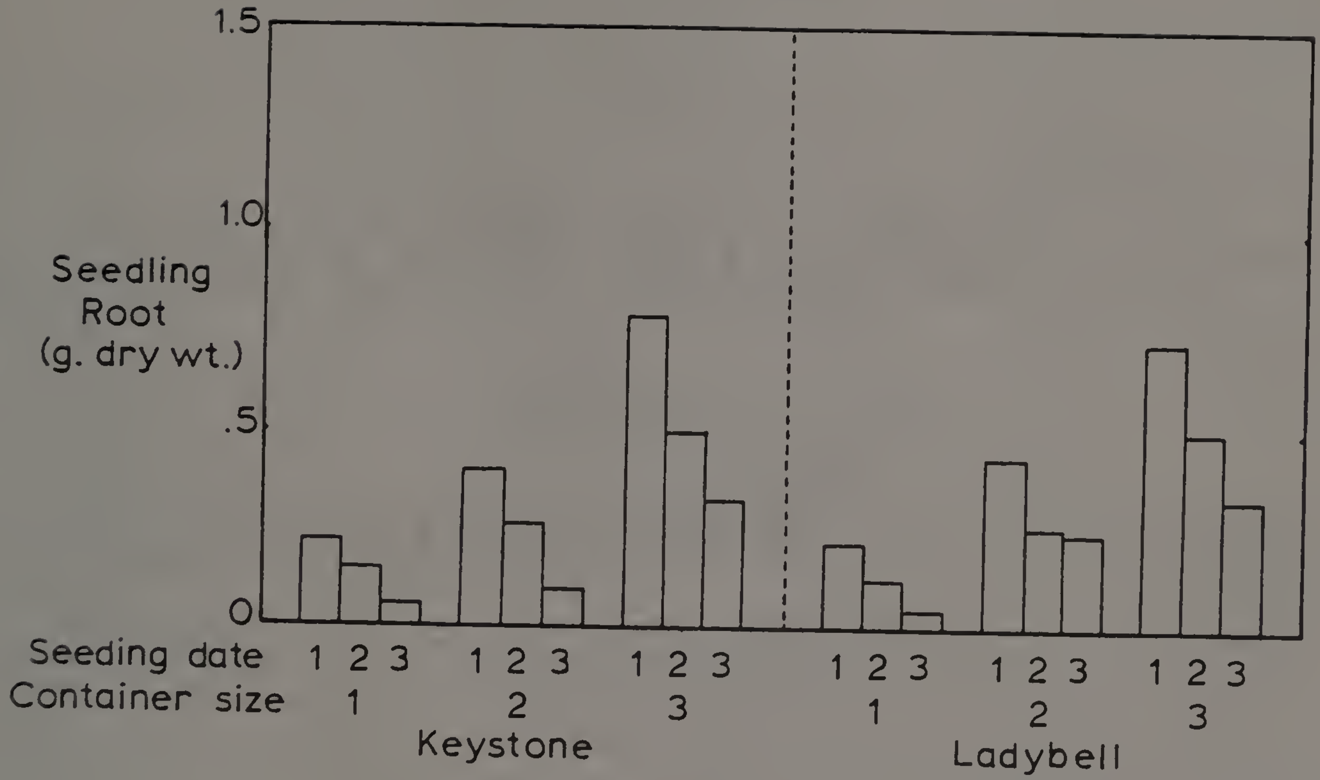

Fig. 14. Effects of variety, container size and seeding date on seedling root dry wt. Experiment 3, 1979. (Seeding Date 1 = 3/30, 2 = 4/10, 3 = 4/21; Container Size (cm^3) 1 = 31, 2 = 66, 3 = 147).

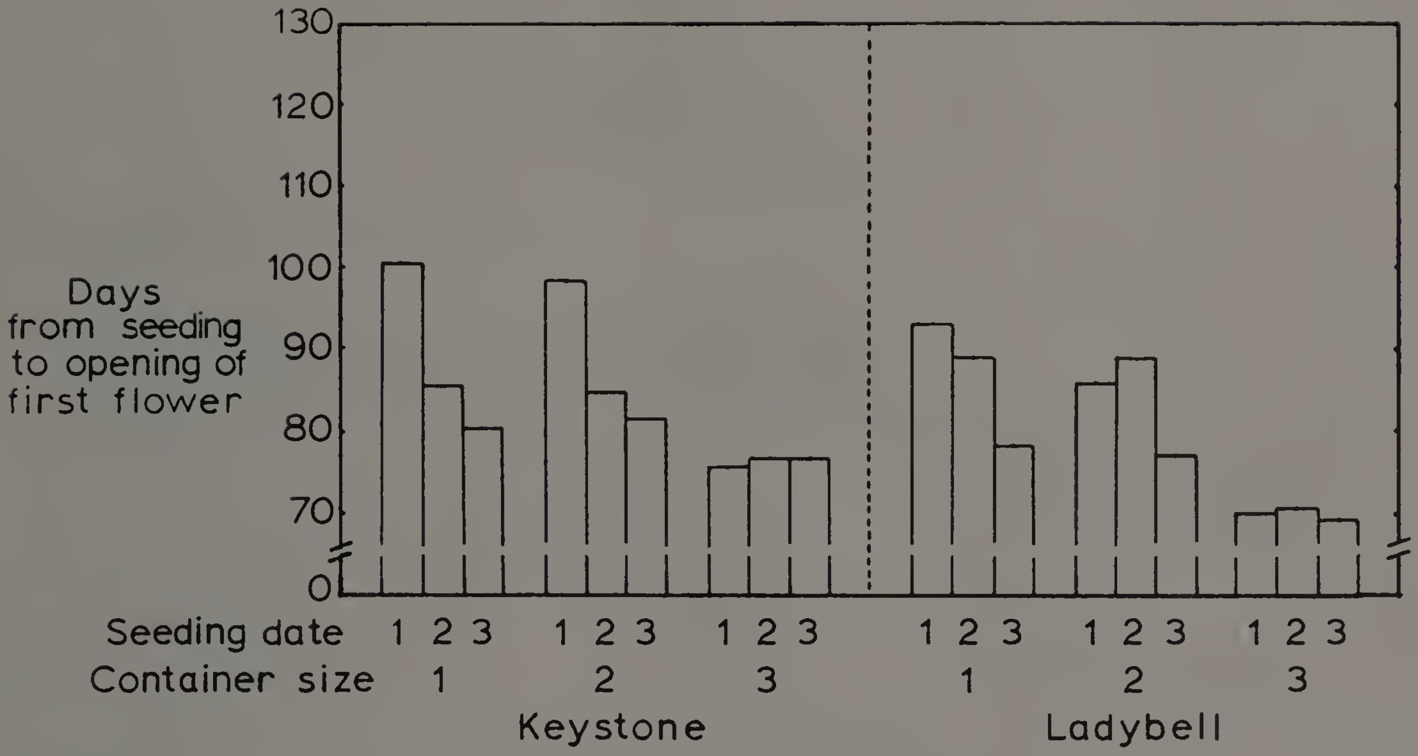

Fig. 15. Effects of variety, container size and seeding date on the number of days from seeding to opening of the first flower. Experiment 3, 1979. (Seeding Date 1 = 3/30, 2 = 4/10, 3 = 4/21; Container Size (cm^3) 1 = 31, 2 = 66, 3 = 147).

Table 4. Multiple Regression of Seedling Shoot Dry Weight with Variety, Container Size and Seeding Date.

Variable	Beta	Std. Error Beta	F	Elasticity
Keystone	-0.17	0.03	35.29^{***}	-0.15
Container Size (CS)	-0.009	0.002	21.40^{***}	-0.77
Seeding Date (SD)	0.46	0.003	2.10^{**}	0.07
CS x SD	0.0003	0.00003	86.00^{***}	1.60
Ladybell (Constant)	-0.05	0.17	0.09	

Model: $Y = -0.05 + 0.009(CS) + 0.46(SD) + 0.0003(SD \times CS) + e$

$R^2 = .88$

$F = 324.59^{***}$

$^{***}p<.001$

Table 5. Multiple Regression of Seedling Root Dry Weight with Variety, Container Size and Seeding Date.

Variable	Beta	Std. Error Beta	F	Elasticity
Keystone	-0.01	0.01	0.67	-0.02
Container Size (CS)	-0.003	0.0008	9.84^{***}	-0.59
Seeding Date (SD)	0.004	0.001	8.44^{***}	0.17
CS x SD	0.0001	0.00002	50.41^{***}	1.39
Ladybell (Constant)	-0.18	0.08	4.83^{*}	

Model: $Y = -0.18 + 0.003(CS) + 0.004(SD) + 0.0001(CS \times SD) + e$

$R^2 = .85$

$F = 243.10^{***}$

$^{***}p < .001$

container size and seeding date (Fig. 15). As container size increased, the number of days from seeding to the opening of the first flower decreased. The later the seeding date, the fewer the number of days from seed to first flower. Both cultivars responded to these treatments in a similar fashion; however, in response to the treatments, the number of days to opening of the first flower was less with Ladybell than Keystone. Therefore, as container size increased and the seeding date was delayed the shorter became the time from seeding to opening of the first flower.

While the number of days from seeding to the opening of the first flower is important in terms of greenhouse space and energy constraints, the number of days from setting plants in the field to opening of the first flower is more important to early yields. Fig. 16 shows that the earlier the flats are seeded, the sooner a given plant is likely to flower in the field. However, this trend was observed only with the largest container sizes. In fact, with Keystone and the smaller container size little early flowering was gained by early seeding.

Container size, seeding date and variety had dramatic effects on early yield in grams fresh weight of fruit of the combined first 2 harvests (Fig. 17). The smaller the container size and the later the seedint date, the lower was the early fruit yield. Ladybell and Keystone both showed this trend, but the effects were greater with Ladybell than with Keystone. These results are summarized in a

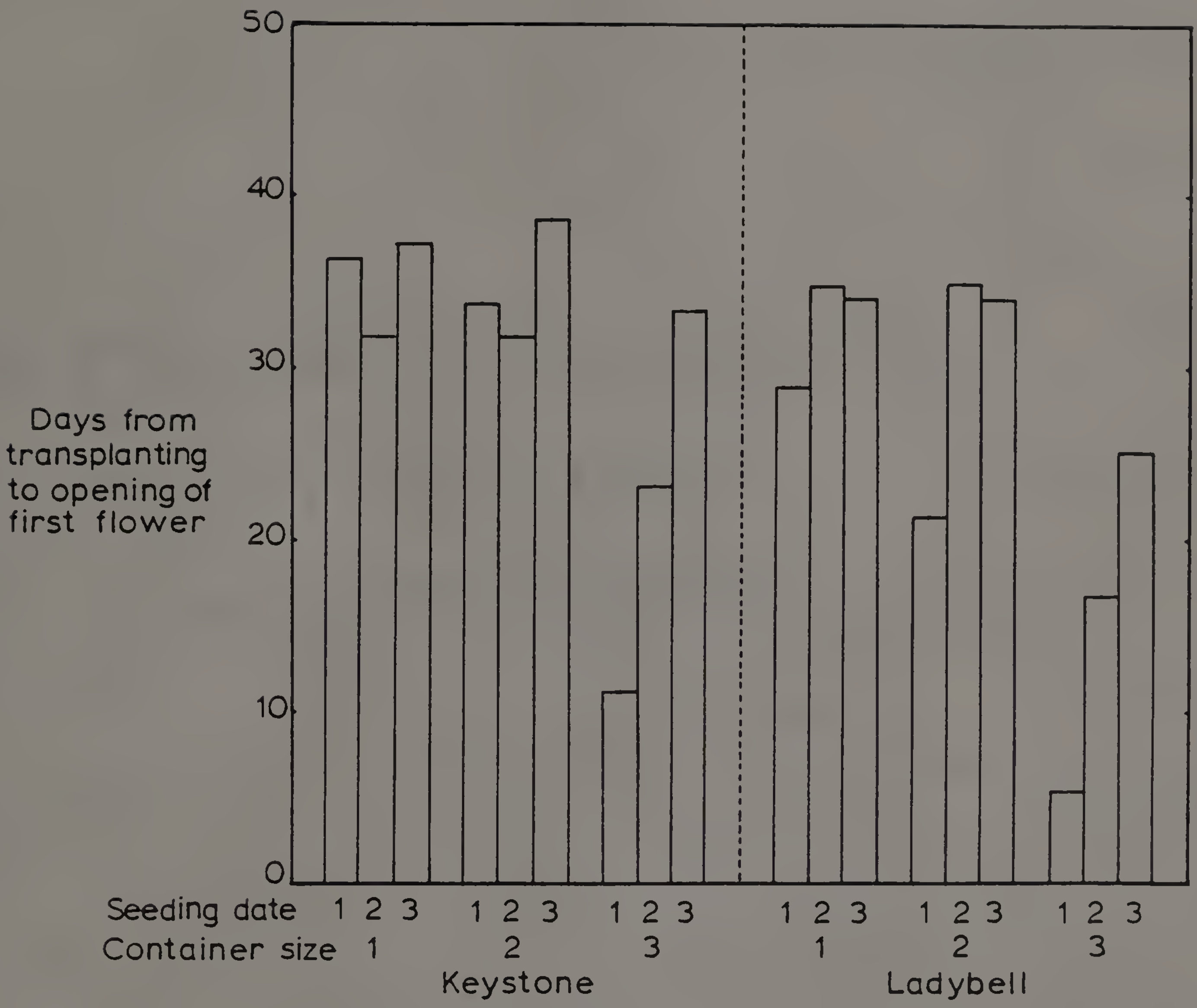

Fig. 16. Effects of variety, container size and seeding date on the number of days from transplanting to opening of the first flower. Experiment 3, 1979. (Seeding Date 1 = 3/30, 2 = 4/10, 3 = 4/21; Container Size (cm^3) 1 = 31, 2 = 66, 3 = 147).

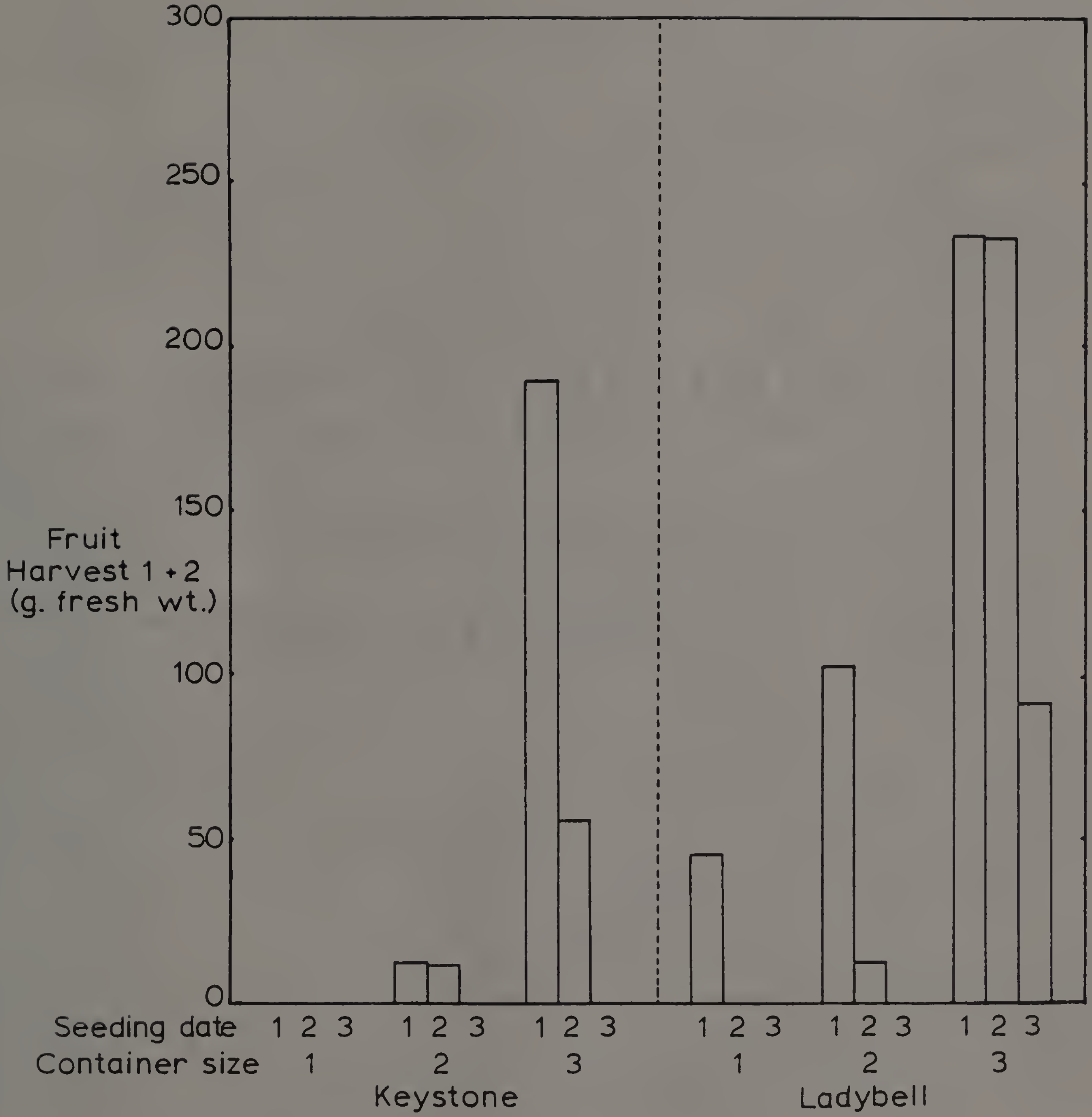

Fig. 17. Effects of variety, container size and seeding date on fruit fresh wt per plant from combined harvests 1 and 2. Experiment 3, 1979. (Seeding Date 1 = 3/30, 2 = 4/10, 3 = 4/21; Container Size (cm^3) 1 = 31, 2 = 66, 3 = 147).

multiple regression (Table 6) of the sum of harvests 1 and 2 with variety, container size and seeding date.

Comparing Fig. 16 and 17, those conditions which resulted in early flower opening were the same conditions which resulted in the greatest early yields. When fruit fresh weights of the combined first 2 harvests were regressed with variety, container size, seeding date, and the interaction between container size and seeding date, all of these independent variables except seeding date were highly significant (Table 6). When the combined fruit weights of harvests 3 - 8 were regressed (Table 7), the only significant variable was variety. These results show that the effects of container size and seeding date disappeared in the later harvests. Total fruit yields for the entire season (Fig. 18) were twice as great for Ladybell as for Keystone, and the effect of container size and seeding date were not significant.

During the latter part of the summer of 1979, a bacterial leaf spot disease developed and partially defoliated many plants. As a result, shoot dry weights were so variable that no trends could be recognized, and partitioning of the dry matter had to be ignored due to the unreliable total plant dry weights.

Experiment 4 (1979) combined the treatments of experiments 1 and 2 (1978) in a factorial design testing the combined effects of plastic mulches and defloration upon vegetative and fruit yields of the cultivar Ladybell.

Table 6. Multiple Regression of Fruit Fresh Weight from Harvests 1 and 2 with Variety, Container Size and Seeding Date.

Variable	Beta	Std. Error Beta	F	Elasticity
Keystone	-49.57	8.74	32.20^{***}	-0.22
Container Size (CS)	-2.06	0.57	12.95^{***}	-0.90
Seeding Date (SD)	-0.85	0.99	0.74	-0.07
CS x SD	0.06	0.01	31.69^{***}	1.46
Ladybell (Constant)	34.32	54.47	0.40	

Model: $Y = 34.32 + 2.06(CS) + 0.85(SD) + 0.06(CS \times SD) + e$

$R^2 = .42$

$F = 70.28^{***}$

$^{***}p<.001$

Table 7. Multiple Regression of Fruit Fresh Weight from Harvests 3 - 8 with Variety, Container Size and Seeding Date.

Variable	Beta	Std. Error Beta	F	Elasticity
Keystone	-725.65	41.10	311.65^{***}	-0.46
Container Size (CS)	-0.67	0.42	2.55	-0.07
Seeding Date (SD)	-0.11	2.40	0.002	-0.008
CS x SD	-0.12	0.49	0.58	-0.06
Ladybell (Constant)	1211.64	137.70	77.42^{***}	

Model: $Y = 1159.76 - 0.31(CS) + 0.85(SD) - 0.12(CS \times SD) + e$

$R^2 = .46$

$F = 78.37^{***}$

$^{***}p < .001$

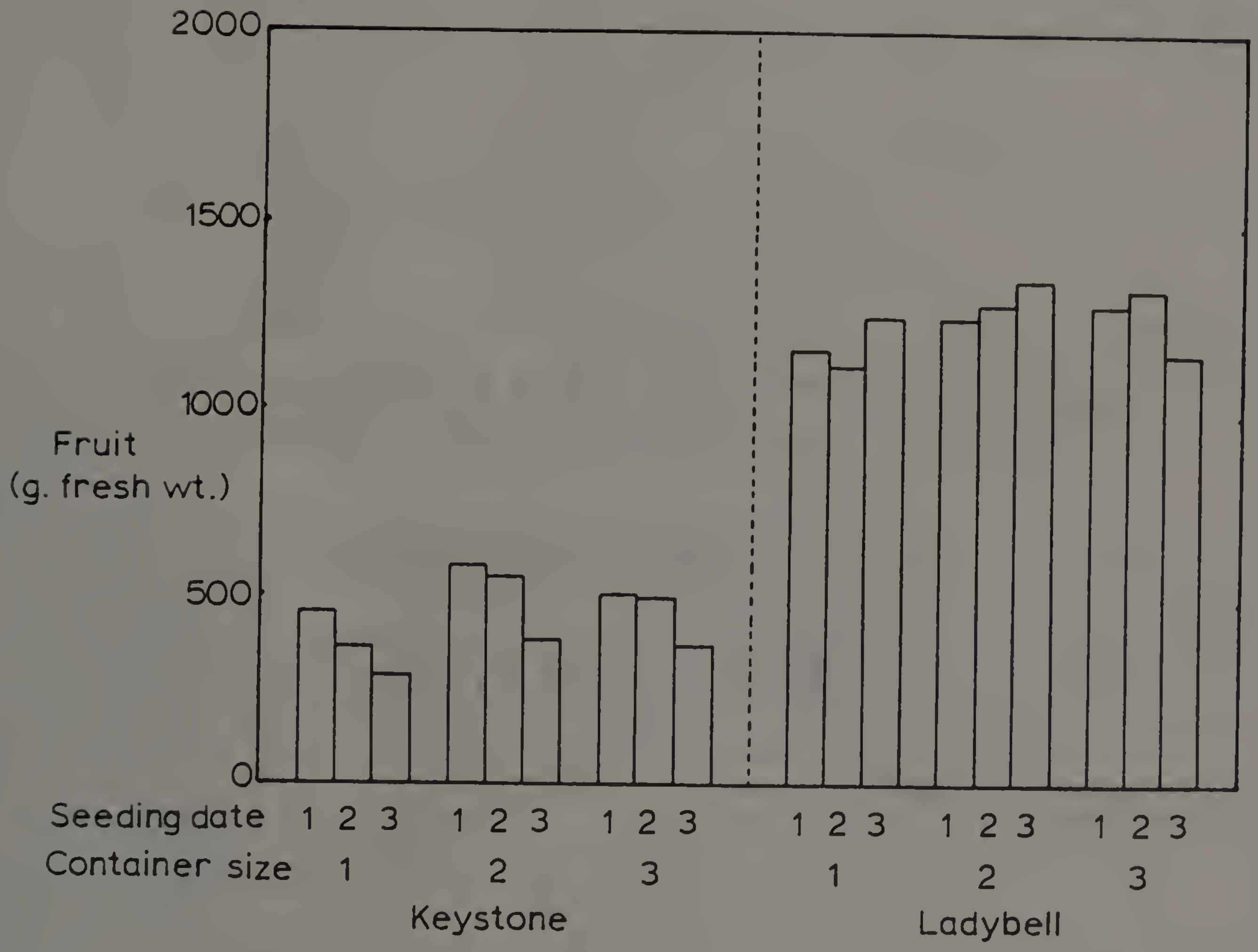

Fig. 18. Effects of variety, container size and seeding date on total fruit fresh wt per plant. Experiment 3, 1979. (Seeding Date 1 = 3/30, 2 = 4/10, 3 = 4/21; Container Size (cm3) 1 = 31, 2 = 66, 3 = 147).

The mulches used in 1979 differed from those of 1978 in that in 1978 aluminum-coated kraft paper was used, and in 1979 aluminum-coated black plastic was used. Soil temperatures between the 2 aluminum mulches differed dramatically. In 1978 soil temperatures produced under the aluminum-coated kraft paper were well below that of the bare soil control (Fig. 9), whereas in 1979, the temperatures measured beneath the aluminum-coated black plastic were greater than that of the control (Fig. 19). Otherwise, the other mulches showed the same trend as in 1978, with both clear and black plastic producing higher soil temperatures than bare soil, and clear plastic producing a higher temperature than black plastic.

About 80 days were required from seeding to first flower opening regardless of type of mulch (Fig. 20). The bare soil control took significantly longer (81.5 days) for first flowering. The sum of the first 2 harvests from those plants not deflorated (control) was highest for the three mulches, which were the same, followed by the bare soil control (Fig. 21).

As in 1978, deflorating the plants increased the fruit yields in 1979 (Fig. 22). However, in 1979 the defloration treatments started and ended later (July 2 - July 30) than in 1978 (June 8 - July 6). The later imposition of the treatments was intended to push fruit production to the limit. If yields increased as in 1978 as a result of defloration, it would be possible to observe a decrease in fruit production with the longest defloration treatments due to termination

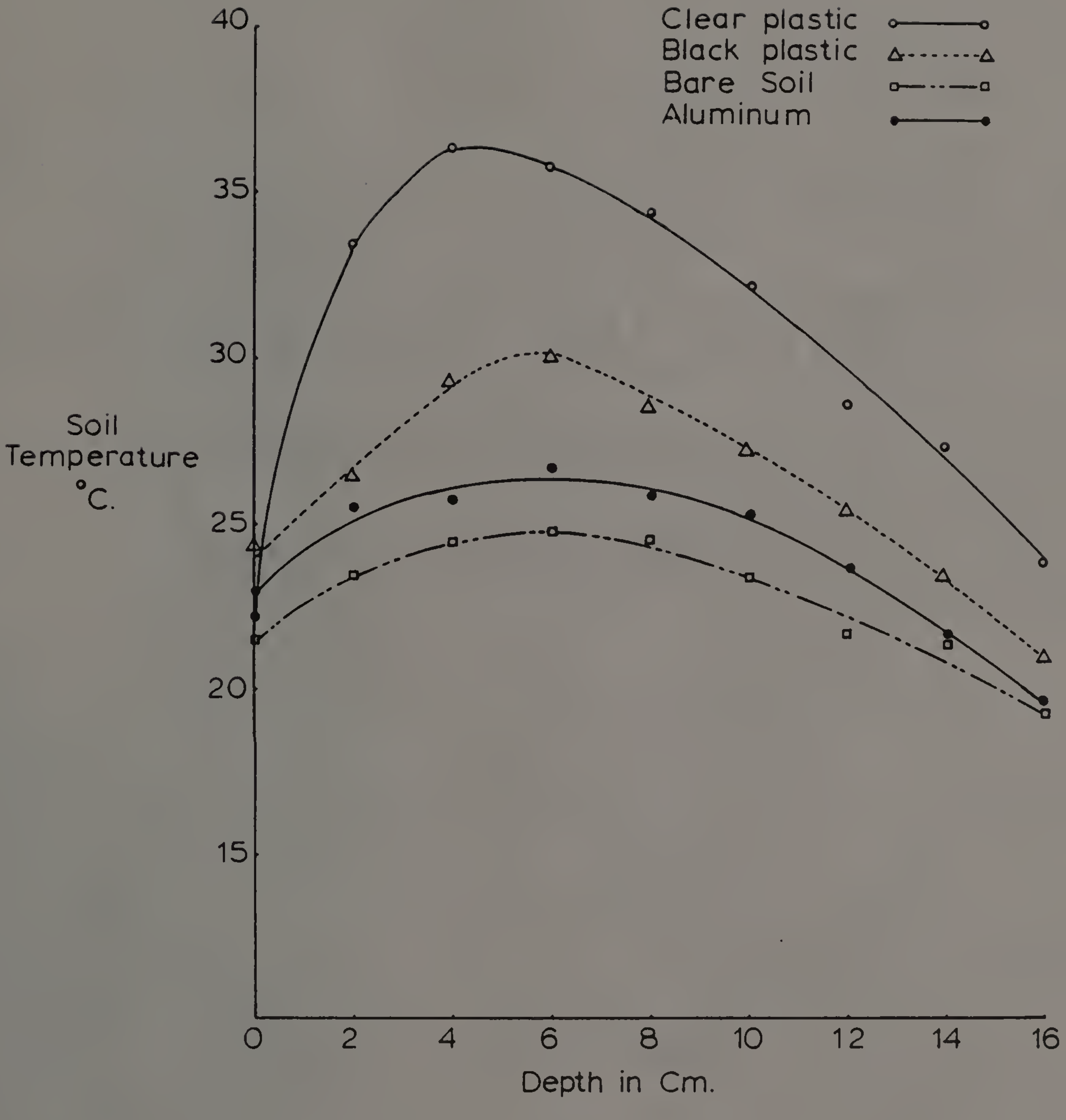

Fig. 19. Soil temperatures under mulches. Experiment 4, 1979.

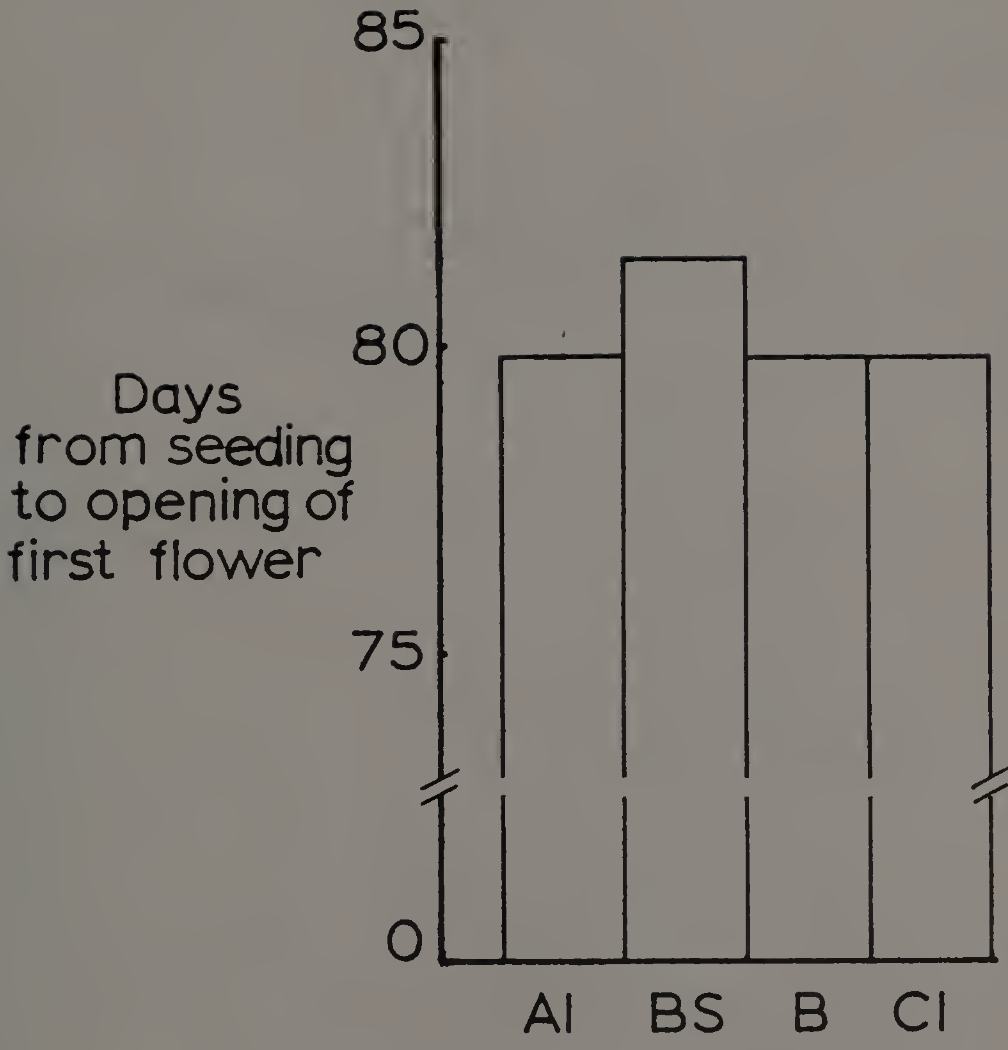

Fig. 20. Effects of mulch treatments on the number of days from seeding to opening of the first flower. Experiment 4, 1979. (Al, aluminum; BS, bare soil control; B, Black plastic; Cl, Clear plastic).

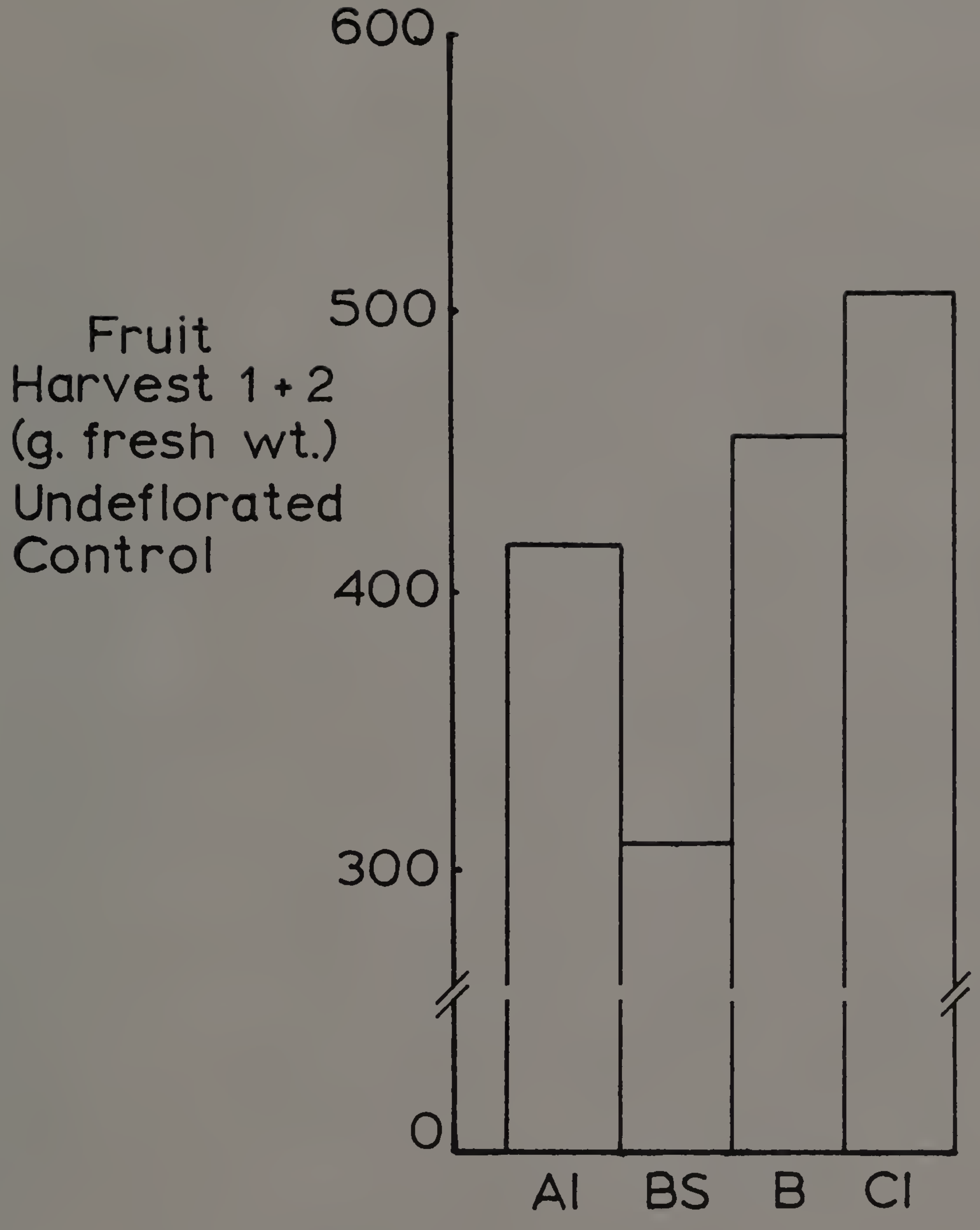

Fig. 21. Effects of mulch treatments on fruit fresh wt per plant from combined harvests 1 and 2 of the undeflorated control. Experiment 4, 1979. (Al, aluminum; BS, bare soil control; B, Black plastic; Cl, Clear plastic).

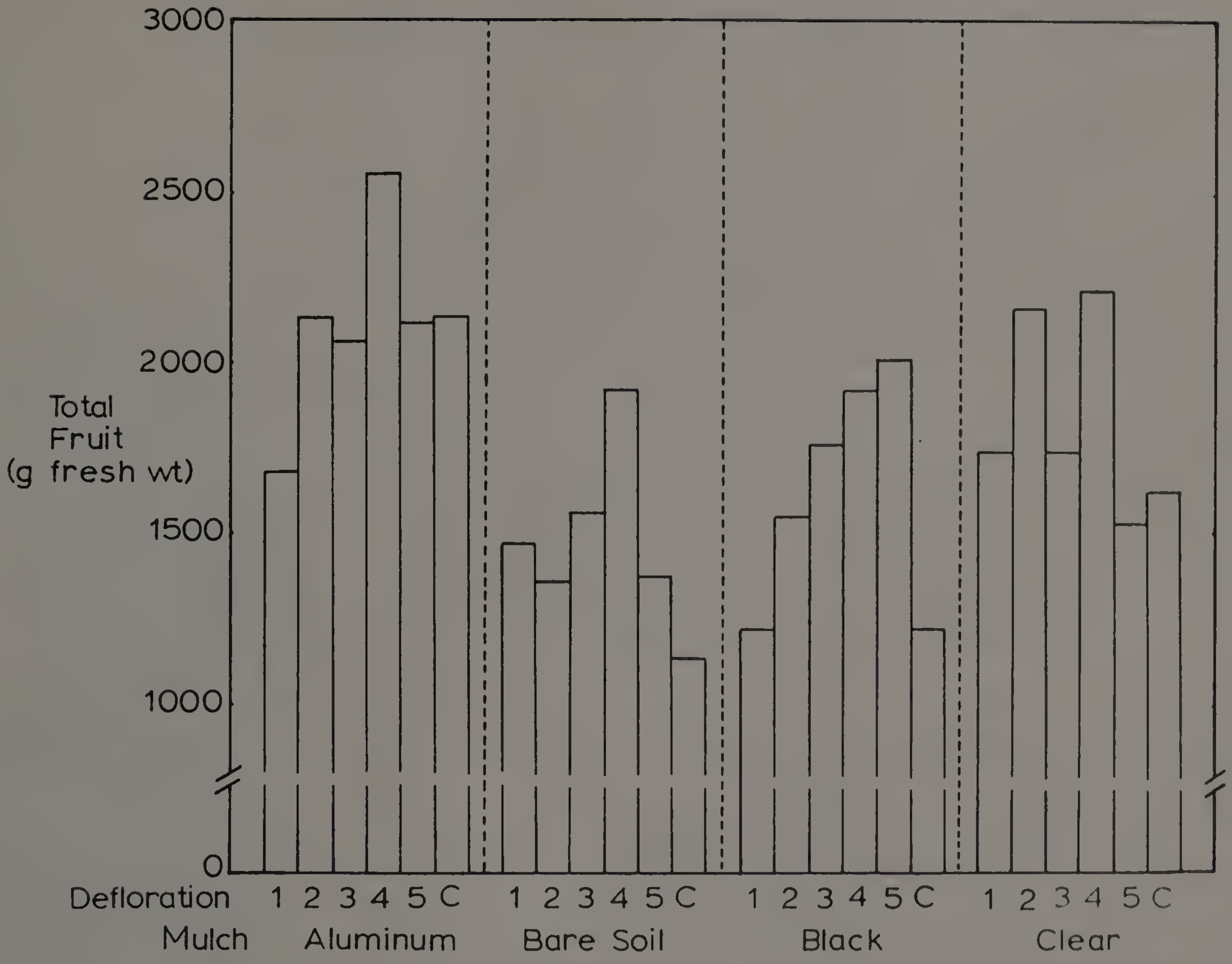

Fig. 22. Effects of mulch and defloration treatments on total fruit fresh wt per plant. Experiment 4, 1979. (Al, aluminum; BS, bare soil control; B, Black plastic; Cl, Clear plastic). Defloration; 1, to 7/2; 2, to 7/9; 3, to 7/16; 4, to 7/23; 5, to 7/30; C, no defloration).

by frost. As expected, this was the case in 1979. The first 4 defloration treatments resulted in greater total yields, measured in fruit fresh weight, with the fifth defloration treatment showing a decrease. On the other hand, when fruit yield was measured by total number of fruit (Fig. 23), no depression was realized with the fifth defloration treatment. (Note: total number of fruit here includes an eighth harvest which was comprised of immature fruit.) The control (no defloration) produced a fresh weight yield that was greater than the first defloration treatment with the aluminum mulch, but with bare soil the converse was true: the first defloration treatment out-yielded the control plants. No defloration and the first defloration treatment yielded the same fruit fresh weight. Total fruit yields were the same from the control plants as those of the first defloration treatment for all mulches.

Vegetative growth was greatly affected by the defloration treatments, and these effects were not greatly modified by type of mulch. Shoot dry weights (Fig. 24) increased with duration of defloration, though these trends were not as clearly defined as in 1978 (possibly due to having 3 plants per treatment per block instead of 5). This trend was observed with all mulches. Root dry weights (Fig. 25) responded similarly to shoot dry weight, though most durations of defloration produced a non-significant trend.

Total plant dry weights (the sum of fruit, shoot and root) generally increased with duration of defloration treatment, as

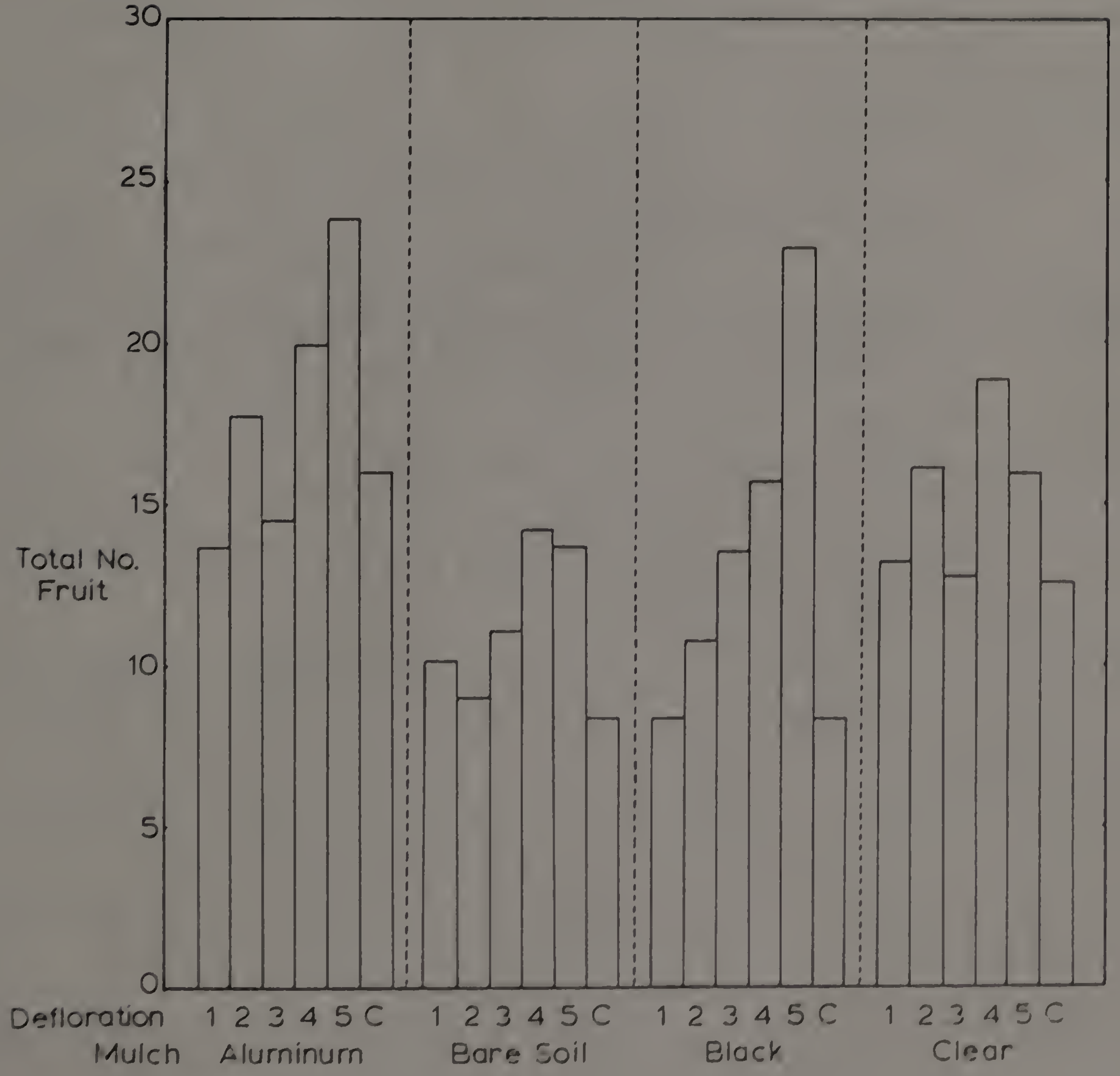

Fig. 23. Effects of mulch and defloration treatments on total number of fruit per plant. Experiment 4, 1979. (Al, aluminum; BS, bare soil control; B, Black plastic; Cl, Clear plastic). Defloration; 1, to 7/2; 2, to 7/9; 3, to 7/16; 4, to 7/23; 5, to 7/30; C, no defloration).

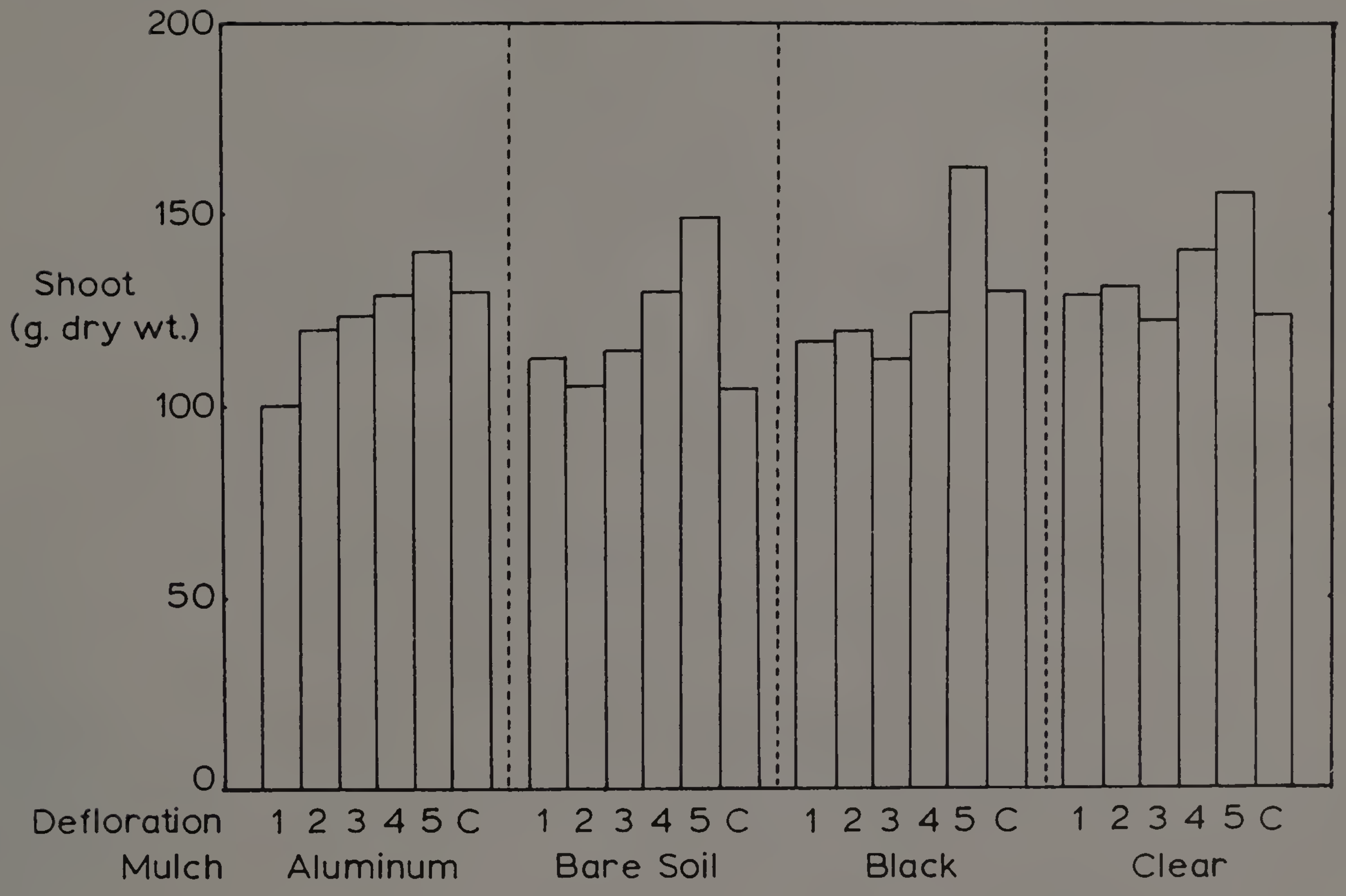

Fig. 24. Effects of mulch and defloration treatments on shoot dry wt. Experiment 4, 1979. (Al, aluminum; BS, bare soil control; B, Black plastic; Cl, Clear plastic). Defloration; 1, to 7/2; 2, to 7/9; 3, to 7/16; 4, to 7/23; 5, to 7/30; C, no defloration).

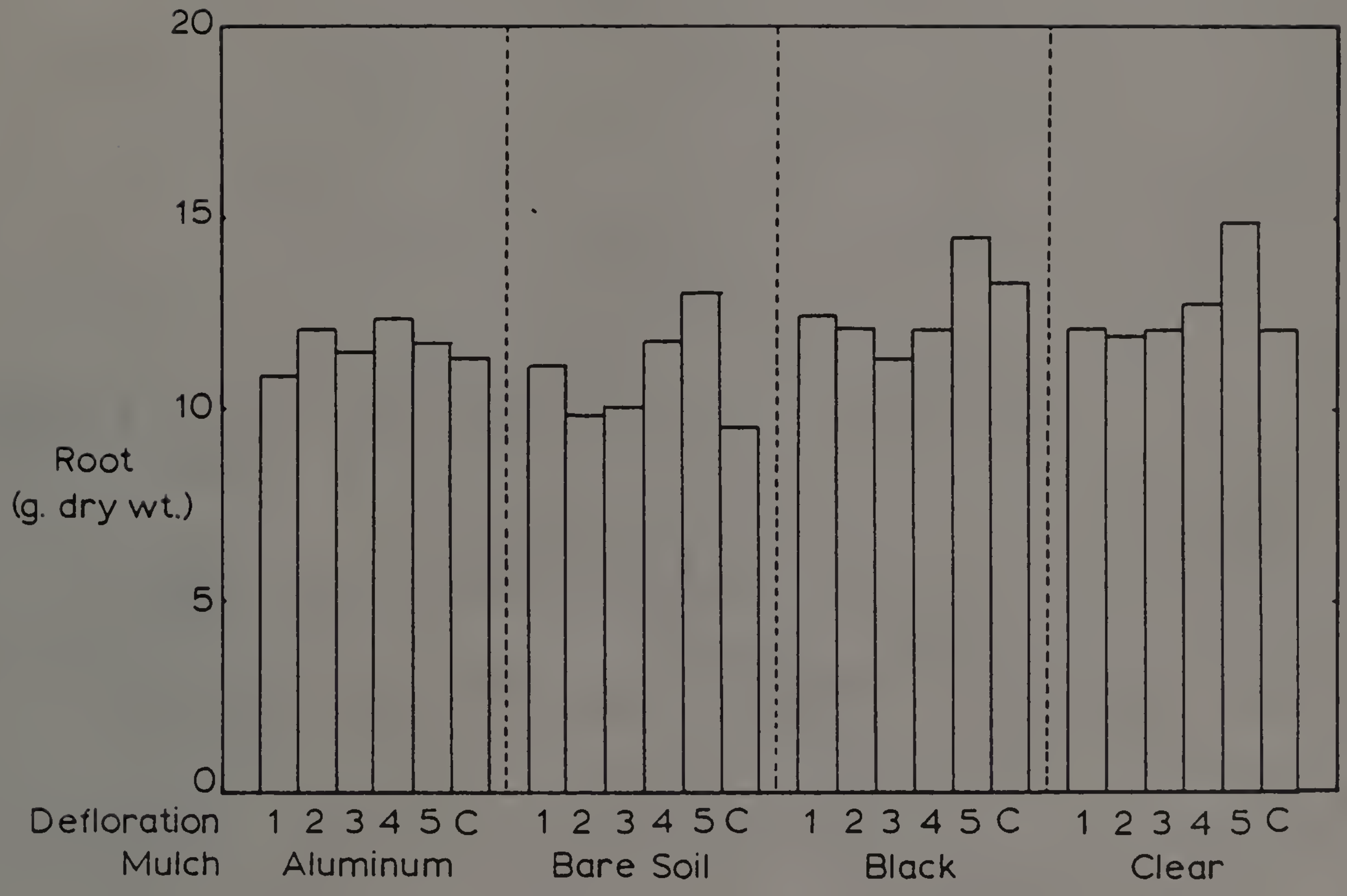

Fig. 25. Effects of mulch and defloration treatments on root dry wt. Experiment 4, 1979. (Al, aluminum; BS, bare soil control; B, Black plastic; Cl, Clear plastic). Defloration; 1, to 7/2; 2, to 7/9; 3, to 7/16; 4, to 7/23; 5, to 7/30; C, no defloration).

observed in 1978 (Fig. 26). This response was most dramatic with the black plastic mulch. The same trend occurred with the other mulch treatments, though many of the total plant dry weight means were not significantly different for all levels of defloration. Mulch effects did not differ greatly in magnitude, but differed in the consistency of the response to the vegetative duration increases.

Partitioning of the total plant dry matter into shoot, root and fruit dry weights (as percent of total plant dry weight) to total plant dry weights showed the same response as in 1978. As defloration increased, the dry wt ratio shoot/total decreased (Fig. 27). The root/total dry wt ratio (Fig. 28) did not show a clear trend among the mulches, and fruit/total dry wt ratio (Fig. 29) increased. These responses were observed in only the first 4 defloration treatments and showed the reverse response with the fifth defloration treatment.

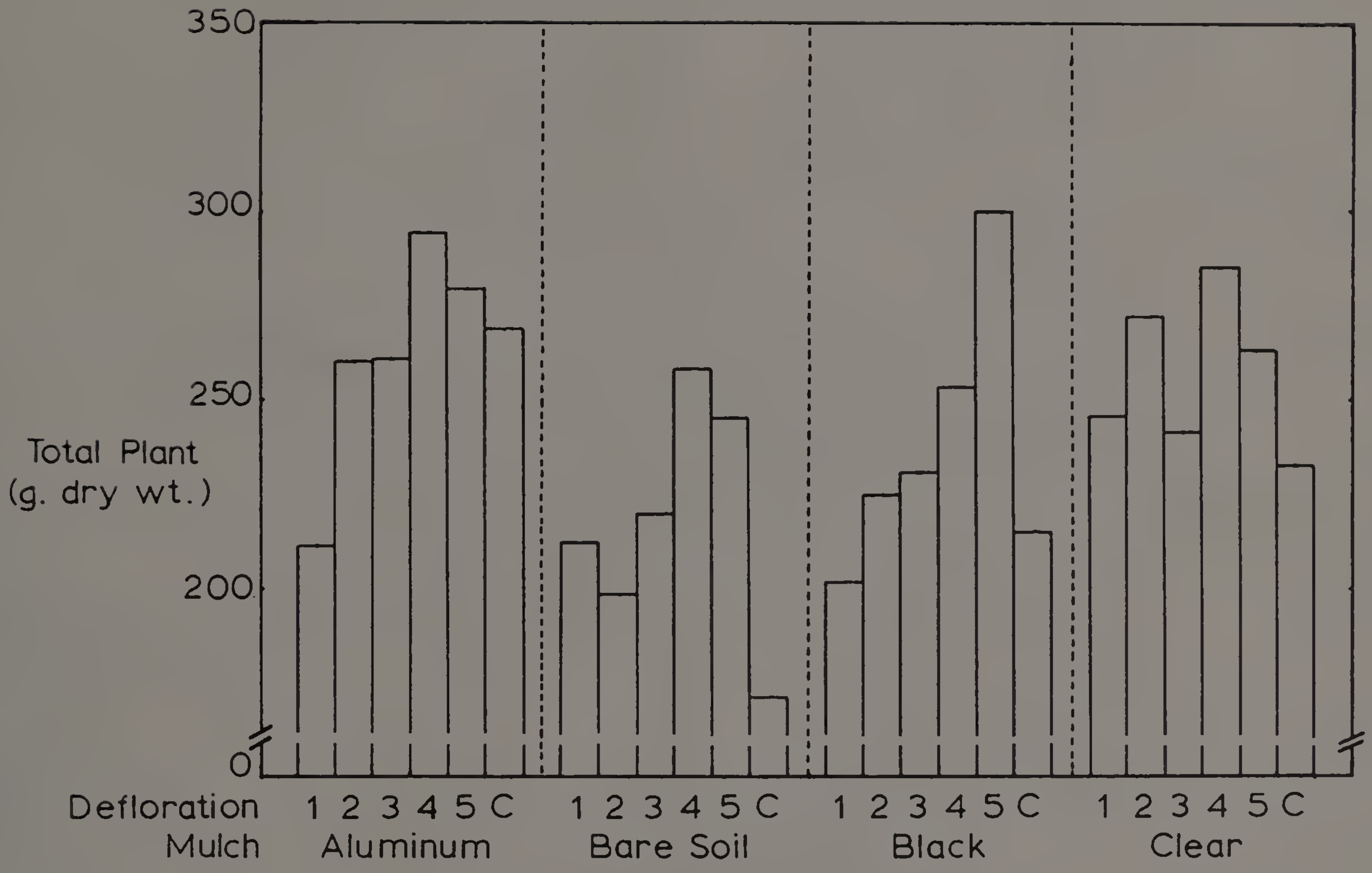

Fig. 26. Effects of mulch and defloration treatments on total plant dry wt. Experiment 4, 1979. (Al, aluminum; BS, bare soil control; B, Black plastic; Cl, Clear plastic). Defloration; 1, to 7/2; 2, to 7/9; 3, to 7/16; 4, to 7/23; 5, to 7/30; C, no defloration).

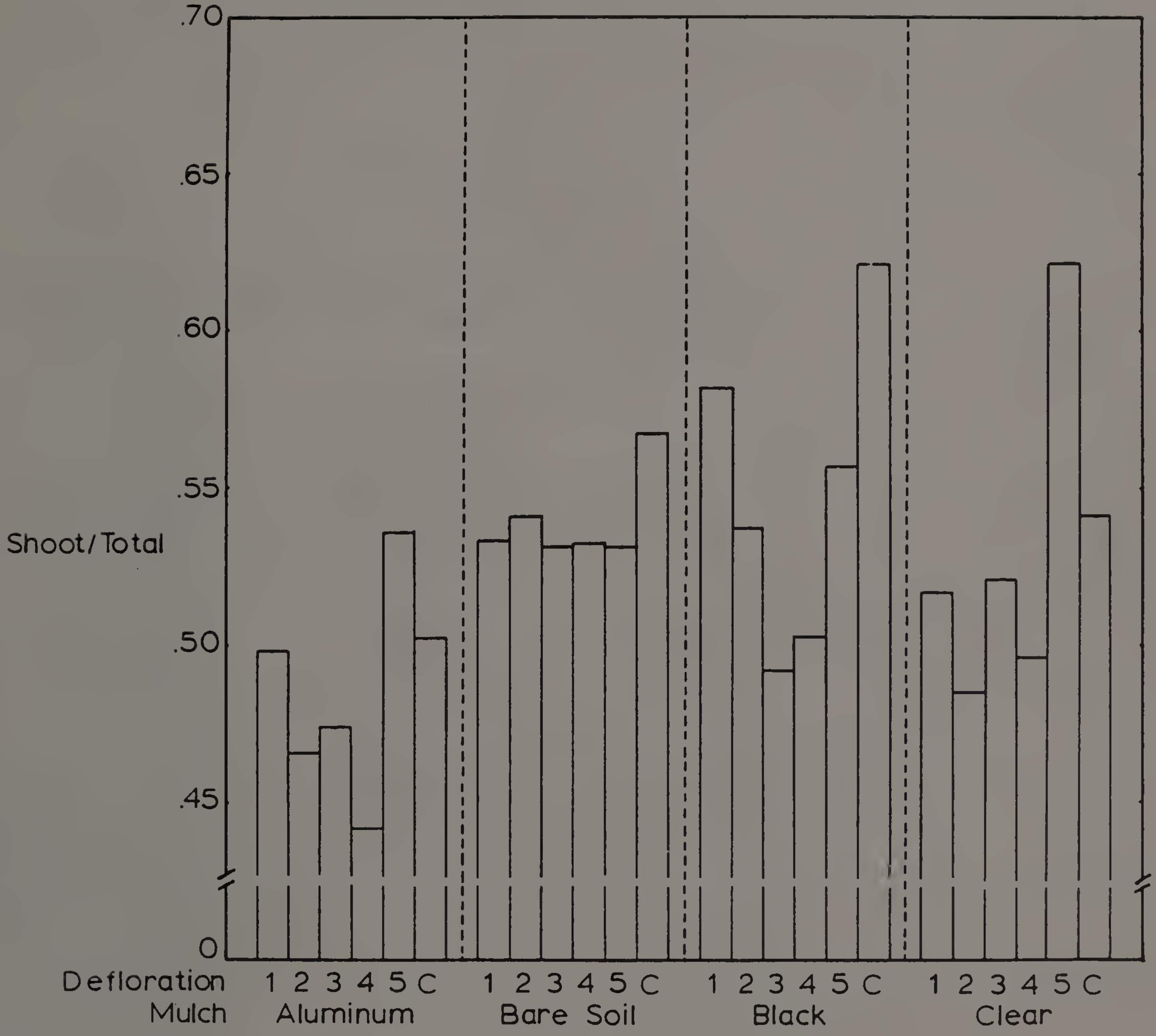

Fig. 27. Effects of mulch and defloration treatments on shoot/total dry wt ratio. Experiment 4, 1979. (Al, aluminum; BS, bare soil control; B, Black plastic; Cl, Clear plastic). Defloration; 1, to 7/2; 2, to 7/9; 3, to 7/16; 4, to 7/23; 5, to 7/30; C, no defloration).

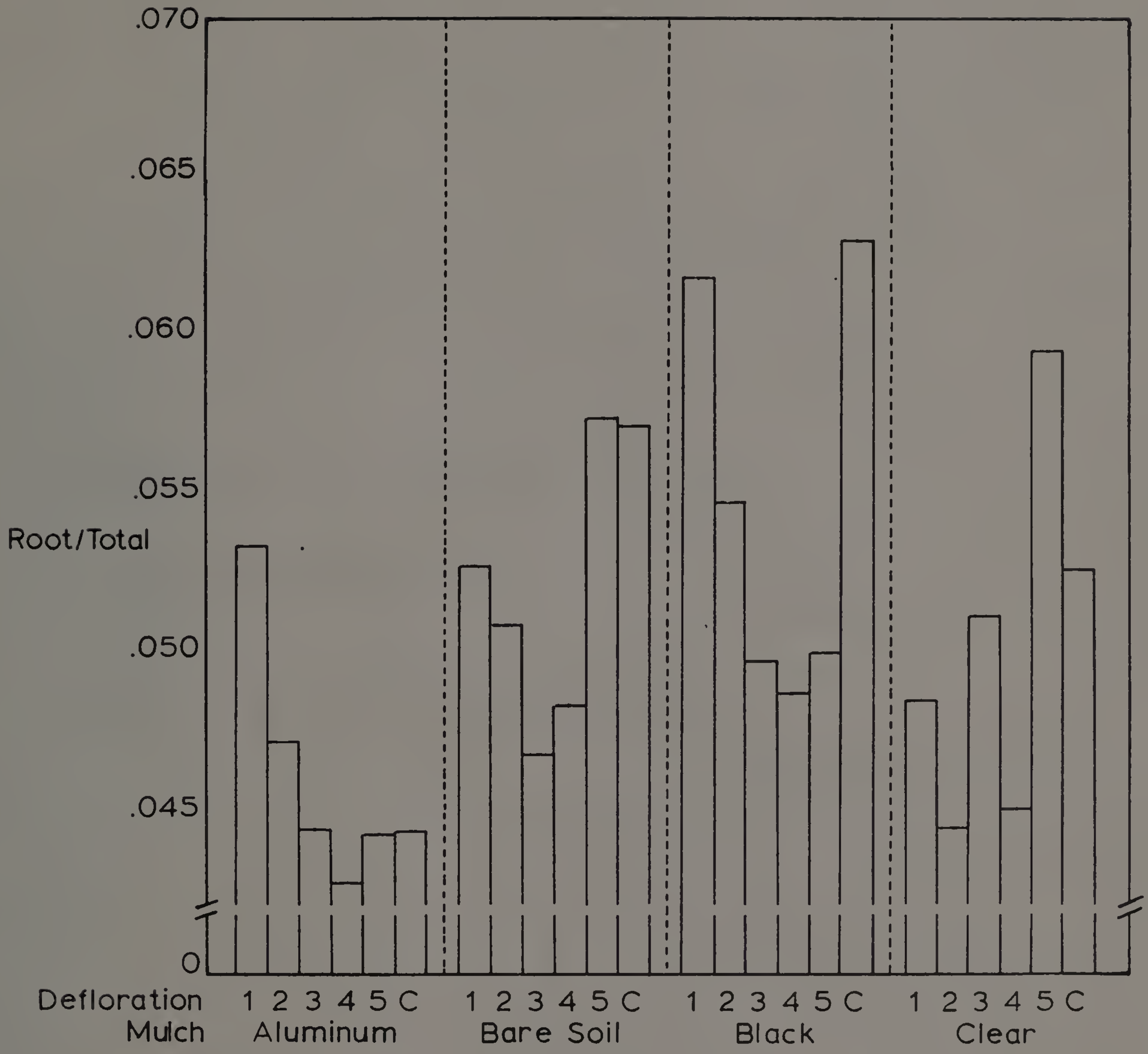

Fig. 28. Effects of mulch and defloration treatments on root/total dry wt ratio. Experiment 4, 1979. (Al, aluminum; BS, bare soil control; B, Black plastic; Cl, Clear plastic). Defloration; 1, to 7/2; 2, to 7/9; 3, to 7/16; 4, to 7/23; 5, to 7/30; C, no defloration).

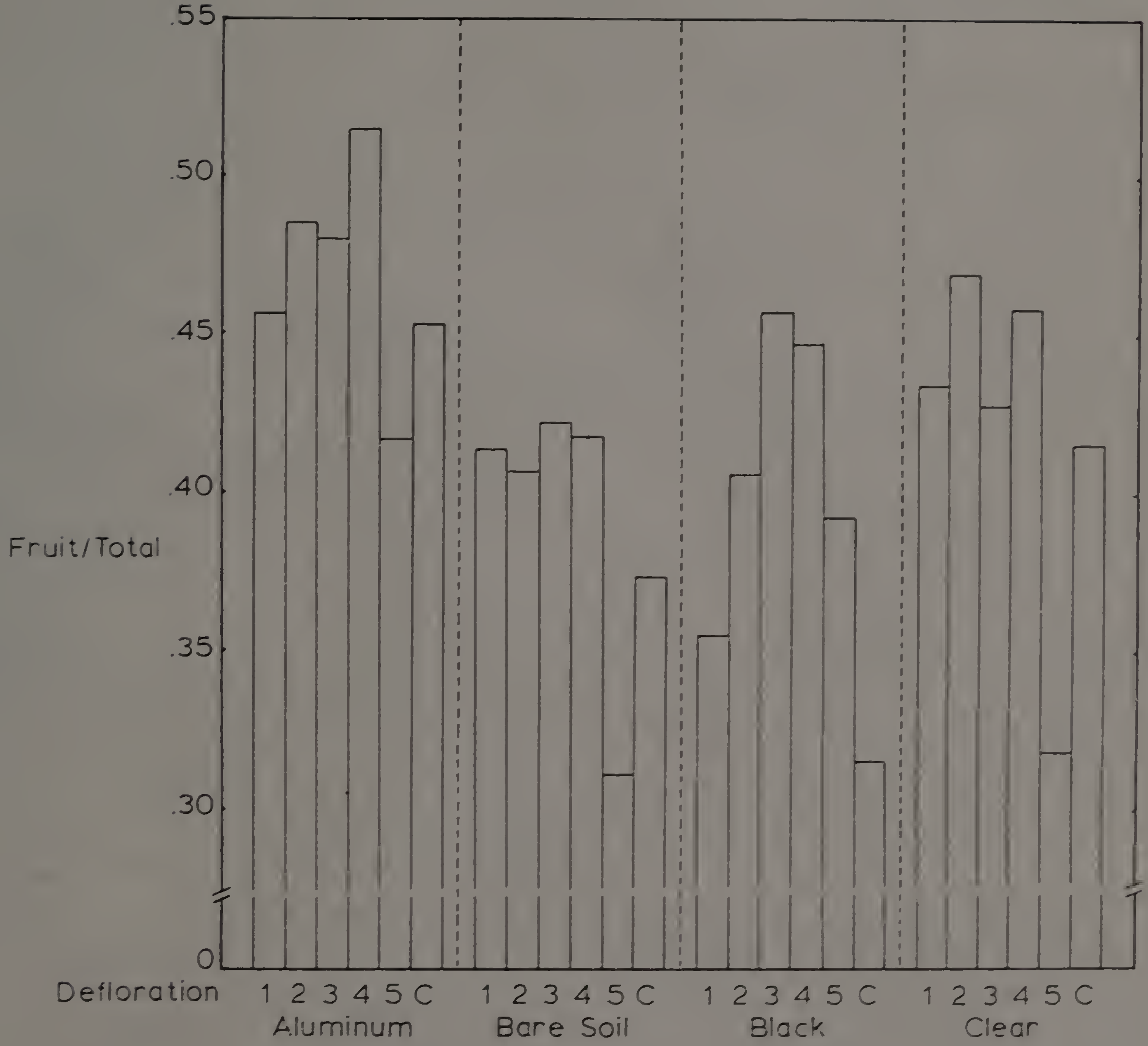

Fig. 29. Effects of mulch and defloration treatments on fruit/total dry wt ratio. Experiment 4, 1979. (Al, aluminum; BS, bare soil control; B, Black plastic; Cl, Clear plastic). Defloration; 1, to 7/2; 2, to 7/9; 3, to 7/16; 4, to 7/23; 5, to 7/30; C, no defloration).

CHAPTER V

Discussion

Hall's study (28) of vegetative growth rates as a function of deflorated vs. fruiting plants provided the foundation for the hypothesis tested by these experiments. In each of the three periods of development (seed to vegetative transplant, vegetative transplant to flowering seedling, and flowering seedling to the productive plant) the effects of manipulating the amount of vegetative matter were reflected in subsequent yields. The fruiting response showed how close a relationship there was between vegetative and subsequent reproductive growth. All treatments which caused an increase in vegetative growth resulted in increased fruit yields.

Hall's data suggest that when fruit growth rates are greatest, there is inhibition of vegetative growth rates, most notably in the stem and root. However, there is little difference in total plant growth between deflorated and fruiting plants. If this is the case, then the greatest difference between deflorated and flowering plants is in the way dry matter is partitioned.

Cyclical fruiting patterns have been observed in other vegetable crops, notably cantaloup (65), cucumbers (53), okra (62), and watermelon (22). With the decline of fruit growth rates, there was a "flush" of vegetative growth with subsequent growth of flower buds and fruitlets. This cyclical pattern suggested by Hall's study (26) was borne out in the present study (Figs. 1, 2 and 10). These results agree with findings in many other crops (43). Although this increase in vegetative growth was not measured directly, the production of flowers is a result of a dichotomous branching pattern and the "breaking" of late season axillary buds. Any peaks observed in fruit production would have necessarily been a result of this vegetative branching pattern.

The treatments of experiments 1-4 manipulated the amount of vegetative growth that occurred during different stages of development. Experiment 3 manipulated the amount of vegetative growth during period 1, the period of vegetative growth in the greenhouse. Both container size and seeding date affected the seedlings quantitatively. Early seeding dates and large container sizes resulted in maximum dry weights in both the shoot and root of the seedlings, while these dry weights were minimal with later seeding dates and smaller containers. The conditions that resulted in the greatest dry weights in the seedlings resulted in maximum production of early fruit. As seedling dry weights decreased so did early fruit production. Casseres (10) obtained similar results with tomato, noting a definite relationship between early and total yields and the condition of the seedlings when they were set in the field. With pepper Lloyd (46) got the greatest early yields with seedlings produced in 4" pots. The capacity to set early fruit then is in part a function of those conditions which result in the largest seedlings or the greatest mass of the seedlings. The conditions imposed upon the plants, however, may have qualitatively affected seedling morphology. For example, the degree of hardening could be very different among the treatments. Early seeding dates and small containers limited root volumes which may have resulted in a greater degree of hardening than with later seeding dates and larger containers, due perhaps to moisture or nutrient stresses. Hardening of vegetable seedlings is associated with checked growth and it is generally accepted that, while hardened plants can withstand wider ranges of environmental conditions, early yields are reduced (8). Tomato seedlings from early seedings tend to outgrow their containers, becoming overhardened and severely checked (13).

Although container size and seeding date affected early fruit yields differentially (Fig. 17), total yields were equivalent for all treatments, differing solely by cultivar. Similar observations have been made in tomato (67). These results can be explained by the cycling due to differential growth rates between vegetative and reproductive parts of the plant (26). Those plants which set early fruit would have reduced vegetative growth rates, whereas the plants which did not set early fruit would presumably have greater vegetative growth rates. If fruit set is a function of prior vegetative growth, then those plants which produced early fruit might very well have set fewer fruit later in the season while those plants which set few or no fruit early in the season should or would set more fruit later. This situation could provide an explanation for differential early set with no observable treatment differences over the entire season.

Defloration treatments increased the dry weight mass of the vegetative fractions observed when the plants were harvested at season's end. As predicted by Hall's work, the greatest increases were observed in the root fraction. In grapevines the increase in vegetative growth is greatest in the roots, but shoots also respond positively (11). The vigor of tomato plants was increased by defloration (86). The shoot fraction of tomato did not respond positively with defloration, however this might be explained by Hall's finding that there was little difference in leaf growth rates between deflorated and fruiting plants. The shoot fraction is comprised of the leaf and stem components of which the leaf component dominates.

Total fruit yields increased dramatically with increasing defloration both years. During the second year (experiment 4) fruit yields declined for those plants deflorated the longest (to 30 July). This was probably a result of having exceeded the upper limit of defloration that particular year, where the limit was defined by the season's first killing frost. This increase in fruit production increased the dry weight of the total plant. However, increased fruit production was not solely due to production of larger plants.

This is illustrated in Figs. 7 and 8, where the partitioning of dry matter was plotted as a function of defloration. While the shoot/total dry wt ratio decreased, the dry wt ratios of fruit/total increased, and root/total remained the same. These results suggest that the entire plant increased in the capacity to support fruit. Although defloration ultimately increased total fruit yields, there was a concomitant decrease in early fruit yields (though offset presumably by greater early vegetative growth).

An alternative method of increasing early and total vegetative and reproductive growth is to increase the vigor of the plants. Two approaches are obvious:

1. Choose cultivars which are vigorous, or have the genetic capacity to grow under a wider range of environmental conditions. Varieties with these qualities are often hybrids such as Ladybell used in several of these experiments.
2. Optimize the field conditions of the plants with cultural practices which modify the microclimate.

Plastic mulches are well known for their effect upon early and total yields (14,27,48). Of the various effects of plastic mulches, the increased soil temperature is probably responsible for many of the increases in crop performance. The mulches used in this set of experiments raised the soil temperatures over the bare soil control both years, while the aluminum coated kraft paper used during 1978 reduced soil temperatures below that of control. Increases in both vegetative and reproductive growth closely followed increases of temperature observed with the different mulch treatments. The results support the findings of others on the effects of mulches on yields (19,27,48,83). During the summer of 1978, those soils which were warmest (measured on the hottest day of the summer when differences in soil temperature under the mulches were presumed greatest) also produced the greatest amount of vegetative and reproductive growth. The results during the second year for the different mulches were different. In 1978 the clear plastic mulch resulted in the greatest fruit yields followed by the black plastic, bare soil, and aluminum kraft paper. In 1979, however, the aluminum-coated black plastic was followed by the black plastic, clear plastic and finally the control. The differences seen between the 2 years may be a result of the temperature difference between the 2 seasons, since 1979 had a much warmer season.

Other factors interacting with temperature under plastic mulches cannot be ignored. Soil moisture, soil friability, minimal nutrient losses, improved gas tensions due to less compaction, reduced weed competition, and the absence of any herbicidal interaction, could all be important growth parameters. Mulch affects the growth of the pepper plant during both vegetative and reproductive growth periods.

The only available measure of increased vegetative growth other than total vegetative growth in this study is that of the number of days from seeding to first flower opening. This parameter can be used as a relative measure of growth rates. During 1979, all of the mulches resulted in the same decrease in the number of days from seeding to the opening of the first flower relative to the control. This suggests that the rate of growth increased with the use of the mulches. This response, however, was only observed during 1979, and may be due to the fact that the transplants were already close to or at reproductive maturity when they were set in the field during 1978. In addition no differences were observed in the number of days from seeding to the opening of the first flower among the mulch treatments during 1979. This result could be due to the weather conditions that season, such as extended periods of overcast and/or cool windy days which would produce the same or similar temperatures under the mulch. he increased growth rate, the same for all mulches, may be a result of the other mulch effects. Early yields were also similar for the 3 mulch treatments during 1979, with increased fruit production for those mulches which resulted in the greatest soil temperatures (Figs. 19 and 20).

Differential total yields as a function of defloration and mulches were observed during 1979 which suggests that the greatest effect of the mulches may have been on growth during the entire season. Thus, where defloration extended the duration of vegetative growth (or duration of high vegetative growth rates), the mulches provided root environments which also produced differential growth rates.

Varietal differences between Keystone Resistant Giant and Ladybell were consistent in experiments where comparisons could be made (Experiments 1 and 3). Ladybell responded to container size and seeding date with increased early fruit production (Harvest 1 + 2) and outproduced Keystone in total fruit production by a ratio of 2 to 1. The mass of the Ladybell seedlings (root and shoot, Figs. 13 and 14) was also greater than that of Keystone when they were set in the field, suggesting that during the same period under similar conditions, Ladybell displayed greater growth rates or vigor. The great increase in early fruit yields of Ladybell over Keystone was most likely a result of Ladybell's genetic makeup, producing growth rates that were greater than Keystone's in both the greenhouse and the field. Ladybell was much better able to exploit the environment than was Keystone. This advantage may not be solely due to quantitative differences in growth discussed above but may also be a result of qualitative differences. The literature abounds with reports of heterosis in pepper, and it is no surprise that hybrid varieties continue to increase in popularity.

Experiment 1 (1978), where Keystone and Ladybell were subjected to defloration, showed varietal differences. The data showed no clear trend for increases in the shoot fraction as a function of defloration for either variety (Fig. 4) but the root fractions do, showing the same positive response for both varieties. As in experiment 3 (1979), Ladybell surpassed Keystone by a factor of 2 to

1 (Fig. 6) in fruiting response. In addition, the dry material partitioned into fruit (Figs. 7 and 8), was twice as great for Ladybell as for Keystone.

The ability of Ladybell to out-perform Keystone was utilized in this study where one of the criteria for cultivar selection was that of differential fruit setting performance. Ladybell has, since its introduction, been preferred over Keystone by many growers in New England. These varieties differ in their genome, not only in the fact that Ladybell is an F_1 hybrid and Keystone is an open-pollinated pureline, but also in that they probably differ as well in their parentage. The difference in response to all treatments in every applicable experiment in this study may be one of heterosis shown by the hybrid.

Conclusions

1. Production of early yields is dependent upon prior vegetative development. The environment prior to field transplanting can dramatically affect early fruit yields but is not reflected in total fruit yields.

2. Those plants which do not produce early fruit yields produce a period of vegetative growth free from "fruit stress". These plants show increased later yields which could be a response to the extended period of vegetative growth. Plants which produce early yields show decreased later yields. This suggests that not only are environmental constraints imposed upon plant performance but "fruiting" constraints are also important.

3. Microclimate modification such as the use of plastic mulches results in increased vegetative production, presumably by providing a root environment more conducive to root growth. Treatments resulting in increased root growth always showed increased fruit yields.

4. Fruit production is limited by field constraints and optimized by cultivar and management. These constraints are elastic because increasing the duration of vegetative growth by defloration resulted in increased fruit production.

Literature Cited

1. Aldrich, W.W. 1931. Effect of fruit thinning upon carbohydrate accumulation, formation of buds and set of bloom in apple trees. *Proc. Amer. Soc. Hort. Sci.* 28:599-604.

2. Atkinson, and Davidson. 1971. The effect of phosphorus deficiency on growth of *Epilobium montana*. *New. Phytol.* 70:789-797.

3. Auchter, E. C. 19 . Apple pollen and pollination studies in Maryland. *Proc. Amer. Soc. Hort. Sci.* 18:51-80.

4. Austin, S. 1935. Effects of exfloration on plant metabolism. *Pl. Physiol.* 10:225-243.

5. Bailey, J. S. 1929. Effect of apple blossom removal on flower bud formation. *Proc. Amer. Soc. Hort. Sci.* 25:198-201.

6. Baker, C. E. 1937. Early fruiting of tomatoes as induced by the use of soluble phosphates. *Proc. Amer. Soc. Hort. Sci.* 36:668-672.

7. Brantly, B. B. and G. F. Warren, 1961. Effect of nitrogen nutrition on flowering, fruiting and quality in the muskmelon. *Proc. Amer. Soc. Hort. Sci.* 77:424-431.

8. Brasher, E. P. and K. C. Westover. 1937. The effect on yield of hardening the tomato plant. *Proc. Amer. Soc. Hort. Sci.* 35:686-689.

9. Brenchley, W. F., 1929. The phosphate requirement of barley at different periods of growth. *Ann. Bot.* (London) 43:89-110.

10. Casseres, E. H.- 1947. Effect of date of sowing, spacing, and foliage trimming of plants in flats on yield of tomatoes. *Proc. Amer. Soc. Hort. Sci.* 50:285-289.

11. Chandler, W. H. and A. J. Heinicke. 1925. Some effects of fruiting on the growth of grapevines. *Proc. Amer. Soc. Hort. Sci.* 22:74-80.

12. Charles, W. B. and R. E. Harris. 1972. Tomato fruit-set at high and low temperatures. *Can. J. Plant. Sci.* 52:497-506.

13. Chipman, E. W. 1961. The effect of seeding and plant topping on the production of early and total yields of ripe tomatoes. Proc. Amer. Soc. Hort. Sci. 77:483-486.

14. Clarkson, V. A. 1957. Effect of paper and polyethylene mulches and plastic caps on cantaloup yields and earliness. Proc. Amer. Soc. Hort. Sci. 69:400-404.

15. Cochran, H. L. 1932. Factors affecting flowering and fruit setting in the pepper. Proc. Amer. Soc. Hort. Sci. 29:434-437.

16. Cochran, H. L. 1936. Some factors influencing growth and fruit setting in the pepper, Capsicum frutescens L. Cor. Univ. Exp. Sta. Mem. 190:1-41.

17. Cochran, H. L. 1936. Some factors which influence the germination of pepper seeds. Proc. Amer. Soc. Hort. Sci. 33:477-480.

18. Courtier, J. W. and N. F. Oebker. 1964. Comparisons of paper and polyethylene mulching on yields of certain vegetable crops. Proc. Amer. Soc. Hort. Sci. 85:528-531.

19. Crist, J. W. 1928. Ultimate effect of hardening tomato plants. Mich. Tech. Bul. 89.

20. Crow, J. W. 1920. Biennial fruit bearing in the apple. Proc. Amer. Soc. Hort. Sci. 17:52-54.

23. Crowther, F. 1941. Studies in growth analyses of the cotton plant under irrigation in the sudan. II. Seasonal variations in development and yield. Ann. Bot. (London) n.s. 5:509-533.

24. Cunningham, C. R. 1939. Fruit setting of watermelons. Proc. Amer. Soc. Hort. Sci. 37:811-814.

21. Davis, L. D. 1942. The effect of deflorating or defruiting upon blossom-bud differentiation in the sugar prune. Proc. Amer. Soc. Hort. Sci. 40:126-127.

22. Deli, J. and H. Tiessen. 1969. Interaction of temperature and light intensity on flowering of Capsicum frutescens var. grossum cv. California Wonder. J. Am. Soc. Hort. Sci. 94(4):349-351.

25. Dorland, R. E. and F. W. Went. 1947. Plant growth under controlled conditions. VIII. Growth and fruiting of the chili pepper. Amer. J. Bot. 34(8):393-401.

26. Drain, B. D. 1924. Annual crops from biennial bearing apple trees. Proc. Amer. Soc. Hort. Sci. 21:300-302.

27. Emmert, E. M. 1957. Black polyethylene for mulching vegetables. Proc. Amer. Soc. Hort. Sci. 69: 464-469.

28. Hall, A. J. 1977. Assimilate source-sink relationships in Capsicum annuum L. I. The dynamics of growth in fruiting and deflorated plants. Aust. J. Pl. Physiol. 4:623-636.

29. Hall, A. J. 1978. Assimilate source-sink relationships in Capsicum annuum L. III. The effects of fruit excision on photosynthesis and leaf and stem carbohydrates. Aust. J. Pl. Physiol. 5:1-13.

30. Harris, R. E. 1965. Polyethylene covers and mulches for corn and bean production in northern regions. Proc. Amer. Soc. Hort. Sci. 87:288-294.

31. Hicks, D. R., J. W. Pendleton. 1969. Effect of floral bud removal on performance of soybeans. Crop. Sci. 9:435-437.

32. Hopen, H. J. 1965. Effects of black and transparent polyethylene mulches on soil temperature, sweet corn growth and maturity in a cool growing season. Proc. Amer. Soc. Hort. Sci. 88:415-420.

33. Howlett, F. S. 1936. The effect of carbohydrate and of nitrogen deficiency upon microsporogenesis and the development of the male gametophyte in the tomato. Lycopersicon esculentum Mill. Ann. Bot. (London) 50:767-804.

34. Hudson, J. P. 1960. Relations between root and shoot growth in tomatoes. Scientia. Hort. 14:49-54.

35. Hurd, R. G., A. P. Gay and A. C. Mountifield. 1979. The effect of partial flower removal on the relation between root, shoot and growth in the indeterminate tomato. Ann. Appl. Bot. 93:77-89.

36. Johnston, J., Econometric Methods. 2nd Ed., McGraw-Hill Book Co., New York: 1972.

37. Knavel, D. E. 1965. Influence of container size, and spray on growth of transplants and yields in tomato. Proc. Amer. Soc. Hort. Sci. 86:582-586.

38. Knavel, D. E. and Mohr, H. C. 1967. Distribution of roots of four different vegetables under paper and polyethylene mulches. Proc. Amer. Soc. Hort. Sci. 91:589-597.

39. Knavel, D. E. 1977. The influence of nitrogen on pepper transplant growth and yielding potential of plants with different levels of nitrogen. J. Am. Soc. Hort. Sci. 102:533-535.

40. Kraus, E. J. and H. R. Kraybill. 1918. Vegetation and reproduction with special reference to the tomato. Ore. Agr. Exp. Sta. Bul. 149.

41. Lachman, W. H., et al. 1941. The effect of methods of growing and transplanting the plants on the yield of peppers. Proc. Amer. Soc. Hort. Sci. 38:554-556.

42. Leonard, E. R. and G. C. Head. 1958. Technique and preliminary observations on growth of the roots of glasshouse tomatoes in relation to that of the tops. J. Hort. Sci. 33:171-185.

43. Leonard, E. R. 1962. Inter-relations of vegetative and reproductive growth, with special reference to indeterminate plants. Bot. Rev. 28(3):353-410.

44. Lingle, J. C. And R. M. Davis. 1959. The influence of soil temperature and phosphorus fertilization on the growth and mineral absorption of tomato seedlings. Proc. Amer. Soc. Hort. Sci. 73:312-322.

45. Lippert, L. F., et al. 1964. Soil moisture under bands of petroleum and polyethylene mulches. Proc. Amer. Soc. Hort. Sci. 85:541-546.

46. Lloyd, J. W. 1926. Some tests in the culture of peppers. Ill. Agr. Exp. Sta. Bul. 274.

47. Lorenz, O. A. and D. N. Maynard, Knott's Handbook for Vegetable Growers (2nd. Ed.) John Wiley and Sons. New York, Chichester, Brisbane, Toronto: 1980.

48. Loy, J. B. and O. S. Wells. 1975. Response of hybrid

muskmelons to polyethylene row covers and black polyethylene mulch. *Scientia*. *Hort*. 3:223-230.

49. Luckwill, L. C. 1953. Studies of fruit development in relation to plant hormones I. Hormone production by the developing apple seed in relation to fruit drop. *J*. *Hort*. *Sci*. 28:14-24.

50. Mack, W. B. 1924. Habits of growth and bearing of apple varieties as related to biennial bearing. *Proc*. *Amer*. *Soc*. *Hort*. *Sci*. 21:296-300.

51. Maggs, D. H. 1963. The reduction in growth of apple trees brought about by fruiting. *J*. *Hort*. *Sci*. 38:119-128.

52. Maynard, D. N., *et al*. 1962. The influence of nitrogen levels on flowering and fruit set of peppers. *Proc*. *Amer*. *Soc*. *Hort*. *Sci*. 81:385-389.

53. McCollum, J. P. 1934. Vegetative and reproductive responses associated with fruit development In the cucumber. *Cor*. *Univ*. *Exp*. *Sta*. *Mem*. 163.

54. Miller, C. H. 1961. Some effect of different levels of five nutrient elements on bell peppers. *Proc*. *Amer*. *Soc*. *Hort*. *Sci*. 77:440-448.

55. Miller, C. H., *et al*. 1979. Relationships between growth of bell peppers (*Capsicum annuum* L.) and nutrient accumulation during ontogeny in field environments. *J*. *Am*. *Soc*. *Hort*. *Sci*. 104(6):852-857.

56. Mulcahy, D. L. 1978. Personal Communication.

57. Murneek, A. E. 1924. The effects of fruit on vegetative growth in plants. *Proc*. *Amer*. *Soc*. *Hort*. *Sci*. 21:274-276.

58. Murneek, A. E. 1926a. The effects of correlation between reproductive functions in the tomato (*Lycopersicon esculentum* Mill) *Pl*. *Physiol*. 1:3-56.

59. Nightingale, G. T., *et al*. 1928. The growth status of the tomato as correlated with organic nitrogen and carbohydrate in roots, stems and leaves. *New*. *Jersey*. *Exp*. *Sta*. *Bull*. 461:3-38.

60. Oebker, N. F. and H. J. Hopen. 1974. Microclimate modification and the vegetable crop ecosystem. Hort. Sci. 9(6):564-568.

61. Olney, A. J. 1918. Some experiments with tomatoes. Kentucky. Agr. Exp. Sta. Bul. 218.

62. Perkins, D. Y., *et al*. 1952. Influence of pod maturity on the vegetative and reproductive behavior of okra. Proc. Amer. Soc. Hort. Sci. 60:311-314.

63. Radspinner, W. A. 1922. Effects of certain physiological factors on blossom drop and yield of tomatoes. Proc. Amer. Soc. Hort. Sci. 19:71-82.

64. Rosa, J. T. 1923. Tomato production in California. Cal. Agr. Exp. Sta. 263.

65. Rosa, J. T. 1924. Fruiting habit and pollination of cantaloup. Proc. Amer. Soc. Hort. Sci. 21:51-57.

66. Rylski, I. 1972. Effect of the early environment on flowering in pepper. (*Capsicum annuum* L.) J. Am. Soc. Hort. Sci. 97(5):648-651.

67. Sayre, C. B. 1948. Early and total yields of tomatoes as affected by time of seeding, topping the plants and space in flats. Proc. Amer. Soc. Hort. Sci. 51:367-370.

68. Shannon, S., *et al*. 1967. Influence of low temperature on fruit set of tomatoes. Farm Research. 31(1):13, Tomato Genetics Coop. Rpt. 15:57, 16:33.

69. Singh, K. 1962. Responses of bell peppers (*Capsicum annuum* L.) to excision of initial flowers and fruits and fertilization with nitrogen and calcium. Ph.D. Thesis, University of Florida, Gainesville. 1962.

70. Singh, K. and V. F. Nettles. 1962. Effect of defloration, defruiting, nitrogen and calcium on the growth and fruiting responses of bell peppers. Proc. Amer. Soc. Hort. Sci. 74:204-209.

71. Slack, G. and A. Calvert. 1977. The effect of truss removal on the yield of early sown tomatoes. J. Hort. Sci. 52:309-315.

72. Smith, O. 1932. Relation of temperature to anthesis and blossom drop of the tomato, together with a histological study of the pistils. J. Agr. Res. 44:183-190.

73. Smith, O. 1935. Pollination and life history studies of the tomato. Cor. Univ. Exp. Sta. Mem. 184:1-16.

74. Smith, O. and H. L. Cochran. 1935. Temperature and pollen germination in the tomato. Cor. Univ. Exp. Sta. Mem. 175:1-11.

75. Steel, R. G. D. and J. H. Torrie. Principles and Procedures of Statistics, McGraw-Hill Book So. New York, Toronto, London: 1972.

76. Struckmeyer, B. E. and R. H. Roberts. 1941. The time of blossom induction in wealthy apples as determined by defloration and defoliation. Proc. Amer. Soc. Hort. Sci. 38:93.

77. Takatori, f. H., L. F. Lippert and F. L. Whiting. 1964. The effect of petroleum mulch and polyethylene films on soil temperature and plant growth. Proc. Amer. Soc. Hort. Sci. 85:532-540.

78. Tamas, I. A., et al. 1979. Effect of older fruits on abortion and abscisic acid concentration of younger fruits in Phaseolus vulgaris L. Pl. Physiol. 64(4):620-622.

79. Taranovsky, W. G. 1923. Uber veranderungen welche in Pflanzendurch das Kastration verfahren herforgenfuen werden. Zhur. Opytn, Agron. 23:127-164.

80. Tayo, T. O. 1977. Effect of flower or pod removal on the performance of soybeans (Glycine max, L.) J. Am. Soc. Hort. Sci. , Cambridge, 89:229-234.

81. Thies, W. H. 1933. Effect of defloration on leaf spur area in McIntosh apple. Proc. Amer. Soc. Hort. Sci. 30:309-312.

82. Thomas, J. R. and M. D. Heilman. 1964. Nitrogen and phosphorus content of leaf tissue in relation to sweet pepper yields. Proc. Amer. Soc. Hort. Sci. 85:419-425.

83. Thompson, H. C. and H. Platenius. 1931. Results of paper mulch experiments with vegetable crops. Proc. Amer. Soc. Hort. Sci. 28:305-308.

84. Veliath, J. A. and A. C. Ferguson. 19 . The effect of deblossoming in fruit size on yield, and earliness in tomato. Hort. Sci. 7(3):278-279.

85. Wadleigh, C. H. 1944. Growth status of the cotton plant as influenced by the supply of nitrogen. Ark. Agr. Exp. Sta. Bul. 446.

86. Waggoner, P. E., et al. 1960. Plastic mulching in principle and effect. Conn. Agr. Exp. Sta. Bul. 634.

87. Ware, G. W. and J. P. McCollum, Producing Vegetable Crops, 2nd Ed. Interstate Printers and Publishers, Inc. Danville, Ill.: 1975.

88. Watts, V. M. 1931. Some factors which influence growth and fruiting of the tomato plant. Ark. Agr. Exp. Sta. Bul. 267.

89. Willis, W. O., W. E. Larson, and D. Kirkham. 1957. Corn growth as affected by soil temperature and mulch Agron. J. 49:323-328.

APPENDIX

APPENDIX A

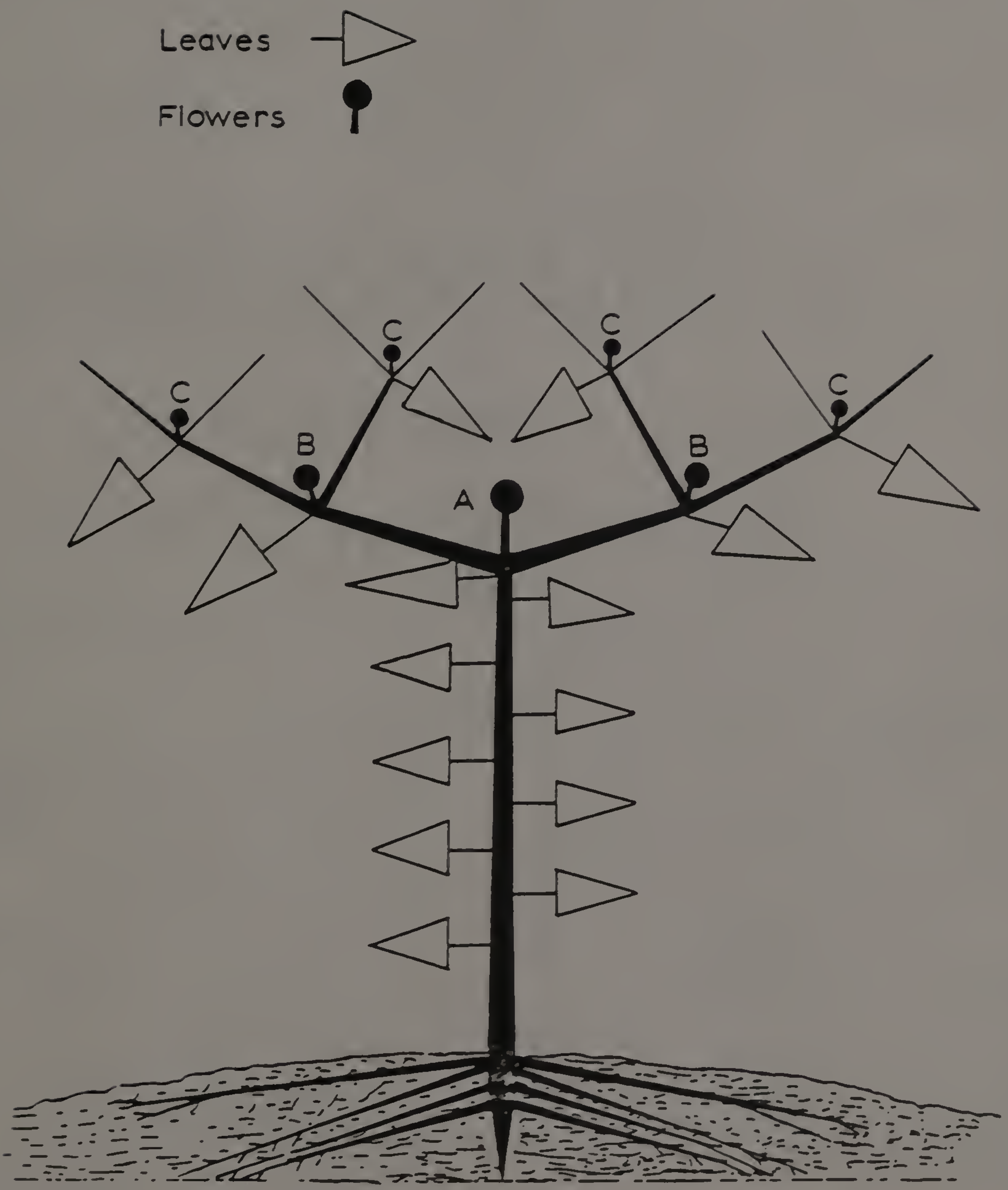

Fig. 30. Schematic of the pepper plant.

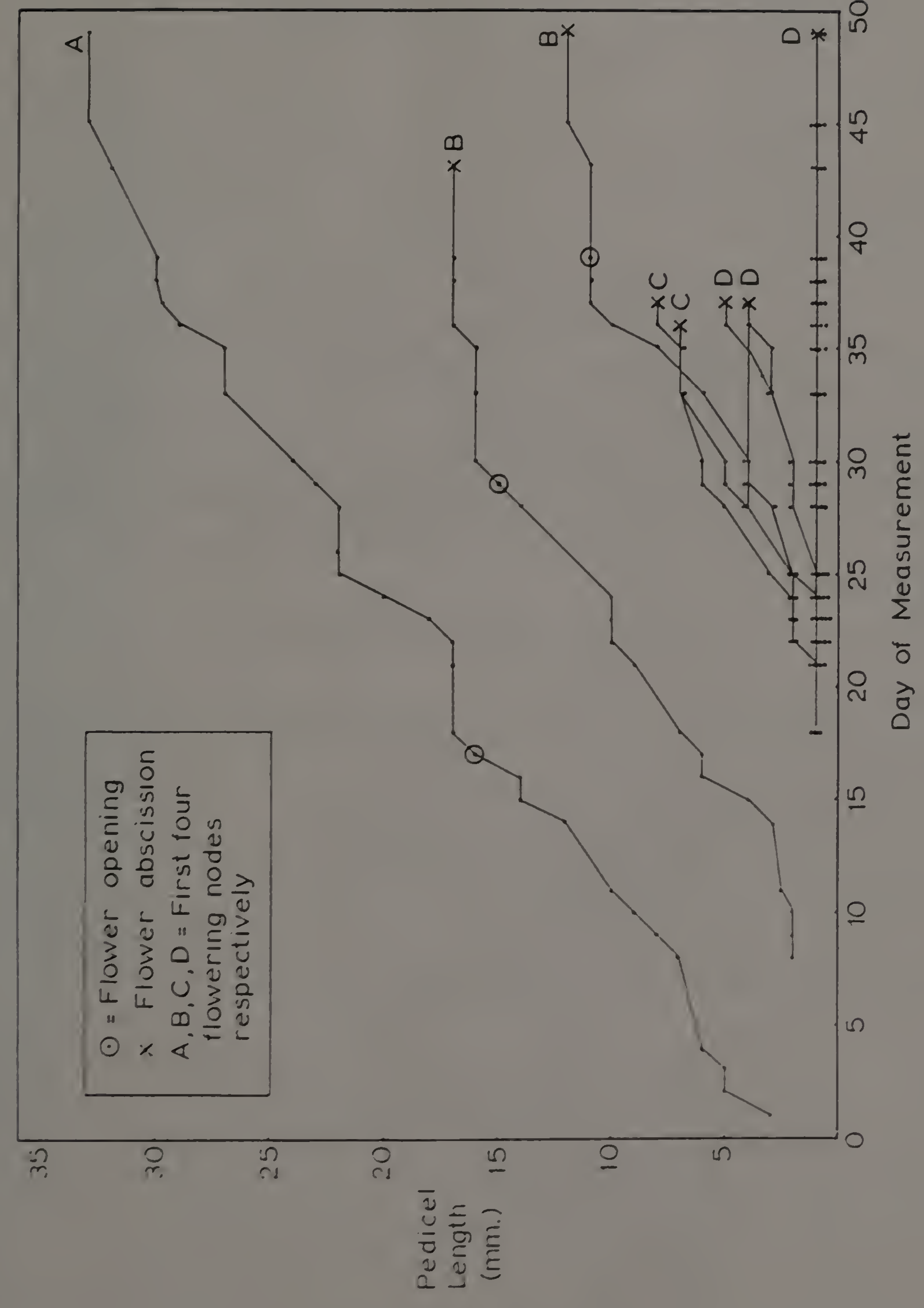

Fig. 31. Pedicel lengths of the first four flowering nodes of a pepper plant over time.

APPENDIX B

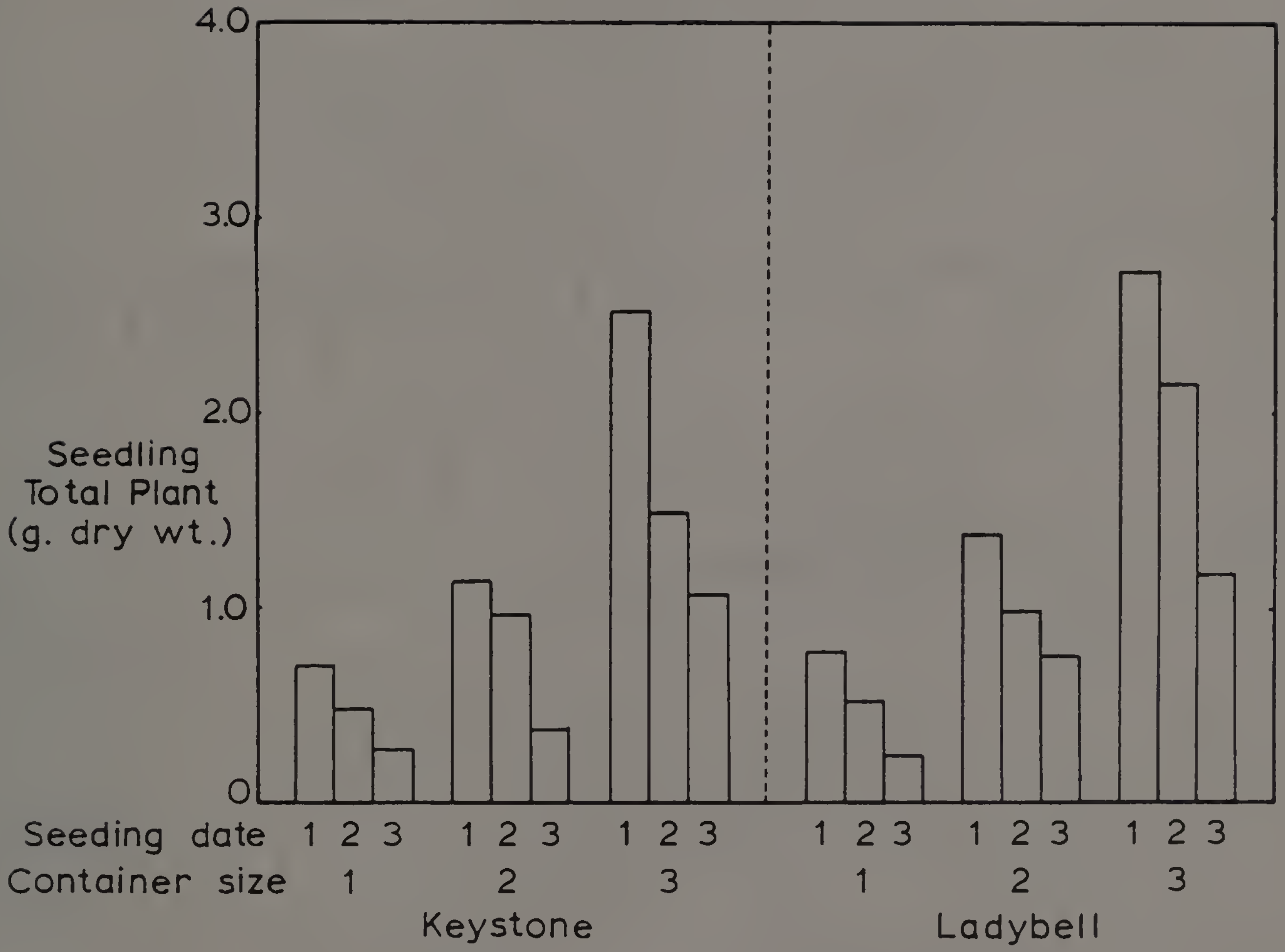

Fig. 32. Effects of variety, container size and seeding date on seedling total plant dry wt. Experiment 3, 1979. (Seeding Date 1 = 3/30, 2 = 4/10, 3 = 4/21; Container Size (cm3) 1 = 31, 2 = 66, 3 = 147).

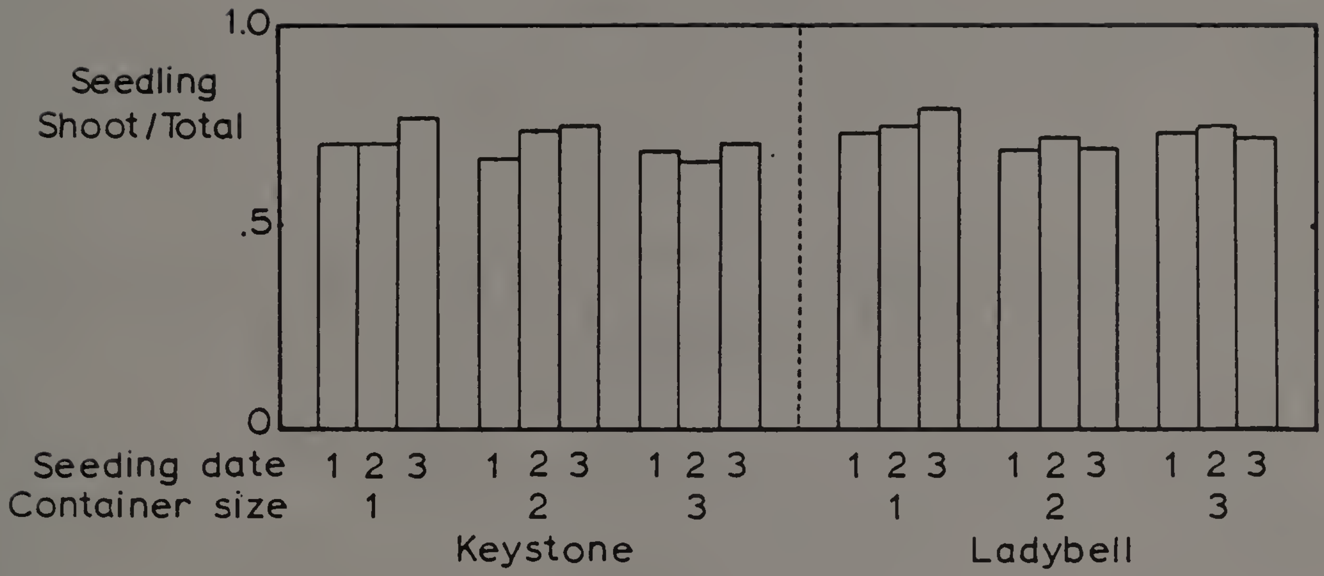

Fig. 33. Effects of variety, container size and seeding date on seedling shoot/total dry wt ratio. Experiment 3, 1979. (Seeding Date 1 = 3/30, 2 = 4/10, 3 = 4/21; Container Size (cm3) 1 = 31, 2 = 66, 3 = 147).

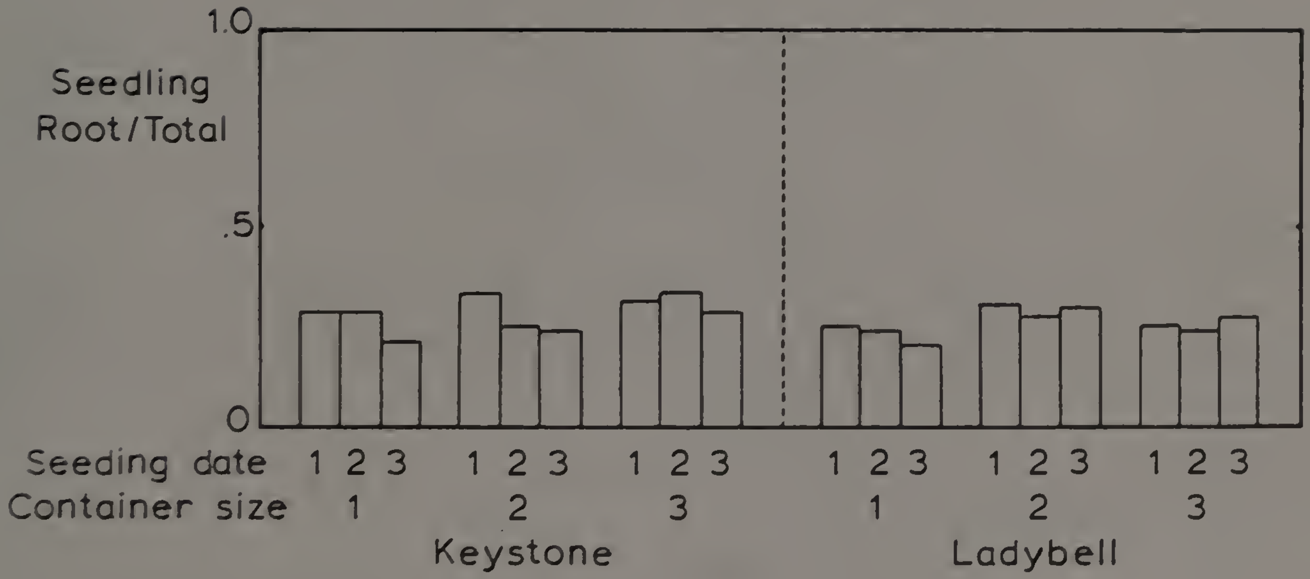

Fig. 34. Effects of variety, container size and seeding date on seedling root/total dry wt ratio. Experiment 3, 1979. (Seeding Date 1 = 3/30, 2 = 4/10, 3 = 4/21; Container Size (cm^3) 1 = 31, 2 = 66, 3 = 147).

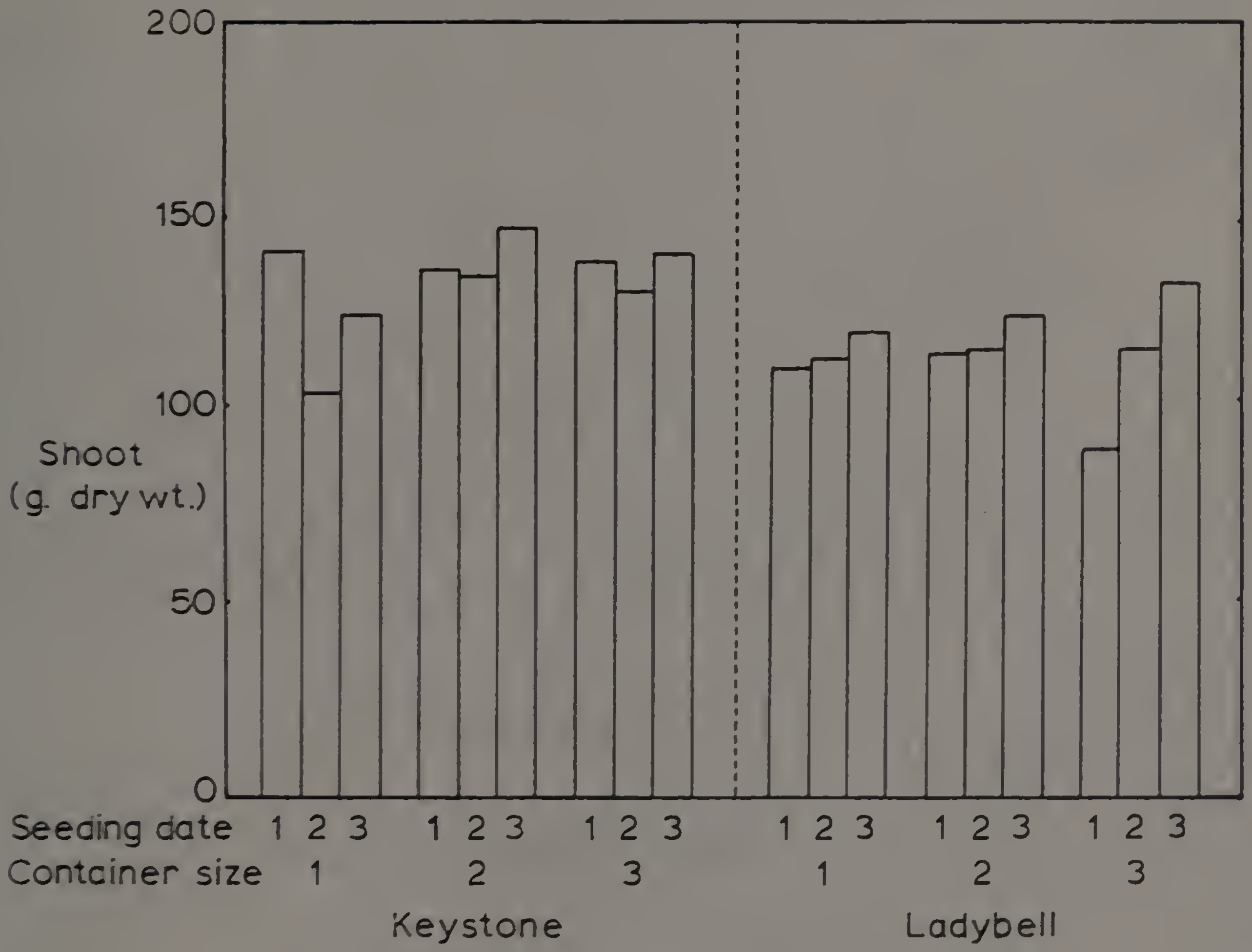

Fig. 35. Effects of variety, container size and seeding date on shoot dry wt. Experiment 3, 1979. (Seeding Date 1 = 3/30, 2 = 4/10, 3 = 4/21; Container Size (cm^3) 1 = 31, 2 = 66, 3 = 147).

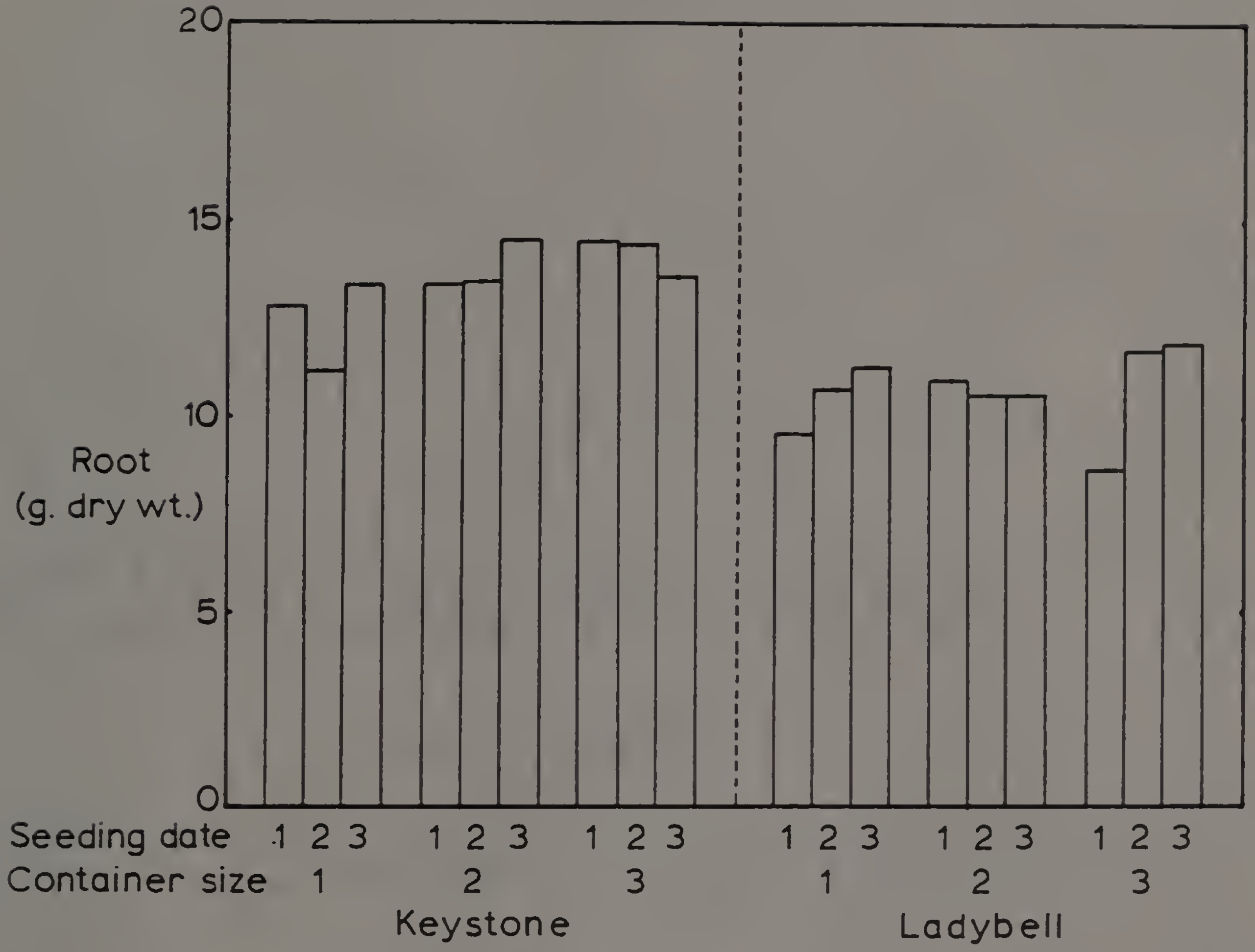

Fig. 36. Effects of variety, container size and seeding date on root dry wt. Experiment 3, 1979. (Seeding Date 1 = 3/30, 2 = 4/10, 3 = 4/21; Container Size (cm^3) 1 = 31, 2 = 66, 3 = 147).

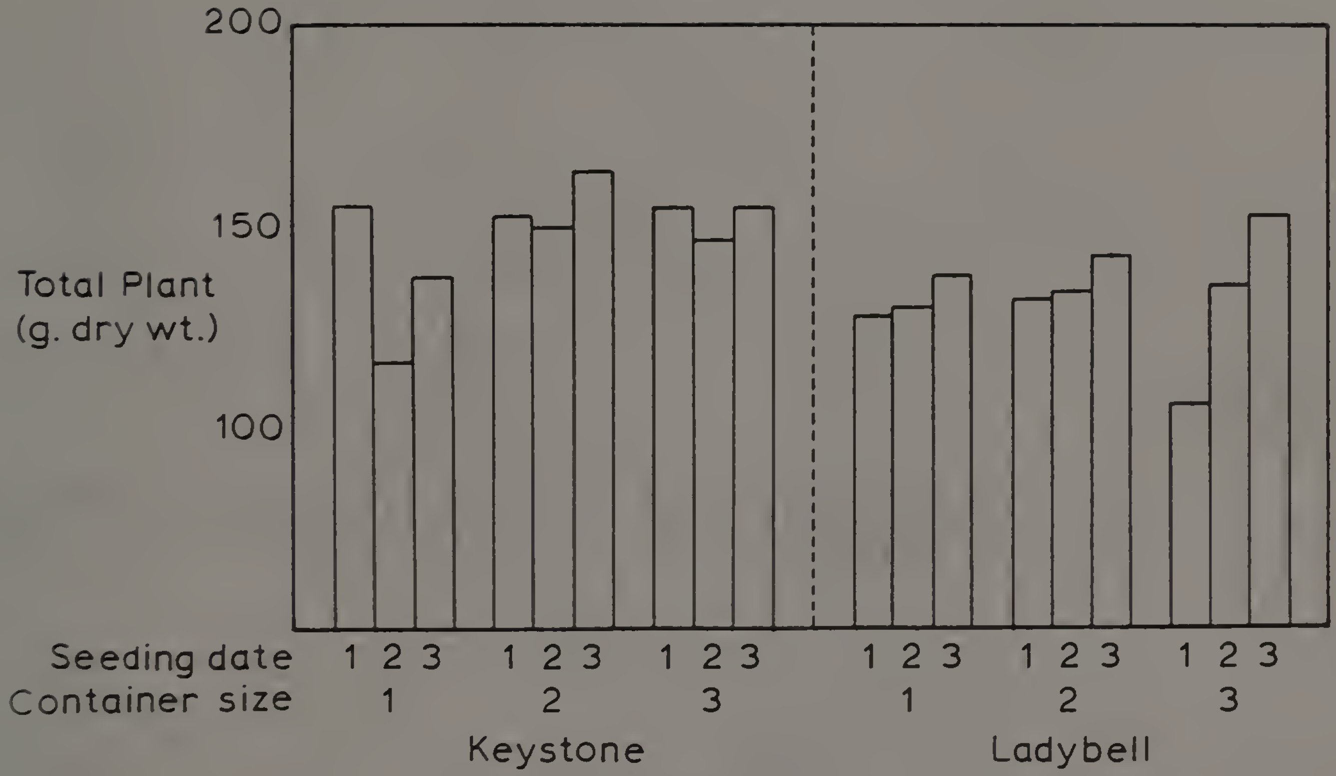

Fig. 37. Effects of variety, container size and seeding date on total plant dry wt. Experiment 3, 1979. (Seeding Date 1 = 3/30, 2 = 4/10, 3 = 4/21; Container Size (cm^3) 1 = 31, 2 = 66, 3 = 147).

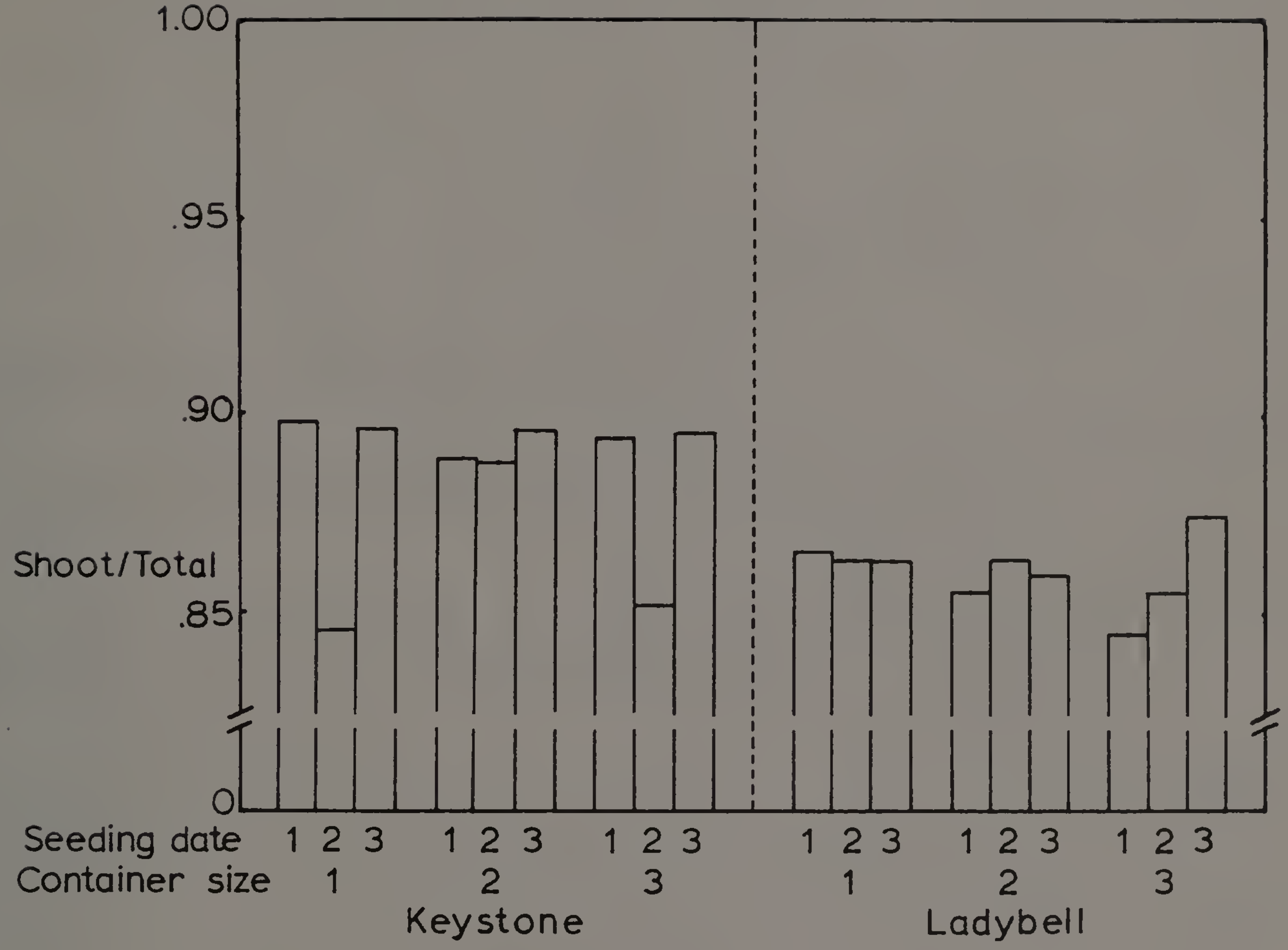

Fig. 38. Effects of variety, container size and seeding date on shoot/total dry wt ratio. Experiment 3, 1979. (Seeding Date 1 = 3/30, 2 = 4/10, 3 = 4/21; Container Size (cm^3) 1 = 31, 2 = 66, 3 = 147).

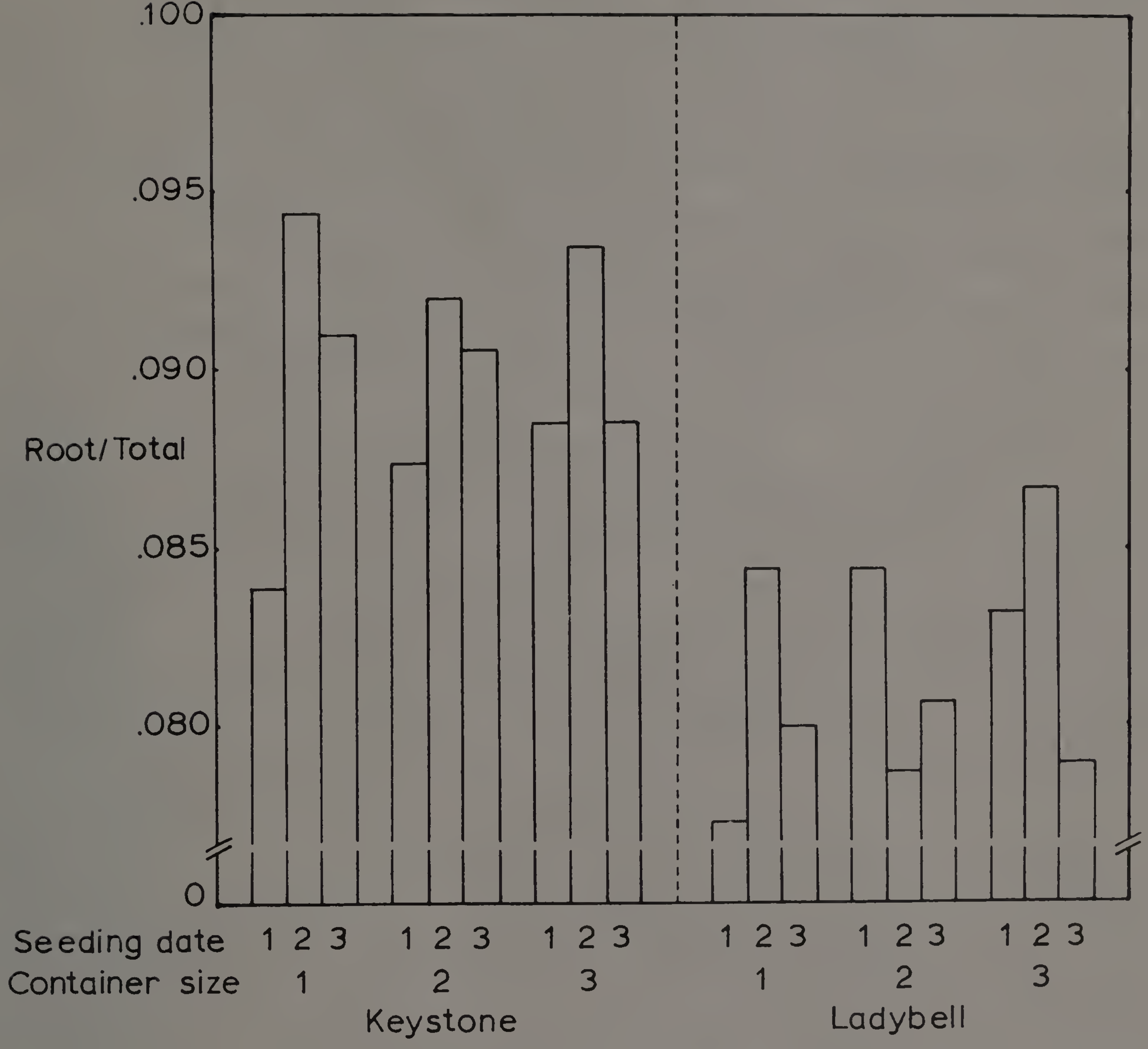

Fig. 39. Effects of variety, container size and seeding date on root/total dry wt ratio. Experiment 3, 1979. (Seeding Date 1 = 3/30, 2 = 4/10, 3 = 4/21; Container Size (cm^3) 1 = 31, 2 = 66, 3 = 147).

APPENDIX C

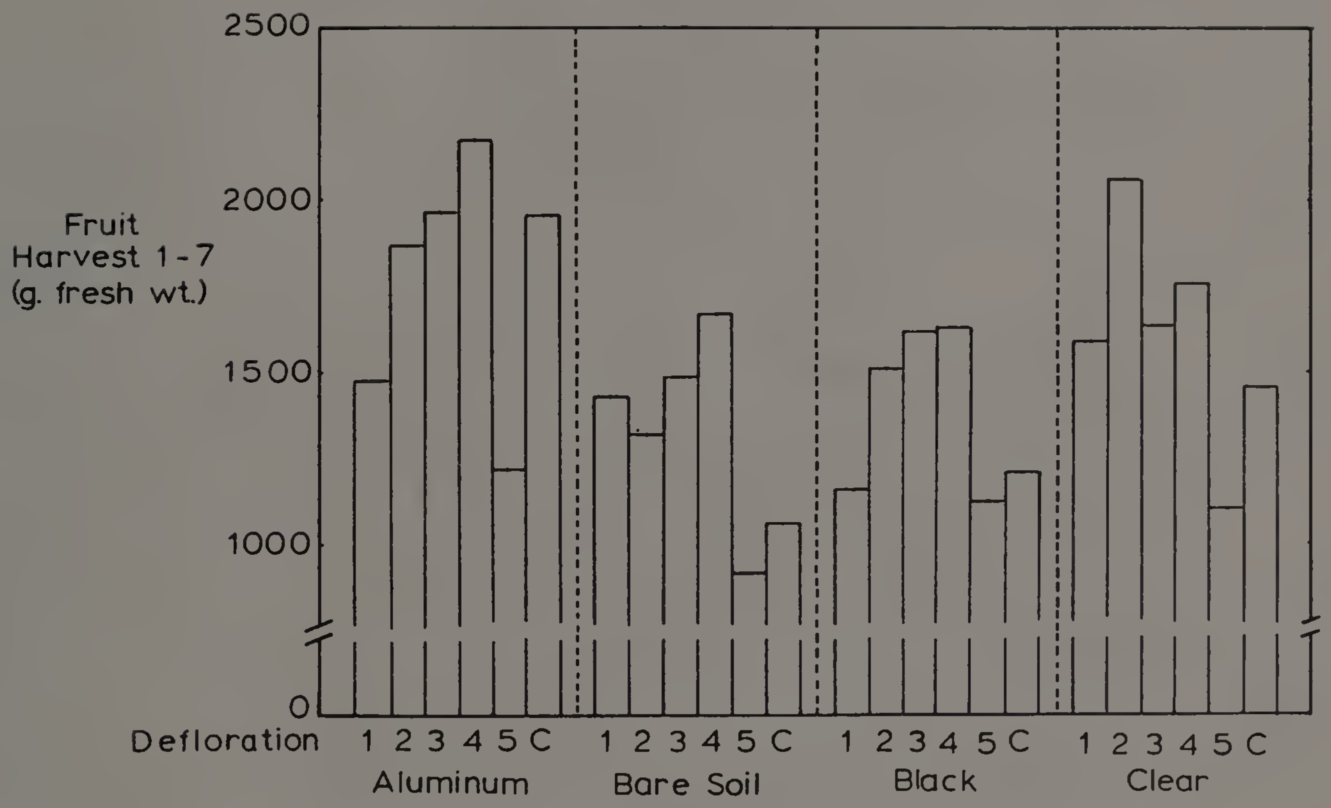

Fig. 40. Effects of mulch and defloration treatments on fruit fresh wt per plant from combined harvests 1 - 7. Experiment 4, 1979. (Al, aluminum; BS, bare soil control; B, Black plastic; Cl, Clear plastic. Defloration; 1, to 7/2; 2, to 7/9; 3, to 7/16; 4, to 7/23; 5, to 7/30; C, no defloration).

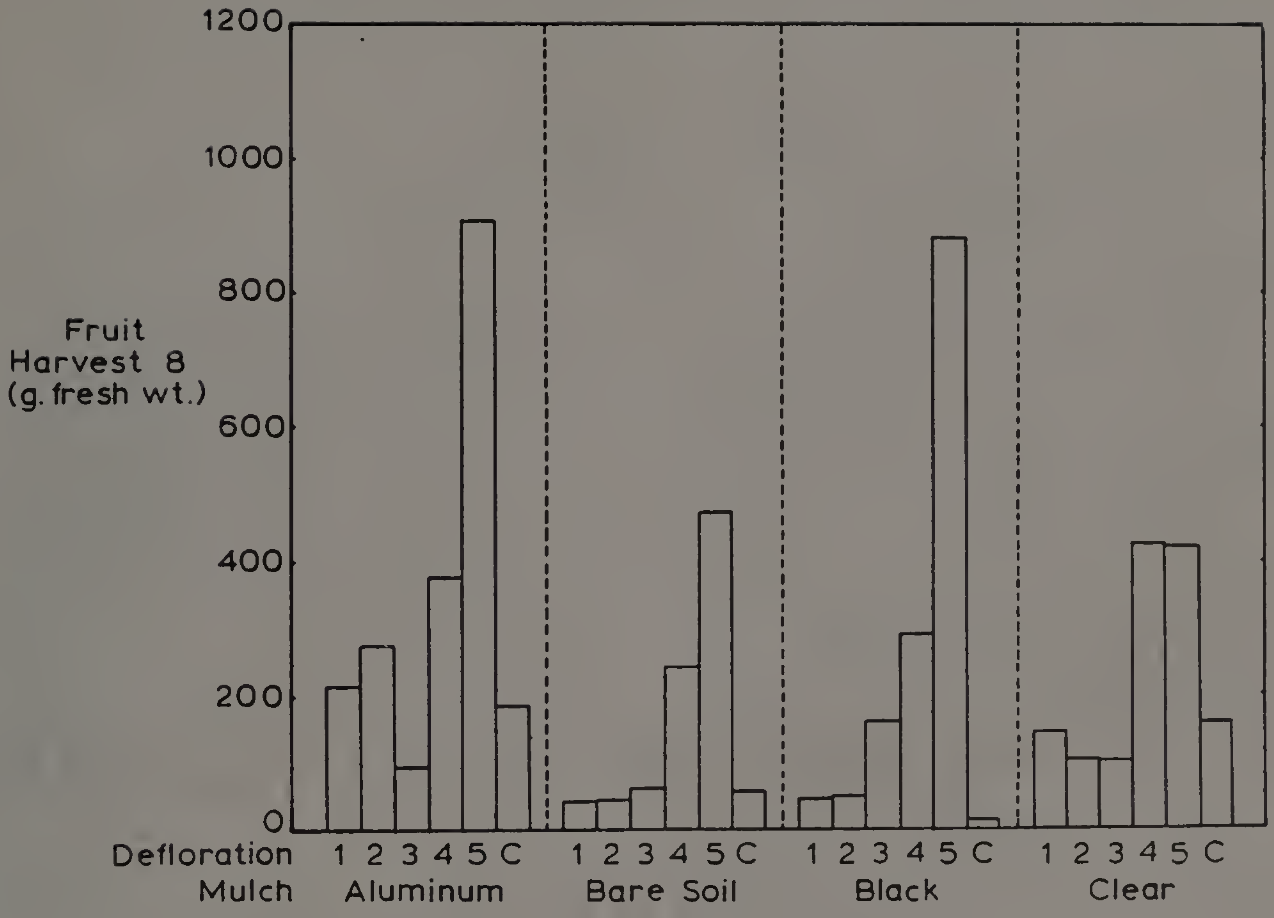

Fig. 41. Effects of mulch and defloration treatments on fruit fresh wt per plant from harvest 8. Experiment 4, 1979. (Al, aluminum; BS, bare soil control; B, Black plastic; Cl, Clear plastic. Defloration; 1, to 7/2; 2, to 7/9; 3, to 7/16; 4, to 7/23; 5, to 7/30; C, no defloration).

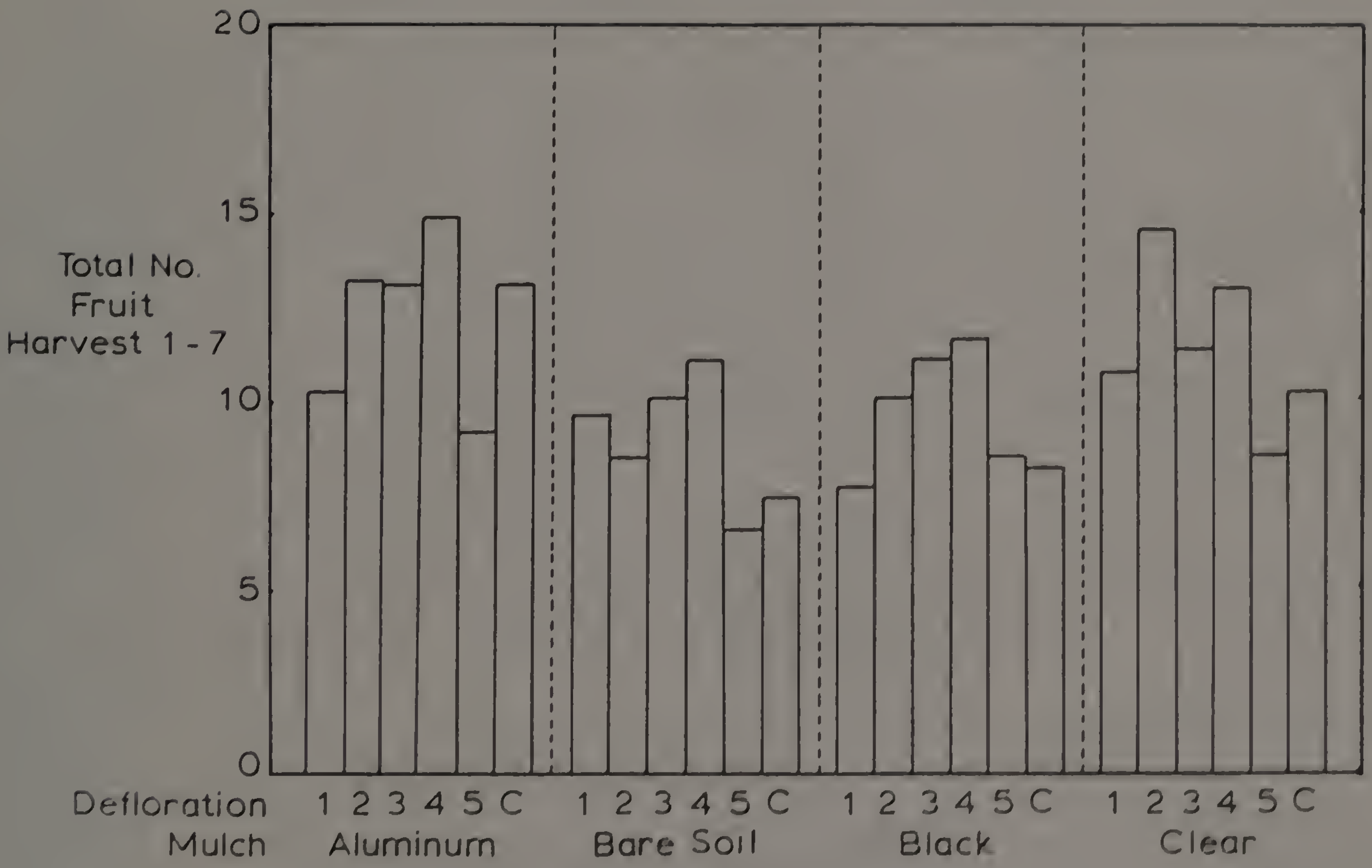

Fig. 42. Effects of mulch and defloration treatments on number of fruit per plant from combined harvests 1 - 7. Experiment 4, 1979. (Al, aluminum; BS, bare soil control; B, Black plastic; Cl, Clear plastic. Defloration; 1, to 7/2; 2, to 7/9; 3, to 7/16; 4, to 7/23; 5, to 7/30; C, no defloration).

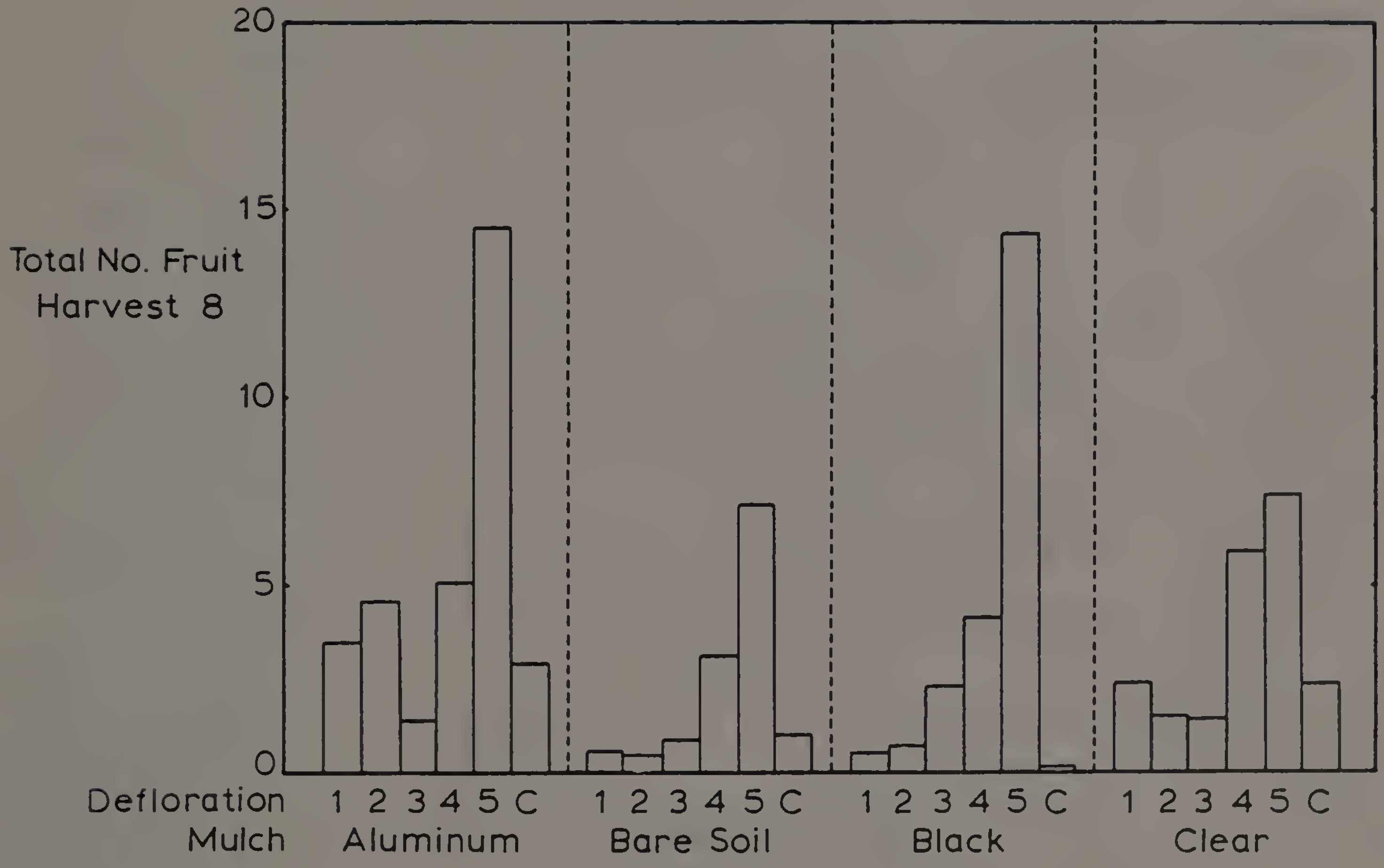

Fig. 43. Effects of mulch and defloration treatments on number of fruit per plant from harvest 8. Experiment 4, 1979. (Al, aluminum; BS, bare soil control; B, Black plastic; Cl, Clear plastic. Defloration; 1, to 7/2; 2, to 7/9; 3, to 7/16; 4, to 7/23; 5, to 7/30; C, no defloration).

APPENDIX D

Experiment 5, 1979 : Transplanting Depth Experiment

The effects of different transplanting depths upon the number of days from seeding to the opening of the first flower, early and total fruit harvests and partitioning of dry matter within the plant were examined in Experiment 5, 1979.

Ladybell was seeded on April 12, 1979 in flexible black plastic flats with 2 in round cups. Seedlings were transplanted to the field in beds under 3 ft x 1.5 mil black polyethylene mulch (Polyagro) on June 4th (53 days in age). Rows were 4' apart and plants were spaced 2' apart within rows. The seedlings were transplanted at three different depths+ : at the level of the root ball, at the cotyledonary node, and at the level of the first primary leaf. Peter's special formula starter solution (9-45-15) was given to the seedlings as they were set in the ground at one cup per plant. Harvesting was conducted in the same fashion as the other experiments conducted during 1979.

The number of days to first flower (Fig. 44) was the same for all transplanting depths, as were the fruit yields (fruit number or fruit fresh weight) from harvests 1 and 2. Total fruit yield (Fig. 45) was greatest for those plants transplanted at the level of the root ball (Fig. 46). Conversely, shoot dry weights were least for those plants set at the level of the root ball (Fig. 47). There were no differences in root dry wts (Fig. 48) or total plant dry wts (Fig. 49) among the treatments.

Partitioning of dry matter is shown in Fig. 50. The shoot/total dry wt ratio was greatest in those plants set in the field at the level of the cotyledons, followed by the level of the first primary leaves at the root ball. More dry matter was partitioned into fruit in those plants transplanted to the depth of the root ball with little difference between the other two treatments. There were no differences among the treatments in regard root/total dry wt ratios.

The data suggest that plants which are set in the field at depths greater than the root ball will have lower fruit yields, however the differences were very small. The decrease in shoot dry weight is in accordance with the findings of the other studies reported here. When fruit yields increased, there was a corresponding decrease in shoot dry weight. Greater differences might have resulted had the plants not have been set in beds, as beds increase the surface area affected by the mulches, temperatures may not have been very different at the depths used. In addition the soil remained friable under the mulch, and gas tensions may have been the same or similar at all depths tested. It would be useful to run the experiment again with no beds and with the appropriate soil parameters measured such that they could be entered into the model.

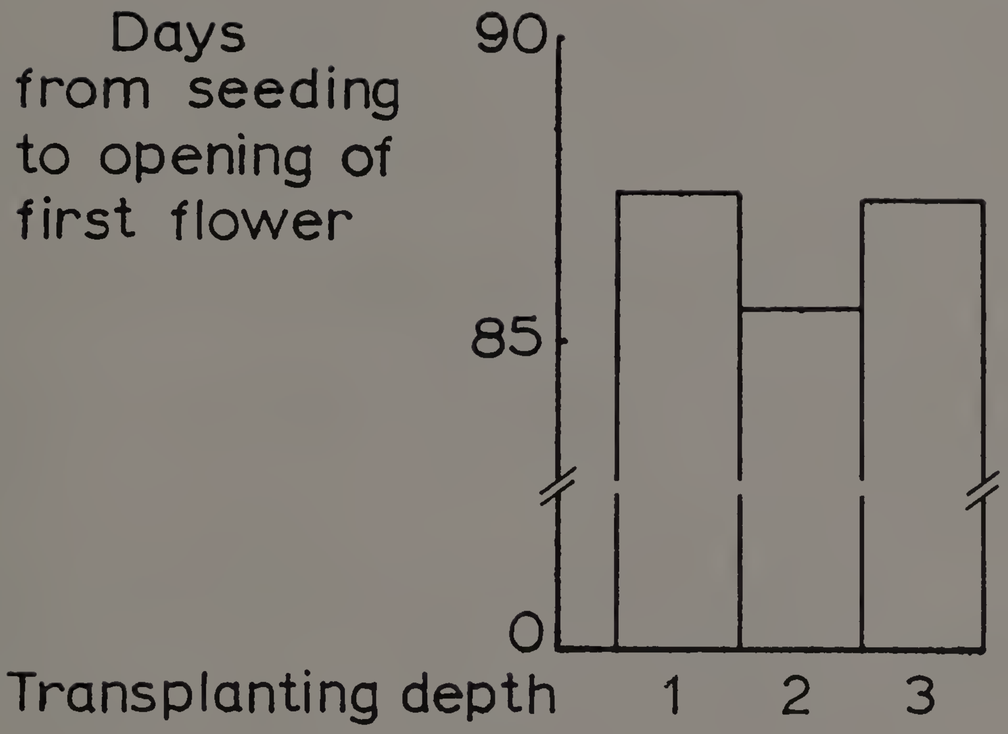

Fig. 44. Effect of transplanting depth on the number of days from seeding to opening of the first flower. Experiment 5, 1979. Transplanting depth: 1 = to root ball, 2 = to cotyledonary node, 3 = to first primary leaf node).

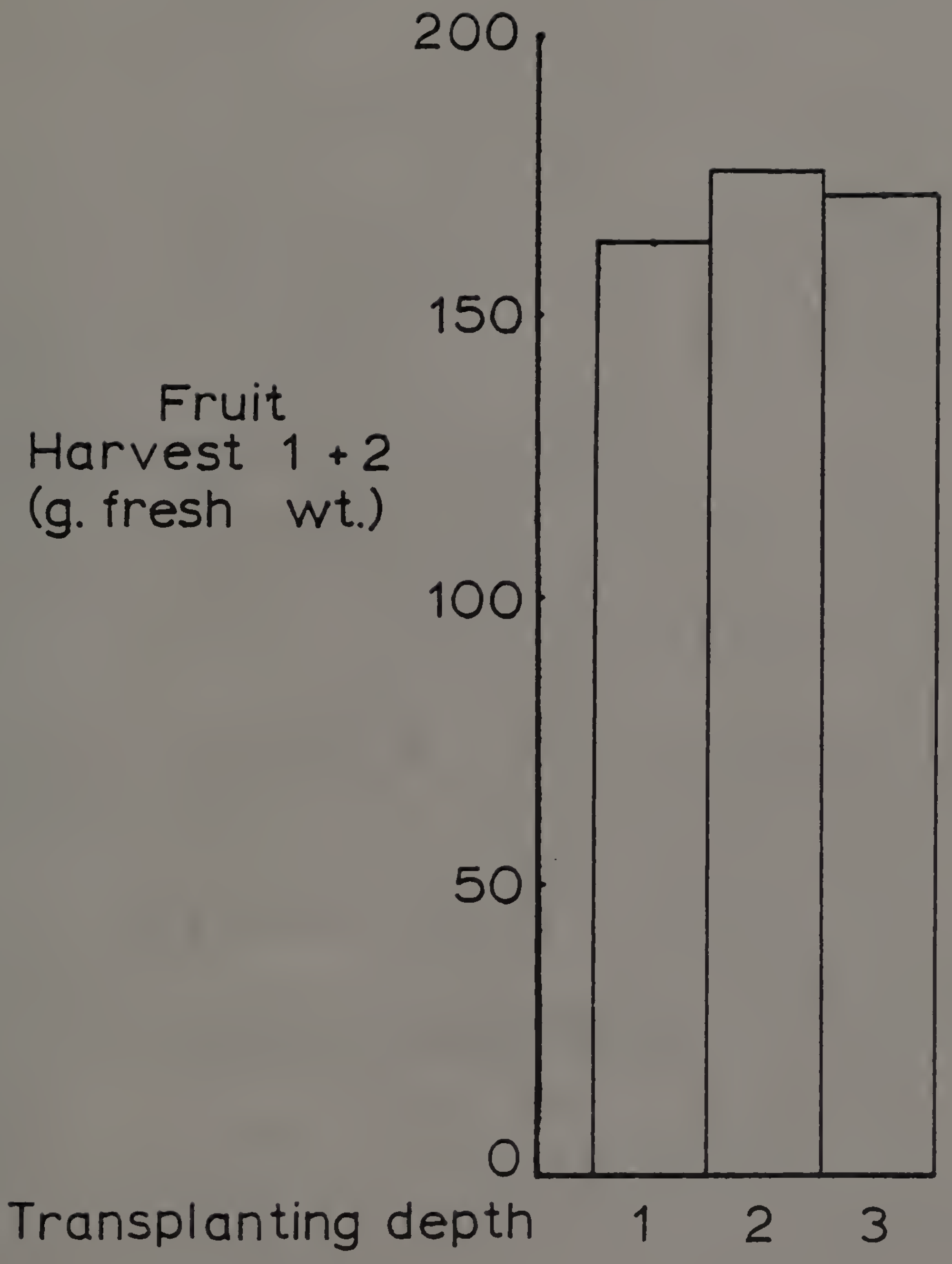

Fig. 45. Effect of transplanting depth on fruit fresh wt per plant from combined harvests 1 - 2. Experiment 5, 1979. Transplanting depth: 1 = to root ball, 2 = to cotyledonary node, 3 = to first primary leaf node).

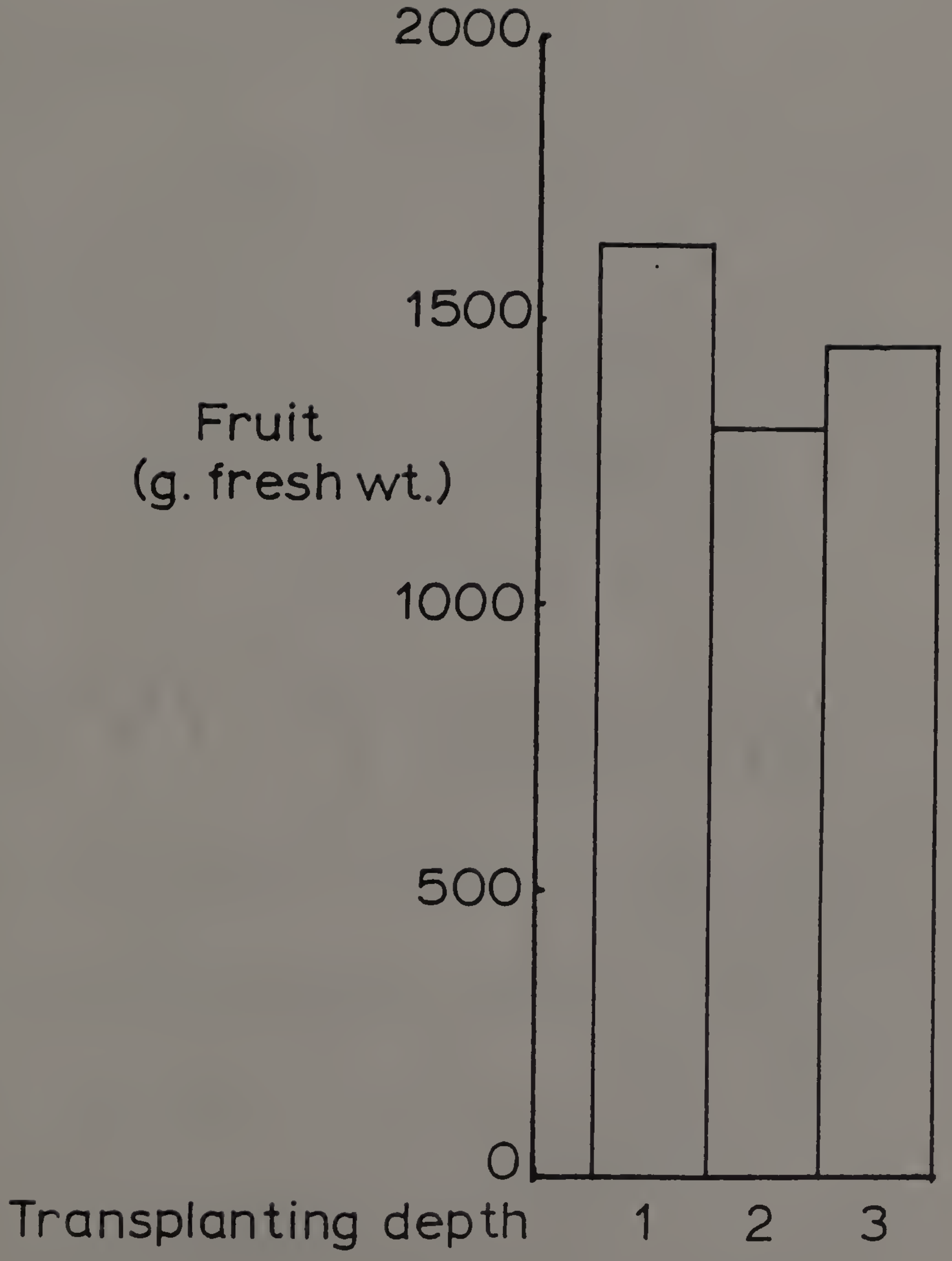

Fig. 46. Effect of transplanting depth on total fruit fresh wt per plant. Experiment 5, 1979. Transplanting depth: 1 = to root ball, 2 = to cotyledonary node, 3 = to first primary leaf node).

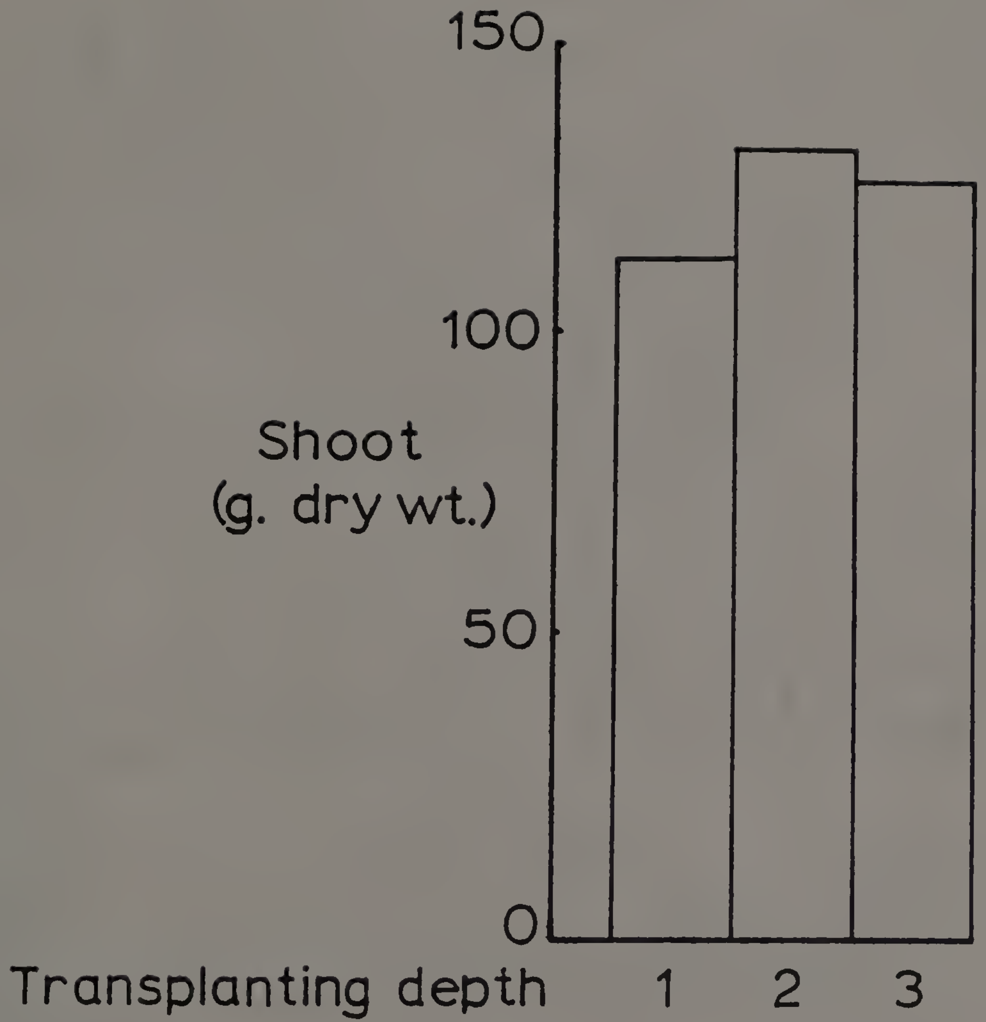

Fig. 47. Effect of transplanting depth on shoot dry wt. Experiment 5, 1979. Transplanting depth: 1 = to root ball, 2 = to cotyledonary node, 3 = to first primary leaf node).

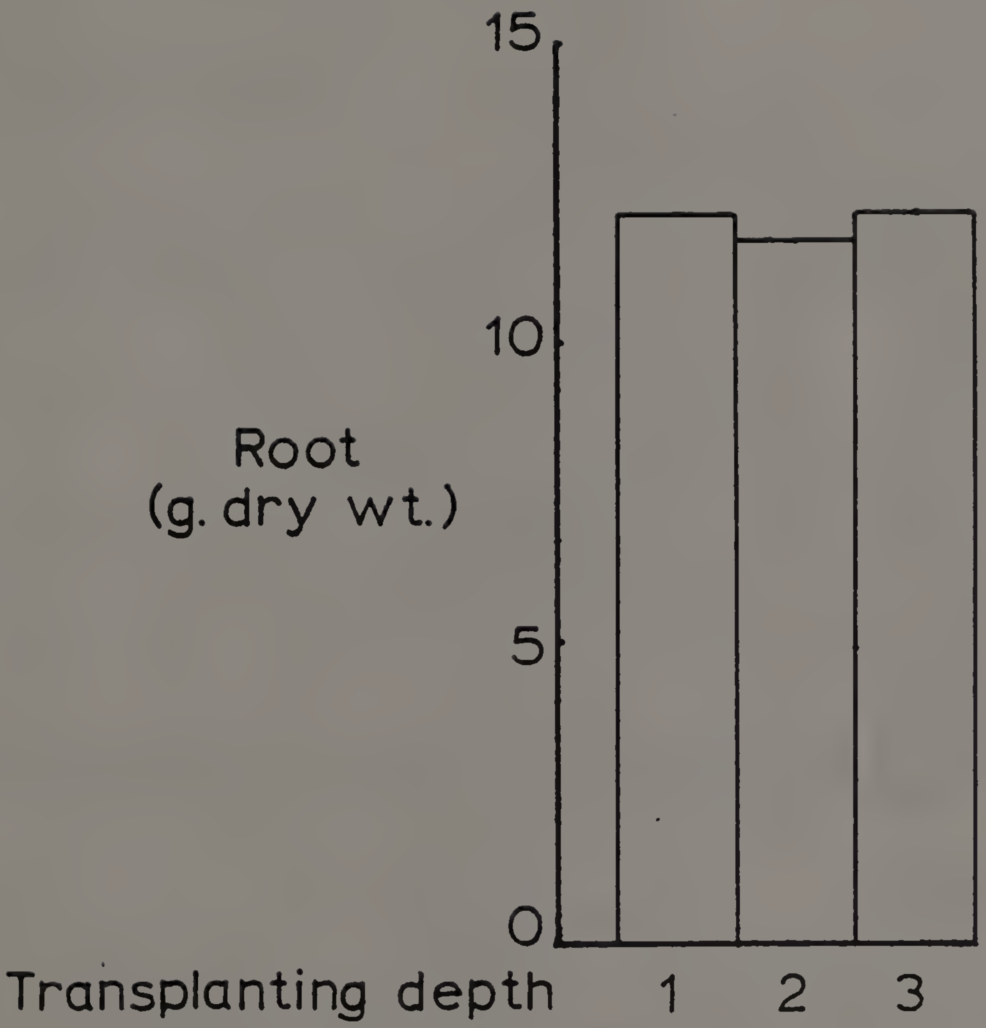

Fig. 48. Effect of transplanting depth on root dry wt. Experiment 5, 1979. Transplanting depth: 1 = to root ball, 2 = to cotyledonary node, 3 = to first primary leaf node).

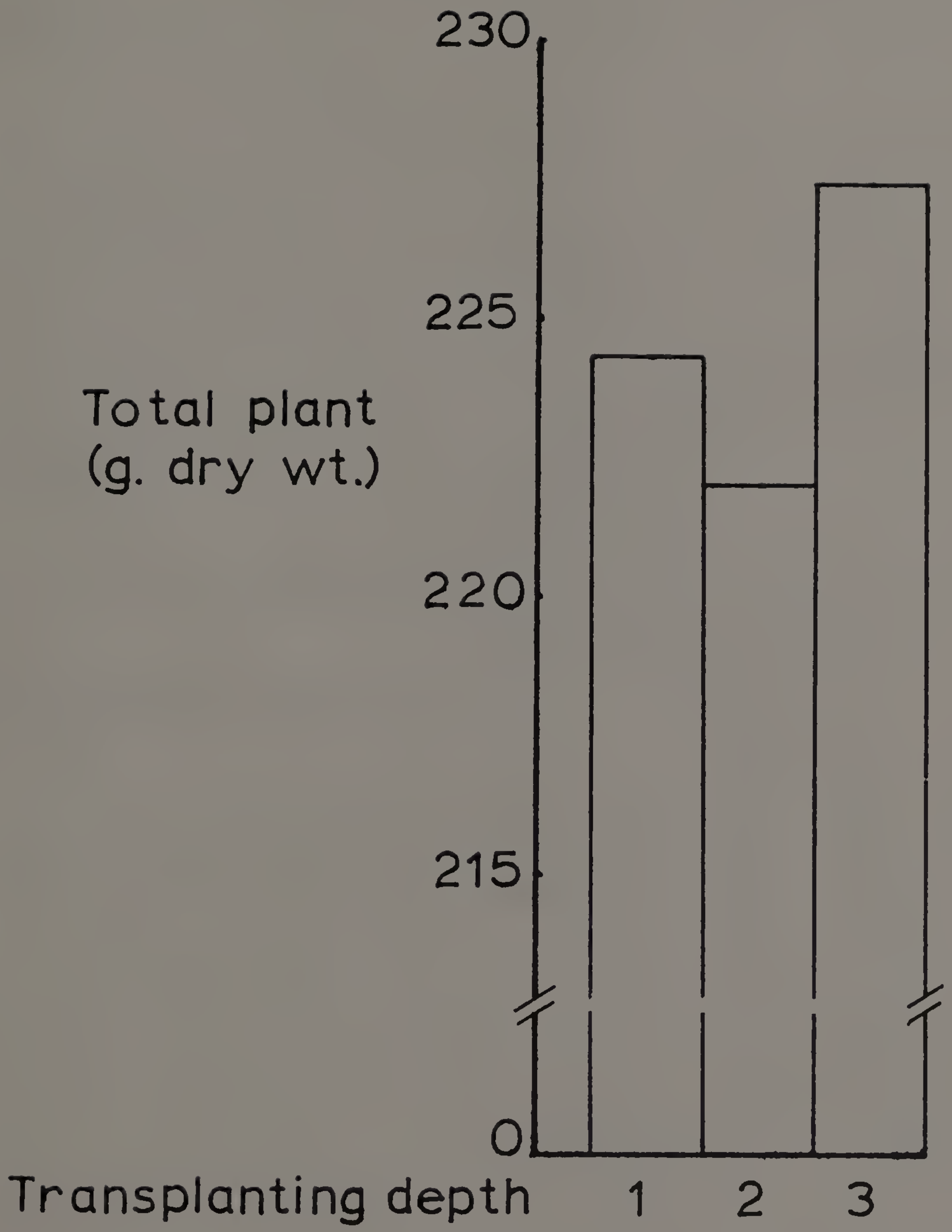

Fig. 49. Effect of transplanting depth on total plant dry wt. Experiment 5, 1979. Transplanting depth: 1 = to root ball, 2 = to cotyledonary node, 3 = to first primary leaf node).

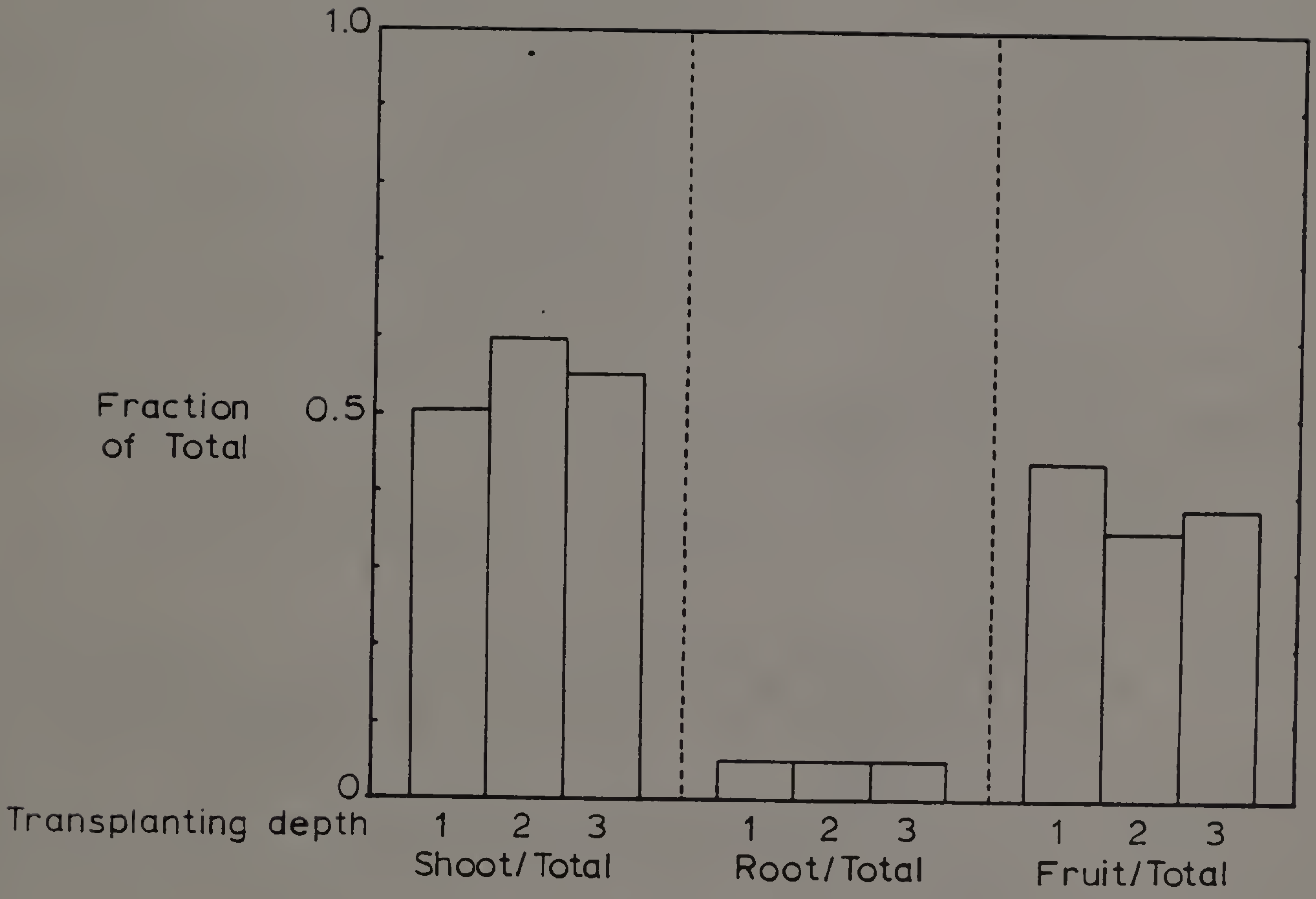

Fig. 50. Effect of transplanting depth on dry matter partitioning. Experiment 5, 1979. Transplanting depth: 1 = to root ball, 2 = to cotyledonary node, 3 = to first primary leaf node).