AN ABSTRACT OF THE THESIS OF

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Title: Effect of Date of Renovation on Yield Components of Strawberries

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Two experiments were conducted from 1987 to 1990 to study the effect of date of renovation on strawberry yield and yield components. In the first experiment, 'Benton' plants were renovated from July 6, 1988 (1 week after harvest - WAH) to August 24, 1988 (8 WAH). In the second experiment 'Benton', 'Totem', and 'Redcrest' were studied. Treatments were date of renovation from July 12, 1989 (2 WAH) to August 16, 1989 (7 WAH), and a control (un-renovated).

Date of renovation affected the number of runners per plant in fall, 1988 and 1989. The number of runners showed either a negative linear relationship ('Totem', 1989) or a quadratic relationship ('Benton', 1988 and 1989; 'Redcrest' 1989) with date of renovation -- early-renovated plants (3 WAH or early) had the greatest number of runners. Thus, early-renovation may be more important in a matted row system than in a hill system.

In the fall, 1988, early renovated 'Benton' plants (3 WAH or earlier) had a greater number of trusses and flowers per plant.

The following summer the pattern was reversed; late-renovated plants (4 to 8 WAH) produced a higher yield. There was a positive linear relationship between date of renovation and the number of trusses and flowers per plant in 'Benton' in the summer of 1989.

In the second experiment, 'Benton', 'Totem' and 'Redcrest' responded differently to date of renovation in the fall of 1989 as well as in the summer of 1990.

There was very little flowering of 'Totem' in fall, 1989.

In 'Benton', early-renovated plants (up to 6 WAH) did not differ significantly in number of trusses and flowers per plant compared to the control. However, early-renovated plants had a greater number of trusses and flowers per plant than late-renovated plants in the fall of 1989.

In 'Redcrest', a negative linear relationship was present between date of renovation and the number of trusses and flowers per plant the fall of 1989.

In summer, 1990, there was no significant difference between treatments and the control in number of trusses, number of flowers, leaf area (LA) per plant, plant fresh weight (PFW), and yield per plant in 'Totem'.

Response of 'Redcrest' plants in summer, 1990 to date of renovation in 1989 was similar to 'Totem' expect that PFW differed between the treatments and control groups. Early-renovation (2 to 5 WAH) led to higher LA per plant.

In 'Benton', plants renovated from 3 to 5 WAH had more trusses, flowers and LA per plant, and more PFW than late renovated plants (6 and 7 WAH). Un-renovated control plants tended to have the highest LA and PFW but did not differ significantly from early-renovated plants (2 to 5 WAH). The number of trusses and flowers on control plants was significantly lower than on early-renovated plants (2 to 5 WAH).

Date of renovation had no significant effect on yield per plant in the summer of 1990 for all 3 cultivars individually. However, compared with the un-renovated control plants, the pooled yields of 'Benton', 'Totem', and 'Redcrest' showed a significant increase for early renovated plants (5 WAH or earlier). Compared with un-renovated plants, renovation significantly increased berry size in 'Totem', and delayed the date of harvest in 'Totem' and 'Redcrest' but not in 'Benton'.

Effect of Date of Renovation on Yield Components of Strawberries

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This thesis is dedicated to my parents who encourage me spiritually; and to my wife, xiuping sun, who loves me and supported me through my field and laboratory work.

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INTRODUCTION

Oregon is the third largest state in strawberry production, after California and Florida (Bringhurst et al., 1990). The strawberry crop is one of the largest income sources for the state in small fruits. Many aspects of strawberry production have been improved through breeding and alternative cultural practices. Renovation (mowing off foliage after harvest) is practiced to increase yield of many varieties in many regions (Wilson and Roger, 1954; Guttridge and Wood 1961; Guttridge and Mason, 1966; Moore, 1968; Puffer, et al., 1968; Kerrkhoff, et al., 1988; Pristt, 1988). This cultural practice has been used in Oregon for a long time (Waldo, 1939). Thus, the value of this practice has been recognized, although the results have not been uniform. Previous research has shown that many factors can influence the effects of renovation, such as varieties (Guttridge and Mason, 1966; Nestby, 1985), location (Albregts and Howard, 1972), and date of renovation (Guttridge and Wood, 1961; Guttridge and Mason, 1961 & 1966; Mason, 1967; Moore, 1968; Nestby, 1985).

Although scientists have generally agreed that date of renovation is important, there has been little work done to specifically answer 1) how date of renovation affects yield components; 2) whether there is an optimum date to renovate and 3) whether varieties respond differently. These questions are very important to strawberry growers. This research program was designed to answer the above questions.

CHAPTER I. LITERATURE REVIEW

Part I: Morphology and physiology of strawberry plant parts

A. Roots

1. Morphology

A mature strawberry plant usually has 20 to 35 primary roots but may have as many as 100. The white rootlets absorb most of the water and nutrients directly.

Root system size depends on the natural vigor of each clone and the conditions for plant growth. In the matted row system, both mother plants and daughter plants may have relatively small root systems because of individual plant size. (Galletta et al., 1990)

2. Growth, distribution and physiology

Primary roots normally live approximately one year. They may live for a longer period under favorable circumstances, while in stress or disease-infected conditions, they may only survive less than a few weeks.

The primary roots are usually the soil-penetrating roots. They may penetrate soils to a depth of 100-105 cm (Hanson, 1931; Hughes, 1965), but 50 to 90% of the root system is usually confined to the upper 15 cm of soil (Schrader, 1941), and 25 to 50% of the roots is in upper 7.5 cm (Rom and Dana, 1960). Root penetration is usually greater on lighter (more porous or sandier) soil or well-prepared soil than on less porous or more poorly prepared soil. The environment in the surface 15 cm of the soil is most critical for strawberries.

Strawberry roots arise adventitiously from the base of new leaves along the crown to maintain their perennial nature (Dana, 1980). Roots will not emerge unless they are in contact with, or partially covered by, moist soil.

Photoperiod and temperature have an effect on starch accumulation in strawberry roots. Generally, the shorter photoperiod resulted in greater starch accumulation regardless of temperature (Maas 1986).

The color and consistency of the central vascular cylinder (the stele) of the strawberry root are often used as indicators of root and plant health (Marini and Boyce, 1977)

B. Stems (Crowns)

1. Morphology

The strawberry stem, or crown, is compressed into a rosetted structure, which is about 2.5 cm long and is covered on the outside by overlapping leaf bases (stipules). The crown produces leaves at very close intervals along the axis, and roots are formed at the base of the crown. Branch crowns are morphologically identical to the main crown axis and to daughter plants on stolons. A branch crown does not produce a root system separately from that of the parent plant. The strawberry crown forms buds or axillary meristems in the axil of each leaf. These axillary buds relate to the subsequent development of the strawberry plant (Dana, 1980)

2. Growth and development

A strawberry crown contains a terminal bud in the top position and axillary buds aside. The terminal bud usually contains five to seven developing leaves, enclosed within the stipples of the last emerged leaf (Arney, 1953 a & b). When the terminal meristem becomes a truss (inflorescence), vegetative crown extension is continued by the upper most axillary bud. The continuing vegetative crown growth displaces the truss of the original terminal axis off to one side. Axillary buds may also form trusses at the terminus of the shoot after initiating two- to four-leaf primordia (Galletta et al. 1990).

Axillary buds may remain dormant or may extend to become runners or branch crowns. Branch crowns will be formed under the shortened photoperiod of late summer and fall in the high latitudes. Once established, a branch crown forms leaves in the same sequence as the main crown and functions independently of the main crown (Jahn and Dana, 1970b).

3. Winter injury

Strawberry plants are less cold hardy than most fruit crops. Low temperatures often injure strawberry plants, causing reductions of plant vigor and yield. According to Marini and Boyce (1977), plants may be injured at low-temperatures from -8 to -16^{o}C by showing browning in crown tissues, and can be killed at -20°C.

In laboratory studies, the degree of injury can be determined by electrical conductivity measurements (Boyce and Smith, 1967; Harris, 1970; 1973), or amount of regrowth (Angelo et al., 1939; Brierley and Landon, 1944; Steel et al, 1934). Under field conditions, tissue discoloration or degree of browning revealed by longitudinally cutting crowns also indicates low-temperature injury (Angelo et al., 1939). Plants with little injury develop browning at the base of the medulla, while severely injured crowns also show dark brown color just below the apex (Angelo et al, 1939). Vascular tissue is most resistant to freezing injury and most important for plant survival (Marini and Boyce, 1977). The cortex and medulla, composed primarily of parenchyma cells, appear to be the most susceptible to low temperature injury (White, 1929). Plants survived even when more than half of the medulla was destroyed; however, no surviving plants developed extensive browning in the vascular systems (Marini and Boyce 1977).

C. Leaves

1. Morphology

Strawberry leaves are pinnately compound and trifoliate, consisting of three leaflets attached to the main leaf stem which is enlarged at the base to form a winged stipple that wraps around the crown. Upper leaf surfaces have characteristic colors varying from light yellow-green to very dark green. Lower leaf surfaces are often waxy, very light green with prominent veins. All leaf and petiole surfaces have amounts and types of hairiness that are a characteristic of clone and plant age.

The number of leaves and the leaf area on plants in the fall has been positively correlated with fruit production in the following year (Morrow, 1940; Sproat et al., 1935; Strik and Proctor, 1988a).

2. Leaf initiation and development

Leaves are arranged in a tight 2/5 spiral around the crown, each sixth leaf located above the first. Leaves vary in "normal" plastochron interval between 8 to 12 days (Arney, 1953a; Jahn and Dana 1970a).

The terminal vegetative axis carries between 5 and 10 unexpended leaves, or primordia (Arney, 1953a & b). During winter dormancy there are more primordia than during the active growing season (Arney, 1955a). Mature plants normally carry 7 or 8 primordia, young plants have fewer (Arney, 1953a, 1955b; Guttridge, 1955; Jahn and Dana, 1970b). The growth and development of leaf primordia prior to emergence is largely due to cell division (Arney, 1953a, 1954).

Individual leaves may live from 1 to 3 months and vary widely in thickness, area, and cuticle thickness. Because of a large number of stomata and large inter-cellular areas (Darrow, 1966), strawberry leaves are capable of very heavy water use; they wilt easily, and leaf and feeder roots may die in warm, dry periods (Galletta et al, 1990).

Cell numbers, cell enlargement, and leaf size are affected by environmental conditions at the time of leaf emergence (Arney, 1954 and 1956). The rate of leaf production is temperature sensitive and tends to be more rapid in early spring than during the warmer part of the growing season. The cool temperatures of autumn slow and finally stop new leaf production in northern growing areas.

D. Flowers and trusses (Inflorescence)

1. Morphology

In a perfect strawberry flower both male and female sexual parts are present. A primary flower may have 400 or more pistils, the secondary 200-300, and the tertiary 50-150 (Janick and Eggert, 1968; Valleau, 1918). Cultivar and growing conditions may influence the number of pistols in any given flower but do not alter the relationship among flowers at different positions on the inflorescence.

The strawberry truss is known as "dichasial cyme", but it is variable in detailed structure (Guttridge, 1985). In a perfect strawberry fruit truss one would expect to find one primary flower, leading to a primary berry at late stage, two secondaries, four tertiaries, eight quaternaries, and sixteen quinary flowers (or berries), a total of 31 flowers (or berries).

The truss terminates a growth axis whether it is the primary, in a dominant position, or secondary or lower order growth axis. The first visual evidence (microscopically) of induction of flowering is a slight enlargement and flattening of the terminal meristem which is beside the last leaf primary primordium to be initiated on this axis (Dana, 1980).

More detailed information about flower bud initiation will be discussed in a later part (part II) of this review.

E. Fruits

1. Fruit formation

The fertilized ovule develops into a seed within the dry, hard, single-seeded fruit or achene. The edible structure is an enlarged, fleshy receptacle upon which the many individual achenes are borne.

From pollination to berry ripening takes 20 to 50 days, depending on cultivar, temperatures, pollen availability, berry size, and regularity of fertilization. The shape and form of the strawberry is a function of the extent and uniformity of fertilization of ovules on the surface of the receptacle (Dana, 1980). Large-fruited primary berries ripening in the spring are often irregular in shape and ripen in 20 to 23 days.

2. Fruit (Berry) size

Fruit size is a function of blossom position, number of achenes, fruit competition, and plant vigor. Flower position has a determinative influence. In addition to the relationship between achene number and flower position, fruit size is influenced by apical dominance (Janick and Eggert, 1968). The decrease in fruit size in the lower position of a truss may be related to a decrease of cell number of the receptacle tissue and a decrease in auxin contributed or stimulated by the developing achenes (Nitsch, 1950).

After ripening, berry size is not affected as much by time of harvest. Irrigation in the critical time (such as flower bud initiation) increases the total number of berries. A linear relationship exists between number of berries and length of harvest. Proper irrigation does not affect the soluble solids content of the fruit or pH of the juice (Shoemaker 1975).

F. Runners

1. Formation and development

Runners (or stolons) originate from axillary buds on the crown. Runner production varies from clone to clone. (Galletta et al., 1990). Daughter plants rooted early in the season have been shown to be more productive than runners rooted late in the season (Davis, 1922; Shoemaker, 1929).
A vigorous plant may develop 10 to 15 runners in the course of the growing season.

The first runner of the season usually originates from the axil of the first new leaf initiated on the crown in the spring, rather than the first leaf to expand in the spring, which was initiated the previous fall. The first internode of the runner elongates for several inches and ceases growth with the bract and an axillary bud (often call the 'blind' node). This first or blind node grows out another prostrate and elongated branch runner or stem internode identical to the original runner from which it arose. This runner from the first node ends in a second node that has a bract and axillary bud. A succession of very short internodes produce leaves and more axillary buds, which form a daughter plant, thus terminating the original runner after apparently two nodes. The first axillary bud of the original daughter plant may produce another stolon, with two nodes and another daughter plant to form a runner chain. The runnering process is continued from successive daughter plants until environmental factors become limiting for further extension of runners. Under optimum conditions a runner plant could survive if runner support were interrupted after 2 to 3 weeks (Rom and Dana, 1960).

2. Environmental factors affecting runner formation and growth

Runners form and elongate under the long day conditions of spring and summer in the temperate zones; in general, the longer the day length the more runners produced. But this is not markedly affected by varying the photoperiod from 12 to 18 hours (Dennis et al. 1970). Runner production is inversely proportional to flowering, and is promoted in June by long days and high temperature. Hartmann (1947) reported that a long light period was more important than a short dark period in promoting runner production in Junebearers. This suggested that the process of runner formation differed from true photoperiodic responses in which the length of dark period is critical.

Research by Hellman and Travis (1988) indicated that runner growth was inhibited by high temperatures, particularly above 40°C. Runner growth inhibition was found to begin within 3 days of exposure to high temperatures and to persist for at least 4 days following a return to moderate temperatures. The critical temperature range for strawberry growth inhibition was between 35 to 40°C.

Part II. Flower bud initiation and related environmental factors

A. Flower bud initiation

Strawberry flower bud initiation is a very complex physiological process. As a perennial plant, it has to be balanced in its vegetative growth and reproduction (Strik, 1985). When a flower bud starts to initiate, the first indication is a broadening and flattening of the apex (Guttridge, 1952; Waldo, 1930), with the terminal flower appearing first (Ruef and Richey, 1926). The sepals appear first followed by the petals, stamens, and pistils (Schilletter and Richey, 1931; Waldo, 1930). Then, secondary flowers appear in the axils of the bracts of the truss (Guttridge, 1952). The secondary flowers are at a younger stage compared to the terminals (Ruef and Richey, 1926; Waldo, 1930). Since the truss is determinate, vegetative growth continues through extension crowns developing from the meristems in upper axillary positions. Flower initiation may also occur on these extension crowns (Arney, 1955a; Guttridge, 1952). Cultivars may differ in truss structure (Darrow, 1929).

B. Environmental factors and flower bud initiation

Photoperiod and temperature are two of the most important factors affecting flower bud initiation and differentiation in strawberries. Flower induction occurs because of leaf exposure to certain photoperiod and temperature, resulting in the production of a flower bud (Durner and Poling, 1988). The transition from vegetative growth to flower bud initiation is also related to photoperiod and temperature. The interaction of photoperiod and temperature on flower bud initiation in strawberry has been well recognized and studied (Darrow and Waldo, 1934; Darrow, 1936; Durner et al, 1984; Hartmann, 1947a & b; Heide, 1977).

1. Photoperiod

Based on flowering response to photoperiod, cultivars can be classified into three groups: Junebearers, short day plants; everbearers, long day plants (Darrow and Waldo, 1934); and day-neutrals, essentially not affected by daylength. Length of night is the important factor in flower bud initiation rather than daylength (Vince-Prue and Guttridge, 1973).

a. Junebearers

In Junebearing cultivars, flower buds initiate in the short days of late September or early October in North America (Goff, 1900; Hill and Davis, 1929; Jahn and Dana, 1969; Schilletter and Richey, 1930, 1931) as well as in Europe (Arney, 1954, 1956). Darrow and Waldo (1934) found that flower bud initiation in Junebearers did not normally occur until the daily light period was sufficiently short, which occurred during the fall of the year. The number of individual flower initials per crown is between 6 to 12 until late January or February when an increase in floral initials occurs (Robertson and Wood 1954). The increased number of initials is due to an enhanced development of previously initiated buds. There is no evidence that new trusses are initiated in the spring although it may occur in temperate climates.

b. Everbearers

Everbearing cultivars generally initiate flower buds throughout the growing season except during the early spring when initial fruiting takes place (Darrow and Waldo 1934). Meristems of runners often initiate flower buds before rooting and axillary buds become floral soon after the production of several leaves in the spring (Waldo 1930). Initiation does not normally occur in branch crowns until it has taken place in the primary terminal meristem, and axillary flower buds seldom develop to maturity (Guttridge 1955).

c. Day-neutrals

Day-neutral cultivars initiate flower buds throughout the growing season. However, they do show some peak times of flowering. Day-neutral plants will produce flowers and runners simultaneously (Strik, 1985).

2. Temperature

Temperature determines many metabolic and growth and developmental processes. Temperature levels set the length of the growing season, and cumulative high or lower temperatures are necessary to trigger such phenomena as bud and leaf expansion, flower opening, and onset of fruiting. Under high temperatures, flower bud initiation is inhibited greatly in day-neutral cultivars. During mid-summer even if day-length is shortened, fewer flowers are produced. If temperatures are too hot, flower bud development will be stopped (Durner et al. 1984). Extreme temperatures injure plants or critical plant parts such as flower buds.

3. Other factors

Light intensity is important in flower bud initiation. Smeet (1955) and Went (1957) found that high light intensities reduced flower initiation in strawberry.

Nitrogen (N) is the major element applied after planting during bed establishment for matted row culture. Late-summer and early fall application is also recommended in established plantings. Applications of N are required to maintain adequate plant nutrient status and vegetative vigor during the critical flower bud initiation period (Long 1939).

Some researchers (Collins, 1965; Guttridge, 1959 a & b) reported that there may be a GA-like substance present in old strawberry leaves which may inhibit flower bud, or truss, initiation. However, there is no direct evidence to prove this theory.

Supplemental irrigation during fruit-bud formation may increase yield. Irrigation during bloom may aid in preventing frost damage to blossoms (Shoemaker 1975).

Part III. Strawberry Yield Components

Genetic (including plant size) and environmental factors (including temperature, solar radiation, nutrition, irrigation etc.) determine the yield of specific varieties by affecting the development of the truss (Guttridge, 1955). The yield of a strawberry plant is determined by the effects of at least four components: the number of crowns/plant, the number of trusses/crown, the number of flowers (berries)/truss, and the mean berry weight (Hondlemann, 1965; Strik and Proctor, 1988d; Webb, et al. 1973).

A. Genotype and yield

1. Variety and yield

Studies of strawberry genotypes during flower bud differentiation showed that they differed in the mean number of crowns, crown dry weight, number of leaves, leaf dry weight, leaf area, and number and weight of runners. However, only the mean crown dry weight, leaf dry weight, and leaf area in the fall were correlated with yield among genotypes the following summer (Strik and Proctor 1988a).

During fruiting, yield per plant within genotypes was mainly dependent on berry number (Strik and Proctor, 1988d). When genotypes were grown in matted rows, vegetative parameters, such as crown dry weight and leaf dry weight, were most correlated with yield (Strik and Proctor, 1988b and d).

However, in the hill system, with less inter-plant competition, reproductive variables, such as berry number and truss number, were correlated with yield as well (Strik and Proctor, 1988c and d).

2. Plant size and yield

Plant size is an important parameter to measure in assessing yield potential of strawberry genotypes (Guttridge and Anderson, 1981). Both positive and negative correlations of plant size and yield have been reported in previous research.

a. Negative correlation

Some reports indicated that container-grown strawberry plants in a controlled environment showed a negative relationship between truss initiation and vegetative growth (Borthwick and Parker, 1952; Guttridge, 1960).

A field study in Scotland (Guttridge and Anderson, 1973) showed that with increasing plant size there was a reduction in the number of flower trusses, some crowns being barren of fruit the following summer. It was concluded that flower truss initiation is more likely to fail in large than small plants, but factors other than plant size may also play an important role. Mason (1966) suggested that a tendency toward barrenness is related to a cultivar's sensitivity to photoperiodic induction of the flower trusses, with the less sensitive genotypes displaying more barrenness. Hughes (1972) noted greater truss deficiencies in high than in lower latitudes (e.g., Scotland vs. England).

A decrease in the number of trusses/crown also was noted for 'Redgauntlet' in Scotland as the size of the plant increased (Guttridge and Anderson, 1973).

b. Positive correlation

On the other hand, the leaf canopy is the major region of photosynthate production in the strawberry plant. Jahn and Dana (1970b) found that plants that had the largest leaf area early in the season continued to grow more rapidly than those with less leaf area.

The number of leaves and leaf area in the fall have been positively correlated with fruit production the following year (Lacey, 1973; Sproat et al., 1935; Strik and Proctor, 1988a). Lacey (1973) found plant size in fall to be positively correlated with the following's yield. Larger plants in fall have been found to produce more flowers (Morrow and Darrow, 1940; Rogers and Edgar, 1938), and greater yields than smaller plants (Peacock, 1939). However, Guttridge and Anderson (1973) found that in one field, an increase in plant size gave a steep increase in yield, while in another field there was only a moderate increase in yield with increasing plant size. They suggested that some direct measure of plant size (not crown number) is essential to accurately assess the yield characteristics and potential of a cultivar.

B. Yield components

1. Crown and crowns/plant

Mason and Rath (1980) found that in commercial plantings of the cultivar 'Cambridge Favourite', crown numbers accounted for more than 50% of the yield variance. Several studies document increased yields with an increasing number of crowns per hectare (Anderson and Guttridge, 1976; Christopher and Shutak, 1938; Craig and Aalders,1966; Craig et al. 1973; Hondlemann, 1965; Waister, 1972; Williams, 1975). However, inter-crown competition can lead to depressed yields (Albregts et al., 1974; Anderson and Guttridge, 1976; Childs, 1942; Christopher, 1941; Christopher and Shutak, 1938; Crane and Haut, 1941; Ricketson, 1970). Anderson and Guttridge (1976) found that parent plants without runners produced more crowns/plant and trusses/plant than did plants with runners in matted or spaced beds, presumably due to reduced inter-crown competition.

2. Truss, trusses/crown and flowers/truss

Guttridge and Anderson (1981) concluded that crown number was not the most reliable guide for assessing fruiting characteristics of a strawberry clone. Rather, individual plant records of trusses/crown, trusses/plant, fruit/truss (correlated with flowers/truss), and mean berry weight were sufficient for analysis of fruit yields. Research on runner removal, earlier time of rooting, and nitrogen fertilization showed that the number of trusses per plant was the most important determinant of yield (Anderson and Guttridge, 1976;

Breen and Martin, 1981; Guttridge and Anderson, 1973; Webb et al., 1973). Exceptions to this occur with some cultivars. For example, in 'Redgauntlet' and 'Talisman', trusses/crown was the most important yield component (Guttridge and Mason, 1966) while 'Cambridge Favourite' had a low coefficient of variation for the number of trusses/crown (Guttridge and Mason, 1966; Mason, 1966).

3. Berry weight and size

Berry size is affected by time of harvest. Primary berries have the largest size. The weight of primary berries is about 15% of total berry weight (Shoemaker, 1975). Irrigation increases the total number of berries, and a linear relationship exists between number of berries and length of harvest (Shoemaker, 1975). Defoliation and some other cultural practices may increase berry size.

Part IV. Renovation and strawberry production

A. Concept and historical background

Renovation is commonly practiced in strawberry production to increase yield the following season. The standard practice of renovation involves removing leaves by cutting the petioles just above the crowns. Renovation also includes runner removal, fertilizing, and irrigating. Since the main procedure of renovation is removing foliage above crowns after harvest, it is also termed topping, or (post-harvest) defoliation.

Defoliation, was recommended in England even before the 19th century. In 1798, the Scots gardener, Walter Nicol, recommended that strawberries being prepared for forcing should have their leaves dressed off in fall (Guttridge, et al., 1961). In California, mowing is recommended during January and February. In that case, it is primarily as sanitation practice for fields which are being cropped for a second year (Shoemaker, 1975). Haller (1943) suggested this as a possible means of reducing desiccation in storage. In Oregon, mowing has been recommended to help control the crown borer (Largestedt, 1965).

Systematic research into renovation started in the mid 1930's by Dr. Waldo at Corvallis, Oregon (Waldo, 1939). The research work indicated that topped plants produced far fewer runners than untopped plants, and appeared to have higher yields.

B. Controversial results of renovation practices

Many researchers have shown increases in yields with renovation. Wilson and Roger (1954) obtained increases in yield of about 20-25% following post harvest defoliation of 'Huxley'. In some trials higher yields were obtained by defoliation up to four to five consecutive growing seasons in the same plantings (Guttridge and Wood, 1961; Guttridge and Mason 1966). Kerkhoff et al (1988) also found that defoliation increased berry size by 18%.

However, the results of defoliation are not always positive. Some reports have shown that renovation caused a decrease in yield. Moore (1968) found that there were yield reductions in all defoliated plants compared with non-defoliated controls. Berry size was also reduced when plants were defoliated on October 1. Welch (1984) found that early defoliation of 'Tioga', 'Aiko', and 'Pajaro' resulted in significant loss of yield. He suggested that severe defoliation, whether early or late, reduced total yield of strawberries. Other researchers also found that there was a negative linear relationship between the number of leaves removed and the number of new leaves and runners produced (Chandler et al., 1988).

C. Reasons why renovation leads to different results

1. Varietal differences

Defoliation of strawberry plants increased truss numbers and fruit yield in some varieties, but not in others. Guttridge and Mason (1966) found that truss numbers and fruit yields were increased more often in the variety 'Talisman' than in 'Redgauntlet', but decreased both in 'Cambridge Favourite' and 'Cambridge Reaguard'. Nestby (1985) found that defoliation at the end of harvest of 'Senga Sengana' had a tendency to increase yield, but both 'Bounty' and 'Fructana' had a reduced yield following defoliation.

2. Location (climatic) differences

The effect of defoliation may also vary with location. In southern Florida, Albregts and Howard (1972) found that when local-grown 'Tioga' and 'Sequoia' plants were defoliated, vigor was reduced 30% lower and total yield was decreased. When California-grown plants of the same varieties were planted in Florida, no detrimental effect was seen from defoliation. The authors attributed this to the difference in chilling history of the plants. Those grown in California had accumulated starch in the roots, which is characteristic of strawberries as they enter dormancy. Florida-grown plants had received no field chilling; consequently, no starch was detected in the roots, apparently resulting in weakened plants.

3. Plant health differences

Renovation may be detrimental for old or unhealthy plants. Research suggests that when strawberry plants are not healthy, defoliation after harvest may actually decrease yield. Pritts (1988) found that early defoliation had a detrimental effect on plant survival and yield the following year when plants were severely infected with root weevils.

D. Physiological reasons why renovation may increase yields

Renovation increases the number of crowns and trusses, flower bud number (Guttridge et al. 1961, Pritts 1988) and flowers per truss (Nestby, 1985). Also, an increased proportion of crowns formed fruit trusses with an increased number of trusses per crown (Guttridge and Mason 1966). An increase in yield by defoliation may be due to the following factors:

1) There may be a flowering inhibitor in old leaves with defoliation removing this inhibitor. Thus renovation promotes flower bud initiation (Guttridge 1959a & b; Thompson and Guttridge 1960). Some evidence indicates that this inhibitor may be a GA-like substance forming under long day conditions (Guttridge and Thompson 1964, Jonkers 1965, Unematsu and Katsura 1983). However, to date this has not been proved.

2) Renovation affects flower bud initiation indirectly by affecting growth. Mason (1966) suggested that the strawberry varieties 'Talisman' and 'Redgauntlet' initiated flower trusses in two phases: Phase I in summer and Phase II in fall. Defoliation in August (after completion of Phase I) frequently increased the amount fall truss initiation and promoted the emergence, in the fall, of trusses formed in the summer. Since Phase I initiation was observed rarely in 'Cambridge Favourite' and never in 'Royal Sovereign', defoliation immediately reduced the rate of Phase II initiation.

Moore (1968) suggested that defoliation may not be of benefit in varieties in which only fall floral initiation normally occurs. In those varieties removal of the leaves not only fails to promote flower initiation but may actually disturb the normal initiation process.

E. Importance of date of renovation

One of the important factors that appears to affect the success of renovation is date of renovation. This has been noted by some researchers (Guttridge and Wood, 1961; Guttridge and Mason, 1961 & 1966; Mason, 1967; Moore, 1968; Nestby, 1985). Some scientists suggested that plants may benefit from mowing right after harvest; however, some did not agreed with this. All researchers believe that defoliation should not be done too late. Guttridge and Wood (1961) suggested that 'Talisman' and 'Redgauntlet' would produce consistently high yields if defoliation has been done before mid-August beginning after the first full crop. Guttridge and Mason (1961 and 1966) found that delaying defoliation (especially later than early September) did not maximize yields, due to lower rate of truss initiation, fewer crowns, crown death, and less yield of fruit per truss, compared with uncut controls. Mason (1967) found that early defoliation (July 27) had little effect on the number of trusses initiated, but defoliation on 19 August increased truss initiation.

Chapter II: METHODS AND MATERIALS

Two experiments were conducted in this research project. Strawberry plants of three local commercial cultivars, 'Benton', 'Totem', and 'Redcrest', were selected. 'Benton' and 'Totem' are the major cultivars grown in Oregon and the PNW. 'Redcrest' was selected from the OSU and USDA breeding program in 1990. It was tested as ORUS 4930 and is mostly suitable for the processing market. 'Benton' is a cold susceptible but disease-resistant cultivar (Galletta, 1990). 'Totem' is a winter hardy variety (Daubeny, 1971). 'Redcrest' has hardiness characteristics between 'Benton' and 'Totem', and has resistance to some diseases.

Part I. Experiment 1.

On May 17, 1987, 'Benton' plants were established in a hill system at a 38.1 cm (15 in) spacing with 101.6 cm (40 in) between rows. Plots were maintained according to standard commercial practice.

The experimental design was completely randomized (CRD), with 8 renovation treatments and 5 replicates (plots) in each treatment. There were twelve plants in a plot. The treatments were different dates of renovation (Table 1). Plots were renovated weekly from July 6, 1988, one week after harvest (WAH), to August 24 (8 WAH). Renovation consisted of: 1)

Table 1. Relationship between date of renovation treatments and weeks after last harvest. Accumulative degree day temperatures for each renovation treatment are also given.

WAH*	1	2	3	4	5	6	7	8
1988	7/6	7/13	7/20	7/27	8/3	8/10	8/17	8/24
1989	---	7/12	7/19	7/26	8/2	8/9	8/16	---
ADDT**								
1988	2239	2355	2323	2338	2310	2254	2198	2170
1989	----	2248	2244	2244	2262	2245	2265	----

*: Week after harvest

**: Accumulative degree day temperatures of 5 weeks starting from one week after the equivalent renovation date.

mowing the foliage off above the crown; 2. removal of all runners from the plants; 3) application of fertilizer at rate of 30 kg of nitrogen and 15 kg of potassium and phosphate per acre; and 4) irrigation.

From September 27 through October 3, 1988, the number of flowers, trusses, and runners per plant were recorded. Runners were then removed to maintain plants in the hill system.

From June 8 through June 25, 1989, strawberries were harvested three times at approximately one week intervals. At each harvest the fruits were separated into marketable yield and non-marketable yield. Rotted fruit were weighted seperately. Berry size was based on the average weight of 25 berries taken at randomly from each harvest with a weighted mean for the season.

After harvest, the number of flowers (by counting pedicels), trusses, and crowns per plant were determined by destructively sampling 3 plants in each plot.

Due to the small plot area available, the non-renovated treatment was taken from the guard rows in 5 different areas. The number of crowns, trusses, and flowers per plant were recorded for comparison with the renovated treatments.

Part II. Experiment 2.

On May 20, 1988, strawberry plants of three cultivars, 'Benton', 'Totem', and 'Redcrest', were planted. The experimental design and plant spacing were similar to those previously described. However, there were only 6 renovation treatments plus a control (unrenovated) with 4 replicates. Renovation treatments were from July 12 (2 WAH), 1989, to August 16 (7 WAH), 1989, weekly.

The method of renovation and all other cultural practices were similar to the those described in Experiment 1. On July 26 (4 WAH), due to poor adjustment of the mower, the crown tips were cut partially in 'Benton' plantings (this problem was discovered, and corrected when the 'Totem' and 'Redcrest' plantings were mowed). This may have influenced the growth and yield of those 'Benton' plants in the fall and the following summer in Experiment 2.

In October, 1989, the number of flowers and trusses per plant (on 4 plants within each replicate) and the number of runners per plant (on 12 plants in a replicate) were recorded.

From April 26 through 29, 1990, the number of flowers per plant (on 4 plants selected in each replicate the previous fall) was recorded.

'Benton' and 'Redcrest' were harvested 3 times, and 'Totem' 4 times in summer 1990. Berry size was calculated as in Experiment 1. However, data for berry size were not calculated on the fourth picking in 'Totem', because of time availability.

After harvest, the number of crowns, trusses, and flowers per plant were determined as in Experiment 1. The fresh weight of trusses (including small remaining fruits) and plants (including leaves, petioles, crowns and roots) of two plants in each replicate were recorded. Leaf number was recorded for 'Totem' and 'Redcrest' at the same time. Leaf area was measured with a leaf area machine. Each plot was assigned by a specific X_{ijab} label system (X-cultivars; i-treatments; j-replicates; ab-position, counting form North to South in the field, of an individual plant in a plot). The following replicates were lost during the experiment: B_{24}, B_{33}, B_{34}, T_{34}, R_{24}, due to experimental error (first time renovated plants were mixed with the side plants), B_{41}, B_{42}, and B_{43} due to mechanical damage of the crown during renovation, and B_{74} due to plant growth (completely died).

The results were analyzed by one-way ANOVA, multiple factors (subsampling) ANOVA, and simple and multiple regression analysis (Peterson, 1985).

Dates of renovation in 1988 and 1989 and the accumulative degree day temperatures (ADDT) of 35 days (from 1 to 5 weeks after renovation) were calculated and summarized in Table 1. ADDT is a sum of temperatures starting from one week after each renovation date, and the most important period for fall flower emergence.

CHAPTER III: RESULTS

Part I. Experiment 1.

A. Fall 1988

In fall 1988, the number of runners per plant in those plants renovated from 1 to 3 weeks after harvest (WAH) was much greater than in plants that were renovated later (Table 2). The number of runners per plant showed a negative quadratic relationship with date of renovation (Fig. 1).

Date of renovation in 1988 had a significant effect on the number of trusses ($P < 0.05$) and flowers ($P < 0.01$) per plant in the fall. Early renovation (July 20 or earlier) led to a greater number of trusses and flowers per plant (Table 2). The highest number of trusses per plant resulted from renovation 3 WAH (July 20) (Table 2, Fig. 2A). Renovation 2 WAH (July 13) led to the greatest number of flowers per plant (Table 2, Fig. 2B). Both the number of trusses and flowers per plant had a negative quadratic relationship with date of renovation (Fig. 2).

Date of renovation had a significant effect ($P < 0.01$) on the number of flowers per truss (Table 2), showing a negative linear relationship ($r=-0.66$) (Fig. 3).

B. Summer 1989

Date of renovation of 'Benton' in 1988 had no significant

Table 2. Effect of date of renovation in 1988 on yield components of 'Benton' in the fall of 1988.

Date (1988)	Trusses /plant	Flowers /plant	Flowers /truss	Runners /plant
7/6	13.0bc*	93.2cd	7.2de	11.4d
7/13	14.2bc	110.2d	7.8e	11.3d
7/20	15.2c	97.0cd	6.4bc	6.1c
7/27	13.2bc	86.1bc	6.5bcd	3.0b
8/3	12.4ab	83.3bc	6.7cd	1.5ab
8/10	12.6ab	82.2bc	6.5bcd	0.7a
8/17	12.4ab	72.2ab	6.0bc	0.2a
8/24	10.2a	58.3a	5.7abc	0.1a
LSD	2.51	19.1	0.7	2.0
P**	0.05	0.01	0.01	0.01

*: means followed by the same letter are not significantly different by LSD.

**: Significant at $P < 0.05$, or $P < 0.01$, and not significant (NS) as indicated.

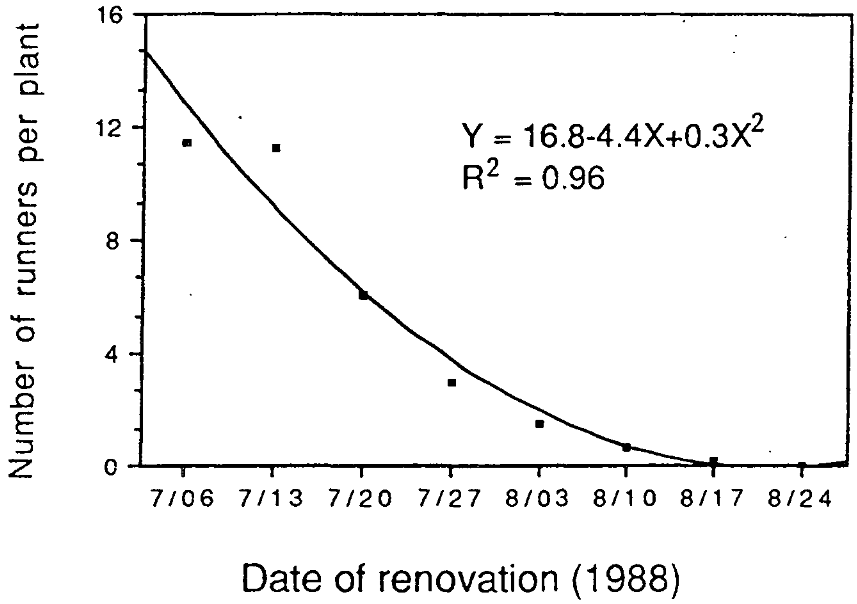

Fig. 1 Relationship between date of renovation of 'Benton' in 1988 and the number of runners per plant in fall 1988

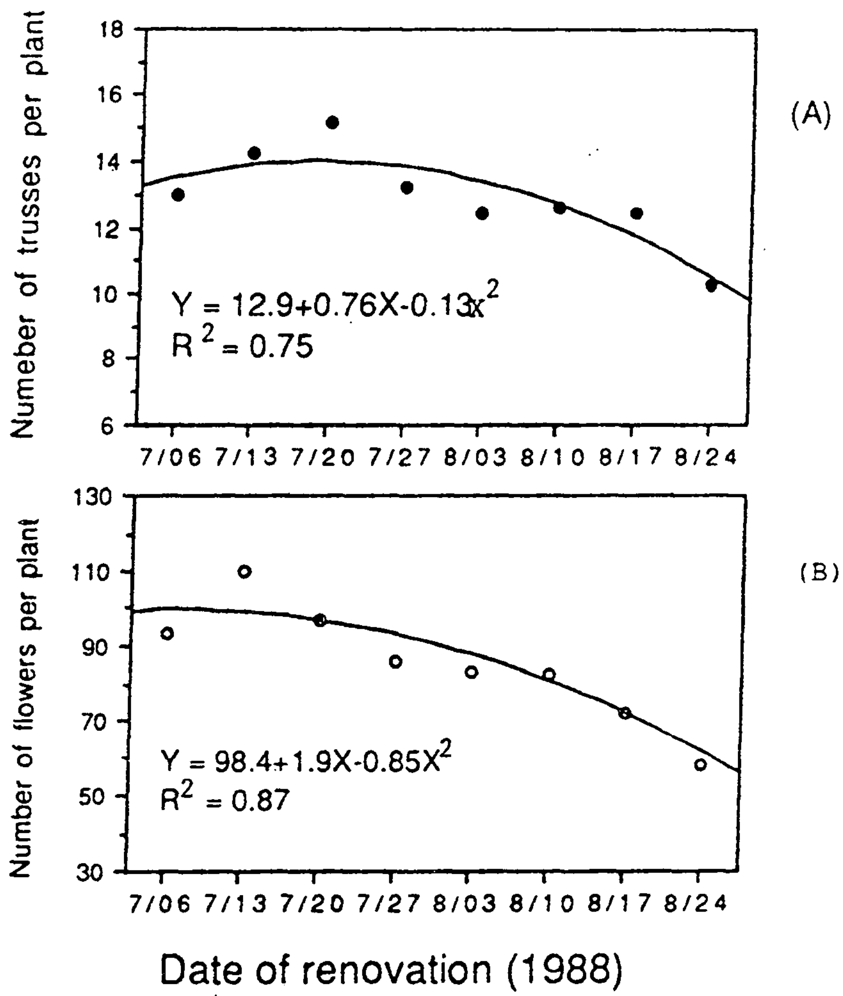

Fig. 2 Relationship between date of renovation of 'Benton' in 1988 and the number of trusses (A) and flowers (B) per plant in the fall of 1988

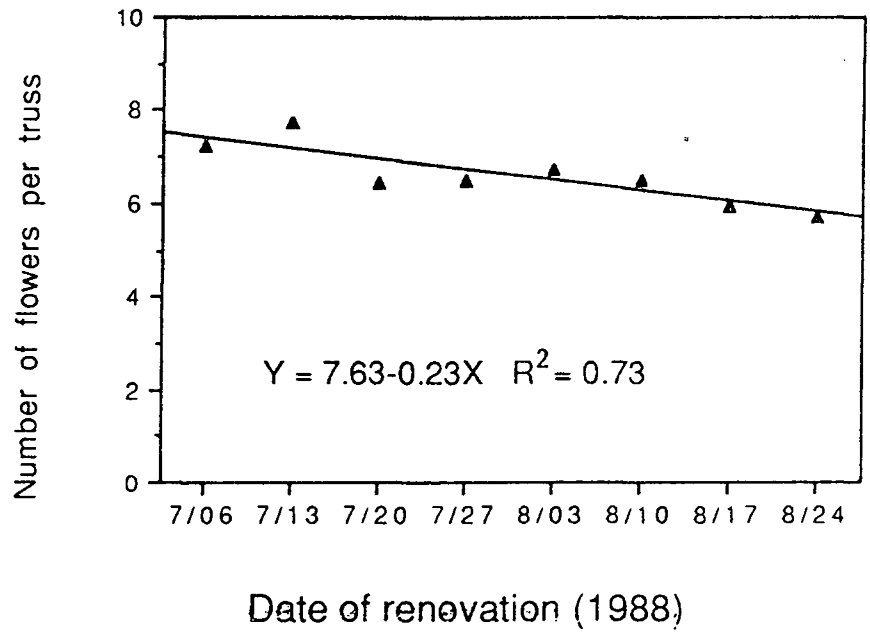

Fig. 3 Effect of date of renovation of 'Benton' in 1988 on the number of flowers per truss in the fall of 1988

effect on the number of crowns per plant in the summer of 1989 (Table 3). However, there was a tendency for un-renovated (control) plants to have a higher number of crowns per plant than renovated plants (Table 3). Based upon field observation, un-renovated plants had apparently larger sized crowns than those of renovated plants. Crown number per plant in 1989 was not significantly correlated with yield per plant in 1989 (Table 4A).

Plants renovated 4 WAH (July 27) or later had a higher number of trusses and flowers per plant than those renovated earlier (Table 3). The difference between early- and late-renovated groups was significant at the 1% level. Control plants (un-renovated) did not differ from renovated plants, on average, in the number of trusses per plant, but had a lower than average number of flowers per plant (Table 3). The numbers of trusses and flowers per plant were linearly correlated with date of renovation (Fig. 4).

Date of renovation had a significant effect on the number of flowers per truss (Table 3). Un-renovated plants had a lower number of flowers per truss than early-renovated plants (Table 3). There was no significant linear or quadratic relationship between date of renovation and number of flowers per truss.

Yield per plant of 'Benton' in the summer of 1989 was significantly ($P < 0.05$) affected by date of renovation in 1988 (Table 3). Plants renovated from 4 to 8 WAH (July 27 to

Table 3. Effect of date of renovation in 1988 on yield components of 'Benton' in the summer of 1989.

Date(1989)	Crowns /plant	Trusses /plant	Flowers /plant	Flowers /truss	Berry size (g)	Yield /plant (g)
Control	36.2	35.6abcd*	182a	5.3a		
7/6	30.6	30.3a	183ab	6.1bc	8.1	619a
7/13	32.1	30.9ab	186abc	6.2bc	8.0	634ab
7/20	30.1	32.1abc	180a	5.7ab	8.0	597a
7/27	32.9	36.9bcd	221cd	6.0bc	8.8	732abc
8/3	33.1	37.5cd	241d	6.5c	8.5	760bc
8/10	32.1	40.9d	222cd	5.5ab	7.7	717abc
8/17	32.3	41.2d	234d	5.7ab	8.5	767bc
8/24	30.8	39.2d	218bcd	5.6ab	8.6	796c
LSD	5.7	8.4	51.5	1.0	1.0	141
P**	NS	0.01	0.01	0.05	NS	0.05

*: means followed by the same letter are not significantly different by LSD.

**: Significant at $P < 0.05$, or $P < 0.01$, and not significant (NS) as indicated.

Table 4. Correlation coefficients between yield per plant in the summer of 1989 and yield components for 'Benton' in the summer of 1989 (A) and fall 1988 (B).

(A) Correlation coefficients between yield per plant and yield components for 'Benton' in the summer of 1989.

	Crowns/plant	Trusses/plant	Flowers/plant	Truss/crown
Yield /plant	0.53	0.87**	0.91**	0.82**

*,**: significant at P < 0.05 and P < 0.01, respectively.

(B) Correlation coefficients between yield per plant in the summer of 1989 and yield components for 'Benton' in the fall 1988.

		Fall, 1988		
		Trusses /plant	Flowers /plant	Runners /plant
	Crown	-0.15	-0.02	-0.35
Summer	Truss	-0.65	-0.81*	-0.68
1989	Flower	-0.66	-0.70	-0.88**
	Yield	-0.85**	-0.85**	-0.86**

*,**: significant at P < 0.05, and P < 0.01.

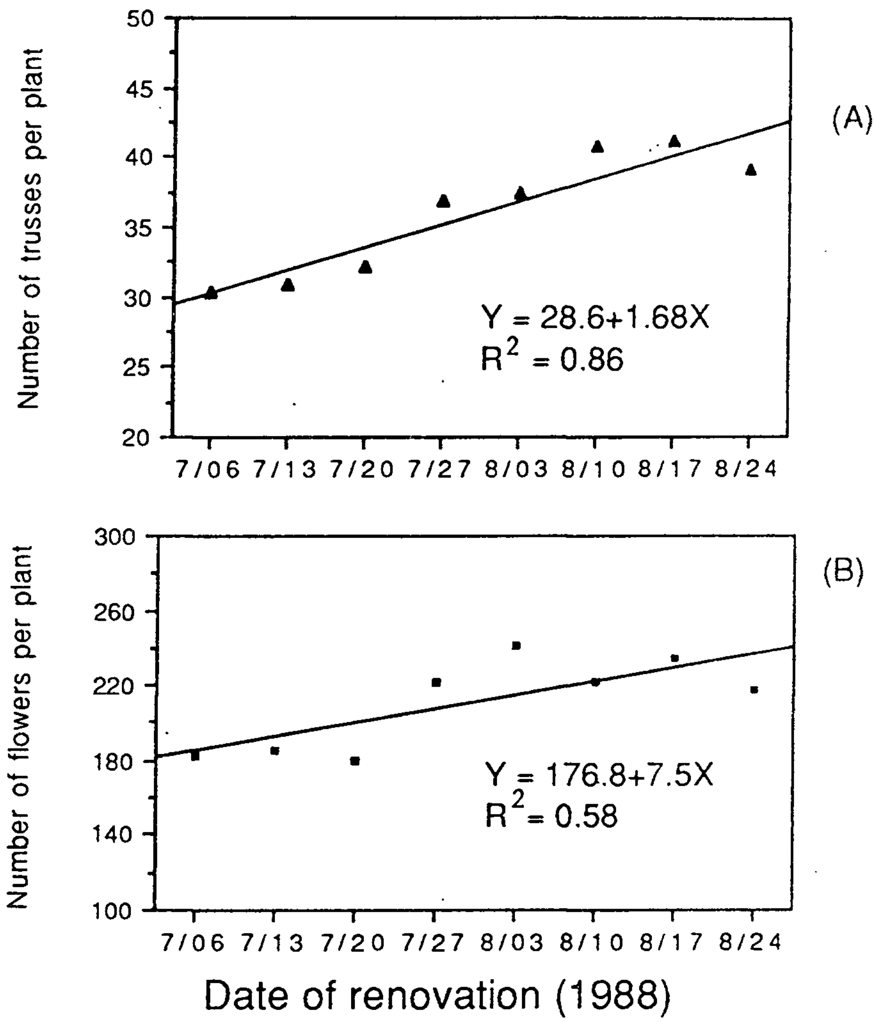

Fig. 4 Relationship between date of renovation of 'Benton' in 1988 and the number of trusses (A) and flowers (B) per plant in the summer of 1989

August 24) tended to have greater yields than those renovated from 1 to 3 WAH (Table 3, Fig. 5). Yield per plant showed asignificant linear relationship with date of renovation (Fig. 5).

There was no significant difference in berry size among the renovation treatments (Table 3). However, yield per plant was significantly correlated with the number of trusses and flowers per plant and the number of trusses per crown in 1989 (Table 4A).

Yield per plant in the summer of 1989 was negatively correlated with the number of trusses, flowers, and runners per plant the previous fall (Table 4B). Renovated plants that produced a large number of flowers in the fall, produced fewer flowers the following summer (Fig. 6).

Part II. Experiment 2.

A. Fall 1989

'Benton', 'Totem' and 'Redcrest' differed in the effect of date of renovation in 1989 on the number of runners per plant in fall 1989 (Table 5). In general, 'Totem' had the greatest number of runners, while 'Benton' had the lowest number. In 'Totem' and 'Redcrest', there were fewer runners on plants renovated 4 WAH (July 26, 1989) or later than on un-renovated (control) plants (Table 5). In 'Benton', renovation at all dates, except 2 WAH, led to fewer runners per plant

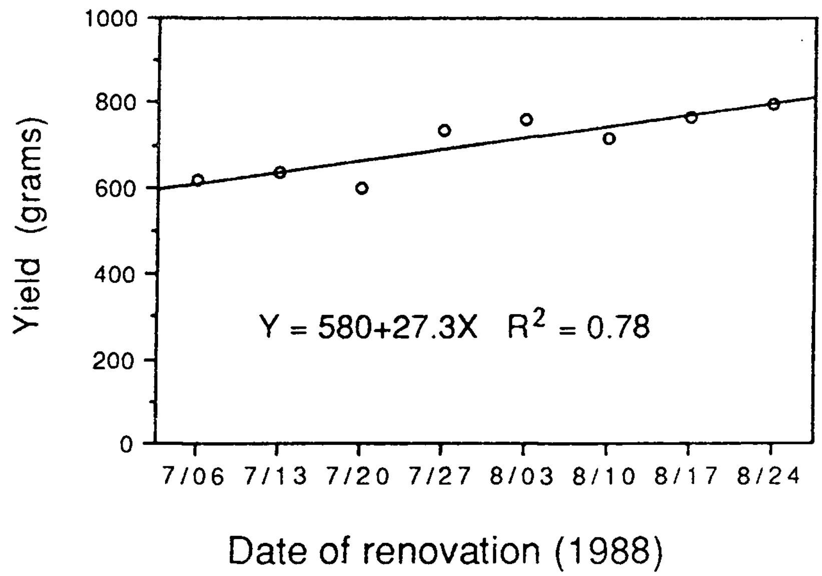

Fig. 5 Effect of date of renovation of 'Benton' in 1988 on yield per plant in 1989

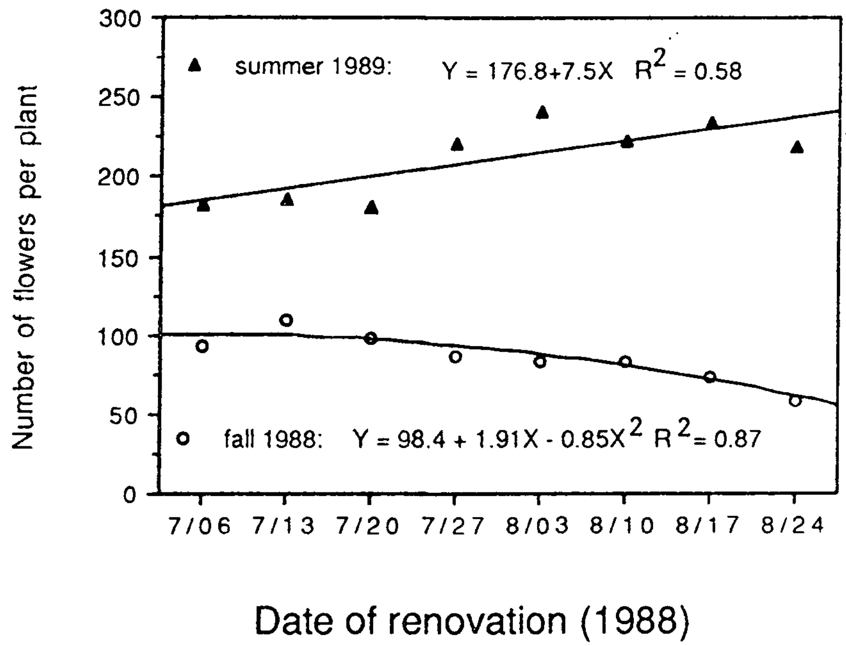

Fig. 6 Effect of date of renovation in 1988 on the number of flowers per plant of 'Benton' in the fall of 1988 and the summer of 1989

Table 5. Effect of date of renovation in 1989 on number of runners per plant for 'Benton', 'Totem', and 'Redcrest' in the fall of 1989.

Date(1989)	Benton	Totem	Redcrest
Control	7.3d*	18.8d	10.2c
7/12	6.8d	22.3e	14.7d
7/19	4.3c	18.9d	10.9c
7/26	1.1b	13.9c	4.9b
8/2	0.1ab	6.2b	3.2b
8/9	0.1a	2.0a	1.4ab
8/16	0.0a	0.7a	0.5a
LSD	1.7	3.8	3.0
P**	0.01	0.01	0.01

*: means followed by the same letter are not significantly different by LSD.

**: Significant at $P < 0.05$, or $P < 0.01$, and not significant (NS) as indicated.

than the control (Table 5). In 'Benton' and 'Redcrest', there was a quadratic relationship between the number of runners per plant and the date of renovation (Fig. 7). However, in 'Totem' there was a negative linear relationship between the number of runners per plant and date of renovation (Fig. 7).

Cultivars responded differently to date of renovation in terms of fall fruiting (number of trusses and flowers per plant) in 1989. In 'Benton', there was no significant treatment effect on the number of trusses and flowers per plant. However, there was a quadratic relationship between date of renovation and the number of trusses and flowers per plant ($P < 0.05$). The peak of the quadratic line was around 4 to 5 WAH (Table 6A, Fig. 8).

A comparison of fruiting (number of trusses and flowers per plant) in the fall of 1988 and 1989, illustrated that the patterns were reversed. Early renovation in 1988 led to the greatest number of trusses and flowers per plant; however this did not occur in 1989 (Fig. 9)

'Totem' had little fruit production in fall 1989 (Table 6B).

In 'Redcrest', there was a significant effect of date of renovation on the number of trusses ($P < 0.05$) and flowers ($P < 0.01$) per plant (Table 6C). Late-renovated plants (6 and 7 WAH) had the lowest number of trusses and flowers per plant. In 'Redcrest', date of renovation showed a significant negative linear relationship with the number of trusses (P <

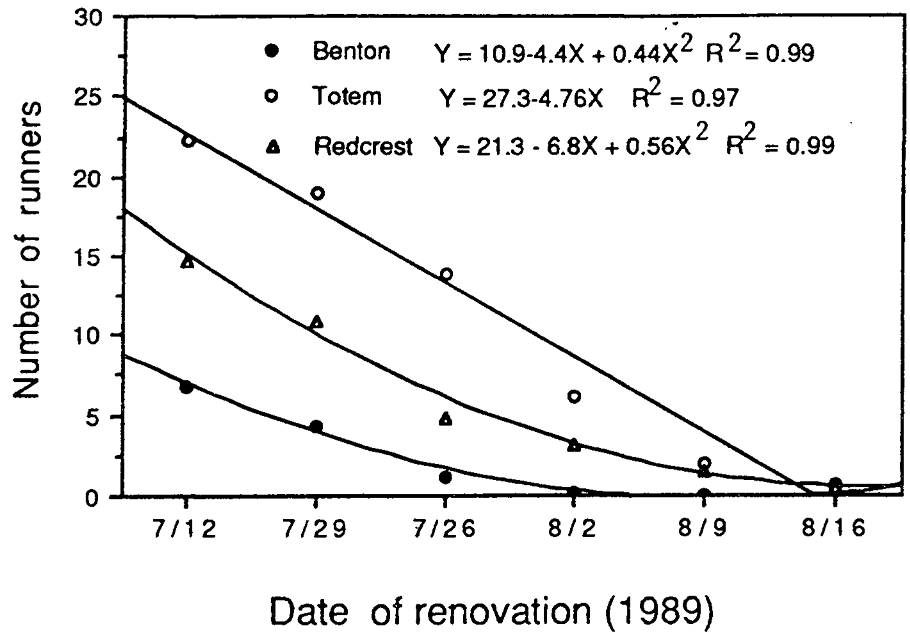

Fig. 7 Relationship between date of renovation of 'Benton', 'Totem', and 'Redcrest' in 1989 and the number of runners per plant in the fall of 1989

Table 6. Effect of date of renovation in 1989 on yield components of 'Benton' (A), 'Totem' (B), and 'Redcrest' (C) in the fall of 1989.

(A) Benton

Date(1989)	Trusses/plant	Flowers/plant	Flowers/truss
Control	7.4	44.3	6.1
7/12	8.8	57.7	6.3
7/19	8.9	69.5	7.3
7/26	10.0	64.5	5.8
8/2	11.9	71.8	6.4
8/9	12.7	71.8	5.5
8/16	7.8	45.6	5.5
LSD	6.3	39.2	1.7
P*	NS	NS	NS

*: Significant at P < 0.05, or P < 0.01, and not significant (NS) as indicated.

(B) Totem

Date(1989)	Trusses/plant	Flowers/plant	Flowers/truss
Control	0.1	0.5	5.2
7/12	0.2	1.1	5.5
7/19	0.8	5.3	6.6
7/26	0.2	2.4	7.7
8/2	0.4	3.3	7.9
8/9	0.4	2.7	6.7
8/16	0.4	2.7	6.8
LSD	1.0	6.8	3.2
P	NS	NS	NS

*: Significant at P < 0.05, or P < 0.01, and not significant (NS) as indicated.

(Continued on the next page)

(Table 6, continued)

(C) Redcrest

Date(1989)	Trusses/plant	Flowers/plant	Flowers/truss
Control	10.1bc**	76.6bc	7.8ab
7/12	10.3bc	98.3cd	9.6c
7/19	11.4c	100.6d	9.1c
7/26	10.4bc	94.6cd	8.8bc
8/2	10.0bc	80.8bcd	8.0ab
8/9	7.9ab	58.1ab	7.5a
8/16	6.6a	50.8a	7.6a
LSD	4.0	33.5	1.5
P**	0.05	0.01	0.01

*: means followed by the same letter are not significantly different by LSD.

**: Significant at $P < 0.05$, or $P < 0.01$, and not significant (NS) as indicated.

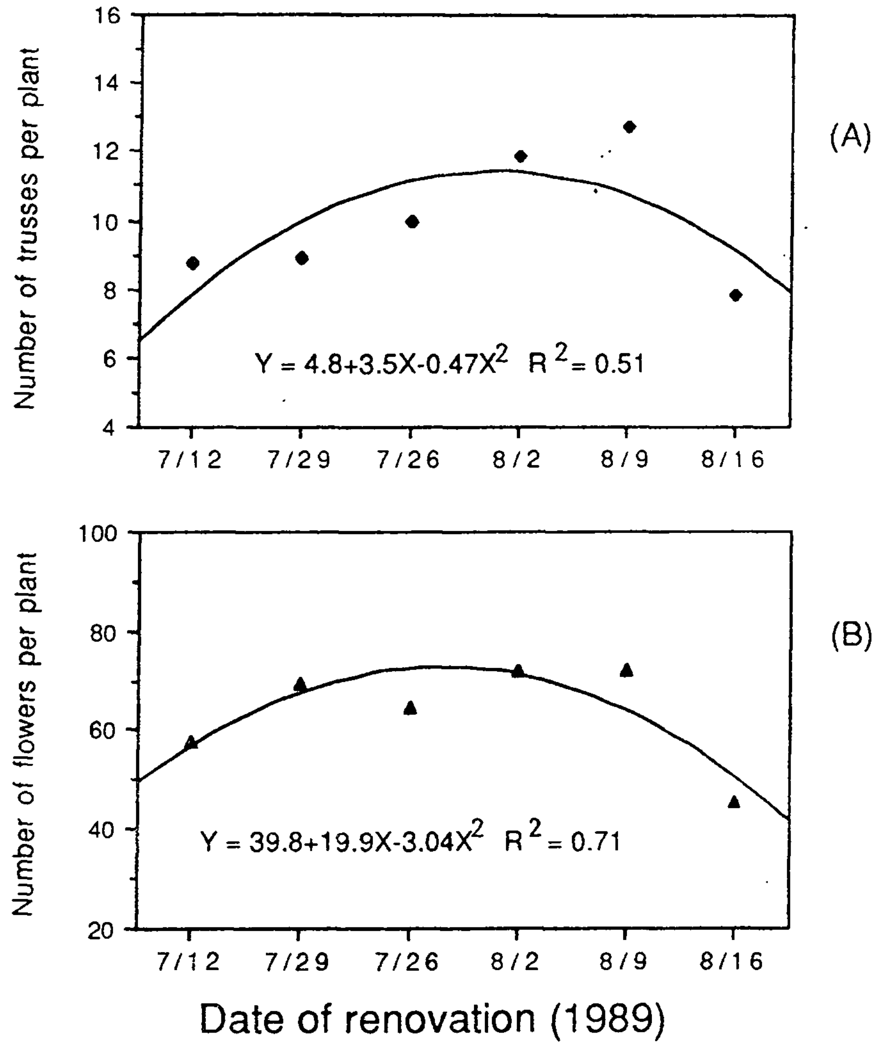

Fig. 8 Relationship between date of renovation of 'Benton' in 1989 and the number of trusses (A) and flowers (B) per plant in the fall of 1989

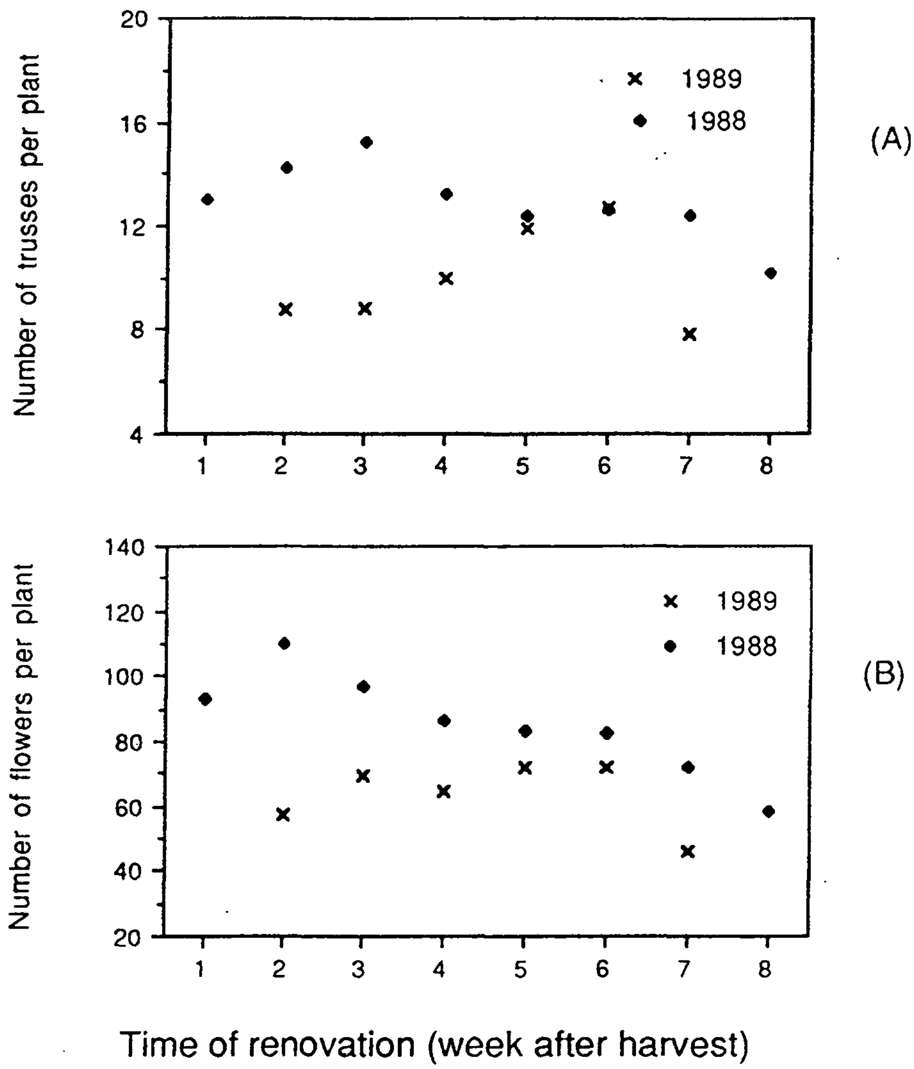

Fig. 9 Comparison of the number of trusses (A) and flowers (B) per plant in the fall of 1988 and 1989 for 'Benton'

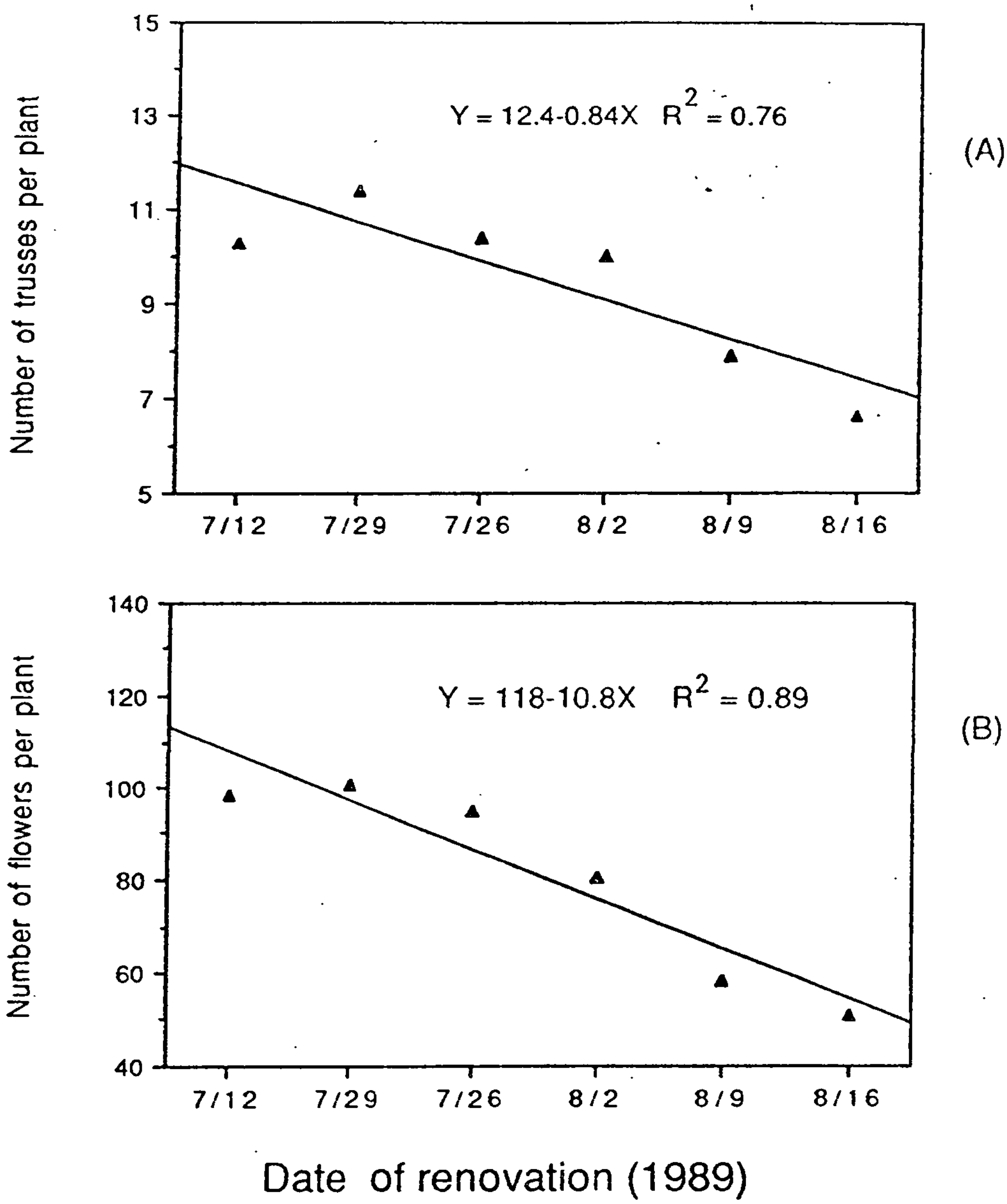

Fig. 10 Relationship between date of renovation in 1989 and the number of trusses (A) and flowers (B) in the fall for 'Redcrest'

0.05) and flowers ($P < 0.01$) per plant (Fig. 10). Unlike 'Benton', the number of flowers per truss differed significantly among treatments in 'Redcrest' (Table 6C). Early-renovated plants (2 and 3 WAH) had greater number of flowers pertruss than late-renovated plants (Table 6C).

B. Summer 1990

In 'Benton', contrary to renovation in 1988, there was a significant effect of date of renovation in 1989 on the number of crowns per plant the following summer (Table 7, Fig. 11). Renovation 6 and 7 WAH (August 9 and 16) led to fewer crowns per plant than the control and early (5 WAH or earlier) renovated plants (Table 7). The number of crowns in 'Benton' showed a quadratic relationship ($P < 0.05$) with date of renovation (Fig. 11). Similar to the previous summer, the control plants had a slightly higher number of crowns per plant than renovated plants (Table 3 and 7).

In 'Totem' and 'Redcrest' there was no significant treatment effect on the number of crowns per plant (Table 7).

In 'Benton', summer 1990, there were a greater number of trusses and flowers per plant in early-renovated (5 WAH or earlier) plants than in late-renovated plants or control plants (Table 8A). Both the number of trusses and flowers per plant showed a quadratic relationship with date of renovation in 'Benton' (Fig. 12).

Summer fruiting of 'Benton' in 1990 showed a reversed

Table 7. Effect of date of renovation on the number of crowns per plant of 'Benton', 'Totem', and 'Redcrest' in summer 1990

Date(1989)	Benton	Totem	Redcrest
Control	37.1d*	19.4	16.5
7/12	31.0abc	19.3	19.2
7/19	31.0abcd	16.3	17.4
7/26	32.3bcd	15.8	20.0
8/2	33.1cd	18.0	19.4
8/9	27.4ab	17.4	16.6
8/16	24.7a	18.3	16.3
LSD	5.3	5.0	4.6
P**	0.01	NS	NS

*: means followed by the same letter are not significantly different by LSD.

**: Significant at $P < 0.05$, or $P < 0.01$, and not significant (NS) as indicated.

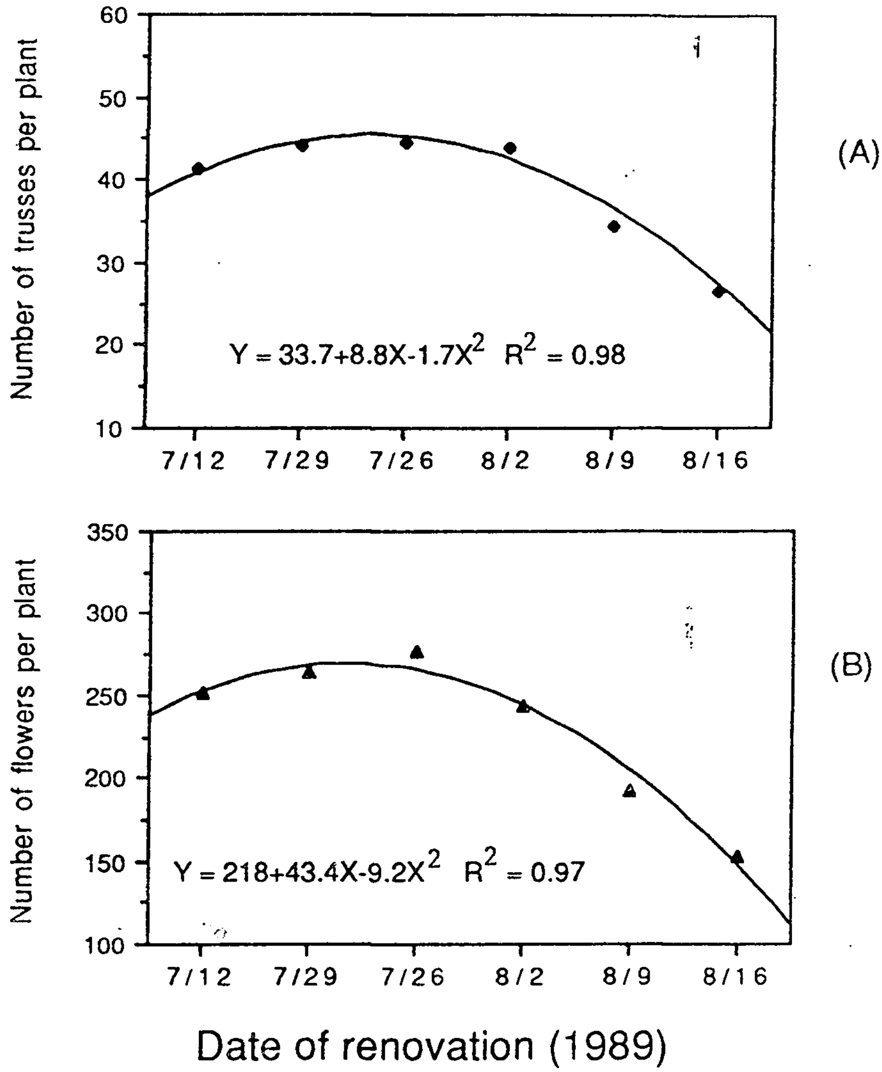

Fig. 11 Relationship between date of renovation of 'Benton' in 1989 and the number of crowns per plant in the summer of 1990

Table 8. Effect of date of renovation in 1989 on the number of trusses and flowers per plant, and flowers per truss of 'Benton', 'Totem', and 'Redcrest' in the summer of 1990.

(A) Benton

Date(1989)	Trusses /plant	Flowers /plant	Flowers /truss
Control	30.6ab*	170a	5.5
7/12	41.2bc	251bc	6.2
7/19	44.1c	264c	6.9
7/26	44.5c	276c	6.0
8/2	43.9c	243bc	5.6
8/9	34.4abc	192ab	5.6
8/16	26.3a	152a	5.6
LSD	10.7	53.5	0.9
P**	0.05	0.01	NS

*: means followed by the same letter are not significantly different by LSD.
**: Significant at P < 0.05, or P < 0.01, and not significant (NS) as indicated.

(B) Totem

Date(1989)	Trusses /plant	Flowers /plant	Flowers /truss
Control	28.5	198	6.9
7/12	31.6	202	6.4
7/19	24.3	170	7.1
7/26	26.3	183	7.0
8/2	27.1	186	6.9
8/9	25.0	184	7.4
8/16	23.0	168	7.4
LSD	7.0	45	0.7
P*	NS	NS	NS

*: Significant at P < 0.05, or P < 0.01, and not significant (NS) as indicated.

(Continued on next page)

(Table 8, continued)

(C) Redcrest

Date(1989)	Trusses /plant	Flowers /plant	Flowers /truss
Control	32.4	180	5.6
7/12	33.7	195	5.8
7/19	32.0	180	5.6
7/26	35.1	203	5.8
8/2	36.5	201	5.6
8/9	32.6	190	5.9
8/16	31.0	184	6.0
LSD	8.0	50	0.7
P*	NS	NS	NS

*: Significant at $P < 0.05$, or $P < 0.01$, and not significant (NS) as indicated.

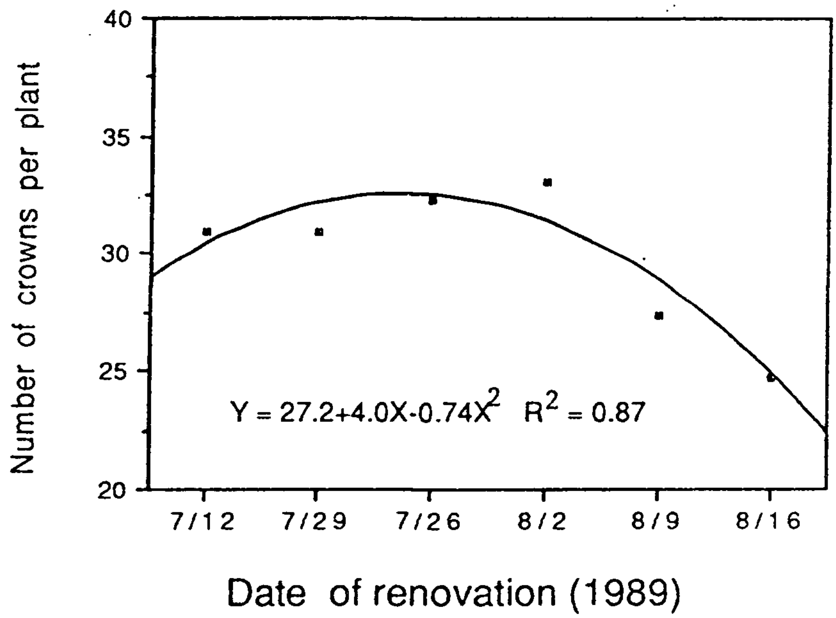

Fig. 12 Effect of date of renovation of 'Benton' in 1989 on the number of trusses (A) and flowers (B) per plant in the summer of 1990

pattern compared with the previous year. Early renovation (4 WAH) led to the greatest number of trusses and flowers per plant in the summer of 1990; however, in 1989 renovation on those dates led to the fewest number of trusses and flowers per plant (Fig. 13 A&B).

There was no significant treatment effect on the number of flowers and trusses per plant in 'Totem' and 'Redcrest' (Table 8B & C).

Date of renovation in 1989 had a significant effect on leaf area per plant (summer 1990) in 'Benton', but not in 'Totem' or 'Redcrest' (Table 9). Leaf area showed a negative linear relationship with date of renovation in 'Benton' ($P < 0.05$) (Fig. 14). In 'Benton', the leaf area per plant in renovation treatments was lower than control (un-renovated) plants (Table 9).

In 'Benton' and 'Redcrest', date of renovation had a significant effect on plant fresh weight (Table 9). Plant fresh weight included crowns, roots, and leaves. In 'Benton', the fresh weight of plants renovated 6 and 7 WAH tended to be lower than other renovation treatments and control plants (Table 9). There was a significant negative quadratic relationship between plant fresh weight and date of renovation in 'Benton' ($P < 0.05$) (Fig. 15A), and a negative linear relationship in 'Redcrest' ($P < 0.05$) (Fig. 15B).

There was a significant difference in harvest date (percent of total yield picked in first harvest) among

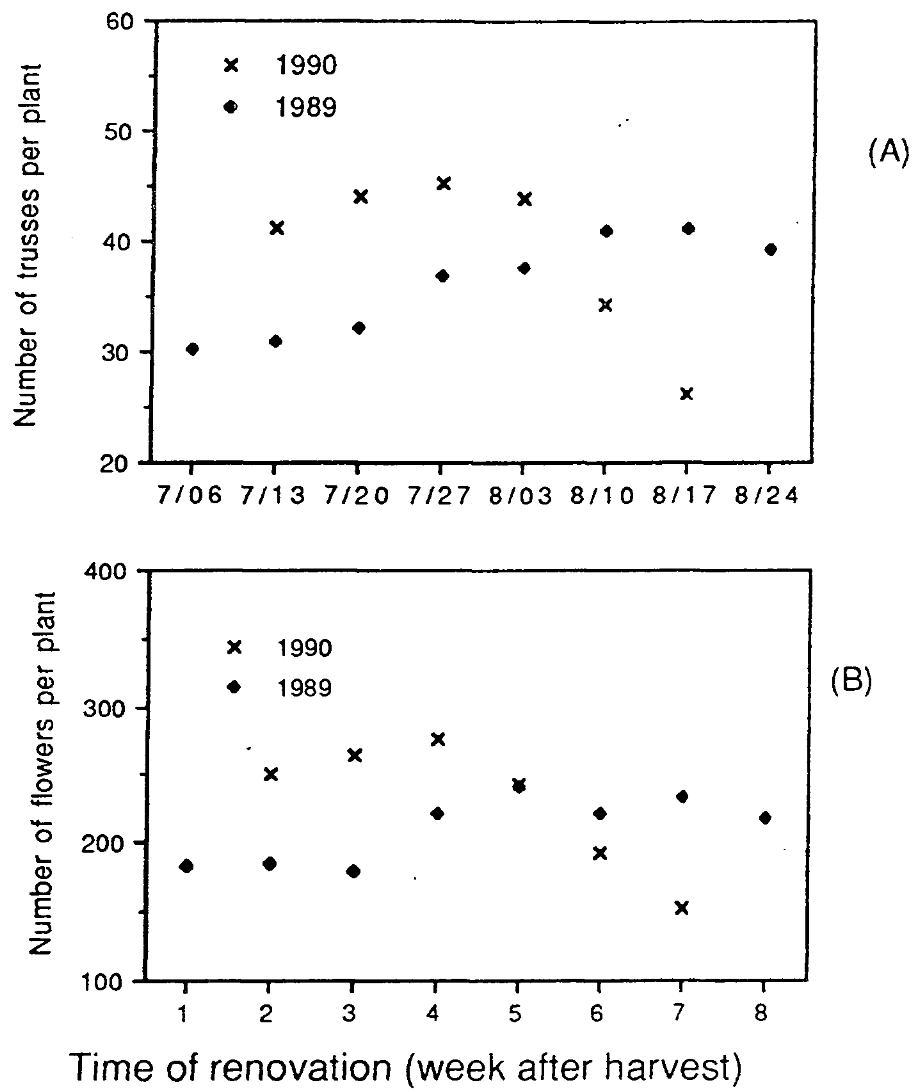

Fig. 13 Comparison of the effect of date of renovation on the number of trusses (A) and flowers (B) per plant in the summer of 1989 and 1990

Table 9. Effect of date of renovation on leaf area (LA) and fresh weight (PFW) per plant in 'Benton', 'Totem', and 'Redcrest' summer 1990.

	Benton		Totem		Redcrest	
Date(1989)	Leaf area (cm^2)	Plant weight (g)	Leaf area (cm^2)	Plant weight (g)	Leaf area (cm^2)	Plant weight (g)
Control	8825d*	744d	4572	436	2951	321a
7/12	6125abc	578abcd	5913	492	5051	495c
7/19	6955cd	605acd	5783	545	3979	396abc
7/26	6894cd	620cd	6081	565	4643	439bc
8/2	6233bc	612cd	6050	535	3823	357ab
8/9	4264a	414ab	6495	570	3416	365ab
8/16	4312ab	411ab	5340	512	3112	329ab
LSD	2194	217	1591	165	1726	137
P**	0.05	0.01	NS	NS	NS	0.05

*: means followed by the same letter are not significantly different by LSD.

**: Significant at $P < 0.05$, or $P < 0.01$, and not significant (NS) as indicated.

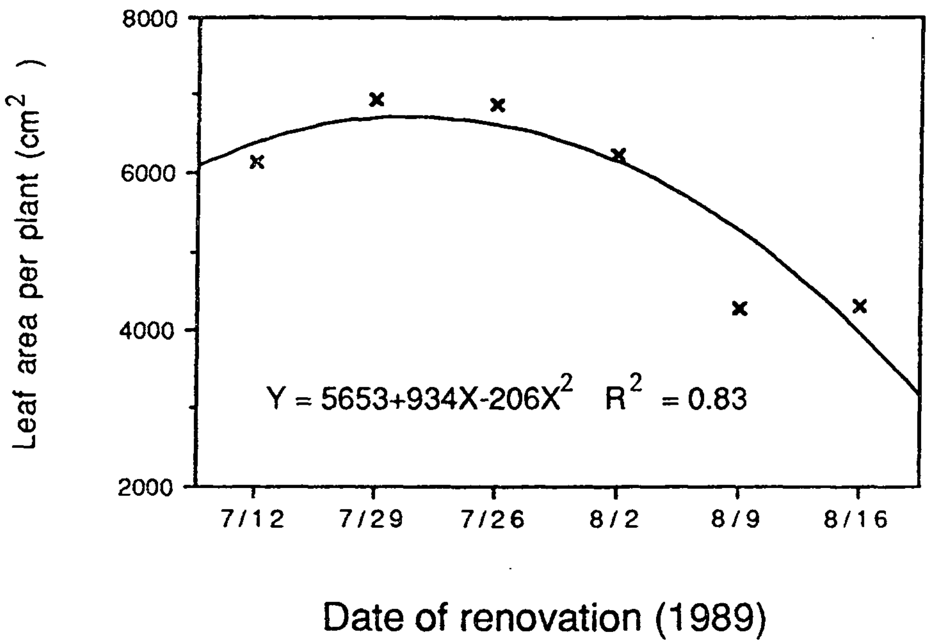

Fig. 14 Relationship between date of renovation in 1989 and leaf area (cm) per plant in 1990 for 'Benton'

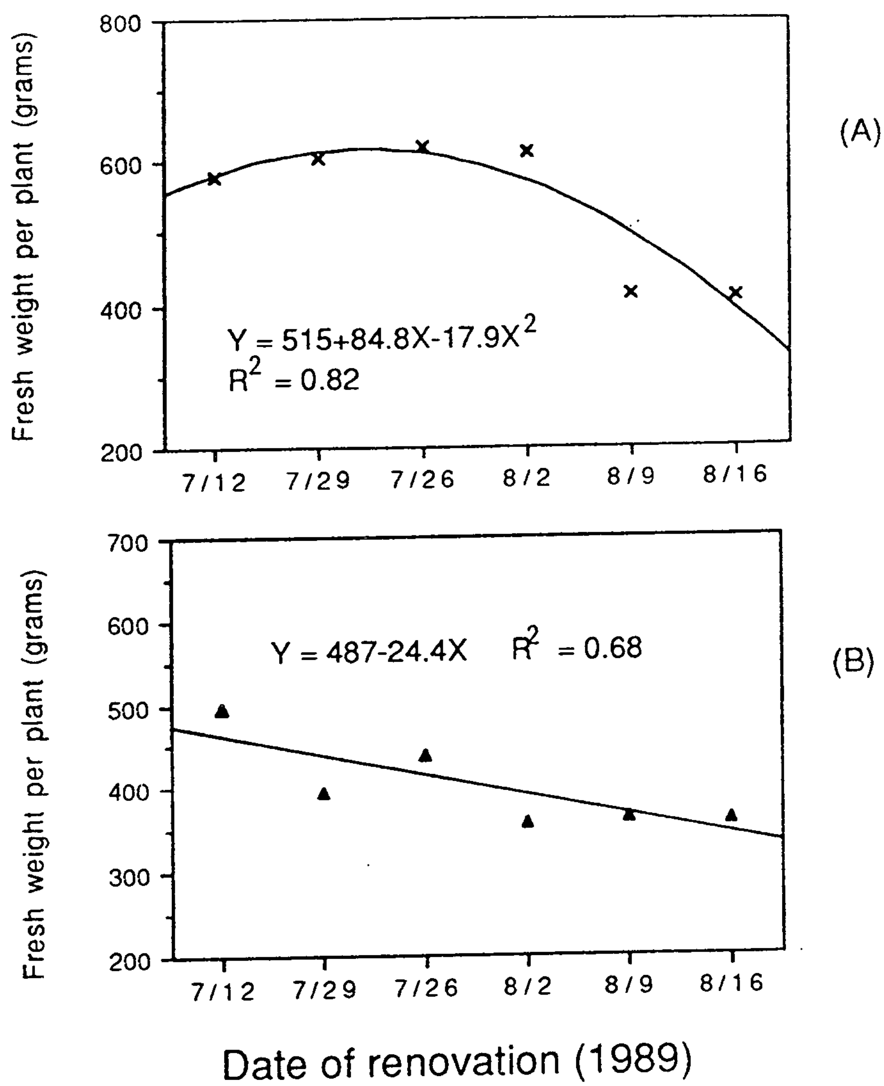

Fig. 15 Relationship between date of renovation in 1989 and plant fresh weight in 1990 for 'Benton' (A) and 'Redcrest' (B)

treatments for 'Totem' ($P < 0.01$) and 'Redcrest' ($P < 0.05$)(Table 10B and C); however, there was no difference for 'Benton' (Table 10A). In 'Totem' and 'Redcrest', un-renovated plants had a significantly higher percentage of total yield in the first harvest, indicating earlier flowering and fruiting (Table 10B and C).

In 'Totem', renovated plants produced larger berries than un-renovated plants (Table 10B). However, in 'Benton' and 'Redcrest' there was no treatment effect on berry size (Table 10A and C).

There was no significant difference in yield among the renovation treatments and the control for all three cultivars studied at 0.05 level (Table 10). However, there was a trend for early-renovated (5 WAH or earlier) plants to have greater yields than control or late-renovated plants in all cultivars (Table 10). Yield was significantly correlated with leaf area and plant fresh weight for all cultivars (Table 11). In 'Totem' and 'Redcrest' yield was correlated with truss number per plant. Flower number per plant was correlated with yield in 'Benton' and 'Redcrest'. In 'Benton', crown number per plant was correlated with yield (Table 11).

There was no significant interaction between cultivars and treatments in Experiment 2 (Appendix 1). The pooled reslut of the yield indicated that, compared with control group, early renovation (5 WAH or earlier) led to a higher yield the next summer ($P < 0.05$)(Appendix 2 and 3).

Table 10. Effect of date of renovation on berry size, yield per plant, and percentage of total yield in each harvest in 'Benton', 'Totem', and 'Redcrest' summer 1990.

(A) Benton

Date(1989)	Berry size (g)	Yield /plant (g)	1st harvest (%)	2nd harvest (%)	3rd harvest (%)
Control	10.0	683	29	31	39
7/12	9.9	901	29	34	38
7/19	10.0	911	22	34	45
7/26	9.7	1034	24	40	35
8/2	10.3	999	23	37	41
8/9	8.6	601	36	39	25
8/16	8.6	639	45	35	21
LSD	1.8	328	19	12	21
P*	NS	NS	NS	NS	NS

*: Significant at P < 0.05, or P < 0.01, and not significant (NS) as indicated.

(B) Totem

Date(1989)	Berry size (g)	Yield /plant (g)	1st harvest (%)	2nd harvest (%)	3rd harvest (%)
Control	9.0a*	659	35b	37a	28a
7/12	10.9b	713	16a	37a	46b
7/19	11.5b	810	13a	45b	42ab
7/26	11.5b	705	12a	38a	50b
8/2	11.6b	736	11a	41ab	48b
8/9	11.8b	644	11a	37a	52b
8/16	11.3b	660	16a	42ab	42ab
LSD	1.3	202	10.6	7.91	4.8
P**	0.01	NS	0.01	0.05	0.01

*: means followed by the same letter are not significantly different by LSD.
**: Significant at P < 0.05, or P < 0.01, and not significant (NS) as indicated.

(Continued on the next page)

(Table 10, continued)

(C) Redcrest

Date(1989)	Berry size (g)	Yield /plant (g)	1st harvest (%)	2nd harvest (%)	3rd harvest (%)
Control	7.1	667	56b	29a	15
7/12	6.7	1055	36a	38bcd	26
7/19	6.5	875	39a	36bc	25
7/26	6.6	856	39a	41d	20
8/2	6.6	800	41a	40cd	19
8/9	7.7	828	46ab	34b	20
8/16	7.2	747	45ab	37bc	18
LSD	1.4	372	15	6	14
P**	NS	NS	0.05	0.01	NS

*: means followed by the same letter are not significantly different by LSD.

**: Significant at P < 0.05, or P < 0.01, and not significant (NS) as indicated.

Table 11. Correlation coefficients between yield and yield components of 'Benton', 'Totem', and 'Redcrest' in the summer of 1990.

	Yield		
	Benton	Totem	Redcrest
Crown	0.48*	0.19	0.40
Truss	0.23	0.46*	0.43*
Flower	0.51*	0.40	0.57**
Leaf (cm^2)	0.90**	0.43*	0.76**
Plant (grams)	0.90**	0.46*	0.77**

*, **: significance at 0.05 and 0.01 respectively.

CHAPTER IV: DISCUSSION

Part I. Effect of date of renovation on yield components (runner, truss, and flower number) in fall.

A. The effect of date of renovation on runner production

Date of renovation significantly influenced the number of runners in 'Benton' the fall of 1988 and 'Benton', 'Totem', and 'Redcrest' in the fall of 1989. Treatments with early renovation (3 WAH or before) had a much greater number of runners per plant in fall, 1988, and 1989. Compared with the fall of 1988 (Experiment 1), 'Benton' plants in fall, 1989 (Experiment 2), had a lower number of runners per plant at equivalent dates of renovation (Table 2 and 5).

Runner production is influenced by climate, especially photoperiod and temperature of that year (Dennis et al. 1970; Hallman and Travis, 1988; Hartmann, 1947). The lower number of runners per plant in the fall of 1989 may have been due to climatic differences between 1988 and 1989. In late July through early September, 1988, the main period of runner growth, the average mean temperatures were higher than the same period in 1989 (Fig. 16).

'Benton', 'Totem', and 'Redcrest' plants renovated 3 WAH or earlier had a higher number of runners (Table 2 and 5). Early renovation has the advantage of producing earlier runners, which are more productive the following year than

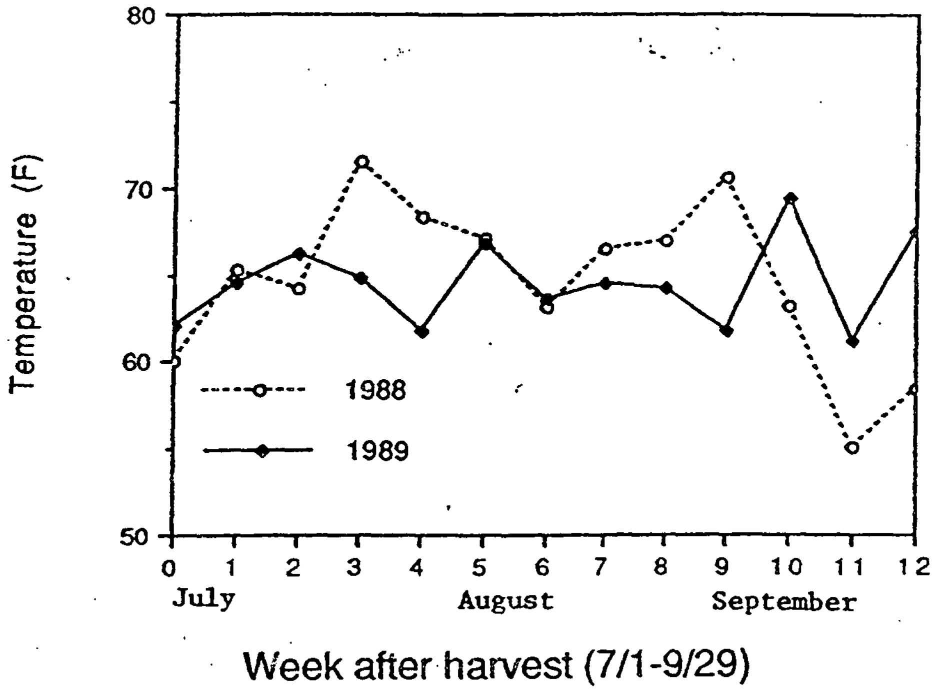

Fig. 16 Comparison of the weekly mean temperatures of summer (from 7/1 to 9/29) of 1988 and 1989

late-rooted runners (Davis, 1922; Shoemaker, 1929). Renovatedplants of 'Benton' had fewer runners than un-renovated plants (Table 2 and 5). Thus in a matted row production system of 'Benton', early renovation (no later than 3 WAH, or July 20) may lead to greater productivity per unit area due to a greater production of earlier-rooted runners. In this study, plants were maintained in a hill system. Therefore, the effect of date of renovation on productivity per unit area could not be determined.

B. Effect of date of renovation of 'Benton' on fall truss and flower production in 1988 and 1989

Date of renovation had a significant effect on numbers of trusses and flowers per plant. 'Benton' plants which were renovated early (3 WAH or earlier) had more flowering in the fall of 1988. The vegetative growth in early renovated plants was stimulated earlier, leading to more truss and flower production. Truss development and flowering in the fall following renovation may also depend on favorable environmental conditions.

The flowering pattern in renovated plants of 'Benton' in the 2nd experiment (fall 1989) was different from the pattern of the 1st experiment (fall 1988) (Fig. 9). In fall 1989 late-renovated (except 7 WAH) plants had the greatest flowering and fruiting. There was a quadratic relationship between fall fruiting and date of renovation in the fall of

1989 (Fig. 8). This difference between the two years may have been caused by different climatic conditions, especially temperature, during the time that was critical to fall truss development, flower emergence, and vegetative growth.

Fig. 17 presents the relationship between the number of trusses and flowers in the fall and the accumulative degree day temperature (ADDT) for 5 weeks, from 1 WAR to 5 WAR (which would be the most important time for renovated plants to regrow and become reproductive). A linear relationship was found between the number of trusses (and flowers) per plant and the ADDT. This suggests that summer temperature does affect the pattern of fall flowering and fruiting.

C. Differences among 'Benton', 'Totem', and 'Redcrest' in responding to date of renovation in fall fruiting (1989)

Cultivars respond to climatic conditions differently. In Experiment 2 (1989), 'Redcrest' plants, renovated on the same date as 'Benton' plants, responded differently. In 'Redcrest', early-renovated plants (5 WAH or earlier) had more trusses and flowers per plant (Table 6A and 6C). 'Totem' plants had almost no fall fruiting (table 6B). This may be due to genetic differences. Another possible reason for 'Totem' having only little fall fruiting may be that the ADDT was not enough for those trusses to develop and emerge in the fall. In other words, cultivars may require different ADDT to satisfy truss development and flower emergence.

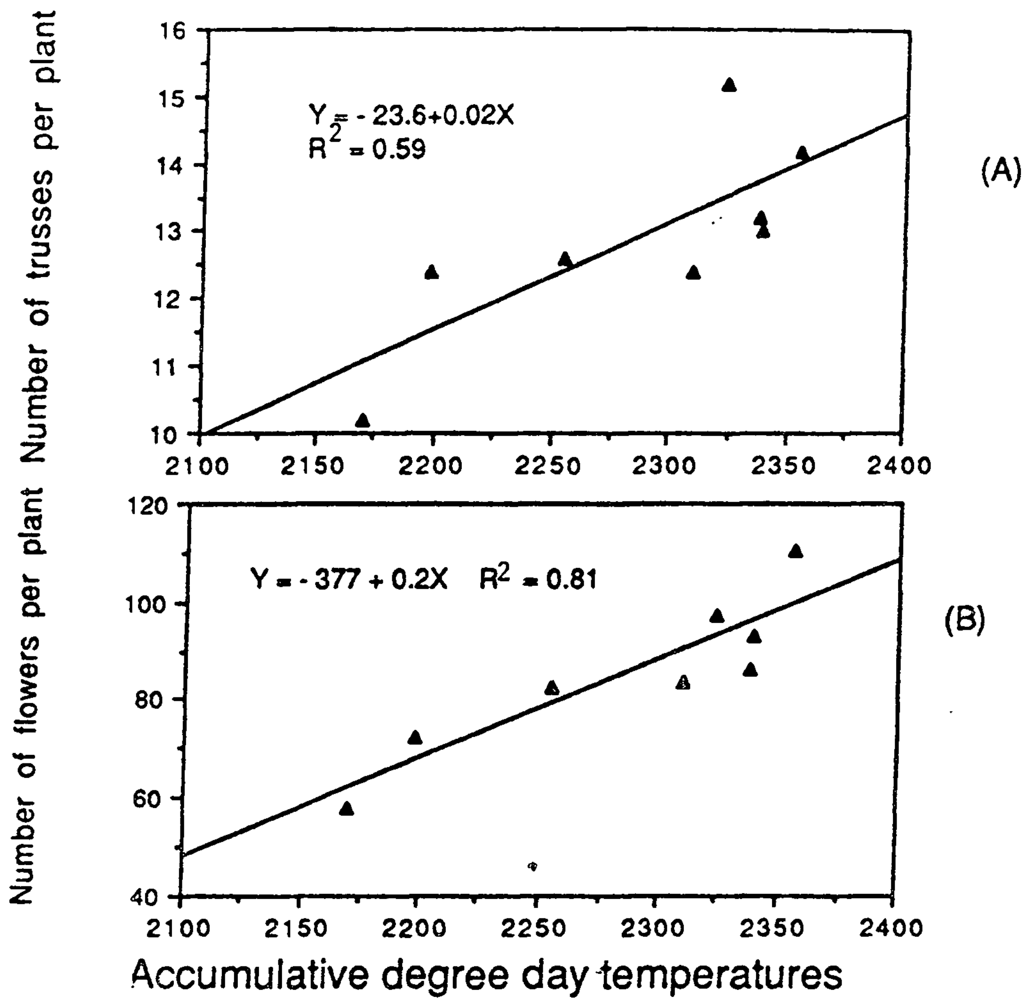

Fig. 17 Relationship between accumulative degree day temperature of 35 days (1 to 5 weeks after renovation) and the number of trusses (A) and flowers (B) per plant in the fall of 1989 for 'Benton'

Part II. Effect of date of renovation on yield and yield components in the summer of the following year

A. Winter injury

Cultivars differ in hardiness. Temperature in the winter of 18 to 3°F may cause some damage, and plants usually are seriously damaged at -4°F (Angelo et al., 1939; Harris, 1970 & 1973; Marini and Boyce, 1977).

Among the cultivars studied in this experiment, 'Benton' is known to be the most susceptible to cold temperature, while 'Totem' is the most hardy (Daubeny, 1971).

In early February, 1989, there was a sudden drop in temperature, and the lowest temperature was about 8 °F (Fig. 18). There was evidence of winter damage in 'Benton' after harvest. When plant crowns were cut longitudinally, the dark brown color of the crowns indicated that 'Benton' plants suffered from winter injury (Fig. 19). Because of winter injury, 'Benton' plants in Experiment 2 responded to renovation differently than plants in Experiment 1.

The lower number of runners in 'Benton' the fall of 1989 may have been caused by low temperature the previous winter. All renovated 'Benton' plants had lower numbers of runners compared to the control groups. This was not found in 'Totem' and 'Redcrest' plants, which are more cold hardy.

B. Effect of date of renovation on crown growth

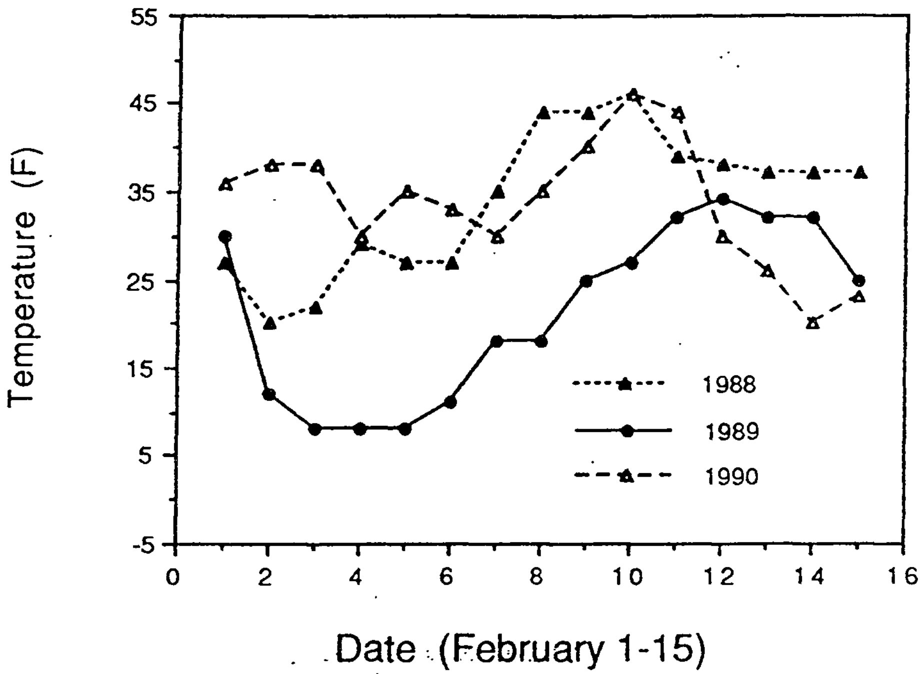

Fig. 18 Comparison of the temperatures in the first 15 days of February from 1988 to 1990

Fig. 19 Crowns of 'Benton' cut longitudinally to show effect of winter injury

The number of crowns per plant in summer 1990 (Experiment 2) were similar to the summer of 1989 (Experiment 1) in 'Benton'. However, plants from the last two dates of renovation had lower crown numbers than plants treated on the same date in 1989 (Table 3 and 7; Fig. 20). Thus, in 1990, the number of crowns had a significant quadratic relationship with date of renovation (Fig. 11). There was no such relationship with date of renovation in Experiment 1 (1989). This difference may have been caused by winter injury as mentioned previously.

In 'Totem' and 'Redcrest', date of renovation had no effect on number of crowns per plant.

C. Effect of date of renovation on the number of trusses and flowers

In the summer of 1989, the number of trusses and flowers per plant were negatively, linearly related to date of renovation; however, the number of trusses and flowers per plant for the last treatment were reduced (Fig. 4). If the treatments could have been extended, the quadratic relationship, found in 1990, might also have been found in 1989.

Number of trusses and flowers of 'Benton' in the summer of 1990 showed a reverse pattern compared to those in experiment 1 (Fig. 13). The number of trusses and flowers per plant in early treatments (5 WAH or earlier) were higher than

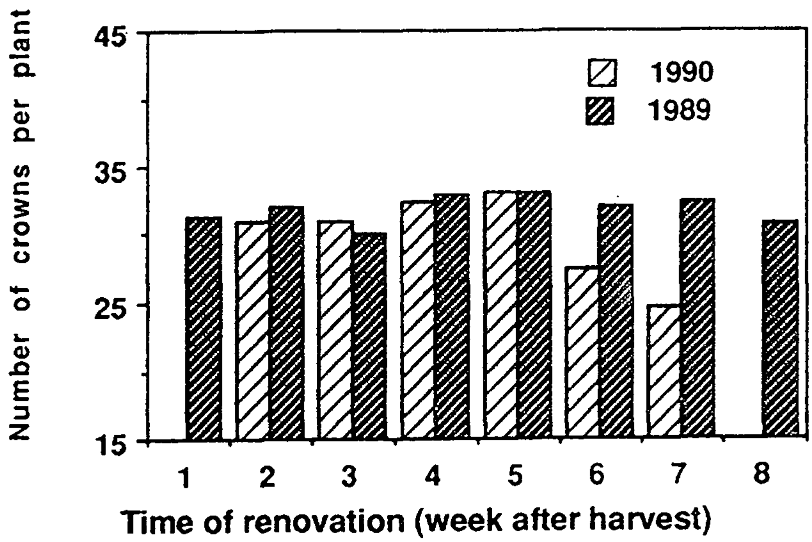

Fig. 20 Comparison of the effect of time of renovation in 1988 and 1989 on the number of crowns per plant the following summer for 'Benton'

those treated later (6 and 7 WAH). Yield was correlated with the number of crowns and flowers per plant of 'Benton' in thesummer of 1990 (Table 7, 8A, and 10A).

In Experiment 2, date of renovation of 'Benton' had no significant effect on fall truss and flower production. However, renovation dates significantly affected the number of trusses and flowers the following summer of 1990 (Table 6 and 8). Late-renovated plants (6 and 7 WAH) had significantly lower numbers of trusses and flowers (Fig. 10). Compared to the previous summer, the number of trusses and flowers was decreased (Fig. 13). This may indicate that 'Benton' plants in the second experiment were weakened due to winter injury in February 1989. Renovation was found harmful to weak plants (Pritts, 1988).

Date of renovation in 1989 had no effect on the number of trusses and flowers in 'Totem' and 'Redcrest' in summer, 1990.

D. Effect of date of renovation on leaf area (LA) and plant fresh weight (PFW)

All renovated plants had less LA and PFW than unrenovated control plants in Experiment 2 of 'Benton' (Table 9). Early-renovated (5 WAH or earlier) plants had a relatively greater LA and PFW than late-renovated plants.

The lower LA and PFW of plants renovated 6 WAH and 7 WAH in 'Benton' for Experiment 2 (Table 9) may in part be due to winter injury the previous year. Since late-renovated

'Benton' plants had a lower number of crowns, trusses, flowers, trusses, LA per plant and lower PFW (Table 7, Table 8A, and Table 9), it may indicate that later renovation may be more harmful to those plants which were weakened. It is possible that plants renovated later in the summer may still be in an active vegetative growth. Such plants did not develop into their full, potential, plant size and hardiness. The plants did not have sufficient time to store enough carbohydrates and become hardy enough to resist cold. So it is likely that early-renovated plants may be more winter hardy, especially for winter susceptible cultivars such as 'Benton'.

In 'Totem' and 'Redcrest', all the renovated plants had a larger LA and greater PFW than those of un-renovated control plants (Table 9). However, the differences were not statistically significant, except for PFW in 'Redcrest'. This may indicate that date of renovation had less effect on vegetative growth for those relatively winter hardy cultivars.

E. The relationship between plant size and fruiting (yield)

Plant size is not always positively associated with final yield and is not constant among cultivars (Borthwick and Parker, 1952; Guttridge, 1960; Mason, 1966). From field observation, it was noted that unrenovated plants (control groups) had a larger plant size than the renovated plants. Post-harvest defoliation of 'Benton' inhibited vegetative growth and decreased plant size the following season. Since the yields in those controls were not available (data not collected), it is not known how the renovation treatments affected final yields in experiment 1. In Experiment 2, yield per plant of 'Benton' was correlated with LA and PFW in the renovated treatments (Table 11). However, control plants of 'Benton' which had the greatest LA per plant and PFW (Table 9) had a relatively lower yield per plant (Table 10A). The lower yield of control plants appeared to be due to lower number of flowers and trusses per plant in 'Benton' (Table 8A). Thus, in the un-renovated control plants of 'Benton', carbohydrates appeared to be diverted to vegetative growth such as plant size (Table 9) and crown number (Table 7) rather than reproductive growth such as trusses and flowers or yield (Table 8A and 10A).

F. Effect of date of renovation on summer yield

1. Effect of date of renovation on harvest time

Date of renovation did not affect fruit harvest time directly, but it affected harvest time indirectly by affecting plant size. Compared with the control groups, date harvest in all treatments of 'Totem' and 'Redcrest' was delayed (Table 10). The delay of fruit ripening in 'Totem' and 'Redcrest' due to renovation may have been due to differences in plant size. In 'Totem' and 'Redcrest', renovated plants had a larger plant size (measured by LA and

PFW) than control or un-renovated plants. Thus, large plant size may have caused more shading of fruits, thus delaying the ripening. The relationship between plant size and fruit ripening was not as evident in 'Benton'. The treatments with lower LA and PFW (6 WAH and 7 WAH) had a higher percentage of total yield in the 1st harvest, although the differences were not significant (Table 10).

2. Relationship between fall flowering and summer yield

In 'Benton' it was found that, although plants renovated early (1 WAH to 3 WAH) had a high number of trusses and flowers per plant in the fall of 1988, these plants had a lower number of trusses and flowers per plant the next summer (Fig 6). In other words, the fruiting pattern in the summer of 1989 was reversed compared with the fall of 1988. Early renovation did not result in the highest yield in the summer of 1989.

Regression studies showed that there was a negative correlation between yield in the summer of 1989 and truss, flower, and runner number per plant the previous fall across all dates of renovation (Table 4B).

Thus, fall fruiting of 1988 was detrimental to yield the following summer in 'Benton'. This suggests that total (potential) yield may be determined by truss and flower bud initiation in late summer and early fall. Fall fruiting was not compensated for by further initiation in late fall or the following spring thus yields were decreased. However, this negative correlation was not significant in 'Benton' and 'Redcrest' in Experiment 2. This may have been due to high variability among replicates.

The higher yields on the later renovated plants were due to higher numbers of flowers and trusses per plant in summer 1989 (Table 3), as there was no difference in berry size among treatments (Table 3).

Since 'Totem' plants had little fall fruiting in the fall of 1989, it is difficult to compare the fall fruiting with summer yield.

The fall fruiting (measured by number of trusses and flowers) of 'Redcrest' plants was negatively linearly related with date of renovation (Table 10C). Early renovation (5 WAH or earlier) showed an advantage for fall fruiting. Although there was no significant difference between treatments in 'Redcrest' in the summer of 1990, there was a trend toward a quadratic relationship between the number of trusses (and flowers) and date of renovation.

3. Yield analysis

There was no significant difference in yield per plant among the treatments and controls at 0.05 level in all 3 individual cultivars in 1990 (Table 10). In 'Benton', yields ranged from 683 g/plant to 1034 g/plant (table 10A). In 'Redcrest', the lowest yield was 667g/plant (control) and the highest was 1055 g/plant (2 WAH)(Table 10C). In all 3 varieties there was a trend toward higher yields per plant from early renovation (5 WAH or early). Treatments of 5 WAH or earlier (August 2 or earlier) had a higher yield than the controls in all 3 cultivars studied (average of 40.7% greater for 'Benton', 12.4% for 'Totem', and 34.4% for 'Redcrest').

Since the pooled result of yield of 3 cultivars showed a significant increase for early renovated plants (5 WAH, or earlier)(Appendix 2 and 3), compared with control plants, it indicates that early renovation is a valid practice in strawberry production. However, 'Benton' cultivars varied from year to year, may be due to the difference of envionmental condition.

Part III. Interaction between yield and yield components.

Cultivars may also differ in their relationship between yield and yield components. After renovation, LA and PFW were decreased in 'Benton', but increased in 'Totem' and 'Redcrest'. This change may play a role in harvest date. The correlation coefficients between LA-yield, and PFW-yield were high in 'Benton' (r=0.90 in both cases) and 'Redcrest' (r=0.76 and r=0.77, respectively). In other words, LA and PFW of 'Benton' and 'Redcrest' were more closely related to yield than 'Totem' (Table 11). In 'Benton', the number of flowers was more closely related with yield than truss number, while in 'Totem' the opposite situation was true (Table 11). This is related to genetic differences of these cultivars as

'Benton' has many flowers but fewer trusses while 'Totem' has the reverse.

Yield is the result of both vegetative and reproductive growth. Thus, the number of crowns per plant, LA per plant and PFW influence final yield directly and indirectly. Some treatments which had more trusses and flowers did not have enough LA to support them; thus, these plants had a reduced yields. Thus, treatments with the highest number of trusses and flowers per plant did not necessarily have the highest yield.

CHAPTER V: CONCLUSIONS

In summary, date of renovation did affect yield components such as the number of trusses and flowers and yield. Date of renovation only affected crown number per plant of 'Benton' in 1990.

In 'Benton', early renovation led to a greater number of trusses and flowers per plant, thus more fruiting, in the fall of 1988. However, the number of trusses and flowers per plant in the summer, 1989, was reversed to the pattern of the previous fall. Early renovation led to lower numbers of trusses and flowers. However, despite the linear relationship with date of renovation, there was a trend for plants renovated 4-8 WAH to have a relatively higher number of trusses and flowers. Yield of 'Benton' had a negative linear relationship with date of renovation in summer, 1989.

Annual flower and truss initiation may have an upper limit. Thus, too many fall flowers and fruits will decrease yields the following summer.

The effect of date of renovation on fall flowering and fruiting may be dependant on the accumulative degree day temperature (ADDT). Climatic factors, especially temperature, may cause plants to respond differently to date of renovation among years. Plants which were weakened by low winter temperatures should not be renovated.

The number of runners per plant in the fall had either a negative linear ('Totem') or a negatively quadratic ('Benton' and 'Redcrest') relationship with date of renovation.

Cultivars responded to date of renovation differently in yield components. In 'Benton', number of trusses and flowers per plant showed a quadratic relationship with date of renovation in summer 1990. The highest number of trusses and flowers per plant resulted from renovation on July 26 (4 WAH). In 'Totem' and 'Redcrest', number of trusses and flowers per plant were not affected by date of renovation, but were relatively higher in early-renovated plants. In general, for the three cultivars renovated in summer 1989, early renovation (within 5 weeks after harvest) led to a higher average yield per plant (as well as number of trusses and flowers) than late renovation.

Higher correlation coefficients were found between yield-LA and yield-PFW in 'Benton' and 'Redcrest' than the relationship of yield to trusses, flowers, or runners. In 'Totem', yield was significantly correlated to truss number, LA, and PFW, but not to flower and crown number.

Compared to un-renovated plants, renovation delayed the date of harvest in 'Totem' and 'Redcrest', and increased berry size in 'Totem'.

In conclusion, date of renovation does affect strawberry yield and yield components. Renovation, if properly scheduled, can increase yield. There was a significant increase in yield in late-renovated plants (8 WAH) compared to early-renovated plants (1 to 3 WAH) in the first experiment.

Cultivars did not show a significant difference to date of renovation. However, renovation had a positive effect on yield the next season in all 3 cultivars. In experiment 2, date of renovation affected yield components (crown, truss, and flower number) in 'Benton', but not in 'Totem' and 'Redcrest'. 'Benton' plants had a relatively high yield per plant in the treatments of 4 and 5 WAH in Experiment 2. Early renovation led to a significant increase in a pooled yield of 'Benton', 'Totem', and 'Redcrest' in the summer of 1990.

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APPENDIX

1. Analysis of varience for pooled yield of 'Benton', 'Totem', and 'Redcrest' <u>with</u> interaction.

Source of variation	SS	d.f.	MS	F	P
Mean effects	766245	8	95781	2.19	0.04
cultivars	232861	2	116430	2.67	0.08
treatments	545568	6	90928	2.08	0.07
2-fact interactioN	377852	12	31488	0.721	0.72
cultvr x trtmnt	377852	12	31488	0.721	0.72
Residual	2357983	54	43666		
Total	3502080	74			

9 missing values have been excluded.

2. Analysis of varience for pooled yield of 'Benton', 'Totem', and 'Redcrest' without interaction.

Source of variation	SS	d.f.	MS	F	P
Mean effects	766245	8	95781	2.31	0.03
cultivars	232861	2	116430	2.81	0.07
treatments	545568	6	90928	2.19	0.05
Residual	2735835	66	41452		
Total	3502080	74			

9 missing values have been excluded.

3. Mean table of the pooled yield for 'Benton', 'Totem', and 'Redcrest'.

Level	Count	Average	S.E. (internal)	S.E. (pooled)
Cultivar				
1	21	791ab*	55.0	44.4
2	27	700a	25.1	39.2
3	27	824b	47.3	39.2
Treatment				
Control	12	670a	33.0	58.8
7/12	10	872d	58.2	64.4
7/19	9	862cd	68.2	67.9
7/26	9	809bc	77.4	67.9
8/2	12	845cd	80.3	58.8
8/9	12	691ab	62.0	58.8
8/16	11	686ab	60.0	61.4
LSD		123		
P**		0.05		

*: means followed by the same letter are not significantly different by LSD.

**: Significant at P < 0.05, or P < 0.01, and not significant (NS) as indicated.