Runnering and other growth phenomena of everbearing strawberry cultivars

by

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INTRODUCTION

Everbearing strawberries bear continuously through the growing season. They initiate fruit buds under both long and short days. The large-fruited octoploid everbearing strawberry has relatively recently been introduced to the strawberry industry compared to the Junebearing strawberry. Because of this relative newness and its lack of production of commercially large amounts of fruit, less research has been done with the everbearing strawberry.

Everbearers, as they are also called, have some characteristics that might help solve problems of the Junebearers. For example, everbearers' fruit buds seem able to acclimate to cold temperatures better than those of Junebearers (6). Also, the repeated fruit bud initiation trait could be useful in areas where Junebearers are subject to late spring freezes that kill fruit buds. These are some of the characteristics worth studying, but a better understanding of everbearers is needed before thay can be applied to Junebearers.

The purpose of this study was to examine the general growth processes of everbearers. These consist of fruit production, runner production, leaf production, and plant growth. The interrelationships of these factors were also explored. The six cultivars used were also examined to observe differences among them.

The study consisted of a field experiment of six cultivars in four replications in a randomized complete block design.

REVIEW OF THE LITERATURE

General trends in food consumption show Americans are eating more fruits (42). Commercial strawberry acreages have been increasing yearly (41), in addition to more home garden plantings. Part of the strawberry's popularity is its adaptability to a wide range of climates. Strawberries can be grown from Alaska to Florida and from California to New England. In 1977, a total of 6,509,000 lbs were produced commercially, and, in 1978, an estimated 6,476,000 lbs were reported (41).

The strawberry was first mentioned in literature by the ancient Romans and Greeks. Their references were to its medicinal value or to its being a wild fruit. It was not until the 1300s that it was reported in cultivarion in Europe. This strawberry was the common wood strawberry, *Fragaria vesca*, which is native to Europe, northern Asia, North America, northern Africa, and the higher elevations in the West Indies, Mexico, and South America. It was described as having a small round fruit, which is quite aromatic (17).

Because of its great range, it is very adaptable. Many cultivars have been proposed, but most differ only slightly. An interesting form is *F. vesca semperflorens*, an everbearing type. It was first recorded in the 1500s, but did not become well-known until the late 1700s (17). It has since been found its everbearing trait is controlled by a single major gene, where seasonal flowering is dominant to perpetual flowering (8).

Europeans may not have been the first to cultivate strawberries. The Chilean strawberry, *F. chiloensis*, was cultivated by the Mupuche and

Huilliche Indians of Chile long before the Spanish arrived in the 1500s. It is not known when they first started cultivating strawberries (17).

Fragaria chiloensis was brought to Europe in August, 1714, by a French spy, Amédée Francois Freizer, who happened to be an impulsive plant collector. Many of the great botanists of that time were very interested in this "New World Wonder" with large fruits. The only problem was that Freizer had brought only female plants since he selected plants with the largest fruits (17).

Fragaria vesca, a diploid, would not make fertile crosses with *F. chiloensis*, an octoploid. So *F. chiloensis* was in need of a suitable pollinator to produce fruit. This problem may seem elementary today, but, at that time, most botanists did not understand the separation of sexes in strawberry, and how ploidy level affects crosses in plants (17).

Before *F. chiloensis* was introduced, another octoploid, *F. virginiana*, was brought to Europe in the early 1600s from Virginia in the New World. Soon after *F. chiloensis* arrived, it was noticed that when it was planted with *F. virginiana*, it fruited. It was then found *F. virginiana* made a suitable pollinator (17).

Antoine Nicolas Duchesne was the first botanist to describe the plants resulting from the cross of *F. chiloensis*, the female parent, and *F. virginiana*, the male parent. This hybrid was named *F. ananassa*. Ananassa refers to its pineapple-like aroma and fruit shape. *F. ananassa*, through breeding, has parented the modern large fruited strawberry (17, 47).

Another species besides *F. chiloensis* and *F. virginiana* which is important in the development of the American everbearing strawberry cultivars is *F. ovalis*. *F. ovalis*, a native to western North America, has three outstanding characteristics which are everbearingness, drought resistance, and hardiness. *F. ovalis* is also an octoploid, and intercrosses readily with *F. ananassa*, *F. chiloensis* and *F. virginiana* (17). Being an octoploid, the inheritance of the everbearingness is quite complex (8, 9).

Everbearing strawberries are so called because they are able to produce several crops throughout the growing season. The more commonly grown springbearing or Junebearing strawberries produce only one crop per season. They are considered short day plants in that their fruit buds are formed under the short days and cooler temperatures of fall (22, 27, 44, 46). These buds overwinter in the crown and produce fruit the next spring.

Fruit buds, runners, and branch crowns are initiated in leaf axils and the apices of crowns (45). Runners differ from branch crowns in that the first internode of runners elongates, whereas branch crowns' do not (25). It is believed that photoperiod and temperature control whether a fruitbud, runner, or branch crown is initiated (16, 24, 27, 28, 37).

Darrow and Waldo (18), found that runners were initiated under the longest days, that branch crowns were initiated when days were too short for runner initiation, and that fruit buds were initiated when days were too short for both runner and branch crown initiation. They also found that a minimum of 60°F (16°C) and 10 hours or less of daily light was needed for fruit bud initiation (18).

Everbearers vary in their response to day length and temperature depending on their habitat. In the Midwest, they respond to long days and higher temperatures by initiating fruit buds (18, 46). Two or more crops are then produced each year, a spring crop from overwintering fruit buds, and a late summer-fall crop from fruit buds formed under the long days of June and July (45). This second crop continues until fall freezes kill the open fruit buds and the plants become dormant. They also initiate runners, and branch crowns under long days. Under favorable conditions, everbearers may be differentiating fruit buds, branch crowns, and runners at the same time (45).

Everbearers are mainly cultivated in home gardens. They are less adapted to commercial use for several reasons. First, their total fruit production is less than Junebearers in the Midwest (36). Second, their crop is spread over several weeks so picking is long term; and third, their culture is very labor intensive. They do offer the home gardener some advantages in that they will produce a continuous supply of fresh fruit for a long period. They often have an attractive plant which can serve as a border for a flower garden, and their culture is usually adapted to the schedule of the home gardener.

Everbearer culture differs slightly from that of Junebearers in a few aspects such as planting systems, mulches, and fruit bud and runner removal. Otherwise, the culture is similar (12, 14).

Everbearers are recommended to be planted in a three-row hill system (20, 29, 32, 36). In this system, the three rows are planted one foot apart with one foot between the plants within the rows (20, 32). To maximize the space available to each plant, the rows are staggered. The runners are then removed as they appear during the growing season (13, 32). This is done to build up the mother plant for maximum fruit production (13, 32).

Runner removal is usually a manual labor operation. Due to the planting system, runner removal does not lend itself to mechanization. In experiments with Off-Shoot T (TM), Benoit (4) found that it reduced the number of runners and maintained acceptable yields, but yields were less than plants whose runners were removed manually.

A variation, the modified three-row hill system, reduces the number of plants needed (32, 36). Plants are only set in the center row and allowed to form two runners which are trained to form the outside rows (32, 36). Then all other runners are removed (32, 36).

Plants are set in the spring and can be expected to produce a crop that summer and fall. Everbearers may be treated as annuals and replanted every spring. To insure a good crop, fruit buds are manually removed from the planting until the first week of July, depending on how well the plants have established themselves (32, 33). Chemical regulators have been used without much effectiveness in fruit bud removal (35). One of the curious effects of fruit bud removal is that it seems to cause the initiation of more fruit buds (40).

In the Midwest, a summer mulch of an organic material is recommended (20, 29, 32). Since the plants bear during the hot dry part of summer, the mulch conserves soil moisture and lowers the soil temperature (20). The mulch adds other benefits of controlling weeds and keeping the fruit clean (20). If the planting is cropped more than one year, then an application of nitrogen fertilizer is recommended to overcome the nitrogen lost to the degradation of the mulch (39).

One of the chief breeding goals for everbearers has been to produce plants that form few runners so cultural requirements are less. This has presented quite a problem to the propagator, because the runner plants are the conventional way of propagating strawberries. Stock plants are set in the field and allowed to runner freely. In the fall, the plants formed by the runners are dug and sold (36).

Other forms of propagation include crown division, which is occasionally used, but produces fewer plants per stock plant and requires more labor. Also, in Europe, tissue culture is being used to propagate strawberries. The main purpose is to clean the plants of viruses, and not as a more efficient method of propagation (11, 48).

Researchers (1, 5, 19, 21, 23, 26, 30, 33, 34, 40, 43) have looked to chemicals for increasing runner production. They have found that chemicals can give a quicker and less permanent response than most other methods. Morphactin (23) and chlorflurenol (1) were found to increase branch crowns. Although chlorflurenol had been found to decrease the number of runners (1), morphactin in combination with benzyladenine (BA) was found to increase the number of runners.

Gibberellic acid (GA) has been found to give the same effect as long days (31, 34). It increases vegetative growth and inhibits floral formation (34). Everbearers sprayed with GA have increased the number of runners formed and inhibited floral formation (19, 21, 26, 30, 33, 34, 40). Moore and Scott (33) found that everbearers gave a greater response to GA than Junebearers did. A mixture of GA and BA was found to increase runnering in 'Geneva', a shy runner maker (30). Dennis and Bennett (21) found that root development may be inhibited in plants treated with GA so new runner plants may be of poorer quality. Their recommendations for using

GA were if stock plants produced less than four runners per plant, then they should be sprayed with 50 ppm GA_3 six and eight weeks after planting (21).

GA and BA may be of use in the future, but the response of the everbearer must be better known before they will be helpful. Not much research has been done on everbearers, presumably because they are of less commercial value. Very few general studies (14, 32) have been done on everbearers. Everbearers may lend themselves to research and practical applications more than some think.

Unlocking the key to the genetics of octoploid everbearingness may be very helpful in improving yields of Junebearers. Correlating the general aspects of growth and development of Junebearers with everbearers may be necessary.

Boyce and Marini (6) found that everbearer blossoms were more cold acclimated than Junebearers were. Gaining a better understanding of this mechanism and using it may help save Junebearer crops from spring freezes.

An area for examination should be plant vigor. This could help determine why everbearers do not seem as productive as Junebearers. This would entail an assessment of their ability to photosynthesize. Even though there may be poor correlation between yield and photosynthesis, it must make a difference some way (7).

A greater understanding of the mechanisms triggering runner initiation is needed. This would involve time of runner initiation, its competition with other plant functions, and its manipulation for easier propagation or other cultural demands.

Another area worth examination is fruit production. Questions to be answered are what factors are limiting, how competitive is it with other plant processes, and can yields be increased to make it more competitive with Junebearers.

These areas tend to interrelate and interact, and answering these questions will bring a better understanding of everbearing strawberries.

MATERIALS AND METHODS

This study was conducted during the spring, summer, and fall of 1980. Since everbearers are often grown as annuals, it was felt this would provide adequate time. Six everbearing cultivars were used. They were as follows:

'Ft. Laramie' Strain A

'Ft. Laramie' Strain B

'Ozark Beauty'

'Quinault'

'Streamliner'

'Sunburst'.

'Ft. Laramie' was developed at the U.S. Department of Agriculture Horticultural Field Station at Cheyenne, Wyoming. It originated from a cross of 'Geneva' and S. 65122 ('Earlidawn' x 'Bemidji Chief') in 1966. The seedling was selected by G. S. Howard and J. P. Hack in 1968. The fruit is large and bright scarlet-red in color. It is round-conic in shape and quite aromatic. The plants are quite vigorous, very disease resistant, and very cold hardy. It was released in 1972 (G. S. Howard, U.S. Dep. Agric. Horticultural Field Station, Cheyenne, WY, personal communication, 1981).

'Ozark Beauty' was the product of a private breeder, J. B. Winn, of West Fork, Arkansas. Its parentage is 'Red Rich' x 'Twentieth Century'. It produces sweet, attractive, good-flavored fruit and is also a good runner-plant maker. It was released in 1955 (17) (J. N. Moore, Department of

Horticulture and Forestry, University of Arkansas, Fayetteville, AR, personal communication, 1981).

'Quinault' was developed at the Western Washington Research and Extension Center at Puyallup, Washington. It originated from a cross of 'Puget Beauty' and WSU 901 ('Rockhill' x 'Evermore'). 'Evermore' is a Junebearer, while the others are everbearers. Its fruit is large, solid crimson in color, well-flavored, but the flesh is soft. Fruit clusters are not numerous, but size of the fruit is medium to large, so it is well-suited to home gardens. It was released in 1967 (R. M. Davidson, Western Washington Research and Extension Center, Puyallap, WA, personal communication, 1981).

There is very little information available on the cultivar, 'Streamliner'. It was found by Edgmond in Oregon, in 1938, and was introduced in 1944. It has high flavor and was used as a parent in crosses that resulted in 'Geneva' and 'Sunburst' (17) (J. C. Davids, Davids and Royston Bulb Company, Inc., Gardena, CA, personal communciation, 1981).

'Sunburst' was developed by H. L. Boll of Champaign, Illinois. It was the result of a cross of [('Carnall' x 'Twentieth Century') x self] x 'Streamliner' made in 1964. The fruit has a characteristic light orangish-red color and sweet flavor. The plants are reported to be vigorous and moderate runner makers. It was patented in 1975 (J. C. Davids, Davids and Royston Bulb Company, Inc., Gardena, CA, personal communication, 1981).

The 'Streamliner' plants were obtained from Buntings' Nurseries, Inc., Selbyville, Maryland, and the other cultivars were obtained from Davids and Royston Bulb Company, Inc., Gardena, California. Two strains of 'Ft. Laramie' were sent because Davids and Royston Bulb Company, Inc. felt there were apparent differences worth examination. These differences could be a mutation, a virus-induced condition or incorrect labeling of plants.

Before planting, a random sample of 32 plants of each cultivar was selected. Each plant was weighed, measured in crown length and diameter, and had the number of crown (branch crowns) recorded. Crown diameter was measured at the widest point of the crown with a caliper.

The plants were set out in plots at the Iowa State University Horticulture Station. The plots were in a randomized complete block design with six treatments (the cultivars) and four replications (Fig. 1). Plants were hand set in the three-row hill system (20, 29, 32, 36). Each plot consisted of 30 plants with the three rows one foot apart with one foot between each plant within the row. The rows were then staggered to maximize the area around each plant. The plots within each block were spaced with five foot centers between the center rows, and five foot alleys were left between the blocks to facilitate mechanical cultivation and spraying.

It is common cultural practice with everbearers to continually remove runners and to remove all fruit buds the first six to eight weeks after planting. Approximately two and a half weeks after planting, the plants were first observed for runners and fruit buds. At this time, both were removed and counted and totals for each plot were recorded.

Thereafter, fruit buds were removed once per week until July 8. From then on plants were permitted to bloom and set fruit. Buds emerging from the crown were identified as fruit buds or vegetative buds. Fruit buds have a round hard core which can be felt at an early age. The fruit buds were then pinched as close as possible to the point of origin. In this

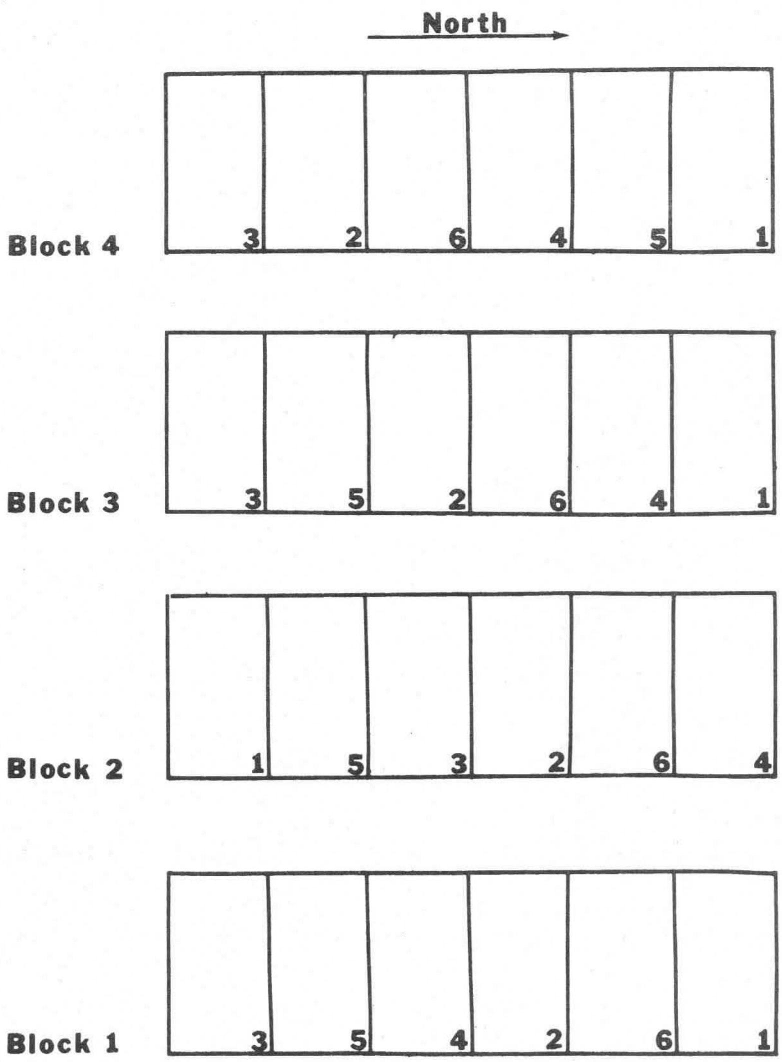


Figure 1. Plot layout: 1 = 'Ft. Laramie' Strain A, 2 = 'Ft. Laramie' Strain B, 3 = 'Ozark Beauty', 4 = 'Quinault', 5 = 'Streamliner' and 6 = 'Sunburst'

process, usually an entire fruit bud cluster is removed. Then, all visible buds were considered fruit buds and counted as such.

Once per week for the rest of the season, runners were removed and totals per plot recorded. Except in Block Four, the plants were allowed to runner freely after July 8. This coincided with the date after which the plants were permitted to bloom. This was done at the suggestion of Mr. Jerry Davids of Davids and Royston Bulb Company, Inc. His objective was to see if runner production would have a profound effect on fruit production, since most amateur gardeners dislike destroying healthy plant parts such as in runner removal. Runners were manually removed by pinching them off as close as possible to the crown.

As a judge of plant vigor and photosynthetic ability, per plant leaf counts were taken. Eight randomly selected plants from each plot had their numbers of leaves counted and recorded every two weeks. This started three weeks after planting and continued throughout the season.

The fruit harvest started August 5. The weight and number of marketable and unmarketable fruit were recorded for each plot. The plots were harvested at approximately three day intervals.

The criteria for judging whether a fruit was marketable or unmarketable were fruit size and freedom from blemishes. All fruit greater than 1.5 cm was harvested and anything smaller was left on the plant. The distinction between marketable and unmarketable was that marketable fruit were unblemished.

All field data collection ceased October 24. By then, there had been at least one killing frost. Most of the open flowers were dead, the unripe berries had been frozen, and the plants had ceased growing for the season.

On November 7, the plants on which leaf counts were made were dug, labeled, placed in plastic bags, and put in cold storage until they could be evaluated.

The evaluation consisted of branch crown number, crown diameter, plant weight, and leaf number per plant. The length of crown was not measured because it was decided that it was a very subjective measurement and it could not be discerned if the old crown should be included.

Also, on November 7, a random sample of fifty leaves was selected from each plot. From these was obtained a leaf area index as described by Darrow (15). The products of the length times the width of each leaflet were summed to give the leaf area index for each leaf. This was done to gain more information on photosynthetic ability of the plants. Arney (2) found that crown production reduces leaf production. He also found that short days at lower temperatures reduces leaf size (3), so it may have been advantageous to take more than one sampling.

During the course of the season, the investigator made several subjective observations of the plots. Observations were made on plant size, leaf size, habit, health, fruit characteristics and other outstanding traits.

Statistical design

The arrangement of the plots was a randomized complete block design. The different cultivars served as treatments. The blocks were divisions across the field.

Separate analyses of variance were computed for leaf area index; fruit yield; individual fruit size; percent marketable fruit; total leaf number; initial branch crown number, crown diameter, and plant weight; increase in branch crown number, crown diameter and plant weight; final branch crown number, crown diameter, and plant weight; runner production and fruit buds removed (10, 38). The Appendix shows a complete ANOVA table for all of these variables (Tables 7 through 17).

The following model was used to classify the data.

$$X_{ij} = \mu + \tau_i + \beta_{ij} + \varepsilon_{ij}$$

where

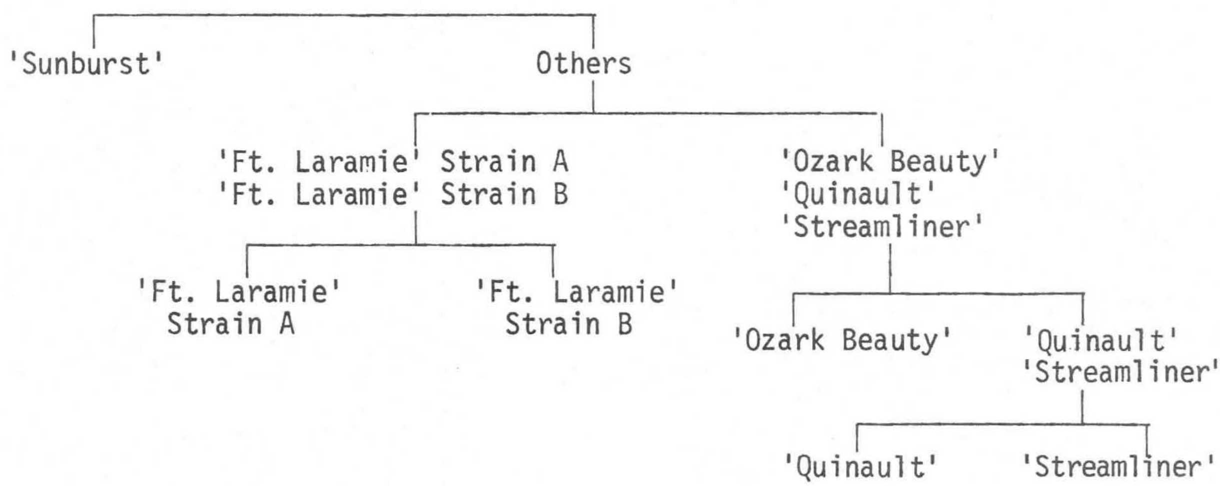
μ = Overall means

τ_i = Treatment effects (cultivars)

β_j = Block effects

ε_{ij} = Experimental error.

Duncan's new multiple range test (38) was used to assess differences in the means. Orthogonal comparisons were also used to partition the sums of squares of the cultivar and block effects (10, 38). Comparisons were tested using an F test with one degree of freedom. The comparisons are diagrammed below.



The basis for the first comparison was that the 'Sunburst' plants seemed to have been mixed with a large leaved non-bearing type of plant.

The 'Ft. Laramie' strains were compared to the other true everbearer cultivars, 'Ozark Beauty', 'Quinault' and 'Streamliner'. 'Ft. Laramie' was developed at Cheyenne, Wyoming, where temperature extremes and drought are common (G. S. Howard, U.S. Dep. Agric. Horticultural Field Station, Cheyenne, WY, personal communication, 1981).

The two 'Ft. Laramie' strains were compared to each other to see if there were any real differences between the two strains. 'Ozark Beauty' was compared to 'Quinault' and 'Streamliner' because it was developed in the southern Midwest, while the others were developed in the Pacific Northwest (17) (R. M. Davidson, Western Washington Research and Extension Center, Puyallap, WA, personal communication, 1981; and J. N. Moore, Department of Horticulture and Forestry, University of Arkansas, Fayetteville, AR, personal communication, 1981).

'Quinault' was compared to 'Streamliner' for the reason that 'Quinault' is a relatively new cultivar whereas 'Streamliner' is a considerably older cultivar (17) (R. M. Davidson, Western Washington Research and Extension Center, Puyallap, WA, personal communication, 1981).

RESULTS

Analysis of the initial data shows that the cultivars were statistically different in branch crown number, plant weight, and crown diameter. Mean branch crown number per plant ranged from 2.13 branch crowns for 'Sunburst' to 1.00 branch crowns for 'Quinault' (Table 1). The differences in the cultivars were highly significant (Table 7). These were attributed to comparisons of differences of 'Ft. Laramie' Strain A to 'Ft. Laramie' Strain B; 'Quinault' to 'Streamliner'; and 'Sunburst' to the others (Table 7).

Table 1. Mean values of branch crown number[1,2]

Cultivar	Mean branch crown number		
	Initial	Final	Increase
'Ft. Laramie' Strain A	1.97 a	9.31 ab	7.34 b
'Ft. Laramie' Strain B	1.13 b	10.53 a	9.40 a
'Ozark Beauty'	1.25 b	8.59 ab	7.34 b
'Quinault	1.00 b	6.59 bc	5.59 bc
'Streamliner'	2.00 a	6.68 bc	4.68 cd
'Sunburst'	2.13 a	5.31 c	3.18 d

[1]Data are based on 32 plants of each cultivar.

[2]Means followed by the same letter do not differ significantly at the 5% level, Duncan's New Multiple Range Test.

Mean plant weight ranged from 13.80 g for 'Ft. Laramie' Strain A to 8.14 g for 'Ft. Laramie' Strain B (Table 2). The cultivar differences were all attributed to the differences between these two strains (Table 7).

Table 2. Mean values of plant weight[1,2]

	Mean plant weight (g)		
Cultivar	Initial	Final	Increase
'Ft. Laramie' Strain A	13.80 a	76.91 b	63.11 abc
'Ft. Laramie' Strain B	8.14 b	75.81 b	67.67 abc
'Ozark Beauty'	9.06 b	84.25 b	75.19 ab
'Quinault'	8.18 b	66.75 b	58.57 bc
'Streamliner'	10.17 b	53.19 b	43.02 c
'Sunburst'	10.15 b	95.88 a	85.73 a

[1]Data are based on 32 plants of each cultivar.

[2]Means followed by the same letter do not differ significantly at the 5% level, Duncan's New Multiple Range Test.

Mean crown diameter per plant ranged from 16.90 mm for 'Ft. Laramie' Strain A to 8.73 mm for 'Quinault' (Table 3). These differences in crown diameter were significant and were accounted by comparisons of differences of 'Ft. Laramie' Strain A to 'Ft. Laramie' Strain B, and 'Quinault' to 'Streamliner' (Table 7).

Analysis of the final data of branch crown number, plant weight, and crown diameter indicate that some of the original differences were overcome.

Mean branch crown number per plant ranged from 10.53 branch crowns for 'Ft. Laramie' Strain A to 5.31 branch crowns for 'Sunburst' (Table 1). Using orthogonal comparison, the difference between 'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B compared to 'Ozark Beauty', 'Quinault' and

'Streamliner' was statistically important, as was the difference of 'Sunburst' compared to the other cultivars. All other comparisons were not of statistical significance (Table 8).

Table 3. Mean values of crown diameter (mm)[1,2]

	Mean crown diameter (mm)		
Cultivar	Initial	Final	Increase
'Ft. Laramie' Strain A	16.90 a	43.56 ab	26.66 ab
'Ft. Laramie' Strain B	10.14 cd	40.62 ab	30.48 ab
'Ozark Beauty'	11.91 bc	44.55 a	32.64 a
'Quinalt'	8.73 d	37.13 ab	28.40 ab
'Streamliner'	14.59 ab	32.30 b	17.71 c
'Sunburst'	14.53 ab	38.95 ab	24.42 bc

[1]Data are based on 32 plants of each cultivar.

[2]Means followed by the same letter do not differ significantly at the 5% level, Duncan's New Multiple Range Test.

Mean plant weight ranged from 95.88 g for 'Sunburst' to 53.19 g for 'Streamliner' (Table 2). Cultivar differences in weight were solely attributable to the comparison of 'Sunburst' to the other cultivars (Table 8).

Mean crown diameter per plant ranged from 44.55 mm for 'Ozark Beauty' to 32.30 mm for 'Streamliner' (Table 3). The difference in mean crown diameters of 'Ozark Beauty' compared to 'Quinault' and 'Streamliner' was statistically important, as was the difference of 'Quinault' to 'Streamliner' (Table 8).

Mean increase in branch crown number ranged from 9.40 crowns for 'Ft. Laramie' Strain B to 3.18 crowns for 'Sunburst' (Table 1). All comparisons of differences except those of 'Quinault' to 'Streamliner' were statistically significant (Table 9).

Mean increase in plant weight ranged from 85.73 g for 'Sunburst' to 43.02 g for 'Streamliner' (Table 2). Statistical differences among the cultivars were attributable to the comparisons of 'Sunburst' to the others, and of 'Ozark Beauty' to 'Quinault' and 'Streamliner' (Table 9).

Mean increase in crown diameter ranged from 32.64 mm for 'Ozark Beauty' to 17.71 mm for 'Streamliner' (Table 3). The differences in cultivars were attributable to the comparisons of 'Ozark Beauty' to 'Quinault' and 'Streamliner' and of 'Quinault' to 'Streamliner' (Table 8).

The range for mean fruit buds removed per plot was 106.61 buds for 'Streamliner' to 61.00 buds for 'Quinault' (Table 4). Time was a significant factor. The linear model was significant as well as the lack of fit of that linear model (Table 10). When examining Figures 2a and 2b, two peaks in fruit bud production are apparent in late May and early July. The difference between 'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B was highly significant as was the difference between 'Quinault' and 'Streamliner'. 'Sunburst' was also significantly different from the others (Table 10). The time by cultivar interaction was highly significant (Table 10).

Mean runners removed per plot ranged from 9.44 runners for 'Sunburst' to 3.38 for 'Streamliner' (Table 4). The time of removal was a significant

Table 4. Mean values of fruit buds removed,[1] runners removed,[2] leaf area index (cm^2)[3] and total leaf number[4,5]

Cultivar	Mean fruit buds removed per plot per pruning	Mean runners removed per plot per pruning	Mean leaf area index (cm^2)	Mean total leaf number per count
'Ft. Laramie' Strain A	91.31 b	4.40 b	43.37 c	277.50 a
'Ft. Laramie' Strain B	66.81 c	5.07 b	41.47 c	260.39 a
'Ozark Beauty'	73.69 c	4.81 b	51.10 b	218.21 b
'Quinault'	61.00 c	4.14 b	54.01 b	175.61 cd
'Streamliner'	106.61 a	3.38 b	38.55 c	160.19 d
'Sunburst'	67.11 c	9.44 a	88.34 a	186.83 c

[1]Data are based on four plots of 30 plants each of each cultivar over nine prunings.

[2]Data are based on four plots of 30 plants each of each cultivar over 22 prunings.

[3]Data are based on 50 leaves from the four replications of each cultivar.

[4]Data are based on eight plants from each of the four replications of each cultivar over 14 countings.

[5]Means followed by the same letter do not differ significantly at the 5% level, Duncan's New Multiple Range Test.

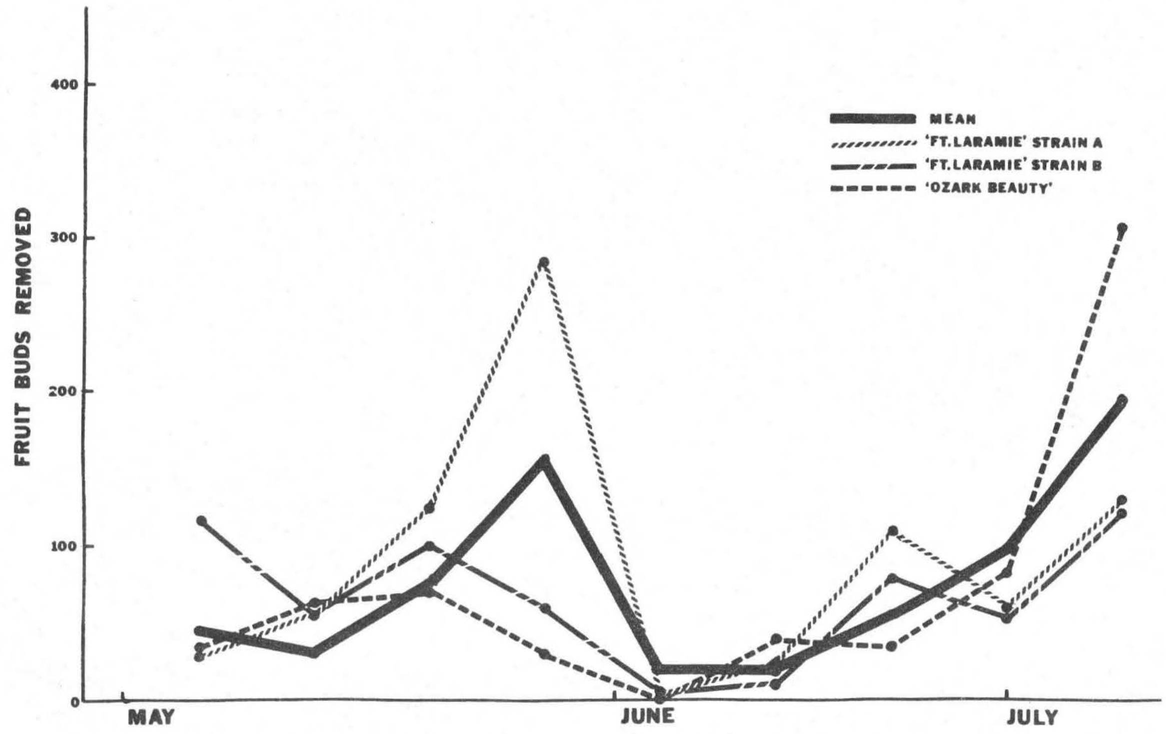


Figure 2a. Fruit buds removed. Mean number of fruit buds removed per plant over time for cultivars: 'Ft. Laramie' Strain A, 'Ft. Laramie' Strain B, 'Ozark Beauty' and overall mean

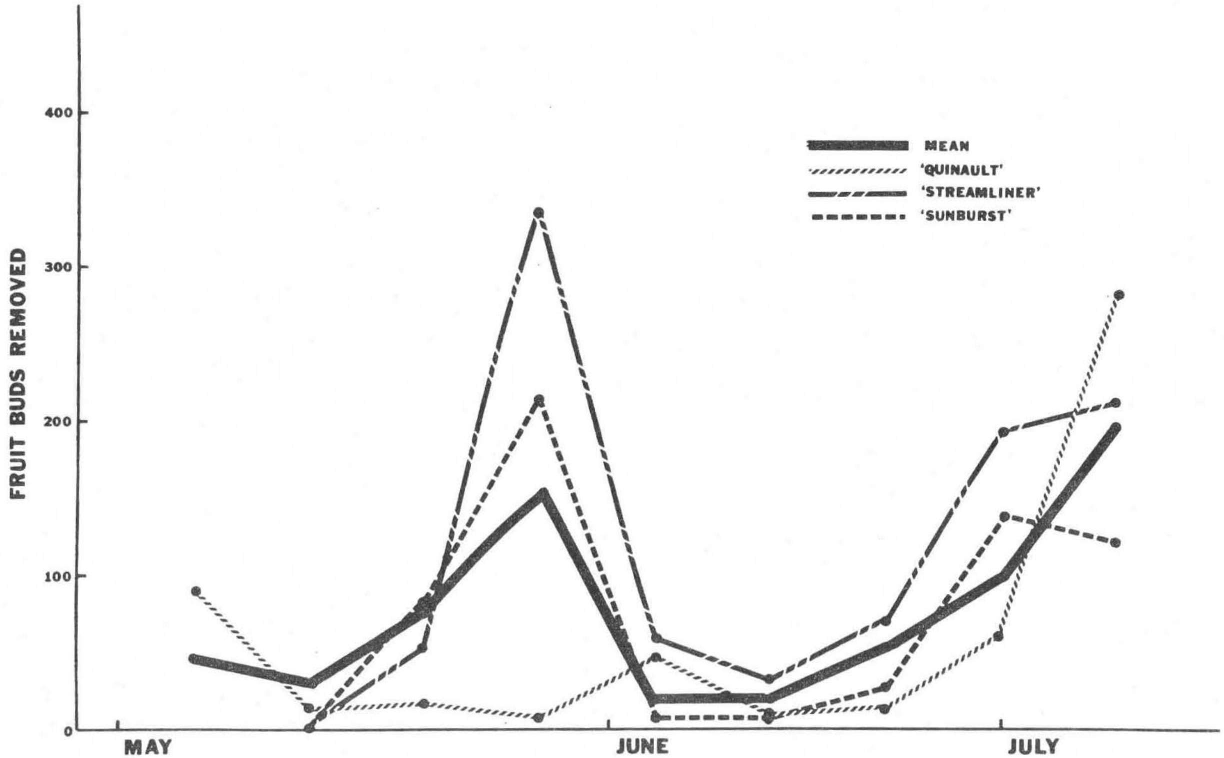


Figure 2b. Fruit buds removed. Mean number of fruit buds removed per plant over time for cultivars: 'Quinault', 'Streamliner', 'Sunburst', and overall mean

factor. This was attributable to both linear model and the lack of fit of linear model (Table 11). Examination of Figures 3a and 3b shows that, for most cultivars, runner production peaked in June, then decreased steadily for the rest of the season. The exception is 'Sunburst' which accounts for considerable statistical difference in the cultivars (Table 11).

Examination of Figures 4a and 4b shows mean total leaf number increases steadily until late August, after which the number decreases with a small rise at the last count. Time of the counts was a statistically significant factor. This was attributable to the linear model and its lack of fit. As expected, the time by cultivar interaction was significant (Table 12).

Differences in the number of leaves in Block Four to the others were significantly less than the other blocks (Table 6). The cultivar differences in mean total leaf numbers ranged from 277.50 leaves for 'Ft. Laramie Strain A to 160.19 leaves for 'Streamliner' (Table 4). Statistical differences were found only in the comparison of the two 'Ft. Laramie' strains to 'Ozark Beauty', 'Quinault' and 'Streamliner' (Table 12).

Mean leaf area index (15) ranged from 88.34 cm^2 for 'Sunburst' to 38.55 cm^2 for 'Streamliner' (Table 4). All statistical differences among cultivars were attributed to the comparison of 'Sunburst' to the others (Table 13).

Fruit yield was divided into three categories, total, marketable, and unmarketable. Total mean fruit yield ranged from 285.64 g for 'Ft. Laramie' Strain B to 106.04 g for 'Sunburst' (Table 5). All comparisons except 'Quinault' to 'Streamliner' showed significant differences (Table 14).

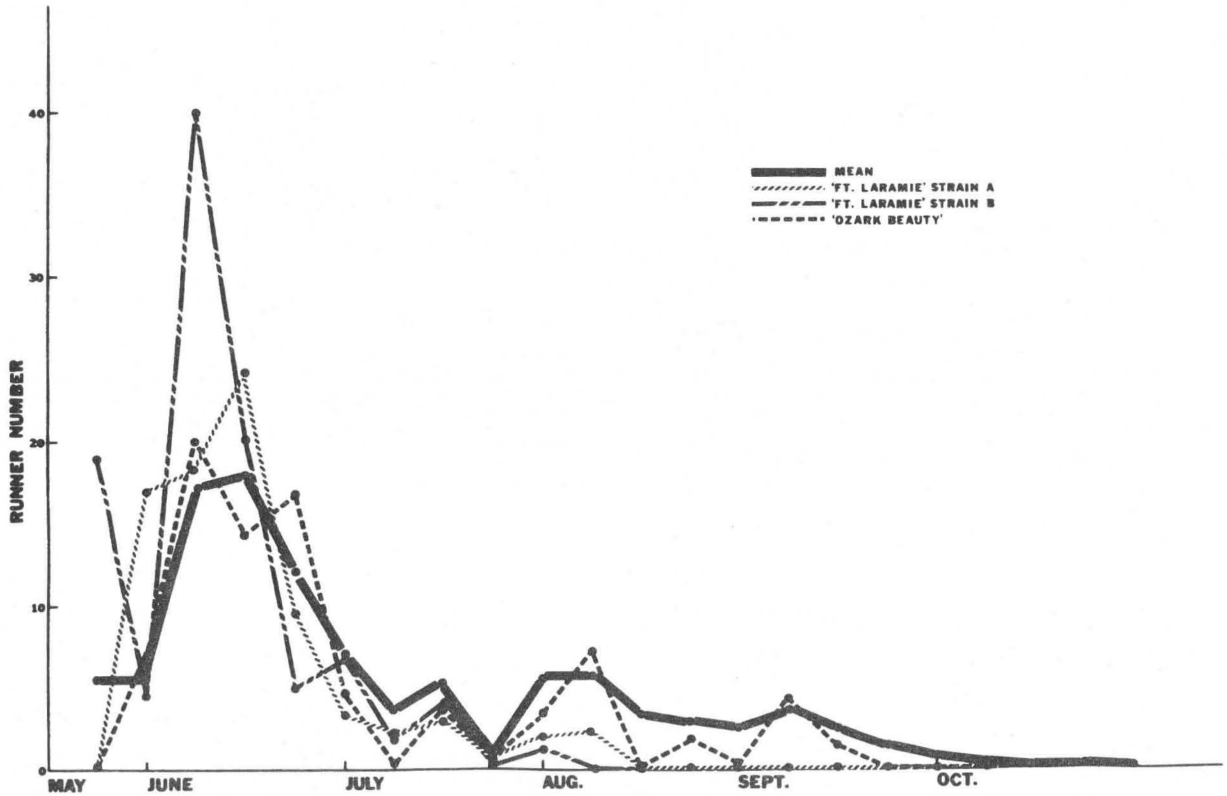


Figure 3a. Runner production. Mean number of runners removed per plant over time for cultivars: 'Ft. Laramie' Strain A, 'Ft. Laramie' Strain B, 'Ozark Beauty' and overall mean

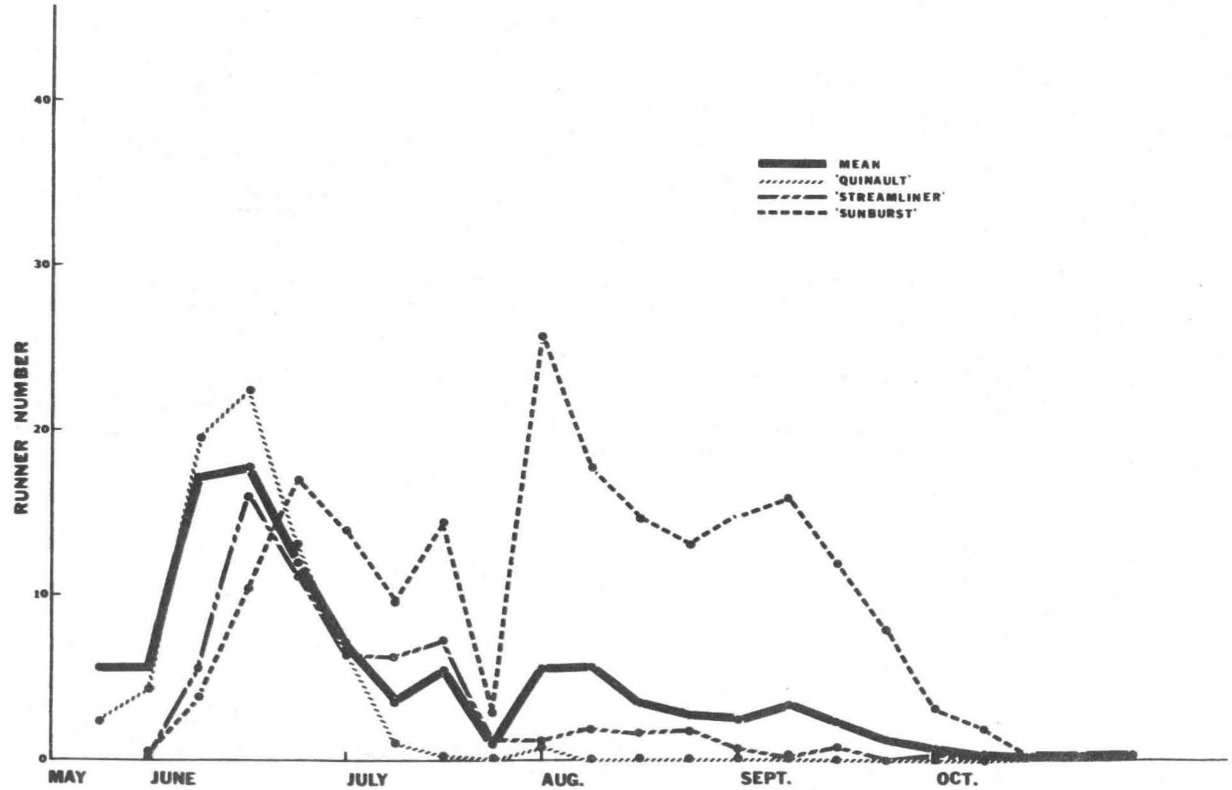


Figure 3b. Runner production. Mean number of runners removed per plant over time for cultivars: 'Quinault', 'Streamliner', 'Sunburst' and overall mean

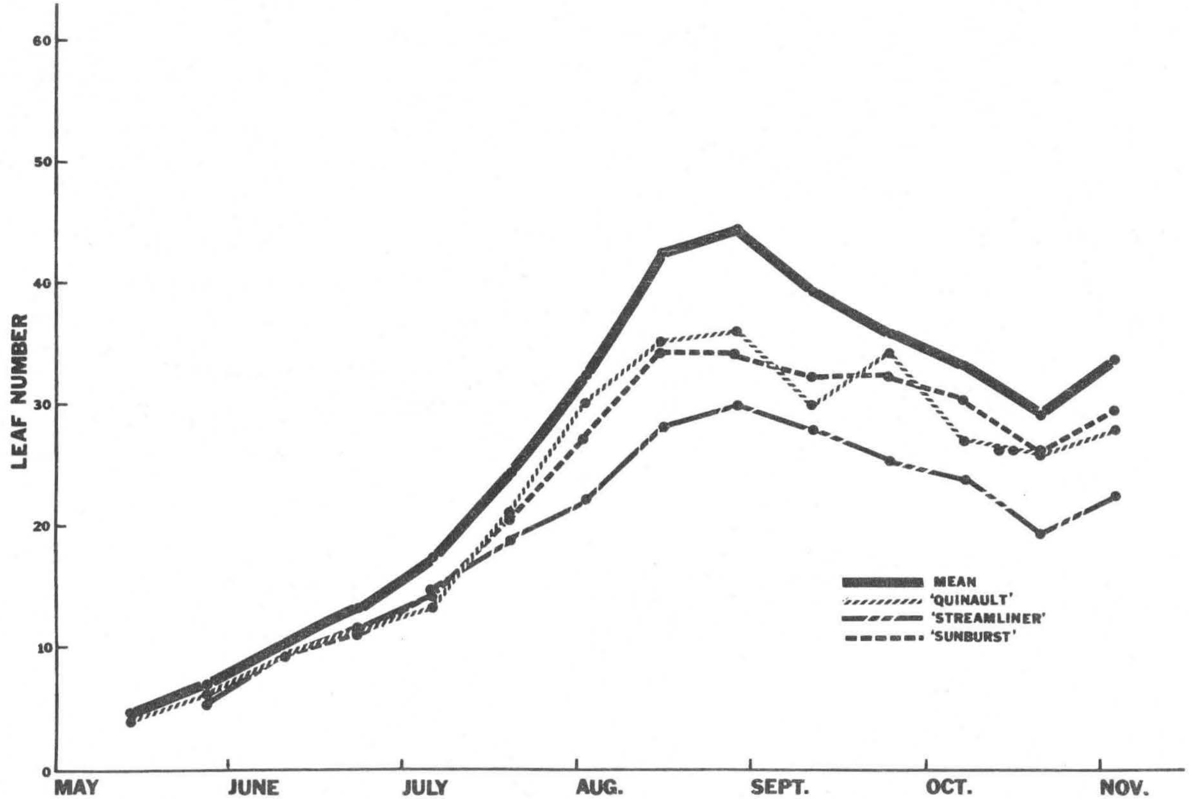


Figure 4a. Leaf production. Mean number of leaves per plant over time for cultivars: 'Ft. Laramie' Strain A, 'Ft. Laramie' Strain B, 'Ozark Beauty' and overall mean

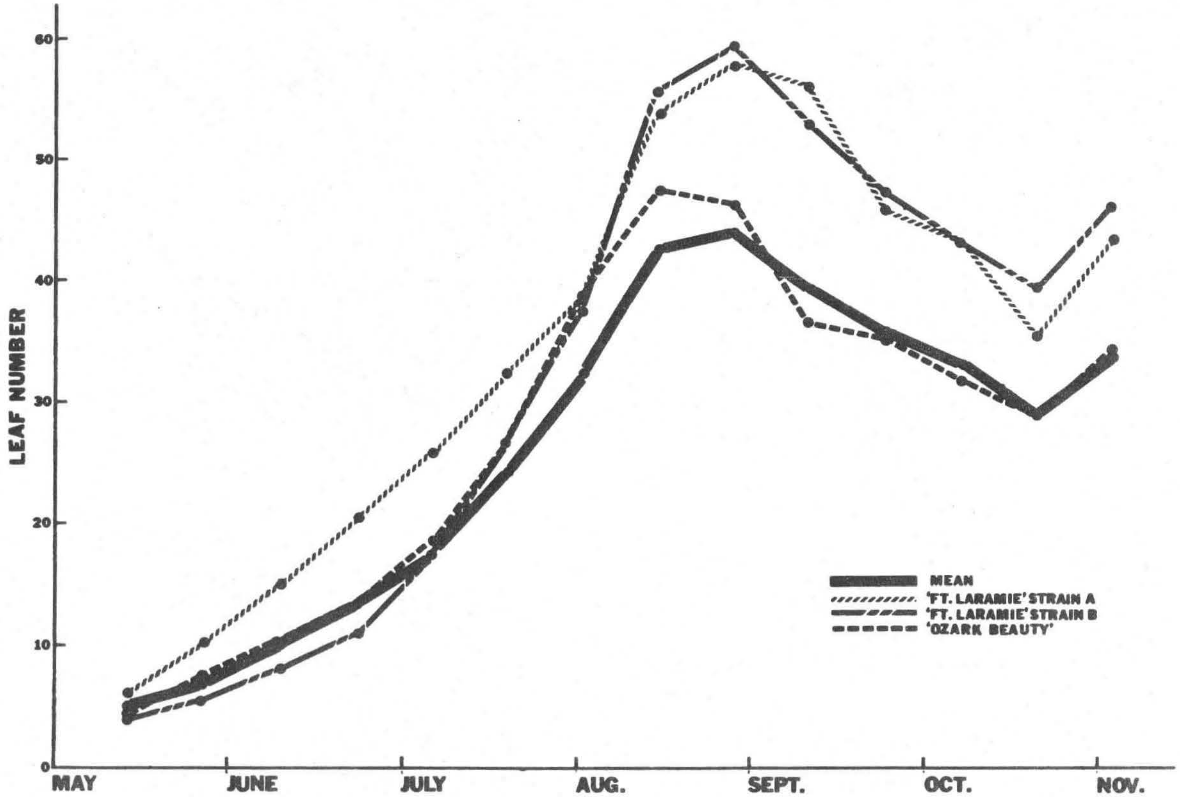


Figure 4b. Leaf production. Mean number of leaves per plant over time for cultivars: 'Quinault', 'Streamliner', 'Sunburst' and overall mean

Table 5. Mean values of total fruit yield, total individual fruit size, marketable fruit yield, marketable individual fruit size, unmarketable fruit yield, unmarketable individual fruit size, and percent marketable fruit[1,2,3]

Cultivar	Total		Marketable		Unmarketable		
	Yield per plot per harvest (g)	Individual fruit size (g)	Yield per plot per harvest (g)	Individual fruit size (g)	Yield per plot per harvest (g)	Individual fruit size (g)	Percent marketable (%)
'Ft. Laramie' Strain A	228.59 b	7.46 a	152.40 b	7.36 b	76.19 a	8.33 a	70.15 c
'Ft. Laramie' Strain B	285.64 a	7.68 a	200.79 a	7.53 b	84.85 a	8.56 a	75.49 b
'Ozark Beauty'	223.71 b	6.54 b	151.36 b	6.42 c	72.35 a	7.11 b	74.74 b
'Quinault'	179.49 bc	7.64 a	111.13 c	7.69 b	68.36 b	8.52 a	66.38 c
'Streamliner'	143.68 cd	7.72 a	70.98 cd	8.96 a	72.71 a	7.47 ab	58.51 d
'Sunburst'	106.04 d	7.62 a	73.98 cd	7.50 b	32.05 c	8.44 a	81.25 a

[1]Data are based on four plots of 30 plants each of each cultivar over 24 harvests.

[2]Individual fruit size was calculated by dividing the weight of the total number of berries by the number of the berries.

[3]Means followed by the same letter do not differ significantly at the 5% level by Duncan's New Multiple Range Test.

Table 6. Mean values of blocks for total leaf number,[1] leaf area index (15),[2] final branch crown number,[3] final plant weight,[3] final crown diameter,[3] total individual fruit size,[4] marketable individual fruit size,[4] unmarketable individual fruit size,[4] total fruit yield,[4] marketable fruit yield,[4] unmarketable fruit yield,[4] and percent marketable fruit[4,5]

Blocks	Total leaf number	Leaf area index (cm^2)	Final branch crown number	Final plant weight (g)	Final crown diameter (mm)	Total individual fruit size (g)
1	211.22 a	50.16 a	7.58 ab	68.35 ab	37.45 ab	7.40 ab
2	225.52 a	50.22 a	8.06 ab	61.58 b	39.63 ab	7.24 b
3	246.72 a	55.99 a	9.19 a	80.40 ab	45.14 a	7.29 b
4	172.89 a	54.85 a	6.52 b	91.52 a	35.86 b	7.84 a

Blocks	Marketable individual fruit size (g)	Unmarketable individual fruit size (g)	Total fruit yield per plot per harvest (g)	Marketable fruit yield per plot per harvest (g)	Unmarketable fruit yield per plot per harvest (g)	Percent marketable fruit (%)
1	7.49 ab	8.20 a	176.28 b	114.02 b	62.26 a	68.92 b
2	7.35 b	7.74 a	205.09 ab	133.68 ab	71.41 a	70.60 ab
3	7.45 ab	7.79 a	222.55 a	148.72 a	73.83 a	72.73 a
4	7.95 a	8.50 a	174.18 b	110.67 b	63.51 a	71.82 ab

[1]Data are based on eight plants from the six plots within the block over 14 countings.

[2]Data are based on 50 leaves from the six plots within the block.

[3]Data are based on eight plants from the six plots within the blocks.

[4]Data are based on the six plots of 30 plants each within the block over 24 harvests.

[5]Means followed by the same letter do not differ significantly at the 5% level, Duncan's New Multiple Range Test.

Time of harvest was a significant factor. The linear model and the lack of fit of it were both significant. Examining Figure 5, the general trend shows fruit yield peaked in late August, then tapered off. As expected, the time by cultivar interaction was significant (Table 14).

Total mean individual fruit size ranged from 7.72 g per fruit for 'Streamliner' to 6.54 g per fruit for 'Ozark Beauty' (Table 5). Block Four fruit were significantly larger than those of the other blocks (Tables 6, 14). Differences among the cultivars were attributable to the comparison of 'Ozark Beauty' to 'Quinault' and 'Streamliner' (Table 14).

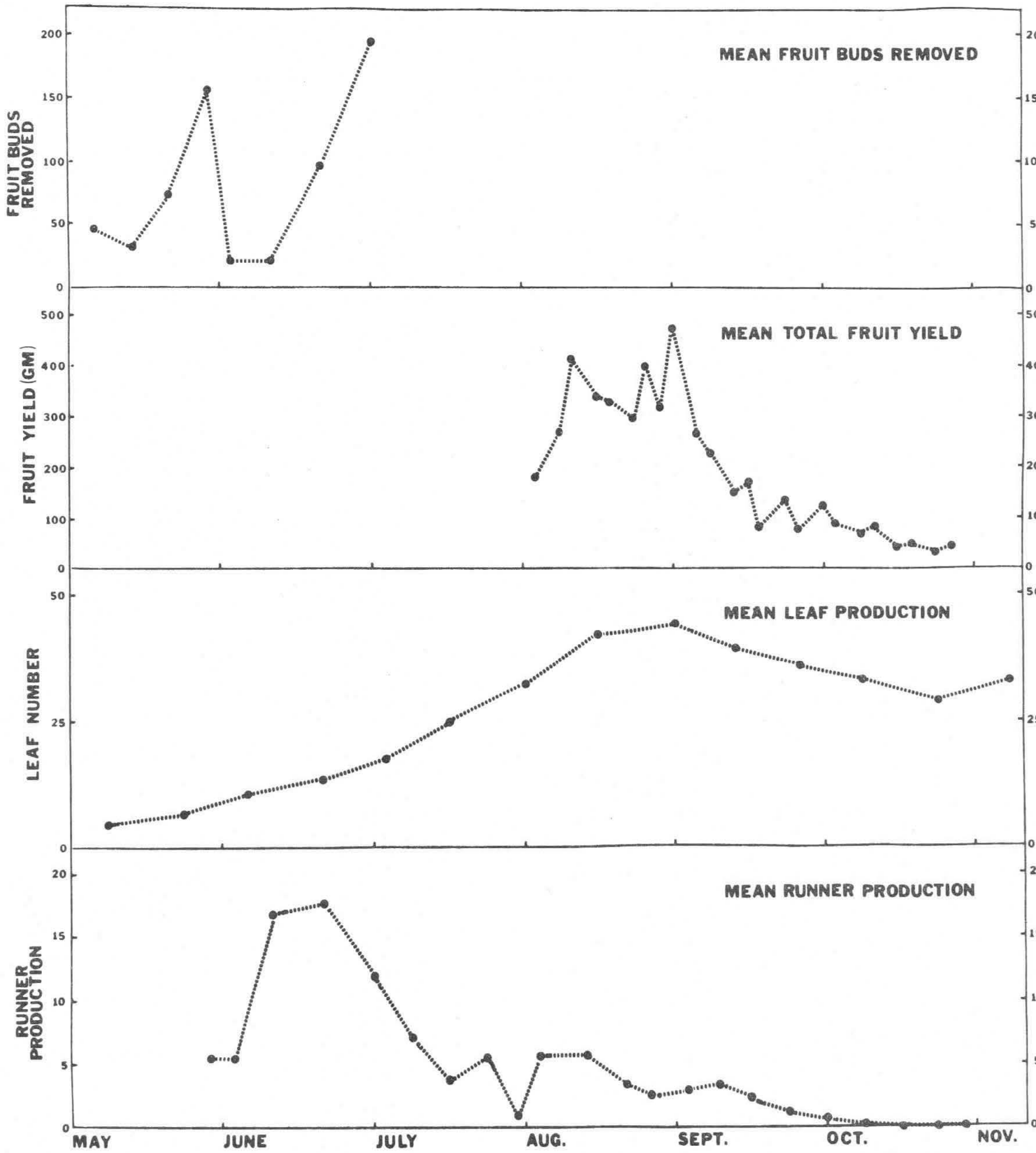
Time was important in influencing fruit size, but the linear model did not explain it. The time by cultivar interaction was not significant (Table 14).

Of considerable interest is the marketable fruit yield. Mean marketable fruit yield ranged from 200.79 g for 'Ft. Laramie' Strain B to 70.98 g for 'Streamliner' (Table 5). All comparisons made showed statistical differences (Table 15). Time, which was highly significant, was attributable to both the linear model and the lack of fit (Table 15). The time by cultivar interaction was significant (Table 15).

Mean marketable individual fruit size followed the same pattern as mean total fruit size. Size ranged from 8.96 g for 'Streamliner' to 6.42 g for 'Ozark Beauty' (Table 5). Block Four fruits were significantly larger than the others (Table 6, 15). Statistical differences were observed in comparisons of 'Ozark Beauty' to 'Streamliner' and 'Quinault' and of 'Streamliner' to 'Quinault' (Table 15).

Mean unmarketable fruit yield ranged from 84.85 g for 'Ft. Laramie' Strain B to 32.05 g for 'Sunburst' (Table 5). Statistical difference was

Figure 5. Overall mean runner production, mean total leaf production, mean total fruit yield, and fruit buds removed


MEAN FRUIT BUDS REMOVED
FRUIT BUDS REMOVED
200
150
100
50
0
MEAN TOTAL FRUIT YIELD
FRUIT YIELD (GM)
500
400
300
200
100
0
MEAN LEAF PRODUCTION
LEAF NUMBER
50
25
0
MEAN RUNNER PRODUCTION
RUNNER PRODUCTION
20
15
10
5
0
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.

found only in the comparison of 'Sunburst' to the others (Table 16). Time was of significant importance. The linear model and lack of fit were both significant in explaining the effect of time (Table 16). The time by cultivar interaction was also significant (Table 16).

Mean individual fruit size for unmarketable fruit showed no differences due to cultivar effects (Table 16). Time was a significant factor with only the linear model explaining the effect of time on fruit size. The time by cultivar interaction was not significant (Table 17).

'Sunburst' produced the greatest percent marketable fruit, while 'Streamliner' produced the lowest percentage (Table 5). All comparisons made in Table 17 revealed that all differences were statistically significant. Time effects were attributable to the linear model and its lack of fit (Table 17). The time by cultivar interaction was not significant (Table 17).

DISCUSSION

The purpose of this study was to examine more closely everbearing strawberries. As expected, differences among the cultivars were seen. The differences in the cultivars of the parameters measured will be discussed first, then the experiment of letting Block Four plants runner will be discussed. The cultivar comparisons will be evaluated after the runner experiments.

Lastly, plant relationships will be discussed. This section pertains to the relationships of fruit production to leaf and runner production, and also fruit size to leaf and runner production. This part will emphasize everbearers.

The parameters measured acquainted the investigator with the nature of the plant and whether it is healthy or diseased.

The first data collected were those of branch crown number, plant weight, and crown diameter of the plants. These data were termed the initial data. The differences among the cultivars in the initial data can be explained by the plants' probably being grown in different nurseries. Even though most of the plants were obtained from the same company, Davids and Royston Bulb Company, Inc., this company is a plant brokerage firm that acts as a middleman between growers, and mail-order nurseries and wholesalers. They deal with several growers on the West Coast.

One of the most important factors affecting plant development is the environment. Included in the environment are uncontrollable factors, such as weather, climate and topography; and controllable factors, such as cultural practices including planting and digging dates, fertilization, and irrigation. Variations in these can cause differences in plant size.

Most plants bought are single crown runner plants and quite small. From the data, a direct relationship can be seen among plant weight, branch crown number and crown diameter (Tables 1, 2 and 3). Initial plant size should affect plant establishment, so those which are larger would become established more readily.

The final data taken after the plants were dug were branch crown number, plant weight, crown diameter, and leaf numbers per plant. The leaf number data will be discussed later with the other leaf number data.

For the most part, initial differences in these parameters were overcome. In Block Four, plant weights were significantly greater than the other blocks (Table 6). This was due to the way the plants were weighed. The whole plant plus runners and runner plants that were allowed to form in that block were weighed so they would weigh more. Cultivar differences in plant weight were found only in the comparison of 'Sunburst' to the other cultivars (Table 8). The reasons for this difference will be explained later in the section discussing the specific cultivars.

The 'Ft. Laramie' strains had significantly greater numbers of branch crowns as compared to 'Ozark Beauty', 'Quinault', and 'Streamliner', while 'Sunburst' has significantly fewer branch crowns that the rest (Tables 1 and 8). The 'Sunburst' plants had fewer branch crowns because some of the plants were judged to be Junebearers, which produce fewer branch crowns. Basis for this claim will be explained in more detail later. The 'Ft. Laramie' strains have proven to be vigorous and robust plants, so it was no surprise to see them having the greatest number of branch crowns.

Crown diameter should be related to branch crown number, but the data do not show this. 'Ozark Beauty' which had a moderate number of branch crowns had the greatest mean crown diameter (Table 3). This could be attributable to the ability of 'Ozark Beauty' to store more carbohydrates in one crown, lessening the need to produce more branch crowns for food storage.

The most interesting occurrence was how the cultivars overcame initial differences to produce fairly uniform plants throughout the season. This suggests the growing conditions affected plants equally and the initial differences were not critical in determining plant size and vigor.

Factors in determining plant vigor were the increases in branch crown numbers, crown diameter and plant weight. It was noted that 'Streamliner' was among those to have the least increases, while the 'Ft. Laramie' strains were usually among those with the greatest increases. Overall, this could be explained by adaptability and age of the cultivars. 'Streamliner' is a quite old cultivar, which appears not well-adapted to the Midwest, while 'Ft. Laramie', which was introduced in 1972, is well-adapted to the Midwest. The findings on increase in branch crown number, crown diameter, and plant weight substantiate the claims of the vigor and productiveness of the 'Ft. Laramie' strains.

Figures 2a and 2b show two peaks in the fruit buds removed from the cultivars. The first peak which occurred in late May can be attributed to the development of fruit buds initiated the previous fall. These fruit buds overwintered in the crown and would have produced the spring crop for the everbearers. The numbers of fruit buds in this peak are a function of the conditions the plant encountered the previous season and severity of overwintering conditions. Most of the differences among the cultivars occurred before and during this peak.

The second peak was starting to appear at the time the removal of fruit buds stopped. Between the peaks the number of fruit buds varied little among the cultivars, but spread out at the last pruning.

The peaks occurred about four to five weeks apart. The first peak occurred about six weeks after planting. It was assumed it took four to five weeks from fruit bud initiation to development of visible buds. This could not be known for certain unless microscopic studies were made of the buds to pinpoint the time of initiation. Consulting Figure 5, the overall trend shows that daylength seems to have little or no effect on fruit bud initiation. Usually, strawberry fruit buds are initiated under short days. The shorter hours of daylight reduces the inhibitory effect GA has on fruit bud initiation (31, 34).

Runnering in strawberries is one of the most interesting phenomena of the plant. In the leaf axil within the crown is a bud which, depending on the environmental conditions, can develop into a fruit bud, a branch crown, or a runner (18, 25, 44). From a runner, new plants identical to the parent plant can form at the nodes of the runner. Man has put runners to his use by using them to propagate new plants. Since the cultivated strawberry is an octoploid and a cross-pollinated crop, it rarely breeds true, so the best way to propagate the plant is asexually by runners.

Standard cultural practice for everbearers is to remove the runners to lessen the competition of runner production with other plant processes

(32, 39). To reduce the labor required in cultivating everbearers, new cultivars have been selected for their shy runner production quality. This is a problem for the propagator who would prefer the plants to be profuse runner producers.

In this study, it was found that all statistical differences in runner number among the cultivars were found in the comparison of 'Sunburst' to the other cultivars (Table 11). The reasons for 'Sunburst' being such a good runner maker will be discussed in detail later. The 'Sunburst' plants appeared to be mixed with Junebearer plants, which are usually prolific runner producers.

Figures 3a and 3b show that the other cultivars follow the same trend over time, where runner production peaks during the long days of June. After the peak, the number of runners produced slowly tapers off as fruit production commences and competes for the plants' photosynthates and nutrients.

The time during the growing season appears to be an important factor in determining how many runners were produced. This study supports the accepted theory that runners are initiated and produced under long days and that initiation and production decreases in the shorter days of late summer and fall (18).

Leaves are the basic photosynthetic unit of the plant. The evolution of the leaf into its flat blade-like structure to intercept solar energy efficiently is now being utilized in producing heat and electrical energy from solar energy.

Darrow (15) said "Leaf production is one of the main forms of activity in strawberry plants and may be considered as an index of general activity or growth." The size, condition and number of leaves is a good indicator to the well-being of the plant. There is a very high correlation between the number of healthy leaves on the plant in the fall and the number of fruit produced the next spring (15). The more leaves, the more leaf axils, the more axillary buds that can become fruit buds.

In this study, the live leaves of eight plants within each plot were counted and recorded every two weeks. Figures 4a and 4b show the trends of the mean leaf number for each cultivar. The greatest number of leaves coincides with the peak in fruit production in mid- to late-August (Figure 5).

The trends shown in growth exhibit no explainable occurrences. The leaf numbers increase more under the warmer, longer days of June and July, then peak in mid- to late-August. This peak is sustained for approximately two weeks; then as the days grow shorter and temperatures get cooler, the number declines slowly. Since the plants are evergreen, some of the leaves overwinter. The sharp rise in the last count was due to the leaves being counted after they were dug and stored for approximately one week. It was difficult to decide which leaves were dead and which were alive in the final count.

These counts do not consider the longevity of the leaves. So, in the analysis of variance of the total leaf number (Table 12), the leaves included are often counted more than once in the analysis. This may bias the analysis, because the different cultivars probably have different leaf life spans. But, it was done uniformly to the cultivars, so the bias should be uniform. Darrow (15) found the mean strawberry leaf life span is 56 days with a range of 21 to 77 days and the leaves usually die in sequence of formation.

Block Four plants had significantly less leaves than the other blocks (Table 6). So, it appears leaf production might be in competition for photosynthates and nutrients with runner production.

Significance among the cultivars occurred in the comparison of the differences of the two 'Ft. Laramie' strains to 'Ozark Beauty', 'Quinault' and 'Streamliner'. The two 'Ft. Laramie' strains had significantly greater mean total leaf numbers (Table 4). This finding substantiates the ability of 'Ft. Laramie' to be a productive cultivar.

The other parameter measured on the leaves was a leaf area index, described by Darrow (15). This index is the sum of the products of the length times the width of the three leaflets of the leaf. It was found that the actual leaf area was 75% of the corresponding leaf area, with little variation from this figure. This measurement was found to be more reliable than any other of the leaves, such as the area of a single leaflet, or any linear dimension (15).

This measurement was taken at the end of the season. It may have been better to measure this several times during the season, but some cultivars would have suffered if that many leaves would have been removed every two weeks. Also, removal of leaves would have adversely affected growth processes such as fruit and runner production.

Significant differences in the cultivars occurred only in the comparison of 'Sunburst', which had the greatest leaf area index, to the other cultivars (Tables 4 and 13). This parameter did not relate well to fruit production. This relationship was seen only in 'Sunburst' which is attributable to the large-leaved Junebearer plants, which were rogues among the cultivar. From the analysis in Table 13, no differences in leaf area index were shown among the other cultivars. This parameter may not be valuable in determining the photosynthetic potential in strawberries.

The fruit yield data may be biased. The portable scales used to weigh the fruit decreased in accuracy as the weight of the fruit decreased. So, the weight of a small number of fruit may be greater than it should be. This could also affect individual fruit size data by representing cultivars with lower yields as producing larger fruit. Consulting Table 5, this relationship is seen in total, marketable and unmarketable yields.

Significance was frequently seen in the total, marketable, and unmarketable fruit yields and percent marketable fruit, but there were few differences in the individual fruit size. The only comparison of total fruit yield that lacked significance was 'Quinault' to 'Streamliner'.

'Sunburst' had the least amount of total fruit yield. This was expected since the plants were mixed with non-bearing Junebearer plants. 'Streamliner' had the next least amount (Table 5). Overall, the plants were of poor vigor, which may be a reflection of the age of the cultivar.

The differences in yield of 'Quinault', 'Ozark Beauty' and 'Ft. Laramie' Strain A were not statistically significant (Table 5). When 'Ft. Laramie' Strain B was added to the comparison, so it was 'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B versus 'Ozark Beauty', 'Quinault', and 'Streamliner', the result was significant differences (Table 14).

The reason 'Ft. Laramie' Strain B produced significantly more fruit than the other cultivars is not readily explainable. The Strain B plants were even initially smaller than the Strain A plants. The Strain A plants may have a virus which is limiting their growth and productiveness.

Marketable fruit yield had the same significant comparisons as total fruit yield, except the comparison of 'Quinault' to 'Streamliner' was now also significant. This was caused by the great amount of unmarketable fruit in 'Streamliner'.

Overall, the cultivars had the same amount of unmarketable fruit, except 'Sunburst, which had the least amount of unmarketable fruit (Table 5). This measurement is somewhat deceptive, since it is based on the total yield and those with lower total yields would also have lower unmarketable fruit yields. A better indicator of the amount of marketable and unmarketable yields is the percent marketable fruit.

All the comparisons of percent marketable fruit were statistically significant (Table 17). 'Sunburst' had the greatest percent of marketable fruit (Table 5). 'Streamliner', which had difficulty producing fruit, also had difficulty producing marketable fruit. It had the lowest percent of marketable fruit (Table 5). The fruit bruised easily, had a tendency to waterspot and rarely turned completely red without rotting first.

The other cultivars' percent of marketable fruits ranged from approximately 66-75% (Table 5). The differences among these were significant, but cannot be readily explained (Table 17).

For total individual fruit size, the comparison of the differences of 'Ozark Beauty' to 'Quinault' and 'Streamliner' was the only one to be significant (Table 14). For marketable individual fruit size, the comparison of the differences of 'Ozark Beauty' to 'Quinault' and 'Streamliner' and of 'Quinault' to 'Streamliner' were the only ones to be significant (Table 15).

In total individual fruit size, the comparison which was significant was made between one which was statistically less than the other two cultivars. And that one cultivar was the only one to be different from the other cultivars (Tables 5 and 14).

The same is true in marketable individual fruit size, except 'Quinault' and 'Streamliner' are also significantly different (Table 15). These three cultivars in question had slightly lower yields than those with smaller individual fruit size. It is known that different cultivars partition photosynthates and nutrients differently, such that some produce more fruit while others produce larger fruit. An example of this is the cultivar 'Quinault' (R. M. Davidson, Western Washington Research and Extension Center, Puyallap, WA, personal communication, 1981).

The statistical design of this study was a completely randomized block design. The purpose of this design was to minimize variation in the experiment due to location in the field. When the block effect is significant in the analyses of variance, it usually means it was a good idea to block the experiment.

In this study, a smaller experiment was conducted by letting the Block Four plots runner freely after the last fruit buds were removed. This was done to see if runner production competed adversely with other plant processes, such as fruit production, leaf production, and plant size. If there were no differences found, then it may be a labor-saving recommendation to cease removing runners after the plants are allowed to fruit.

Differences were found in final plant weight between Block Four plants and plants of the other blocks (Table 6). Block Four plants had a greater plant weight than the others. This is attributable to the technique used in measuring the plants. The whole plant, runners and runner plants were weighed to determine the total biomass produced by the plant. To gain more insight, it would have been advisable to weigh the parent plant separately for a better comparison.

Total leaf number was the least for Block Four plants. The difference between Block Four and the others was of statistical importance. This could be due to the partitioning of photosynthates such that the runner and fruit production have a higher priority over leaf production for them.

Block Four produced significantly larger fruit for total yield and marketable yield (Tables 14 and 15). This is not as easily explained as the other significant parameters, because the fruit yield was not significantly different (Tables 14, 15, 16). It may be explained in that the plants partitioned their photosynthates and nutrients to fewer fruits in greater amounts.

There were no significant differences in fruit yield between Block Four and the other blocks (Tables 14, 15, 16). Since fruit yield is the most important factor to consider, there was no effect on yield by letting the plants runner. An interesting point to follow further would be to observe the crop next spring to see if it will be affected by allowing the plants to produce runners.

Even though six cultivars were used in this study, the overall objective of this study was to examine the growth habits of everbearers in general. Growth habits included fruit production, fruit bud production, runner production, leaf production, branch crown production and other general aspects. Cultivar differences cannot be overlooked and questioned if they were solely due to the genetic variation in the different cultivars. This study can show which cultivars are best adapted to Iowa. The data show 'Ft. Laramie' Strain B has the greatest total fruit yield (Table 5). Even in Block Four, where runners were not removed after the fruit buds were allowed to fruit, this cultivar had the greatest yield.

Comparisons were made among the cultivars for the purpose of seeing if differences could be attributed to age, origin, or other factors known about the cultivars. These factors were covered more specifically in the Materials and Methods.

One of the problems examined was whether the two 'Ft. Laramie' strains differed significantly. In visual observations of the plants over the growing season, no gross morphological differences in the plants were found. Both strains had a dense mounded shape with abundant leaves, and very similar fruit. The only visible difference was Strain B's leaves were cupped more than Strain A's. Of the parameters measured, marketable fruit yield, total fruit yield, percent of marketable fruit, fruit buds removed, the initial data and increase in branch crown number had significant differences.

Most of these differences are due to the fact that the plants used probably came from different sources where they were grown and stored under different conditions. This can explain the differences in the initial data.

The initial differences in branch crown number, plant weight, and crown diameter were overcome by the end of the season. Even though the difference in final branch crown number was not statistically different, the difference in the increase from initial to final branch crown number was significant. 'Ft. Laramie' Strain B overcame being significantly less than 'Ft. Laramie' Strain A to be significantly greater than Strain A (Tables 1 and 8).

The difference in fruit buds removed can be explained by the differences in plant source. Looking at Figure 2a, it can be seen that the greatest difference in the two strains occurs during the first peak, which was the fruit buds initiated the previous season. After that, the differences lessen for the peak due to the fruit buds initiated the present season.

Strain A produced the greater amount of fruit buds; it also had the greater branch crown diameter, plant weight and crown weight. It stands to reason that the greater the crown and plant size, the greater the potential to produce fruit buds, runners and leaves.

The processes of fruit, runner, and leaf production are metabolic sinks in the physiology of the plant. Great quantities of photosynthates and nutrients are needed to complete these processes. Often, the photosynthetic capacity of the leaves is not enough to keep up with the demand, so the carbohydrates stored in the crown are utilized.

The differences in total fruit yield and marketable fruit yield cannot be as easily explained by attributing them to the differences in the source of the plants or to Strain A having a greater initial plant size. Strain B, which had a significantly smaller initial plant size, produced a significantly greater amount of total and marketable fruit. This could be due to the location of the plots in the field. Always being on the border of the plots may have affected Strain A enough to cause the difference (Figure 1).

Overall, the investigator felt these two strains are the same cultivar. It appears Strain B is slightly more productive and efficient than Strain A. It would be helpful if a virus index would be performed to see if this can explain some of the differences. But this amount of variation within a cultivar may be normal and the differences are not of significance.

Another problem occurred in the cultivars. 'Sunburst' exhibited a wide variation in plant type and fruiting habit. Some of the plants had a short, small, dense habit with small dark green leaves. These plants were shy runner makers and produced a late summer and fall crop. The fruit had a characteristically light orangish-red color and sweet flavor, which fit the description supplied by J. C. Davids (Davids and Royston Seed Company, Inc., Gardena, CA, personal communication, 1981).

The other plant type had a sparse habit with large medium green leaves, produced runners prolifically and produced no fruit. From these observations, it is believed that these plants are not true 'Sunburst' plants and are probably a Junebearer cultivar which had contaminated the 'Sunburst' plants in either the nursery or in a mix-up of the packaging of the dormant plants. It is almost impossible to make cultivar identification on dormant plants, and unless a person is very familiar with a certain cultivar, it is also hard to determine different cultivars of growing non-fruiting plants.

Since these plants were grossly different, then the assumption made that the 'Sunburst' plants were contaminated by the Junebearer plants seems to be correct.

All the differences among the cultivars for the parameters of runner production and leaf area index were attributable to 'Sunburst'. This was caused by the presence of Junebearer plants which usually runner profusely throughout most of the season. The Junebearer leaves were larger than the 'Sunburst' leaves and other cultivars' leaves. This accounts for the differences in leaf area index.

'Sunburst' also produced the least amount of fruit, which is attributable to only part of the plants producing fruit. A plus for this cultivar was that approximately 81% of the total crop was of marketable quality (Table 5). 'Sunburst' was also found to have the greatest individual fruit size (Table 5). These findings are deceiving in that, as already stated, the accuracy of the scales used to weight the fruit became less as the quantity of the fruit decreased.

Examination of the final data shows that 'Sunburst' had the least number of branch crowns and the least amount of increase in the number of branch crowns (Table 1). This was probably caused by the Junebearer plants which runnered profusely. Runner production and branch crown production are competitive processes (45); also, some plants have a greater ability to do one more than the other (13). Usually, Junebearer plants favor runner production.

'Sunburst' also had the greatest final plant weight and increase in plant weight (Table 2). The Junebearer plants were visually much larger than the 'Sunburst' plants and the other cultivars. Even though they produced fewer branch crowns, it appears that the crowns stored more carbohydrates within them as opposed to partitioning them among several crowns.

Overall, the investigator believes that the off-type plants were Junebearers. And where differences occurred among the cultivars where 'Sunburst' is the only cultivar different, these were attributable to the Junebearer plants.

It is regrettable that such errors occur in the nursery business. It would have been interesting to have had all 'Sunburst' plants in the study and to see how they compared with the other cultivars.

Most of the previous work shows 'Ft. Laramie' to be one of the best cultivars adapted to Iowa (32, 39). The comparison was made of the two 'Ft. Laramie' Strains to the other known everbearers, 'Ozark Beauty', 'Quinault', and 'Streamliner'. Significant differences were found among these cultivars in final branch crown number, increase in branch crown number, fruit buds removed, leaf production, total fruit yield, marketable fruit yield, and percent marketable fruit.

The 'Ft. Laramie' strains had a significantly greater final branch crown number and increase in branch crown number (Tables 8 and 9). This could mean 'Ft. Laramie' is more vigorous than the others, but the difference in final plant weight and crown diameter were not significant (Table 8). This would indicate that 'Ft. Laramie' is merely a better branch crown producer.

The significance of the differences in fruit buds removed is not so easily explained. Consulting Table 4, it can be seen the mean fruit buds for the cultivars are not grouped as nicely as the mean branch crown number in Table 1 were with the two 'Ft. Laramie' strains, greater than the rest.

Time of removal was an important factor in understanding this comparison. Figures 2a and 2b show at the last pruning 'Ozark Beauty', 'Quinault' and 'Streamliner' had a greater number of fruit buds removed than the two 'Ft. Laramie' strains. Other than at that time do the cultivars involved in the comparison follows this pattern.

Figures 3a and 3b show the trends of leaf production. It was not until late August that differences were visible between the 'Ft. Laramie' strains, and 'Ozark Beauty', 'Quinault', and 'Streamliner'. These differences were sustained over the rest of the season. The 'Ft. Laramie' strains overall produced more leaves than the other three cultivars (Table 4).

Fruit yield was greater for the 'Ft. Laramie' strains. In the comparisons 'Ozark Beauty's' mean value for total fruit yield and marketable fruit yield were not significantly different from 'Ft. Laramie' Strain A. Because it was grouped with 'Quinault' and 'Streamliner', which had significantly lower yields, the comparison of the differences was significant (Tables 4, 5, and 14). The same was true for percent marketable yield (Tables 5 and 17).

A plausible reason for the next comparison was that 'Ozark Beauty' was developed in the Midwest while 'Quinault' and 'Streamliner' were developed in the Pacific Northwest.

Significant differences of the comparison were found in final plant weight, increase in branch crown number, plant weight and crown diameter, total fruit yield, total individual fruit size, marketable fruit yield, marketable individual fruit size and percent marketable fruit.

'Ozark Beauty' had a significantly greater final plant weight and increases in branch crown number, plant weight, and crown diameter than the other two cultivars (Tables 1, 2, and 3). This indicates 'Ozark Beauty' appears to be more vigorous than the others.

A greater fruit yield also showed that 'Ozark Beauty' appeared to be more adapted to Iowa growing conditions. Total and marketable fruit yield were significantly greater for 'Ozark Beauty' (Table 5). 'Ozark Beauty' also had a greater percent marketable fruit (Table 5).

What was of interest was 'Ozark Beauty' had significantly smaller fruit size than the other two cultivars (Table 5). The best explanation for this would be that under Iowa growing season 'Ozark Beauty' produces smaller fruit.

Examining the differences and the reasons, it could be said that 'Ozark Beauty' is better suited for Iowa growing conditions than 'Quinault' and 'Streamliner'.

'Quinault' and 'Streamliner' were both developed in the Pacific Northwest. 'Quinault' is a relatively new cultivar, which was released in 1967, while 'Streamliner' was released in 1944. The purpose of this comparison was to determine if age of the cultivars developed from the same area can be a factor in causing differences in the cultivars. It is known with increasing age the vigor of a cultivar often decreases. This decline in vigor is usually due to virus infestation (17). So 'Quinault' was expected to perform better than 'Streamliner'.

Statistical differences were seen in initial branch crown numbers and crown diameter, final plant weight, increase in crown diameter, fruit buds removed, marketable fruit yield, marketable individual fruit size and percent marketable fruit.

Initially, 'Streamliner' had a greater mean branch crown number and mean crown diameter (Tables 1 and 3). But, 'Quinault' overcame these differences. The final plant weight was the only final data parameter that was significantly greater for 'Quinault' (Table 2). Increase in crown diameter was statistically different to the extent that 'Quinault's' increase was greater than 'Streamliner's' (Table 3). If these two cultivars were of equal vigor then 'Streamliner' should have sustained its significant differences in branch crown number, plant weight, and crown diameter over 'Quinault', which it did not do.

'Streamliner' had significantly more fruit buds removed than 'Quinault'. Figure 2b shows the greatest differences in the two occurred during the first peak in fruit buds removed after which the differences were minimal. This peak was related to the number of overwintering buds formed the previous fall. 'Streamliner' has a very pronounced peak, while 'Quinault' shows none at all. The difference in fruit buds removed may be related to 'Streamliner' having a greater mean branch crown number and mean crown diameter.

As expected, 'Quinault' produced a statistically greater amount of marketable fruit and greater percent marketable fruit (Table 5). It was interesting that 'Streamliner's' marketable fruit was significantly larger. This is probably due to the genetic potential of the cultivar. The findings show that 'Streamliner' was inferior to 'Quinault' in plant vigor and fruit production.

An overall assessment of the cultivars in this study showed 'Ft. Laramie' Strain A was really no different from Strain B. The 'Ft. Laramie- strains seem to be the best adapted to Iowa. They were heavy fruit producers, more disease tolerant and good plant makers.

'Ozark Beauty' was also well-adapted to Iowa growing conditions. The plants were vigorous and produced an adequate amount of fruit. The investigator felt the fruit was not as attractive as 'Ft. Laramie's',

'Quinault' had disease problems with leaf scorch caused by *Marssonina sp.*. In August and September, several plants within the plots lost all their leaves. Also, the fruit was often affected. Fruit yields were reduced due to the lack of leaves and the disease itself.

'Streamliner' had a lack of vigor and substance. This was exhibited in the poor fruit yield, the poor quality of the fruit and the poor plant size.

'Sunburst' produced a light orangish-red fruit that was quite sweet. It also produced the greatest percent marketable fruit. It was unfortunate that the planting was mixed with Junebearer plants. This cultivar showed merit based on the above qualities.

Because little work has been done to observe the growth habits of everbearers, the major objective of this study was to do this. The point was to see how the different growth processes are interrelated with each other. These processes include branch crown production, leaf production, fruit production, runner production, and other general growth indicators.

Junebearers produce runners under the long days of summer and initiate fruit buds for the next year's crop in the preceding fall under short days (13, 16, 17, 25, 27, 28, 46). Branch crowns are formed under daylengths intermediate between the two. Everbearers are also considered long day plants, which vary in their degree of response to daylength (18). Everbearers can produce runners, fruit buds, fruit, and branch crowns under long days simultaneously (45, 46).

Some investigators (21, 40) believe that runner production and fruit bud initiation are independent. This study shows that runner production increased when fruit buds were removed and decreased after fruit buds were allowed to set fruit (Figure 5).

This would support the theory that runner production and fruit bud initiation are in direct competition with each other for photosynthates and nutrients. So, for the propagator, it may be useful to remove fruit buds throughout the season to promote runner procution.

As discussed earlier, runner production seemed to have the effect of decreasing leaf number and final plant size, but little effect on fruit yield and individual fruit size, which is the most important factor the grower examines. So, it would seem runner production does not affect fruit production adversely. Figure 5 shows that runner production decreases steadily as the plant starts fruiting. The plant itself may regulate runner production by partitioning photosynthates and nutrients away from that process toward fruiting so runner removal may not make that much difference, since the plant seems to naturally inhibit runner production.

Figure 5 also shows that fruit production peaks when leaf number peaks. This would suggest that leaf number increases with the demand for photosynthates for fruit production. But, it has been found that photosynthesis is poorly correlated to yield (7).

Fruit size seemed to be poorly correlated to yield over time. As stated earlier, this may be due to the inaccuracy of the scales. Fruit size is usually a function of the number of achenes fertilized and the climatic conditions.

Leaf area seems to show no relationship to the other growth processes of the plant. If more samples were taken throughout the season, differences may have been more apparent among the other cultivars and more relationships may have been seen.

Overall, with 'Sunburst' eliminated from the comparisons, the cultivars having the greatest total fruit yield also had a large total leaf number, fruit bud number, final branch crown number, marketable fruit yield and increase in branch crown number, plant weight, and crown diameter. This shows the plant itself (leaves and crown), is responsible for affecting the quantity and quality of the crop.

SUMMARY

This study shows that the source of plants is very important. A shipment of plants from any nursery may contain plants of the same cultivar from different sources. This may cause differences in the vigor and productivity of the plants. Also, plants can be mislabeled, so the grower will not receive the correct cultivar. If this mislabeling is within Junebearers or everbearers, the problem is not so apparent to the amateur grower.

But, if Junebearers are mixed with everbearers, problems can arise. This is believed to be the problem with the cultivar 'Sunburst'. This can happen easily if the mistake is made when working with dormant plants which all look alike.

On this same topic of plant differences within a cultivar, it is the judgment of the investigator based on the data collected and analyzed that the two 'Ft. Laramie' strains are the same. The differences that did occur between the strains were easily explained.

The data showed that 'Streamliner', which is an old cultivar, performed poorly compared to the other cultivars. The data also showed that the Midwestern cultivars, 'Ft. Laramie' and 'Ozark Beauty', performed better in the Midwest than 'Quinault' and 'Streamliner' which were developed in the Pacific Northwest. The overall assessment was that 'Ft. Laramie' performed the best of all the cultivars.

The everbearers in this study behaved as expected. They produced fruit buds under the long days of summer and fruited in the late summer and fall. They tended to be shy runner producers, but did produce branch crowns.

The most interesting relationship established in this study was that of fruit and runner production. During the first part of the season, fruit buds and runners were removed. At this time the number of runners produced increased. This could be explained by occurrence of long days at that time, or the lack of competition from the fruit buds. When the plants were allowed to set fruit, the number of runners produced decreased and remained at a low level the rest of the season. This would indicate a competition between the two processes. This is also supported by the findings that the fruit yield of the runner-producing plants of Block Four did not differ statistically from the other blocks. This study shows that fruit and runner production are not independent of each other, do compete for the same photosynthates and nutrients, and fruit production usually takes priority over runner production.

Another interesting relationship seen in this study was that fruit yield peaked the same time leaf number peaked, even though there has been found a poor correlation between yield and photosynthesis (7). This would seem to support a correlation of the two.

With further research to substantiate these findings, recommendations could be made to the propagator to remove fruit buds the whole season to reduce the competition of fruit production with runner production.

For the grower who is trying to reduce the labor involved in growing everbearers, ceasing to remove runners when fruit buds are no longer removed may be of help. This study found no difference in fruit production between the plants allowed to runner after fruit bud removal ceased and the plants not allowed to runner, although further study would be needed to confirm this.

Lastly, this study showed that plants which had the greatest fruit yield were also those that had good leaf production and increases in plant weight, crown diameter and branch crown number. So, overall plant growth and vigor are important for good yields.

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APPENDIX: STATISTICAL ANALYSES

Table 7. Analyses of variance for initial branch crown number, initial plant weight and initial crown diameter

Source	df	MS	F
Branch crown number			
Total	191		
Cultivars	5	8.17	9.05**
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	11.39	12.61**
'Sunburst' vs. rest	(1)	11.40	12.71**
'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	0.65	0.72
'Ozark Beauty' vs' Quinault' and 'Streamliner'	(1)	1.33	1.48
'Quinault' vs. 'Streamliner'	(1)	16.01	19.79**
Experimental error	186	0.90	
Crown weight			
Total	191		
Cultivar	5	141.76	3.37**
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	513.57	12.22**
'Sunburst' vs. others	(1)	2.09	0.05
'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B vs. 'Ozark Beauty, 'Quinault' and 'Streamliner'	(1)	129.54	3.08
'Ozark Beauty' vs. 'Quinault' and 'Streamliner'	(1)	0.28	0.01
'Quinault' vs. 'Streamliner'	(1)	63.27	1.51
Experimental error	186	42.01	

*Significant at $\alpha = 0.05$.

**Significant at $\alpha = 0.01$.

Table 7. *Continued*

Source	df	MS	F
Plant diameter			
Total	191		
Cultivar	5	303.65	8.19**
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	731.05	19.72**
'Sunburst' vs. others	(1)	115.37	3.11
'Ft. Laramie' Strain A and 'Ft. Laramie 'Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	121.33	3.47
'Ozark Beauty' vs. 'Quinault' and 'Streamliner'	(1)	1.32	0.04
'Quinault' vs. 'Streamliner'	(1)	549.16	14.81**
Experimental error	186	37.07	

Table 8. Analyses of variance for final branch crown number, final crown diameter, and final plant weight

Source	df	MS	F
Branch crown number			
Total	191		
Blocks	3	58.74	2.17
Block Four vs. others	(1)	111.11	4.10
Rest	(1)	32.56	1.20
Cultivars	5	123.19	4.54*
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	23.77	0.88
'Sunburst' vs. others	(1)	245.03	9.03**

*Significant at $\alpha = 0.05$.
**Significant at $\alpha = 0.01$.

Table 8. *Continued*

Source	df	MS	F
'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	190.94	7.04*
'Ozark Beauty' vs. 'Quinault' and 'Streamliner'	(1)	81.38	3.00
'Quinault' vs. 'Streamliner'	(1)	74.84	2.76
Experimental error	15	27.13	
Sampling error	168	12.08	
Crown diameter			
Total	191		
Blocks	3	787.44	2.00
Block Four vs. others	(1)	855.02	2.17
Rest	(2)	753.64	1.91
Cultivars	5	646.64	1.39
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	137.36	0.35
'Sunburst' vs. others	(1)	12.48	0.03
'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	646.03	1.64
'Ozark Beauty' vs. 'Quinault' and 'Streamliner'	(1)	2063.51	5.23*
'Quinault' vs. 'Streamliner'	(1)	2859.38	7.25*
Experimental error	15	394.63	
Sampling error	168	155.48	
Plant weight			
Total	191		
Blocks	3	8,405.88	2.86
Block Four vs. others	(1)	16,501.97	5.62*
Rest	(2)	4,357.84	1.48

Table 8. *Continued*

Source	df	MS	F
Cultivars	5	6,836.36	2.33
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	19.36	0.01
'Sunburst' vs. others	(1)	15,990.99	5.45*
'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	2,643.25	0.90
'Ozark Beauty' vs. 'Quinault' and 'Streamliner'	(1)	12,576.39	4.28
'Quinault' vs. 'Streamliner'	(1)	2,951.78	1.01
Experimental error	15	2,936.31	
Sampling error	168	2,247.48	

Table 9. Analyses of variance for increase in branch crown number, increase in plant weight and increase in crown diameter

Source	df	MS	F
Branch crown number			
Total	191		
Cultivars	5	157.47	11.46**
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	68.56	4.99*
'Sunburst' vs. other	(1)	361.92	26.34**
'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	240.32	17.49**

*Significant at $\alpha = 0.05$.

**Significant at $\alpha = 0.01$.

Table 9. *Continued*

Source	df	MS	F
'Ozark Beauty' vs. 'Quinault' and 'Streamliner'	(1)	103.25	7.51**
'Quinault' vs. 'Streamliner'	(1)	12.96	0.94
Experimental error	186	13.74	
Crown weight			
Total	191		
Cultivar	5	6,827.17	2.83*
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	335.60	0.14
'Sunburst' vs. others	(1)	15,640.31	6.48**
'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	1,604.15	0.66
'Ozark Beauty' vs. 'Quinault' and 'Streamliner'	(1)	12,695.81	5.26*
'Quinault' vs.' 'Streamliner'	(1)	3,868.84	1.60
Experimental error	186	2,414.23	
Plant diameter			
Total	191		
Cultivar	5	886.63	4.33**
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	234.70	1.14
'Sunburst' vs. others	(1)	203.14	0.99
'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	207.58	1.01
'Ozark Beauty' vs. 'Quinault' and 'Streamliner'	(1)	1,959.94	9.56**
'Quinault' vs. Streamliner'	(1)	1,828.42	8.92**
Experimental error	186	204.99	

Table 10. Analysis of variance for fruit buds removed[1]

Source	df[†]	MS	F
Total	215		
Whole plots			
Blocks	3	2,896.38	3.71*
Cultivars	5	11,136.19	14.25**
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	10,804.50	13.83**
'Sunburst' vs. others	(1)	102.45	0.13
'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	4,902.92	6.28*
'Ozark Beauty' vs. 'Quinault' and 'Streamliner'	(1)	2,455.52	3.14
'Quinault' vs. 'Streamliner'	(1)	37,415.58	47.89**
Error A	15	781.29	
Split plots			
Time	8	92,343.13	164.70**
Linear	(1)	160,064.67	285.49**
Lack of fit	(7)	82.668.62	147.45**
Time by cultivar	40	17,140.64	30.57**
Error B	144	560.66	

[1]Degrees of freedom are reduced by one for each missing observation.

[†]Conservative degrees of freedom were used in the analysis of the split plots as suggested by Cochran and Cox (10).

*Significant at $\alpha = 0.05$.

**Significant at $\alpha = 0.01$.

Table 11. Analysis of variance for runners removed[1]

Source	df†	MS	F
Total	424		
Whole plots			
Blocks	3	258.16	3.81*
Cultivars	5	317.39	4.68**
'Ft. Laramie' Strain A vs. 'Ft. Laramie' STrain B	(1)	15.97	0.24
'Sunburst' vs. others	(1)	1,472.51	21.71**
'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	29.29	0.43
'Ozark Beauty' vs. 'Quinault' and 'Streamliner'	(1)	56.78	0.84
'Quinault' vs. 'Streamliner'	(1)	12.41	0.18
Error A	15	67.84	
Split plots			
Time	21	563.44	56.86**
Linear	(1)	6,515.54	657.47**
Lack of fit	(20)	265.84	26.83**
Time by cultivar	105	91.02	9.18**
Error B	275	9.91	

[1]Degrees of freedom are reduced by one for each missing observation.

†Conservative degrees of freedom were used in the analysis of the split plots as suggested by Cochran and Cox (10).

*Significant at $\alpha = 0.05$.

**Significant at $\alpha = 0.01$.

Table 12. Analysis of variance for total leaf number[1]

Source	df[†]	MS	F
Total	327		
Whole plots			
Blocks	3	79,296.46	2.38
Block Four vs. others	(1)	185,564.25	5.56*
Rest	(2)	26,162.56	0.78
Cultivars	5	123,764.15	3.71*
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	8,197.06	0.002
'Sunburst' vs. others	(1)	44,628.31	1.34
'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	466,538.28	13.98**
'Ozark Beauty' vs. 'Quinault' and 'Streamliner'	(1)	90,361.29	2.71
'Quinault' vs. 'Streamliner'	(1)	9,095.83	0.27
Error A	15	33,370.42	
Split Plots			
Time	13	258,292.19	131.25**
Linear	(1)	207,907.26	105.65**
Lack of fit	(12)	262,490.93	133.38**
Time by Cultivar	65	7,422.76	3.77*
Error B	225	1,967.94	

[1]Degrees of freedom are reduced by one for each missing observation.

[†]Conservative degrees of freedom were used in the analysis of the split plots as suggested by Cochran and Cox (10).

*Significant at $\alpha = 0.05$.

**Significant at $\alpha = 0.01$.

Table 13. Analysis of variance for leaf area index (15)

Source	df	MS	F
Total	1199		
Blocks	3	2,795.12	0.46
Block Four vs. others	(1)	1,665.70	0.27
Rest	(2)	3,359.84	0.55
Cultivars	5	67,498.08	11.08**
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	361.00	0.06
'Sunburst' vs. others	(1)	302,965.44	49.75**
'Ft. Laramie' Strain A, and 'Ft. Laramie' Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	7,170.95	1.18
'Ozark Beauty' vs. 'Quinault' and 'Streamliner'	(1)	3,097.65	0.51
'Quinault' vs. 'Streamliner'	(1)	23,883.23	3.92
Experimental error	15	6,089.26	
Sampling error	1176	1,070.49	

*Significant at $\alpha = 0.05$.

**Significant at $\alpha = 0.01$.

Table 14. Analysis of variance for total yield and total individual fruit size[1]

Source	df[†]	MS	F
Yield			
Total	575		
Whole Plots			
Blocks	3	78,900.71	3.35*
Block Four vs. others	(1)	79,472.45	3.38
Rest	(2)	78,614.84	3.34
Cultivars	5	402,344.92	17.10**
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	155,952.00	27.43**
'Sunburst' vs. others	(1)	902,615.07	38.36**
'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	645,439.33	27.43**
'Ozark Beauty' vs' Quinault' and 'Streamliner'	(1)	247,009.00	10.50**
'Quinault' vs. 'Streamliner'	(1)	60,709.20	2.58
Error A	15	23,532.71	
Split plots			
Time	23	446,716.65	70.44**
Linear	(1)	6,916,665.54	1090.62**
Lack of fit	(22)	152,628.07	24.07**
Time by cultivar	115	20,061.22	3.16*
Error B	414	6,341.98	

[1]Degrees of freedom are reduced by one for each missing observation.

[†]Conservative degrees of freedom were used in the analysis of the split plots as suggested by Cochran and Cox (10).

*Significant at $\alpha = 0.05$.

**Significant at $\alpha = 0.01$.

Table 14. *Continued*

Source	df†	MS	F
Individual fruit size			
Total	570		
Whole plots			
Blocks	3	10.64	2.60
Block Four vs. others	(1)	30.21	7.39*
Rest	(2)	0.87	0.21
Cultivars	5	19.52	4.77**
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	2.18	0.53
'Sunburst' vs. others	(1)	4.35	1.06
'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	7.51	1.84
'Ozark Beauty' vs. 'Quinault and 'Streamliner'	(1)	83.58	20.44**
'Quinault' vs. 'Streamliner'	(1)	0.00	0.00
Error A	15	4.09	
Split plots			
Time	23	12.26	6.26*
Linear	(1)	0.04	0.02
Lack of fit	(22)	12.81	6.54*
Time by cultivar	115	3.90	1.99
Error B	409	1.96	

Table 15. Analysis of variance for marketable yield and marketable individual berry size[1]

Source	df†	MS	F
Yield			
Total	575		
Whole plots			
Blocks	3	45,670.65	3.11
Block Four vs. other	(1)	49,783.78	3.39
Rest	(2)	43,614.09	2.97
Cultivars	5	247,392.66	16.85**
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	112,396.42	7.66*
'Sunburst' vs. others	(1)	321,078.07	21.87**
'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	493,306.61	33.60**
'Ozark Beauty' vs. 'Quinault' and 'Streamliner'	(1)	232,748.35	15.85**
'Quinault' vs. 'Streamliner'	(1)	77,433.80	5.27*
Error A	15	14,682.25	
Split plots			
Time	23	151,775.57	40.89**
Linear	(1)	2,167,430.47	583.86**
Lack of fit	(22)	60,154.90	16.20**
Time by cultivar	115	14,055.67	3.79*
Error B	414	3,712.24	

[1]Degrees of freedom are reduced by one for each missing observation.

†Conservative degrees of freedom were used in the analysis of the split plots as suggested by Cochran and Cox (10).

*Significant at $\alpha = 0.05$.

**Significant at $\alpha = 0.01$.

Table 15. *Continued*

Source	df†	MS	F
Individual fruit size			
Total	564		
Whole plots			
Blocks	3	11.88	2.58
Block Four vs. others	(1)	31.22	6.77*
Rest	(2)	2.21	0.48
Cultivars	5	62.12	13.48**
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	1.50	0.33
'Sunburst' vs. others	(1)	2.94	0.64
'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	5.98	1.30
'Ozark Beauty' vs. 'Quinault' and 'Streamliner'	(1)	233.74	50.70**
'Quinault' vs. 'Streamliner'	(1)	66.46	14.42**
Error A	15	4.61	
Split plots			
Time	23	17.44	6.01*
Linear	(1)	2.68	0.92
Lack of fit	(22)	18.11	6.25*
Time by cultivar	115	6.58	2.27
Error B	403	2.90	

Table 16. Analyses of variance for unmarketable yield and unmarketable individual berry size[1]

Source	df[†]	MS	F
Yield			
Total	575		
Whole plots			
Blocks	3	4,723.96	2.05
Block Four vs. others	(1)	3,455.77	1.50
Rest	(2)	5,358.05	2.32
Cultivars	5	23,330.70	14.00**
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	3,599.79	1.56
'Sunburst' vs. others	(1)	146,821.25	63.56**
'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	10,143.01	4.39
'Ozark beauty' vs. 'Quinault' and 'Streamliner'	(1)	211.99	0.09
'Quinault' vs. 'Streamliner'	(1)	877.47	0.38
Error A	15	2,309.93	
Split plots			
Time	23	94,303.20	90.15**
Linear	(1)	1,340,352.31	1,259.65**
Lack of fit	(22)	37,664.61	36.01**
Time by cultivar	115	2,189.35	37,664.61**
Error B	414	1,046.07	2,189.35

[1]Degrees of freedom are reduced by one for each missing observation.

[†]Conservative degrees of freedom were used in the analysis of the split plots as suggested by Cochran and Cox (10).

*Significant at $\alpha = 0.05$.

**Significant at $\alpha = 0.01$.

Table 16. *Continued*

Source	df†	MS	F
Individual fruit size			
Total	460		
Whole plot			
Blocks	3	14.39	1.07
Block Four vs. others	(1)	28.29	2.11
rest	(2)	7.44	0.55
Cultivars	5	29.96	2.23
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	1.67	0.12
'Sunburst vs. others	(1)	9.38	0.70
'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	52.06	3.88
'Ozark Beauty' vs. 'Quinault' and 'Streamliner'	(1)	38.68	2.88
'Quinault' vs. 'Streamliner'	(1)	48.00	3.57
Error A	15	13.43	
Split plots			
Time	23	33.93	2.77
Linear	(1)	76.21	4.94*
Lack of fit	(22)	32.01	2.08
Time by cultivar	105	15.42	1.26
Error B	309	12.25	

Table 17. Analysis of variance for percent marketable yield[1]

Source	df†	MS	F
Total	570		
Whole plots			
Blocks	3	389.59	2.16
Block Four vs. others	(1)	164.94	0.92
Rest	(2)	501.91	2.78
Cultivars	5	6,020.41	33.40**
'Ft. Laramie' Strain A vs. 'Ft. Laramie' Strain B	(1)	1,346.34	7.47*
'Sunburst' vs. others	(1)	12,005.09	66.02**
'Ft. Laramie' Strain A and 'Ft. Laramie' Strain B vs. 'Ozark Beauty', 'Quinault' and 'Streamliner'	(1)	4,381.90	24.31**
'Ozark Beauty' vs. 'Quinault' and 'Streamliner'	(1)	9,570.76	53.10**
'Quinault' vs. 'Streamliner'	(1)	3,797.94	15.52**
Error A	15	180.25	
Split plots			
Time	23	4,772.42	25.54**
Linear	(1)	50,547.39	270.47**
Lack of fit	(22)	2,691.74	14.40**
Time by cultivar	115	429.62	2.30
Error B	409	186.89	

[1]Degrees of freedom are reduced by one for each missing observation.

†Conservative degrees of freedom were used in the analysis of the split plots as suggested by Cochran and Cox (10).

*Significant at $\alpha = 0.05$

**Significant at $\alpha = 0.01$.