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Influence of Nursery Harvest Date, Cold Storage, and Planting Date on Performance of Winter Planted California Strawberries[1]

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Abstract. Eight non-everbearing California strawberry cultivars were evaluated under the standard winter planting system (October-November) in comparisons involving differentials in plant harvest and transplanting dates and comparing approximately 30, 15 and 0 days of cold storage conditioning at Santa Ana, a relatively warm-winter south coastal California site. The varieties differed greatly in performance and the results were consistent with that which is known of their varying performance under commercial conditions. 'Sequoia' was almost an ideal performer but the fruit lacks firmness. Photoperiod is important in governing the reproductive response under this planting system since the duration of the fruiting period for a given variety was directly associated with how long the plant had grown under short days. However, chilling appeared to be the dominant factor governing *acceptable* performance in all varieties except 'Sequoia'. 'Sequoia' performed satisfactorily over the entire range of treatments and although it responded to chilling, apparently it has a short rest period. Of the other varieties that are of great economic importance in California, 'Fresno' and 'Shasta' evidently have relatively long rest periods and cannot be manipulated satisfactorily under the winter planting system whereas 'Tioga' is intermediate and responds favorably to manipulation.

About 25% of the California strawberry acreage is winter planted. Since early fruit production is the main reason for winter planting, most of it is done in coastal southern California where the winters are mild. Plants are harvested from high elevation nurseries in northern California in October, and either transplanted directly or after receiving from about 10 to 20 days of cold storage. Planting is usually completed for most cultivars by about November 10.

The success of winter planting depends entirely upon how well the plants grow during the short days of December and January. The more active they are, the more flower buds are initiated and the greater the crop. Ambient temperatures control the rate of growth and soil temperatures may be increased significantly by the use of clear polyethylene bed mulch, a standard practice in California (3, 5). The chilling history of the plant also affects the growth rate and performance (1, 2, 4). If the plants fail to receive enough chilling, they lack vigor and will not grow rapidly enough to produce a good early crop although they flower profusely for a long time. If they receive too much chilling, they will be very vigorous producing runners instead of fruit. The optimum planting date and the amount of cold storage that will benefit the plants can be determined for a given cultivar so that the plants can be manipulated accordingly.

The experiments described in this report were designed to increase our understanding of the interaction of the factors that govern the reproductive response of cultivated non-everbearing strawberries; to characterize cultivars that have been or are now used in winter planting in California with regard to optimum nursery harvest and transplanting dates; and to evaluate their chilling requirements.

Materials and Methods

Plants of University cultivars 'Sequoia', 'Tioga', 'Fresno', 'Torrey', 'Aliso', 'Salinas', 'Shasta' and 'Lassen' from commercial high elevation nurseries (near McArthur, Shasta County, Latitude 41°N, elevation circa 1,000 M) were compared in plantings from plant harvests of October 13, October 30 and November 11. 'Tioga' plants were not available for the last harvest. For each lot and each cultivar, plants transplanted immediately after minimum storage were compared with those from the same lot transplanted after about 15 days or about 30 days of cold storage. Fruiting sites were south coastal California (Santa Ana) and central coastal California (Watsonville and Salinas). The cold storage box temperature was 28°F (−2.2°C).

Double row raised beds were used, spaced at 40 inches with 9 inches between plants and 16 plants per plot under the hill system. Clear polyethylene bed mulch was applied within 2 weeks after transplanting, a standard practice for winter plantings.

The soil at a given location was very uniform in composition and texture. The experimental design was a modified randomized complete block with a minimum of 4 replicates. Replications were across the rows so that any

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"cut and fill" effect from the leveling done to facilitate the necessary furrow irrigation was removed in the analysis. Plantings for a given cultivar and treatment were paired in adjacent rows. Different planting dates cannot be mixed in the same row because the irrigation, fertilization, mulching and pest control practices that must be initiated immediately after planting change the soil environment confounding the time of planting responses.

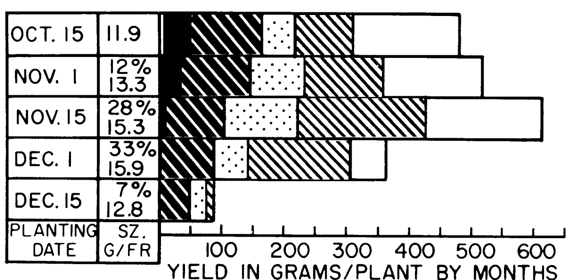
The harvest began in January and continued through June. Fruit was harvested at least once each week and only marketable fruit was evaluated.

Measurements included; *yield* by weight, reduced to a grams per plant basis; *fruit size* estimated at each harvest by the weight of a random sample of 10 fruits, reduced to a grams per fruit basis; and *firmness* measured by a penetrometer. An eye-score value for *appearance* was also assigned at each harvest. Only the data for yield and fruit size are presented. Firmness was omitted because differences among treatments over cultivars were not significant. Appearance was omitted because it was correlated with fruit size. Data were analyzed on the computer (analysis of variance) and a 5% confidence value was calculated in each case. The confidence values were the basis for the statements on significance comparing 2 means. Results were similar at the 3 locations but for purposes of brevity only the Santa Ana data are presented because the treatment effects were more clearly defined there due to the higher ambient temperatures.

Results and Discussion

Planting dates. For Fig. 1, the results were pooled over all varieties and planting dates only were considered. The data compare favorably with those presented for high elevation plants in 1958 (4) if the fact is considered that polyethylene bed mulch was not used then. October 15 plantings gave the highest production for all planting dates through March but production fell off in April in comparison with the November 1 and 15 plantings. November 1 plantings averaged the highest through April and fell off sharply in May compared with November 15 and December 1 plantings. November 15 plantings gave the highest yields of all because of heavy production in May and June. The lack of production for the December 1 plantings in June and in general for the December 15 plantings was due to an early change to runner production and a correlated termination of fruit production.

Plant vigor as expressed by leaf size, petiole length or the above-mentioned runner production was negatively associated with the fruiting response. Plants set October



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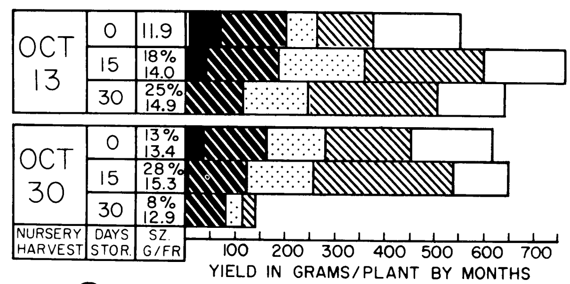
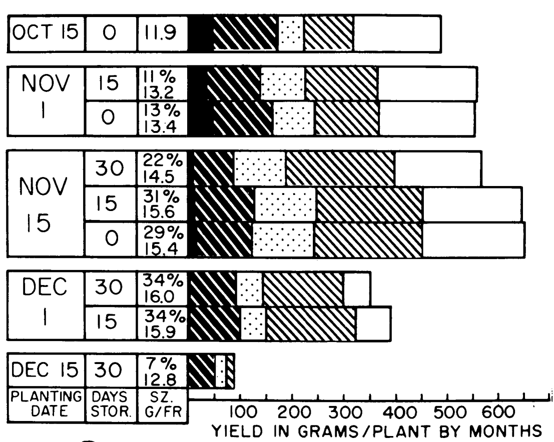


3 TIOGA



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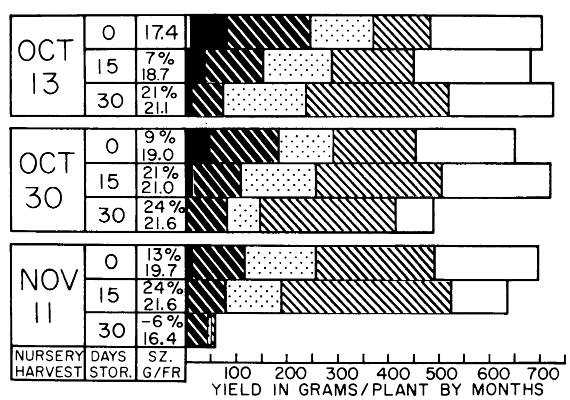


4 SEQUOIA

Fig. 1–4. Black = February, dark cross = March, dotted = April, light cross = May and open = June. [Percentage value for fruit size represents the increase or in one case (*Fig. 4,* Nov. 11, 30 days) the decrease in comparison with the fruit size for the first planting date for that figure.]—*Fig. 1.* Averaged over all cultivars comparing planting dates only. Differences in fruit size and in yield by months or total are significant @ 5% level.—*Fig. 2.* Averaged over all varieties comparing planting dates and storage treatments. Differences in yield for November 15 planting are significant by months and total. Differences in yield for December 1 planting are significant for total only. Differences in fruit size are significant.—*Fig. 3 & 4.* Comparing nursery harvest dates and storage treatments by varieties.—*Fig. 3.* Tioga—For October 13 harvest, differences by months and in total yield are significant. For October 30 harvest, differences by months for 0 vs. 15 days storage are significant but total yield difference is not. Comparing 30 days storage, October 13 harvest vs. 15 days storage, October 30 harvest, differences by months or in total not significant. Differences in fruit size are significant.—*Fig. 4.* Sequoia—For October 13 harvest, differences by months and differences in fruit size are significant. Total yield differences are not. For October 30 harvest differences by months, total yield and fruit size are significant. In total yield over all plant harvests, only the 30 day stored for the October 30 and November 11 harvest differ significantly.

15 were the least vigorous and those set December 15 were the most vigorous by far. This is normal since strawberry plants that are in a fruiting state are only moderately active vegetatively. The shift to runner production in plantings of this type is obvious even before runners appear because the change is always preceded by petiole elongation and increased leaf size (1, 4).

The fruit size data reflect the same general response, showing a continuous increase up through the December 1 plantings (33%). The fruit of the December 15 plantings, while larger than that for the October 15 group, was smaller than the rest. The excessive vigor of plants set that late was such that the relatively few flower stocks that developed were shaded out.

Cold storage. In the 1958 report (4), we suggested that differences in the vegetative response of the plants were associated with chilling, whether it was received in the propagation nursery, in 28°F storage, or at the fruiting site after planting. Part of this proposition is strongly supported by the data presented in Fig. 2. Averaged over all varieties, the results for plants receiving approximately 0, 15 or 30 days of cold storage were grouped for comparison by planting dates. In both cases, there was no significant difference between plants receiving no cold storage and those receiving 15 days (Nov. 1 and Nov. 15 plantings), comparing monthly yields or totals.

However, in both comparisons, those receiving 30 days storage yielded significantly less in total than those receiving 15 days storage or no storage (Nov. 15 and Dec. 1 planting dates). For the November 15 planting date, the difference was due largely to the significantly less February production since differences between yields for the other months were not significant. For the December 1 planting, the significant difference in total yield was a cumulative difference since the monthly yield differences were not significant.

The results were consistent and the most logical explanation points to a chilling differential. In both cases, the 30 day storage plants that yielded significantly less than those planted the same day, but receiving less storage, were more vigorous vegetatively. The plants in cold storage (theoretically, at least) received a full month of cold storage, 24 hours a day. In contrast, those receiving all or half of their accumulated chilling hours under natural conditions received considerably less because of rather great diurnal fluctuations. Thus the fact that there was a difference here strengthens the thesis, since that difference is where it would be expected if chilling is accepted as the cause of the difference.

The thesis is supported further by the fact that comparable plants set at the colder winter sites (Salinas and Watsonville) where considerably more chilling was received than at warmer Santa Ana, started later and produced less fruit during the early summer.

Varietal characteristics. 'Tioga' is the principal winter planting cultivar, accounting for 80 to 85% of the southern California acreage, with 'Sequoia', 'Fresno', 'Torrey' and 'Aliso' making up the rest. 'Shasta' and 'Lassen', the cultivars involved in earlier reports (1, 4), are no longer winter planted.

Cultivars differed considerably in their response to the variables of these experiments. The data for individual cultivars are grouped by plant harvest dates for presentation. 'Tioga' must be planted about November 1 after about 15 days cold storage for best results (Fig. 3). On plants transplanted immediately after harvest in mid-October, the early fruit harvest was considerable but the average fruit size was much too small. The small fruit size (about 20% too small) largely accounted for the significantly lower yield. If the plants were set too late however, both earliness and yield were sacrificed.

In these experiments, 'Sequoia' manifested most of the characteristics of an ideal variety for winter planting (Fig. 4). In total yield, there were no significant differences among plants harvested in mid-October regardless of treatment, or among treatments for the other 2 harvest dates except when they were given 30 days of cold storage. Differences in pattern of production were great and fruit size increased as the plants were given more chilling. Fruit size was not a problem in early planted 'Sequoia' since fruit from the earliest planting was still larger than the largest 'Tioga' fruit. However, 'Sequoia' fruit is very soft compared with 'Tioga' and that limits the usefulness of the cultivar.

'Fresno' was different from 'Tioga' or 'Sequoia' (Fig. 5) in that it responded very little to cold storage. The only acceptable performance came with the mid-November planting and no cold storage. This restricts the cultivar because of the lack of early fruit and the fact that unfavorable weather in the nurseries in November may prevent plant harvest.

'Torrey' failed to produce much early fruit even though it responded favorably to cold storage and manifested more flexibility in some respects than 'Tioga' (Fig. 6). Small nursery plant size may at least partially account for this and the limited acceptance it has enjoyed in winter planting.

Only the mid-November plantings of 'Aliso' performed well, particularly after receiving 15 days cold storage (Fig. 7). Earliness must be sacrificed to get production, large fruit size and fruit quality. Quality is a problem with 'Aliso' since a high percentage of the fruit from early plantings failed to fill out at the tips due to partial abortion or pollination failure.

Over the various plantings, 'Lassen' (Fig. 8) behaved very much like 'Sequoia'. The principal problems with 'Lassen' were small fruit size, lack of firmness, and poor dessert quality. Once, the dominant winter planting cultivar in southern California, it has been replaced by better performing 'Tioga' because of the above problems.

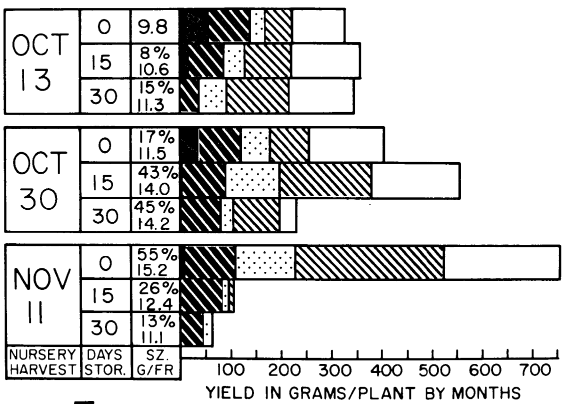
Apparently, 'Shasta' is a low yielding type under winter planting (Fig. 9). Although the plants responded to chilling as evidenced by the increased fruit size, yields were unsatisfactory over all treatments. Once widely winter planted in the central coast, it was always necessary to carry 'Shasta' for at least 2 harvest years in order to justify winter planting. Now it is summer planted only.

In these experiments, 'Salinas' (Fig. 10) responded similarly but somewhat better than 'Shasta'. This was not good enough however to justify recommendation.

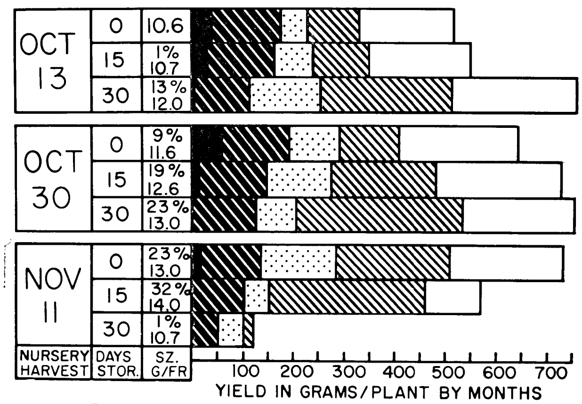
In general, the results of these experiments explain why 'Tioga' and, to a lesser extent, the other cultivars are successfully winter planted in southern California and why 'Lassen', 'Shasta' and 'Salinas' are not. It is obvious that improved cultivars would be desirable. A firm fruited cultivar with the other performance characteristics of 'Sequoia' would be very useful.

The optimum dates of planting arrived at for the various cultivars in this study are consistent with those determined in other experiments at the several fruiting sites (unpublished). Furthermore, growers' experience has also indicated that the same dates are best. For example, the first week of November has been best for 'Tioga' when planting dates only are considered, regardless of test location or plant conditioning, but at least 2 weeks of cold storage chilling is needed to optimize performance.

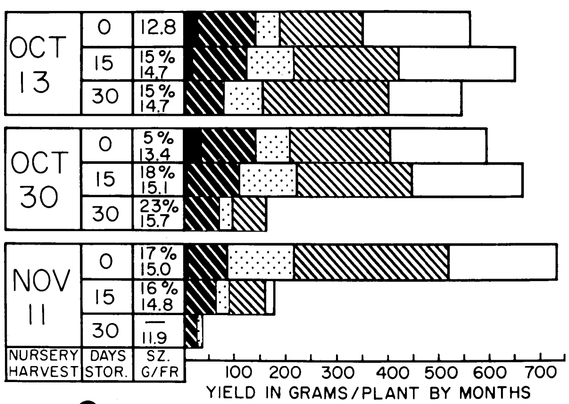
Photoperiodic response certainly is an important factor since the general fruitfulness of a given cultivar was directly related to the amount of time the plant had grown under short days. Chilling appeared to be the dominant factor governing acceptable performance, however, when other things are equal. 'Sequoia' has a chilling requirement because a response to chilling was clearly manifested in increased fruit size. However, the requirement must be small since it performed well when planted early with little or no cold storage or natural chilling. In contrast, 'Fresno' evidently has a relatively high chilling



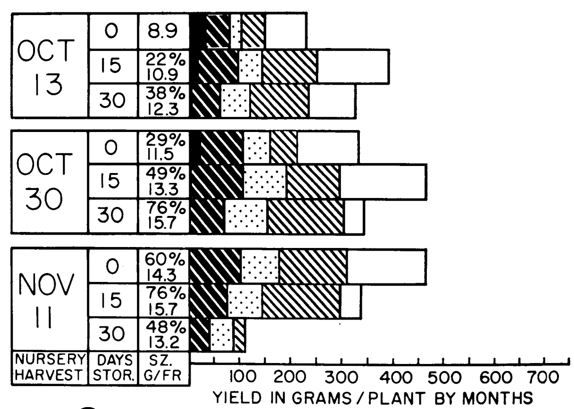
5 **FRESNO**



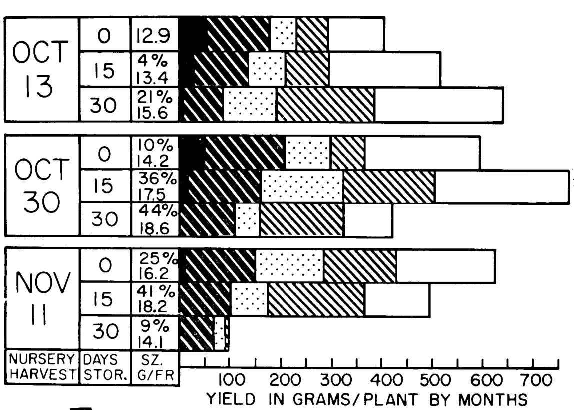
8 **LASSEN**



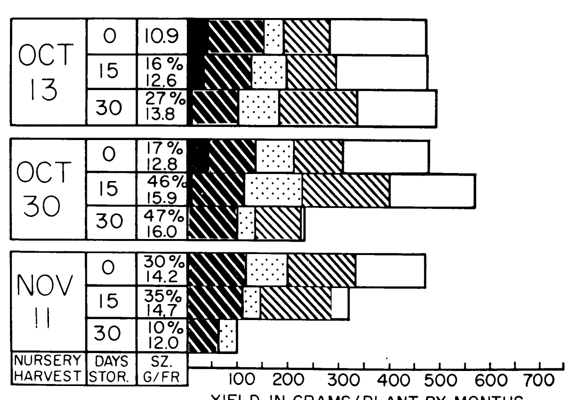
6 **TORREY**



9 **SHASTA**



7 **ALISO**



10 **SALINAS**

Fig. 5–10. Black = February, dark cross = March, dotted = April, light cross = May and open = June. [Percentage value for fruit size represents the increase over the fruit size for the first planting date for that figure.] Comparing nursery harvest dates and storage treatments by varieties.—*Fig. 5.* Fresno—all differences significant. —*Fig. 6.* Torrey—all differences significant.—*Fig. 7.* Aliso—all differences significant.—*Fig. 8.* Lassen—differences among 30 days stored, October 13 harvest vs. 15 days stored, October 30 harvest vs. 0 days stored, November 11 harvest not significant. Other differences are significant.—*Fig. 9.* Shasta—differences between 15 days stored, October 30 harvest vs. 0 days stored, November 11 harvest not significant. Other differences are significant.—*Fig. 10.* Salinas—differences between 30 days stored, October 13 harvest vs. 0 days stored, November 11 harvest not significant. Other differences are significant.

requirement and did not respond to early cold storage treatment. 'Tioga' is intermediate, responding favorably to some treatments but not all.

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Peach Cultivar Responses to Fruit Thinning with CPA[1]

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Abstract. Chemical thinning of peaches was conducted under orchard conditions using CPA,[3] followed by standard hand thinning, on the cultivars 'Jerseyqueen,' 'Sunhigh,' 'Redhaven', 'Sunqueen' and 'Rio Oso Gem.' Timing of the 3 sprays at 150 ppm was based on the water volume displacement of 100 fruits selected at random from each plot: a) at 200 ml displacement, b) at 280 ml, and c) at 280 ml plus 4 days. The control was hand thinned only. Ovule length was measured at each spray timing and found to be 7–10 mm at the 280 ml water displacement; both ovule length and water displacement techniques were used to time CPA sprays in over 2000 acres of New Jersey orchards in 1968.

Timing of the CPA thinner for optimum effectiveness in this experiment varied with cultivar. Individual fruit weight was greater on CPA-thinned trees than on the controls for the cultivars 'Redhaven,' 'Rio Oso Gem,' 'Sunqueen' and 'Sunhigh' at harvest. Chemically thinned 'Jerseyqueen' did not show an increased mean fruit weight at harvest. Yield reductions occurred on 'Sunhigh' at the 280 ml timing and on 'Redhaven' at the 280 ml + 4 days timing, due apparently to subsequent over-thinning by hand. Shading increased the thinning effectiveness of CPA on all cultivars. 'Jerseyqueen' and 'Redhaven' were difficult to thin with CPA under the conditions of this experiment. 'Rio Oso Gem' was moderately difficult, while 'Sunhigh' and 'Sunqueen' were thinned readily.

Fruit growers have been slow to accept chemical fruit thinning of peaches in frost-prone areas because of the lack of effective chemicals that can be applied after the danger of frost without adversely affecting fruit growth and quality (4, 9). The auxin 2–3 chlorophenoxy propionamide (CPA) has shown promise as a desirable chemical peach thinner, but cultivars have been found to respond differently under different conditions (3, 5). The objective of this work was to determine the best timing of CPA sprays for 5 commercial peach cultivars.

Materials and Methods

The cultivars used in order of ripening and which matured over a period of 6 weeks were 'Redhaven,' 'Sunhigh,' 'Sunqueen,' 'Jerseyqueen,' and 'Rio Oso Gem.' Trees were planted 24 ft apart in rows 20 ft apart and selected for uniformity of vigor. Each treated tree was separated in a row by at least one buffer tree. A split plot design was used consisting of 4 trees per treatment replicated 2 times with a total of 180 trees in all treatments. The experiment was located on a sandy loam soil (Freehold series) at Larchmont Farms in Burlington County east of Camden, New Jersey. The data were subjected to analysis of variance and multiple comparisons performed according to the Tukey "t" test.

Full bloom for all cultivars was April 14, 1968. The commercially prepared form of CPA was used at 150 ppm. Timing of the sprays was based on water volume displacement by 100 fruits of a cultivar as described by White and Kepka.[4] The peaches were selected at random and placed in a 1000 ml graduated cylinder holding enough water so that the pubescent peaches could be submerged before the volume reading was taken. Volume readings at which the sprays were applied were: C, control, only hand thinned; T_1, 200 ml water displacement; T_2, 280 ml water displacement; T_3, 280 ml water displacement + 4 days. Ovule measurements were made on 25 fruits selected at random and used in the volume displacement technique. Each fruit was cut along the suture and the ovule length measured. Both methods are being used by researchers and growers to time CPA sprays. Before the fruit thinning sprays were applied, 100 fruits were tagged on single branches on 4 sides of a tree for a total of 400 tagged fruits per tree. Fruit counts were taken on tagged areas to determine the fruit thinned off on each side of the tree and also to evaluate any effects of shading on fruit thinning. Dates of spray application on the 5 cultivars are given in Table 1.

Temperature at the time of spray application was be-

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[3]Commercially known as Fruitone[R] 3-CPA (2–3 chlorophenoxy propionamide, 7.9% plus 2–3 chlorophenoxy proprionic acid—0.4%). The Amdal Co., Abbott Laboratories, North Chicago, Illinois.

[4]White, D. G., and Marion Kepka. 1964. Results from using 3-chlorophenoxy-proprionamide (3-CPA) for thinning peaches. Rutgers University, New Brunswick, N. J. (Unpublished.)