Initial Bare-root Crown Size and Early-season Flower Cluster Removal Has Little Effect on Subsequent Plant Performance in Day-neutral Strawberry

Mark P. Bolda[1]

Keywords. canopy diameter, *Fragaria ×ananassa*, fruit size, fruit yield, varieties

Abstract. **In strawberry (*Fragaria ×ananassa*), initial bare-root crown diameter and early-season flower cluster removal have been two factors suspected of influencing fruit yield and size. This study evaluated the effect of these two factors on the day-neutral strawberry varieties Monterey and Cabrillo. Bare-root crowns with three different diameters were categorized into small (< 0.5 cm), medium (> 0.5 to 1 cm), and large (> 1 cm) at planting. Each of the crown diameter treatments was split into two plots for flower removal or no flower removal in the early season and data on canopy diameter, fruit yield, and fruit size collected in the subsequent months of production. The study was conducted over two growing seasons (2019–20 and 2020–21). No difference was found in plant canopy diameters measured in February, ~3 months after planting, between any of the treatments in either year. Although early-season flower removal and some crown sizes resulted in lower fruit yield in March and April, none of these treatments resulted in any fruit yield or size differences in subsequent months nor in season end totals.**

California is the leading producer of fresh market strawberries (*Fragaria ×ananassa*) in the United States, with a production value of more than $2 billion in 2021, representing some 79% of the strawberries consumed in the United States and exporting 16% of the total state production, mostly to Canada, Mexico, Japan, and Hong Kong (Agricultural Marketing Resource Center 2021).

The Central Coast region consisting of Watsonville and Salinas is the leading strawberry production district in California. Ground preparation starts in midsummer, followed by soil fumigation in August and early September, and then bedding, placement of preplant fertilizer, and drip irrigation tape in late September and early October, followed by plastic mulch placement shortly thereafter. Planting is done during the last week of October through mid-November. Plants are maintained through the winter, and harvest generally commences in late March or early April of the following year and continues on through August or September (Bolda et al. 2021) after which the field is rotated to vegetable production for at least 1 year.

Although fruit quantity and size are a priority to the grower, the plant itself is the critical element in determining both of these characteristics. Two important aspects of plant management for fruit production for growers, yet not well understood for the day-neutral varieties grown on the Central Coast of California, are the role of initial bare-root crown diameter at transplanting time and the management of flowering, in particular the early removal of the flower clusters, in shifting and enhancing fruit yield and size to take advantage of more lucrative market times.

Strawberry crowns are compressed stems that produce the flowers, leaves, and roots. Bare-root crowns are subsequent generations of genetically identical daughter plants arising from stolons from the main mother plant. These are grown at high elevation in northern California in plant nurseries during summer and early fall and compose nearly the entire plant stock of California strawberry production (University of California 2008). Bare-root crowns grown for transplants intended for planting in the Watsonville-Salinas area are harvested from the middle of October through early November, then shipped in refrigerated trucks and stored locally for a requisite period of time, usually from 7 to 14 d, at 1 °C to obtain sufficient cold conditioning (University of California 2008).

There is a substantial variation in crown sizes harvested in the California nurseries, from crowns of only a few millimeters diameter and few roots, others being ~1 cm diameter and with abundant root formation, and ranging up to crowns of substantial root development and diameters greater than 1 cm diameter (Bolda MP, unpublished data). Given the wide variation in crown sizes provided by nurseries to California growers every season, of which up to a third can be of very small size (<0.5 cm) with few roots (Bolda MP, unpublished data), it would be a useful question to answer for growers how these different bare-root crown sizes ultimately perform in the field.

A larger crown size, being generally representative of the first or second daughter plants produced, has more roots, more leaves, more starch reserves, and more early-stage flower buds because it is more developed than later produced smaller daughter plants

Received for publication 26 Oct 2022. Accepted for publication 4 May 2023.

Published online 26 Jun 2023.

[1]University of California Cooperative Extension, Santa Cruz County, 1430 Freedom Boulevard, Suite E, Watsonville, CA 95076, USA

I acknowledge the generous and enthusiastic assistance of strawberry growers Rod Koda and Hank Guerrero, who provided the space and helped to make this 2-year study possible.

M.P.B. is the corresponding author. E-mail: mpbolda@ucanr.edu.

https://doi.org/10.21273/HORTTECH05161-22

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
102.7902	acre-inch(es)	m^3	0.0097
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
1.1209	lb/acre	$kg \cdot ha^{-1}$	0.8922
0.0254	mil(s)	mm	39.3701
28.3495	oz	g	0.0353
(°F − 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

(University of California 2008). Because several studies have indicated positive correlations of crown size and total fruit production (Bartczak et al. 2010; Menzel and Smith 2012; Takeda et al. 2004) with other strawberry varieties in other growing regions, it would be valuable to investigate such a correlation on the Central Coast of California with other varieties.

None of the previously cited work and observations applies to the day-neutral varieties, being that those varieties are less responsive to daylength (Galletta and Bringhurst 1989), which compose a large portion of the strawberries planted in California, especially on the Central Coast. As opposed to the short-day varieties, day-neutral varieties do not need photoperiods of less than 14 h for flower initiation (Galletta and Bringhurst 1989), and they flower and fruit continuously without regard to photoperiod. Therefore, in addition to the question regarding effect of bare-root crown size on strawberry productivity, there is also the question of early-season flower cluster removal from day-neutral varieties, which do not need photoperiods of a set length to initiate flowers and subsequently produce fruit.

Flowers arise from the crown and represent a sink for plant energy reserves, and their removal can increase the proportion of leaf area to inflorescence number and result in a more vigorous plant (Nicoll and Galletta 1987). Flower removal is frequently practiced by California strawberry growers to delay fruiting and with the intention to promote vegetative growth, and costs in the area of $200 to $400 per acre (Bolda MP, unpublished data).

The effect of early flower removal on strawberry plant performance in the field has not been empirically evaluated in California. Flower removal in the early part of the season has been shown in work done in Delaware (Ernest and Johnson 2015) to delay fruiting and resulted in greater fruiting later in the season. Other work (Takeda and Hokanson 2003) showed that removal of flowers in the first weeks of growth resulted in higher yields and fruit weight later in the season in several day-neutral varieties and one short-day variety grown hydroponically. In another study (Portz and Nonnecke 2010), larger fruit resulted after removal of flowers and runners in the varieties Albion and Tribute, but not in Seascape. However, other work (Demirsoy et al. 2019) on the day-neutral strawberry variety Albion and the short-day variety Sweet Anne with four regimens of flower removal, including one with no removal, found no significant differences in total fruit yield or plant biomass between any of the treatments. Work exploring the effect of the removal of strawberry flowers in the short-day variety Elsanta (Cross and Burgess 1998) found that although smaller plants resulted in reduced yield in proportion to the flower buds removed, the larger plants of the study compensated for the removal by producing larger fruit from the remaining buds and the production of more buds overall.

Because the number of flowers has been positively correlated to crown size (Nicoll and Galletta 1987), the relation of these two factors is an important part of this study, along with their observation independent of one another. The purpose of this study was to evaluate the interaction of bare-root crown size at planting and early-season flower cluster removal and subsequent plant performance in the day-neutral strawberry varieties Cabrillo and Monterey on the Central Coast of California.

Table 1. Strawberry plant canopy diameters 16 and 11 weeks after planting (WAP) in response to three bare-root crown diameters [small (< 0.5 cm), medium (> 0.5 to 1 cm), large (> 1 cm)] and early-season flower removal or no removal in the strawberry variety Cabrillo.

		Plant canopy diam (cm)[i]	
Crown size	Flower removal	16 WAP	11 WAP
Large crowns	Flowers not removed	14.2	18.4
Large crowns	Flowers removed	16.9	18.7
Medium crowns	Flowers not removed	15.3	16.0
Medium crowns	Flowers removed	16.4	16.9
Small crowns	Flowers not removed	15.3	17.6
Small crowns	Flowers removed	16.7	17.8
Significance		NS[ii]	NS

[i] 1 cm = 0.3937 inch.
[ii] Nonsignificant at $P = 0.05$ according to Fisher's protected least significant difference test.

Material and methods

The research was conducted in two major commercial strawberry production areas in California (Watsonville and Salinas) for 2 consecutive years (2019–20 and 2020–21). In all cases, strawberry plots were planted as an annual crop; planted in the fall, grown through the winter and summer of the following year, and then removed in the following fall. The management of the test plots resembled the fertility, irrigation, and pest control practices common to the Central Coast of California strawberry industry. After transplanting, plots were immediately irrigated using overhead sprinklers delivering ~1 acre-inch of water, and subsequently irrigated as needed with overhead for the next month, after which plots were irrigated with drip irrigation as needed, about twice per week.

Table 2. Strawberry plant canopy diameters at 13 and 10 weeks after planting (WAP) in response to three bare-root crown diameters [small (< 0.5 cm), medium (> 0.5 to 1 cm), large (> 1 cm)] and early-season flower removal or no removal in the strawberry variety Monterey.

		Plant canopy diam (cm)[i]	
Crown size	Flower removal	13 WAP	10 WAP
Large crowns	Flowers not removed	19.0	17.7
Large crowns	Flowers removed	18.3	18.0
Medium crowns	Flowers not removed	17.8	17.9
Medium crowns	Flowers removed	17.4	17.1
Small crowns	Flowers not removed	19.2	17.5
Small crowns	Flowers removed	18.3	18.7
Significance		NS[ii]	NS

[i] 1 cm = 0.3937 inch.
[ii] Nonsignificant at $P = 0.05$ according to Fisher's protected least significant difference test.

Table 3. Fruit yield and size by month in 2020 in response to three bare-root crown diameters [small (< 0.5 cm), medium (> 0.5 cm to 1 cm), large (> 1 cm)] and early-season flower removal or no removal in the strawberry variety Monterey.

Crown size, flower removal	Mar yield ($kg \cdot ha^{-1}$)[i]	Mar fruit size (g)[i]	Apr yield ($kg \cdot ha^{-1}$)	Apr fruit size(g)	May yield ($kg \cdot ha^{-1}$)	May fruit size(g)	Jun yield ($kg \cdot ha^{-1}$)	Jun fruit size (g)	Jul yield ($kg \cdot ha^{-1}$)	Jul fruit size (g)	Aug yield ($kg \cdot ha^{-1}$)	Aug fruit size (g)	Sep yield ($kg \cdot ha^{-1}$)	Sep fruit size (g)	Total yield ($kg \cdot ha^{-1}$)	Avg fruit size (g)
Large crowns, flowers not removed	807 ab	18.4 d	3676 a	39.9	14082	39.0	19398	26.2	11662	23.4	19162	25.6	8701	23.7	77488	28.0
Large crowns, flowers removed	65 c	40.0 a	3025 ab	44.4	14397	36.1	20294	25.7	11988	25.3	18513	24.7	8707	23.3	76989	31.5
Medium crowns, flowers not removed	538 b	21.7 cd	1620 c	39.1	12339	39.4	20146	26.0	12179	24.1	19472	24.7	8284	24.6	74578	28.9
Medium crowns, flowers removed	132 c	30.7 b	1256 c	42.2	10687	40.5	19832	20.7	13283	24.5	17614	24.3	8374	24.0	71179	30.1
Small crowns, flowers not removed	962 a	24.3 c	2261 bc	40.9	12596	34.8	21035	26.5	12834	25.4	21869	25.5	8040	20.6	84730	29.7
Small crowns, flowers removed	56 c	34.5 ab	1447 c	42.7	12989	38.6	20056	25.2	11557	24.2	18307	24.6	7616	23.7	72028	31.2
Significance[ii]	*	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[i] 1 $kg \cdot ha^{-1}$ = 0.8922 lb/acre, 1 g = 0.0353 oz.

[ii] Values followed by different letters mean treatments are significantly different (P = 0.05) according to Fisher's protected least significant difference test within weeks after planting; NS = nonsignificant, * = significant.

In both Watsonville and Salinas, before planting, strawberry bare-root crowns were sorted into three groups, each of which roughly composes one-third of each 1000-transplant box purchased by the grower (Bolda MP, unpublished data), based on crown diameter. The strawberry crowns, which are generally round, were measured with a caliper (Empire Slide Pocket Caliper; Empire Level Manufacturing Co., Mukwonago, WI, USA), and sorted by diameter into those larger than 1 cm, those between 0.5 and 1 cm, and those defined as small, being very narrow in diameter (less than 0.5 cm), and having only two to three roots. Once sorted, crowns were immediately planted into pre-punched holes in the plastic mulch followed by packing soil around them and irrigating them in the standard manner (University of California 2008).

Variety Cabrillo, grown in Salinas: In both years, strawberry transplants of the variety Cabrillo were planted into beds 52 inches wide and covered with a 1.5-mil flat silver plastic film (EcoPoly, Hollister, CA, USA). The soil for both years is classified as a Chualar sandy loam (fine-loamy, mixed, superactive, thermic Typic Argixerolls). In year 1, bare-root transplants were harvested from Macdoel, CA, USA on 4 Nov 2019, held at ~1 °C until 13 Nov 2019 when crowns were removed from refrigeration and planted. The location of the field was northeast of Salinas (lat. 36.73°N, long. 121.65°W). In year 2, bare-root transplants were harvested from Macdoel on 29 Oct 2020, held at ~1 °C until 9 Nov 2020 when crowns were removed from refrigeration and planted. Location of the field was northwest of Salinas (lat. 36.73°N, long. 121.71°W) and is a soil classified as a Chualar sandy loam.

Variety Monterey, grown in Watsonville: In both years, strawberry transplants of the variety Monterey were planted into beds 54 inches wide and covered with a 1.5-mil flat silver plastic film (TRM Manufacturing, Torrance, CA, USA). The soil of the fields for both years is classified as a Baywood loamy sand (sandy, mixed, thermic Haploxerolls). In year 1, bare-root transplants were harvested from Macdoel, CA, on 28 Oct 2019, held at ~1 °C until 6 Nov 2019 when crowns were removed from cold storage and planted. Location of the field is in the area west of Watsonville (lat.

Table 4. Fruit yield and size by month in 2021 in response to three bare-root crown diameters [small (< 0.5 cm), medium (> 0.5 cm to 1 cm), large (> 1 cm)] and early-season flower removal or no removal in the strawberry variety Monterey.

Crown size, flower removal	Mar yield (kg·ha^{-1})[i]	Mar fruit size(g)[i]	Apr yield (kg·ha^{-1})	Apr fruit size (g)	May yield (kg·ha^{-1})	May fruit size (g)	Jun yield (kg·ha^{-1})	Jun fruit size (g)	Jul yield (kg·ha^{-1})	Jul fruit size (g)	Aug yield (kg·ha^{-1})	Aug fruit size (g)	Sep yield (kg·ha^{-1})	Sep fruit size (g)	Total yield (kg·ha^{-1})	Avg fruit size (g)
Large crowns, flowers not removed	3625 a	ND[ii]	8228 a	35.0	22857	45.4	41317	34.9	19657	28.6	17437	29.9	6247	26.6	119374	32.9
Large crowns, flowers removed	106 c	ND	5211 c	36.3	20827	42.1	41736	32.7	20300	29.9	17409	30.7	5680	27.6	111368	35.0
Medium crowns, flowers not removed	2622 ab	ND	7642 ab	41.8	22156	42.1	41061	32.2	22206	28.9	19864	29.9	5864	26.7	121432	31.3
Medium crowns, flowers removed	24 c	ND	5638 c	45.7	22103	43.5	41955	33.1	20043	27.8	18836	30.4	6880	26.8	115502	32.2
Small crowns, flowers not removed	2158 b	ND	6363 bc	42.1	18077	44.8	34879	32.9	19054	28.8	18789	28.4	6494	26.7	106840	31.8
Small crowns, flowers removed	6 c	ND	5068 c	52.5	20160	44.2	40876	32.6	19950	27.5	21139	29.8	5429	26.7	112640	32.9
Significance[iii]	*	ND	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[i] 1 kg·ha^{-1} = 0.8922 lb/acre, 1 g = 0.0353 oz.
[ii] ND = no data.
[iii] Values followed by different letters mean treatments are significantly different (P = 0.05) according to Fisher's protected least significant difference test within weeks after planting; NS = nonsignificant, * = significant.

36.90°N, long. 121.82°W). In year 2, bare-root transplants were harvested from Macdoel on 31 Oct 2020, held at ~1 °C until 10 Nov 2020 when crowns were removed from cold storage and planted. Location of the field is west of Watsonville (lat. 36.90°N, long. 121.82°W).

The experiment was laid out in a split-plot design in a randomized complete block, with each block consisting of one replicate of each treatment. Replicate plots of 40 plants of one crown size were split into two subplots, one for removal of flowers and the other for no flower removal, resulting in each replicate plot consisting of 20 plants. In each field of the study, two blocks were consecutive on a bed, and the next two blocks in the bed next to it. For statistical analysis, the factors of growing year, crown size, and flower removal and their interactions were tested for significance ($P < 0.05$), and the measured parameters of plant canopy diameter, fruit yield, and fruit size were compared by factorial analysis of variance using a mean comparison test (ARM version 9; GDM Solutions, Inc., Brookings, SD, USA). Treatment means were compared using Fisher's protected least significant difference test ($P < 0.05$).

In year 1, any visible flowers, flower clusters, and forming fruit were removed by hand from the plants in plots designated to be "no flowers" on 8 Jan, 22 Jan, and 21 Feb 2020 at the Monterey site and 9 Jan, 23 Jan, and 21 Feb 2020 at the Cabrillo site, and in year 2 of the study, visible flowers, flower clusters, and forming fruit were removed from the Monterey site on 5 and 18 Feb 2021, and on 4 Feb, 18 Feb, and 3 Mar 2021 at the Cabrillo site. To evaluate early-season plant vigor, on 19 Feb 2020 for both varieties, and on 4 and 5 Feb 2021 for the Monterey plots and Cabrillo plots, respectively, the canopy diameters of 20 plants were taken by measuring once across the widest breadth of each plant with a ruler marked in millimeters.

Harvesting for both years was done once or twice per week as per commercial practice, meaning all the fully mature and market-quality fruit of at least an approximate 20 g in weight were picked out of each 20-plant treatment replicate, weighed in grams, and counted. Fruit size for each harvest date was determined by dividing the total weight of all fruit from each

replicate plot and dividing by the number of fruit counted. Note that in 2021, fruit size was not measured until May in the Cabrillo site and until April in the Monterey site because number of fruit was too low for meaningful analysis until these months. Fruit size and yield for each variety and each year was evaluated by month and are presented as such.

Results and discussion

There was no significant variation in plant diameters between any of the treatments in Monterey when measured at 13 and 10 weeks after planting (WAP) in 2020 and 2021 (Table 1), respectively. Likewise, in the variety Cabrillo there was no variation in plant diameters 16 and 11 WAP in 2020 and 2021 (Table 2), respectively.

That all plant diameters were statistically the same in size by late winter points to a similar rate of vegetative growth of all three bare-root crown sizes once planted. This similarity in canopy sizes from different bare-root crown sizes several months after transplant has been observed a study similar to this one (Torres-Quezada et al. 2015).

There was a significant interaction between growing year and total fruit yields for both varieties in this study, and thus data were analyzed by growing season (Tables 2–6).

There was no significant interaction between crown size and flower removal in any variety or year, and there was no consistent differential response of any crown size to presence or absence of flowers in any month or in season totals.

In Mar 2020 and 2021, in Monterey, all crown size treatments with no flower removed yielded significantly more fruit than those crowns where flowers remained (Tables 3 and 4). In Mar 2020 within the group of crowns with flowers not removed, small crowns yielded significantly more than medium crowns with flowers, but were not significantly higher than the large crowns, and in Mar 2021, this effect was reversed and large crowns produced significantly more fruit than small crowns (Table 3). For both years, some significant differences between treatments continued into April, with both treatments of large crowns being significantly higher than both medium crown treatments in 2020, and in 2021 large and medium crowns with no flowers

Table 5. Fruit yield and size by month in 2020 in response to three bare-root crown diameters [small (< 0.5 cm), medium (> 0.5 cm to 1 cm), large (> 1 cm)] and early-season flower removal or no removal in the strawberry variety Cabrillo.

Crown size, flower removal	Mar yield (kg·ha^{-1})[i]	Mar fruit size (g)[i]	Apr yield (kg·ha^{-1})	Apr fruit size (g)	May yield (kg·ha^{-1})	May fruit size (g)	Jun yield (kg·ha^{-1})	Jun fruit size (g)	Jul yield (kg·ha^{-1})	Jul fruit size (g)	Aug yield (kg·ha^{-1})	Aug fruit size (g)	Sep yield (kg·ha^{-1})	Sep fruit size (g)	Total yield (kg·ha^{-1})	Avg fruit size (g)
Large crowns, flowers not removed	482	22.9	864	43.0	7919	25.3	33659	30.6	30668	26.8	16354	27.8	9528	28.3	99473	29.0
Large crowns, flowers removed	67	17.8	1432	39.5	7751	22.8	36100	31.4	32258	26.9	15024	27.9	9479	29.1	102110	28.3
Medium crowns, flowers not removed	335	23.8	1418	36.0	6636	21.5	34054	29.1	32259	26.5	14142	26.7	9361	27.9	99206	27.3
Medium crowns, flowers removed	137	26.4	1472	40.6	7237	20.5	35016	30.4	29443	26.3	16068	28.3	9258	26.9	98631	27.5
Small crowns, flowers not removed	439	23.4	1276	33.6	7588	24.6	31086	29.7	29678	27.4	15436	26.5	9895	28.4	95398	27.9
Small crowns, flowers removed	154	19.6	1212	30.7	7253	23.6	32063	31.0	30394	28.4	14255	26.3	9418	27.4	94748	27.5
Significance[ii]	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[i] 1 kg·ha^{-1} = 0.8922 lb/acre, 1 g = 0.0353 oz.

[ii] Values followed by different letters mean treatments are significantly different (P = 0.05) according to Fisher's protected least significant difference test within weeks after planting; NS = nonsignificant, * = significant.

Table 6. Fruit yield and size in 2021 by month in response to three bare-root crown diameters [small (< 0.5 cm), medium (> 0.5 cm to 1 cm), large (> 1 cm)] and early-season flower removal or no removal in the strawberry variety Cabrillo.

Crown size, flower removal	Mar yield (kg·ha^{-1})[i]	Mar fruit size (g)[i]	Apr yield (kg·ha^{-1})	Apr fruit size (g)	May yield (kg·ha^{-1})	May fruit size (g)	Jun yield (kg·ha^{-1})	Jun fruit size (g)	Jul yield (kg·ha^{-1})	Jul fruit size (g)	Aug yield (kg·ha^{-1})	Aug fruit size (g)	Total yield (kg·ha^{-1})	Avg fruit size (g)
Large crowns, flowers not removed	249 a	ND[ii]	145 ab	ND	7217	57.1	19604	38.4	10460	28.7	20692	25.4	58090	32.6
Large crowns, flowers removed	89 bc	ND	18 b	ND	6227	59.2	15172	40.8	8481	30.0	19221	24.9	48233	32.0
Medium crowns, flowers not removed	118 bc	ND	214 a	ND	3977	45.1	13452	42.6	11054	32.8	19515	25.6	48207	30.1
Medium crowns, flowers removed	0 c	ND	15 b	ND	3187	49.9	12018	39.2	10867	28.4	17661	24.8	43884	29.1
Small crowns, flowers not removed	120 b	ND	190 a	ND	6090	47.0	17943	40.4	9598	29.7	21472	24.0	55490	31.1
Small crowns, flowers removed	14 bc	ND	4 b	ND	5690	51.6	17977	38.4	12595	26.6	22597	24.1	59031	29.9
Significance[iii]	*	ND	*	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[i] 1 kg·ha^{-1} = 0.8922 lb/acre, 1 g = 0.0353 oz.

[ii] ND = no data

[iii] Values followed by different letters mean treatments are significantly different (P = 0.05) according to Fisher's protected least significant difference test within weeks after planting; NS = nonsignificant, * = significant.

removed yielded significantly higher than those in which the flowers were removed (Tables 3 and 4). In both years in the months after April, along with season yield totals and fruit size averages, no significant differences were found (Tables 3 and 4).

In 2020, for Cabrillo, no differences were found between any treatments for fruit yield or size, in any month, nor were any statistical differences found in the season totals or fruit size averages (Table 5). However, in Mar 2021, in Cabrillo, treatments of large crowns with no flowers removed were significantly higher in fruit yield than all other treatments, with some continuation of this trend into April, but with the other two treatments of no flower removal now statistically equivalent to it (Table 6). As with the other tests of this study, there were no significant differences found between treatments in the following April, nor any differences in the season yield totals or average fruit sizes (Table 6).

In summary, although there was some variation of production of fruit by crown size and flower removal in the first and second month of harvest (Tables 3–6), for both Monterey and Cabrillo in both years, starting in May, the amount of fruit produced and fruit size did not significantly vary in any month nor did the total amount of fruit harvested or average fruit size vary at the end of the fruiting season. The conclusion drawn from this is that initial size of the crown at transplanting has no bearing on the bulk of strawberry fruit production for either Monterey or Cabrillo.

Variations in early yield can be attributed to larger crowns generally representing the earlier generations of daughter plants and therefore have had more time to initiate flowers than those smaller and generally of a later generation (Galletta and Bringhurst 1989). The lack of variation in total yield of varying bare-root crown size at transplant finds explanation in that crowns and roots, while supplying a significant source of carbohydrates during plant establishment, do not represent the highest percentage of biomass during fruiting (Torres-Quezada et al. 2015), which in the day-neutral strawberry culture of the Central Coast of California goes on for 6 months or more (University of California, 2008), and is a much longer season than other areas where the effects of differences in

transplant crown size have been studied (Bartczak et al. 2010; Menzel and Smith 2012; Takeda et al. 2004).

Yields often varied in the initial harvest month because of the physical absence of flowers in treatments where flower removal was done, but total yields did not vary in any treatment or any year in both strawberry varieties, indicating no shift in flowering or fruiting because of early flower removal into the later season. Because there are few to no fruit ready for picking from where flowers were removed only a few weeks previous, winter flower removal should result in less fruit harvested in those plots in the first month and sometimes the second month of harvest, because it normally takes from 3 to 6 weeks for a strawberry fruit to mature (Galletta and Bringhurst 1989). However, the amount of fruit harvested in May, June, July, and August is many times that of what was harvested in earlier months, subsequently resulting in no significant differences in fruit totals.

This study shows that over a 2-year period on the Central Coast in California, differences in bare-root transplant crown size or early-season flower removal in the two day-neutral varieties Monterey and Cabrillo do not result in significant differences in yield when measured over the whole season. Still, variations in yield in the first 2 months of production stemming from these two factors may be of use to growers seeking to modify their production during this window of time.

References cited

Agricultural Marketing Resource Center. 2021. Strawberries. www.agmrc.org/commodities-products/fruits/strawberries. [accessed 13 Mar 2023].

Bartczak MJ, Lisiecka J, Knaflewski M. 2010. Correlation between selected parameters of planting material and strawberry yield. Folia Hortic. 22:9–12. https://doi.org/10.2478/fhort-2013-0144.

Bolda MP, Murdock J, Goodrich B, Sumner DH. 2021. Sample costs to produce and harvest strawberries. https://coststudyfiles.ucdavis.edu/uploads/pub/2022/01/04/strawberrycentralcoastfinaldraft-121321.pdf. [accessed 14 Mar 2023].

Cross JV, Burgess CM. 1998. Strawberry fruit yield and quality responses to flower bud removal: A simulation to damage by strawberry blossom weevil (*Anthonomus rubi*). J Hortic Sci Biotechnol. 73:676–680. https://doi.org/10.1080/14620316.1998.11511032.

Demirsoy L, Soysal D, Lizalo A, Demirsoy H. 2019. The effects of flower removal on summer and fall fruit production of 'Albion' and 'Sweet Ann' strawberries. Acta Hortic. 1265:263–270. https://doi.org/10.17660/ActaHortic.2019.1265.37.

Ernest EG, Johnson G. 2015. Day-neutral strawberry production. https://sites.udel.edu/weeklycropupdate/?p=7998. [accessed 10 Apr 2023].

Galletta GJ, Bringhurst R. 1989. Strawberry management, p 83–156. In: Galletta GJ, Himelrick DG (eds). Small fruit crop management. Prentice Hall, Englewood Cliffs, NJ, USA.

Menzel CM, Smith L. 2012. Effect of time of planting and plant size on the productivity of 'Festival' and 'Florida Fortuna' strawberry plants in a subtropical environment. HortTechnology. 22:330–337. https://doi.org/10.21273/HORTTECH.22.3.330.

Nicoll MF, Galletta GJ. 1987. Variation in growth and flowering habits of June-bearing and Everbearing strawberries. J Am Soc Hortic Sci. 112:872–890. https://doi.org/10.21273/JASHS.112.5.872.

Portz DN, Nonnecke GR. 2010. Effect of removal of runners and flowers from day-neutral strawberries on time of harvest and total yields. https://doi.org/10.31274/farmprogressreports-180814-2437. [accessed 10 Apr 2023].

Takeda F, Hokanson SC, Enns JM. 2004. Influence of daughter weight and position on strawberry transplant production and field performance in annual plasticulture. HortScience. 39:1592–1595. https://doi.org/10.17660/ActaHortic.2006.708.34.

Takeda F, Hokanson SC. 2003. Strawberry fruit and plug plant production in the greenhouse. Acta Hortic. 626:283–285. https://doi.org/10.17660/ActaHortic.2003.626.39.

Torres-Quezada EA, Zotarelli L, Whitaker VM, Santos BM, Hernandez-Ochoa I. 2015. Initial diameter of strawberry bare-root transplants affects early and total fruit yield. HortTechnology. 25:203–208. https://doi.org/10.21273/HORTTECH.25.2.203.

University of California. 2008. Integrated pest management for strawberries (2nd ed). Statewide Integrated Pest Management Program, Univ California Agric Natural Resources Pub 3351.