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Cover Page Footnote

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Impact of Stolon Removal on Yield and Fruit Quality of Day-Neutral Fragaria X Ananassa "Cabrillo" Grown in Outdoor Soilless Conditions

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Abstract. Strawberries are among the most consumed fruits in the U.S. and demand for locally grown fruit is high. Although most production in Minnesota is dominated by June-bearers, new techniques for growing day-neutral strawberries are becoming increasingly prevalent. These techniques include in-ground plasticulture and soilless tabletop production, and growers are generally advised to remove stolons (runners) from day-neutral plants. There is relatively little information available to confirm that this practice, and its attendant labor increase, is a necessity in soilless tabletop production. This study's objective was to determine whether this practice is necessary to maximize yield and fruit quality, using the day-neutral Fragaria xananassa cultivar 'Cabrillo'. Plants in the runner removal treatment had significantly higher yields for both fruit weight and fruit number than plants without runner removal. We, therefore, recommend that growers remove runners periodically from day-neutral strawberry plants grown in outdoor soilless tabletop systems to achieve economically viable yields..

INTRODUCTION

Strawberries are one of the most consumed fruits in the United States, and there is strong demand for high-quality, locally grown berries (Feldman & Hamm, 2015; USDA, 2018). However, 99% of fresh strawberry production takes place in either California or Florida; the remaining 1% is distributed across the other 48 states (Samtani et al., 2019). In Minnesota, climatic conditions characterized by relatively harsh winters and a short growing season contribute to a domination of strawberry production by June-bearing cultivars, which yield fruit for only a short time each year (Klodd, 2021). However, recent cultural and technological advances have made day-neutral strawberry production increasingly feasible for growers in the Upper Midwest; these advances include annual plasticulture (Petran et al., 2017) and outdoor soilless tabletop production (Fessler et al., 2023). Despite its higher startup costs, tabletop production can be particularly advantageous for its demonstrated increase in marketable yield, fruit quality, and ease of harvest (Fessler et al., 2023). However, there are still some best practices for tabletop production in the Upper Midwest that Extension professionals and growers must understand, such as the potential benefits and tradeoffs associated with the common practice of stolon removal for day-neutral strawberry plants (Sanchez, 1999).

Strawberries either reproduce sexually, via seeds, or asexually, via stolons (most commonly referred to as "runners"); in asexual reproduction, stolons arise from the crown and root at the node to give rise to daughter plants that are genetically identical to the mother (Darrow, 1966). Although this is a common method of propagating strawberry plants (Kubota & Kroggel, 2017), the development of runners and their role in commercial fruit production vary by environmental factors, cultivation method, and cultivar(s) (Durner et al., 1984). June-bearing strawberry types, which (in Minnesota) are most often produced using the perennial matted row (PMR) system, are allowed to grow runners in order to establish the eponymous interwoven "mat" that serves the dual purpose of suppressing weeds and establishing new daughter plants for the next season (Hoover et al., 2016). However, common convention dictates that runners be removed from day-neutral strawberry plants to encourage foliar and fruit development, contributing greatly to the labor associated with cultivating these types (Wimmer et al., 2021). There is no existing research that verifies the necessity of this practice for plants grown in an outdoor tabletop production system. Therefore, the goal of this study was to determine whether this practice is necessary

to achieve economically acceptable yield and fruit quality in day-neutral strawberries grown in Minnesota.

MATERIALS AND METHODS

We conducted our field research outdoors on a 100x12-ft plot covered with black landscape plastic for weed suppression (DeWitt Sunbelt Ground Cover 3.2oz 12x300', DeWitt Company, Sikeston, MO). We installed one 80-ft steel gutter system (10 cm high and 14c m wide; Meteor Systems, Leamington, Canada) with a north-south orientation on the University of Minnesota Agricultural Experiment Station during April 2022 (Saint Paul, MN; 44°59'19.6"N 93°10'57.2"W). We filled twenty-four 16-L black plastic troughs (Bato Meter Trough Wave, Zevenbergen, Netherlands) with a rehydrated peat and wood fiber soilless media blend (BM4 Natural Fiber Wood, Berger, Saint Modeste, QC, Canada). We then planted 9 Cabrillo day-neutral, bare-root, strawberry plants in each trough on May 9, 2022— as soon as nighttime temperatures consistently reached 21°F (81 plants/m^2; Wortman et al., 2016). These 24 troughs served as experimental units and were randomly assigned to each of the two treatments—plus or minus runners—for a total of 12 troughs per treatment. Crop production methods followed those outlined in Fessler et al. (2023). Plants were fertigated at least twice per day with JR Peters' Strawberry Part A (N-P-K ratio 8-10-26; Appendix 1) and Cal Nit Part B (N-P-K ratio 15-0-0; Appendix 1) (JR Peters Co., 80 ppm N; MixRite 3.5 series injector). Plants were scouted for pests each week and electro-conductivity (EC, soluble salt concentration) was maintained below 1.0 μS cm^{-1} by flushing plain water into the irrigation system as necessary. The media acidity was maintained at a target pH of 5.5-6.5 using sulfuric acid (35%).

As soon as runners began developing, those assigned to the runners-off treatment were removed twice per week; those assigned to the runners-on treatment were left to grow. Fruit was harvested two to three times per week from June 24 to October 11 and pooled by trough. The fruit from each trough was sorted into marketable and unmarketable categories, counted, and weighed in grams. Fruit was categorized as unmarketable if it weighed <5 g or showed evidence of disease, malformation, insect damage, or rain damage. One marketable berry was randomly chosen from each of the 24 troughs (12 berries for each of the two treatments) and further analyzed for total soluble solid content (TSS, a proxy for fruit sugar content; Watrelot et al., 2020) via °BRIX (Atago PAL series refractometer, Bellevue, WA). These measurements were taken at early-, mid-, and late-season intervals corresponding to weeks 30, 37, and 42.

We used R statistical software build 2022.07.2+576 for all statistical analyses (RStudio team, 2022). We compared yield and TSS between the two treatments using a two-way ANOVA test, and we used the Bonferroni Procedure at a significance of $p < 0.01$ for pairwise comparisons (model assumptions for these tests were met).

RESULTS AND DISCUSSION

Overall yield was relatively low compared to most day-neutral hydroponic systems due to nutritional issues caused by low magnesium and challenges in maintaining pH, climatic conditions, and theft (Fessler et al., 2023). Nonetheless, there were significant yield differences between the two treatments: the plants receiving the runners-off treatment consistently produced a higher yield within each harvest and over the course of the year ($p < .001$; Figure 1; Table 1). Plants with runners removed produced an average of 341 g (fresh weight) per plant; the plants with runners on produced an average of 165 g per plant. The runner removal treatment also yielded a higher total number of fruit and a higher number of marketable fruits. These marketable fruits were larger on average than those from plants with the runners left on, with fruit weighing an average of 12.3 g and 9.8 g respectively. The proportion of marketable fruit from the plants assigned to the runner-removal treatment was 81%; this same proportion was 78.5% for those plants with no runner removal.

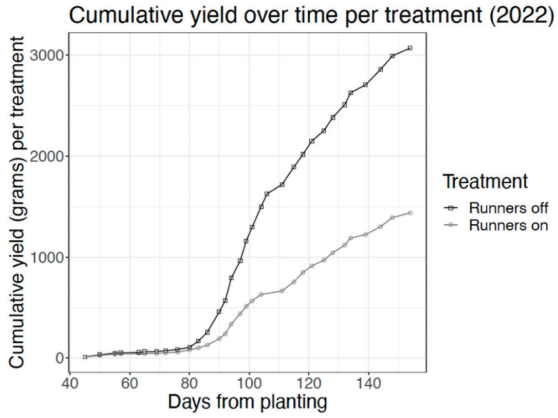

Figure 1. Cumulative yield over time, per treatment.

Table 1. Analysis of Variance in Weight (g) of Marketable Fruit

Analysis of variance, grams marketable					
	Df	**Sum Sq**	**Mean Sq**	**F-value**	**P-value**
Treatment	1	472836	472836	112.12	2.2×10^{-16}***
Residuals	764	3222097	4217		

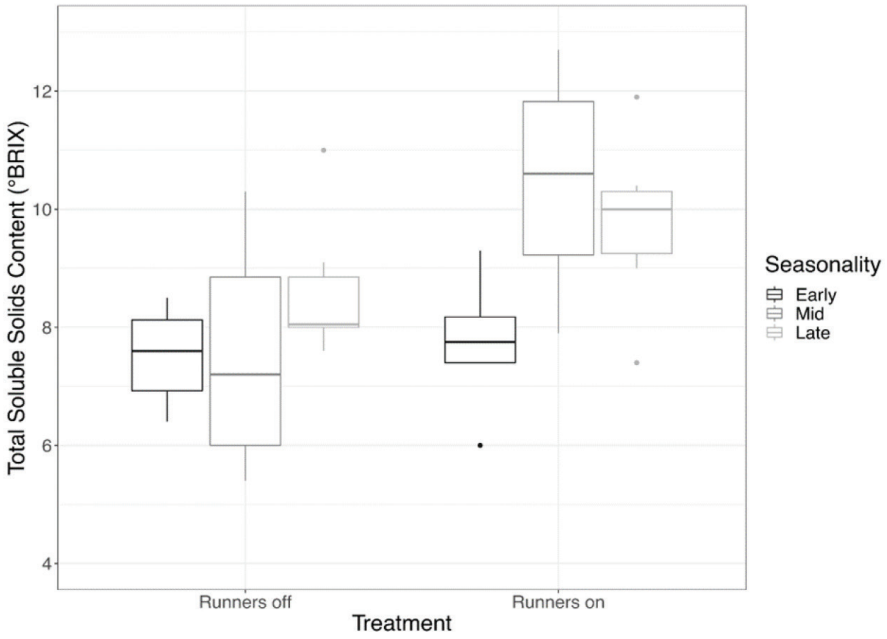

Figure 2. Comparison of total soluble solids (TSS) content between two treatments across three measurement periods.

Table 2. Analysis of TSS Content Variance

Analysis of variance, total soluble solids content					
	Df	**Sum Sq**	**Mean Sq**	**F-value**	**P-value**
Treatment	1	18.634	18.6336	8.5286	0.006578
Seasonality	2	17.687	8.8433	4.0476	0.027782
Treatment x Seasonality	2	11.582	5.7911	2.6506	0.087092
Residuals	30	65.545	2.1848		

While the runners-off treatment also produced a larger amount of unmarketable fruit by number and fresh weight ($p < .01$), this can be accounted for by the significantly higher overall yield for these plants; the proportion of their yield that was unmarketable was still lower than that of the plants subject to the runners-on treatment. Plants subject to the runners-on treatment produced 21.5% unmarketable fruit; 19% of fruit from the plants receiving the runners-off treatment was unmarketable. The unmarketable fruit from the runners-off treatment were still larger than those from the runners-on treatment; unmarketable fruit from runners-off plants weighed an average of 7.6 g, while unmarketable from runners-on plants weighed an average of 5.3 g.

There was a significant difference between the treatments for TSS content and for the timing (seasonality) of the measurements, but the interaction between treatments and seasonality was not significant (Figure 2). Notably, average TSS content was higher for fruit from the runners-on treatment than for fruit from the runners-off treatment ($p < .01$; Table 2). The runners-off treatment exhibited a small decline in mean TSS content during the mid-season harvest, whereas the runners-on treatment had its highest TSS on average during the mid-season harvest. Further research must be conducted to elucidate the causes of this apparent relationship.

CONCLUSIONS

Although the plants with runners left on did yield fruit with higher TSS, this potential benefit to flavor does not outweigh the significantly lower overall yield relative to the plants with runners removed. Flavor is a complex trait in fruits and could be the subject of future study in terms of how it is affected by runner removal. Plants that were allowed to grow runners exhibited lower fruit number, weight, and total yield, and had a higher proportion of unmarketable fruit than did those plants with the runners removed. An increase in total and marketable yield may outweigh the cost of the increased labor required to remove runners in an outdoor tabletop strawberry system. Based on the results of this study, we recommend that Extension professionals advise commercial strawberry growers to remove the runners from day-neutral strawberry plants grown in outdoor hydroponic production systems in the Upper Midwest.

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APPENDIX. FERTILIZER ELEMENTAL CONCENTRATIONS: 2022: JR PETERS' JACK'S STRAWBERRY PART A (N-P-K RATIO 8-10-26) AND CAL NIT PART B (N-P-K RATIO 15-0-0)

	Part A	Part B	Total
Element	**ppm**	**ppm**	**ppm**
N	45	35	80
NO3	38	33	71
NH4	6	2	8
P	24	0	24
P2O5	55	0	55
K	121	0	121
K2O	145	0	145
Ca	0	42	42
Mg	13	0	13
S	50	0	50
B	0.36	0	0.36
Cu	0.05	0	0.05
Fe	2.1	0	2.1
Mn	0.6	0	0.6
Mo	0.01	0	0.01
Zn	0.6	0	0.6
Cl	10	0	10

Source: Jack's Nutrients, 2022.