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Strawberry Crown Plugs Provide Flexibility and Improved Performance in Cold Climate Plasticulture Production

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Abstract: Annual plasticulture strawberry production has not been adopted as rapidly in cold climate regions as has occurred in warmer production areas due to uncertainty about potential benefits. Recent trials have demonstrated the potential of regionally adapted varieties in the annual plasticulture system in cold regions, but optimal production practices have not been determined. Summer planting of short-day varieties in these areas would increase flexibility for growers, allowing additional cropping options and improved land use management. The performance of six short-day strawberry varieties (Chandler, Clancy, Jewel, Ovation, Seneca and Ventana) was examined in a series of four annual production trials using cold-stored bare-root crowns for spring planting or a new type of planting stock termed a 'crown plug' for two summer plantings. Procedures for producing crown plugs from cold-stored crowns are described. The crown plug summer plantings significantly outperformed the spring planted bare-root plants across all varieties. The July planting established using crown plugs had higher yield and higher mean berry weight across all six varieties compared to the May bare-root planting (623 g/plant—12.5 g mean fruit weight vs. 330 g/plant—10.6 g mean fruit weight, respectively). In the July planting, 'Seneca', 'Ventana' and 'Jewel' exceeded the mean yield per plant for the planting as a whole and the other three varieties also produced more than previously reported for the May planting established with bare-root plants. The August crown plug planting was less productive than the July planting (623 g/plant vs. 498 g/plant, respectively) but was still more productive than both spring plantings. No difference was observed between the April and May plantings across the six varieties. Utilizing crown plugs also reduced the duration of weed control measures needed, improved efficiency of setting plants and limited the need for blossom and runner removal in the field, thus demonstrating labor cost savings that can offset the cost of crown plug production while also producing higher overall yield and mean fruit weight in the varieties in the trial. The summer plantings established with crown plugs demonstrated improved survival through a second winter dormancy period but produced relatively poor yield and berry size in the second harvest season. Crown plugs provide flexibility and improved productivity for growers utilizing annual plasticulture production in cold climate regions.

Keywords: annual hill production; perennial production; variety trial

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1. Introduction

Annual hill or plasticulture production has revolutionized strawberry production worldwide starting in the 1970s with increased yield and quality, resulting in year-round availability of strawberries in developed markets [1,2]. However, the use of this system has been concentrated in warm climate production areas typified by California, Florida, southern Spain and North Africa [3]; http://www.fao.org/faostat/en/#search/strawberries (last accessed 16 August 2021) and more recently in moderate climate locations such as parts of the Midwestern and Southeastern US [4–8]. The current production area in cold climate regions in the US and around the world totals thousands of hectares [3] (http://www.fao.org/faostat/en/#search/strawberries last accessed 16 August 2021), but the adoption of the annual plasticulture production system in these regions has lagged due to uncertainty in its potential economic benefits as well as inconsistency in recommended production practices and variety selection. Guidelines for annual plasticulture production in cold climate regions utilizing short-day plants include variable recommendations on planting stock, planting date, irrigation practices, renovation practices, winter protection and variety choice [6,7]. Recent trials have shown the potential for utilizing regionally adapted varieties for production in an annual plasticulture system in a colder region [9]. Several varieties were shown to be productive in a cycle that mimics the matted-row production cycle typically followed in the region with spring planting of cold-stored bare-root crowns [9]. However, this cycle presents challenges in weed control and labor during the 6–8-month establishment and vegetative growth phase from spring planting to winter dormancy in the planting year. It also requires valuable land to be economically unproductive for an entire growing season prior to harvest.

Production guides for plasticulture production recommend both bare-root crowns (cold-stored or fresh-dug) and plug plants as planting stock, depending on plant availability and recommended planting date for any given region [5–8,10]. Plug plants or fresh-dug plants are commonly used for fall plantings in many production areas for winter and early spring production [6,11]. Fresh-dug plants have been found to produce lower yields in South Carolina at planting dates after the first of October [11]. Fresh dug plants are not commercially available until early fall in the US, making this type of plant unsuitable for summer planting in colder regions.

The use of plug plants to establish new plantings in cold climate regions promises increased flexibility in planting date as well as producing less transplant shock and improving plant establishment as a result of a developed root system, especially during warmer periods of the year. Summer planting would shorten the duration of needed weed control, reduce disease and insect control requirements as well as irrigation and fertilizer inputs and reduce or eliminate certain field operations such as flower and runner removal. However, research has shown that storing bare-root plants for summer planting leads to reduced crown vigor, poor stand establishment and lower yields [12].

Unfortunately, preliminary trial results indicate that planting plug plants in September in cold regions, when such transplants are commercially available in the US, is unlikely to produce acceptable yields. In a trial established with commercially available plug plants in early September in Geneva, NY, USA, yield was very low across a wide range of short-day varieties commonly grown in different regions of the US (Camino Real, Chandler, Festival, Jewel, Palomar, Radiance, AC Wendy) in the following production season, ranging from 35 g to 135 g/plant. The short timeframe from early September to the onset of freezing temperatures in October is not an adequate time period for the vegetative phase and resulted in a small plant size and low yield in the following spring/summer. For this study, we hypothesized that earlier summer planting of plugs would be required to allow sufficient time for plants to develop adequately for acceptable yields.

However, since plugs are not available until early September, a new type of stock plant would be required for summer planting of annual strawberry production in cold climate regions if the annual strawberry production is to be optimized. This project explores the use of a new type of planting stock termed a 'crown plug' developed from cold-stored, bare-root plants for summer planting of annual strawberry production in western NY, USA. The protocol for developing these plugs is described, and the productivity of spring-planted, cold-stored, bare-root plants is compared to summer-planted, crown plugs for six short-day strawberry varieties, including several standard varieties for the region. Total yield and mean berry weights are compared across varieties, planting stock type and planting dates. Potential efficiencies in weed management, establishment year field operations and cropping cycles options are also discussed.

2. Materials and Methods

2.1. Site Description and Preparation

The trials were performed in adjacent field plots at Cornell AgriTech at the New York State Agricultural Experiment Station in Geneva, NY, USA (lat. 42.87° N, long. 76.99° W) in the hardiness zone 6a [13] in a Honeoye loam soil (mesic Glossic Hapludalfs) with 3% to 8% slope [14]. The site is well protected with good air drainage, which lowers the incidence of spring frost events. While frost protection was available utilizing floating row covers, it was not needed as previously reported, as no frost events occurred that threatened bloom or fruit development in the varieties planted [9].

The field in which the four plantings were established was prepared in the summer and fall prior to planting. A summer cover crop of sorghum–sudangrass (*Sorghum x drummondii* (Nees ex. Steud.) Millsp. & Chase) was mowed and then worked into the site approximately 8 weeks prior to fall bed formation. For the spring planting dates (26 April and 24 May 2013), beds were formed in October in the year prior to planting and allowed to rest over the winter to enable early spring planting when soil conditions are typically unsuitable for bed formation. For the summer planting dates (16 July and 13 August 2013), the beds were formed and covered 1 week prior to planting. For all the trials, the unfumigated site was rotovated prior to bed formation so that soil would flow in the bedmaker. Raised beds with 15 cm high × 61 cm wide dimensions spaced 1.7 m center to center were formed and covered with 1.5 mil black plastic (Filmtech Corp., Allentown, PA, USA). Irrigation was supplied with a single center 10-mil T-tape drip line with 30 cm emitter spacing (Rivulis Irrigation, San Diego, CA, USA).

2.2. Experimental Design and Statistical Analysis

A completely randomized design was used in each planting with four replicates of six varieties (Chandler, Clancy, Jewel, Ovation, Seneca, Ventana). 'Jewel', 'Clancy', 'Ovation' and 'Seneca' were developed for matted-row production in the region [15–18]. 'Chandler' and 'Ventana' were developed for annual plasticulture production in California and similar climate locations [19,20].

Two plantings were established using cold-stored bare-root plants in the spring planting period (26 April and 25 May 2013), and two plantings using crown plugs were established in the summer period (16 July and 16 August 2013). Each planting was established with four 25-plant plots of each variety. Border rows and plots were planted on the sides and ends of the plantings to avoid edge effects. An analysis of variance (ANOVA) was carried out in spreadsheets developed by the author in Excel (Microsoft Corp., Redmond, WA, USA.) using the procedures outlined in Gomez and Gomez [21]. Formulas for calculating variance for a CRD design on each planting's yield and berry weight formulas were set up in the spreadsheet program for the calculations. Means were separated utilizing Duncan's multiple range test ($p \leq 0.05$) following the finding of significant treatment effects, following the procedures outlined in Gomez and Gomez [21] in additional spreadsheets developed by the author in Excel for means analysis. Analyses were completed comparing all planting dates, spring planting dates vs. summer planting dates, spring planting dates and summer planting dates directly and cold-stored bare-root planting stock vs. crown plug stock. Yield and mean fruit weight for each individual variety were also analyzed across all four planting dates.

2.3. Bareroot Planting Establishment

Dormant cold-stored, bare-root crowns were purchased from commercial nurseries and stored at 2 °C prior to planting directly in the spring. On each day of spring planting, the crown bundles were soaked in tap water for 2 h prior to planting to ensure adequate hydration in the root systems. Double offset rows were planted in the bed at 30 cm spacing between plants and between rows within the bed. This spacing was chosen based on soil conditions and available equipment and resulted in a plant density equivalent to 39,124 plants per ha. Crowns were set by hand through the plastic using an L-shaped special tool (20 cm × 10 cm) made by bending a 30 cm piece of 3.8 cm wide metal at a 90 angle. This tool is used to push the roots through the plastic and into the soil. This is the technique recommended by a local commercial nursery (www.noursefarms.com/resources/pdfs/plasticulture/plasticulture.pdf) (last accessed 13 July 2021) and sets the plants while minimizing the size of the hole in the plastic to help reduce weed encroachment around the plants. The flush of flowers that emerged from the dormant crowns was removed at approximately 4 weeks post-planting to encourage establishment and vegetative growth. Locally sourced wheat straw (*Triticum aestivum* L.) was spread between the row to suppress weeds with supplemental manual weed removal as needed through the season.

2.4. Crown Plug Development and Planting Establishment

Dormant cold-stored bare-root crowns from the same batch purchased for the spring planting stored at 2 °C were used for crown plug production. Crown plugs for each summer planting were initiated 6 weeks prior to the target planting date based on preliminary data, indicating that this was an adequate time period for the development of a transplantable plug. The planting dates for the two summer trials were 16 July and 13 August 2013. Cold-stored bare-root crowns were removed from the cooler, and the roots from each crown were trimmed to approximately 5 cm in length with sharp scissors. The resulting crowns with shortened roots were placed in empty 50-cell plug trays (5.1 × 5.1 × 7 cm^3), and the crowns were set in the trays by filling in around the roots with moistened soil-less potting mix (LM-3 All Purpose Mix, Rivière-Ouelle, QC, Canada). The trays of set crowns were watered in and placed outdoors for growth. Additional potting mix was added to cells where it had settled to cover any exposed roots. Plants were kept watered daily and fertilized weekly with a solution of 20-20-20 (N-P-K) general-purpose soluble fertilizer following the label recommendation (Jack's Fertilizer, JR Peters, Inc., Allentown, PA, USA). At 4 weeks post-planting, flowering trusses that had emerged were removed. Any remaining trusses or initiated runners present at planting were removed prior to setting the crown plugs in the field. The mature crown plugs were set in the field beds in double-offset rows at 30 cm spacing between rows and plants utilizing a water wheel transplanter (Rain-Flo Irrigation, East Earl, PA, USA) using water to help set the crown plugs into the planting holes. Wheat straw was spread between the row to suppress weeds with supplemental manual weed removal as needed through the season.

2.5. Planting Management

Plots were fertigated starting after planting with 20-20-20 (N-P-K) general-purpose soluble fertilizer (Jack's Fertilizer, JR Peters, Inc., Allentown, PA, USA) on a weekly basis to supply approximately 5.6 kg N/ha equivalent per week during the growing season. Irrigation was supplied three times weekly to total 2.5 cm of water per week during the vegetative phase. The beds/plants were covered with locally sourced wheat straw in mid-December of each planting year for a depth of 7.5 to 15 cm for winter protection, as recommended for the region [6]. In the following spring, the straw was removed on or about March 15 to allow the plants to emerge from dormancy. During the following development and harvest periods, fertilizer was supplied as in the previous year, and irrigation was supplied for a total of 5 cm per week. Pest management in the harvest year was targeted at peak phenological dates across all varieties but could not be optimized by variety due to the mixed variety design. This necessarily reduced the effectiveness of control of common diseases occurring in the planting. An application of fenhexamid fungicide (Elevate 50 WDG, Arysta Life Science, Cary, NC, USA) was applied at early bloom for the trial each year for control of gray mold caused by *Botrytis cinerea* Pers., and azoxystrobin fungicide (Abound 2.08F, Syngenta Crop Protection, Inc., Greensboro, NC, USA) was applied after fruit set to target anthracnose (*Colletotrichum acutatum* Simmonds) and leather rot (*Phytophthora cactorum* (Lebert & Cohn) Schröt.) following the manufacturers' label. No further applications were made. Scouting through the harvest season detected no significant insect/mite pressure resulting in no insecticide applications in these trials.

Locally sourced wheat straw (*Triticum aestivum* L.) was spread between the row to suppress weeds with supplemental manual weed removal as needed through the season.

Ten-plant sections were harvested from the four replicate plots of each variety three days a week (M, W, F) starting on 4 June 2014 and continuing through 9 July. Fruit was weighed and counted at each harvest for yield and fruit weight calculations. As previously reported for the May planting [9], survival and second harvest potential after a second dormant period were investigated for all trials. Briefly, plants were renovated in July after the harvest was complete to encourage regrowth. Plants were carried through the second winter as previously described [9] and evaluated in the following spring for harvest potential. Plots with at least 75% healthy plants (19 of the original 25 plants) were harvested in the second year. This harvest began on 10 June 2015.

3. Results and Discussion

As previously reported, the harvest period lasted from 4 June to 9 July 2014 across all varieties in the trials [9]. Mirroring the data reported for the May planting [9], significant differences were found among the varieties for yield and mean fruit weight at each individual planting date (data not shown). Analysis of variance (ANOVA) comparing all planting dates showed significant differences between trials, with the July planting having the greatest total yield followed by the August planting (Table 1; Figure 1). There was no difference between the April and May plantings utilizing bare-root plants (Figure 1).

Table 1. Values from an analysis of variance (ANOVA) on total yield per plant and mean berry weight for six strawberry varieties at planted at four dates in the same season using cold-stored bare-roots directly (April and May plantings) or as a source for crown plugs (July and August plantings). Data were analyzed at each planting date separately, comparing spring and summer planting dates, bare-root vs. crown plug stock and individual variety.

Source of Variation	Degrees of Freedom	Calculated F Value [1]	Threshold F Values ($p < 0.05$; 0.01)
April Planting			
Variety:			
Total yield	5	**4.65**	2.77; 4.25
Mean fruit weight	5	**0.82**	
Error	18		
May Planting			
Variety:			
Total yield	5	**6.54**	2.77; 4.25
Mean fruit weight	5	**4.11**	
Error	18		
July Planting			
Variety:			
Total yield	5	**4.07**	2.77; 4.25
Mean fruit weight	5	**12.00**	
Error	18		
August Planting			
Variety:			
Total yield	5	**5.35**	2.77; 4.25
Mean fruit weight	5	**11.65**	
Error	18		
April vs. May			
Planting date	1	0.80	5.99; 13.74
Variety (yield)	5	**8.71**	2.53; 3.70
Date × Variety	5	1.48	2.53; 3.70
Error	30		

Table 1. *Cont.*

Source of Variation	Degrees of Freedom	Calculated F Value [1]	Threshold F Values ($p < 0.05; 0.01$)
July vs. August			
Planting date	1	**84.29**	5.99; 13.74
Variety (yield)	5	**31.85**	2.53; 3.70
Date × Variety	5	**4.71**	2.53; 3.70
Error	30		
Spring vs. Summer Planting			
Season:			
Yield	1	**68.27**	
Mean berry wt.	1	**26.17**	
Variety:			
Yield	5	**10.14**	3.98; 7.01
Mean berry wt.	5	**3.88**	2.35; 3.29
Season × Variety:			
Yield	5	**5.67**	
Mean berry wt.	5	**3.21**	
Error	70		
Bare-root vs. Crown Plug			
Planting stock	1	**8.56**	4.96; 10.04
Error	10		
Chandler across seasons			
Yield per plant	3	**5.52**	
Mean berry weight	3	2.93	3.49; 5.95
Error	12		
Clancy across seasons			
Yield per plant	3	**19.72**	
Mean berry weight	3	**8.83**	3.49; 5.95
Error	12		
Jewel across seasons			
Yield per plant	3	**5.64**	
Mean berry weight	3	2.82	3.49; 5.95
Error	12		
Ovation across seasons			
Yield per plant	3	**7.46**	
Mean berry weight	3	0.97	3.49; 5.95
Error	12		
Seneca across seasons			
Yield per plant	3	**10.88**	
Mean berry weight	3	**4.34**	3.49; 5.95
Error	12		
Ventana across seasons			
Yield per plant	3	**20.97**	
Mean berry weight	3	**27.12**	3.49; 5.95
Error	12		

[1] F values in bold are significant at the $p < 0.05$ or 0.01 level.

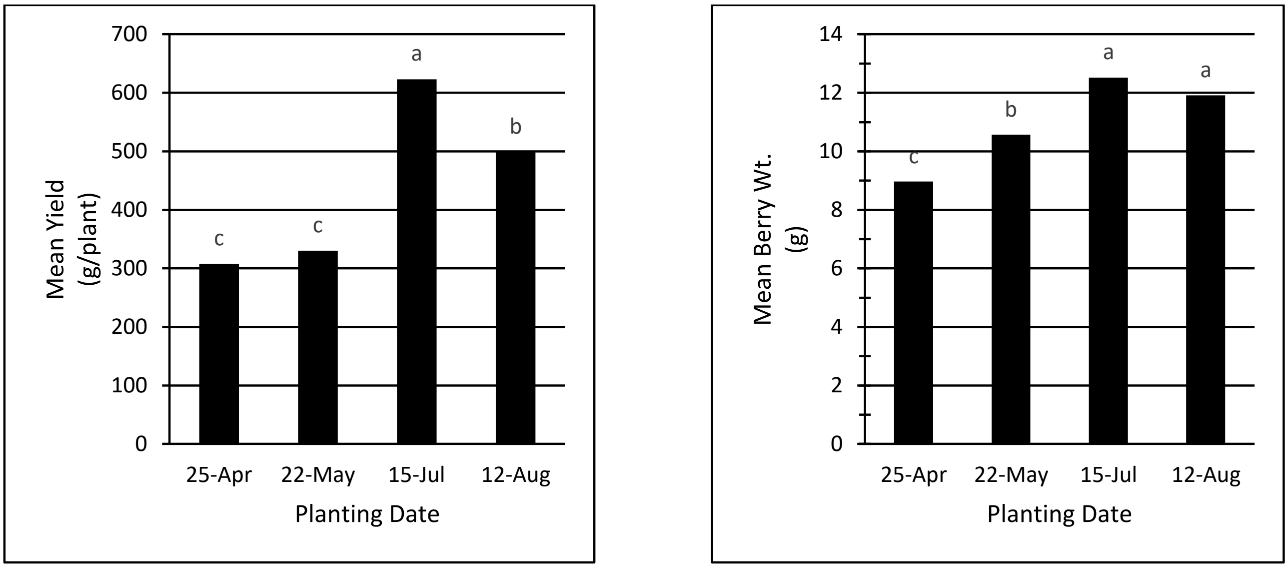
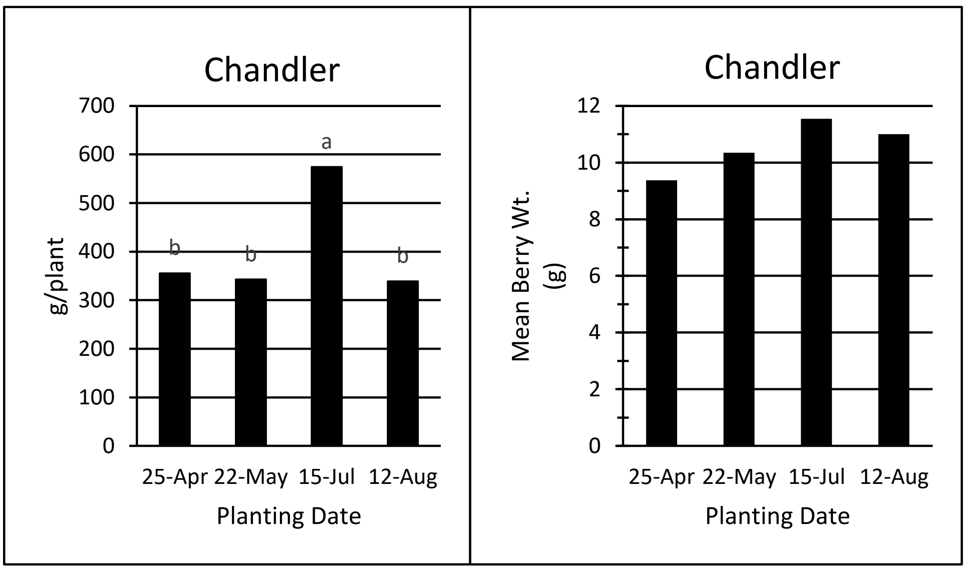


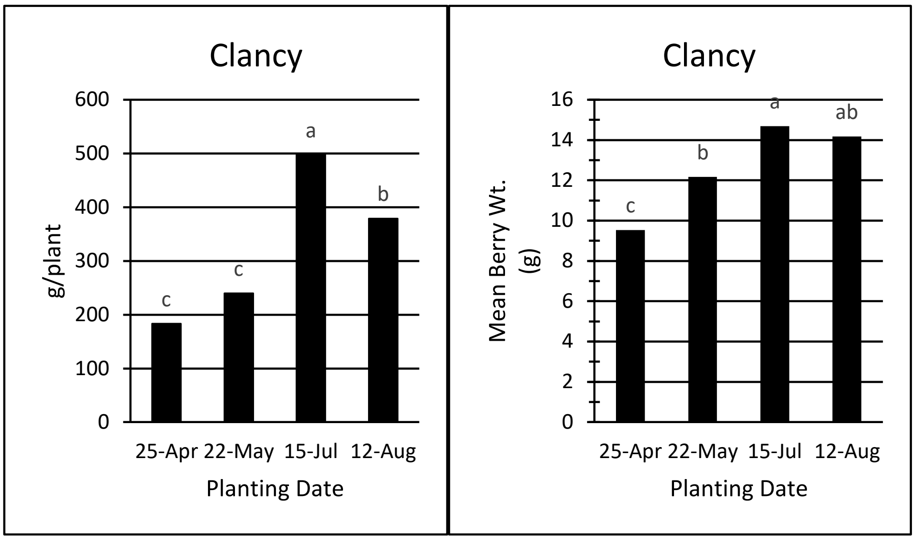
Figure 1. Mean yield per plant and mean fruit weight across six short-day strawberry varieties (Chandler, Clancy, Jewel, Ovation, Seneca, Ventana) in four trials established with either cold-stored bare-root crowns or crown plugs developed from the same planted in the spring and summer of 2013 and harvested in 2014 in Geneva, NY. Bars with the same letter in each graph are not significantly different from each other based on Duncan's Multiple Range Test means comparison ($p < 0.05$).

Mean berry weight showed a similar pattern, with the July planting having the highest overall mean berry weight across all varieties, followed by the August planting and then the May and April plantings, respectively (Figure 2). However, while all varieties displayed the same trend in mean berry weight, only three were significantly different across planting dates (Clancy, Seneca and Ventana). It is likely the plants from the spring planting developed more branch crowns during the extended vegetative period, leading to higher berry counts and smaller size, but variability among varieties is high. Further evaluation of branch crown formation among strawberry varieties may lead to a clearer understanding of berry weight variation in different production systems.



(**A**).

Figure 2. *Cont.*



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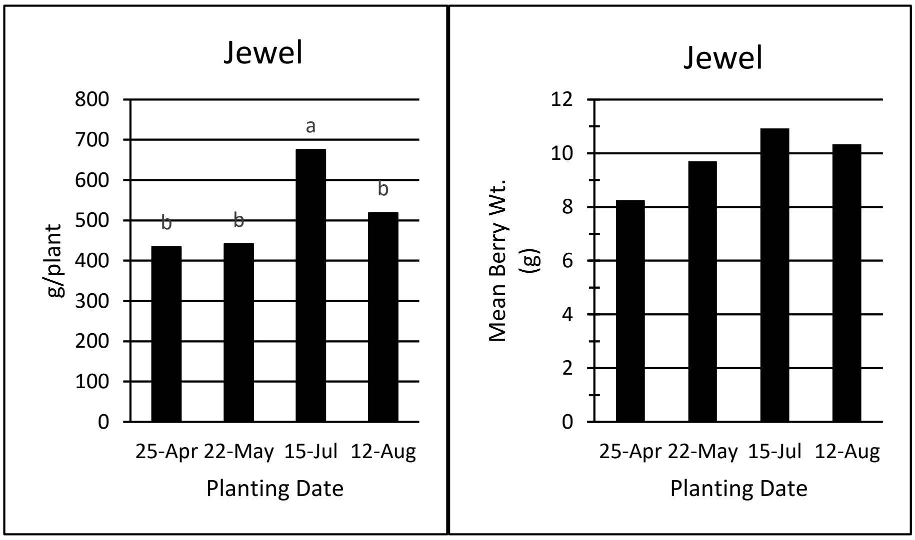

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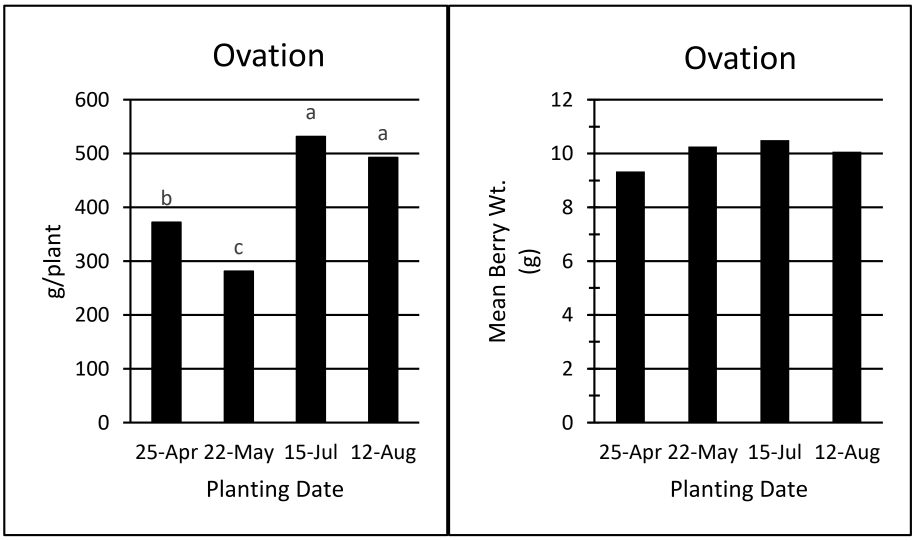
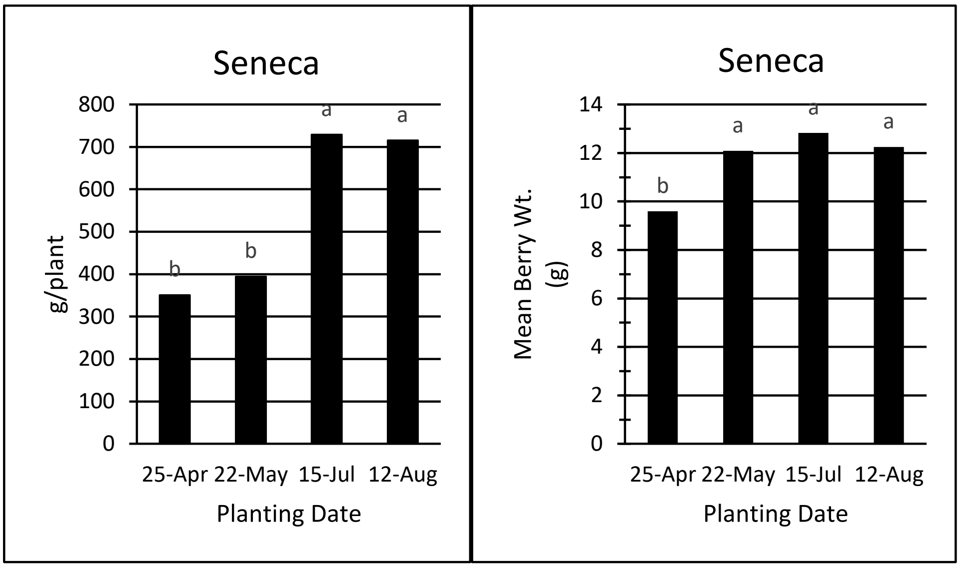
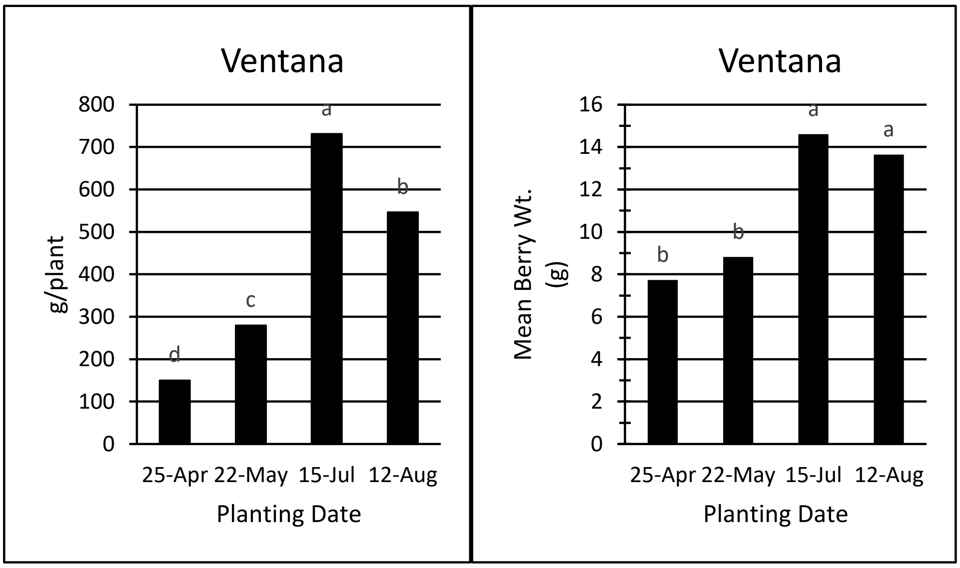


(**D**).

Figure 2. *Cont.*



(**E**).



(**F**).

Figure 2. Mean yield per plant and mean berry weight for six short-day strawberry varieties ((**A**) Chandler; (**B**) Clancy; (**C**) Jewel; (**D**) Ovation; (**E**) Seneca; (**F**) Ventana) in four trials established with either cold-stored bare-root crowns or crown plugs developed from the same planted in the spring and summer of 2013 and harvested in 2014 in Geneva, NY. Bars with the same letter in each graph are not significantly different from each other based on Duncan's Multiple Range Test means comparison ($p < 0.05$). Mean berry weight in 'Chandler', 'Jewel' and 'Ovation' did not differ significantly across planting date trials.

This pattern of production was typical across all varieties, with some minor variations. For all varieties, the July planting established with crown plugs had the highest total yield and highest mean fruit weight (Figure 2A–F). 'Chandler' produced uniform yield across the other three planting dates and 'Ovation' had a higher yield in the April planting compared to the May planting, but both had higher yield from the summer-planted crown plugs compared to the spring plantings. The other varieties following the overall pattern across planting dates, with the summer crown plug plantings producing the highest yields (Figure 2A–F).

Comparing the two spring planting dates (established with bare-root plants) with the two summer planting dates (established with crown plants) showed significant differences between planting stock for both total yield per plant as well as mean fruit weight (Table 1; Figure 1). For both parameters, the crown plugs produced superior results. Further, comparing the July planting to the August planting, there was a significant yield difference between the planting dates, with July-planted crown plugs outperforming August-planted crown plugs. However, the August planting of crown plugs still outperformed the spring plantings overall but was more variable across varieties (Figure 2A–F).

Yield in the summer planted trials established with crown plugs was higher than previous trials in New Jersey [22] and Maryland [23], in which 'Chandler' was also included. In those trials, which were fall-planted with runner tip plugs, total yield for 'Chandler' averaged 203 g/plant in NJ over 2 years and 424 g/plant in MD over 5 years. A similar total yield was recorded in MD for 'Allstar' and 'Northeaster', which are short-day varieties adapted to matted row production in cold climate regions [23]. The yield observed across varieties in the July plantings presented here generally exceeded those observed in the MD and NJ trials. The total yield for 'Chandler' in the July trial was 574 g/plant (Figure 2A) which exceeded previous trials, but the August trial produced a yield similar to the spring trials and trials in other states. The spring plantings established with bare-root plants produced similar yields to the MD and NJ trials. The potential for holding over plantings for a second season as recommended in some production guides (www.noursefarms.com/resources/pdfs/plasticulture/plasticulture.pdf, accessed on 13 July 2021) was also investigated. All four trials were held over for a second harvest season to gauge the yield potential in the second harvest of each variety. Plant survival for each plot was evaluated on approximately 1 May 2015 (6 weeks after the straw winter protection was removed) to determine if a viable harvest could be made. As was previously reported, 'Ovation' was the only variety for which all four plots had at least 75% survival through the second winter in the May trial [9], and this was also the case in the trial planted in April. Additionally, in the April trial, one plot of 'Chandler' met the 75% survival threshold. None of the remaining plots of the five other varieties in the planting met the 75% survival threshold. As previously reported for the May planting, 'Seneca' had three plots, and 'Chandler' had two plots with 75% survival, and no other varieties had any plots that met the 75% survival threshold. Survival was much higher in the summer-planted trials established with crown plugs. From the July planting, all four plots of 'Jewel', 'Seneca' and 'Ovation' met the 75% survival threshold as well as three plots of 'Chandler'. 'Clancy' had two plots survive, and only one plot of 'Ventana' survived a second winter. Survival in the August plantings was less successful than the July plantings, with only 'Ovation' and 'Seneca' having all four plots with acceptable survival. 'Jewel' and 'Clancy' had three plots survive, and 'Chandler' and 'Ventana' had no plots meeting the 75% survival threshold.

Yield in the surviving plots was greatly reduced in the second harvest season, averaging 64% less total yield than the first harvest season. Additionally, fruit size was reduced in those plots that were harvestable, with the only exception being in 'Ovation', which had a similar fruit size in the second season for the summer plantings. Excluding 'Ovation', the other varieties showed a 33% mean reduction in mean berry weight across the surviving plots. This fruit size disparity is accentuated in annual plasticulture because the production comes from the original crown planted that has been in the ground through two winters at the time of the second harvest. In the perennial matted row production system, each subsequent year's harvest is primarily from newly produced daughter plants that have not produced extensive branch crowns. These plants produced berries that are similar in weight to that of the original mother plants. In contrast, 2-year-old mother plants with extensive branch crown development would be expected to produce a higher number of berries with generally reduced size due to over-competition for resources in the plant. Overall, it is unlikely that growers would find the second-year harvest or fruit size acceptable. This is doubly so when, based on results presented here, superior results can be obtained by establishing a new planting in the summer each year.

The mechanism behind the improved performance is likely due to plant growth and development factors associated with better water and fertilizer management during plug production compared to open field establishment. Crown plugs also experience less stress from transplant shock compared to bare-root plants because the roots are fully develop within the plug media at planting. The root ball experiences less water stress that can inhibit the establishment and growth of bare-root plants. Additionally, the bare-root plants are exposed to soil disease organisms during the transplant period when they are more susceptible, and the organisms such as *Phytophthora fragariae* var. *fragariae* and *Pythium* species are more active [24,25]. These factors are all likely contributors to the better plant health, winter survival and productivity of the crown plug plantings.

4. Conclusions

Overall, the use of crown plugs for mid-summer planting in an annual plasticulture system holds great potential for growers in cold climates. All six varieties tested in this project demonstrated superior performance when crown plugs were used to establish a planting in July. The small reduction in yield in the August planting indicates that there is some flexibility from mid-July to mid-August for establishing new plantings using crown plugs. This system mimics the production cycle followed in warmer regions, where traditional plug plants can be utilized at later planting dates [5]. Added flexibility in planting date may also be achieved by utilizing low tunnels or other protection to extend the growing season in the fall.

Further, this system provides much-improved cropping flexibility to growers in cold regions, freeing up land for an extra crop in the spring of the planting year. Additionally, a new crop for the fall or following spring could be planted quickly after the summer harvest and planting removal. Reducing the vegetative period for establishing the strawberry planting from 6–8 months to 3–4 months also provides weed-control benefits by reducing the period during which control is needed. The flowering trusses must still be removed as they emerge from the dormant crowns, but this operation can be completed while the plants are developing in plug trays, which is much more efficient than field removal. Runner removal required is also greatly reduced in the field, as any initiated runners can be removed before planting, and few are produced in the field that would survive the initial winter dormancy period. Other potential modifications to the annual plasticulture system, such as the use of row covers and/or low tunnels to advance the season or provide additional protection from weather events, could make the system more reliable and productive. Greater adoption of the annual plasticulture production system for strawberries in cold climate regions is likely over time as new varieties that are more adapted to the system are developed and specific production details are optimized.

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