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Title: Season extension of day-neutral strawberry in the Pacific Northwest

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Abstract:

Strawberries are a well-beloved dessert fruit; however, the local supply cannot meet the demand as the off-season approaches in BC, due to climactic restrictions. At this time, BC consumers must turn to out-of-season strawberries grown in California or farther abroad, or they must forgo eating strawberries altogether. Furthermore, imported strawberries are expensive and may lack eating quality, and have poorer nutrition due to premature harvesting and transportation. During the off-season, farmers are losing the opportunity to make profit to Californian growers. From the consumer's perspective, there is a dearth of local fruits during winter, and the quality declines rapidly upon reaching the late winter months (Feb.- Apr.). Furthermore, season extension would help provide more variety, and shorten the period of unavailability of local fruit, thereby helping to encourage British Columbians to get their daily servings of fruit. In this experiment, we tested the effects of passive season extension technologies: low tunnel, row cover and low tunnel/row cover combination on day-neutral strawberry. Both low tunnel and row cover advanced the onset of flower buds and flowers leading to an earlier marketable harvest.

Keywords: strawberries, day-neutral, season extension, low tunnel, row cover, BC

Introduction

Strawberries are a high value crop, and growers may get higher returns from them as compared to other crops, because the demand for local strawberries often exceeds available supply. (Guerena and Born 2017). In North America, the demand for year-round supply of strawberries has grown, and provides an opportunity for producers that have the necessary resources to fulfil this demand (Ballington, Poling and Olive 2008). Season extension of strawberries is costlier, but increased cost of production can be offset by off-season premiums, and by the higher net returns obtained through direct sales (Maughan 2015).

Unlike june-bearing strawberry, everbearing and day-neutral strawberries have the characteristic of producing smaller berries, and having lower yields, but they make up for these disadvantages by producing several flushes throughout the season as they are insensitive to day-length (Gorman n.d.; Guerena and Born 2017). Day-neutrals will produce flowers between 4°C and 29°C (Ruan Lee Yeoung 2013). Day-neutral strawberry generally has better fruit quality than everbearing strawberry and produces fruit longer throughout the season – normally until first frost - (Bauman et al 1993, Gorman n.d.) making them ideal for season-extension production systems.

Strawberries are successfully grown in a wide range of climatic conditions using a diversity of season extension technologies: for example, strawberries are grown with plastic mulch and overhead row cover in Alaska (Seefeldt 2015); raised bed system with plastic mulch, in the Fraser Valley of BC (Bauman et al 1993); under high tunnels in Finland (Hietaranta and Karhu 2012) using a combination of high tunnel, and low tunnel, in the US intermountain west (Maughan 2015); in polytunnels in Quebec (Van Sterthem.2013), and in Korea at 750m of altitude (Ruan Lee Yeoung 2013). Strawberries are also produced in greenhouses (Guerena and Born 2017), and in hydroponic systems (Durner 2016).

The hill system is most commonly used for everbearing and day neutral strawberries (Gorman n.d.) Additionally, plastic mulch is commonly used throughout the industry because it provides the following benefits: weed control, earlier and longer harvests, cleaner fruit, increased quality of fruit, and higher yields (Ballington, Poling and Olive 2008; Bauman et al 1993; Guerena and Born 2017; Seefeldt 2015; Van Sterthem, A. 2013). Some systems may involve the use of row cover in addition to plastic mulch. The use of protective row cover creates a warm micro-environment, and the use of plastic helps to warm the soil, thereby extending the season. (Seefeldt 2015). This system also increases fruit cleanliness and minimizes rot, as is equally true for the use of polytunnels (Van Sterthem, A. 2013). Varieties used in this system must be insensitive to daylength for flower initiation. (Seefeldt 2015). Row cover was found to advance harvest by 10 to 14 days during early spring, in North Carolina (Ballington, Poling and Olive 2008). While a study has been performed on the economics of using a combination of high-tunnels and low tunnels in the intermountain US (Maughan 2015), and researchers in Quebec (Van Sterthem 2013) have made use of polytunnels for extending the strawberry season, no study has specifically attempted the combination of polytunnel and row-cover in Southwestern British Columbia.

In summary, locally-grown strawberries can contribute to a more sustainable food system if they are produced using low-impact, environmentally sensitive, and affordable techniques and yield enough return to farm management. Making use of passive solar tactics to advance onset of the local strawberry season could enable farmers to command premium prices for early fruit without burning heating fuel. Consumers could benefit through increased access to high quality, locally-grown fruit.

The growing season for everbearing and day-neutral strawberries is often thought to coincide with the frost-free period. Southwest BC's mild winters offer a largely untapped potential for spring production to begin before the last frost and fall production to continue past first frost. This study is intended to foster appreciation for this potential and inspire and motivate others to test other crops and season extension methods.

This study examines two simple passive-solar season extension technologies, plastic low tunnels and polyester row covers. A plastic low tunnel is constructed from a single layer of transparent greenhouse plastic supported by wire hoops spanning a single growing bed. A row cover is a translucent, water-permeable spun-bonded polyester blanket laid directly over the crop. Both are used to retain heat. We predicted that the addition of a row cover protection under low tunnel for day-neutral strawberry plants will advance the growth and production of this crop so that it produces earlier in the spring shoulder season than the sole use of low tunnel or no protection at all.

Materials and Methods:

Study site and Experimental design

In June 2017, the experiment was established at the KPU orchard, located at the south end of Gilbert Rd. near the south arm of the Fraser River, Richmond, British Columbia, Canada (49°06'43'' N, 123°08'46'' W). Soils at this location were composed of shallow muck over Ladner silt loam. Using a completely randomized split plot design, a single 36.58 x 0.45 m raised bed was divided into eight main plots, 4.5 m in length, to which a low tunnel treatment and a control treatment were assigned in four replicates. Each main plot was then subdivided in two and assigned either a row cover treatment or control treatment. The four final treatments: the control, row cover only, low tunnel only, and low tunnel and row cover combination were equally distributed across 16 subplots. The strawberry plants (*Fragaria ananassa,* 'Albion' cultivar), were planted 15 cm apart, in two offset rows 30 cm apart, with plastic-mulch and drip irrigation using a flatbed hill system. Prior to bed formation, a layer of compost was spread evenly across the plot and incorporated with a BCS. Plots were hand weeded, and the aisles were hoed and covered with a mulch of dead corn stalks and straw. The main plots were irrigated based on water deficit.

Data collection and analysis

Between mid-March and late May (2018), counts were performed on 11 days for flower buds, open flowers, set fruits, and ripe fruits (marketable and unmarketable). Marketable fruit was defined as any fruit that is: firm, full of colour and free of rot (Guerena and Born 2017). Peak bud and flower dates, *d*, were calculated for each subplot as follows:

$$d = \frac{\sum_{m=03/16}^{05/22} bm}{\sum_{m=03/16}^{05/22} b}$$

Where *m* = monitoring date between 16 March and 22 May, expressed as Julian date and *b* = number of buds (or flowers). Data was tested for normality using the Shapiro wilk test. All data was normal except for mean buds per plant – this variable could not be transformed to create a normal distribution. An ANOVA was used to test for low tunnel and row cover effects, and any interaction between the two, on peak budding and flowering dates, and the number of buds and flowers produced per plant. All analysis were conducted in the R statistical computing environment.

Results:

Flower buds

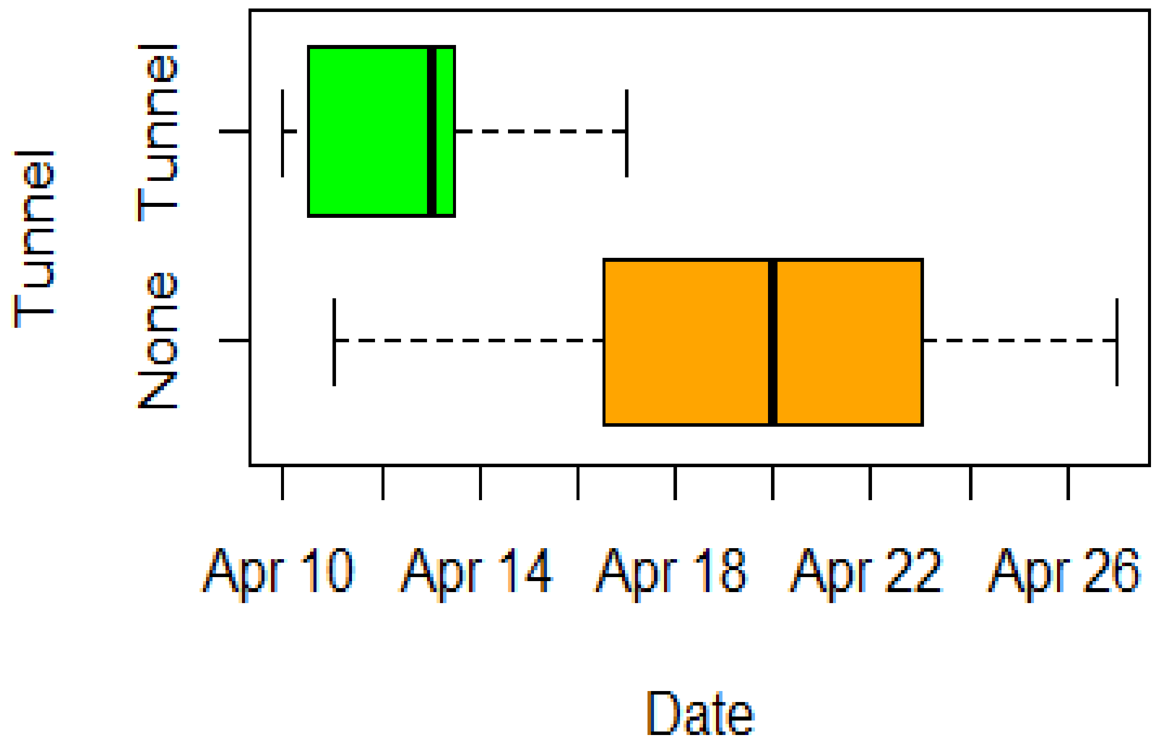
Both low tunnel and row cover advanced the peak budding date by one week relative to untreated controls (Fig. 1, $P < 0.01$). Combining row covers with low tunnels advanced peak budding date by two weeks (Fig. 2A). No significant interactions were observed between factors. No significant effects of treatments or interaction effects were detected on mean flower bud counts over the observation period.

Open flowers

Both low tunnel and row cover advanced the peak flowering date by almost two weeks relative to untreated controls (Fig. 3, $P < 0.01$). Combining row covers with low tunnels advanced peak flowering date by three weeks (Fig. 2B). No significant interactions were observed between factors. No significant effects of treatments or interaction effects were detected on mean flower counts over the observation period.

Fruit Set

The counts ended before peak fruit set was reached in the untreated control plots. and plots with season extension treatments had not yet finished a complete cycle (Fig. 4A).



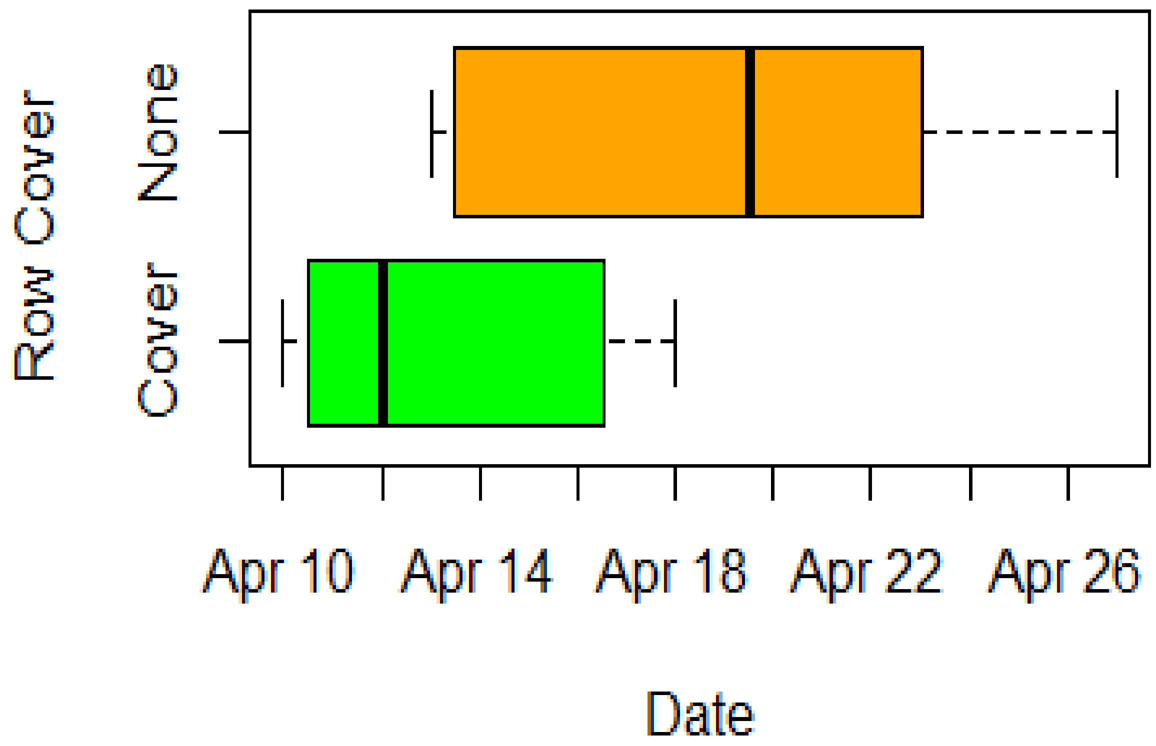
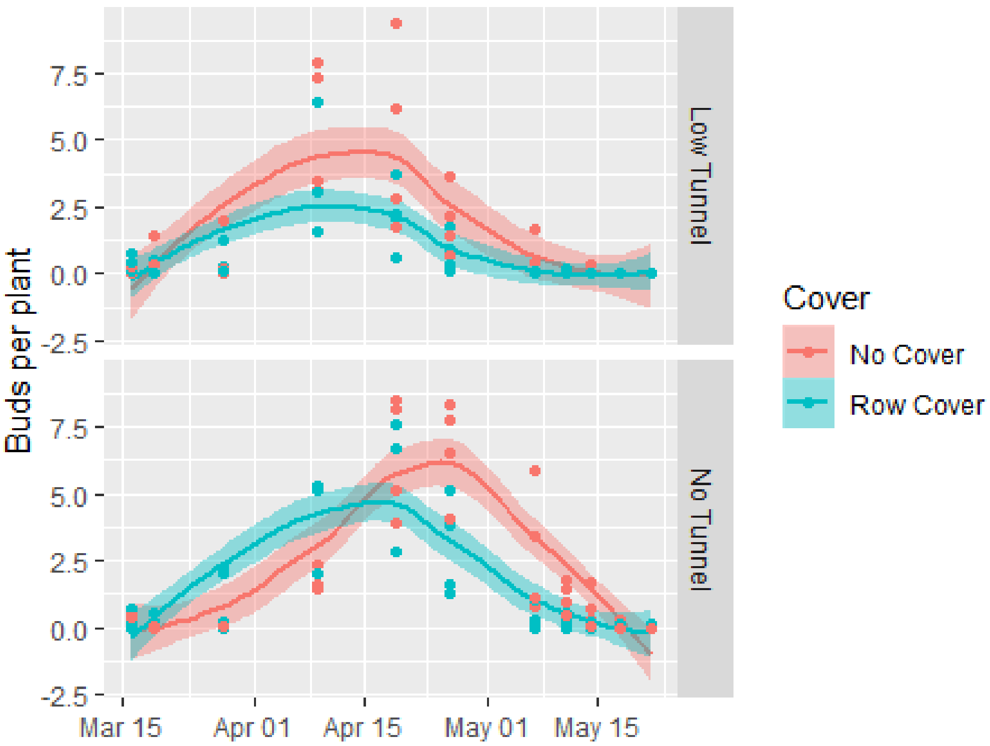


Figure 1. Peak budding date with, and without, low tunnels and row covers (top and bottom diagrams, respectively). Season extension treatments are represented by the green boxplots.

A



B

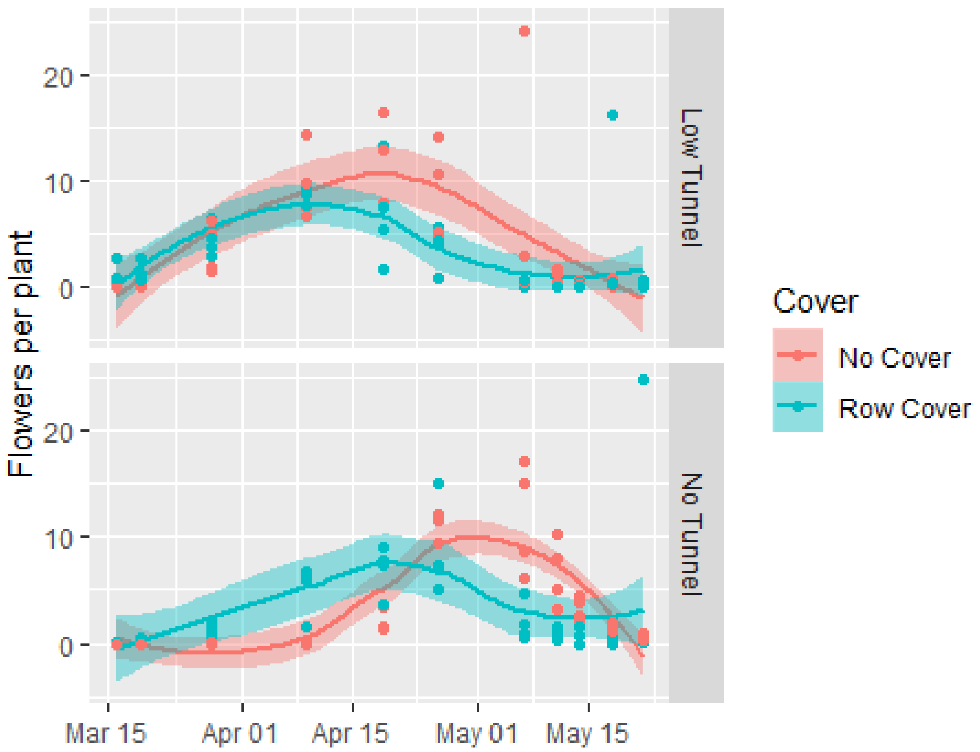


Figure 2. Count of flower buds (A), flowers (B), in day-neutral strawberry grown with, and without, plastic low tunnels (top and bottom of each chart, respectively) and row covers (blue and red, respectively) by date.

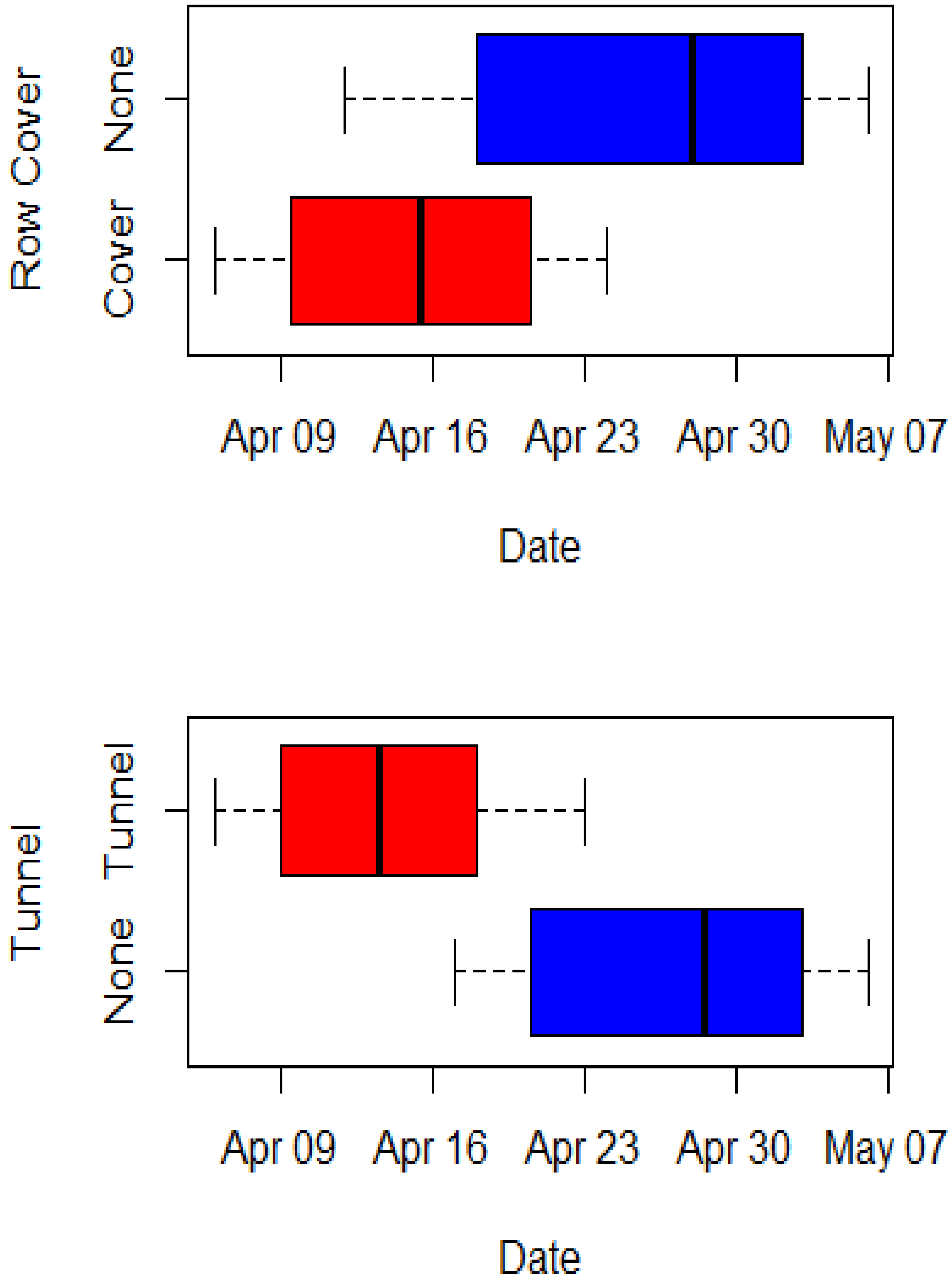
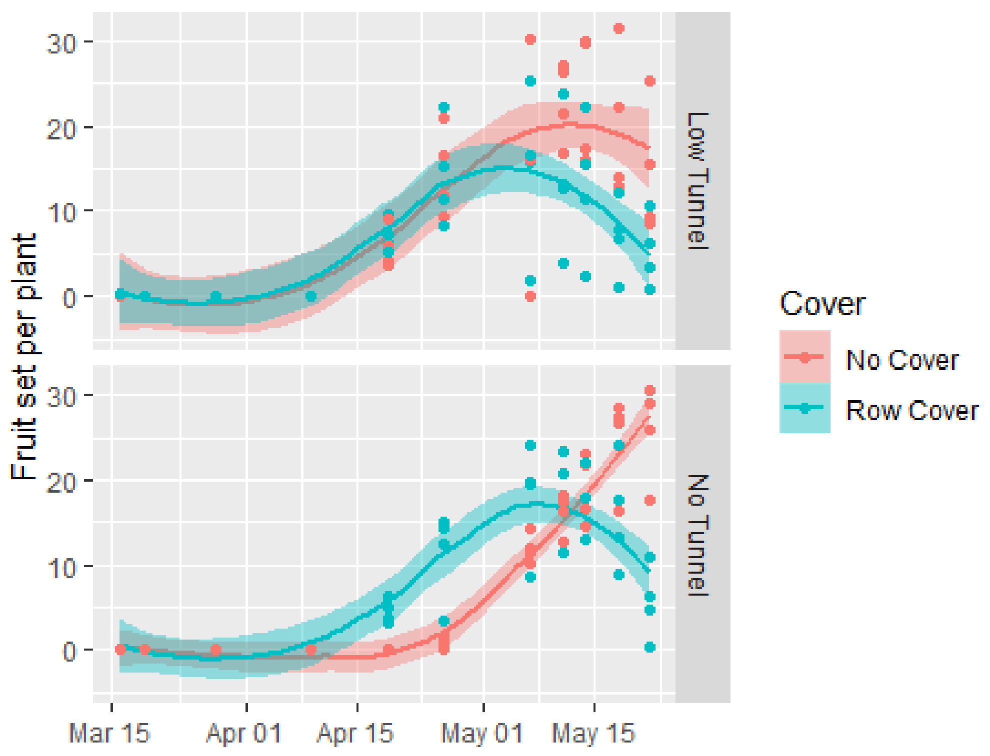


Figure 3. Peak flowering date with, and without, low tunnels and row covers (top and bottom diagrams, respectively). Season extension treatments are represented by the red boxplots.

A



B

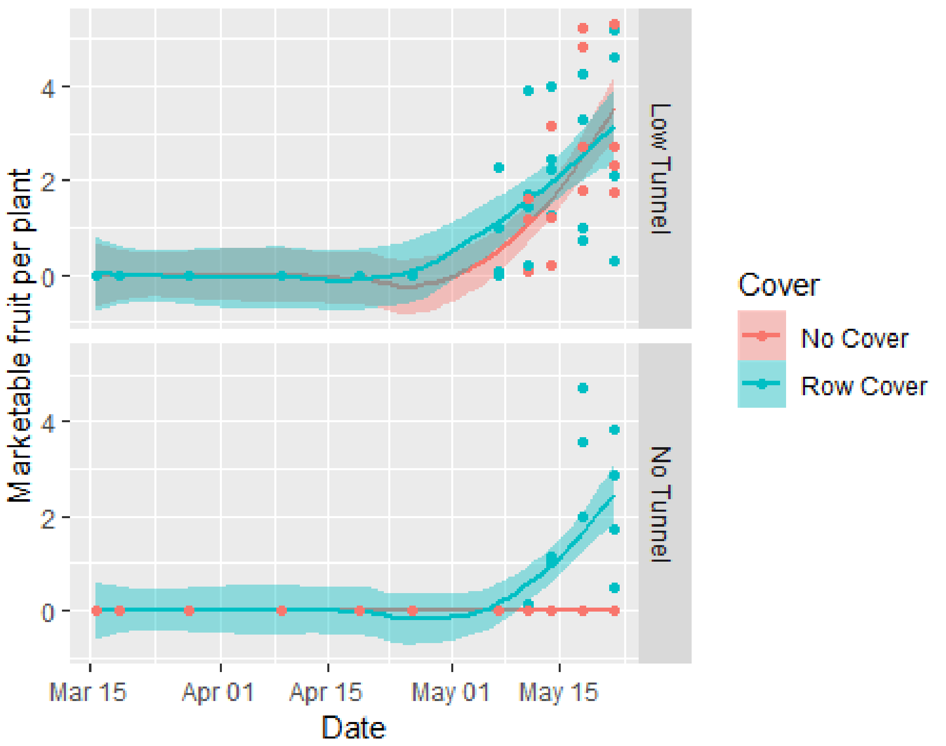


Figure 4. Count of fruit set (A), and marketable berries (B) in day-neutral strawberry grown with, and without, plastic low tunnels (top and bottom of each chart, respectively) and row covers (blue and red, respectively) by date.

Marketable fruit and Unmarketable fruit

Only subplots with season extension treatments yielded marketable fruit within the observation period, and none of these plots had reached the peak of their first fruiting cycle (Fig. 4B). An insignificant amount of ripe fruit was unmarketable.

Discussion:

The day-neutral strawberry plants initiated budding and flowering earlier under the low tunnel and row cover season extension treatments, leading to earlier harvest of marketable fruit, approximately two weeks before other farms in Richmond (Pers. Comm. with Rebecca Harbut). The mean flower bud and flower counts did not increase with row cover or tunnel treatments. These two findings suggest that season extension treatments may produce more flower buds and flowers over a season because even though the amount of flower buds and flowers were equal for the first cycle of all treatments, the season extension treatments would likely produce more flowering/fruiting cycles than the control. This phenomenon may in turn lead to higher yields, provided that the fruit quality of additional cycles is not diminished. Alternatively, the number of fruiting cycles may not significantly differ between any treatments because heat build-up under season extension treatments during midsummer may inhibit flower bud production, particularly under low tunnels, as the optimal temperature for strawberry production is 20-26°C (Van Sterthem 2013). Likely, a farmer would need to fertilize after each fruiting cycle and possibly remove the plastic low tunnel during the hottest part of summer to maximize the potential of day-neutral strawberry to produce fruit. Further research is needed to follow a complete first cycle of fruit production in spring, as well as any additional cycles throughout the season; and to determine the potential of plastic low tunnels and row covers to extend day-neutral strawberry harvest into the fall.

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