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# White-striped plastic mulch reduces root-zone temperatures during establishment and increases early season yields of annual winter strawberry

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ABSTRACT

Early-season yields are critical to winter strawberry (*Fragaria* ×*ananassa* Duch.) production in Florida and other winter and spring production regions around the world. Although advancing planting dates is a common practice to improve earliness, it can increase heat stress during establishment, especially on black plastic mulch. This problem could be addressed by adding a white center stripe to black plastic mulch. The white center stripe should cool the root zone during establishment while the black bed shoulders remain exposed to the sun to warm the soil during the winter. We conducted three field trials across two seasons to compare black plastic mulch (black mulch) to black plastic mulch with a white center stripe (white-striped mulch) using three cultivars (Florida Radiance, Florida Beauty, and Florida Brilliance). Bare-root transplants were planted on 26 Sept. in 2015 and 29 Sept. and 17 Oct. in 2016. Compared to black mulch, white-striped mulch reduced root-zone temperatures (10-cm depth) under the white stripe by up to 4.5 °C in November, while maintaining the same soil warming capacity on the bed shoulders throughout the growing season. White-striped mulch treatments resulted in increased growth, earliness, and yields, although the magnitude of improvement depended on cultivars and seasonal weather conditions. Early-season ambient temperatures were unusually high in the 2015–16 trial and the 2016–17 later-planted trial. In these two trials, white-striped mulch increased early yields by 20%–31% across cultivars. In the 2015–16 trial, white-striped mulch also increased canopy area by 11% during the early harvest period and root biomass by 26% at the end of the trial. Because late-season yields were unaffected in all trials, white-striped mulch only improved total yields for the second planting of 2016–17. By contrast, cultivar-specific effects were only observed for the first planting of 2016–17, in which white-striped mulch improved early and total yields of 'Florida Radiance' by 46% and 28%, respectively, compared to black mulch. Our results suggest that white-striped mulch is an easily implementable strategy for improving earliness of winter strawberry production in warm climates.

## 1. Introduction

Early season yields are critical to winter strawberry (*Fragaria* ×*ananassa* Duch.) production in Florida and other winter and spring production regions of the world, such as Queensland, Australia. The U.S. strawberry market data from 2012–17 show that on average, growers received $22.80 per 3.6-kg flat in November, steadily declining thereafter to $18.94, $14.38, $11.40, and $8.88 for the months of December through March, respectively (USDA, 2018). To capture price premiums associated with earliness, Florida strawberry growers typically plant in early to mid-October. For four to six weeks after transplanting, the plants are exposed to daily air temperatures as high as 34 °C while flower buds initiate and develop in the crowns and the plants establish a leaf canopy capable of supporting fruit production, which usually begins in mid-November. Yields gradually increase throughout the winter and spring, with peak production occurring in March. In both Florida and Queensland, the mild winter and early spring months offered by subtropical conditions make each state the primary producer of winter strawberries in their respective countries (Menzel and Smith, 2013). Yet in order to remain profitable growers require further improvements in early yield (Herrington et al., 2007; Wu et al., 2015).

For decades, the University of Florida has been attempting to help shift production into the early season through the development of new early-yielding cultivars, growing practices, and crop management recommendations (Chandler et al., 2009; Kirschbaum, 1998). Growers have also recently begun advancing transplanting dates from mid-October to late-September with the expectation that canopy establishment

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and yield will shift earlier in the season as well. As a result, fragile bare-root transplants are exposed to greater heat stress. For example, maximum daily air temperatures were around 34 °C in third week of September 2016, but dropped to only 28 °C during the second week of October 2016. During this period, soil temperatures can often rise above 35 °C, which is beyond the temperature at which growth inhibition begins to occur for strawberry (Hellman and Travis, 1988). Furthermore, heat stress conditions may be intensified using black plastic mulch, which has long been recommended for winter strawberries in Florida (Brooks, 1959).

It has been well-reported that white plastic mulch is effective at reducing soil temperatures in warm conditions (Tarara, 2000). In 1989, researchers in South Carolina published their findings that white mulch reduced the average maximum daily soil temperature during the spring tomato season by 4.8 °C compared to black mulch (Decoteau et al., 1989). Since that time, white mulch has been tested in combination with many other crops, including bell pepper (Diaz-Perez, 2010; Vos et al., 1995), strawberry (Albregts and Chandler, 1993; Shiukhy et al., 2015), and various Cucurbitaceae genera (Ahmed et al., 2017; Andino and Motsenbocker, 2004; Ibarra-Jiménez et al., 2008). The effects of white mulch for strawberry production have been inconsistent and seem to vary greatly depending on geographical location, climate, and cultivar selection (Albregts and Chandler, 1993; Hughes et al., 2013; Johnson and Fennimore, 2005; Pandey et al., 2015). The 1993 report by Albregts and Chandler showed positive trends of early yield improvement by entirely white plastic mulch for Florida strawberry production. However, they also showed that white mulch reduced late season yields compared to black plastic mulch, which is likely the reason white mulch was never adopted by subtropical strawberry growers.

The challenge of optimizing plant development and yield throughout the highly variable temperatures of a subtropical strawberry production season could be addressed by using plastic mulch that is white in the center and black on the shoulders. A white center stripe should cool the root-zone during establishment while the black shoulders remain exposed to warm soils during the colder months of peak production. Combining two different colors in one plastic mulch, mostly adding a black center stripe on reflective silver mulch, has been tested in several previous studies (Csizinszky et al., 1999; Diaz-Perez, 2010; Hutton and Handley, 2007). The observed beneficial effects of this multi-colored mulch compared to entirely black or silver mulch include increased soil temperatures during spring establishment (Diaz-Perez, 2010), increased reflected photosynthetically active radiation (Diaz-Perez, 2010), increased yield of bell pepper (Hutton and Handley, 2007), and reduced occurrence of virus symptoms in tomatoes (Csizinszky et al., 1999). To our knowledge, the approach of using black plastic mulch with a white center stripe for early season soil cooling and late season soil warming has not yet been tested for any crop production system.

The objective of the present study is to examine the effects of white-striped plastic mulch on soil temperature, plant growth, fruit yield, and earliness across three of Florida's most current early-yielding strawberry cultivars. 'Florida Radiance', which currently accounts for about 60% of Florida's strawberry market, is a short-day cultivar not recommended for September planting dates since high temperatures during fruit development can lead to elongated, sometimes unmarketable fruits. 'Florida Beauty' is an early-yielding cultivar released by the University of Florida in 2016. It is day-neutral and possesses a compact canopy, making it well-suited for advanced planting dates. 'Florida Brilliance', released in 2017, can quickly establish a robust and open canopy before producing relatively high early season yields. It will be important to understand how white-striped mulch affects strawberry cultivars with varying heat stress sensitivity and growth characteristics. To conduct our trial in accordance with recent growing trends, we examined the effect of white-striped mulch when planting was advanced to late September in two seasons.

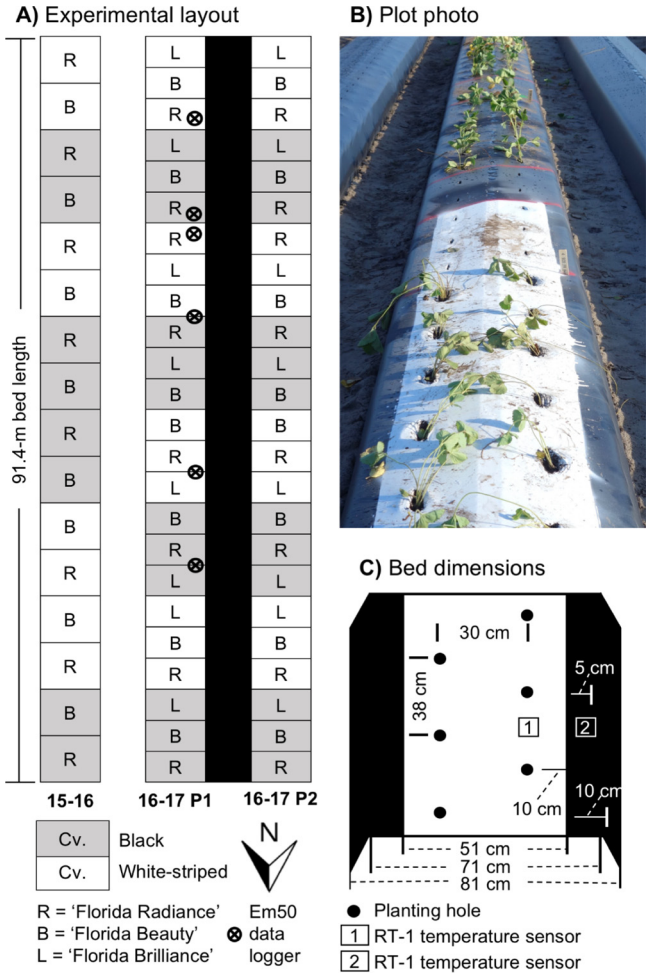


**Fig. 1.** (**A**) Experimental layout in the 2015–16 and 2016–17 seasons. The mulch type and cultivar for each plot as well as data logger placement are given. (**B**) A representative photo of 'Florida Radiance' transplants on white-striped mulch (foreground) and black mulch (background) taken on 29 Sept. 2016. (**C**) Overall bed width, shoulder width, and white stripe width are provided alongside placement of planting holes and root-zone temperature sensors.

## 2. Materials and methods

### 2.1. Plant establishment and treatments

Strawberry (*Fragaria ×ananassa* Duch.) field trials were conducted at the University of Florida Institute of Food and Agricultural Science Gulf Coast Research and Education Center in Balm, FL during the 2015–16 and 2016–17 seasons. The site's soil (Myakka fine sand siliceous hyperthermic Oxyaquic Alorthod) had a pH and organic matter content of 6.8 and 1.5%, respectively. In both seasons, 91.4-m long pressed beds were prepared in late August. To reduce the occurrence of weeds and soil pathogens, the beds were fumigated according to commercial standards with PicClor 60 (1,3-dichloropropene + chloropicrin; 122.5 kg/ acre). Each bed had one line of drip irrigation tubing (0.87 l 30.5 $m^{-1}$ $min^{-1}$, 30.5 cm emitter spacing) laid 2.5 cm deep at the bed's center. The beds were then covered with black 0.7-mil thick high density polyethylene mulch.

A map of the experimental layout for each season is given in Fig. 1A. In mid-September of both seasons, half of the plots on each bed had a 51-cm wide white stripe applied (Fig. 1B) to the bed center using inverted marking paint (Rust-oleum Corporation, Vernon Hills, IL). Paint was applied in a uniform, opaque layer such that the black mulch was completely covered within the 51-cm wide center stripe. Bare-root