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Influence of Summer Cover Crops on Organic Strawberry Production

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In this study, two summer legumes, sunn hemp (*Crotalaria juncea* L.) and hairy indigo (*Indigofera hirsuta* L.), were grown and incorporated into the soil prior to planting a strawberry crop. A weedy fallow was included as a control. Plug plants of three strawberry cultivars including Sensation™ 'Florida127', Winterstar™ 'FL 05-107', and 'Strawberry Festival' were transplanted on 9 Oct. 2014. The experiment was conducted in an open field on certified organic land at the Plant Science Research and Education Unit in Citra, FL. A split plot design with four replicates was used. Cover crop management was the whole plot factor and strawberry cultivar was the subplot factor. Summer cover crops had no significant effect on plant growth and strawberry yield performance, whereas some significant differences were observed among strawberry cultivars. 'Strawberry Festival' showed the lowest chlorophyll content index during the early season. In terms of fruit yield components during the production season, 'Florida127' had the greatest average fruit weight but the lowest number of marketable fruit, while 'Strawberry Festival' was the opposite. No significant difference was found in marketable or total fruit yield among the three cultivars.

Strawberry (*Fragaria* x *ananassa* Duch.) is an important small fruit crop in the United States, which generated approximately $2,865 million in 2014 (U.S. Department of Agriculture, 2015). While the majority of the U.S. strawberry production is conventional, consumer demand for organic strawberries has been increasing in recent years, and interest in organic strawberry production is growing among producers. Florida is the second largest strawberry producing state, behind California, due to its focus on winter strawberry production.

The National Organic Program requires the use of cover crops as a part of the management strategy for soil fertility and conservation. Summer cover crops can be grown prior to the strawberry season and incorporated into the field before planting. Cover crops benefit the soil by contributing organic matter, reducing soil compaction, suppressing weeds, and preventing soil erosion. Moreover, leguminous cover crops can fix atmospheric nitrogen (N), leading to increased N availability (Muramoto et al., 2011; Parr et al., 2014). Sunn hemp and hairy indigo are two common legumes, which can produce around 12,000 and 8,000 kg/ha dry biomass, and contribute 100–200 and 100–150 kg/ha of N, respectively (Linares et al., 2008; Newman et al., 2010). These cover crops are also non-hosts or poor hosts to the sting nematode (*Belonolaimus longicaudatus*), a key pest of Florida strawberries (Noling, 2015)

Preplant legume cover crops may affect the growth and yield of strawberries because of the extra N provided and other benefits to the soil. In previous studies, results have varied. A study conducted in Iowa showed that cover crops not only suppressed weed populations and reduced weed biomass, but also influenced plant establishment and yield (Portz et al., 2011). However, a study conducted in North Carolina showed that cover crops only suppressed weed populations, while no effect on strawberry growth or yield was found (Garland et al., 2011).

Summer cover crops have been used in organic strawberry systems in Florida; however, research-based information is rather limited. This study was conducted to assess growth and fruit yield of three strawberry cultivars with hairy indigo and sunn hemp cover crops planted during summer and incorporated prior to the strawberry season.

Materials and Methods

The field trial was conducted on certified organic land at the University of Florida Plant Science Research and Education Unit (PSREU) in Citra, FL. Two summer cover crops, sunn hemp and hairy indigo, were planted on 15 July 2014 at a seeding rate of 44.8 kg/ha and 22.4 kg/ha, respectively. After two months of biomass accumulation, cover crops were flail mowed and incorporated into the soil before flowering on 18 Sept 2014. Raised beds with black plastic mulch and drip irrigation were used. Three short-day strawberry cultivars were used in this study: Sensation™ 'Florida127', Winterstar™ 'FL 05-107', and 'Strawberry Festival' (released by University of Florida in 2013, 2011, and 2000, respectively). Strawberry plugs (Luc Lareault Nursery, Lavaltrie, Quebec, Canada) were transplanted into the organically managed field on 9 Oct. 2014. A split plot design with four replicates was used in this experiment, with whole plots arranged in a randomized complete-block design. The two cover crops and a weedy control were the whole plot treatments and the three strawberry cultivars were the subplot treatments. There were 80 plants per replicate in each treatment, grown in two rows spaced at 0.3 m across the bed. The spacing between bed centers was 1.5 m with the plant spacing at 0.3 m.

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Preplant fertilization used an N rate of 84 kg/ha with MicroSTART60 3N–0.87P–2.49K and Bone meal 7N–5.24P–0K. Weekly fertigation with GATOR 96002/3N–0P–4.98K Organic Liquid was applied at the N rate of 0.67 kg/ha per day starting 14 Nov. 2014. This was adjusted to 1.12 kg/ha and 1.34 kg/ha per day on 15 Dec. 2014 and 6 Mar. 2015, respectively.

Strawberry growth measurements included the number of leaves, crown and canopy sizes, and leaf chlorophyll content index. Measurements were carried out throughout the strawberry season at early stage, peak harvest, and late season. Leaf chlorophyll content index was measured using a SPAD 502 Plus Chlorophyll Meter (Spectrum Technologies, Inc., Aurora, IL) and expressed as a unitless SPAD value. Open flowers were counted three times in Nov. 2014 and runners were removed on 18 Nov. and 2 Dec. 2014.

Strawberries were harvested twice per week at the red ripe stage with calyxes attached from Nov. 2014 to Apr. 2015. A marketable strawberry fruit was defined as over 5 g in weight, with 80% fully red color on surface, free of decay, disease, or mechanical injury. Marketable and cull fruit numbers and weights were determined. Total marketable fruit weight came from a composite of 30 harvests. Yields from the first 9 harvests (Nov.–Dec. 2014) were classified as early yield.

Analysis of variance was performed using the Glimmix procedure of SAS statistical software package for Windows (Version 9.2; SAS Institute, Cary, NC). Multiple comparisons for all the measurements were conducted using Fisher's Least Significant Difference (LSD) test at $\alpha = 0.05$.

Results and Discussion

Overall, summer cover crops did not show any significant effects on plant leaf number, canopy or crown size (Table 1) or strawberry yield during the entire season. Some significant differences were observed among the strawberry cultivars (Table 2).

In terms of early-season open flower and runner counts, significant differences were found among strawberry cultivars (Table 3). 'FL 05-107' had the greatest open flower counts but the lowest number of runners, whereas 'Florida127' showed more runners than 'FL 05-107'. The three strawberry cultivars also differed significantly in leaf chlorophyll content index during Nov.–Dec. 2014 (Table 4). 'Strawberry Festival' consistently showed the lowest chlorophyll content index value, while it also tended to have a smaller canopy and fewer leaves (data not shown).

With respect to early fruit yield, 'Florida127' had the greatest average fruit weight, but the lowest number of marketable fruit. By contrast, 'FL 05-107' had the highest number of marketable fruit as well as total fruit number. 'Strawberry Festival' had the lowest marketable yield as well as total yield (data not shown). For fruit yield components during the production season, strawberry cultivars had some pronounced effects as well (Table 5). 'Florida127' had the greatest average fruit weight but the lowest number of marketable fruit, while 'Strawberry Festival' was the opposite. No significant difference was found in marketable or total fruit yield among the three cultivars.

These results demonstrated that cultivar differences outweighed the effect of summer cover crops on plant growth and yield per-

Table 1. Analysis of variance of the effects of cover crop (CC) and cultivar (cv) on strawberry growth parameters during the growing season (Nov. 2014–Apr. 2015) in Citra, FL.

		Leaf number per plant					Canopy size (cm)					Crown size (cm)				
Effect	df	14 Nov.	18 Dec.	22 Jan.	12 Mar.	24 Apr.	14 Nov.	18 Dec.	22 Jan.	12 Mar.	24 Apr.	14 Nov.	18 Dec.	22 Jan.	12 Mar.	24 Apr.
CC	2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
cv	2	ns	ns	ns	***	**	**	ns	ns	ns	ns	ns	ns	ns	ns	ns
CC x cv	4	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

ns, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 2. Analysis of variance of the effects of cover crop (CC) and cultivar (cv) on strawberry yield components during the production season (Dec. 2014–Apr. 2015) in Citra, FL.

Effect	df	Marketable fruit number per plant	Marketable weight per plant	Total fruit number per plant	Total fruit weight per plant	Average marketable fruit weight
CC	2	ns	ns	ns	ns	ns
cv	2	***	ns	ns	ns	***
CC x cv	4	ns	ns	ns	ns	ns

ns, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 3. Cultivar effects on runner and open flower numbers of strawberry during early stage in Citra, FL (cumulatively throughout Nov.–Dec. 2014).

Cultivar	Runner (no./plant)	Open flower (no./plant)
Florida127	0.14[z] a	0.6 b
FL 05-107	0.04 b	1.2 a
Strawberry Festival	0.09 ab	0.6 b

[z]Means within the same column followed by the same letter do not differ significantly by Fisher's least significant difference test at $P \leq 0.05$.

Table 4. Cultivar effects on leaf chlorophyll content index of strawberry during early stage in Citra, FL (Nov.–Dec. 2014)

	Chlorophyll content index (SPAD value)		
Cultivar	14 Nov.	2 Dec.	18 Dec.
Florida12'	46.6[z] a	48.2 b	50.7 b
FL 05-107	47.0 a	50.2 a	52.5 a
Strawberry Festival	40.3 b	44.2 c	48.2 c

[z]Means within the same column followed by the same letter do not differ significantly by Fisher's least significant difference test at $P \leq 0.05$.

Table 5. Cultivar effects on total and marketable strawberry yield during the 2014–15 production season, Citra, FL.

Cultivar	Marketable fruit number (no./plant)	Average marketable fruit weight (g/fruit)	Marketable fruit yield (g/plant)	Total fruit yield (g/plant)
'Florida127'	10.8[z] c	22.8 a	245.7 a	399.3 a
'FL 05-107'	12.8 b	18.0 b	230.0 a	385.1 a
'Strawberry Festival'	14.9 a	14.8 c	219.4 a	352.7 a

[z]Means within the same column followed by the same letter do not differ significantly by Fisher's least significant difference test at $P \leq 0.05$.

formance of organically grown strawberry in the present study. Initial weed infestation during the cover cropping period was low in the weedy fallow and did not differ from the cover crop treatments (Chase unpublished). Additionally, no sting nematodes were identified in soil sampled at this location (Chase unpublished). It was likely that nutrients, especially nitrogen, were not limiting in the plots without summer legumes. Another possibility is that nutrient release from the cover crops as green manure did not match the crop's needs for fruit yield development. Nutrient needs of crops vary during the different stages of development, so it is critical that appropriate nutrients be made available at the right time, right rate and right place (Roberts, 2007). In addition, the alteration of soil C:N ratios by incorporating cover crops might have influenced nutrient bioavailability. Long-term effects of cover crops need to be measured in order to elucidate the impacts of summer legumes on plant growth and yield performance of strawberry under organic production. Moreover, future studies also need to address the potential influence of summer cover crops on strawberry quality attributes.

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