Journal of the American Pomological Society 74(3): 169-179 2020

Reflective Mulch Application and Cover Crop Usage to Stimulate Earlier Banana Flowering

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Additional index words: Musa spp., crimson clover *(Trifolium incarnatum)*, hairy vetch *(Vicia villosia.)* bahiagrass *(Paspalum notatum)*

Abstract

Bananas possess unique potential as a specialty crop, but require considerable inputs making their production cost prohibitive for smaller farm operations. Innovative production practices of interest are the incorporation of reflective mulches and cover crops in banana production systems. Reflective mulches and cover crop effects on banana phenology were documented under sub-tropical conditions of the Alabama Gulf Coast. Flower emergence of *Musa* AAB (Mysore subgroup) was 5 days earlier in plants grown on white mulch, but was delayed by 26 days on reflective silver mulch compared to the control. Banana bunches from plants on white or reflective silver mulch were 27% and 15% heavier and were produced on pseudostems that were 12% and 3% taller, respectively, compared to control bunches. *Musa* ABB 'Dwarf Orinoco' bananas were planted into experimental plots of crimson clover (*Trifolium incarnatum*), hairy vetch (*Vicia villosia*) or into natural cover that was 60% bahiagrass (*Paspalum notatum*) as the control. Banana leaf area was 24% greater in the crimson clover and 10% greater in the hairy vetch compared to the control. Banana pseudostems in crimson clover and hairy vetch were 20% and 8% taller, respectively, than those of the control. Use of mulches or cover crops provided slight gains in advancing productivity of sub-tropical banana cultivars in the Alabama Gulf Coast.

The development of cold-tolerant, short-cycle banana cultivars has made production possible beyond the tropics into the cool subtropical regions of the U.S. (Lahav and Lowengart, 1998). In coastal Alabama, cardinal temperature range of 14 °C to 31 °C (Robinson, 1996) for bananas is maintained for approximately 7 months, and temperatures below this range are not usually lethal to the below ground rhizomes as new ratoon plants or suckers are generated after exposure to warm spring temperatures (Vinson et al., 2018). Unfortunately, suboptimal conditions can result in reduced growth rates and delayed flowering and harvest in the cooler subtropics.

Reliable and consistent production of bananas in the subtropics will need cultural practice modifications to encourage a shortened cropping cycle and harvest within the frost-free production window to make economic banana production in the cooler subtropics possible.

Improving light environment. High planting density, which is common in banana production systems, encourages a slower leaf emergence rate (LER), which results in delayed cropping cycles (Daniels et al., 1985; Robinson and Nel, 1989; Turner, 1972). In the densely populated banana monocultures, leaves of the upper canopy receive full sun, but partially shade the lower profile leaves. Shaded leaves adjust to decreasing light, maintaining a positive carbon balance, but the continued addition of leaves to the upper canopy ultimately increase shade below the limits of compensation, causing leaf senescence (Brouwer et al., 2012). Subsequent leaf yellowing, which is largely a genetic factor, is the result of the eventual degradation of chlorophyll (Schelbert et al., 2009; Yoshida, 1962).

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Alternatively, increased light penetration improves LER, reduces number of leaves required prior to flowering, and therefore, encourages a shorter production cycle (Robinson, 1996). Reflective plastic mulch and fabrics previously investigated as alternative strategies for deterring insects, reducing vectored disease-causing agents, and improving yields (Csizinszky et al., 1995; Adlerz and Everett, 1968; Brown and Brown, 1992; Wolfenbarger and Moore, 1968) has potential to improve light environment of lower profile banana leaves. Specifically, white reflective fabric was demonstrated previously to improve light environment, increasing photosynthetic activity by as much as 95% and yield by 18% in mature, low-density 'd' Anjou' pear orchards. The resulting yield increase was attributed to enhanced fruit set in the lower canopy (Einhorn et al., 2012). Reflective fabrics may be a practical modification of banana production systems with the goal of reducing banana production cycles, which is necessary for the relatively short production season of the subtropics.

Cover Crop Usage in Banana Production

Cover cropping is one of the most important sustainable practices used in global management strategies in agricultural systems to improve soils by increasing organic matter, nutrient cycling, N fixation, and increase yield of target crops (Baligar et al., 2006; Robinson, 1996; Lu et al., 2000; Tixier et al., 2011; Hayden et al., 2012). Though cover cropping is not a new technology, there has been a surge in the incorporation of cover crops in agricultural systems as it reduces inputs and suppresses pests by reintroducing biodiversity (Tixier et al., 2011). In some cases, incorporation of cover crops eliminates the use of pesticides, controls soil erosion, and reduces depletion of natural resources (Lu et al., 2000).

Intensive banana production systems usually involve bare ground and therefore require large quantities of pesticides and fertilizers, which presents challenges for delicate environmental systems around the world (Tixier et. Al., 2007). Cover crops increase sustainability by lowering inputs more effectively than some conventional cultural practices such as polyethylene mulch. For example, hairy vetch (*Vicia villosia*) fixed enough N (280 kg • ha^{-1}) to overall inputs in a tomato planting system that used synthetic fertilizer and plastic mulch by $371 per ha in inputs. A suitable cover crop should produce sufficient biomass to effectively outcompete weeds while not competing with the main crop. Cover crops are usually evaluated in terms of main crop yield performance relative to bare ground (Costello and Altieri, 1994; Tixier et al., 2011).

The objective of this study was to determine the effects of reflective mulch cover materials and the incorporation of crimson clover and hairy vetch cover crops on the phenology and physiology of banana plants. The first hypothesis was that reflective ground cover materials would enhance the light environment of understory banana leaves providing a reduction in crop cycle time. This is important for banana production in subtropics that are subject to frosts and shorter cropping seasons compared to tropical regions. The second hypothesis was that both main crop (bananas) and secondary crop (cover crop) could be mutually cultivated without creating adverse effects on the phenology of the main crop.

Materials and Methods

Reflective mulch. A study designed to test the effects of two reflective mulch materials on phenology of banana plants was established at the Gulf Coast Research and Extension Center (GCREC) near Fairhope, AL (30°31'35.018" North, 87°53'44.473" West) on 10 July 2014. *Musa* AAB (Mysore subgroup) 'Mysore' bananas obtained from tissue culture (Agri-Starts Inc, Apopka, FL) were planted on existing centipede turf (*Eremochloa ophiuroides*) on a Malbis sandy loam soil. A tiller was used to establish raised beds that were 0.9 m wide and 0.15 m high. Experimental plots consisted of three bananas spaced 2.4 m apart within a row and rows were set on 6 m centers. Row spacing was selected to prevent confounding effects of reflective mulches. Existing turf was maintained between rows.

Silver reflective, high density, polyethylene film (Wilson Orchard and Vineyard Supply Yakima, WA) with a thickness of 0.025 mm, and white woven polypropylene ground cover fabric with weight of 0.1 $kg \cdot m^{-1}$ were used to form panels 7.3 m long and 2 m wide. To improve durability of the silver metallic mulch, white, woven polypropylene fabric was attached to the underside of the silver mulch material. Mulch panels were installed on 20 April 2015. Panels were placed parallel to and on both sides of the raised beds leaving a 0.6 m gap between panels to accommodate the expanding banana mats, which consisted of previous and current season below ground and aboveground banana plant growth. Panels were fastened in place using metal stakes. As the control, centipede sod was allowed to persist uncovered by a mulch treatment and vegetation was controlled with periodic applications of Glufosinate ammonium broad-spectrum herbicide.

A randomized complete block design with six replications was used. Each block was 30 m long and contained three experimental plots spaced 4.3 m apart. Irrigation was supplied at a rate of approximately 50 mm of water per week. In addition, precipitation was distributed in a mostly consistent manner in Fairhope area during the entire growing season (Fig. 1). Bananas were fertilized according to the recommendations of the Agricultural and Environmental Services Laboratories of the University of Georgia, USA. In 2014 and 2015, 20N–0P–0K and 0N–0P–41.5K were supplied to bananas by injections through the irrigation system at rates of 200 $kg \cdot ha^{-1}$ and 40 $kg \cdot ha^{-1}$, of N and K, respectively.

The parent crop (PC), which were the initial banana plants in the first season, along with the ratoon crop (R_1) or suckers, succumbed to low temperatures during the winter of 2014-15. The R_1 plants were allowed to grow from the rhizomes the following season. Ratoon plants reached the mature vegetative stage indicated by the emergence of mature leaves (leaves 10 cm in width) (Robinson and Galán-Saúco, 2010) by 18 March 2015. Winter-damaged pseudostems of the

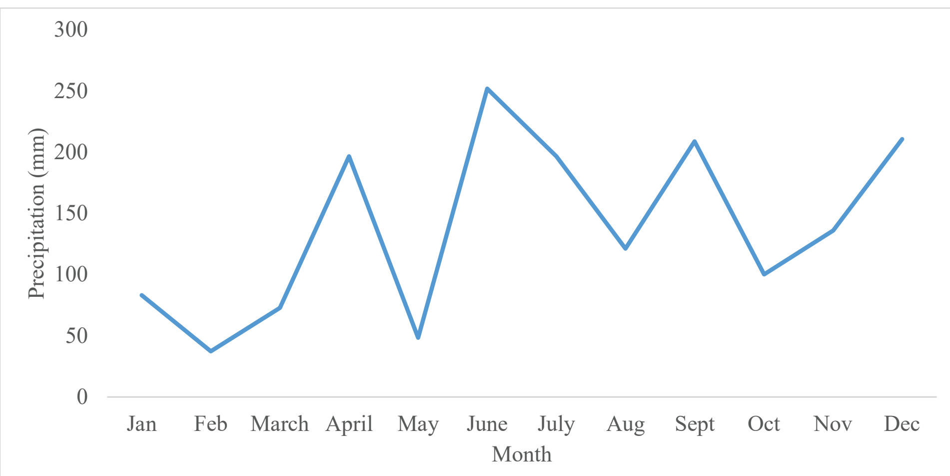

Fig. 1. Mean monthly precipitation at the Gulf Coast Research and Extension Center in 2015, Fairhope, AL

PC were cut to a height of 0.5 m and suckers were selected to replace the PC on 20 April 2015. Soil temperature and moisture data were collected using probes interfaced with WatchDog 1200 Microstation dataloggers (Spectrum Technologies, Aurora, IL) placed in each experimental plot. Soil temperature, was measured using an external temperature probe and on a 2.5 m cable (Spectrum Technologies, Aurora, IL). The soil moisture probe used was a WaterScout SM 100 soil moisture capacitance sensor probe (Spectrum Technologies, Aurora, IL) which measured percent volumetric water capacity by measuring the dielectric permittivity of the soil. Both temperature and moisture probes were set at a depth of 20 cm, underneath the mulch panel 0.15 m from the base of the banana mats. In the mulch treatments, this resulted in the probes being placed underneath the plastic 0.05 m from the edge of the plastic.

Phenology data were collected at flowering. Data collection consisted of pseudostem height (measured from base of the plant to the bifurcation formed by the top two leaf petiole bases), pseudostem circumference (measured 30 cm above the ground), leaf length and width (widest portion) of the third leaf of the plant profile, leaf emergence rate as measured by the number of fully expanded leaves generated semi-monthly, number of leaves present, and leaf area index (LAI) calculated from equation 1 (Nyombi et al., 2009). Production efficiency (ratio of total bunch weight to the non-edible rachis weight of the banana bunch).

Equation 1. $$\text{LAI} = \frac{(\text{LAF x L x W}) \text{ x NLP}}{\text{Plant area spacing}}$$

Where LAF is the leaf area factor which is 0.8, L is the leaf length and W is the leaf width (Potdar and Pawar, 1991). Length and width were determined from the third profile leaf. These values were then multiplied by NLP, which was the number of leaves present at time of data collection. To measure production efficiency, total bunch weight was determined. Bunches were then stripped of banana hands and the weight of the rachis was recorded. Finally, total bunch weight was divided by rachis weight.

Flowering data were days to flower emergence (DFE) counted from date of the emergence of the first mature leaves. Flower emergence occurred when the first set of flowers on the inflorescence was exposed.

Light and photosynthetic activity were measured with an open system TPS-2 photosynthesis analyzer (PP systems, Amherst, MA) in clear, sunny conditions. Light was measured at the central plant 55 days from mature leaf (DFM) at 1200 h and 1230 h. Light and reflectance were measured 60 cm above ground and approximately 60 cm from the pseudostem on the east and west facing sides of the plant. To measure reflectance, the sensor was facing 90° from vertical. A PLC4 broad leaf cuvette was used to measure photosynthetic activity using ambient light from a leaf area of 2.5 cm^2. Photosynthesis was measured at the mid-section of the second and fourth leaf from the top and bottom leaf (leaf 7 or 8) of the leaf profile.

A Minolta SPAD-502 chlorophyll meter (Spectum Technologies, Aurora, IL) was used to measure leaf greenness, which is linearly correlated to chlorophyll content. Leaf greenness was measured on leaves 3 and 5 at 135 d from mature leaf. SPAD measurements were taken from both laminal halves on all three plants in the plot, yielding 12 readings per plot.

Cover crop. An on-farm study to determine the effects of two cover crops on the phenology of *Musa* ABB 'Dwarf Orinoco' bananas was established in Grand Bay, AL, (30° 31' 56.3952" Latitude and -88° 20' 29.9862" Longitude). The designated area was formerly pastureland and the soil type was a Heidel sandy loam. Experimental plots with the dimension of 6 m × 7.3 m were established in Nov. 2013. Experimental plots were replicated five times and arranged in a completely randomized design. Soil samples were collected from each experimental plot to determine initial organic matter content, soil fertility and lime requirements. Crimson clover (*Trifolium incarnatum*) and hairy vetch (*Vicia villosia*) cover crop treatments were then seeded at recommended rates. A control experimental plot consisted of the natural, pre-established cover that was ~ 60% bahiagrass (*Paspalum notatum*).

Biomass samples were collected after cover crops reached full bloom and maximum ground cover in May 2014. Biomass samples were collected by randomly selecting two quadrangular sections with an area of 0.1 m^2 each within each experimental plot. Biomass samples were oven-dried and used to determine C and N content. Cover crops were allowed to persist and decompose on the soil surface. Five bananas were planted in each experimental plot on 4 June 2014. Planting was done by establishing a two-plant row of bananas spaced by 2.4 m on opposite sides of each experimental plot. These two-plant rows were spaced by 3 m. A single banana plant was then placed at the center of the plot resulting in five plants per plot and final plant spacing of 7 m^2 per plant. Growth measurement data were taken from the center plant while outer plants served as guard plants.

Drip irrigation consisted of 16 mm polyethylene tubing with two manually installed emitters at a spacing of 2.4 m for delivery at each plant. Emitters were designed to deliver 7.6 $L \cdot h^{-1} \cdot m^{-1}$ of water. Bananas received 25 mm of water per week through the irrigation system. Additional moisture was supplied through rainfall distributed such that most was received during early and later stages of development (Fig. 2).

Fertility was supplied based on recommendations of the Agricultural and Environmental Services Laboratories of the University of Georgia, USA. From June through August, three 1 kg monthly applications of potash (0N–0P–60K) were hand-applied 30 cm from the base of each plant in circular fashion at a rate of 141 $kg \cdot ha^{-1}$ K.

Cover crop and control experimental plots were mowed on four occasions after cover crop biomass had completely senesced, and the previously established bahiagrass and other weed species became dominant. Mowed plant material was allowed to remain on the surface of each plot for the benefit of nutrient recycling and moisture retention. Banana growth data were collected from the centermost plant in each experimental plot

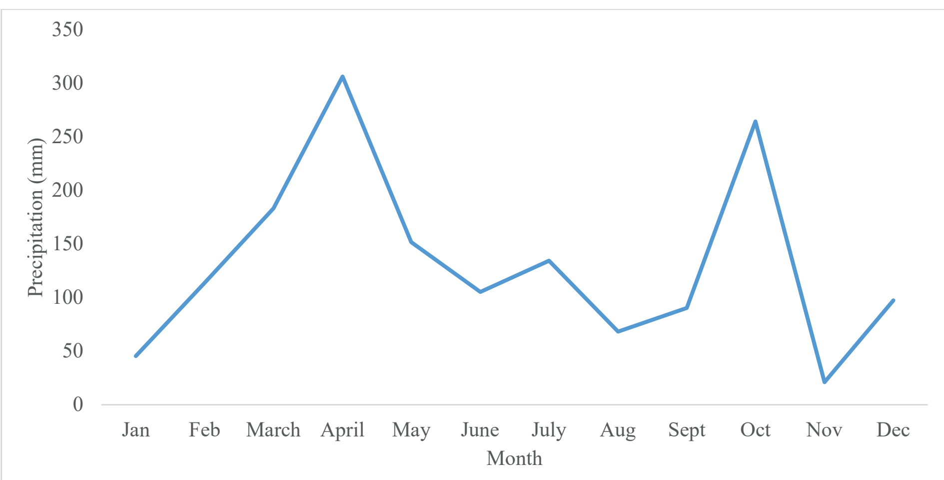

Fig. 2. Mean monthly precipitation at an on-farm location in 2014, Grand Bay, AL

and consisted of growth parameter data such as pseudostem height (determined by measuring from the base of the plant at ground level to the bifurcation of the petiole bases of the top two leaves), pseudostem circumference (measured 30 cm above the ground), leaf area (cm^2 of third leaf multiplied by number of leaves present) emergence rate (number of leaves generated per month). Final soil samples were taken in Oct. 2014.

Statistical analyses. An analysis of variance was performed on all response variables using PROC GLIMMIX in SAS version 9.4 (SAS Institute, Cary, NC).

An analysis of covariance was examined for all responses using PROC GLIMMIX in SAS version 9.4 (SAS Institute, Cary, NC). The treatment design was 1-way with mulches. The experimental design was a randomized complete block. Measured soil moisture and air temperature were included in the model as covariates when there was a significant linear relationship between the response and the covariate(s). A full model with interactions between the covariates and mulch treatments were considered. None of the interactions were significant. Non-significant interactions and covariates were dropped from the final model. Reported least squares means were adjusted for the covariate(s). All possible paired comparisons among mulches were determined using the simulate method. All significances were at $P < 0.05$.

Results

Reflective Mulch. There were differences in soil temperature among the treatments (Table 1). Silver reflective mulch increased temperature significantly above that of the white reflective mulch and the bare ground treatments. Average soil moisture for these treatments was 9.0 %, 10 %, and 8.7 %, respectively, but there were no differences found in soil moisture (data not shown). Light reflectance and interception measured in reflective mulch treatments were significantly increased over the control treatment (Table 1). White fabric treatment increased light reflectance compared to the control by 3.7 fold and 4.1 fold on both East and West facing sides, respectively. Most light interception occurred on the west facing side of banana plants as there was a 2.2 fold increase compared to the control.

In silver mulch reflective treatments, there was a 5 fold increase and 3.7 fold increase in light reflectance compared to the control on East and West facing sides, respectively. As was the case in white reflectance treatments, most light interception occurred on

Table 1. Light reflectance of white fabric and silver film as measured by photosynthetically active radiation (*PAR*). Gulf Coast REC, Fairhope, AL.

Trt	Temp °C	[z]East Reflect. ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	[y]West Reflect. ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	[x]East Intercept ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	[w]West Intercept ($\mu mol \cdot m^{-2} \cdot s^{-1}$)
White Fabric	24.00 b	388.67 a[v]	419.17 a	728.2	1379.8 a
Silver Film	25.50 a	507.33 a	381.83 a	840	1316.2 a
Bare Ground	24.00 b	104.00 b	101.50 b	738.0	606.3 b
P-Value	<0.0001	0.0006	0.0015	0.9082	0.0148

[z] PAR measured facing east 60 cm above ground and 60 cm from the pseudostem.
[y] PAR measured facing west 60 cm above ground and 60 cm from the pseudostem.
[x] Measurement of light under canopy facing east 60 cm above ground and 60 cm from the pseudostem.
[w] Measurement of light under canopy facing west 60 cm above ground and 60 cm from the pseudostem.
[v] Any two means within a column not followed by the same letter are significantly different at P< 0.05 according to the simulated method.

Table 2. Effect of reflective mulches on number of hands per bunch, production efficiency, and timing of flower emergence of Musa (AAB) 'Mysore' bananas at the Gulf Coast Research and Extension Center, Fairhope, AL

Treatment	Number of Hands (Per Bunch)	Production Efficiency (kg bunch / kg rachis)	Days to Emergence
Bare Ground	9ns	4.6ns	221b[z]
Silver Reflective	9.0	5.7	247a
White Reflective	8.0	5.5	216c
P-values from ANCOVA			
Mulch	0.2739	0.1506	<0.0001
Temperature	0.5836	0.0234	<0.0001
Moisture	0.0303	0.8510	0.0409

[z] Means within a columns followed by common letters do not differ significantly (P< 0.05), by the simulate method

the West facing side. Conversely, there was a 14 % increase in light interception in the West facing side though there were no differences among treatments. Photosynthetic rate nor leaf greenness was significantly affected by either reflective mulch treatment when compared to the control treatment (data not included).

Reflective mulch treatments did not affect pseudostem height or pseudostem circumference and hence, overall pseudostem size compared to the control treatment. Additionally, foliar attributes represented as number of leaves present, and cumulative leaf number were not affected by reflective treatments. Leaf emergence rate among the treatments was essentially the same numerically (data not shown).

Number of hands per bunch and production efficiency were the only bunch characteristics that related to soil temperature and/or soil moisture (Table 2). Number of hands increased as soil moisture increased ($p \geq 0.0303$), while production efficiency increased as soil temperature increased ($p \geq 0.0234$). Though soil temperature and soil moisture of the treatment plots affected these bunch characteristics, mulch treatments did not influence either variable.

Flower emergence occurred 5 d sooner in the white reflective mulch treatment compared to the control while flower emergence in the silver mulch treatment occurred 26 d later than in the control treatment and 31 days later than the white reflective mulch treatment (Table 2). Mulch, soil temperature and soil moisture affected flower emergence.

Cover crop usage. Cover crop treatments affected the amount of nutrients and biomass contributions (Table 3). Hairy vetch produced the highest fresh weight (1.8 $kg \cdot m^{-2}$) while crimson clover resulted in the highest dry weight (1.31 $kg \cdot m^{-2}$). The control treatment consisting of ~ 60% bahiagrass had fresh and dry weights of 0.50 $kg \cdot m^{-2}$ and 0.24 $kg \cdot m^{-2}$, respectively. Hairy vetch treatment contributed the highest N percentage to the soil (3.15 %) followed by crimson clover (1.88 %) and control (1.6 %). There were no differences in the amount of C contributed by each treatment, but the C: N ratio of the hairy vetch treatment (13:1) was lower than crimson clover (21:1) and the control cover treatment (20:1).

The soil pH of samples collected prior to cover crop application (2013) was similar in all plots (~ 5.5) (Table 4). Soil test recommendations for banana production suggest

Table 3. Analysis of elemental soil nutrient composition of experimental plots of crimson clover (CC) and hairy vetch (HV) cover crop treatments and a Bahiagrass (BG) control treatment in Grand Bay, AL, from soil samples collected before planting (Nov. 2013) and near the end of active banana growing season (Oct. 2014).

Treatment	pH		P		K		Mg		Ca	
			Kg • ha-1	Kg • ha-1	Kg • ha-1	Kg • ha-1	Kg • ha-1	Kg • ha-1	Kg • ha-1	Kg • ha-1
	2013	*2014*	*2013*	*2014*	*2013*	*2014*	*2013*	*2014*	*2013*	*2014*
BG	5.7	5.6	134.0	150.67	144.0	198.0	71.0	79.0 a	790.0 a	796.4
CC	5.5	5.5	142.1	175.0	141.0	184.1	66.0	81.3 a	691.0 ab	692.5
HV	5.5	5.2	155.8	163.0	127.3	171.3	61.0	56.3 b	6701.0 b	573.0
P-Value	0.116	0.0025	0.7723	0.7575	0.2865	0.4412	0.0573	0.0394	0.0341	0.1906

[z]Means within columns followed by common letters do not differ at P< 0.05, by the simulate method.

applying lime when soil pH is below 5.5. No differences in the soil macronutrients phosphorus, potassium, or magnesium were found among cover crop treatments. Soil calcium in crimson clover treatments was similar to hairy vetch and the control (data not shown). Percent soil organic matter was slightly higher numerically in hairy vetch treatment compared to natural cover (1.64) and crimson clover (1.62). Additionally, there were no differences found in percent soil C or percent soil N among all treatments (Table 3).

A second soil analysis taken after banana plant establishment in Nov. 2014 showed a decrease in pH (5.1) in the hairy vetch treatment (Table 4).

Foliar nutrient content of the banana plants was compared among treatments. Memon et al. (2001) stated previously there is a lack of international standardization of sampling and effects of soil types on banana foliar nutrition. Therefore, there are no apparent nutrient sufficiency ranges available for particular growth stages for bananas produced in the subtropical regions of the southeastern U.S. No significant differences were found in foliar nutrient concentration due to cover crop treatment.

Hairy vetch had significantly higher N than crimson clover or bare ground and higher C than bare ground but not crimson clover. N contribution by hairy vetch (kg•ha^{-1}) was similar to that contributed by crimson clover but higher than bare ground. The C: N ratio for hairy vetch was 13:1, which indicated greater nutrient availability. Conversely, soil C: N ratio of each treatment indicated suffi-

Table 4. Soil nitrogen, carbon and organic matter as influenced by cover crops and bahaigrass control at Grand Bay, AL.

Treatment	Fresh Weight (kg·m^{-2})	Dry Weight (kg·m^{-2})	Nitrogen (%)	Carbon (%)	Nitrogen (kg·ha^{-1})	Organic Matter (%)	C:N Ratio
				Foliar[y]			
HV	1.80 a[z]	0.41 a	3.2 a	42.0a	143 a	.	13:1
CC	1.31 a	0.62 a	1.9 b	39.3ab	121 ab	.	20:1
BG	0.50 b	0.24 b	1.6 b	31.5b	41 b	.	20:1
P-Value	0.0016	0.0143	0.0004	0.036	0.0101	.	.
				Soil[x]			
HV	.	.	0.08	1.72	.	1.72	13:1
BG	.	.	0.082	0.964	.	1.64	12:1
CC	.	.	0.076	0.946	.	1.62	12:1
P-Value	.	.	0.547	0.4438	.	0.3895	.

[z] Means within columns followed by common letters do not differ at P< 0.05, by the simulate method.
[y] Foliar analyses of samples collected May 2014.
[x] Soil samples were measured Nov. 2014.

Table 5. Effect of Cover Crop and Days from Planting on Growth Parameters of 'Dwarf Orinoco' Bananas in Grand Bay, AL, 2014.

Cover Crop	Pseudo-stem Height (cm)	Pseudo-stem Circum (cm)	Leaf Lgth (cm)	Leaf Width (cm)	Leaf Area (cm^2)	Number Stand. Leaves (no. mo^{-1})	Leaf Emer. Rate (leaf $mo.^{-1}$)	Cumul. Leaf (No mo^{-1})
Bahaigrass Control	49.30	13.14	49.75	24.10	1238.70	6.12	3.28	10.20
Crimson Clover	58.02	15.25	54.81	26.87	1590.44	6.76	3.31	10.36
Hairy Vetch	53.60	14.26	52.98	25.32	1362.90	6.36	3.36	10.20
P-values from ANCOVA								
Cover Crop	0.068	0.1155	0.2217	0.2394	0.223	0.1597	0.9911	0.8392
DFP	<.0001	<.0001	<.0001	0.0015	<.0001	<.0001	0.476	<.0001
Cover x DFP	0.8061	0.6703	0.6258	0.5117	0.5349	0.0703	0.9926	0.9413

cient nutrient mineralization and availability to the plant. Soil N, C and organic matter were similar among the treatments.

Crimson clover and hairy vetch also produced taller banana plants (20% and 8%, respectively) than the control, while pseudostem circumference of bananas of the crimson clover and hairy vetch treatments were 20 % and 12 % greater than bananas of the control treatment (Table 5).

Number of standing leaves, LER and total leaves produced were virtually the same for all treatments. Banana growth parameters were consistently higher in crimson clover and hairy vetch treatments when compared to the bahiagrass control, but growth differences were not significant (Table 5). All variables except LER were linearly related to DFP, but DFP did not interact with cover crop in any variables.

Discussion

Improved light properties supplied by reflective mulches did not affect physiology or earliness of flowering banana plants when compared to the control. This observation is consistent with that reported for d'Anjou pear trees in a study by Einhorn et al. (2012) who found no evidence that reflective fabrics advanced fruit maturity. In the current study, light interception reported in both the control and reflective treatments were greater than 600 umol, which is near light saturation for C_3 plants (Mahendra et al., 1974; Sage, 1990). Additional light intercepted above saturation would have been in excess. Therefore, though mulch treatment affected harvest cycle duration, light was not likely a contributing factor.

Although there was no treatment effect, both soil temperature and soil moisture tended to have a positive influence on certain dependent variables. Mean soil temperature of silver reflective mulch was approximately 2 °C higher than white reflective mulch treatment and the control.

In the current study, changes in soil moisture and temperature contributed by mulch treatments were the factors that affected time of flowering and other variables.

Cover crop usage in banana production has been strongly encouraged to lower inputs such as irrigation and fertilization, and pest control for weeds, insects and disease. Conventional thought among researchers and banana producers is that irrigation and fertilizer, especially K and N requirements for banana production, cannot be met solely by cover crops. In fact, at recommended seeding rates, hairy vetch was expected to supply N at a rate of 143 kg·ha^{-1} and crimson clover at a rate of 121 kg·ha^{-1}, which were 72 % and 60 %, respectively, of the N recommendation for commercially produced bananas according to the University of Georgia Agricultural and Environmental Services Laboratories. Incorporation of additional fertilizer, whether conventional or organic, will be needed to supplement banana production in the soil used in this study. Even so, studies have shown that banana production using 100% organic inputs like cover crops produced comparable yields to a system utilizing conventional production methods (Manivannan and Selvamani, 2014).

Soil pH was above the suggested range (below 5.5) for lime requirement. At the second soil sampling, soil pH fell to 5.1, but bananas thrive and can be productive in a pH range of 4.8 – 8.0 (Turner et al., 1989). As benefits of cover crop usage in agricultural systems are measured over several seasons, it is not surprising that cover crops affected little change in the soil compared to the bare ground treatment.

Cover crops selected for this study were used effectively in previous studies and they were two crops for which the owner/operator of the host farm of this study was the most familiar and amenable to planting. Previous efforts have been made to determine best-suited cover crops. To expedite this process, predictive models have been used to select appropriate cover crops based on performance of cover cropping systems in terms of weed population, weed/main crop interactions, genotype/environmental interactions (Holst et al., 2007; Paolini et al., 2006; Rioche et al., 2012; Tixier et al., 2011). Tixier et al. (2011), used a SIMBA-CC predictive model for ideal cover crops for bananas, determined that the most suitable cover crop species were *Alysicarpus ovalifolius*, *Cynodon dactylon*, and *Chamaecrista rotundifolia* to maximize competition with weed species while minimizing competition with the banana crop.

Models can be utilized for prediction in a banana-cover crop production system, but the more definitive method is conducting actual field trials to verify model predictions. More experimentation will be needed to determine the effects of crimson clover and hairy vetch on the growth and yield of banana plants.

Conclusions

White reflective fabric can be used as a mulch to manipulate flowering in banana because of increased soil temperature and percent soil moisture rather than increased light environment. Neither reflective mulch treatment increased plant vigor, but white fabric mulch treatment decreased DTE compared to the no cover control and silver mulch treatments. Other raw, natural materials will increase these soil qualities and would be a less expensive option. Use of silver reflective mulch delays flowering and should be avoided. Additionally, cover crop treatments allowed to persist on the soil surface with developing banana plants did not appear to negatively affect banana plant physiology during establishment. Hairy vetch had the potential to contribute more nutrients and biomass to the soil than crimson clover, but supplemental fertilizer will likely be needed to meet the nutrient requirements of bananas. Additionally, mean C: N ratio and organic matter content of cover crop treatments were the same as the control. More time is needed for cover crop usage to considerably improve soil quality in order to determine effects on banana plant vigor and ultimately harvest cycling time.

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