Proc. Fla. State Hort. Soc. 113:5-11. 2000.

EFFECT OF POLYETHYLENE AND ORGANIC MULCH ON GROWTH AND YIELDS OF 'ARKIN' CARAMBOLA (*AVERRHOA CARAMBOLA* L.) IN SOUTH FLORIDA

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Additional index words. *Averrhoa carambola*, tar fruit, tropical fruit, biosolids.

Abstract. **The effects of mulch treatments on growth and fruit production of 5-year-old 'Arkin' carambola (*Averrhoa carambola* L.) grafted on open-pollinated 'Golden Star' (*Averrhoa carambola* L.) rootstock were investigated under field conditions from July 1999 to March 2000. Treatments included: non-mulched soil (control; C); 10 cm thick layer of avocado wood mulch (organic mulch; OM); black polyethylene (BP); black ground cloth covered with a 10-cm thick layer of avocado wood mulch (GC+OM); and ground cloth covered with a 10-cm thick layer of avocado wood mulch and a film of clear plastic (GC+OM+CP). At a 10-cm depth in the soil, mean temperatures for the GC+OM+CP treatment were 1 to 8°C higher than in all other treatments. At 90 and 180 days after imposing the treatments, there were no significant differences in trunk diameter among treatments. However, the mean percentage of change in canopy volume was significantly greater for trees in the GC+OM+CP and GC+OM mulch treatments than for those of the non-mulched control. Non-mulched trees had lighter green foliage and exhibited more symptoms of chlorosis than trees in the other treatments. When ambient air temperatures dropped below about 10°C during Nov. 1999 to Feb. 2000, the percentage of leaf chlorosis and abscission were consistently greater for non-mulched trees than all other treatments. Crop yields were 16 to 50% greater for trees in the GC+OM+CP treatment than in those in other treatments. In the calcareous soils of south Florida, mulching maintained higher soil temperatures compared to non-mulched controls and mulching enhanced carambola tree growth and yields.**

Carambola is indigenous to southeast Asia and is adapted to continuously hot, humid, lowland tropical conditions (Crane, 1994). In southern Florida, temperatures for growing carambola are suitable for 9 to 10 months of the year, however, low temperatures during December, January and February reduce carambola tree growth and production (Campbell et al., 1985; Crane, 1994; George and Nissen, 1994).

Under tropical conditions carambola trees produce fruit year-round (J. H. Crane, pers. comm.). In south Florida there are two main harvest seasons, July to Oct. and Nov. through February. After the Oct. harvest, trees bloom again; vegetative growth slows and eventually ceases during Nov. (Nuñez-Elisea and Crane, 1998). Anytime from Dec. through Feb./March, interveinal leaf chlorosis, typical of iron deficiency increases, general leaf color changes from green to gray-green, and the rate of leaf senescence increases, resulting in partially to totally defoliated trees by Feb./March. Observations suggest the decline in vegetative and reproductive growth from Oct. through March may be temperature related and that possibly trees are under drought and nutritional stress due to low air and soil temperatures. Mulches are useful for soil and water conservation, preserving and improving soil physical, chemical and biological properties, suppressing weed growth, reducing fertilizer leaching, and ameliorating soil temperature fluctuations (Tumuhairwe and Gums, 1983).

Despite the common use of mulching in vegetable production, mulching is not a widespread practice in south Florida's fruit production. Normally, the mulch that exists in fruit tree orchards is 'natural', primarily the result of fallen leaves and twigs. This investigation was undertaken to determine the effects of organic and polyethylene mulch on soil temperatures, growth, and yields of carambola.

Materials and Methods

Treatments. Five-year-old 'Arkin' carambola trees grafted on open pollinated 'Golden Star' rootstock spaced 4.5 m within × 6.1 m between rows were used for this study from July 1999 to March 2000. Treatment included: non-mulched soil (control; C); 10-cm thick by 4.5 m × 3 m layer of avocado wood mulch (organic mulch; OM); 4.5 m × 3 m film of black polyethylene (0.102 mm thickness) mulch (BP) (Huntsman Packaging, NJ, USA); 4.5 m × 3 m sheet of black ground cloth (0.254 mm thickness) (Lumite Company, GA, USA) covered with a 10-cm thick by 4.5 m × 3 m layer of avocado wood mulch (GC+OM); and 4.5 m × 3 m sheet of ground cloth (0.254 mm thickness) (Lumite Company, GA, USA) covered with a 10-cm thick by 4.5 m × 3 m layer of avocado wood mulch and a film of clear plastic (0.152 mm thickness) (Huntsman Packaging, NJ, USA) of similar dimensions (GC+OM+CP). The organic mulch, ground cloth, and polyethylene films were positioned about 30 to 45 cm away from the tree trunk. Polyethylene films were perforated using a sharp pitch-fork to allow for adequate water infiltration and aeration. The treatments were arranged in a completely randomized design with 12 single-tree replications.

Soil temperature and soil water tension. Soil water tension was monitored at a 15 cm depth using an irrometer (gauge, 0-40 KPa) (Irrometer Company Inc. Riverside, CA, USA) installed at approximately 1 m from the tree trunk under the canopy of one randomly selected tree per treatment. For the non-mulched control and GC+OM+CP treatments, a 45 cm length irrometer was also installed to monitor the soil water at a 45-cm root depth. Soil temperatures were recorded hourly with Hobo® temperature loggers (Onset Computer Corporation, Pocasset, MA, USA) at a depth of 10 cm below the soil surface for one randomly selected tree per treatment. Temperature loggers were positioned 1 m away from the tree trunk on the

Florida Agricultural Experiment Station Journal Series No. N-01955. Acknowledgments: This project was partially funded by the Tropical Fruit Growers of South Florida's Carambola Research Committee and the Tropical Fruit Advisory Council.

southeastern side of two randomly selected trees per treatment. Ambient air (in-tree) temperatures were recorded hourly using two Hobo® temperature loggers positioned at a height of 2 m from the soil surface within the canopy of two randomly selected trees per treatment.

Growth measurements. Trunk diameter was measured at a 15-cm height above the soil line at the commencement of the experiment on 13 July 1999 and subsequently at 90-day intervals. Canopy width was measured on six randomly selected trees per treatment on 11 Aug. 1999 and repeated on 24 Nov. 1999 and 28 Feb. 2000. All trees were topped to a 2.73 m height soon after initiation of the experiment (6 Aug. 1999). Subsequently, at a height of about 1.12 m above the soil level, the mid-canopy width was measured in a north to south, and east to west direction. The percentage of change in canopy volume was then calculated using the mid-canopy, north-south and east-west width measurements.

New shoot extension growth was measured on 4 randomly selected actively growing limbs (7 to 8 mm dia.) on the northern, southern, eastern, and western part of the mid-canopy level of nine randomly selected trees per treatment. Each individual shoot was tagged at a 10-cm distance from the terminal point from where measurements were made at 30-day intervals. New axillary shoot growth arising from three randomly selected topped limbs of similar size (approximately 20-25 mm in diameter) on four randomly selected trees per treatment was measured at 90-day intervals from the time of topping (6 Aug. 1999) to assess differences among the treatments. The duration of time to first emergence of new growth on topped limbs was recorded on each of the 12 trees per treatment.

During late winter/early spring carambola trees initiate new vegetative growth along most laterally oriented limbs and shoots. This new growth signals canopy recovery and leads to profuse flowering one to two months later. To assess differences among mulch treatments, axillary bud break was measured on four randomly selected shoots from five randomly selected trees per treatment. Bud break was determined as buds which had grown to approximately 0.5 to 1 cm or greater in size. Beginning on 18 Jan. 2000, one healthy, actively growing limb, approximately 7-8 mm in dia., was tagged on the northern, southern, eastern, and western part of the mid-canopy area of each of the selected trees. Each individual limb was tagged at a 45 cm distance from the terminal point. The number of growing axillary buds per shoot was determined by counting the total number of buds growing on the shoot at the initial time of tagging and subsequently at 14-day intervals.

Canopy color and defoliation. General canopy color was visually rated on a scale of 1 (dark green), 2 (medium green), and 3 (light green) and the percentage of mid-canopy showing interveinal chlorosis (typical of iron deficiency) was also visually estimated. These ratings were done on 28 July 1999, 29 Oct. 1999 and 20 Jan. 2000. Leaflet chlorophyll index was measured on 15 July 1999, 23 Oct. 1999, 24 Jan. 2000 and 10 March 2000 using a Minolta Chlorophyll Meter SPAD-502 (Minolta Co. LTD, Japan). Ten healthy, recently matured (3rd or 4th counting basipetally from the stem terminal) leaves were sampled from the outer canopy. Chlorophyll content was measured on the middle adaxial surface below the midrib of the 2nd or 3rd leaflet from the leaf apex. From late fall until early winter, the amount of foliage chlorosis and leaf abscission of carambola trees increases which results in partially or completely defoliated trees by December to January. To assess differences among mulch treatments the number of trees showing obvious defoliation and leaf chlorosis (called winter decline) was counted at a 14-day intervals from 5 Nov. to 15 Dec. 1999, and 17 Jan. to 28 Feb. 2000 and reported as a percentage of trees showing winter decline. Twelve trees per treatment were used.

Fruit production. Fruit were harvested between 3 Sept. 1999 and 15 March 2000.

Data analysis. Data were subjected to analysis of variance and Duncan's multiple range test at the 5% level. Because of the initial differences in trunk diameter and canopy width among treatments, these data were analyzed by covariant analysis using initial trunk diameter and canopy width as covariants, respectively. Percentage data were tested for normality using the SAS UNIVARIATE procedure. If data were not normally distributed, then percentage data were transformed by arcsin transformation.

Results

Soil temperature and soil water tension. Throughout the experimental period, soil water content ranged between -3 and -10, and -8 and -13 KPa for all treatments at the 15- and 45- cm soil depths, respectively (Fig. 1). Generally, mean soil temperatures during summer, fall, and winter were higher for the GC+OM+CP mulch treatments compared to all other treatments. Therefore, only the 7-day and 24-h periods during winter with the lowest ambient temperature periods during winter are presented (Figs. 2 and 3). In general, GC+OM+CP and non-mulch control soil temperatures were consistently higher and lower, respectively, than all other mulch treatments. When ambient air temperatures approached freezing, soil temperatures of the GC+OM+CP treatment remained at or above 20°C, whereas temperatures of the other treatments were below 20°C (Fig. 3). Also the mean soil temperature of the GC+OM+CP treatment was 7 to 8°C higher than that of the non-mulched control treatment. The temperature of the BP treatment dropped to below that of the GC+OM and OM treatments, thus indicating that during periods of low to near freezing ambient temperatures, black polyethylene mulches alone may not be as effective for maintaining soil temperatures as mulch treatments composed of organic matter. Our soil temperature results are in agreement with work conducted by Stapleton and Garza-Lopez (1988) under Mexican field conditions. They reported that mulching moist soil with black and clear plastic films for 5 and 9 months, respectively raised soil temperatures at a 23-cm depth by 2 to 6°C compared to an uncovered control. Therefore, it seems that for the calcareous soils of south Florida, the use of GC+OM+CP mulch is more effective than BP, GC+OM, or OM mulches in ameliorating the low rhizosphere temperatures of carambola trees during the winter months.

Tree growth. There was no significant difference in trunk diameter among treatments at the commencement of the experiment or after 90 and 180 days following the first measurement (data not shown). The overall mean trunk diameters for all treatments were 11.1, 11.6, and 14.6 cm on 13 July 1999, 13 Oct. 1999, and 18 Jan. 2000, respectively. Probably the duration of the experiment was not sufficient for significant differences to develop among tree trunk diameters subjected to the various mulch treatments, or there was no treatment effect on the trunk diameter.

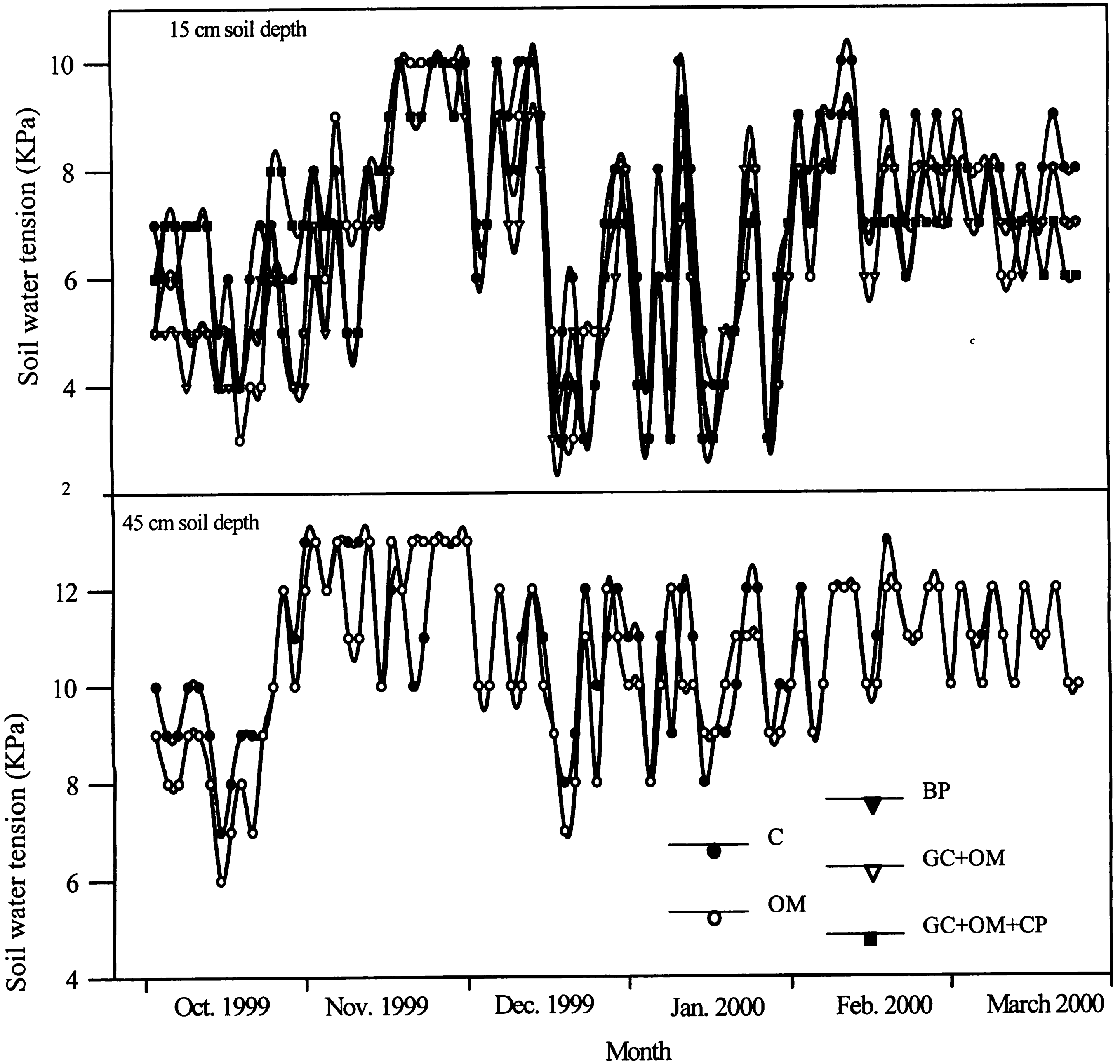

Figure 1. Soil water content (KPa) at a 15-cm root depth for five mulch treatments and at a 45-cm root depth for two mulch treatments of 5-year-old field grown 'Arkin' carambola trees from October 1999 to March 2000. Measurements were made at 2-day intervals between 0800 and 0830 hr. C, non-mulched soil (control); OM, 10 cm thick by 4.5 m × 3 m layer of avocado wood mulch; BP, 4.5 m × 3 m film of black polyethylene mulch; GC+OM, 4.5 m × 3 m sheet of black ground cloth covered with a 4.5 m × 3 m 10 cm thick layer of avocado wood mulch; GC+OM+CP, 4.5 m × 3 m sheet of ground cloth covered with a 4.5 m × 3 m 10 cm thick layer of avocado wood mulch and a 4.5 m × 3 m film of clear plastic.

There were significant differences in the percentage change of the tree canopy volume among the five mulch treatments (Table 1). On 24 Nov. 1999, all the mulch treatments except the GC+OM+CP treatment exhibited a decrease in the average percent change in tree canopy volume. The mean percentage change in canopy volume for trees of the GC+OM+CP mulch treatment was significantly greater than those of the non-mulched control and OM treatments but similar to BP and GC+OM treatments. On 28 Feb. 2000 the mean percent increase in canopy volume for the GC+OM+CP and GC+OM mulch treatments were significantly greater than that of the non-mulched control but similar to those of the BP and OM treatments.

In general, shoot growth of trees in the GC+OM+CP was significantly greater than that of non-mulched controls (Table 2). During the January, February, and March measurement periods the GC+OM+CP, GC+OM, and BP shoot growth was similar and significantly greater than OM and C treatments. There was no difference among treatments in the number of days for new shoots to emerge from topped limbs

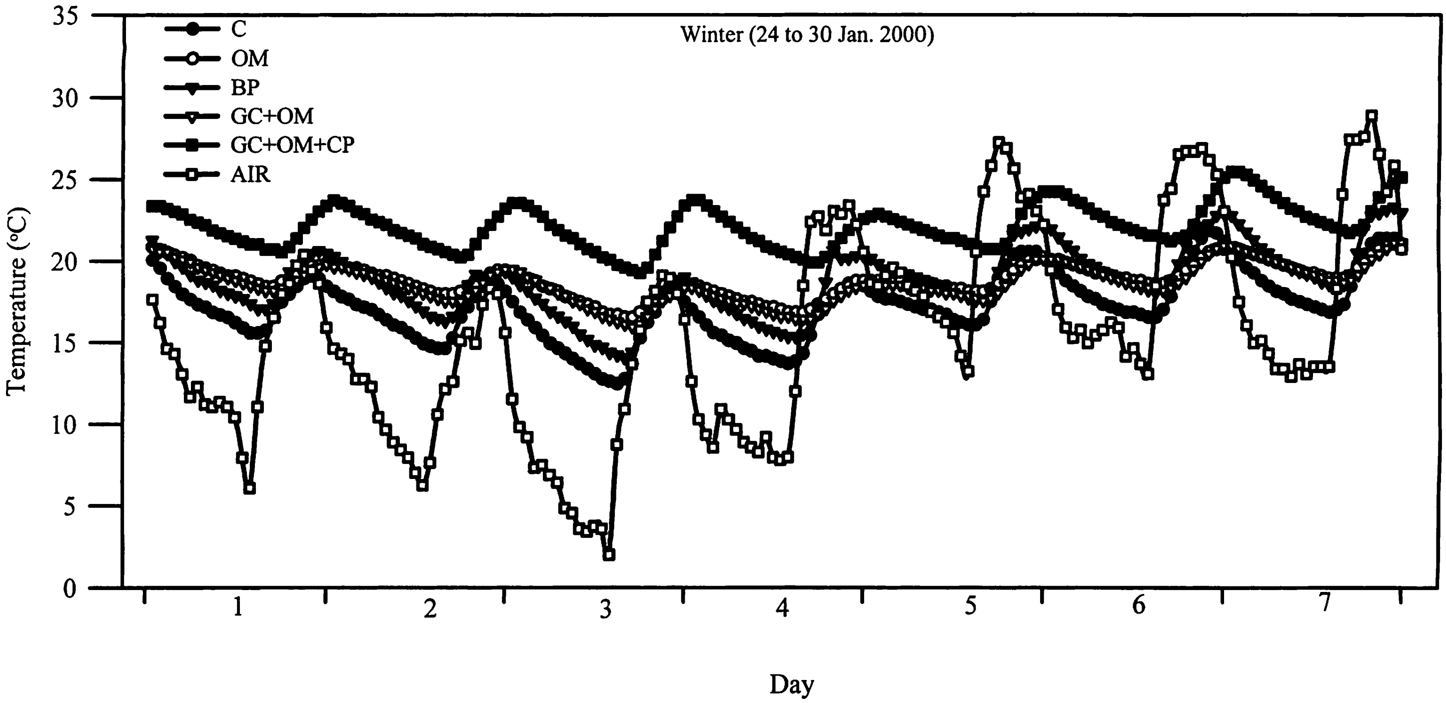

Figure 2. Effect of organic and polyethylene mulch on soil temperature at a 10-cm root depth of 5-year-old field grown 'Arkin' carambola trees compared to air temperature at a 2 m tree height for a 1-week period between 24 to 30 Jan. 2000. Data are hourly readings during the time of the lowest air temperatures and represents the trend of each treatment for the winter. C, non-mulched soil (control); OM, 10 cm thick by 4.5 m × 3 m layer of avocado wood mulch; BP, 4.5 m × 3 m film of black polyethylene mulch; GC+OM, 4.5 m × 3 m sheet of black ground cloth covered with a 4.5 m × 3 m 10-cm thick layer of avocado wood mulch; GC+OM+CP, 4.5 m × 3 m sheet of ground cloth covered with a 4.5 m × 3 m 10-cm thick layer of avocado wood mulch and a 4.5 m × 3 m film of clear plastic; and AIR, air (in-tree) temperature at a height of 2 m.

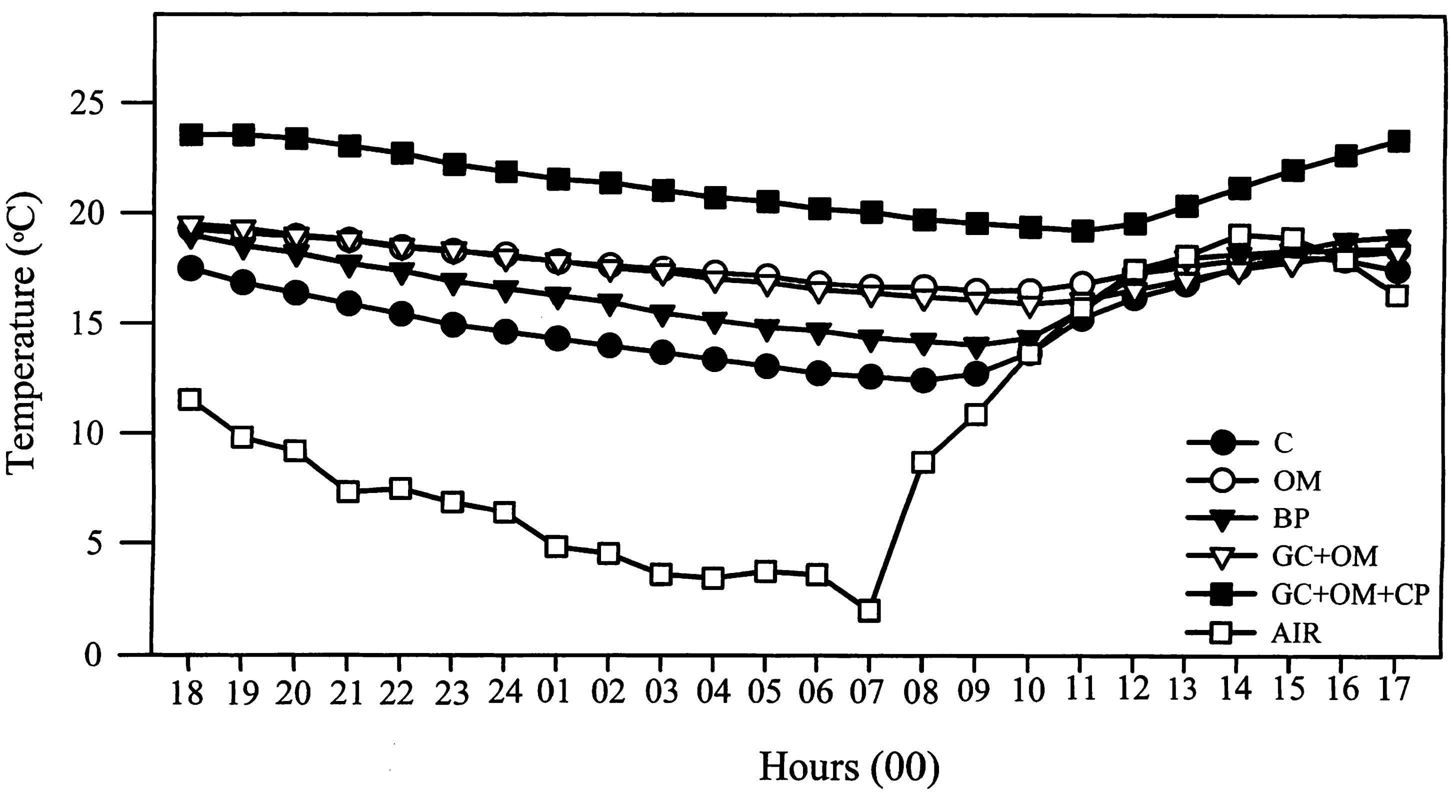

Figure 3. Effect of organic and polyethylene mulch on mean soil temperature at a 10-cm root depth of 5-year-old field grown 'Arkin' carambola trees compared to mean air temperature at a 2 m tree height recorded for the lowest temperature 24-h period, between 26 to 27 Jan. 1999. Each data point is the mean of hourly readings measured between 1800 and 1700 hr. C, non-mulched soil (control); OM, 10-cm thick by 4.5 m × 3 m layer of avocado wood mulch; BP, 4.5 m × 3 m film of black polyethylene mulch; GC+OM, 4.5 m × 3 m sheet of black ground cloth covered with a 4.5 m × 3 m 10-cm thick layer of avocado wood mulch; GC+OM+CP, 4.5 m × 3 m sheet of ground cloth covered with a 4.5 m × 3 m 10-cm thick layer of avocado wood mulch and a 4.5 m × 3 m film of clear plastic; and AIR, air (in-tree) temperature at a height of 2 m.

Table 1. Effect of mulch treatments on percent change in mean canopy volume of 5-year-old field grown, 'Arkin' carambola from November 1999 to February 2000.

Mulch treatment[y]	Date[z]	
	24 Nov. 1999	28 Feb. 2000
	Change (%)[x]	
Control	-19.9 b[w]	-23.7 b
OM	-16.4 b	-6.7 ab
BP	-2.9 ab	-7.2 ab
GC+OM	-4.0 ab	-1.4 a
GC+OM+CP	5.6 a	9.6 a

[z]Measurements were made at approximately 90-day intervals.
[y]C, non-mulched soil (control); OM, 10-cm thick by 4.5 m × 3 m layer of avocado wood mulch; BP, 4.5 m × 3 m film of black polyethylene mulch; GC+OM, 4.5 m × 3 m sheet of black ground cloth covered with a 4.5 m × 3 m 10-cm thick layer of avocado mulch; and GC+OM+CP, 4.5 m × 3 m sheet of ground cloth covered with a 4.5 m × 3 m 10-cm thick layer of avocado mulch and a 4.5 m × 3 m film of clear plastic.
[x]Data were analyzed by covariance analysis and transformed by arcsin transformation.
[w]Mean separation in columns by Duncan's multiple range test, $P \leq 0.05$. Data are the means of six replicates per mulch treatment.

(Table 3). However, axillary shoot growth was significantly greater for the GC+OM+CP treatment compared to non-mulched controls but similar to all other treatments. There was no significant difference in the number of new axillary shoots among mulch treatments during 18 Jan. 2000. However, from early February through March, the number of new axillary shoots was greater for treatments with organic mulch compared to the BP and non-mulch control (Table 4).

Canopy color and defoliation. Generally, trees of the BP mulch treatment showed a darker green canopy color rating and the lowest percentage of leaf chlorosis compared to trees of the other treatments (Table 5). On 29 Oct.1999 mean canopy color rating of the BP trees was significantly greater than that of all other treatments with the exception of the GC+OM treatment. However, by 20 Jan. 2000, color ratings for the BP, GC+OM and GC+OM+CP treatments were similar and the canopy were greener than in the non-mulched control. In general, the percentage of chlorosis for all treatments increased from July to January. Moreover, by 20 Jan. 1999, trees of the non-mulched treatment had significantly more leaves showing interveinal chlorosis compared to trees in all other treatments. Generally, the new foliage that developed on the trees following the winter period was of a lighter green coloration in trees of the non-mulched control compared to those of the other treatments. Chlorophyll index was consistently greater for the BP treatment compared to the non-mulched control (Table 5). However, there was no consistent significant difference among treatments.

Obvious canopy decline during the winter occurred earlier and to a greater extent for trees of the non-mulched treatment compared to all other treatments (Table 6). From 5 Nov. to 27 Nov. 1999, the percentage of trees with winter canopy decline was highest to lowest for the non-mulched control, OM, GC+OM+CP, GC+OM and BP treatments, respectively. By 27 Nov. 1999 all trees of the non-mulched treatment showed obvious winter canopy decline. In contrast, on 10 Dec. 1999 trees of all the treatments except 25% of the trees in the BP treatment showed winter canopy decline.

Crop yield. Total yield per tree harvested from the GC+OM+CP mulch treatment was significantly greater than that of all other treatments (Table 7). Total yield per tree for the GC+OM+CP mulch treatment was 133.5 kg compared to 82.1, 75.5, 74.2, and 69.9 kg for the GC+OM, BP, OM, and the non-mulched control treatments, respectively. The higher yield of the GC+OM+CP mulch treatment may be attributed to the greater, more vigorous growth, and higher root temperatures these trees were exposed to compared to all other treatments.

Discussion

Soil water content was nonlimiting for all the mulch treatments tested, demonstrating that puncturing the plastic mulches allowed sufficient water to penetrate to the soil (Fig. 1). Overall, the results indicate that mean soil temperatures at a 10-cm root depth in a carambola orchard grown in the calcareous soil of south Florida may be modified through the use of organic and polyethylene mulches. However, covering organic mulch with plastic (i.e., GC+OM+CP) maintained the highest soil temperatures throughout the test period, averaging 25°C and above. Soil temperatures under all treatments that included organic mulch fluctuated less than the non-mulched control and black plastic alone (BP). During the coldest 24-hr period the soil temperature of the organic matter covered with clear plastic (GC+OM+CP) treatment remained 7 to 8°C higher than the non-mulched control. Trees

Table 2. Effect of mulch treatments on axillary shoot growth (extension) measured from the mid-canopy area of 5-year-old field grown, 'Arkin' carambola trees from August 1999 to March 2000.

Mulch treatment[y]	Date[z]							
	8 Aug. 1999	14 Sept. 1999	15 Oct. 1999	15 Nov. 1999	16 Dec. 1999	20 Jan. 2000	21 Feb. 2000	24 March 2000
	Shoot growth (extension) (cm)							
C	8.2 b[x]	14.6 b	16.9 b	17.7 b	18.5 b	20.2 c	22.1 b	24.1 b
OM	9.9 ab	17.8 ab	20.5 ab	21.3 ab	21.7 ab	24.9 bc	27.8 b	30.8 b
BP	16.4 a	23.8 ab	28.4 ab	30.2 ab	30.9 ab	33.7 ab	39.9 a	41.9 a
GC+OM	10.9 ab	19.5 ab	22.9 ab	23.5 ab	24.6 ab	37.9 a	40.0 a	42.4 a
GC+OM+CP	15.1 ab	26.2 a	29.8 a	30.7 a	33.5 a	39.5 a	43.7 a	46.4 a

[z]Measurements were made at approximately 30-day intervals.
[y]C, non-mulched soil (control); OM, 10-cm thick by 4.5 m × 3 m layer of avocado wood mulch; BP, 4.5 m × 3 m film of black polyethylene mulch; GC+OM, 4.5 m × 3 m sheet of black ground cloth covered with a 4.5 m × 3 m 10-cm thick layer of avocado mulch; and GC+OM+CP, 4.5 m × 3 m sheet of ground cloth covered with a 4.5 m × 3 m 10-cm thick layer of avocado mulch and a 4.5 m × 3 m film of clear plastic.
[x]Mean separation in columns by Duncan's multiple range test, $P \leq 0.05$. Data are the means of four shoots from each of nine replicates per mulch treatment.

Table 3. Effect of mulch treatments on new axillary shoot growth measured from topped limbs of 5-year-old field grown, 'Arkin' carambola trees from August 1999 to March 2000.

Mulch treatment[y]	Days to 1st shoot emergence	Date[z] New axillary shoot growth (cm) 29 Nov. 1999	29 Feb. 2000
Control	17.1 a[x]	55.6 b	53.1 b
OM	17.1 a	67.3 ab	72.3 ab
BP	17.2 a	74.0 ab	93.2 ab
GC+OM	17.2 a	58.5 ab	68.6 ab
GC+OM+CP	17.2 a	83.5 a	99.0 a

[z]Measurements were made at approximately 90-day intervals.
[y]C, non-mulched soil (control); OM, 10-cm thick by 4.5 m × 3 m layer of avocado wood mulch; BP, 4.5 m × 3 m film of black polyethylene mulch; GC+OM, 4.5 m × 3 m sheet of black ground cloth covered with a 4.5 m × 3 m 10-cm thick layer of avocado mulch; and GC+OM+CP, 4.5 m × 3 m sheet of ground cloth covered with a 4.5 m × 3 m 10-cm thick layer of avocado mulch and a 4.5 m × 3 m film of clear plastic.
[x]Mean separation in columns by Duncan's multiple range test, $P \leq 0.05$. Data are the means of three shoots from twelve replicates per mulch treatment for days to first shoot emergence and three shoots from four replicates per mulch treatment for shoot growth (length).

of the organic matter covered with clear plastic mulch treatment (GC+OM+CP) exhibited greater shoot growth, denser canopies and increased flowering and fruit yields. One drawback of the clear plastic was weed growth, which had to be controlled periodically. Because soil water content was similar among treatments, the greater tree growth and crop yield of GC+OM+CP treatment may be attributed to higher soil temperatures at the 10 cm root depth.

Previous research and observation has demonstrated that carambola trees have the potential to grow and produce fruit year-round (Núñez-Elisea and Crane, 1998, 2000). However, cool/cold ambient and soil temperatures during winter in south Florida preclude year-round tree growth, flowering and fruit production. We have demonstrated that the use of a combination of organic mulch covered with plastic mulch will improve carambola growth and production during the late fall through winter/early spring. Plastic and organic mulches are readily available in south Florida. Perhaps the limiting factor to the use of these mulches is the cost of labor. Producers need to assess the potential for economic benefit from year-round or off-season fruit production before implementing a mulch program.

Table 4. Effect of mulch treatments on mean number of new axillary shoots measured on limbs from the mid-canopy area of 5-year-old field grown, 'Arkin' carambola trees from January to March 2000.

Mulch treatment[y]	Date[z] 18 Jan. 2000	2 Feb. 2000	15 Feb. 2000	20 Feb. 2000	17 Mar. 2000	31 mar. 2000
	Axillary shoots per limb (no.)					
Control	0.6 a[x]	1.8 ab	2.8 b	6.2 b	10.2 c	12.0 c
OM	1.0 a	3.6 ab	5.2 ab	9.0 ab	13.0 bc	16.4 bc
BP	0.0 a	0.4 b	2.2 b	6.2 b	9.0 c	12.6 c
GC+OM	0.6 a	2.6 ab	5.8 ab	12.2 ab	19.0 ab	22.6 ab
GC+OM+CP	1.0 a	5.0 a	8.4 a	15.0 a	21.4 a	26.6 a

[z]Measurements were made at approximately 14-day intervals.
[y]C, non-mulched soil (control); OM, 10-cm thick by 4.5 m × 3 m layer of avocado wood mulch; BP, 4.5 m × 3 m film of black polyethylene mulch; GC+OM, 4.5 m × 3 m sheet of black ground cloth covered with a 4.5 m × 3 m 10-cm thick layer of avocado mulch; and GC+OM+CP, 4.5 m × 3 m sheet of ground cloth covered with a 4.5 m × 3 m 10-cm thick layer of avocado mulch and a 4.5 m × 3 m film of clear plastic.
[x]Mean separation in columns by Duncan's multiple range test, $P \leq 0.05$. Data are the means of four shoots from five replicates per mulch treatment.

Table 5. Effect of mulch treatments on tree canopy color rating, percent canopy chlorosis, and leaf chlorophyll index measured from the mid-canopy area of 5-year-old field grown, 'Arkin' carambola trees from July 1999 to March 2000.

Mulch treatment[w]	Canopy color rating[z] Date[x] 28 July 1999	29 Oct. 1999	20 Jan. 2000	Interveinal chlorosis (%) Date[x] 28 July 1999	29 Oct. 1999	20 Jan. 2000	Chlorophyll index[y] Date[x] 21 Oct. 1999	24 Jan. 2000	16 March 2000
C	1.3 a[v]	2.1 a	2.8 a	1.9 b	20.4 abc	55.8 a	44.1 b	35.7 c	23.4 b
OM	1.2 a	2.0 a	2.3 ab	2.2 ab	16.7 bc	21.3 b	44.3 b	42.7 ab	36.8 a
BP	1.2 a	1.3 b	1.8 b	2.1 ab	11.6 c	17.5 b	53.2 a	47.3 a	39.8 a
GC+OM	1.2 a	1.8 ab	2.1 b	2.0 ab	25.8 ab	22.9 b	44.9 b	40.7 bc	37.9 a
GC+OM+CP	1.3 a	1.9 a	2.1 b	2.4 a	32.5 a	30.4 b	44.6 b	38.4 bc	37.0 a

[z]1, dark green; 2, medium green; 3, light green.
[y]Chlorophyll index is unitless, higher no. indicate greater leaf chlorophyll content.
[x]Measurements were made at approximately 90-day intervals.
[w]C, non-mulched soil (control); OM, 10-cm thick by 4.5 m × 3 m layer of avocado wood mulch; BP, 4.5 m × 3 m film of black polyethylene mulch; GC+OM, 4.5 m × 3 m sheet of black ground cloth covered with a 4.5 m × 3 m 10-cm thick layer of avocado mulch; and GC+OM+CP, 4.5 m × 3 m sheet of ground cloth covered with a 4.5 m × 3 m 10-cm thick layer of avocado mulch and a 4.5 m × 3 m film of clear plastic.
[v]Mean separation in columns by Duncan's multiple range test, $P \leq 0.05$. Data are the means of twelve replicates per mulch treatment for canopy color rating and percent canopy iron chlorosis, and ten leaves from each of three replicates per treatment for chlorophyll measurements.

Table 6. Effect of mulch treatments on the percentage of trees showing winter decline (obvious defoliation and chlorosis) in 5-year-old field grown, 'Arkin' carambola trees from 5 Nov. 1999 to 15 Dec. 1999.

	Percent of trees showing winter decline (%)						
	Date[z]						
Mulch treatment[y]	5 Nov. 1999	12 Nov. 1999	19 Nov. 1999	27 Nov. 1999	3 Dec. 1999	10 Dec. 1999	15 Dec. 1999
C	58.3	75.0	83.3	100.0	100.0	100.0	100.0
OM	41.7	50.0	50.0	75.0	100.0	100.0	100.0
BP	0.0	8.3	16.7	33.3	91.7	75.0	100.0
GC+OM	16.7	33.3	33.3	75.0	91.7	100.0	100.0
GC+OM+CP	25.0	41.7	41.7	75.0	100.0	100.0	100.0

[z]Measurements were made at approximately 7-day intervals.
[y]C, non-mulched soil (control); OM, 10-cm thick by 4.5 m × 3 m layer of avocado wood mulch; BP, 4.5 m × 3 m film of black polyethylene mulch; GC+OM, 4.5 m × 3 m sheet of black ground cloth covered with a 4.5 m × 3 m 10-cm thick layer of avocado mulch; and GC+OM+CP, 4.5 m × 3 m sheet of ground cloth covered with a 4.5 m × 3 m 10-cm thick layer of avocado mulch and a 4.5 m × 3 m film of clear plastic. Data are the percent of twelve single tree replicates per treatment.

Table 7. Effect of mulch treatments on mean total yield per tree of 5-year-old field grown, 'Arkin' carambola trees from September 1999 to March 2000.

Mulch treatment[z]	Total yield per tree (kg)[y]
Control	69.9 b[x]
OM	74.2 b
BP	75.5 b
GC+OM	82.1 b
GC+OM+CP	133.5 a

[z]C, non-mulched soil (control); OM, 10-cm thick by 4.5 m × 3 m layer of avocado wood mulch; BP, 4.5 m × 3 m film of black polyethylene mulch; GC+OM, 4.5 m × 3 m sheet of black ground cloth covered with a 4.5 m × 3 m 10-cm thick layer of avocado mulch; and GC+OM+CP, 4.5 m × 3 m sheet of ground cloth covered with a 4.5 m × 3 m 10-cm thick layer of avocado mulch and a 4.5 m × 3 m film of clear plastic.
[y]Measurements were made between 3 Sep. 1999 through 15 March 2000.
[x]Mean separation in columns by Duncan's multiple range test, $P \leq 0.05$. Data are the means of six replicates per mulch treatment.

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