Differential Watermelon Fruit Size Distribution in Response to Plastic Mulch and Spunbonded Polyester Rowcover

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SUMMARY. Plasticulture has been successfully used to enhance growth and yield of horticultural crops, and also for season extension in cooler climates. The effect of three plastic mulches (silver on black, photoselective thermal green, and black) in combination with spunbonded polyester rowcover (0.9 oz/yard²) on spring-planted watermelon (*Citrullus lanatus*) production was investigated. Two red-fleshed cultivars [Sangria (seeded) and Crimson Jewel (triploid)] were used. Plastic mulches increased early and total marketable yield in comparison with bare ground for both cultivars, but net benefit increased in 'Crimson Jewel' only. In contrast, yield and net benefit were the same among plastic mulches. Rowcover increased soil and air temperature, with the effect being greatest at lower ambient temperatures. During a near-freeze event, air temperature under the rowcover was about 7.2 °F higher than without a rowcover. Rowcover increased early and total marketable yield, but fruit weight decreased in both cultivars. Yield distribution into three fruit size categories was inconsistent between the cultivars. In 'Sangria', the large fruit category had the highest yield proportion for all treatments. In contrast, the highest yield proportion of 'Crimson Jewel', with exception of mulch without rowcover, corresponded to small fruit. Rowcover increased gross income at wholesale prices, but net benefit was not different from without rowcover. Protection of high-value plants, such as triploid watermelon, against light freezes, however, may still justify the use of rowcover in early plantings.

The increasing popularity and market share of triploid (seedless) watermelons is attracting farmers into growing this fruit type (Blank, 1999; Lucier and Lin, 2001). Furthermore, watermelon demand is switching into smaller individual melons to fit better today's smaller households. Several reports have shown that watermelon growth and yield increase in response to plastic mulch and rowcover, but the effect on fruit size distribution has been overlooked (Baker et al., 1998; Marr et al., 1991; Sanders et al., 1999; Soltani et al., 1995). We previously reported that increasing plant density of the triploid watermelon cultivars Crimson Jewel and Honey Heart results in a higher number of fruit per unit area, but primarily of small and extra-small melons (Motsenbocker and Arancibia, 2002). Because the price of watermelon is influenced by fruit size in addition to date of sale, the response of seedless and seeded

watermelon to plastic mulch and rowcover need to be addressed taking into consideration fruit quality. The costs and potential benefits also need to be addressed in order for growers to assess the incorporation of these technologies into a production system.

Modification of the plant environment has been used to enhance plant growth and yield, and to extend the growing season of horticultural crops in cooler climates (Hall and Besemer, 1972; Wells and Loy, 1985). Plastic mulch and rowcover increase soil and air temperatures, offering the possibility for early production and higher yields of

warm-season vegetable crops such as watermelon (Bhella, 1988; Brinen et al., 1979; Sanders et al., 1999). In addition, plastic mulch reduces water evaporation and controls weeds. Wavelength-selective or -reflective plastic mulches are also available for better management of soil temperature and light quality, which may influence plant growth and productivity (Ham et al., 1993; Taber, 1993). In a recent study, plastic mulch increased total yield of watermelon in comparison with bare ground, but there was a different response of the hybrid cultivar Sangria to different wavelength-selective or -reflective plastic mulches (Andino and Motsenbocker, 2004). In contrast, total yield of the triploid cultivar Honey Heart was not different among the plastic mulches. This suggests that small-fruited seedless cultivars may respond differently to plasticulture than large-fruited seeded cultivars.

Rowcover has been used to provide protection against light freezes and to enhance plant growth early in the spring by increasing soil and air temperatures (Soltani et al., 1995; Wells and Loy, 1985). Spunbonded rowcover, however, allows for increased ventilation inside the tunnel, avoiding stressful high temperatures on sunny days, which is often associated with the use of clear polyethylene rowcover. Spunbonded fabrics can also be used as floating cover without wire hoops for freeze control, but physical damage by abrasion on the plants has been reported and may be associated with yield reduction (Baker et al., 1998; Wells and Loy, 1985). Often, rowcover increases early and total watermelon yields, but the effect of rowcover on fruit size has been overlooked (Baker et al., 1998; Sanders et al., 1999; Soltani et al., 1995).

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
45.3592	cwt	kg	0.0220
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
0.4536	lb	kg	2.2046
1.1209	lb/acre	kg-ha ⁻¹	0.8922
33.9057	oz./yard ²	g-m ⁻²	0.0295
2.2417	ton/acre	Mg-ha ⁻¹	0.4461
(°F - 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

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The objective of this study was to investigate the effects of three plastic mulches in combination with spunbonded polyester rowcover on production and fruit quality of two spring-planted watermelon cultivars (a hybrid diploid and a seedless triploid). The treatment effects on soil and air temperature, early and total marketable yield, fruit size distribution, and economic benefit were analyzed.

Materials and methods

Field trials were conducted in Spring 1999 and 2000 at the Burden Center, Louisiana State University Agricultural Center in Baton Rouge, LA. The soil type used was an Olivier silt loam (Typic Paleudults). The trials were set up for a three-factor split-split plot design with four replications (blocks). The treatments (main plots) consisted of three plastic mulches: silver-on-black (SLV; Climagro, LECO Industries, St-Laurent, Quebec, Canada), photoselective thermal (PST) green (Climagro), and black (BLK; Climagro); and bare ground as a control treatment. The subplots consisted of two watermelon cultivars: the seeded hybrid 'Sangria' (Rogers Sandoz Seed, Boise, ID) and the seedless triploid 'Crimson Jewel' (Sakata Seed America, Inc., Morgan Hill, CA). These cultivars were selected because of their excellent performance in previous trials (Motsenbocker and Picha, 1996). The subsubplots consisted of treatments with and without rowcover. Medium weight (0.9 oz/yard²) spunbonded polyester R30 (RoTop, St. Rémi, Quebec, Canada) was used for this study. Greenhouse transplants were initiated in 72-cell polystyrene trays (Speedling, Plant City, FL) filled with soilless medium (Metro Mix 200; Scotts Co., Marysville, OH) on 25 Feb. 1999 and 24 Feb. 2000. For seed germination, the trays were kept at 90 °F for 2 d and then at 70/86 °F night/day in a greenhouse during growing. Transplants were hand planted in the field on 6 Apr. 1999 and 28 Mar. 2000. The spacing was 3 ft in rows and 8 ft between rows. Individual plots (mulch) were two rows 66 ft long with each row corresponding to a subplot (cultivar). Guard rows of the same length were planted with the seeded cultivar Crimson Sweet. The subplot was

divided in two 33-ft subsubplots (with and without rowcover). The rowcover was installed 2 d after transplanting as tunnel over wire hoops spaced 6.5 ft apart. The rowcover was removed 4 weeks later when beehives were brought to the field to ensure adequate pollination. Based on soil sampling and commercial recommendations, preplant fertilizer (8N-10.5P-19.9K) was applied before bed making at a rate of 500 lb/acre. Ammonium nitrate (34N-0P-0K) was applied weekly through irrigation for a total of 62 lb/acre N and 75 lb/acre N in 1999 and 2000 respectively. The field was irrigated daily through trickle irrigation tubing (Turbulent Twin-Wall; Chapin Watermatics, Watertown, NY). Insect, disease, and weed management practices were conducted following the Louisiana Cooperative Extension Service recommendations (Boudreaux, 1994).

Daily maximum, mean, and minimum temperatures were recorded for this period using a data logger (CR10X Measurement and Control System; Campbell Scientific, Logan, UT). Soil and air temperatures were measured with copper/constantan thermocouples at 2 inches deep and 6 inches above the bed surface respectively for 4 weeks until rowcover removal. Because of the capacity of the data logger, two repetitions of BLK mulch and bare ground with and without rowcover were monitored for soil and air temperature and only one repetition for PST and SLV. Therefore, temperatures for PST and SLV were not included in the statistical analysis. Reference daily temperatures were obtained from the climatological station at the Burden Center located 600 ft from the field trial.

Harvest began on 24 June 1999 and 20 June 2000, and was repeated twice at 1-week interval. Each fruit was weighed individually and classified as marketable or cull (extra-small, misshapen, rotten, and damaged). Marketable fruit was graded into three weight categories: small, 8 to <14 lb for 'Crimson Jewel' and 10 to <16 lb for 'Sangria'; medium, 14 to 18 lb for 'Crimson Jewel' and 16 to 22 lb for 'Sangria'; and large, >18 lb for 'Crimson Jewel' and >22 lb for 'Sangria'. The first harvest was considered early yield, and the sum of all harvests was the total yield. Cost-

benefit and marginal analyses [Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), 1988] were performed to determine the feasibility of incorporating plastic mulch or rowcover into watermelon production. The analyses were based on 1 acre for 'Sangria' and two-thirds of an acre 'Crimson Jewel', plus one-third of an acre 'Sangria' for 'Crimson Jewel' because of the need of a pollinator. Gross income and net benefit (gross income - total costs) for 'Sangria' were estimated based on the average price (\$6.75/cwt) reported for watermelons in the region (Alabama, Arkansas, Louisiana, Mississippi, and Texas) between 1995 and 2005 (U.S. Department of Agriculture, 2001, 2006). Because consumers are willing to pay more for seedless watermelons (Marr and Gast, 1991), prices for 'Crimson Jewel' were estimated 30% higher (\$8.78/cwt) than seeded watermelon. Production costs were estimated from a modified watermelon production budget for Louisiana (Hinson and Boudreaux, 2007) and market prices. Costs that vary were plastic mulch (materials, costs of laying and removing, and subtracting labor costs of weeding), rowcover (materials, laying and removing), and additional harvest labor (difference with harvest in bare ground). The cost of rowcover was based on 2 years use of the fabric. Marginal gain of adopting a technology was calculated by the difference between the change in net income (mulch or rowcover over bare ground; rowcover over BLK plastic mulch) and the costs that vary. Marginal rate of return was calculated by the ratio between marginal gain and the costs that vary. Analysis of variance and mean separation was conducted using SAS 9.1.3 mixed procedure (SAS Institute, Cary, NC).

Results and discussion

Black plastic mulch increased soil temperature at 2 inches deep during the first 4 weeks after planting in comparison with bare ground (Table 1). Air temperatures at 6 inches aboveground, however, were unaffected by plastic mulch in this study. Although soil temperatures were different between years, the overall differences in mean, minimum, and maximum soil temperature between BLK mulch and bare ground for both years were 4.9, 2.3, and 8.3 °F

respectively. These differences are consistent with other reports and are the result of the higher energy accumulation during the day as well as the result of the greenhouse effect of plastic mulches at night (Andino and Motsenbocker, 2004; Soltani et al., 1995). Based on 2 years of data, soil temperatures under PST plastic mulch appear to be similar to BLK mulch (data not presented). In contrast, maximum and minimum soil temperatures under SLV without rowcover appear to be lower and slightly higher respectively (data not presented). Similar results with SLV have been reported previously (Andino and Motsenbocker, 2004; Ham et al., 1993). Low infrared transmittance appears to be an inherent characteristic of the additives used to manufacture SLV mulch.

Spunbonded rowcover increased both soil and air temperature under the tunnel compared with rows without rowcover, as shown in Tables 1 and 2. The overall increase in mean, minimum, and maximum soil temperature by using rowcover regardless of mulch was 2.9, 3.8, and 2 °F

respectively. The differences in soil temperatures were more pronounced during the first 2 weeks after planting. By the third and fourth week, enhanced vine growth under rowcover began to shade the mulch, reducing soil temperatures to the same level or even lower than without rowcover (data not presented). This shading effect was noticed in 1999 when the maximum soil temperature under BLK mulch with rowcover appeared to be slightly lower than under BLK mulch without rowcover (Table 1). The shading did not affect air temperatures though. Differences in mean, minimum, and maximum air temperatures between rowcover and without rowcover were 5.8, 3.2, and 15.2 °F respectively. The increase in soil and air temperatures early in the season under rowcover may have enhanced watermelon growth because larger plants in plastic mulch and rowcover were observed at the time of rowcover removal. Higher accumulation of soil and air heat units has been associated with enhanced plant growth in plastic mulch and rowcover (Jenni et al., 1996; Marr

et al., 1991; Soltani et al., 1995; Wolfe et al., 1989). In contrast, reduced plant growth and yield were associated with the time plants were exposed to near-freezing temperatures at planting (Korkmaz and Dufault, 2002). In our study, rowcover effect on minimum air temperature was higher at low temperatures than high temperatures (Fig. 1). As the daily minimum reference temperature decreased, the difference in minimum air temperature increased, indicating that the effect was greater at low temperature. During a near-freeze event (32.5 °F), minimum air temperature under rowcover was ≈7.2 °F higher than without rowcover (Fig. 1). The same treatment effect and linear trend occurred on minimum soil temperature (data not presented). The increase in minimum air temperatures under rowcover when a freeze or near-freeze event occurs may vary depending on several factors such as wind, relative humidity, thickness of the rowcover material, soil temperature, and so on, and may affect the degree of crop protection (Wells and Loy, 1985).

Table 1. Effect of black plastic mulch and rowcover on daily soil temperatures at 2 inches (5.1 cm) deep for 4 weeks after watermelon planting.

Treatment	Soil temperature					
	Mean		Minimum		Maximum	
	1999 (°F) ^z	2000 (°F)	1999 (°F)	2000 (°F)	1999 (°F)	2000 (°F)
Black mulch + rowcover	83.1 a ^y	77.0 a	71.8 a	67.5 a	98.2 a	87.7 a
Black mulch	81.4 a	73.7 ab	67.4 bc	63.1 bc	101.5 a	84.2 ab
Bare + rowcover	79.3 ab	72.2 bc	69.8 ab	63.5 b	91.4 b	82.0 bc
Bare	76.0 b	68.4 c	65.8 c	60.8 c	88.1 b	77.6 c
Significance (2 years)						
Rowcover		**		***		*
Black mulch		*		*		**

^z(°F - 32) ÷ 1.8 = °C.

^yMeans within a column followed by different letters are significantly different from each other using Tukey's multiple range test at $P \leq 0.05$.

***Significantly different at $P \leq 0.05$, 0.01, or 0.001 respectively.

Studies were conducted in Apr. 1999 and 2000 at the Burden Center, Baton Rouge, LA.

Table 2. Effect of rowcover on daily air temperatures at 6 inches (15.2 cm) above soil/mulch surface and inside the tunnel for 4 weeks after watermelon planting.

Treatment	Air temperature					
	Mean		Minimum		Maximum	
	1999 (°F) ^z	2000 (°F)	1999 (°F)	2000 (°F)	1999 (°F)	2000 (°F)
Rowcover	80.7	74.5	60.3	55.5	116.7	105.1
No rowcover	74.4	69.1	57.3	52.3	99.8	91.4
Significance	***	***	***	***	***	***

^z(°F - 32) ÷ 1.8 = °C.

^yBlack plastic mulch and bare ground were not different at $P \leq 0.05$ and were pooled together.

***Significantly different at $P \leq 0.001$.

Studies were conducted in Apr. 1999 and 2000 at the Burden Center, Baton Rouge, LA.

Overall, plastic mulches or rowcover resulted in higher early and total marketable yields in comparison with bare ground with or without rowcover for both watermelon cultivars (Tables 3 and 4). Early and total marketable yield, however, were not different among plastic mulches and were pooled together into the “mulch” treatment. Early marketable yield for ‘Sangria’ and ‘Crimson Jewel’ grown with plastic mulch was 55% and 225% higher than bare ground respectively. Similarly, plastic mulch increased total yield by 23%

and 100% in ‘Sangria’ and ‘Crimson Jewel’ respectively. These results are consistent with the increase in watermelon yield resulting from plastic mulch reported by other researchers (Andino and Motsenbocker, 2004; Baker et al., 1998; Bhella, 1988). The highest early and total marketable yields for both cultivars were obtained when rowcover was combined with plastic mulch (Tables 3 and 4). Rowcover increased early yield by 72% and 31%, and total yield by 38% and 23% for ‘Sangria’ and ‘Crimson Jewel’ respectively in

comparison with no rowcover. Plants in mulch under rowcover were visually much larger at the time rowcover was removed. Consequently, larger plants at the time of pollination appear to be able to set and sustain a higher number of fruit, resulting in higher yields (Tables 3 and 4). Fruit set after rowcover was removed was 45% and 41% higher than mulch without rowcover for ‘Sangria’ and ‘Crimson Jewel’ respectively. The higher number of fruit per unit area (and per plant), however, may have affected fruit growth later during development, resulting in smaller melons (Tables 3 and 4). In contrast, mulch alone had no effect on average fruit weight.

The effect of mulch and rowcover on yield distribution according to watermelon fruit size was different between cultivars (Figs. 2 and 3). When fruit was separated into three size categories, yield distribution of ‘Sangria’ was similar for all treatments (Fig. 2). In general, yield of large fruit was three times higher than yield of small fruit and 32% higher than yield of medium fruit. Although overall plastic mulch and rowcover increased yield of ‘Sangria’ in comparison with bare ground and without rowcover respectively, their effects were on different fruit category. Plastic mulch increased yield of medium and large fruit primarily, but rowcover increased yield of medium and small melons. In the case of ‘Crimson Jewel’, yield distribution by fruit size was inconsistent among treatments because there was an interaction between mulch, rowcover, and fruit size both years. Yields of the three fruit categories were similar in bare

Fig. 1. Effect of rowcover (RC) on daily minimum air temperature at 6 inches (15.2 cm) above soil/mulch surface. Daily temperatures are from 4 weeks after planting and 2 years (1999 and 2000). Plastic mulches and bare ground were similar and pooled together. Reference temperature corresponds to the minimum air temperature for the same day at the Burden Center climatological station in Baton Rouge, LA. $(^{\circ}\text{F} - 32) \div 1.8 = ^{\circ}\text{C}$.

Table 3. Plastic mulch and rowcover effect on yield and fruit weight in ‘Sangria’ watermelon spring production (Apr.–July 1999 and 2000) at the Burden Center, Baton Rouge, LA.

Treatment	Early yield ^z (2 yr)		Marketable yield		Marketable fruit		Fruit wt ^z (lb) ^y
	(ton/acre) ^y	(fruit/acre) ^y	1999 (ton/acre)	2000 (ton/acre)	1999 (fruit/acre)	2000 (fruit/acre)	
Mulch ^z + rowcover	16.1 a ^x	1652 a	26.1 a	34.9 a	2890 a	3319 a	19.6
Mulch	9.3 b	857 b	18.6 b	25.6 b	1867 b	2420 b	20.7
Bare + rowcover	10.6 b	1037 b	17.8 b	27.0 ab	1908 b	2738 ab	19.4
Bare	6.0 b	518 b	14.9 b	21.1 b	1410 b	1908 b	21.8
Significance (2 yr)							
Mulch	**	**	**		**		NS
Rowcover	***	***	***		***		**

^zEarly yield and fruit weight were not different between years at $P \leq 0.05$ and were pooled together. Plastic mulches were not different at $P \leq 0.05$ and were pooled together into mulch treatment.

^y1 ton/acre = 2.2417 Mg·ha⁻¹, 1 fruit/acre = 2.4711 fruit/ha, 1 lb = 0.4536 kg.

^xMeans within columns followed by different letters are significantly different by Tukey's multiple range test at $P \leq 0.05$.

NS, ***, ** Nonsignificant and significant at $P \leq 0.01$ and 0.001 respectively. Interactions were not significant.

Table 4. Plastic mulch and rowcover effect on yield and fruit weight in ‘Crimson Jewel’ watermelon spring production (Apr.–July 1999 and 2000) at the Burden Center, Baton Rouge, LA.

Treatment	Early yield ^z (2 yr)		Marketable yield		Marketable fruit		Fruit wt ^z (lb) ^y
	(tons/acre) ^y	(fruit/acre) ^y	1999 (ton/acre)	2000 (ton/acre)	1999 (fruit/acre)	2000 (fruit/acre)	
Mulch ^z + rowcover	12.4 a ^x	1825 a	25.7 a	34.5 a	3706 a	5047 a	13.7 b
Mulch	9.4 ab	1203 b	23.1 a	26.0 b	2876 b	3346 b	15.9 a
Bare + rowcover	5.8 bc	809 bc	11.1 b	21.2 bc	1618 c	2945 bc	14.1 b
Bare	2.9 c	394 c	11.0 b	13.6 c	1535 c	1867 c	14.3 ab
Significance (2 yr)							
Mulch	***	***	***		***		NS
Rowcover	*	**	**		***		**
Interaction	NS	NS	NS		NS		*

^zEarly yield and fruit weight were not different between years at $P \leq 0.05$ and were pooled together. Plastic mulches were not different at $P \leq 0.05$ and were pooled together into mulch treatment.

^y1 ton/acre = 2.2417 Mg·ha⁻¹, 1 fruit/acre = 2.4711 fruit/ha, 1 lb = 0.4536 kg.

^xMeans within columns followed by different letters are significantly different by Tukey's multiple range test at $P \leq 0.05$.

NS, *, **, ***Nonsignificant and significant at $P \leq 0.05$, 0.01, and 0.001 respectively.

Fig. 2. Effect of plastic mulch and rowcover (RC) on watermelon yield by fruit size category. Watermelon cultivar Sangria F1 (SG) and triploid ‘Crimson Jewel’ (CJ) were used. Fruit size categories were small, 8 to <14 lb/fruit for CJ and 10 to <16 lb/fruit for SG; medium, 14 to 18 lb/fruit for CJ and 16 to 22 lb/fruit for SG; and large, >18 lb/fruit for CJ and >22 lb/fruit for SG. Yields from plastic mulches were similar and pooled together into mulch treatment. Yields are average of 2 years (1999 and 2000). Vertical bars represent the SE. 1 ton/acre = 2.2417 Mg·ha⁻¹, 1 lb = 0.4536 kg.

ground with and without rowcover (Fig. 2). In contrast, yields and fruit size distribution were different in plastic mulch with and without rowcover. Large fruit had the highest yield proportion in mulch without rowcover, then medium fruit, followed by small fruit. In contrast, in

mulch with rowcover, the proportion of small and medium fruit was high and the proportion of large fruit was low. The adoption of plastic mulch (without rowcover) increased yield of medium and large fruit by 100% and 231% respectively compared with bare ground. In contrast, plastic

mulch with rowcover increased yield of small and medium fruit by 95% and 100% respectively compared with bare ground and rowcover. Similarly, spunbonded rowcover with plastic mulch increased yield of small and medium ‘Crimson Jewel’ fruit by 134% and 35% respectively compared with mulch without rowcover. The increase in small and medium size fruit for ‘Crimson Jewel’ appears to occur to the detriment of large fruit yield, which decreased by 49%. The same fruit size distribution in both cultivars was found during the first (early) harvest (data not presented).

The number of fruit harvested for each fruit category at each treatment varied slightly from the yield distribution (Figs. 2 and 3). In general, the number of fruit per unit area for ‘Sangria’ was the same between large and medium fruit categories. Number of fruit per unit area increased by mulch and rowcover, but mainly of medium fruit (Fig. 3). There was also an increase in number of small fruit resulting from mulch alone (without rowcover). In the case of ‘Crimson Jewel’, the proportion of small and large fruit was high and low respectively for bare ground with and without rowcover and for mulch with rowcover (Fig. 3). In contrast, the proportion of harvested fruit was the same for the three categories in mulch without rowcover. The effect of mulch and rowcover on fruit number per unit area was similar to their effect on yield described earlier. These results suggest that larger plants, obtained as a result of enhanced growth by plastic mulch and rowcover, can set and sustain a

significantly higher number of fruit after rowcover is removed (Tables 3 and 4). Plants grown in plastic mulch alone (without rowcover) appear to be able to sustain fruit growth until

harvest, resulting in a higher yield of large and medium melons than bare ground (Fig. 2). In contrast, plants initially grown under rowcover for 4 weeks appear to be unable later on to

sustain fully the growth of the higher number of fruit set after rowcover was removed (Table 4). This resulted in a switch in yield proportions toward small fruit to the detriment of large fruit (Figs. 2 and 3). Changes in the time of rowcover removal and other cultural practices such as plant spacing and fertilization may help to overcome this effect (Motsenbocker and Arancibia, 2002).

Gross income increased with plastic mulch or rowcover in both cultivars; however, net benefit increased only in 'Crimson Jewel' with mulch (Tables 5 and 6). Because there were no differences in yield and gross income among plastic mulches, and differences in the cost of plastic mulches did not affect net benefit (data not presented), only data from BLK plastic mulch is presented in Tables 5 and 6. Overall, BLK plastic mulch increased gross income by 29% and 70% for 'Sangria' and 'Crimson Jewel' respectively. Rowcover also increased gross income by 30% and 31% for 'Sangria' and 'Crimson Jewel' respectively. The increase in net benefit of 'Crimson Jewel' production resulting from BLK plastic mulch was 340% in comparison with bare ground. In contrast, net benefit was unaffected by rowcover in both cultivars and by mulch in 'Sangria' (Tables 5 and 6). These results suggest that the increase in yield under the market condition that this analysis was based appears to be sufficient to cover the additional costs incurred in adopting these technologies. Only

Fig. 3. Effect of plastic mulch and rowcover (RC) on watermelon fruit number by fruit size category. Watermelon cultivars Sangria F1 (SG) and triploid 'Crimson Jewel' (CJ) were used. Fruit size categories were small, 8 to <14 lb/fruit for CJ and 10 to <16 lb/fruit for SG; medium, 14 to 18 lb/fruit for CJ and 16 to 22 lb/fruit for SG; and large, >18 lb/fruit for CJ and >22 lb/fruit for SG. Yields from plastic mulches were similar and pooled together into mulch treatment. Yields are average of 2 years (1999 and 2000). Vertical bars represent the SE. 1 fruit/acre = 2.4711 fruit/ha, 1 lb = 0.4536 kg.

Table 5. Cost-benefit and marginal analyses of incorporating black plastic mulch or rowcover in 'Sangria' watermelon spring production (Apr.-July 1999 and 2000) at the Burden Center, Baton Rouge, LA.

Treatment	Gross income ^a (\$/acre) ^y	Costs that vary			Total costs ^z (\$/acre)	Net benefit ^z (\$/acre)	Marginal return	
		Black mulch ^z (\$/acre)	Rowcover ^z (\$/acre)	Additional harvest ^z (\$/acre)			Gain ^z (\$/acre)	Rate ^z (\$/\$)
Bare (B)	2425 b ^x				1579	846		
Bare + rowcover (RC)	3025 b		734	116	2428	597	(RC - B)	-249 -0.29
Black mulch (M)	2938 b	337		99	2014	923	(M - B)	77 0.18
Black mulch + rowcover (MR)	4110 a	337	734	325	2974	1137	(MR - M)	214 0.22
Significance								
Mulch	**					NS		
Rowcover	***					NS		

^aGross income = yield × price (\$6.75/cwt); \$1.00/cwt = \$0.022/kg. Black mulch = materials + labor (laying + removing - weeding); rowcover = materials (2 years use) + labor (laying + removing); additional harvest = harvest - harvest bare. Total costs are modified from watermelon production budget in Louisiana (Hinson and Boudreaux, 2007). Net benefit = gross income - total costs; marginal gain = difference in net benefit - difference in cost that vary; marginal rate = gain ÷ difference in cost that vary.

^y\$1.00/acre = \$2.4711/ha.

^zMeans within columns followed by different letters are significantly different by Tukey's multiple range test at $P \leq 0.05$.

NS, ***, ** Nonsignificant and significant at $P \leq 0.01$ and 0.001 respectively.

B, bare; M, black mulch; MR, black mulch + rowcover; RC, rowcover.

Table 6. Cost-benefit and marginal analyses of incorporating black plastic mulch or rowcover in ‘Crimson Jewel’ watermelon spring production (Apr.–July 1999 and 2000) at the Burden Center, Baton Rouge, LA.

Treatment	Gross income ^z (\$/acre) ^y	Costs that vary			Total costs ^z (\$/acre)	Net benefit ^z (\$/acre)	Marginal return	
		Black mulch ^z (\$/acre)	Rowcover ^z (\$/acre)	Additional harvest ^z (\$/acre)			Gain ^z (\$/acre)	Rate ^z (\$/\$)
Bare (B)	2241 d ^x				1801	440 b		
Bare + rowcover (RC)	2899 c		734	106	2641	258 b	(RC – B) –182	–0.22
Black mulch (M)	3765 b	337		229	2367	1399 a	(M – B) 959	1.70
Black mulch + rowcover (MR)	4975 a	337	734	432	3303	1672 a	(MR – M) 273	0.29
Significance								
Mulch	***					***		
Rowcover	***					NS		

^zGross income = yield × price (\$8.78/cwt); \$1.00/cwt = \$0.022/kg. Black mulch = materials + labor (laying + removing – weeding); rowcover = materials (2 years use) + labor (laying + removing); additional harvest = harvest – harvest bare. Total costs modified from the watermelon production budget for Louisiana (Hinson and Boudreaux, 2007). Net benefit = gross income – total costs; marginal gain = difference in net benefit – difference in cost that vary; marginal rate = gain/difference in cost that vary.

^y\$1.00/acre = \$2.4711/ha.

^xMeans within columns followed by different letters are significantly different by Tukey’s multiple range test at $P \leq 0.05$.

^{ns,***}Nonsignificant or significant at $P \leq 0.001$ respectively.

B, bare; M, black mulch; MR, black mulch + rowcover; RC, rowcover.

the increase in gross income of ‘Crimson Jewel’ resulting from plastic mulch was high enough to exceed the cost of its adoption and make it profitable. This was also reflected in the marginal gain and rate of return of the additional investment for adopting mulch or rowcover over bare ground and rowcover over BLK plastic mulch. Although there was no significant difference in net benefit between bare ground and rowcover for both cultivars, the marginal rate of return indicates that adopting rowcover over bare ground under these conditions and prices results in a loss of money. Similarly, the rate of return of investing in plastic mulch and rowcover appears not to be very attractive (<30% return) with the exception of ‘Crimson Jewel’ grown with plastic mulch, which had a net return of 170%. It is worthy to note that as the price of watermelon increases, the rate of return increases, also making the investment more attractive (data not presented).

Growers need to be cognizant of the market demands and adjust their practices accordingly to meet market expectations. Prices received by growers depend on the particular market forces. Choice of cultivar is important to satisfy a specific market because it has been reported that consumers are willing to pay more for triploid fruit (Marr and Gast, 1991). The difference in price between ‘Sangria’ (seeded) and ‘Crimson Jewel’ (triploid) watermelon was a factor in the net benefit and rate of return (Tables 5 and 6). Based

on this and previous studies (Motsenbocker and Arancibia, 2002), plasticulture and plant density (in-row spacing) are two important factors to take into consideration when maximizing yield for specific markets. If a grower is interested in large melons, then plastic mulch alone and low plant density appear to be optimal. In contrast, plastic mulch in combination with rowcover and high plant density favor production of small and medium melons. Plastic mulch and rowcover also increase soil and air temperature inside the tunnel, favoring production early in the spring. Full evaluation of rowcover against freezing temperatures was not possible in this study because temperatures were not low enough to kill unprotected plants. Net benefit and marginal return would have been more attractive for rowcover if freezing temperatures would have made replanting necessary. Consequently, protection of high-value plant material, such as triploid watermelon transplants, against light freezes may still justify the use of this technology early in the spring. Finally, adoption of plasticulture may be of particular advantage for small growers with a retail outlet (farmers market) where they can obtain higher prices that would make the rate of return of the additional investment more attractive.

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