Technology & Product Reports

Physical Characteristics of Mulches and Their Impact on Crop Response and Profitability in Muskmelon Production

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ADDITIONAL INDEX WORDS. durability, mulch, plastic film, polyethylene, removal time, soil temperature, strength

SUMMARY. Using polyethylene mulches has increased earliness, yields, and fruit quality in muskmelon, resulting in their extensive use for melon production with numerous commercial products. However, two problems

are associated with polyethylene use: removal and disposal following production. Organic mulches are potential alternatives but, in this study, resulted in significantly lower soil temperatures than all other treatments and generally had lower yields. Soil temperature, yield, fruit size and percent soluble solids were increased by polyethylene mulches compared to bare soil. Crop response differences between polyethylene mulches were not significant for most characteristics measured. There were significant differences in durability and ease of removal of polyethylene mulches. Based on our results, durability and ease of removal are the main characteristics on which to base selection. Proper mulch selection can reduce removal costs and enable commercial producers to leave a mulch in place for the production of a second crop.

Polyethylene mulching films are widely used throughout major vegetable production areas of the world (Bogle et al., 1989). Polyethylene mulch use has become extensive because growers experience improved results compared to bare soil cultivation (Bonanno and Lamont, 1987; Decoteau et al., 1989). Using black and clear polyethylene mulches results in soil warming (Clarkson and Frazier, 1957; Hausher, 1983), water conservation (Bhella, 1988), higher yields (Battikhi and Ghawi, 1987), and cleaner and less diseased fruit (Gerber et al., 1983; Sanders et al., 1986).

Bonanno and Lamont (1987) studied crop responses to different polyethylene mulching films. Hemphill and Clough (1990) recorded crop response and mulch ratings for degradation of different materials. Gerber et

al. (1983) and Sanders et al. (1986) concluded that using these films often results in higher economic returns. Results also indicate that using mulching films provides advantages over bare soil, but crop response between mulching films is not always significant (Brown et al., 1992; Hemphill and Clough, 1990).

Using polyethylene mulching films also has disadvantages, including; additional costs for material, installation, removal, and disposal (Clarkson and Frazier, 1957; Gerber et al., 1983; Hemphill and Clough, 1990; Taber, 1986). Our objective was to compare different polyethylene films and organic mulches for strength, durability, difficulty of removal, soil warming, and crop response.

Materials and methods

A 2-year field study was conducted at the Texas A&M Univ. Research and Extension Center in Weslaco, an area with a subtropical, semiarid climate. Plantings were made each season on free standing beds raised 8 inches from furrow to bed shoulder and crowned at the bed center to height of 12 inches, resulting in bed tops 40 inches wide. Spacing from bed center to center was 80 inches, with a drip irrigation line installed in the center of each bed 6 inches below the surface.

Mulch treatments were selected (Table 1) to represent the range of materials commercially available. Most mulches tested were 1.0- to 1.25-mil-thick, black, embossed polyethylene films but also included were several experimental alternatives. These alternatives included thinner high-density plastic films, different color combinations, and three organic materials made from kenaf or recycled newspaper.

Treatment plots were one bed wide and 50 feet long and were separated by 10-foot alleys. Treatments were replicated five times in 1994 and six times in 1995 in randomized complete-block designs. Polyethylene films were applied using three-point hitch laying equipment with furrow openers, press wheels, and disk closers. Organic mulches were applied by hand. Mulches were laid the first year on 21 Jan. 1994 and the second year on 16 Dec. 1994.

Three seeds of the muskmelon, *Cucumis melo*, cultivar 'Cruiser' (Harris Moran Seed Co., Modesto, Calif.) were hand planted in holes spaced 12

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We gratefully acknowledge the assistance of Juan Bernal, Carlos Rodriguez, Venancio Gonzalez and Eden Hinojosa for assistance in all aspects of this study and to Marvin Baker for help in measuring mulch strengths; we would like to clarify that they are co-authors in as much as all efforts used for planning, implementing, and writing were a team effort. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

inches apart on 25 Feb. 1994 the first year and on 17 Feb. 1995 the second year. These later were thinned to one plant per hole. Irrigation was applied with subsurface drip irrigation as needed based on crop observations. Weed control consisted of hand hoeing and herbicide spot treatment to bed shoulders. Pests were controlled using recommended materials for aphids, leafminers, whitefly, and downy mildew.

Soil temperatures were measured at weekly intervals in each replication's plots. A long-stem thermometer (model 15-078K; Fisher Scientific, Pittsburgh) was inserted at a depth of 4 inches about midway between the center of the bed and the outside bed shoulder. Soil temperature measurements were taken in the afternoon. Yields were determined for each plot by harvesting fruit at the half to full slip stage of maturity. Data were recorded for six harvests in 1994 and four harvests in 1995. Fruit soluble solids were determined on samples taken from the first four harvests in 1994. A core sample was taken from a randomly selected medium-size fruit midway between the stem and blossom ends. The parts of the core closest to the rind and center were removed. Then, a

juice sample was obtained using a garlic press. Percent soluble solids were determined using a hand-held refractometer (model 10430; Leica, Buffalo, N.Y.). Ratings were made for mulch condition in all plots on a scale of 1 = in shreds to 5 = intact. Ratings were recorded on 19 July 1994 and 30 June and 18 Dec. in 1995. Removal times were determined on all replications in the first year and on three of the six replications in the second year. Plots were prepared for mulch removal by first running a cultivator sweep down the middle of each furrow to loosen soil holding the mulches on the sides of the bed. Removal times were determined by measuring the amount of time required for two individuals to pull up and pile the mulch from each plot. The same pair of workers were used for all plots within each replication. Estimated costs of removal per acre were determined by multiplying removal time per plot by a conversion factor to labor hours per acre then multiplying that by a wage cost of \$5.75 per hour (personal communication, 1996 John Nichols Agricultural Economics Dept. Texas A&M Univ.). Mulch strength was determined on samples of exposed mulch taken from bed tops of each plot at the end of each

growing season. The amount of force required to cause tearing was determined on 2-inch-wide samples in directions parallel to and perpendicular to the row using an universal testing instrument (model 1000; Instron Corp., Canton, Mass.). The strength values in both directions were averaged for each plot, and then relative strength was calculated by dividing the value for each mulch by the value obtained for the weakest mulch. All data were analyzed statistically using analysis of variance, Duncan's multiple range test was used to compare individual treatment means, and orthogonal contrasts were used to compare mean groupings (i.e., bare soil vs. all plastic mulches) (SAS Institute, 1988).

Results and discussion

All replications of the kenaf paper mulch in 1994 were torn apart by a thunderstorm that occurred in March of that year. No data is presented for kenaf mulch.

Average soil temperatures under polyethylene mulches were higher for each of the nine sample dates in 1994 and for 13 sample dates in 1995 compared to bare soil (Fig. 1). Average soil temperature for all polyethylene

Table 1. Treatment list of mulches evaluated 1994 and 1995 for melons in the Lower Rio Grande Valley of Texas.

Treatment no.	Company	Thickness (mil)	Description	1994	1995
1	Edison Plastics Co., Aberdeen, N.C. ²	1.25	Black embossed	X	X
2	Tredegar Film Products, Richmond, Va.	1.0	Black embossed	X	X
3	Tredegar Film Products, Richmond, Va. (Tr)	1.25	Black embossed	X	X
4	Four Seasons Agricultural Products, Atlanta	1.0	Black embossed	X	
5	Four Seasons Agricultural Products, Atlanta	1.25	Black embossed	X	
6	Consolidated Thermoplastics Co. Films, Harrington, Del.	1.25	Black embossed	X	
7	Mid South Extrusion Co., Monroe, La.	1.25	Black embossed	X	
8	Climagro, St. Laurent, Qu., Canada	1.1	Black embossed	X	
9	Climagro, St. Laurent, Qu., Canada	1.0	Black embossed		X
10	Climagro, St. Laurent, Qu., Canada	1.1	Green		X
11	Sonoco Products Co., Hartsville, S.C.	0.6	High-density black	X	X
12	Sonoco Products Co., Hartsville, S.C.	0.8	High-density black	X	X
13	AEP Industries, South Hackensack, N.J.	1.25	Infrared transmittable	X	X
14	Polyon Agricultural Sheeting, Menashe, Israel	0.8	Selective low thermic	X	X
15	Polyon Agricultural Sheeting, Menashe, Israel	1.0	Silver on brown	X	X
16	Polyon Agricultural Sheeting, Menashe, Israel	1.0	Selective low thermic		X
17	Tascon, Houston		Fiber mulch		X
18	Tascon, Houston		Pellets		X

²Materials are referred to in the other tables by treatment number the abbreviation for the company, the thickness and the description.

mulches was higher than bare soil by up to 7.2 °F on some dates, and individual mulches resulted in soil temperature higher by as much as 18 °F on certain dates when compared to bare soil. Six of the polyethylene mulches evaluated in the first year and five the second year resulted in average season-long soil temperatures significantly higher than bare soil (Table 2). Highest average soil temperature in 1994 was recorded for AEP Industries infrared transmittable mulch, which was significantly higher than seven of the other mulches and bare soil. In 1995, five mulches had significantly higher average soil temperatures than bare soil and the two paper mulches. These mulches included Climagro black embossed, AEP Industries infrared transmittable, and Polyon's two selective low thermics and silver on black. The two recycled newspaper mulches evaluated in 1995 had season-long average soil temperatures significantly lower than all of the other mulches and bare soil.

Few significant differences were recorded for crop plant responses between polyethylene mulching film treatments in this study, but several were recorded between bare soil and these treatments. Yields increased by all polyethylene films compared to bare soil an average of 42% in 1994 and 27% in 1995 (Table 2). In the first year, no significant differences between plastic films were recorded for total yield. In the second year, Tredegar 1.0-mil black embossed had yields significantly higher than two other mulches. Fruit size increased in treatments using plastic films compared to bare soil, with increases in weight averaging 26% higher in 1994 and 16% higher in 1995 for the plastic films (Table 2). During both years, there were no significant differences recorded between the plastic film treatments for fruit size. Sweetness measured as percent soluble solids was recorded in 1994 and was significantly higher for treatments using plastic films compared to bare soil. Average percent soluble solids for melons produced on plastic were 0.6% higher than those produced on bare soil (Table 2), but, again, there were no significant differences recorded between plastic films.

The durability ratings and strength measurements of polyethylene mulches recorded at end of season showed polyethylene mulches differing in perfor-

Fig. 1. Effects of plastic mulch vs bare soil on soil temperatures over time at the 4 inch depth during 2 growing seasons for cantaloupe production in South Texas.

mance (Table 3). Ratings made 19 July 1994 showed Tredegar 1.0-mil black embossed, Consolidated Thermoplastics films 1.25-mil black embossed, Climagro 1.1-mil black embossed, both Sonoco high-density black embossed, and the Polyon silver on brown retained strength and maintained more durability than other mulches in the study. These mulches had significantly higher durability ratings than four of the other mulches in the trial. In 1995 the polyethylene mulch film with the highest rating after 6 months in the field was Tredegar 1.25-mil black embossed, which had a significantly higher durability rating than nine of the other polyethylene films. After materials were left in the field an additional 6 months, they fell into three distinct statistical groups (Table 3). Tredegar 1.25-mil black embossed, Climagro 1.0-mil black em-

bossed, and Sonoco 0.6-mil high-density black embossed had significantly higher durability ratings than eight of the other polyethylene mulches. The middle group included Edison 1.25 mil, Tredegar 1.0 mil, Sonoco 0.8 mil, and Polyon 1.0 mil silver on brown and had significantly higher durability ratings than four other polyethylene mulches. The group with the lowest durability ratings was significantly lower than seven of the other polyethylene mulches included Climagro 0.8 mil g, AEP 1.25 mil infrared transmittable, Polyon 0.8 mil selective low thermic, and Polyon 1.0 mil selective low thermic.

Removal times generally were highly correlated with durability ratings, mulches having high ratings recorded lower removal times (Table 3). In 1994, Sonoco 0.8-mil high-density black had a removal time of 64 s per

plot and was significantly lower than eight of the other polyethylene mulches. The second year removal time for Climagro 1.1-mil black embossed and Tredegar 1.0-mil black embossed were 59 and 69 s per plot, respectively, and were significantly lower than three other polyethylene mulches.

Estimated costs of removal varied

between mulch treatments for both years (Table 3). Sonoco 0.8-mil high-density black embossed and CT 1.25-mil black embossed films recorded the lowest estimated cost of removal in 1994 and were significantly lower than five other mulches. The two lowest estimated costs of removal in 1995 were recorded by Climagro 1.0-mil

black embossed and Tredegar 1.0-mil black embossed, which had significantly lower removal costs than three other mulches.

Relative strength measurements in 1994 varied significantly between polyethylene mulches (Table 3). Climagro 1.1-mil black embossed had the highest relative strength and was

Table 2. Cantaloupe soil temperatures, total yield, fruit size for two seasons and fruit percent soluble solids for one season for the mulches evaluated.

Treatment number ^a	Avg. soil temp (°F)	1994			1995		
		Total yield (tons/acre)	Fruit size (pounds)	Soluble solids (%)	Avg. soil temp (°F)	Total yield (tons/acre)	Fruit size (pounds)
Bare soil	82.4 d ^b	09.2 b	2.8 b	6.17 b	78.3 b	5.1 d	1.4 a
1	87.8 ab	13.4 ab	3.5 ab	6.71 ab	79.5 ab	6.7 a-c	1.7 a
2	84.7 b-d	12.9 ab	3.4 ab	6.71 ab	79.2 ab	7.4 a	1.7 a
3	85.5 b-d	13.4 ab	3.7 a	7.06 ab	79.9 ab	6.0 b-d	1.6 a
4	85.3 b-d	11.9 ab	3.3 ab	6.99 ab			
5	86.9 a-c	14.4 a	3.7 a	6.96 ab			
6	85.6 b-d	12.5 ab	3.4 ab	7.18 a			
7	85.5 b-d	13.3 ab	3.4 ab	6.98 ab			
8	86.9 a-c	13.5 a	3.5 ab	6.71 ab			
9					81.0 a	6.7 ab	1.7 a
10					80.2 ab	6.0 a-d	1.6 a
11	84.0 cd	13.4 ab	3.5 ab	6.49 ab	79.7 ab	6.2 a-d	1.7 a
12	84.7 b-d	13.9 a	3.82 a	6.85 ab	79.7 ab	6.7 a-c	1.6 a
13	89.6 a	13.9 a	3.5 a	6.91 ab	81.0 a	6.2 a-d	1.7 a
14	87.4 a-c	11.6 ab	3.3 ab	6.31 ab	81.1 a	6.6 a-c	1.7 a
15	87.6 ab	10.8 ab	3.2 ab	6.59 ab	81.0 a	6.7 ab	1.7 a
16					80.6 a	5.8 cd	1.6 a
17					75.0 c	6.0 a-d	1.5 a
18					74.5 c	5.3 cd	1.4 a

^aMulches are identified by a number and correlate to treatment number and descriptions in Table 1.

^bMeans in each column followed by the same letter are not significantly different according to Duncan's multiple range test.

Table 3. Mulch condition ratings on one date the first year and on two dates the second year, removal times, relative strengths and removal costs per acre for two seasons.

Treatment number ^a	1994				1995				
	Rating ^b	Removal time (s)	Relative strength	Cost/acre (\$)	Rating		Removal time (s)	Relative strength	Cost/acre (\$)
					6 month	12 month			
1	3.7 ab ^x	129 a-c	2.1 fg	59 a-c	4.0 bc	2.7 b	105 bc	1.5	42 bc
2	4.0 a	160 a	1.9 g	73 a	3.8 c	2.7 b	69 c	1.2	28 c
3	3.7 ab	126 a-c	2.2 e-g	57 a-c	4.8 a	4.0 a	75 bc	1.6	30 bc
4	2.0 c	17 b-d	1.0 h	53 b-d					
5	2.3 c	141 ab	1.1 h	64 ab					
6	4.0 a	77 de	3.6 c	35 de					
7	3.0 a-c	93 c-e	2.5 de	42 c-e					
8	4.0 a	112 b-d	6.2 a	51 b-d					
9					4.0 bc	3.8 a	59 c	1.4	24 c
10					1.0 f	1.0 c	206 a	1.7	83 a
11	4.0 a	90 c-e	2.3 cf	41 c-e	4.5 ab	3.8 a	100 bc	1.6	40 bc
12	4.0 a	64 e	3.4 c	29 e	4.2 bc	3.2 b	71 bc	1.4	29 bc
13	2.7 bc	100 b-c	5.0 b	45 b-c	1.8 e	1.0 c	152 ab	1.8	61 ab
14	2.7 bc	124 a-c	3.6 c	56 a-c	3.2 d	1.0 c	123 bc	1.1	50 bc
15	4.0 a	107 b-d	2.8 d	49 b-d	4.0 bc	2.8 b	90 bc	1.8	36 bc
16					2.8 d	1.0 c	216 a	1.0	87 a

^aMulches are identified by a number and correlate to treatment number and descriptions in Table 1.

^bRatings were made of the condition of the mulch in each plot on a scale from 1 (in shreds) to 5 (in tact).

^xMeans in each column followed by the same letter are not significantly different according to Duncan's multiple range test. If no letters follow means, no significant differences were found.

significantly higher than the other 12 mulches tested. In 1995, no significant differences were recorded for relative strength.

Conclusions

The organic materials used in this study did not provide for beneficial crop responses compared to polyethylene mulching films. Our results confirm observations in other studies regarding the beneficial effect of polyethylene mulch compared to bare soil. Soil temperatures, total yields, fruit size, and soluble solids were improved significantly both years with most polyethylene mulching films. There were few significant differences in terms of crop performance between polyethylene mulches.

We found significant differences between mulches regarding durability, indicated by mulch ratings, removal time, and estimated cost of removal. Generally, there was a high degree of correlation between these different measurements with mulches that received higher ratings requiring less time and expense to remove. The significance of these differences between plastic films becomes apparent when one considers that there was a 250% and 362% increase between the lowest and highest estimated cost of removal for mulches in the 1994 and 1995 tests, respectively. The increased costs in 1994 and 1995 resulted in a difference of \$44 and \$63 per acre, respectively, between the lowest and highest estimated costs of removal. Therefore, the decision regarding which mulch to use should be based on durability and ease of removal, rather than on differences in how the various mulches affected crop growth.

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A Multilayer Soilless System for Greenhouse Tomato Production Pioneered in Shandong Province, People's Republic of China

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ADDITIONAL INDEX WORDS. *Lycopersicon esculentum*, multilayer cropping, photosynthesis, light interception

SUMMARY. A new multilayer soilless culture system for greenhouse tomato production is described. Experiments over two spring seasons and one winter season demonstrated faster plant growth rate, higher dry matter productivity, higher fruit yield, and better fruit quality with the multilayer soilless culture system compared to the traditional soil-based culture system. The multilayer soilless culture system is suggested as a replacement of the soil-based production system to achieve significant yield improvement in greenhouse tomato production.

At present, the key issues in greenhouse vegetable production are how to increase yields, decrease production costs, and maximize economic benefits. It is rec-

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A.P.P. is indebted to the Government of the People's Republic of China, through its office of the Sciencetech Department of the Ministry of Agriculture, and to the United Nations Development Program in China for providing travel funds. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.