Literature cited

Chen, Y. and T. Aviad. 1990. Effects of humic substances on plant growth, p. 161–186. In: P. MacCarthy, C. Clapp, R. Malcolm, and P. Bloom (eds.). Humic substances in soil and crop sciences, selected readings. Amer. Soc. Agron.–Soil Sci. Soc. Amer., Madison, Wis.

David, P.P., P.V. Nelson, and D.C. Sanders. 1994. A humic acid improves growth of tomato seedlings (sic) in solution culture. J. Plant Nutr. 17:173–184.

Drew, M.C. 1975. Comparison of the effects of a localized supply of phosphate, nitrate, ammonium and potassium on the growth of the seminal root system and the shoot in barley. New Phytol. 75: 479–490.

Drew, M.C. and L.R. Saker. 1975. Nutrient supply and growth of the seminal root system in barley: II. Localized, compensatory increases in lateral root growth and rates of nitrate uptake when nitrate supply is restricted to only part of the root system. J. Expt. Bot. 26:79–90.

Drew, M.C., L.R. Saker, and T.W. Ashley. 1973. Nutrient supply and the growth of the seminal root system in barley: 1. The effect of nitrate concentration on the growth of axes and laterals. J. Expt. Bot. 24:1189–1202.

Granato, T.C. and T.C. Raper. 1989. Proliferation of maize (*Zea mays* L.) roots in response to localized supply of nitrate. J. Expt. Bot. 40:263–275.

Hartwigsen, J.A. and M.R. Evans. 2000. Humic acid seed and substrate treatments promote seedlings root development. HortScience 35(7):1231–1233.

Mylonas, V.A. and C B. McCants. 1980. Effects of humic and fulvic acids on growth of tobacco: I. Root initiation and elongation. Plant Soil 54:485–498.

Sanders, D.C., J.A. Ricotta, and L. Hodges. 1990. Improvement of carrot stands with plant biostimulants and fluid drilling. HortScience 25(2):181–183.

Tan, T.K. and D. Tantiwiramanond. 1983. Effect of humic acids on nodulation and dry matter production of soybean, peanut and clover. Soil Sci. Soc. Amer. J. 47: 1121–1124.

Biodegradable Mulch Films for Weed Suppression in the Establishment Year of Matted-row Strawberries

C.A. Weber[1]

ADDITIONAL INDEX WORDS. weed control, plasticulture, *Fragaria*, strawberry production, degradable mulch

SUMMARY. Adequate weed control in the establishment year of matted-row strawberries (*Fragaria* ×*ananassa*) is crucial for the long-term viability of plantings. Suppression of weed growth until the new strawberry plants are established and runners rooted is an effective strategy in new plantings. Three biodegradable mulch films were compared to standard weed control for establishing matted-row strawberries. Two films were test products using a biodegradable polymer, either clear or black, covering brown 40-lb kraft paper (IP40 Clear and IP40 Black, respectively). The third material was Planters paper, a black paper mulch. The films were evaluated for weed suppression, rate of degradation and effects on runner production and fruit yield. Additionally, the ability of runners that were formed to root as the film degraded was also observed. The IP40 Black mulch reduced the number of weeds compared to the standard control but did not degrade quickly enough for runners to root. The Planters paper also had fewer weeds, but it degraded quickly along the edges where it was covered by soil. This allowed the wind to tear it and blow large pieces off the plots. The IP40 Clear degraded in a timely manner and allowed runner rooting, but it was not acceptable as a weed suppression material. The IP40 Black and Planters paper mulches were effective for weed control in the establishment year, but rate of degradation was too slow in the former case and too fast in the latter. Runner production and fruit yield were not affected by any of the mulch materials compared to standard control.

[1]Assistant professor, Department of Horticultural Sciences, New York State Agricultural Experiment Station, Cornell University, Geneva, NY 14456; e-mail caw34@nysaes.cornell.edu.

This research was funded in part by a grant from the New York State Integrated Pest Management Program.

Weed control is the most pressing problem encountered by strawberry growers using a matted-row strawberry production system. Newly planted strawberries in the matted-row system are most susceptible to weed competition during the first 2 months after planting. Yield losses of up to 65% have been documented when early season weed competition was not controlled (Pritts and Kelley, 2001). Weed control during this period is especially critical for the long-term viability of new plantings and is difficult because only a few herbicides with limited residual activity are available for establishment year weed control (Pritts and Kelley, 2001). Thus, using herbicides alone is not effective for preventing weed competition in the establishment year and yield reduction in future seasons.

In a matted-row system, plants are planted from 12 inches (30.5 cm) to 24 inches (61.0 cm) apart in the row and runners from the transplants fill in the remainder of the row space. Row spacing varies from 42 to 52 inches (106.7 to 132.1 cm) from center to center (Pritts and Handley, 1988). Wheat (*Triticum aestivum*), rye (*Secale cereale*), or barley (*Hordeum vulgare*) straw is applied on established fields in the late fall of each year for winter cold protection and weed control in the following year. However, new plantings are without straw mulch for weed control until the second season. Weed competition within the rows can inhibit stand establishment and reduce future yields. Current plasticulture with non-degradable plastic mulch provides excellent weed control but cannot be used for establishing a matted-row planting because the plastic mulch stops runners from rooting and filling in the row. By using a material that degrades within 60 to 90 d of application, weed suppression during the critical part of the season could be accomplished while still allowing runners to fill in the row as the material degrades. The subsequent straw application in early winter would further aid in the degradation process and prevent blowing of mulch fragments thus making complete degradation more likely.

Photodegradable and biodegradable mulches made of plastic, paper, or other materials have been tested for their utility for annual food production with varying degrees of success (Greer and Dole, 2003). As early as the 1920s researchers developed acceptable production practices with paper mulches in annual vegetable and fruit production (Flint, 1928; Hutchins, 1933) but questioned the economics of the material (Edmond, 1929; Smith, 1931). The application of a thin layer of wax or polyethylene greatly increased the utility of paper mulches (Albregts and Howard, 1972; Peavy, 1973) while maintaining acceptable degradation properties. However, this material has not been adopted for food production.

Photodegradable plastic mulches have been effective but have proven to be unreliable as well as expensive to use (Greer and Dole, 2003). Degradation is inhibited by crops that cover the mulch as they grow because exposure to ultraviolet light is reduced or prevented (Greer and Dole, 2003). Degradation is also slower in areas that receive less solar radiation (Greer and Dole, 2003).

Alternatively, the rapid degradation of biodegradable starch-based plastic mulch has limited the utility of this material (Yang, 1999). Other biodegradable mulches made from latex or treated paper often do not inhibit weed growth (Anderson et al., 1995; Greer and Dole, 2003) thus reducing their usefulness. Shogren (2000) did demonstrate an increase in longevity and the reduction of weed growth when paper mulches were treated with vegetable oil-based resins. However, no degradable materials have been tested on a perennial crop such as matted-row strawberry where the degradation of the material within 60 to 90 d is required. The objective of this study was to determine the suitability of three biodegradable mulch films for providing weed control in the establishment year of matted-row strawberry plantings compared to standard, unmulched weed control practices.

Materials and methods

Bare root strawberries were planted on 31 May 2001 at Cornell University's New York State Agricultural Experiment Station, Geneva, N.Y., in a Honeoye fine sandy loam soil with a 6% slope. The design was a 2 × 5 factorial experiment in a randomized complete block design with two varieties, Jewel and Honeoye. There were three replications of four mulch treatments and a standard weed control for each variety.

Standard weed control in matted-row strawberry combines a preemergent herbicide application before or shortly after planting with supplemental hand and/or mechanical cultivation (Pritts and Handley, 1988). The mulch treatments applied were IP40 Black, IP40 Clear/paper-side down, IP40 Clear/paper-side up (International Paper Co., Stamford, Conn.), and Planters paper (Ken-Bar, Inc., Reading, Mass.). IP40 is a biodgradable polymer covering 40-lb (about 65 $g\cdot m^{-2}$) brown kraft paper. The polymer, as manufactured, is clear and carbon black is added to make the black film. The IP40 Clear was placed in two orientations to see what effect contact with the soil had on the degradation rate of the paper and the polymer. Planters paper is black paper that is commercially available for use as an alternative to black plastic.

Each treatment-variety combination had three 50 ft (15.2 m) replications with T-tape drip irrigation [0.67 gal/min per 100 ft at 8 lb/inch^2 (500 $L\cdot h^{-1}$ per 100 m at 55.2 kPa); T-Systems International, Inc., San Diego). Irrigation was supplied with a split application at a rate equivalent to 1 inch (25.4 mm) per week [0.62 gal/ft^2 (25.2 $L\cdot m^{-2}$)] within the row in the establishment year and 1.5 inches (38.10 mm) per week [0.94 gal/ft^2 (37.8 $L\cdot m^{-2}$)] during the fruiting season. Napropamide preemergent herbicide was applied to all plots at the labeled rate [2.5 lb/acre (2.80 $kg\cdot ha^{-1}$) a.i.] before the mulch was applied. Transplants were planted at 18-inch (45.7 cm) spacing using a water wheel planter (Rain-Flo, East Earl, Pa.).

The total number of weeds were counted and removed biweekly and a cumulative record kept. Weeds were not counted or removed at 4 weeks postplanting in the interest of time because there were so few present. The weeds were removed by hand after each weed count. The percent degradation of the mulches was estimated at 2-week intervals and in the following year based on visual estimates of percentage of material remaining. The total number of runners were counted at 10 weeks postplanting and fruit yield data was taken in the following summer.

An analysis of variance was done according to the procedures of Gomez and Gomez (1984) followed by Duncan's multiple range test when significance was identified for comparing treatments. No interactions between the cultivars and the mulch treatments were calculated for any of the data collected. Therefore, cultivar data was combined for further analysis on the mulch treatments.

Results

Yields among the treatments were comparable to other trials conducted at Geneva using 'Honeoye' and 'Jewel' (Sanford et al., 1985). There were no statistical differences between the treatments for runner formation nor for yield in the following season (Table 1). Total number of weeds and percent mulch degradation differed among the mulches throughout the experiment. For the first 6 weeks after planting, the standard control plot had the most weeds (Table 2). By 8 weeks after application IP40 Clear/paper-side up had 18% more weeds than the standard control and by 10 weeks the IP40 Clear/paper-side up and IP40 Clear/paper-side down had 134% and 131% more weeds, respectively, than the standard control (Table 2). The IP40 Black and Planters paper had 83% and 75% fewer weeds, respectively, than the standard control for the 10-week period (Table 2).

The degradation of the mulches varied greatly thoughout the season.

Table 1. Mean number of runners formed and fruit yield for 'Honeoye' and 'Jewel' strawberry using standard matted-row production practices or biodegradable mulch films [brown kraft paper covered with clear (IP40 Clear) or brown (IP40 Black) polymer, and black paper (Planters paper)]. Runner numbers are means for three 50-ft (15.2-m) plots. Mean yield is extrapolated from three 50-ft plots.

	Runners[z] (no.)		Mean yield[y] (lb/acre)	
Treatment	Honeoye	Jewel	Honeoye	Jewel
Standard matted-row	292	322	12,590	15,030
IP40 Clear/paper-side down	247	414	13,710	19,430
IP40 Clear/paper-side up	158	319	10,390	18,530
IP40 Black	288	378	11,750	16,350
Planters Paper	205	320	11,890	18,810

[z]Analysis of variance showed no difference among treatments for mean number of runners or mean yield for either variety nor any interaction between variety and treatment at $P \leq 0.05$.
[y]Yield is based on 10,922 row ft/acre (8225.9 $m\cdot ha^{-1}$) in a matted-row system using 4-ft (1.2-m) row centers; 1 lb/acre = 1.12 $kg\cdot ha^{-1}$.

Table 2. Total mean number of weeds removed from three 50-ft (15.2-m) plots of new matted-row strawberry plantings treated with standard weed control and biodegradable mulch films [brown kraft paper covered with clear (IP40 Clear) or brown (IP40 Black) polymer, and black paper (Planters paper)] during the establishment season. Hand weeding was done at each data collection date. Weed control at week 4 was not done due to low weed numbers.

	Total no. weeds[z] (no./ plot)			
	Weeks postplanting			
Treatment	**2**	**6**	**8**	**10**
Standard weed control	3 a[y]	120 a	187 a	229 b
IP40 Clear/paper-side down	0 b	11 b	40 b	528 a
IP40 Clear/paper-side up	0 b	28 b	221 a	535 a
IP40 Black	0 b	3 b	14 b	39 c
Planters paper	0 b	8 b	33 b	57 c

[z]Mean of three replications.
[y]Numbers in the same column followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

Table 3. Pecent degradation for biodegradable mulch films [brown kraft paper covered with clear (IP40 Clear) or brown (IP40 Black) polymer, and black paper (Planters paper)] in matted-row strawberry plots on five dates during the establishment year, 2001.

	Degradation[z] (%)				
	Weeks postplanting				
Treatment	**2**	**6**	**8**	**10**	**26**
IP40 Clear/paper-side down	0 a[y]	23.3 b	79.2 c	84.2 c	92.5 c
IP40 Clear/paper-side up	0.33 a	10.8 b	16.7 b	50 b	73.3 b
IP40 Black	0.2 a	2.5 a	4.2 a	11.7 a	60 a
Planters paper	4.3 b	83.3 c	95 d	95.8 d	99.2 c

[z]Mean of three replications.
[y]Numbers in the same column followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

The Planters paper quickly broke down along the edges covered with soil, which allowed the wind to blow under and tear much of the covering. By 6 weeks after planting, most of the Planters paper had blown off the plots even with supplemental soil covering to hold down the edges (Table 3). At 26 weeks postapplication, few traces of the Planters paper could be found on the plots. The IP40 Clear treatments were similar to each other in degradation during the first 6 weeks postapplication, but placing the paper side down did increase the speed of degradation overall (Table 3). Much of the paper backing of this material was blown away by the wind. A large percentage of the IP40 Clear material was degraded by 26 weeks postapplication regardless of which surface was contacting the soil (Table 3). The IP40 Black mulch degraded little during the initial 10-week period. This film had to be slit after 8 weeks to allow runners to root. Degradation of the paper backing proceeded quickly from that time, but the biodegradable polymer was still nearly intact 26 weeks postapplication (Table 3).

In the following season, trace remnants of the IP40 Clear mulch could be found but were not prevalent. Large sections of the IP40 Black mulch were still present in the field. No traces of the Planters paper could be found in any plot. After harvest (14 months postapplication), the field was renovated using standard procedures which included mowing the plants and rotovating between rows to eliminate weeds and make the rows more narrow (Pritts and Handley, 1988). The IP40 Clear mulch had disappeared completely by renovation and remnants were not visible. The IP40 Black mulch still showed remnants after rotovating but was easily worked into the soil where complete degradation occurred during the remainder of the year.

Discussion

IP40 Black and Planters paper soil mulches were more effective at weed control than standard control practices for establishing a matted-row strawberry planting. However, both materials had definite disadvantages. The Planters paper quickly degraded where it was in contact with the soil and wind tore and blew large pieces from the plots. However, it did have a effect on weed control even after it was gone from the plots as weed counts never approached the levels of the IP40 Clear treatments or standard control. Higher temperatures and/or light exclusion under the material possibly worked synergistically with the pre-emergent herbicide to make germinating weed seeds more susceptible to action by the herbicide. To use this material, it would be necessary to cover it with soil or organic material before it blows away or a windbreak would be needed to catch blowing pieces.

IP40 Black soil mulch was very effective at weed control with weeds emerging only at the holes where the strawberries were planted. However, it did not degrade soon enough for rooting of runners and had to be slit so that sufficient runners could fill in the matted row. Placing this mulch with the polymer side toward the soil may increase the rate of degradation, making it more useful. Even with this constraint, IP40 Black may be a viable option as it would reduce the number of weeds that would have to be pulled by hand labor. After 14 months in the field, the biodegradable polymer significantly degraded and was easily worked into the soil with rotovation during the renovation process. This material may also be useful for annual production of strawberries or vegetable crops or as a mulch for other small fruit plantings such as brambles (*Rubus* spp.) or blueberry (*Vaccinium* spp.) because it will break down with cultivation or by covering with organic matter. Alternatively, removing the material from the field after each crop cycle woud also be a sustainable approach because recycling of the material is possible through composting versus discarding non-degradable plastic mulch in a landfill.

The IP40 Clear was not an effective weed control material over the season in either treatment. As the material begins to breakdown, it appears to encourage weed growth by providing a moist, warm environment under the mulch for weed seed germination with sufficient light for growth. This material did degrade well but would not be recommended for weed control.

Biodegradable mulches continue to be developed and may play a larger role in sustainable agriculture systems in the future. The IP40 Black material shows great promise as a soil mulch and would go a long way towards solving the disposal problem created when non-degradable black plastic mulch is used in annual and perennial fruit and vegetable production. Variations in the carbon black additive or in colors may modify the degradation properties of the material to make it more useful for various production practices in the future.

Literature cited

Albregts, E.E. and C.M. Howard. 1972. Comparison of polyethylene and polyethylene-coated bio-degradable paper mulches on strawberries. HortScience 7:568–569.

Anderson, D.F., M.A. Garisto, J.C. Bourrut, M.W. Schonbeck, R. Jaye, A. Wurzberger, and R. DeGregorio. 1995. Evaluation of a paper mulch made from recycled materials as an alternative to plastic film mulch for vegetables. J. Sustainable Agr. 7:39–61.

Edmond, J.B. 1929. Mulch paper for vegetable crops is tested. Mich. Agr. Expt. Sta. Bul. 11: 115–117.

Flint, L.H. 1928. Crop-plant stimulation with paper mulch. USDA Tech. Bul. 75:1–20.

Gomez, K.A. and A.A. Gomez. 1984. Statistical procedures for agricultural research. Wiley, New York.

Greer, L. and J.M. Dole. 2003. Aluminum foil, aluminum-painted, plastic, and degradable mulches increase yields and decrease insect-vectored diseases of vegetables. HortTechnology. 13:276–284.

Hutchins, A.E. 1933. Mulch papers in vegetable production. Minn. Agr. Expt. Sta. Bul. 298.

Peavy, W.S. 1973. Paper mulch for muskmelons in low rainfall areas. Proc. Nat. Agr. Plast. Conf. 11:192.

Pritts, M. and D. Handley (eds.). 1988. Strawberry production guide. N.E. Region. Agr. Eng. Ser. Bul. NRAES-88. Cornell Univ., Ithaca, N.Y.

Pritts, M.P. and M. Kelly. 2001. Early season weed competition reduces yield of newly planted matted row strawberries. HortScience. 36:729–731.

Sanford, J.C., D.K. Ourecky, and J.E. Reich. 1985. 'Jewel' strawberry. New York's Food Life Sci. Bul. 114. New York State Agr. Expt. Sta., Geneva, N.Y.

Shogren, R.L. 2000. Biodegradable mulches from renewable resources. J. Sustainable Agr. 16:33–47.

Smith, A. 1931. Effect of paper mulches on soil temperature, soil moisture, and yields of crops. Hilgardia 6:159–201.

Yang, S. 1999. Degradable plastic films for agricultural applications in Taiwan. Natl. Agr. Plastics Congr. Proc. 28:4–9.

Managing Orchard Floor Vegetation in Flood-irrigated Citrus Groves

Glenn C. Wright,[1] William B. McCloskey,[2] and Kathryn C. Taylor[3]

ADDITIONAL INDEX WORDS. **chemical weed control, citrus limon, citrus sinensis, cover crops, herbicides, lemon, mechanical weed control, orange**

SUMMARY. Several orchard floor management strategies were evaluated beginning in Fall 1993 in a 'Limoneira 8A Lisbon' lemon (*Citrus limon*) grove on the Yuma Mesa in Yuma, Ariz. and in a 'Valencia' orange (*Citrus sinensis*) grove at the University of Arizona Citrus Agricultural Center, Waddell, Ariz. At Yuma, disking provided acceptable weed control except underneath the tree canopies where bermudagrass (*Cynodon dactylon*), purple nutsedge (*Cyperus rotundus*), and other weed species survived. Mowing the orchard floor suppressed broadleaf weed species allowing the spread of grasses, primarily bermudagrass. Preemergence (norflurazon and oryzalin) and postemergence (glyphosate and sethoxydim) herbicides were used to control weeds in the clean culture treatment in Yuma. After three harvest seasons (1994–95 through 1996–97), the cumulative yield of the clean culture treatment was 385 kg (848.8 lb) per tree, which was significantly greater than the 332 kg (731.9 lb) and 320 kg (705.5 lb) per tree harvested in the disking and mowing treatments, respectively. In addition, the clean culture treatment had a significantly greater percentage of fruit in the 115 and larger size category at the first harvest of the 1995–96 season than either the disk or mow treatments. At Waddell, the management strategies compared were clean culture (at this location only postemergence herbicides were used), mowing of resident weeds with a vegetation-free strip in the tree row, and a 'Salina' strawberry clover (*Trifolium fragiferum*) cover crop with a vegetation-free strip. The cumulative 3-year yield (1994–95 through 1996–97) of the clean culture treatment was 131 kg (288.8 lb) per tree, which was significantly greater then the 110 kg (242.5 lb) per tree yield of the mowed resident weed treatment. The yield of the strawberry clover treatment, 115 kg (253.5 lb) of oranges per tree, was not significantly different from the other two treatments. The presence of cover crops or weeds on the orchard floor was found to have beneficial effects on soil nitrogen and soil organic matter content, but no effect on orange leaf nutrient content. The decrease in yield in the disked or mowed resident weed treatments compared to the clean culture treatment in both locations was attributed to competition for water.

The authors would like to thank the Arizona Citrus Research Council and the Yuma County Pest Abatement District for their financial assistance in completing this project. We would also like to thank Glen Curtis Incorporated for their cooperation, and technicians Philip Tilt, Gary Dixon, and Heather Geitzenauer for their invaluable assistance.

[1]Associate specialist, Department of Plant Sciences, Yuma Mesa Agriculture Center, University of Arizona, 2186 W. County 15th St., Somerton, AZ 85350.

[2]Associate specialist, Department of Plant Sciences, Forbes 303, University of Arizona, Tucson, AZ 85721.

[3]Assistant professor. Current address: University of Georgia, Horticulture Department, Southeastern Fruit and Tree Nut Laboratory, 21 Dunbar Rd, Byron, GA 31008.

Managing weeds on orchard floors in flood-irrigated Arizona citrus groves can be accomplished by disking, mowing, applying pre- and postemergence herbicides, or by growing a cover crop. Weeds in flood-irrigated Arizona lemon groves have traditionally been managed by disking of the orchard floor (two to eight times per year) (Hilgeman and Rodney, 1961; Jordan and Day, 1973; personal observation by the authors in 2002). Disking is done in two directions (i.e., crossdisked), so that there is no herbicide-treated strip down the tree middle. Disking adequately controls weeds on the orchard floor except for nondisked areas underneath the tree canopies where bermudagrass, purple nutsedge, and other weeds survive. However, disking prunes tree roots near the soil surface reducing shallow root density compared to clean culture with herbicides (Hogue and Nielsen, 1987; Parker et al., 1993). Additionally, tree shallow root density under cover crops is often even less than in disked areas (Hogue and Nielsen, 1987; Parker et al., 1993). These shallow roots are the primary sites of water and nutrient uptake for the tree (Davies and Albrigo, 1994). Careless operation of equipment also results in broken branches and injured