Alternatives to Plastic Mulch for Organic Vegetable Production

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Introduction. Weed control is one of the primary concerns in organic farming as it is labor intensive, expensive and time consuming. Since its introduction in the 1950s, plastic mulch has become a standard practice for many farmers to control weeds, increase plant growth, and shorten time to harvest, and has contributed significantly to the economic viability of farmers worldwide (Lamont, 1991; American Plastics Council, 2004). Though very effective and affordable, plastic mulch has become an environmental management concern due to disposal issues. On-site disposal options such as open burning and on-site dumping are environmental liabilities, and recycling of dirty plastics is not an economically feasible option at this time (Garthe, 2002). Recently, agricultural plastic recycling has begun, however, the disposal option that most growers choose is the landfill. In 1999, almost 30 million acres worldwide were covered with plastic mulch and more than 185,000 of those acres were in the United States (Takakura and Fang, 2001). Essentially all of this plastic entered the waste stream. An effective, affordable, degradable alternative to the now-standard plastic mulch would contribute the same production benefits as plastic mulch and in addition would reduce non-recyclable and non-renewable waste.

Previous work. In 2003, we conducted a preliminary study at Washington State University Vancouver Research and Extension Unit (WSU VREU) to evaluate paper and cornstarch mulches as alternatives to plastic mulch. We tested 81-lb Kraft paper with and without oil application. We evaluated three oils (soybean, linseed and tung) applied before and after laying the paper. Previous research found that Kraft paper treated with a combination of epoxidized soybean oil and citric acid held up for 13 weeks in the field and withstood wind and rain better than untreated Kraft paper (Shogren, 2003). A field evaluation study at the University of Florida found that watermelon grown on paper mulch coated with polymerized vegetable oil yielded on par with black plastic mulch (Hochmuth, 2001). In our study at WSU VREU, the paper mulch with and without oil proved as high in quality as the plastic mulch (Miles *et al.,* 2003). Though promising, further studies were needed to test different quality papers, additional mulch products and a diversity of vegetable crops.

Objectives. The purpose of this study was to identify degradable mulch products that can be used as effective and affordable alternatives to standard plastic mulch, and to then inform growers of the findings. We tested alternative mulches in an organic vegetable production system to evaluate their durability and effect on weed control, soil temperature and crop yield.

Methods. Black plastic and five alternative mulches were tested in an organic vegetable production system in 2004. The mulches were evaluated for durability and effect on weed control, soil temperature and crop yield. The mulch products included: 81-lb Kraft brown paper, 42-lb Kraft brown paper with

polyethylene coating, Garden BioFilm, Envirocare 1 (XP-4611W), Envirocare 2 (XP-4611J), and 1 ml black plastic (control) (Table 1). Our field site was certified organic and managed accordingly. The experimental design was a randomized complete block with four replications. Plots were 50 feet long by 3 feet wide and each included four subplots, one for each vegetable crop. Lettuce (short season cool, variety "Pirat"), broccoli (long season cool, mixed varieties "Gypsy" and "Green Goliath"), and bell peppers (short season warm, variety "California Wonder") were planted in double 10-foot rows, while icebox watermelon (long season warm, variety "Smile") was planted in single 20-foot rows. The plots were drip irrigated, with drip tape laid beneath the mulch prior to planting. Each plot was rated bi-weekly for mulch quality. Vegetables were harvested at weekly intervals and measured to determine marketable yield, number of fruits or heads, plant biomass, and number of days to harvest. Beneath each mulch product, soil-surface temperatures were gathered throughout the study using Hobo field temperature monitors. The findings of this study are being disseminated to farmers and industry representatives through meetings, conferences, field days, newsletters, and our web site.

Durability. The mulch products evaluated in this study showed significant differences in quality over time (durability) (Table 2). The standard black plastic was the most durable mulch product in this study, with quality declining only slightly over the course of the growing season (Figure 1). The Envirocare mulches were the only products that compared to black plastic's durability. Envirocare 2 was still in very good condition at the end of the growing season and showed slightly better durability than Envirocare 1. Both Kraft paper mulches exhibited fair quality at the end of the season, but were significantly less durable than black plastic and Envirocare mulches. Garden BioFilm was the least durable, with a steadily declining quality rating throughout the season and was nearly completely degraded at the end of the growing season.

Days to first harvest. Crops were planted into the field as seedlings on June 24th, 2004. There was a significant difference among mulch treatments in the number of days to broccoli harvest, but all other crops were not significantly different (Table 3). Broccoli was harvested earliest from plots treated with Garden BioFilm, and latest from plots treated with black plastic. Lettuce was ready for harvest between 32 days (Envirocare 1) and 39 days (Envirocare 2) from transplant. Peppers were ready for harvest between 85 days (BioFilm) and 91 days (black plastic), and watermelon were ready from 80 days (Envirocare 1) to 88 days (Kraft 42).

Crop Yields. The different mulch products significantly affected broccoli and watermelon yields, but not yields of lettuce and pepper (Tables 4 & 5).

- **Lettuce:** Although lettuce yield was not significantly different due to mulch treatments, Envirocare 1 tended to produce the highest lettuce yield (kg) and Kraft 81-lb paper mulch produced the smallest yield. There was very little variability in number of heads produced by the different mulch treatments, therefore these slight differences in yield were due to head size.
- **Broccoli:** Broccoli yield (kg) and number of heads were significantly greatest in the black plastic mulch plots. Garden BioFilm and Kraft 81-lb paper produced large yields as well, while Envirocare 2 was the least productive in both yield and number of heads. There was no significant difference in average head weight.
- **Pepper:** There were no significant differences in pepper yield (kg), number of fruit and average pepper weight due to the different mulches. However, Garden BioFilm tended to produce the greatest yield (kg) followed by black plastic, while Kraft 81-lb paper tended to produce the lowest yield. The number of fruit tended to be highest with Envirocare 1 and lowest with Kraft

42-lb paper.

- **Watermelon:** Watermelon yields (kg) were significantly different due to the different mulch treatments. Envirocare 1 produced the largest yields and number of fruit while Kraft 81-lb produced the lowest. There were no significant differences in average fruit weight, therefore differences in overall yields were due to differences in fruit number.

Underlying Soil Temperature. Black Plastic mulch showed an insulating effect on underlying soil. That is, temperature highs and lows beneath the mulch were less extreme than above it (Figure 2). Temperatures under each mulch treatment in this trial were compared to temperatures under the black plastic (Figures 3-7). All of the mulches appeared similar to Black Plastic in their insulating effect, except for the Kraft 81-lb paper, which showed greater extremes of both high and low temperatures. This is probably due to the porosity of the Kraft paper material, but further studies would be needed to determine this.

Affordability. Approximate costs per acre were calculated for 80% mulch cover. Black plastic costs $252 - $281 per acre, and may differ depending on the source. Envirocare films are similar in price to black plastic, ranging from $215 to $243 per acre, and the coated Kraft 42-lb paper is also similar in cost, approximately $235 per acre. The cost of Garden Bio-Film is higher, ranging from $695 to $1087, and the 81-lb Kraft Paper cost is variable depending on the source. The relatively heavy weight of paper makes shipping costs higher for paper mulches.

Conclusions. Results of this study indicate that there are alternatives to the standard plastic mulch that can produce comparable results in crop productivity, soil temperature, and affordability. Fully degradable mulches provide the added incentives of decreased work and decreased disposal costs because they do not have to be removed from the field. Preliminary results of this study indicate that Envirocare films are effective and affordable degradable alternatives to plastic mulch. They were comparable to black plastic in durability, crop yield, soil temperature, and affordability, and provide growers a choice between longer and shorter degradation times. However, the Envirocare films have not been approved to leave in the soil of certified organic systems, and therefore at this time must be removed. Further studies may be needed to determine the exact end products and possible residues of these films, so that they can be thoroughly reviewed for use in organic systems. Garden BioFilm has been approved for use in organic agriculture, and can be tilled into the soil. It produced good results in this study, and it's quick and thorough biodegradation may be desirable for short-season crops and immediate tillage into the soil, but the cost of this mulch is high, and it's rate of degradation may be too fast for longer-season crops. The paper mulches were less effective in general. Kraft 81-lb paper and K-aft 42-lb coated paper produced similar results in terms of yield and durability, but the Kraft 42-lb coated paper is not degradable and more labor-intensive to remove than black plastic. These results are preliminary, and this study will likely be repeated in 2005.

Future Work. This study to test degradable mulch products in organic vegetable production at WSU VREU will likely continue in 2005. New products become available each year, and in 2005 we hope to test an expanded number of mulch products. We will contact agricultural industry representatives, scientists, and farmers around the country to identify additional products that might be used as degradable alternatives to plastic mulch. Mulch treatments that we have identified so far include: 1) 81-lb Kraft paper, 2) Garden Bio-Film, 3) Envirocare black 1, 4) Envirocare white on black 1, 5) Envirocare black 2, 6) Envirocare white on black 2, 7) Bio-ground cover 1, 8) Bio-ground cover 2 and 9) black

plastic (control). The greatest limitation we see to this work is finding degradable products that are approved to leave in the soil of certified organic systems.

References:

American Plastics Council. 2004. The History of Plastics. American Plastics Council. Arlington, VA. <**www.americanplasticscouncil.org/benefits/about_plastics/history.html**>

Billingham, N.C., M. Bonora, and D. De Corte. 2002. Environmentally degradable plastics based on oxodegradation of conventional polyolefins. www.degradableplastics.com

Garthe, J. W. 2002. Used agricultural plastic mulch as a supplemental boiler fuel. An Overview of Combustion Test Results for Public Dissemination. Energy Institute, Penn State. <http://environmentalrisk.cornell.edu/C&ER/PlasticsDisposal/AgPlasticsRecycling/References/Garthe2002b.pdf>

Hochmuth, R. C. 2001. Field evaluation of watermelon produced on paper mulch coated with polymerized vegetable oil 200-01. NFREC- Suwannee Valley, Cooperative Extension, University of Florida. < http://nfrec-sv.ifas.ufl.edu/2000-01_report.htm>

Lamont, W. J. 1991. The use of plastic mulches for vegetable production. Food and Fertilizer Technology Center. Kansas State University, Manhattan. <www.agnet.org/library/article/eb333.html>

Miles, C., Lydia Garth1, Madhu Sonde, and Martin Nicholson. 2003. Searching for alternatives to plastic mulch. http:// http://agsyst.wsu.edu/MulchReport03.pdf

Shogren, R. L. 2003. Paper mulch coated with vegetable oil offers biodegradable alternative to plastic. 6th International Conference on Frontiers of Polymers and Advanced Materials in Recife, Brazil, May 5-9. ARS, National Center for Agricultural Utilization Research, Peoria, USDA .

Takakura, T. and W. Fang. 2001. Climate under cover. Kluwer Academic Publishers, p 1-10 <http://ecaaser3.ecaa.ntu.edu.tw/weifang/Bio-ctrl/cuc-chap1.pdf>

MULCH SOURCES:

Envirocare 1 and 2: Pliant Corporation; 1475 Woodfield Road, Suite 700, Schaumberg, IL, 60173; 866-878-6188; www.pliantcorp.com

Garden Bio-Film: BIOgroupUSA, Inc., 107 Regents PI., Ponte Vedra Beach, FL 32082; 904-280-5094; www.biogroupusa.com

Kraft 81-lb Paper: Newark Paperboard Products; 620 11th Ave., Longview, WA, 98632; 360-423-3420; www.newarkgroup.com (*No longer available from this source)*

Kraft 42-lb Polyethylene-coated Paper: Graphic Packaging; 814 Livingston Court, Marietta, GA, 30067; 770-644-3000; www.graphicpkg.com

Black Plastic: from Peaceful Valley Farm Supply P.O. Box 2209, Grass Valley, CA 95945; (530) 272-4769; www.groworganic.com

SEED SOURCES:

"Pirat" Lettuce from Wild Garden Seed, www.wildgardenseed.com

"California Wonder" Peppers from Peaceful Valley Farm Supply, www.groworganic.com

"Smile" Watermelon from America Takii Seeds, www.takii.com

"Gypsy" and "Green Goliath" Broccoli, from Burpee, www.burpee.com

Table 1: Specifications of mulch products tested at WSU VREU in 2004.

Mulch Product	Composition	Degradability	Approved for use in organic systems?
Black Plastic	1.0 mil embossed film composed of high density polyethylene. Colored with carbon black pigment.	Not degradable.	Yes. Must be removed from the soil.
Envirocare 1, XP-4611W	Low-density and linear low density polyethylene, with Ciba Envirocare TDPA (Totally Degradable Plastic Additive). Contains no vinyl and no heavy metals. Colored with carbon black pigment.	Completely degradable. Thermal and photo triggers for degradation, beginning at 75 days. End products are CO_2, H_2O, and microbial biomass.	Yes. Must be removed from the soil.
Envirocare 2, XP-4611J	Low-density and linear low density polyethylene, with Ciba Envirocare TDPA (Totally Degradable Plastic Additive). Contains no vinyl and no heavy metals. Colored with carbon black pigment.	Completely degradable. Thermal and photo triggers for degradation, beginning at 140 days. End products are CO_2, H_2O, and microbial biomass.	Yes. Must be removed from the soil.
Garden BioFilm	Biodegradable black plastic film produced from cornstarch and other earth friendly resources. Contains no polyethylene.	Completely degradable. Begins degrading at 50-60 days, and is 95% degraded within 90 days.	Yes. Can remain in the soil.
42-lb Coated Kraft Paper	Brown paper coated with transparent polyethylene. (Commonly used for food packaging.)	Not completely degradable.	Yes. Must be removed from the soil.
81-lb Kraft Paper	Brown paper bonded with cement.	Completely degradable.	Yes. Can remain in the soil.

Figure 1: Mulch quality over time: Average rating of all replications per mulch product. Rated on scale of 0-9, where 0 is the worst and 9 is the best.

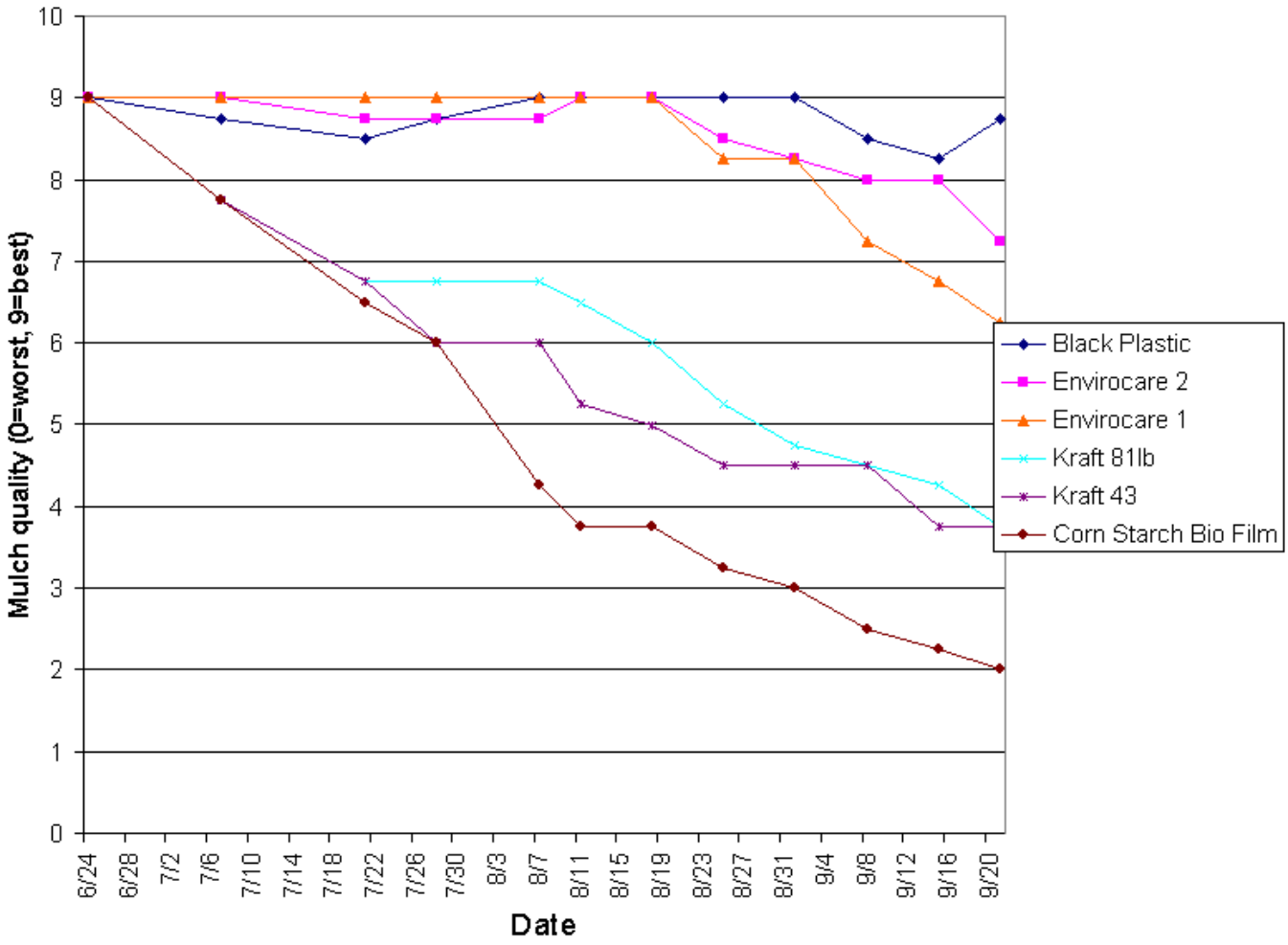


Table 2: Mulch quality over time: Average rating of all replications per mulch product. Rated on scale of 0-9, where 0 is the worst and 9 is the best.

Mulch	21-Jul	28-Jul	7-Aug	11-Aug	18-Aug	25-Aug	1-Sep	08-Sep	15-Sep	21-Sep
Black Plastic	8.5	8.8	9.0	9.0	9.0	9.0	9.0	8.5	8.3	8.8
Envirocare 1	9.0	9.0	9.0	9.0	9.0	8.3	8.3	7.3	6.8	6.3
Envirocare 2	8.8	8.8	8.8	9.0	9.0	8.5	8.3	8.0	8.0	7.3
Garden BioFilm	6.5	6.0	4.3	3.8	3.8	3.3	3.0	2.5	2.3	2.0
Kraft 42-lb	6.8	6.0	6.0	5.3	5.0	4.5	4.5	4.5	3.8	3.8
Kraft 81-lb	6.8	6.8	6.8	6.5	6.0	5.3	4.8	4.5	4.3	3.8
P Value = 0.0000										

Table 3: Mean number of days from transplant to harvest.

Mulch	Lettuce	Broccoli	Peppers	Watermelon
Black Plastic	33.9	75.9	91.2	84.5
Envirocare 1	32.5	67.4	89.2	80.4
Envirocare 2	35.4	70.8	89.4	82.6
Garden BioFilm	33.5	66.9	85.2	83.2
Kraft 42-lb	33.7	67.6	86.5	83.3
Kraft 81-lb	33.0	67.6	85.8	88.1
Mean	**33.7**	**69.4**	**87.9**	**83.7**
P Value	***0.5875***	***0.0687***	***0.3536***	***0.5414***

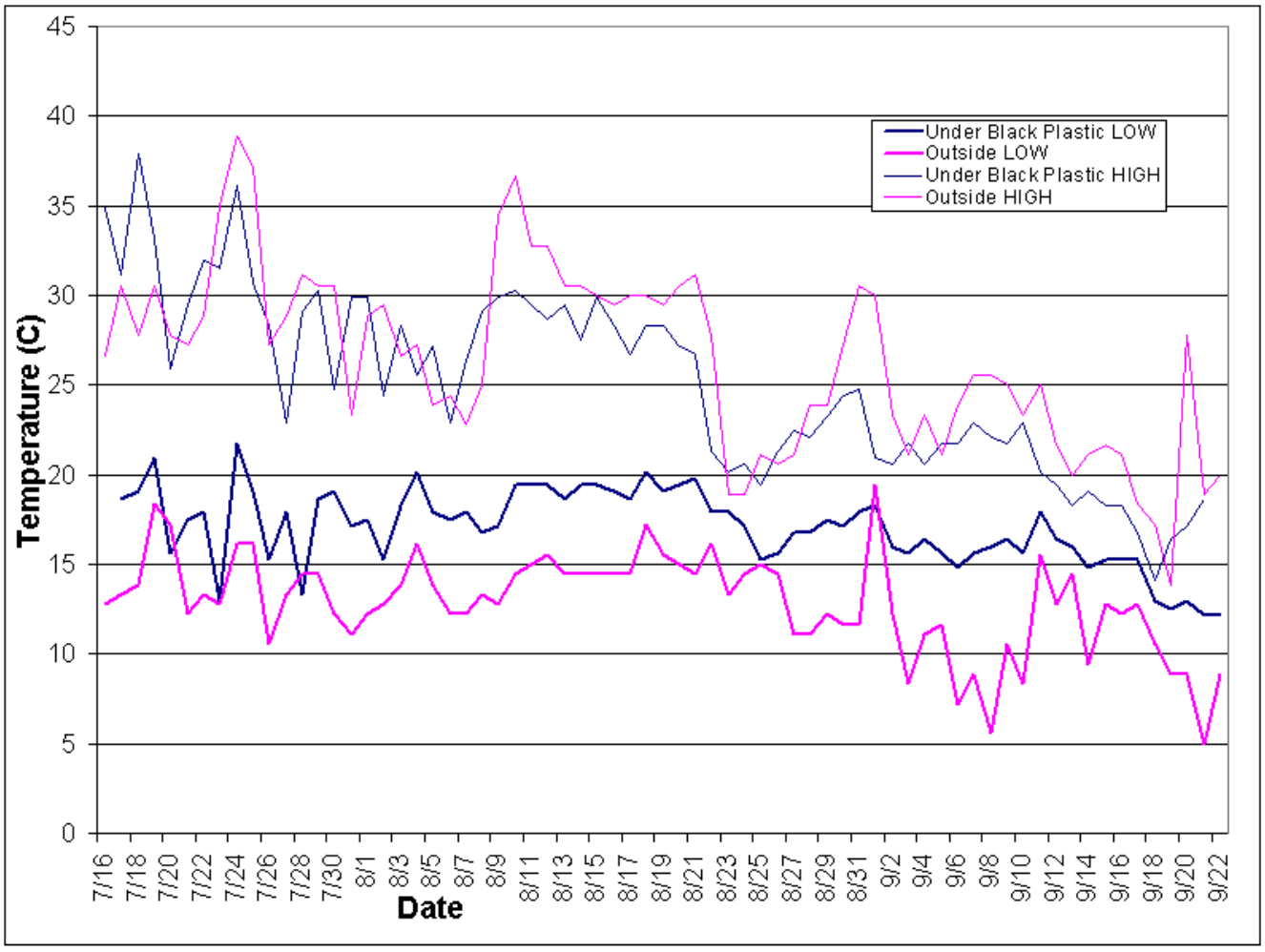
Table 4: Mean plot yield, average head weight, and number of marketable heads of Lettuce and Broccoli.

	LETTUCE						BROCCOLI					
Mulch	Yield (kg)		Avg head wt. (kg)		No. of heads		Yield (kg)		Avg head wt. (kg)		No. of heads	
Black Plastic	4.98	a	0.276	a	18.0	a	7.28	a	0.655	a	12.8	a
Envirocare 1	6.05	a	0.306	a	19.8	a	4.01	b	0.651	a	6.8	b
Envirocare 2	4.63	a	0.251	a	18.0	a	3.22	b	0.573	a	5.3	b
Garden BioFilm	5.03	a	0.252	a	19.8	a	4.78	ab	0.762	a	6.3	b
Kraft 42-lb	4.91	a	0.246	a	20.0	a	3.95	b	0.641	a	6.0	b
Kraft 81-lb	4.47	a	0.232	a	19.3	a	4.68	ab	0.684	a	7.0	b
P Value	0.4588		0.2225		0.5945		0.1046		0.8605		0.091	

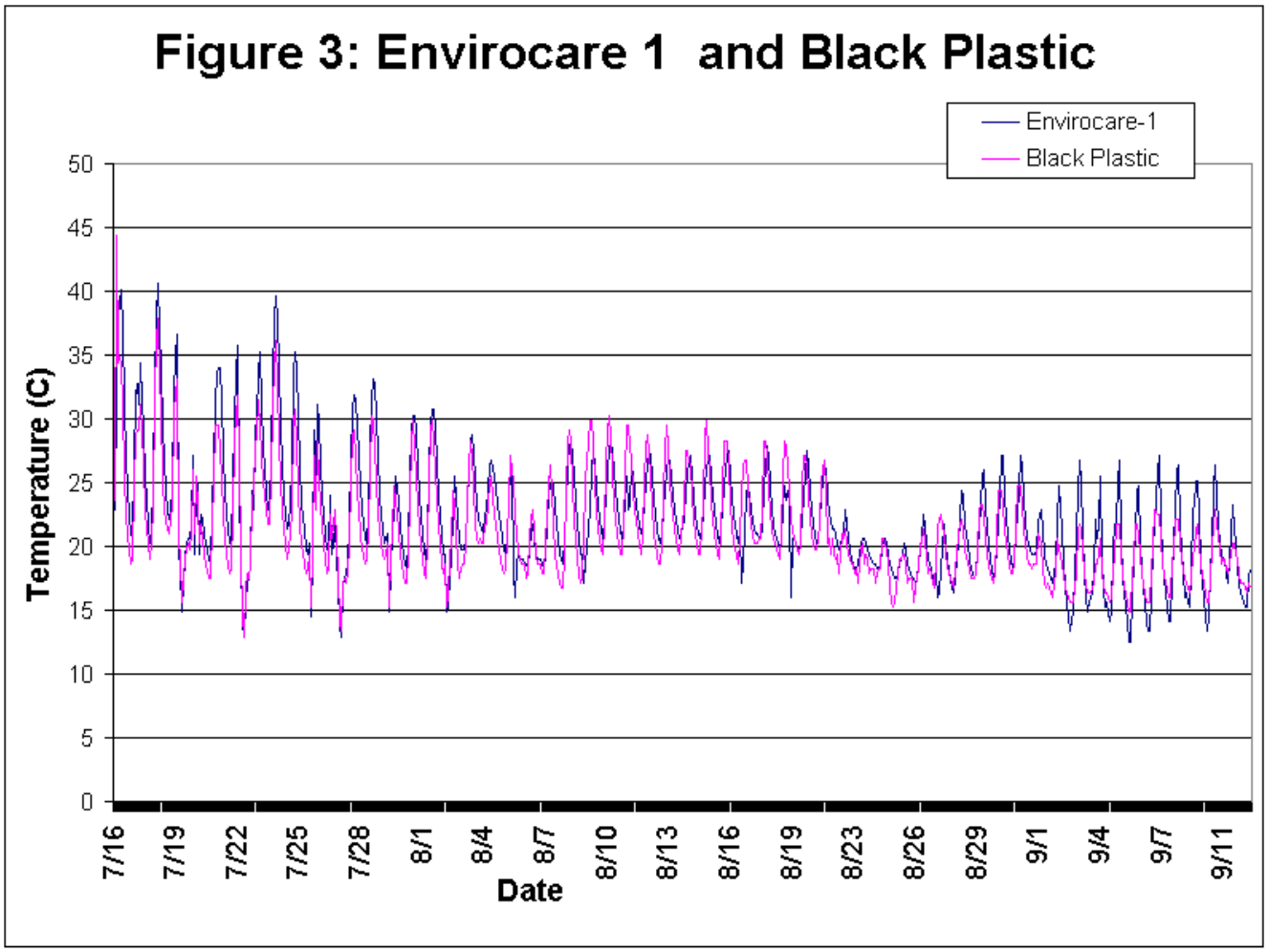
Table 5: Mean plot yield, average fruit weight, and number of marketable fruit of Pepper and Watermelon.

	PEPPER						WATERMELON					
Mulch	**Yield (kg)**		**Avg fruit wt. (kg)**		**No. of fruit**		**Yield**		**Avg fruit wt. (kg)**		**No. of fruit**	
Black Plastic	19.48	a	0.253	a	79.0	a	55.10	a	3.078	a	18.8	ab
Envirocare 1	14.60	a	0.178	a	82.0	a	71.15	a	2.925	a	24.0	a
Envirocare 2	13.44	a	0.175	a	77.3	a	50.37	ab	2.790	a	17.5	ab
Garden BioFilm	22.11	a	0.270	a	80.5	a	47.50	ab	2.953	a	16.3	abc
Kraft 42-lb	15.90	a	0.227	a	62.8	a	44.85	ab	3.245	a	13.8	bc
Kraft 81-lb	11.23	a	0.164	a	70.5	a	19.64	b	2.742	a	7.0	c
P Value	**0.6797**		**0.7115**		**0.5653**		**0.0650**		**0.5727**		**0.0307**	

Figure 2: High and Low Daily Temperatures Under Black Plastic Mulch and Outside



Figures 3-7: Temperatures under black plastic compared with temperatures under alternative mulch products.



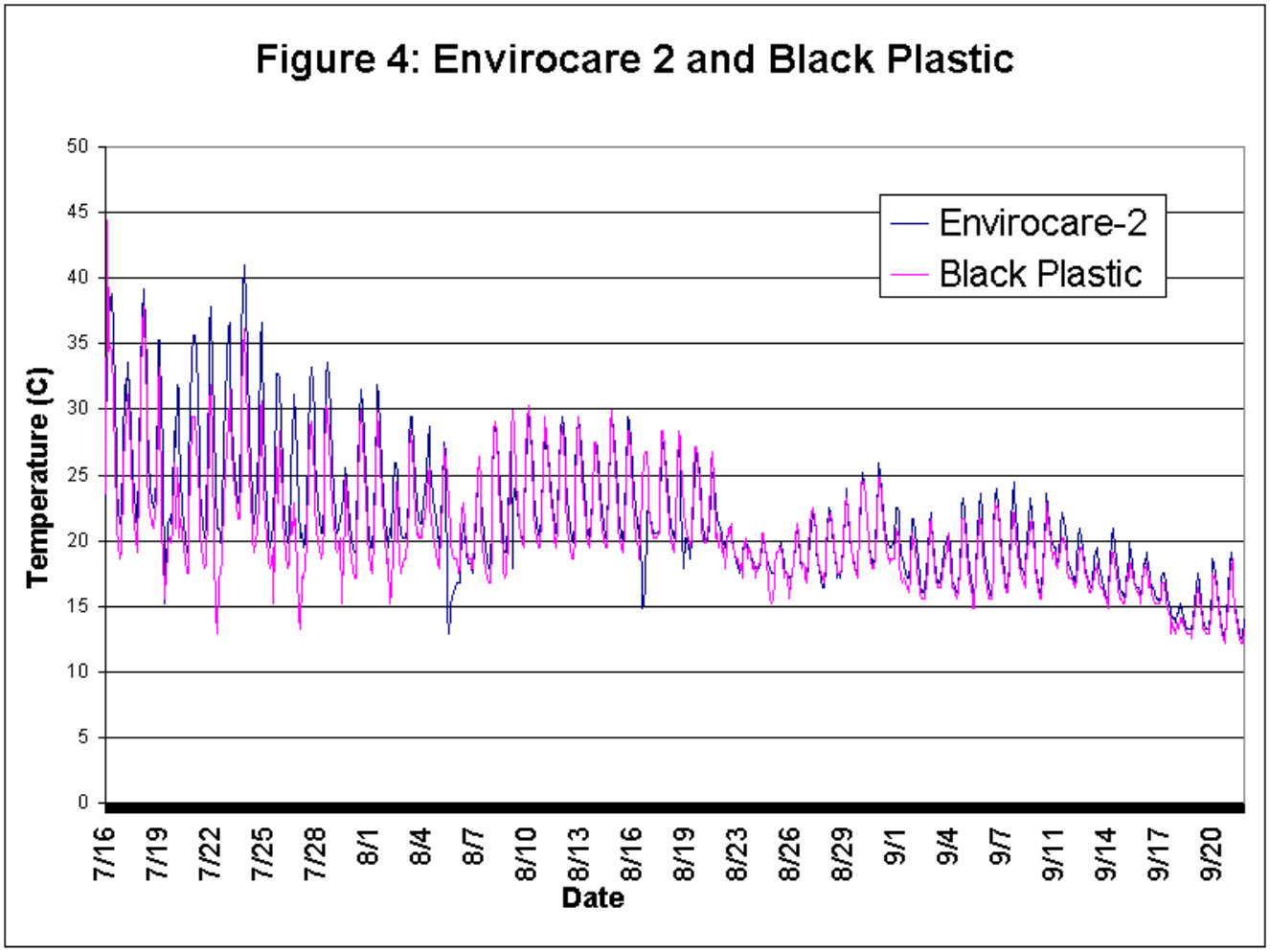


Figure 4: Envirocare 2 and Black Plastic
Envirocare-2
Black Plastic
Temperature (C)
50
45
40
35
30
25
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7/16
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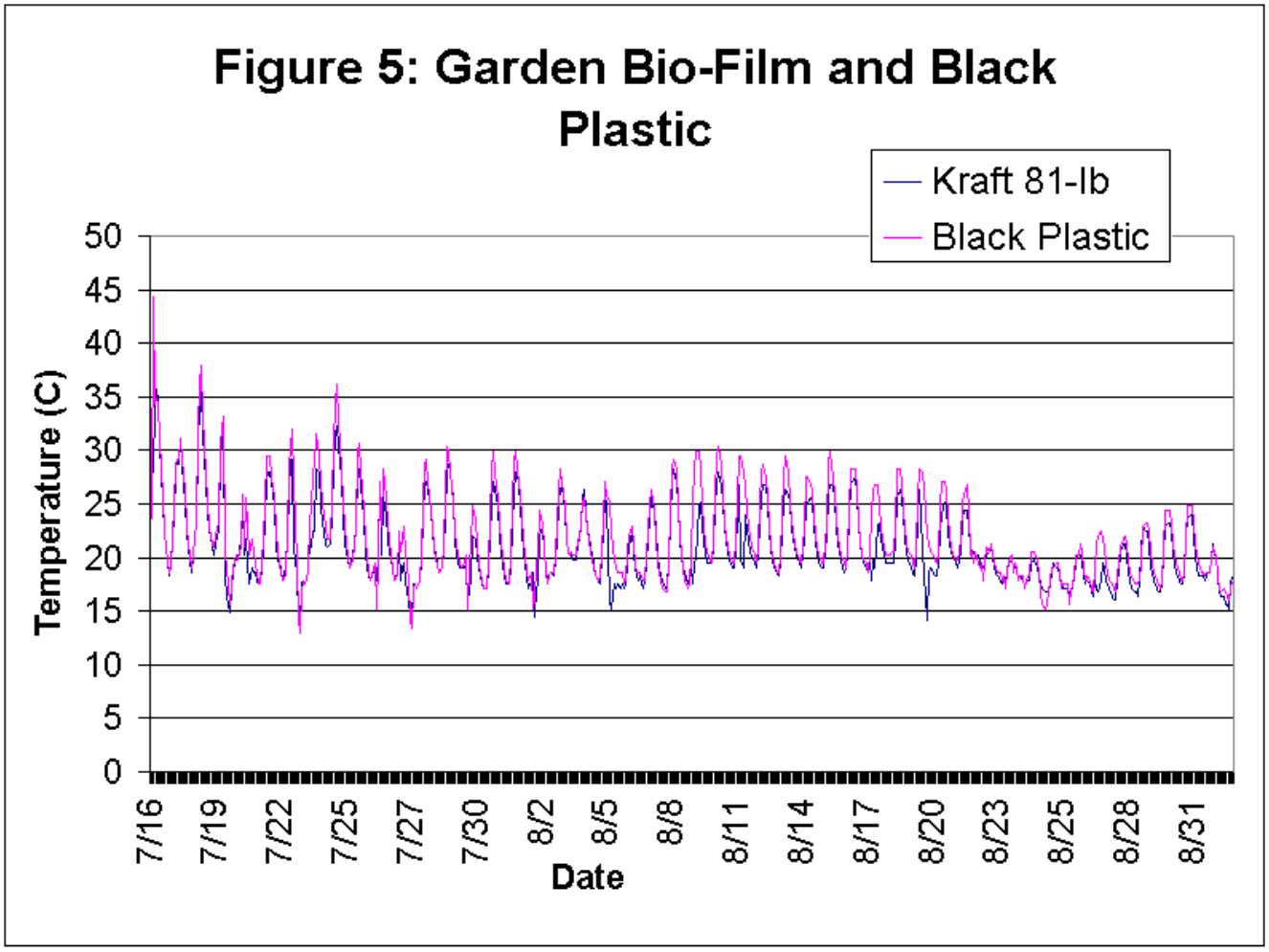
Figure 5: Garden Bio-Film and Black Plastic
Kraft 81-lb
Black Plastic
Temperature (C)
50
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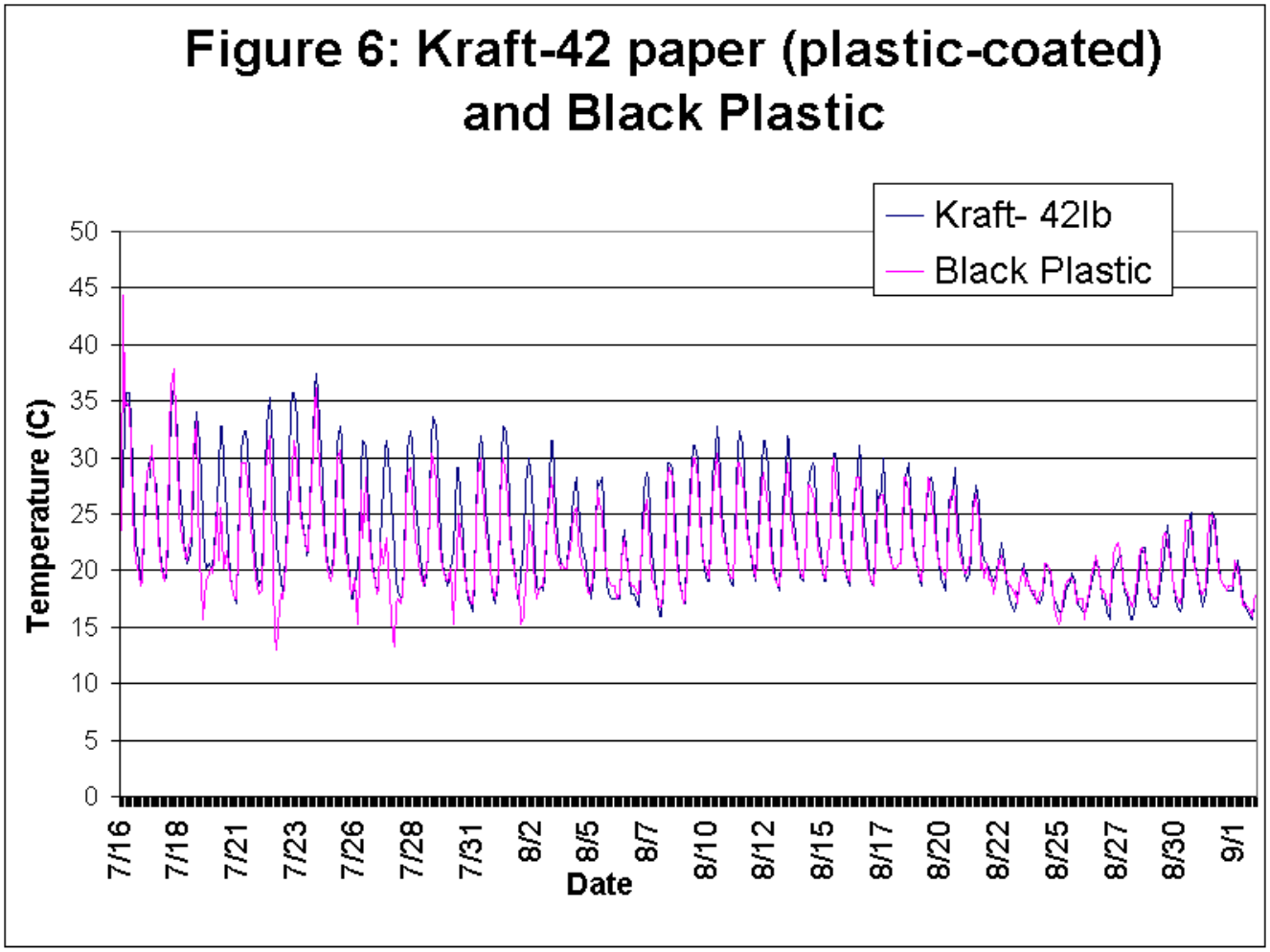
Figure 6: Kraft-42 paper (plastic-coated) and Black Plastic
Kraft- 42lb
Black Plastic
Temperature (C)
50
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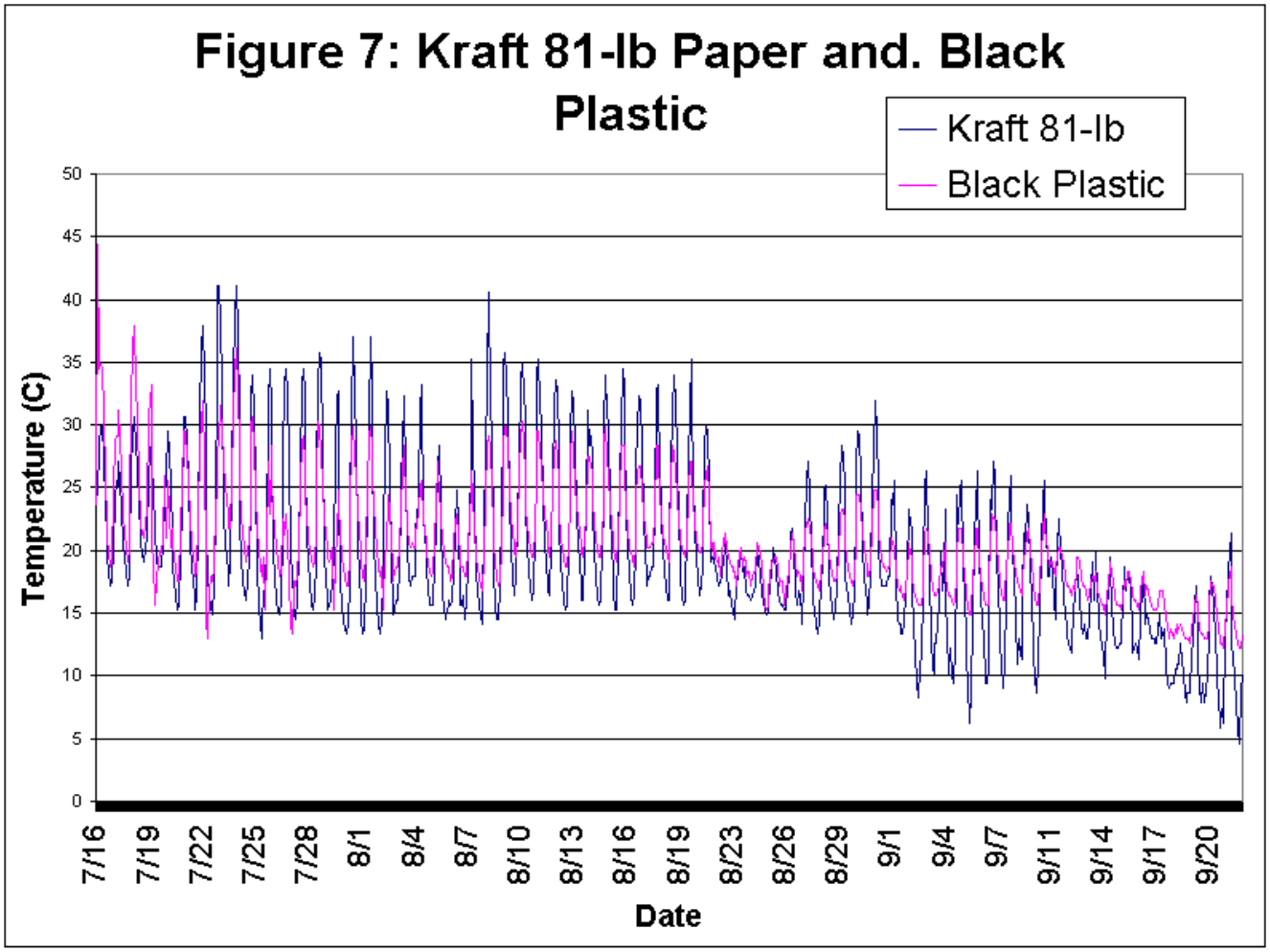
Figure 7: Kraft 81-lb Paper and. Black Plastic
Kraft 81-lb
Black Plastic
Temperature (C)
50
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0
7/16
7/19
7/22
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7/28
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