# Alternatives to Plastic Mulch in Vegetable Production Systems

Carol Miles, Erin Klingler, Liz Nelson, Tracy Smith, and Cheri Cross,
WSU Vancouver Research & Extension Unit
1919 NE 78th Street, Vancouver, WA 98665
(360) 576-6030, milesc@wsu.edu, http://agsyst.wsu.edu

## Introduction

Since its introduction in the 1950s, plastic mulch has become a standard practice used by many farmers to control weeds, increase crop yield, and shorten time to harvest (Lamont, 1991). Plastic mulch has contributed significantly to the economic viability of farmers worldwide, and by 2006 it was estimated that 400,000 acres were covered with plastic mulch in the United States (American Plastics Council, 2004; Takakura and Fang, 2001; Bergholtz, 2006) and 1,800 acres in Washington. Due to tracking difficulties it is impossible to accurately determine the true number of acres. (Garthe, 2006). Each year farmers must dispose of their plastic and the disposal option that most choose is the landfill (Garthe, 2002). Many small-scale and organic farmers choose not to use plastic mulch because of the waste disposal issues. Ideally, farmers would like to plow down the mulch at the end of the season, thereby eliminating removal as well as disposal costs (Sorkin, 2006). Degradable plastics were introduced in the 1980's; however, there remain many questions regarding their efficacy, degradability, and potential residues (Vert *et al*., 1992; Riggle, 1998; Shogren, 2000; Hockmuth, 2001). For organic farming, degradable mulches would need to meet National Organic Program (NOP) standards.

The purpose of this study was to identify and test degradable mulch products that can be used as effective and affordable alternatives to standard plastic mulch. We conducted the study over a four year period, 2004-2007. In the first two years new products were developed and tested (Miles *et.al*., 2005), and in the second two years the most promising products were evaluated. In all years, degradable mulches were tested with four different vegetable crops in an organic vegetable production system to evaluate mulch durability and effects on soil temperature and crop yields. Different vegetable crops have different temperature needs, and it is possible each crop may perform best with a different mulch product. This is a report for 2006 and 2007.

## Materials and Methods

We evaluated 10 alternative mulches in a field study in 2006 and 8 in 2007 (Table 1). Both years, all alternative mulch products were compared to black plastic mulch. In 2006, the study was conducted in a field that was managed organically, and in 2007 the study was conducted in a field that was certified organic. Some of the products tested may not currently be allowed in organic systems, and research such as this study is needed to determine their suitability.

The experimental design both years was a randomized complete block with four replications. Main plots were 55 feet long by 3 feet wide and each included 4 subplots, one for each of 4 vegetable crops. Vegetable crops were selected to represent 2 growing periods (short vs. long) and 2 temperature regimes (cool vs. warm): lettuce – short growing season, cool temperature; broccoli – long growing season, cool temperature; bell pepper – short growing season, warm temperature; and icebox watermelon – long growing season, warm temperature. Plants were seeded in the greenhouse mid-April both years, and transplanted into the field June 9 2006, and May 23 (lettuce), June 12 (peppers and watermelon) and June 24 (broccoli) in 2007. "Pirat" lettuce, "Gypsy" broccoli, and "California Wonder" bell peppers were planted in double 10-foot-long rows, while "Smile" in 2006 and "Triple Play" in 2007 icebox watermelon was planted in a single 21-foot long row. Spacing in the row was 12 inches for lettuce (20 plants per plot), 20 inches for broccoli and peppers (8 plants per plot), and 3 feet for watermelon (6 plants per plot) (Figure 1).

**Table 1.** Descriptions of mulch products evaluated in 2006 and 2007 at Washington State University Vancouver REU. This table is not intended to be used to promote any products listed or detract from any products not included in this field study.

| Product | Description | Year Tested |
|---|---|---|
| **Black plastic (control)** | 1.0 mil embossed black polyethylene plastic film | 2006, 2007 |
| **Envirocare 1** | Black plastic w/ Ciba Envirocare TDPA (Totally Degradable Plastic Additive); 75 days to degradation | 2006 |
| **Envirocare 2** | Black plastic w/ Ciba Envirocare TDPA (Totally Degradable Plastic Additive); 140 days to degradation | 2006 |
| **Garden Biofilm** | Cornstarch-based black film, 100% degradable; | 2006, 2007 |
| **Garden Biofilm NF01U/P 15 mic** | Cornstarch-based black film, 100% degradable; developed for short cycle crops | 2006, 2007 |
| **Garden Biofilm NF803/P 12 mic** | Cornstarch-based black film, 100% degradable; developed for longer cycle crops | 2006, 2007 |
| **Garden Biofilm NF803/P 15 mic** | Cornstarch-based black film, 100% degradable; developed for longer cycle crops | 2006, 2007 |
| **Planters Paper** | Kraft paper with black pigment; 100% recycled fiber | 2006, 2007 |
| **LF 4** | Bag Paper - normally sized, no wet strength; 40% recycled fiber | 2006 |
| **LF 5** | Hi STFI Liner (Hi Performance Liner); medium sized, medium wet strength, 18% recycled fiber | 2006, 2007 |
| **Black LF 5** | Hi STFI Liner (Hi Performance Liner); medium sized, medium wet strength, 18% recycled fiber, coated with black carbon | 2007 |

Mulches were laid using a mulch layer tractor attachment. Drip tape was laid under the plastic at the same time as the mulch. After laying the mulches, holes were manually punched using a bulb setter and vegetables were transplanted by hand. Plots were drip irrigated once a week at the rate of 1 inch. Seedlings were fertilized in the greenhouse with Biogan soluble fish powder (12-2-1) in 2006 and BioLink (5-5-5) in 2007, and soluble seaweed extract powder (Acadian 1-0-4 w/ trace minerals) both years. Plants were fertigated in the field immediately after transplanting and every 3 weeks thereafter for a total of four applications. In 2006, Biogan soluble fish powder (12-2-1), Biolink (5-5-5), and Acadian soluble seaweed extract powder were applied at the lowest label rates, and total N applied was 1.09 lbs N/A. In 2007, fertilizer PAR4 (9-3-7) was applied to beds prior to transplanting at the rate of 87 lbs N per acre. Plants were fertigated at transplanting and every 3 weeks thereafter (total of four applications) with BioLink (14-0-0), seaweed extract powder (Acadian 1-0-4 w/ trace minerals), and BioLink Boron (2-0-0, 3% B) at the rate of 48.36 or 25.42, 5.34 and .016 lbs N/A, respectively.

Temperatures were measured with Hobo field monitors at the soil surface beneath each mulch product, and at a 2-inch depth in the neighboring bare soil. Mulch quality was rated weekly on a scale of 0 to 9 where 0 was 0-9% mulch cover and 9 was 90-100% cover. Vegetables in each plot were harvested when they reached peak maturity, and yield measurements included marketable yield, number of marketable fruits/heads, and number of days to first harvest. In 2006, Envirocare 1 and Envirocare 2 were removed from the field at the same time as black plastic and all other products were tilled into the soil.

**Figure 1.** Field trial of alternatives to plastic mulch at WSU Vancouver REU in 2006.

**Results and Discussion**

**Mulch durability.** Mulch products evaluated in this study showed significant differences in quality (durability) over time (Figure 2). Both years, black plastic was the most durable mulch. Envirocare 1 and 2 in 2006 were as durable as black plastic, but had negligible degradability when tilled into the soil or composted (Miles *et al.*, 2006). LF 5 was the most durable alternative product, with quality declining by less than 20% in 2006 over the course of the growing season. In 2007, quality of LF 5 declined more rapidly than for several other alternative mulch products, although final rating was slightly higher than for others. Durability of Black LF5 was slightly lower than regular LF 5 but not significantly different. Weed growth under the LF 4 paper mulch in 2006 was the primary cause of its decline in quality. Planters paper had relatively good durability in 2006 while in 2007 durability was low. Of the corn starch products, Garden Biofilm NF01U/P15 and Garden Biofilm NF803/P15 were the most durable both years while Garden Biofilm NF803/P12 and Garden Biofilm were the least durable.

**Crop yield.** Yields differed significantly between years and were lower for all crops in 2006 than in 2007 (Tables 2, 3, 4 and 5). In 2006, yields with paper mulches tended to be lower than with other mulch products, and these differences were significant for some crops. Of the paper mulches, LF 4 degraded the earliest and yields were subsequently lower than for all other products. In 2007, there was little difference in crop yield due to mulch product. Watermelon were impacted by poor pollination throughout all plots, likely due to competition for pollinators with a neighboring watermelon crop.

In 2006, yield, number of heads and head weight of lettuce was not significantly impacted by mulch product (Table 2). Number of broccoli heads were greatest with Envirocare 2 and Garden Biofilm, and lowest with Garden Biofilm NF01U/P15 (Table 3). Average head weight of broccoli was greatest with Garden Biofilm NF803/15 and lowest with black plastic and Garden Biofilm. Pepper yield and number of fruit were greatest with Garden Biofilm NF803/15 and lowest with LF 4 (Table 4). Watermelon yield, fruit number, and average fruit weight were greatest with Envirocare 1 and Garden Biofilm NF01U/P15, and lowest with LF 4 and LF 5 (Table 5).

In 2007, yield, number of heads and head weight of lettuce and broccoli were not significantly affected by mulch product (Tables 2 and 3). Pepper yield was greatest with black plastic, Garden Biofilm NF01U/P15, Garden BiofilmNF803/15, and Garden Biofilm803/12, and lowest with Black LF 5, LF 5, Planters Paper, and Garden Biofilm (Table 4). Watermelon yield was not impacted by mulch product, most likely due to overall low pollination in this crop throughout all plots (Table 5).

**Days to crop maturity.** Mulch products had a significant effect on days to maturity for all crops except peppers in 2006, however these effects were generally not consistent (Table 6). Garden Biofilm NF01U/P15 and Garden Biofilm NF803/15 resulted in earlier maturity in lettuce, but later maturity in broccoli and watermelon. Garden Biofilm and Envirocare 1 resulted in earlier maturity in watermelon while LF 4 and LF 5 resulted in later maturity. In 2007 days to maturity of all crops were not significantly affected by mulch product.

**Temperature under mulch.** Both years, maximum temperatures under all products compared to black plastic tended to be more different than minimum temperatures (Figures 3-10). Maximum temperatures under LF5 varied early in the season (fluctuated from lower to higher to lower) but were equivalent to black plastic from August onwards. Maximum temperatures under Black LF5 were greater than black plastic from August onwards while minimum temperatures were lower. Under Planters paper, maximum temperatures were somewhat equivalent as under black plastic early in the season but were higher later in the season. Maximum and minimum temperatures under Garden Biofilm, Garden Biofilm NF01 U/P15, Garden Biofilm NF803/PU15 were very similar to black plastic both years.

## Conclusions

In this study, once mulch cover fell below 50% (a quality rating of 5 or below), the product was ineffective for weed control. Both years Garden Biofilm and Garden Biofilm NF803/P12 reached a rating of 5 by early August while all other degradable mulch products reached a rating of 5 by early to mid September in one year only. Preliminary results indicated that LF 5 was the most durable of all alternative mulches tested, however, durability was significantly lower in the second year of this study. More testing may be needed to determine the expected durability of LF 5 under variable field conditions.

In general, yield of lettuce and broccoli (both cool season crops) were least impacted by paper mulch whereas yield of pepper and watermelon (both warm season crops) were more greatly impacted. Thus, paper mulch products may be more suitable for cool season crops and not as well suited for warm season crops. Temperatures under LF 5 were variable early in the season as compared to under black plastic and this may have contributed to decreased crop yield. Of the cornstarch products, Garden Biofilm

NF01U/P15 and Garden Biofilm NF803/P15 appeared somewhat durable in the field and had the added benefit of resulting in high crop yields.

Ideally, a degradable mulch would degrade in the soil, eliminating the removal and disposal costs. In this study, cornstarch and paper mulches were tilled into the soil at the end of the season and by the following spring, they had broken down to the point where residues were no longer visible to the naked eye. Envirocare 1 and Envirocare 2 were as durable as black plastic in the field and resulted in similar crop yield. However, Envirocare products did not degrade when they were incorporated into the field or when they were incorporated into on-farm compost piles. Therefore these products did not provide reduced farm labor costs or disposal fees. In addition, our organic certifier, WSDA Organic Food Program, determined that these products were not allowable for use in certified organic crop production systems.

**Literature Cited:**

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

Bergholtz, P. 2006. President, Ken-Bar Company. Personal communication, 5 November 2006.

Garth, J.W. 2006. Plastic mulch statistics. Personal communication. 24 October 2006.

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. North Florida Research and Education Center. Suwanee Valley, FL. <http://nfrec-sv.ifas.ufl.edu/reports_mulch.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., J. Reed, E. Klingler, L. Nelson, T. Smith, K. Kolker, and C. Cross. 2006. Alternatives to plastic mulch in vegetable production systems. WSU Vancouver Research & Extension Unit, annual report, http://vegetables.wsu.edu/MulchReport06.pdf >.

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

Riggle, D. 1998. Moving toward consensus on degradable plastic. *Biocycle*: 39(3):64.

Shogren, R.L. 2000. Biodegradable mulches from renewable resources. Journal of Sustainable Agriculture, 16:33-47.

Sorkin, L. 2006. New biodegradable mulch is cheaper than plastic when removal and disposal cost are also considered. *Growing for Market*; May 2006, pp. 8-10.

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>

Vert, M., J. Feijen, A. Albertsson, G. Scott, E. Chiellini. 1992. Biodegradable polymers and plastics. Royal Society of Chemistry. Nov. 1992. Great Britian.

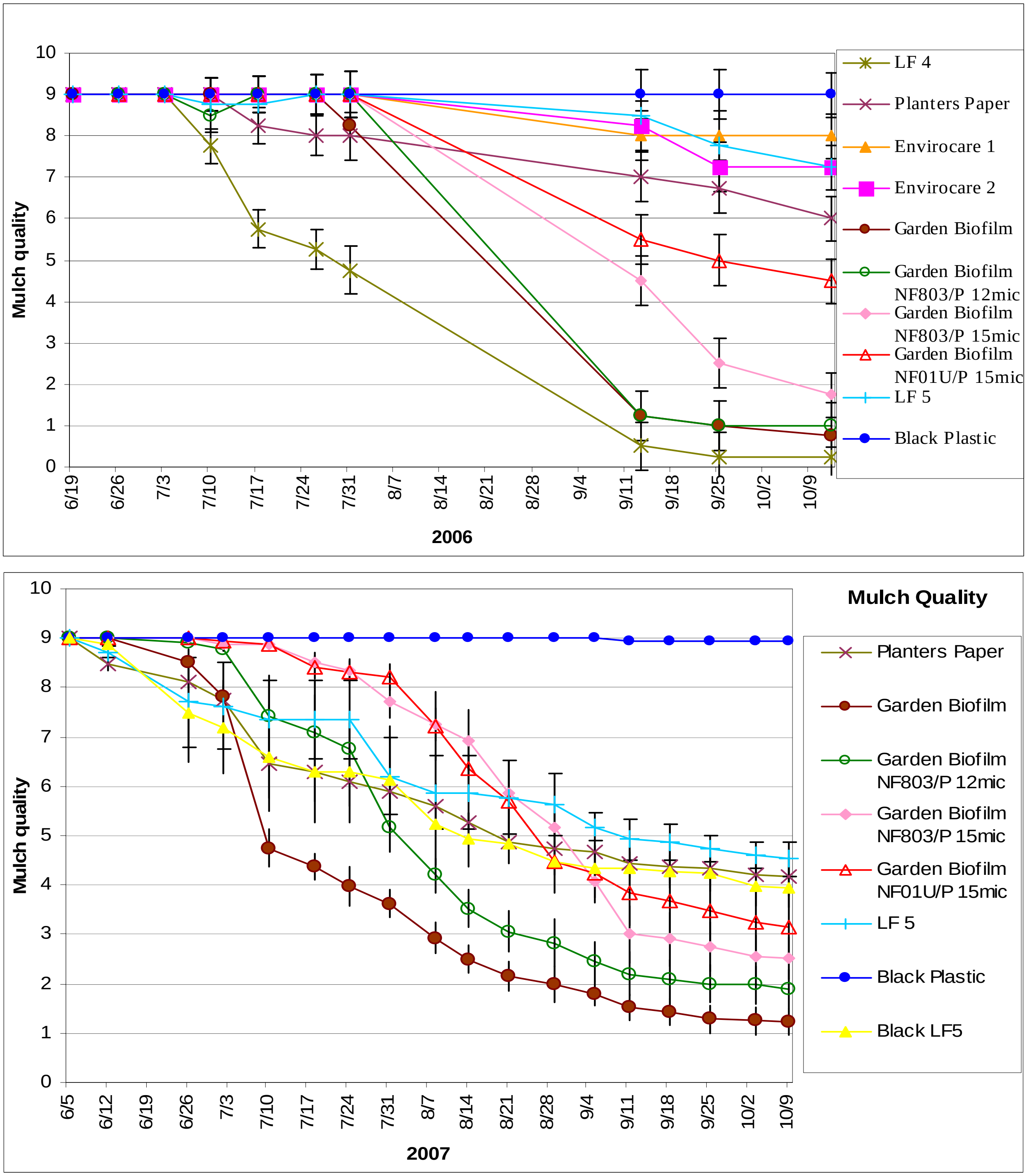



**Figure 2.** Mulch durability (quality over time) on a scale 0-9, where 0 is 0-9% mulch cover and 9 is 90-100% cover, in 2006 and 2007 at WSU Vancouver REU.

**Table 2.** Mean marketable yield (kg) of lettuce, number of marketable heads per plot, and weight per head (g) in 2006 and 2007.

| Mulch Product | Yield (kg) 2006 | Yield (kg) 2007 | No. Heads 2006 | No. Heads 2007 | Head Wt. (g) 2006 | Head Wt. (g) 2007 |
|---|---|---|---|---|---|---|
| **Black plastic** | 2.14 a | 9.14 a | 16 a | 20 a | 135 a | 457 a |
| **Envirocare 1** | 2.59 a | | 16 a | | 162 a | |
| **Envirocare 2** | 2.86 a | | 17 a | | 171 a | |
| **LF 4** | 2.31 a | | 16 a | | 142 a | |
| **LF 5** | 2.73 a | 9.07 a | 17 a | 20 a | 162 a | 451 a |
| **Black LF 5** | | 8.56 a | | 19 a | | 428 a |
| **Planters Paper** | 2.43 a | 8.61 a | 16 a | 19 a | 154 a | 430 a |
| **Garden Biofilm** | 2.20 a | 8.60 a | 20 a | 20 a | 125 a | 429 a |
| **Garden Biofilm NF803/12** | 2.62 a | 10.90 a | 17 a | 20 a | 154 a | 544 a |
| **Garden Biofilm NF01U/P15** | 2.33 a | 10.21 a | 18 a | 20 a | 131 a | 510 a |
| **Garden Biofilm NF803/15** | 2.33 a | 8.67 a | 16 a | 20 a | 144 a | 433 a |
| **P Value** | **0.6475** | **0.7576** | **0.8960** | **0.3611** | **0.2336** | **0.7585** |

**Table 3.** Mean marketable yield (kg) of broccoli, number of marketable heads per plot, and weight per head (g) in 2006 and 2007.

| Mulch | Yield (kg) 2006 | Yield (kg) 2007 | No. Heads 2006 | No. Heads 2007 | Head Wt. (g) 2006 | Head Wt. (g) 2007 |
|---|---|---|---|---|---|---|
| **Black plastic** | 1.18 a | 7.35 a | 8.3 abc | 7.5 a | 137 d | 919 a |
| **Envirocare 1** | 1.50 a | | 8.8 ab | | 164 cd | |
| **Envirocare 2** | 1.78 a | | 9.8 a | | 183 bcd | |
| **LF 4** | 1.25 a | | 7.8 abcd | | 162 cd | |
| **LF 5** | 1.14 a | 7.52 a | 6.3 cd | 8.0 a | 188 bcd | 939 a |
| **Black LF 5** | | 6.50 a | | 8.3 a | | 813 a |
| **Planters Paper** | 1.15 a | 7.23 a | 7.8 abcd | 7.5 a | 150 cd | 903 a |
| **Garden Biofilm** | 1.29 a | 7.30 a | 9.5 a | 8.0 a | 137 d | 913 a |
| **Garden Biofilm NF803/12** | 1.66 a | 7.41 a | 6.5 bcd | 8.3 a | 258 ab | 926 a |
| **Garden Biofilm NF01U/P15** | 1.36 a | 7.54 a | 5.8 d | 7.8 a | 234 abc | 943 a |
| **Garden Biofilm NF803/15** | 2.03 a | 7.10 a | 6.5 bcd | 8.0 a | 318 a | 881 a |
| **P Value** | **0.2506** | **0.9704** | **0.0167** | **0.4694** | **0.0032** | **0.9704** |

**Table 4.** Mean marketable yield (kg) of pepper, number of marketable fruit per plot, and weight per fruit (g) in 2006 and 2007.

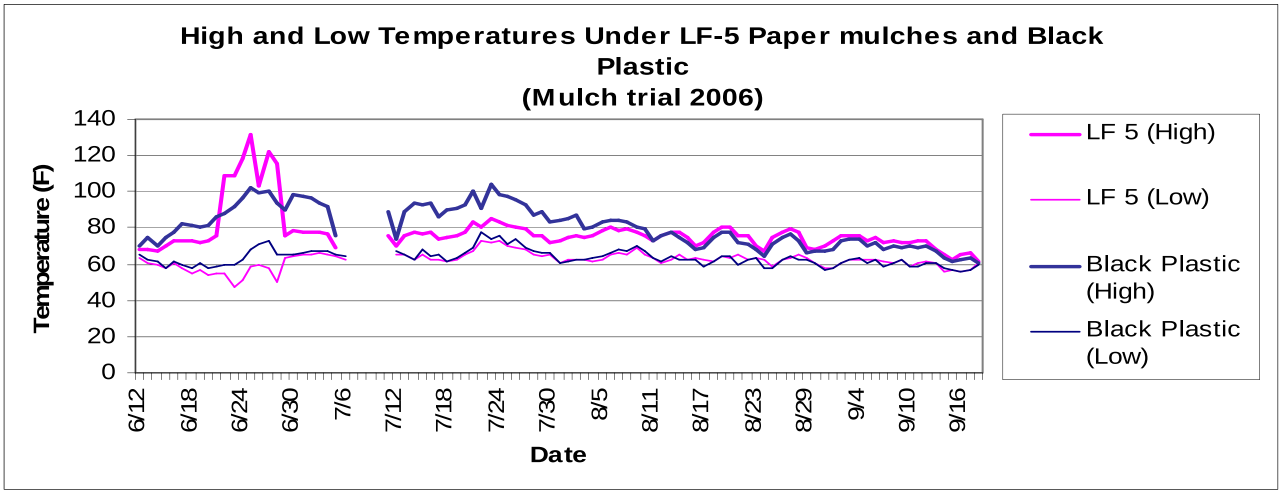
| Mulch | Yield (kg) 2006 | Yield (kg) 2007 | No. Fruit 2006 | No. Fruit 2007 | Fruit Wt. (g) 2006 | Fruit Wt. (g) 2007 |
|---|---|---|---|---|---|---|
| **Black plastic** | 1.86 abc | 8.01a | 15.8 abc | 35.3 a | 114 a | 203 a |
| **Envirocare 1** | 3.31 ab | | 27.8 ab | | 118 a | |
| **Envirocare 2** | 3.70 ab | | 29.5 ab | | 126 a | |
| **LF 4** | 0.40 c | | 3.8 c | | 107 a | |
| **LF 5** | 2.11 abc | 4.29 bc | 19.0 abc | 23.0 a | 111 a | 181 a |
| **Black LF 5** | | 3.54 c | | 20.0 a | | 175 a |
| **Planters Paper** | 1.51 bc | 4.83 bc | 13.8 bc | 21.5 a | 113 a | 188 a |
| **Garden Biofilm** | 2.67 abc | 5.12 bc | 21.0 abc | 30.5 a | 129 a | 175 a |
| **Garden Biofilm NF803/12** | 2.52 abc | 5.69 ab | 18.8 abc | 34.3 a | 159 a | 169 a |
| **Garden Biofilm NF01U/P15** | 3.01 ab | 6.47 ab | 27.8 ab | 27.0 a | 108 a | 174 a |
| **Garden Biofilm NF803/15** | 4.09 a | 5.85 ab | 34.0 a | 33.3 a | 119 a | 166 a |
| **P Value** | **0.0002** | **0.0396** | **0.0003** | **0.2544** | **0.4957** | **0.1119** |

**Table 5.** Mean marketable yield (kg) of watermelon, number of marketable fruit per plot, and weight per fruit (g) in 2006 and 2007.

| Mulch | Yield (kg) 2006 | Yield (kg) 2007 | No. Fruit 2006 | No. Fruit 2007 | Fruit Wt. (kg) 2006 | Fruit Wt. (kg) 2007 |
|---|---|---|---|---|---|---|
| **Black plastic** | 11.4 ab | 15.3 a | 6.5 ab | 2.5 a | 1.7 ab | 6.1 a |
| **Envirocare 1** | 27.3 a | | 12.8 a | | 2.2 a | |
| **Envirocare 2** | 20.2 ab | | 10.8 ab | | 2.0 ab | |
| **LF 4** | 1.9 b | | 1.5 b | | 1.3 ab | |
| **LF 5** | 6.6 b | | 6.5 ab | | 1.1 b | |
| **Black LF 5** | | | | | | |
| **Planters Paper** | 10.5 ab | 6.7 a | 6.8 ab | 1.3 a | 1.4 ab | 4.7 a |
| **Garden Biofilm** | 14.6 ab | 8.9 a | 8.3 ab | 1.6 a | 1.8 ab | 5.3 a |
| **Garden Biofilm NF803/12** | 12.7 ab | 13.9 a | 8.5 ab | 2.5 a | 1.5 ab | 5.5 a |
| **Garden Biofilm NF01U/P15** | 18.0 ab | 11.5 a | 13.8 a | 2.0 a | 1.3 ab | 6.3 a |
| **Garden Biofilm NF803/15** | 18.7 ab | 7.4 a | 11.0 ab | 1.3 a | 1.7 ab | 5.8 a |
| **P Value** | **0.0023** | **0.2606** | **0.0077** | **0.4043** | **0.0471** | **0.7294** |

**Table 6.** Days after transplanting to first harvest of lettuce, broccoli, pepper and watermelon at WSU Vancouver REU in 2006 and 2007.

| | Lettuce | | Broccoli | | Pepper | | Watermelon | |
|---|---|---|---|---|---|---|---|---|
| **Mulch** | **2006** | **2007** | **2006** | **2007** | **2006** | **2007** | **2006** | **2007** |
| **Black plastic** | 39 a | 32 a | 71 bc | 57 a | 109 a | 97 a | 72 abcd | 100 a |
| **Envirocare 1** | 39 a | | 67 c | | 109 a | | 65 d | |
| **Envirocare 2** | 39 a | | 67 c | | 109 a | | 67 cd | |
| **LF 4** | 40 a | | 69 bc | | 113 a | | 81 a | |
| **LF 5** | 38 a | 29 a | 70 bc | 58 a | 109 a | 94 a | 78 a | 100 a |
| **Black LF 5** | | 30 a | | 57 a | | 90 a | | 100 a |
| **Planters Paper** | 39 a | 30 a | 70 bc | 57 a | 109 a | 94 a | 69 bcd | 100 a |
| **Garden Biofilm** | 38 a | 30 a | 68 c | 61 a | 109 a | 84 a | 65 d | 100 a |
| **Garden BiofilmNF803/12** | 34 b | 30 a | 74 bc | 61 a | 112 a | 78 a | 77 ab | 100 a |
| **Garden BiofilmNF01U/P15** | 35 b | 29 a | 84 a | 58 a | 109 a | 82 a | 68 cd | 100 a |
| **GardenBiofilmNF803/15** | 34 b | 29 a | 84 a | 58 a | 109 a | 77 a | 74 abcd | 99 a |
| **P Value** | **0.0000** | **0.6331** | **0.0000** | **0.6912** | **0.124** | **0.313** | **0.0100** | **0.4414** |



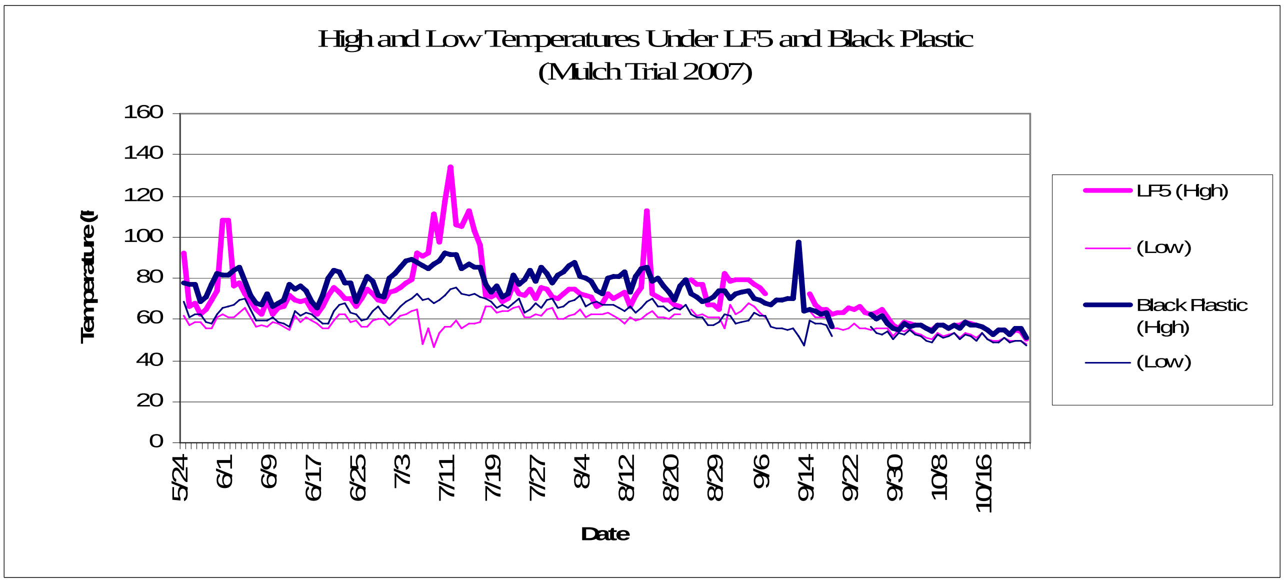
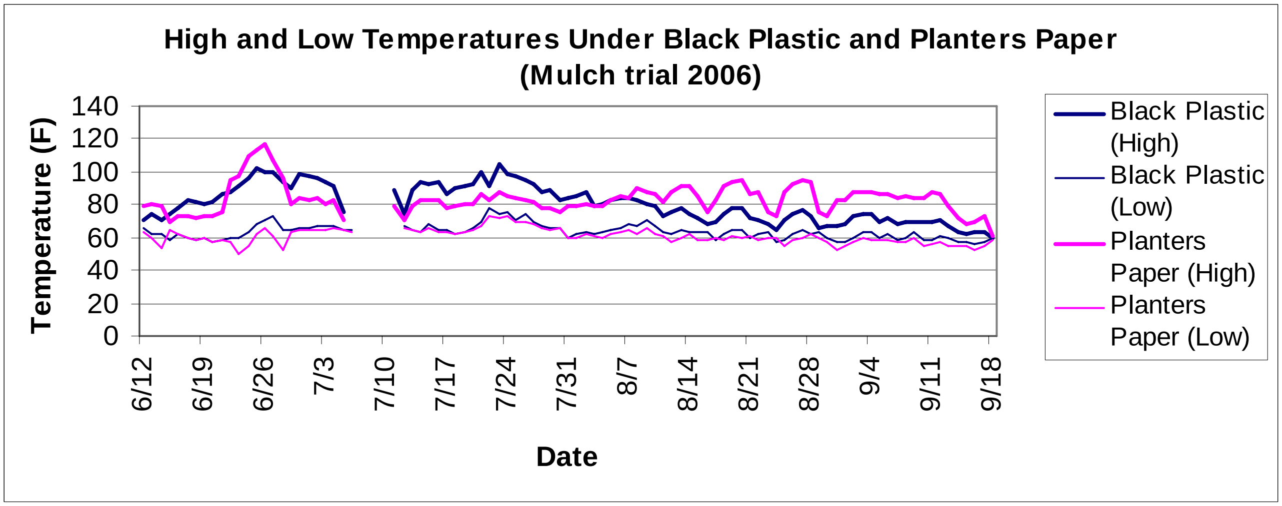




**Figure 5.** Temperatures ($^{o}$F) measured under black plastic and under LF 5 paper mulch in 2006 and 2007.



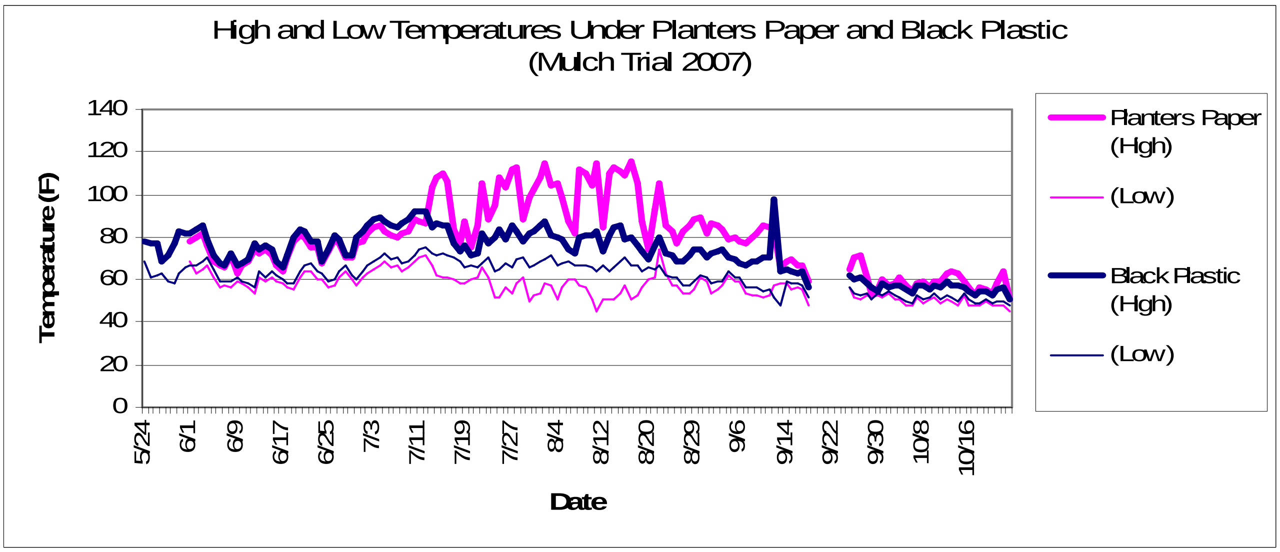
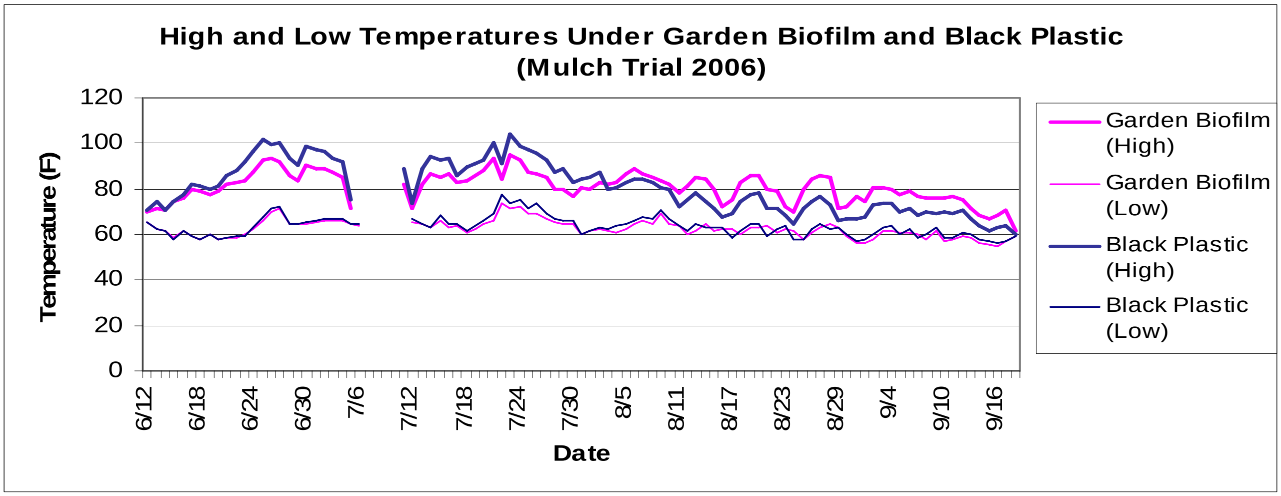




**Figure 6.** Temperatures ($^{o}$F) measured under black plastic and under Planters Paper mulch in 2006 and 2007.



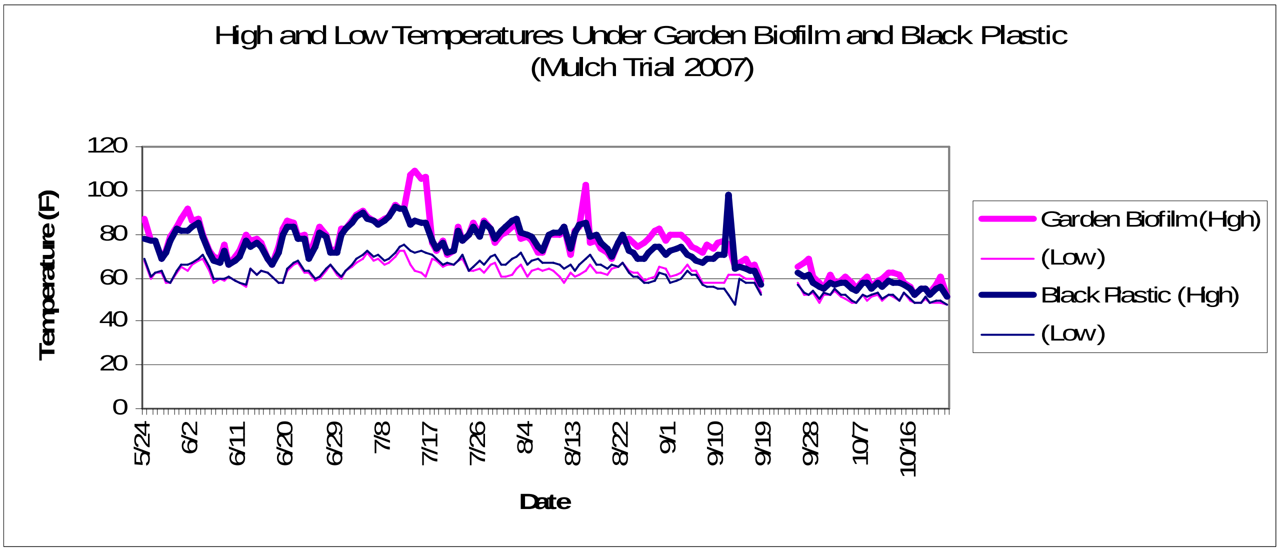
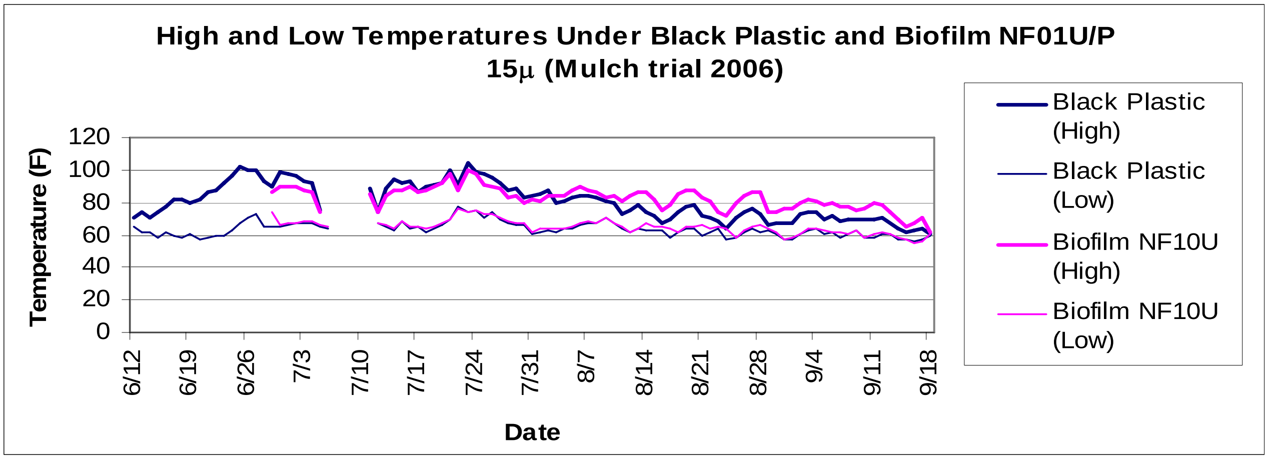
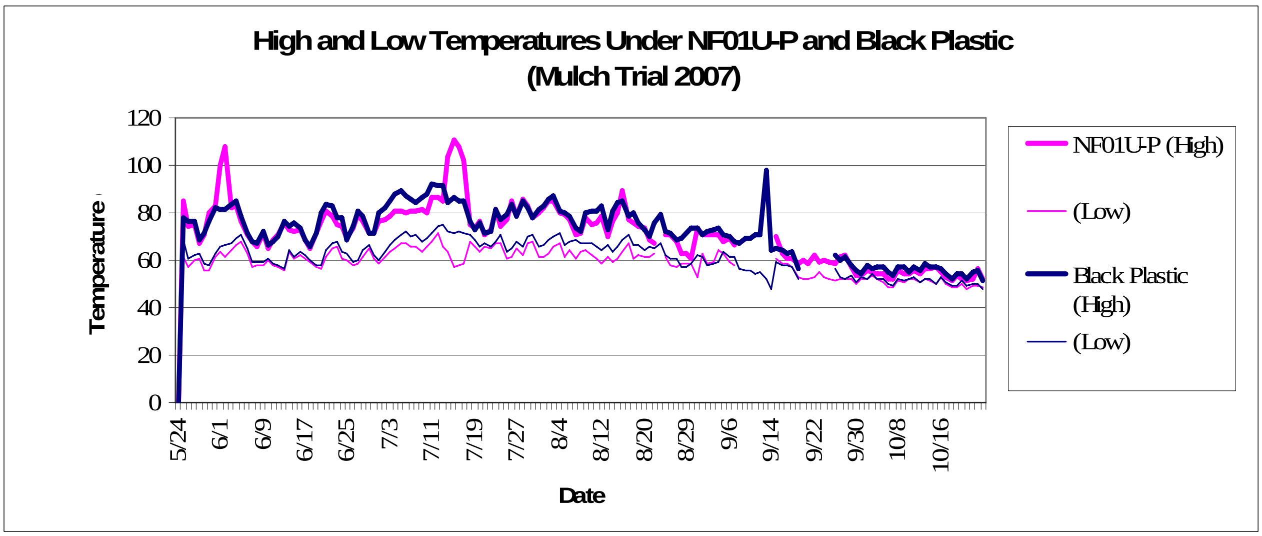
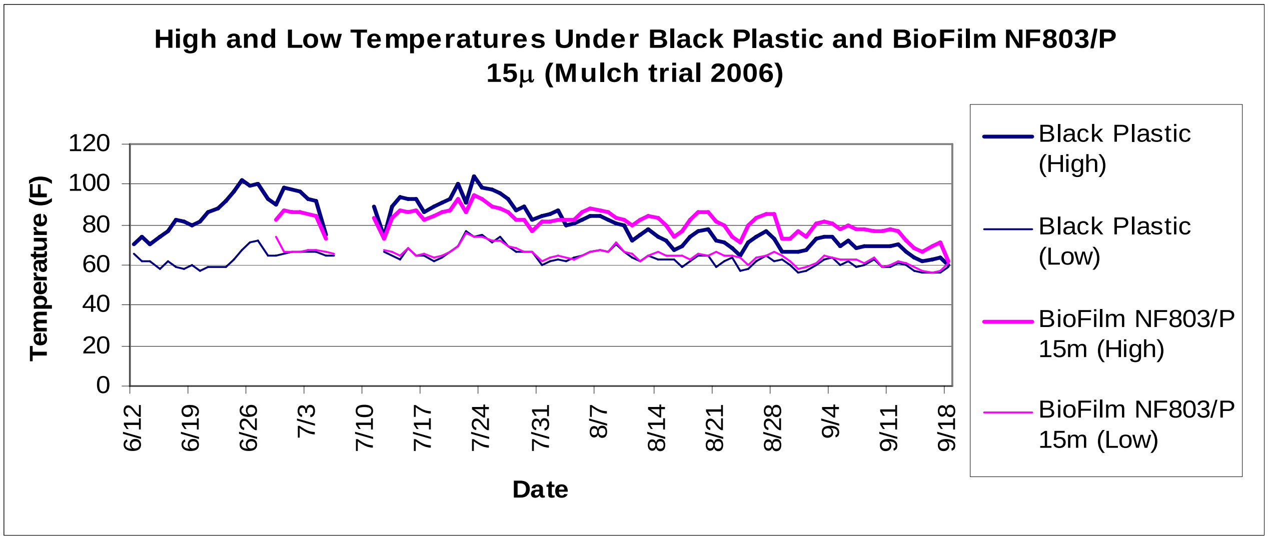
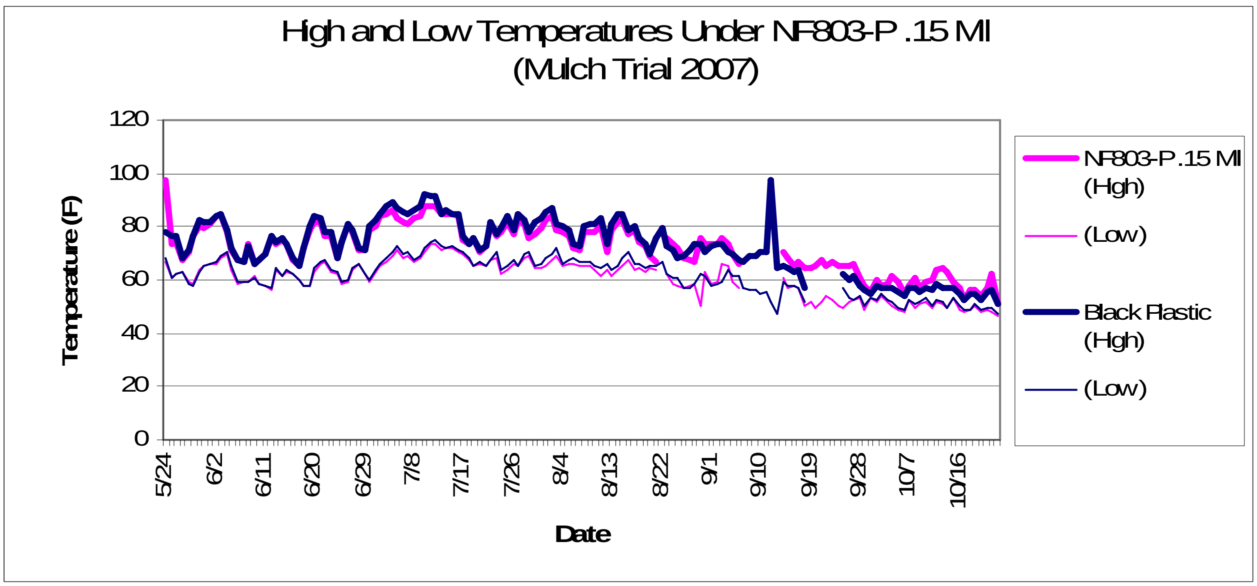



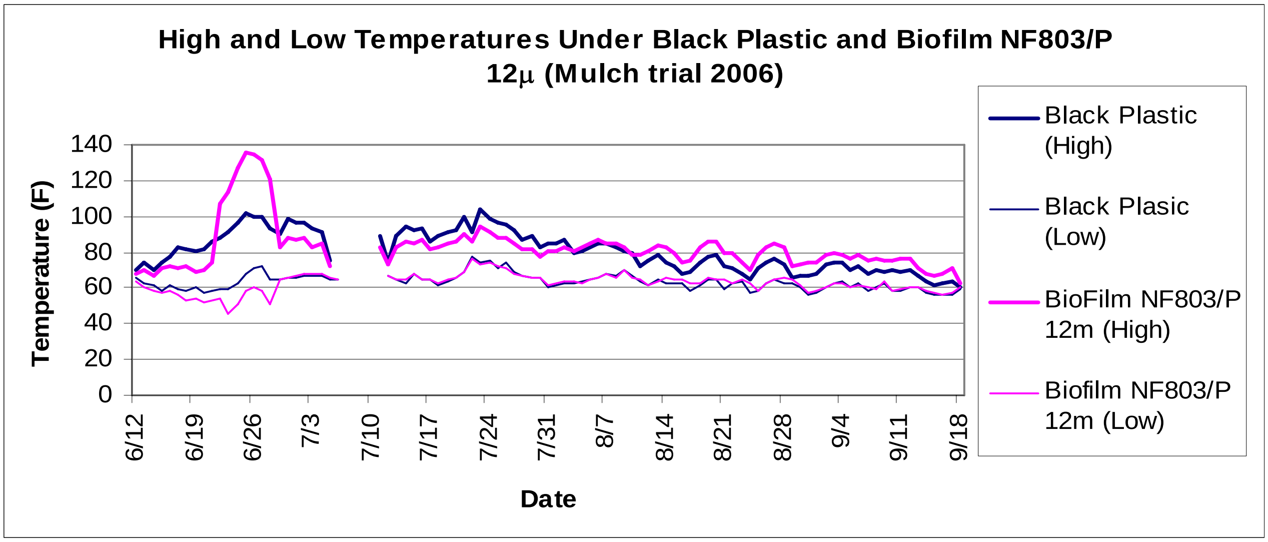

**Figure 9.** Temperatures ($^{o}$F) measured under black plastic and under Garden Biofilm mulch in 2006 and 2007.


High and Low Temperatures Under Black Plastic and Biofilm NF01U/P 15µ (Mulch trial 2006)
Temperature (F)
120
100
80
60
40
20
0
6/12
6/19
6/26
7/3
7/10
7/17
7/24
7/31
8/7
8/14
8/21
8/28
9/4
9/11
9/18
Date
Black Plastic (High)
Black Plastic (Low)
Biofilm NF10U (High)
Biofilm NF10U (Low)


High and Low Temperatures Under NF01U-P and Black Plastic (Mulch Trial 2007)
Temperature
120
100
80
60
40
20
0
5/24
6/1
6/9
6/17
6/25
7/3
7/11
7/19
7/27
8/4
8/12
8/20
8/29
9/6
9/14
9/22
9/30
10/8
10/16
Date
NF01U-P (High)
(Low)
Black Plastic (High)
(Low)


High and Low Temperatures Under Black Plastic and BioFilm NF803/P
15µ (Mulch trial 2006)
Temperature (F)
120
100
80
60
40
20
0
6/12
6/19
6/26
7/3
7/10
7/17
7/24
7/31
8/7
8/14
8/21
8/28
9/4
9/11
9/18
Date
Black Plastic (High)
Black Plastic (Low)
BioFilm NF803/P 15m (High)
BioFilm NF803/P 15m (Low)


High and Low Temperatures Under NF803-P .15 Ml
(Mulch Trial 2007)
Temperature (F)
120
100
80
60
40
20
0
5/24
6/2
6/11
6/20
6/29
7/8
7/17
7/26
8/4
8/13
8/22
9/1
9/10
9/19
9/28
10/7
10/16
Date
NF803-P .15 Ml (High)
(Low)
Black Plastic (High)
(Low)



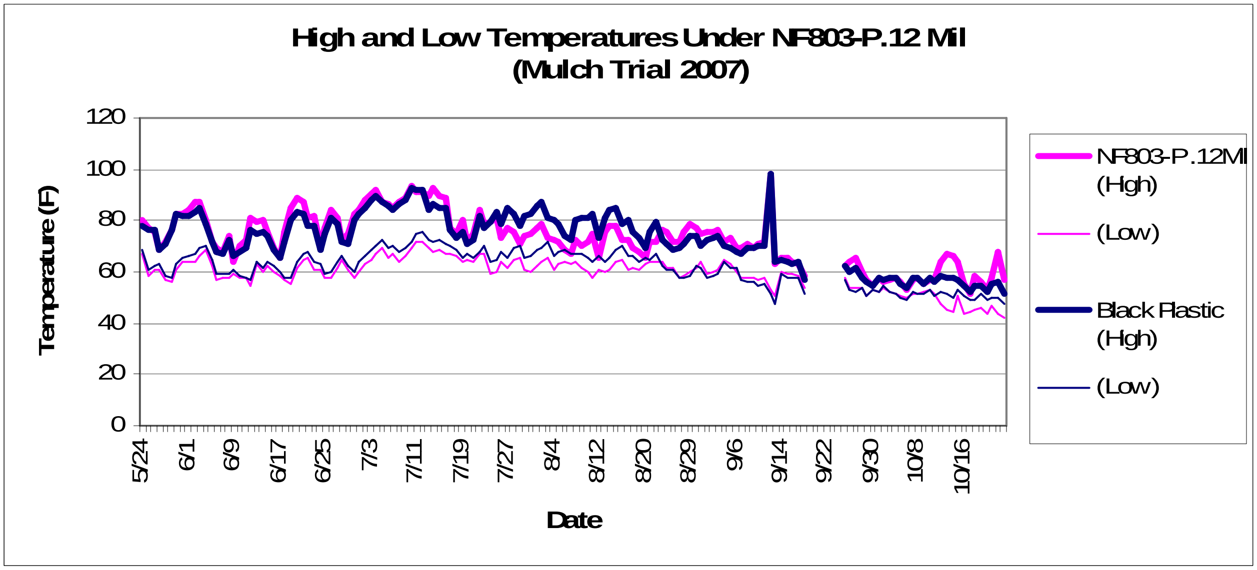




**Figure 10.** Temperatures ($^{o}$F) measured underneath three new Garden Biofilm products and compared to Black plastic in 2006 and 2007.

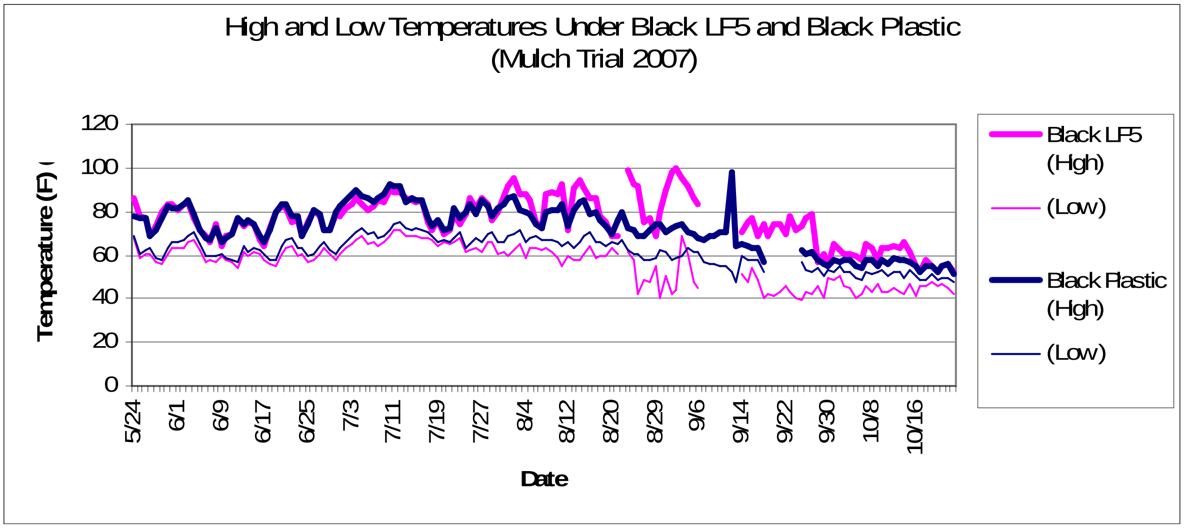



**Figure 11.** Temperatures ($^{o}$F) measured underneath Black LF5 compared to Black plastic in 2007.