Season Extension: Using Row Covers and Plasticulture to Produce an Earlier Harvest and Greater Yields

Table of Contents

1.0 Summary

We compared the effects of red and black plastic mulch with and without row cover to soil without row cover for tomatoes, peppers, eggplant, and melons. Our objective was to determine whether earlier harvests and greater yields could be achieved by planting early, using row covers and plasticulture to protect plants and enhance growth. We succeeded in getting greater yields by as much a month earlier with plastic and row cover compared to soil. Three cultivars of tomato, eggplant and pepper were used and two cultivars of melons. We recorded each harvest date and weights of harvest for each treatment. Some treatments produced yields of double and triple the amount produced on soil. The best treatment to use will vary for each user depending on the importance placed on factors such as earliness, overall yield, or cost of materials.

2.0 Materials and Methods

We started all of our transplants in a green house. We ordered our SRM red and black plastic mulch, drip tape (8 mil t-tape) and Agrofabric Pro 19 row cover early enough that we had it on hand. We had compost spread in May and then had the field plowed and disked. On May 17 we borrowed a mulch layer and began laying mulch and drip tape as soon as the field was finished being disked. The mulch layer was pulled behind our tractor. One person drove and another person watched to make sure the mulch was being laid correctly and shoveled dirt on any spots that were missed or not fully covered. Level field preparation can not be stressed enough to make the mulch layer work well. We chose 4-foot wide mulch and used normal black mulch and SRM red. We laid drip tape on the surface under the mulch.

We bought a water wheel transplanter ($2400 - not grant money) to help speed up the transplanting and to avoid the physical punishment of hand transplanting. The transplanter pokes a hole in the mulch and creates a hole for the transplant. It fills the hole with water, which helps the survival of transplants.

Transplanting began on May 19th, which was 4 days later than we had hoped to get started, and we finished by the 21st. We normally use June 1 as our frost free safe date although it has been known to freeze in June. We started with tomatoes and then moved to peppers and eggplant. We transplanted melons last. Had it frozen, the added benefit of row cover would have been tested.

Once the transplants were in we installed wire hoops about every 3 feet on the 4.5 rows getting row cover. We decided to use sand bags filled with dirt to hold down the row cover. Filling and moving all the bags was a big project. We think it worked better than using piles of dirt to hold down the row cover since it did not tear the cover and a shovel was not needed every time the cover was moved. The bags were easy to move for inspections, pollination and for removal of the row cover. The Agrofabric Pro 19 worked well but began to deteriorate in 60 days, which was much more quickly than we thought it would.

Once everything was planted we kept it weeded. Our farm is certified organic so we did not use any herbicides, pesticides, or chemical fertilizers. The plastic mulch required less than 1/3 of the weeding time of the bare soil rows. We did need to carefully remove weeds, especially bindweed, that would grow up through the holes in the much that were made for the transplants. The sides of the mulch where soil had been mounded up to hold it down were difficult to weed. We had to hand pull the weeds since a hoe punctured the plastic. We would like to try a flame weeder in the future to control the weeds on the sides of the mulch. Amazingly, we only used the drip tape to water when the transplants were first planted. It rained so often that we never watered again the entire season. We removed the row cover earlier than anticipated because it was tearing, the plants were growing through it, and we had pollination concerns. It would have been nice to have been able to re-cover the plants in the fall to protect from frost. This was not practical since the cover was shredded and the plants had grown so large that the cover would not have been big enough. The plants on plastic grew much larger than we had anticipated and grew larger than any previously grown on our farm.

For the experiment we planted five 365 foot rows of tomatoes and melons. For the peppers and eggplant 91 feet of each were planted per treatment. Each cultivar of each crop was trialed on red mulch, red mulch with row cover, black mulch, and black mulch with row cover. Bare soil was used as a control for comparison.

For tomatoes and melons 20 plants of each cultivar for each treatment were selected and marked twice on each plant with florescent surveyor tape. For peppers and eggplant 10 of each cultivar on each treatment were selected. We harvested every few days once the crops began to ripen. We carefully picked from the marked plants in each treatment, weighed and recorded the data. We personally did almost all of the harvesting from the plants in the experimental section of the farm to try and prevent mistakes. We were concerned that if we had somebody helping who was not integrally involved in the experiment that non-experiment plants would be included or experiment plants would accidentally be picked but not recorded. In the grant proposal we

agreed to pick only fully ripened fruit. Melons were picked at full slip, tomatoes at full red, peppers at full red and eggplant at what we felt was a reasonable size for that cultivar. Damaged or otherwise un-sellable fruit was not accounted for.

Below are diagrams showing the experiment field layout.

Tomatoes

Tomatoes were planted 7 inches off center in rows with 2 feet between plants and 5 feet between rows.

Tomatoes Covered, Black Plastic

Cultivar 1 (Early Cascade)	Cultivar 2 (Striped German)	Cultivar 3 (Fantastic)

Tomatoes Uncovered, Black Plastic

Cultivar 1 (Early Cascade)	Cultivar 2 (Striped German)	Cultivar 3 (Fantastic)

Tomatoes Covered, Red Plastic

Cultivar 1 (Early Cascade)	Cultivar 2 (Striped German)	Cultivar 3 (Fantastic)

Tomatoes Uncovered, Red Plastic

Cultivar 1 (Early Cascade)	Cultivar 2 (Striped German)	Cultivar 3 (Fantastic)

Tomatoes No Mulch, No Cover

Cultivar 1 (Early Cascade)	Cultivar 2 (Striped German)	Cultivar 3 (Fantastic)

<----------365 ft ----------->

Peppers and Eggplants

Peppers and eggplants were planted 18 inches apart in rows with plants staggered 7 inches off center and with 5 feet between rows. Cultivars used for eggplant were Orient express, Rosa Bianca, and Dusky. Cultivars used for peppers were Ace, Lady Bell, and Lipstick.

Eggplant Uncovered	Peppers Uncovered	Eggplant Covered	Peppers Covered	Eggplant Covered	Peppers Covered	Eggplant Uncovered	Peppers Uncovered

<----------Black Mulch 183 feet----------> <----------Red Mulch 183 feet---------->

Eggplant Uncovered	Peppers Uncovered

<----------No Mulch 183 feet ---------->

Melons

Melons were planted 7 inches off center in rows with 2 feet between plants and 10 feet between rows.

Melons Covered, Black Plastic

Cultivar 1 (French Orange)	Cultivar 2 (Roadside)

Melons Uncovered, Black Plastic

Cultivar 1 (French Orange)	Cultivar 2 (Roadside)

Melons Covered, Red Plastic

Cultivar 1 (French Orange)	Cultivar 2 (Roadside)

Melons Uncovered, Red Plastic

Cultivar 1 (French Orange)	Cultivar 2 (Roadside)

Melons Uncovered, No Plastic

Cultivar 1 (French Orange)	Cultivar 2 (Roadside)

<----------365 feet ----------->

At the end of the season we had to remove all of the drip tape and plastic mulch. Originally we hoped to reuse some of the mulch and drip tape. The mulch had holes in it and was deteriorating from sunlight. It would not be cost effective if it was even possible to reuse the mulch. The drip tape may have been salvageable but we were not careful enough. The mulch was covered in rotting smelly tomatoes and had mice living under it. The melons plants had withered enough that the mulch could be pulled and the plants would disintegrate. On the tomatoes each plant was cut off at the base so the mulch would pull free. On the peppers and eggplant we tore the mulch up in such a way as to leave the plants standing. The mulch pulled free with a bit of work and some good gloves. It took about 35 minutes to remove one 365 foot row of mulch and drip tape. On soil where the drip was buried 3-4 inches it took almost as long to just remove the tape. It has been recommended to use a bush-hog mower to cut the plants before removing the mulch.

3.0 Results

We harvested the experiment and weighed the yield several times each week and the results are presented in Table 1. For each cultivar, all the ripe fruit was harvested in each treatment and weighed separately according to treatment. We did not attempt to record the harvest from individual plants. It should be noted that only marketable vegetables were harvested. Produce that had significant hail, insect, sun, or other damage and was therefore not sellable was not included in the experiment harvest. Experiment yield results are also shown in Figure 1. The average cumulative yield per plant is shown over the course of the harvest period.

We also photographed the plants in this experiment at several points during the development of the plants. A significant difference in the development of the plants in different treatments is visible, especially in the earlier stages of growth. (see photos)

4.0 Conclusions and Discussion

The results from our experiment clearly show that increased yields and earliness can be achieved by using plastic mulch and row cover (see Figure 1 and Table 1). However, there was no single treatment that was definitively the best for all the crops and cultivars. In this section we will discuss the results for each cultivar then discuss other factors that we believe affected the results

and should be considered when evaluating the different treatments to achieve your individual goals.

4.1 Discussion of Results for Individual Crops

Eggplant

The first crop in our experiment to produce ripe fruit was eggplant. In general, eggplant produced the greatest yield on red or black plastic with row cover. These treatments provided significantly earlier yields with some eggplant cultivars, but not others. The following table is a summary of eggplant yields:

		Red w/ cover	Red no cover	Black w/ cover	Black no cover	Bare Soil
Dusky	Total yield/plant (lbs)	3.6	3.0	2.8	2.0	1.7
Dusky	% increase over bare soil	106%	74%	63%	15%	0%
Orient Express	Total yield/plant (lbs)	2.5	1.9	2.7	1.4	1.9
Orient Express	% increase over bare soil	36%	3%	44%	-27%	0%
Rosa Bianca	Total yield/plant (lbs)	2.4	1.1	1.9	1.2	0.9
Rosa Bianca	% increase over bare soil	150%	21%	99%	32%	0%

We harvested Orient Express for the first time on July 27. The black mulch with row cover produced the greatest yield, followed by red mulch with row cover. The black mulch with row cover yielded 44% more than bare soil. The mulch and row cover treatments did not seem to have a large effect on earliness for Orient Express.

The red mulch with row cover yielded the most Dusky eggplant with a yield 106% greater than bare soil. In addition, Dusky was harvested almost a full month earlier on the red mulch with row cover than on bare soil (Aug 4 vs. Sept 1).

Rosa Bianca (heirloom) was in general a very late producing eggplant. The first Rosa Bianca was harvested on August 10 from black mulch with row cover. However, the bulk of the Rosa Bianca harvest did not begin until early September. Row cover made a big difference in the yield of this cultivar. Red plastic with row cover had the greatest yield, followed by black plastic with row cover. The yields for these two treatments were 150% and 99% greater than bare soil, respectively.

Peppers

For this experiment, peppers were harvested when they were full red ripe. A lot of the peppers suffered from sun scald in between being green and turning red and therefore were discarded. Using plastic mulch increased the yield for all three cultivars over bare soil. In general, we had poor results with peppers ripening on bare soil. The plastic mulch also seemed to produce earlier ripe fruit. Using row cover had mixed results, increasing the yield in some cases, but not in others. For the future, it would be interesting to use row cover on the pepper plants once they have set fruit to see if that would speed up ripening. The following table is a summary of pepper yields:

		Red w/ cover	Red no cover	Black w/ cover	Black no cover	Bare Soil
Ace	Total yield/plant (lbs)	2.1	1.8	1.8	1.3	0.4
Ace	% increase over bare soil	405%	346%	331%	213%	0%
LadyBell	Total yield/plant (lbs)	1.0	1.4	1.3	1.5	0.6
LadyBell	% increase over bare soil	65%	150%	121%	163%	0%
Lipstick	Total yield/plant (lbs)	1.2	1.3	0.7	1.0	0.7
Lipstick	% increase over bare soil	64%	75%	1%	35%	0%

Ace peppers produced the greatest yield on red plastic with row cover. Red plastic with row cover yielded 405% more ripe peppers than bare soil. Ace peppers grown on bare soil produced very few ripe peppers.

Lady Bell peppers produced the greatest yield on black plastic with no row cover, followed by red plastic with row cover. These two treatments yielded 163% and 150% more than on bare soil, respectively.

Red mulch with no row cover produced the most ripe Lipstick peppers, followed by red mulch with row cover. These two treatments yielded 75% and 64% more than bare soil, respectively.

Tomatoes

Plastic mulch increased the yield of tomatoes for all three cultivars. Row cover also increased the tomato yield. However, these treatments did not seem to make a large difference in earliness of tomato production. We encountered two problems during our growing season that may have affected these results. We had several hail storms early in the season that damaged a lot of the fruit. Our tomato plants also suffered from two viruses that decreased yield from the plants. The following table is a summary of tomato yields:

		Red w/ cover	Red no cover	Black w/ cover	Black no cover	Bare Soil
Early Cascade	Total yield/plant (lbs)	5.7	5.8	7.1	5.7	3.5
Early Cascade	% increase over bare soil	63%	68%	103%	64%	0%
Fantastic	Total yield/plant (lbs)	3.0	1.8	1.6	0.9	0.7
Fantastic	% increase over bare soil	346%	171%	143%	31%	0%
Striped German	Total yield/plant (lbs)	0.8	0.6	0.9	0.7	0.1
Striped German	% increase over bare soil	525%	334%	598%	473%	0%

Black mulch with row cover produced the greatest yield for Early Cascade tomatoes. This treatment produced 103% more than bare soil. However, this treatment did not seem to have much effect on earliness.

Fantastic tomatoes produced the greatest yield on red plastic with row cover. This treatment yielded 346% more than bare soil. Again, the mulch and row cover did not seem to affect earliness much for this cultivar.

Striped German (heirloom) tomatoes produced very poorly in general with less than one pound per plant on average. Black plastic with row cover produced 598% more than bare soil, but none of the treatments seemed to have much effect on earliness.

Melons

Plastic mulch and row cover increased the yield of melon plants, but the more noticeable difference was in earliness. Using different treatments staggered the melon harvest, which was beneficial in that it gave us a longer period of time where we were harvesting melons. The plants grown on plastic and especially the ones with row cover grew very fast early on (see photos). The melon plants on bare soil seemed to suffer from transplant shock and took a while to really start growing again. However, the melons grown on bare soil did produce a good amount later in the season. It should also be mentioned that we lost at least half of the melons to cracking. We had a wet summer and we think this moisture lead to having so many melons crack. The Roadside melons grown on red mulch with row cover suffered the worst loss due to cracking. Again, only melons that were of market quality were included in the yield measurements. Cracked melons were discarded.The following table is a summary of melons yields:

		Red w/ cover	Red no cover	Black w/ cover	Black no cover	Bare Soil
French Orange	Total yield/plant (lbs)	2.3	2.0	2.0	3.6	1.8
French Orange	% increase over bare soil	26%	10%	7%	98%	0%
Roadside	Total yield/plant (lbs)	2.6	3.5	3.6	5.9	4.0
Roadside	% increase over bare soil	-35%	-13%	-11%	48%	0%

Black mulch with no cover produced the greatest yield of French Orange melons. This treatment produced 98% more melons than bare soil. However, this treatment also produced melons relatively late when compared to the other treatments. The two treatments with row cover produced melons about two weeks earlier than the other treatments.

Black mulch with no cover also produced the greatest yield of Roadside melons. This treatment produced 48% more than bare soil. However, bare soil produced the second highest yield of these melons. Although we did not keep records of it, the plants on these two treatments produced fewer but much larger melons than the Roadside melons on other treatments. Again, the melon harvest was staggered with the red mulch and row cover producing the earliest ripe melons. However, over half of the melons in this treatment were lost due to cracking.

4.2 Additional Factors Affecting Experiment Results

We learned that crop yield and earliness can be improved with plastic mulch and row cover. However, many other factors will affect these results and must be evaluated when deciding which combination of mulch and row cover to use. We encountered a number of additional factors that may have affected the experiment results and in some ways may make the results unique to this growing season. We will discuss these other factors below to be used when considering the results of this experiment.

The summer of 2004 was cooler and wetter than regular summers in Boulder, Colorado. The cooler temperatures may have affected the yield from the heat-loving crops that were used in this experiment. We would like to see how using mulch and row cover would affect these crops in a hotter, more typical summer.

We planted the crops in the experiment several weeks earlier than we would usually plant the summer transplants. We did not experience a frost late in the spring this year. If we had, the row cover may have been a lot more valuable in protecting the transplants from freezing.

We also had several hail storms and we believe these may have affected the results of the experiment. The row covers were still on some of the plants when we had the first hail storm. The hail shredded the row cover and we had to remove the damaged cover before we planned to. The melon plants that were grown under row cover grew a lot faster than the uncovered plants. We had a hail storm after we uncovered these melon plants and the hail smashed a lot of the large leaves on the plants grown under row cover. The plants that were grown without cover had smaller leaves at this point and they were not damaged as badly as the larger leaves on the other plants. There were also a lot of tomato plants that had recently set fruit and the hail damaged these tomatoes. These tomatoes had to be discarded when we harvested several months later.

We also did not expect such vigorous plant growth from using the plastic mulch and row cover. The tomato plants especially grew much larger than what we have grown in the past on bare soil. The plants grew so large and so close together that it was difficult to find a place to step when harvesting the tomatoes (see photos). Increasing the spacing between the plants grown on plastic may affect the results in the future.

Some of our tomato plants were infected with two wilt viruses this summer. We removed a lot of the diseased plants, but we believe that a lot of the plants were weakened and this may have decreased the yields.

We lost a lot of melons due to cracking, especially on red mulch with row cover. This summer was a lot wetter than usual and our clayey soil retained a lot of moisture. Other than an initial watering right after transplanting, we did not need to irrigate the crops in this experiment. The crops received moisture solely from rainfall. This excess or uneven moisture may have lead to having so many melons crack.

The plastic mulch attracted a lot of mice. We did not see any direct damage to the crops in the experiment from the mice. However, we direct-seeded crops into plastic mulch in another part of our field and the mice ate a lot of the seed before it could germinate.

We did not use any fertilizers during the growing season. We also did not ever spray for Colorado potato beetle or flea beetles. However, we did see damage to the uncovered melon plants from these insects.

4.3 Additional Costs and Labor

The results of this experiment were evaluated on the basis of earliness and yield. However, we believe that additional costs and labor must be considered when evaluating the benefit of the different treatments.

The costs of the supplies we used in this experiment are listed below:

Red SRM plastic mulch	$0.10/ft
Black plastic mulch	$0.028/ft
Agrofabric Pro 19 row cover	$0.152/ft
Sandbags	$0.25 each (we used one sandbag every 10 ft)

In Appendix A we used these prices along with our market prices for vegetables and the yields for this experiment to calculate the dollar yield per plant.

These costs are used along with labor to evaluate the treatments below. The cost of additional labor should be considered as well as the timing of the additional labor during the season. It should be noted that because it was such a wet summer, we did not irrigate the crops in this experiment and therefore could not evaluate costs or savings that might be associated with irrigation in a dry summer.

Bare soil

- No additional material costs.
- No additional labor to install and remove plastic mulch or row cover.
- Additional labor required for weeding during growing season.

Plastic Mulch

- Additional cost of plastic mulch.
- Additional labor to install and remove plastic mulch at beginning and end of season. (Installation may require use of a mulch layer.)
- Reduced labor for weeding in rows.
- May reduce irrigation.

Row Cover

- Additional cost of row cover. May also need hoops to support cover and sandbags to hold row cover down.
- Must use plastic mulch with row cover to control weeds.
- Additional labor to install cover at beginning of season and remove cover at some point during season.
- May provide benefit of protection against frost in early season.

5.0 Outreach

In our proposal we agreed to have at least one field day and to link our results to the CSU web page. Invitations to the field day were given to many of the farmers at the Boulder Farmers market and invitations were sent by email by Frank Stonaker to people he knew. We had great

results in terms of plant growth early in the season. So we had out first field day on June 13. The plants on plastic with row cover were more than twice the size of the others (see photos). We had a good turnout of about 15 farmers and CSU people. We had a second field day on September 7 to show the plants at harvest time. Not as many people came to the second one. In addition to the field days a group of 12 farmers and interns came out from another local farm in June. When the final results are completed we are planning to link this report to CSU specialty crops web page. A few other local farmers have requested copies of our results and will be getting them shortly.

6.0 Final Budget Sheet

Budget Category	Description	Funds Received from SCP	Funds Used	Matching Funds
Personnel	Installing/removing drip tape, plastic mulch, and row cover; transplanting, weeding, harvesting, record keeping, technical advisor	$5,184	$4,720*	$2,260
Materials and supplies	seed and transplants, drip tape, plastic mulch, row covers, sand bags, wire hoops	$1,084	$1,595*	$100
Outreach expense	Field day, film, paper, report writing time			$300
Misc.	Land, water, tractor use, field work/prep, fuel, compost			$1,350
Total		$6,268	$6,315	$4,110

*For detailed costs please see Appendix B.

7.0 Signature of project leader and date

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Wyatt Barnes Date