Early Season Soil Tarping Impacts on Weed Pressure and Onion Yield

Hannah Voye, Graduate Research Assistant SDSU Agronomy, Horticulture and Plant Science Department
Kristine Lang, Assistant Professor & SDSU Extension Consumer Horticulture Specialist
Rhoda Burrows, Professor & SDSU Extension Horticulture Specialist

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Introduction

Farmers are always looking for effective ways to reduce weed competition within their vegetable crops. One method is soil tarping. When tarps are applied in early spring and removed before planting, they can reduce weed pressure for early season crops like onions. Since onions have a very minimal canopy and therefore do not provide much soil coverage, they have high susceptibility to weed pressure.

Two tarping methods are solarization and occultation. Solarization uses clear plastic to harness energy from the sun and warm the soil. The goal behind solarization is to exhaust the weed seed bank before planting to reduce the number of weeds coming up during the growing season. In some cases, it can raise temperatures high enough to kill germinated weed seedlings. Occultation uses an opaque material to stop light from hitting weed seeds and therefore stops germination. It can deprive any existing seedlings or perennial plant parts of light needed for survival. The length of time a tarp is on the ground may also impact weed pressure.

Much of the research and usage of tarping has occurred in more humid areas in the eastern United States (Kennenbrew et al. 2023). The purpose of this tarping project is to study the performance of tarping to reduce weed pressure and increase yield under sunnier, windier conditions.

Materials and Methods

Location and Experimental Design

Field research was conducted in Brookings, SD to study the effects of soil tarping on weed pressure and onion yield (Figure 1). Soil type and organic matter can affect wetting pattern from irrigation as well as nutrient holding ability and microbial composition. The soil type in the area of interest was clay loam (Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture 2024). Soil tests taken six inches deep at the beginning of the season showed soil organic matter ranging between three and four percent.

Figure 1. The SDSU Specialty Crop Research Field in Brookings, South Dakota.

Three types of tarps were evaluated: black silage tarps, white silage tarps, and clear greenhouse plastic. A control (bare ground) treatment plot was also included. The amount of time the ground was tarped was another factor explored. Each type of tarp was placed at six, four, or two weeks before onion planting. The experimental design was a completely randomized block design with onion cultivar as a split plot within tarping treatment. There were four blocks and ten treatment plots within each block. Blocks were twenty-four feet wide by one hundred feet long, making each treatment plot twenty-four feet wide by ten feet long (Figure 2 a-d).

Figure 2a. Black-tarp plot in SDSU Specialty Crop Field on May 26, 2023. (Hannah Voye photo)

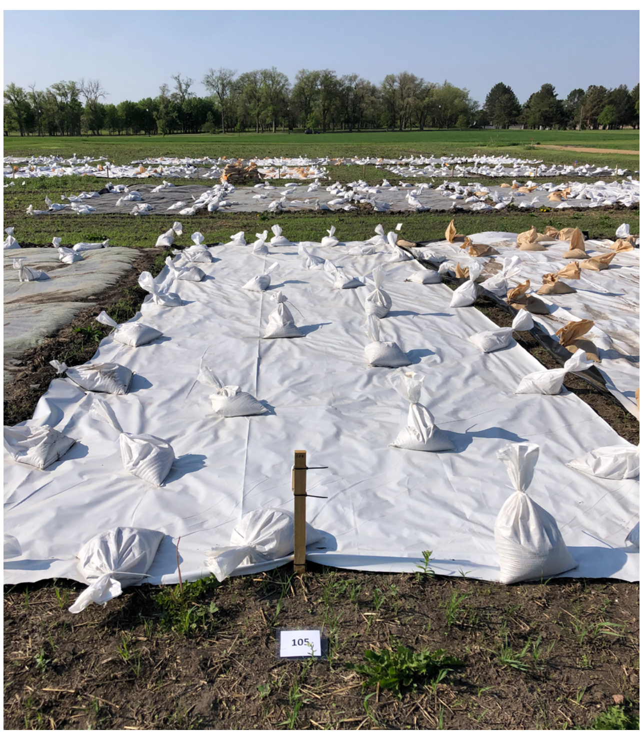

Figure 2b. White-tarp plot in SDSU Specialty Crop Field on May 26, 2023. (Hannah Voye photo)

Figure 2c. Clear-tarp plot in SDSU Specialty Crop Field on May 25, 2023. (Hannah Voye photo)

Figure 2d. Control plot with no tarp in SDSU Specialty Crop Field on May 30, 2023. (Hannah Voye photo)

Soil Tarping

Opaque silage tarps with one side black and one side white were obtained from Farm Plastic Supply for the occultation treatments. Clear greenhouse plastic (UV resistant six mil from Farm Plastic Supply) was also obtained for solarization treatments. Tarps were cut into pieces twenty-four feet wide by ten feet long to match plot size. They were laid down on the soil on April 18, May 5, and May 17 so each tarp type covered the soil for durations of roughly six, four, and two weeds prior to onion planting. Black side up and white side up tarps were secured with twenty-five to thirty fifteen-pound sandbags. Clear tarps were secured with sandbags as well as burying the edges.

All tarps were removed May 30 (Figure 3). Data on weed count, height, biomass, and type of weed were collected from each treatment plot. This was done by randomly throwing three 50 by 50 centimeter PVC quadrats into each treatment plot and collecting data on weeds within the quadrat area. Weeds within the quadrat were separated by broadleaves and grasses. For each weed type, three random weeds were selected to be measured for height. All weeds within the quadrats were clipped to soil level, counted separately by broadleaves and grasses, dried, and weighed to measure biomass.

Figure 3. Black-tarped plot (left) and clear-tarped plot (right) after tarp removal on May 30, 2023. (Hannah Voye photo)

After data collection, clear tarp and control treatment plots were tilled using a BSC tiller to clear out the germinated weeds for planting. These treatments were tilled lightly at a two-and-a-half-inch depth so as to not bring up more weed seeds to the soil surface. Black and white tarped plots did not need to be tilled at removal of tarps, as there were very minimal to no weeds in these treatment plots.

Planting Onions

Onion *(Allium cepa)* cultivars Barolo, Patterson, and Candy were seeded in size 128-cell trays in the South Dakota State University campus greenhouse on February 28 through March 2 (Figure 4). Greenhouse temperatures were set 68 to 74°F for daytime and 64 to 70°F for nighttime. Four-hundred-watt, high pressure sodium lights were active from 6:00 a.m. to 10:00 p.m. each day. Onions were watered on an as needed basis. Onion seeds began germinating March 8. Once onions reached about two inches in height, they were fertigated weekly with Nature's Source Organic Plant Food 3-1-1 on an at-need basis. See Table 1 for dates and rates of fertilizer application. On May 24, onions were placed outdoors in a holding area to acclimate before planting into treatment plots.

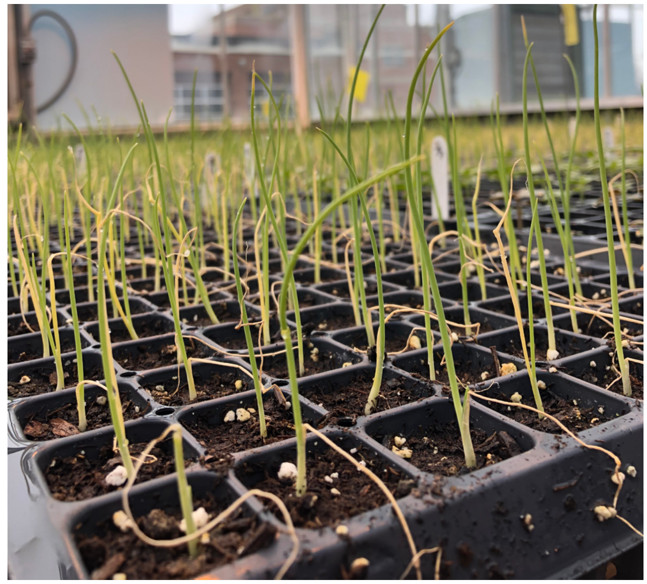

Figure 4. Onion transplants in the SDSU campus greenhouse on April 3, 2023. (Hannah Voye photo)

Table 1. Dates and rates of fertilizer application for onions grown in the SDSU campus greenhouse using Nature's Source Organic Plant Food 3-1-1.

Date	Rate (ppm)
24-Mar	100
31-Mar	150
7-Apr	150
11-Apr	150
19-Apr	100
21-Apr	100
23-Apr	100
25-Apr	100
29-Apr	100
30-Apr	100
1-May	100
2-May	200
3-May	200
4-May	200
8-May	200
10-May	300
24-May	300

To prepare field plots for onions, granular fertilizer was applied. Amendments and amounts used were based on pre-season soil tests and nutrient recommendations for onions from the 2023 Midwest Vegetable Production Guide. Multi-K GG Potassium Nitrate granular fertilizer was broadcast applied by hand within each onion bed area; four and a half pounds of potassium nitrate fertilizer was applied for every 2,400-square foot block. To loosen soil for transplanting and evenly distribute fertilizer, a BCS with power harrow attachment was run through all onion bed areas at a depth of three inches.

Onion planting beds and walkways were established within each treatment plot. Four rows of Patterson onions were spaced six by nine inches apart to fill 2.5 x 10-ft. beds. The same was done for Candy onions. Two rows of Barolo onions spaced six by nine inches apart into 1.25 x 10 ft. beds served as guard rows. Walkways between beds were 3.5 ft. wide, and a 3-ft.-wide walkway was left on the edges of the plots.

Once beds were fully prepped, drip irrigation was laid. Two lines of drip tape were laid for each four-row data cultivar and one line for each two-row guard row. Onions were transplanted by hand on May 31.

Onion Irrigation and Fertilization

Onions were irrigated in the field weekly on an as-needed basis with a rainfall equivalent target rate of one inch per week. Nature's Source 3-1-1 fertilizer was distributed through three fertigation applications midseason at a rate of 66.8 gallons per acre. There was a total rainfall of 5.6 inches June through August according to SDState Mesonet archives (South Dakota Mesonet, South Dakota State University 2024). Precipitation occurred on 26 days during these three months, the greatest amount occurring on August 5 at 1.33 inches.

Growing Season Data Collection and Cultivation

During the growing season, weed pressure was measured on a bi-weekly basis followed by hand weeding (Figure 5). Data were collected on June 12, July 5, July 18, August 1, and August 17. To collect weed data, two 25 by 25 centimeter square PCV quadrats were thrown randomly within the center eight feet of each cultivar row. Within each quadrat, weeds were separated by broadleaf and grass type. Three random heights were collected for each weed type. The number of each type of weed was counted and weeds were clipped at the soil level, bagged, dried for three days at approximately 140°F, and weighed to measure weed biomass.

Figure 5. Onion field weeding in SDSU Specialty Crop Field on July 7, 2023. (Hannah Voye photo)

Observations were noted on insect pressure and weed species throughout the growing season. There were not many insect pests found on the onions. Some thrip damage was noted, although not to an extreme extent. Throughout the growing season, weeds found in the plots were noted (Table 2). The most prevalent weeds were Venice mallow and redroot pigweed which are both warm season annuals.

Table 2. Perennial, biennial, and annual weeds noted in SDSU Specialty Crop Field, Brookings, SD research plots during 2023 growing season.

Annual weeds

Broadleaf

- Common lambsquarter, *Chenopodium album L.*
- Field cocklebur, *Xanthium strumarium*
- Ladysthumb, *Persicaria maculosa*
- Prostrate knotweed, *Polygonum aviculare L.*
- Prostrate pigweed, *Amaranthus blitoides*
- Purselane, *Portulaca oleracea*
- Redroot pigweed, *Amaranthus retroflexus L.*
- Venice mallow, *Hibiscus trionum L.*
- Waterhemp, *Amaranthus tuberculatus*
- Western salsify, *Tragopogon dubius*

Grass

- Barnyard grass, *Echinochloa crus-galli*
- Crabgrass, *Digitaria sanguinalis*
- Giant foxtail, *Setaria faberi*
- Green foxtail, *Setaria viridis*
- Wooly cupgrass, *Eriochloa villosa*
- Yellow foxtail, *Setaria pumila*

Biennial weeds

Broadleaf

- Bull thistle, *Arctium minus*
- Common burdock, *Cirsium vulgare*

Perennial weeds

Broadleaf

- Canada thistle, *Cirsium arvense*
- Common milkweed, *Asclepias syrianca*
- Dandelion, *Taraxacum offinale*
- Field bindweed, *Convolvulus arvensis*
- Hedge bindweed, *Calystegia sepium*
- Kochia, *Bassia scoparia L.*
- Perennial sowthistle, *Sonchus arvensis*

Grass

- Foxtail barley, *Hordeum jubatum*

Onion Harvest and Curing

Onions were harvested once 50 to 80% of all onion leaves for each cultivar collapsed in the field. Candy onions matured and showed collapsed leaves slightly earlier than Patterson onions. Patterson and Candy onions were harvested from the center six feet of each treatment plot. This resulted in 48 onions in each treatment cultivar 15 square foot bed. Onions were bagged with corresponding plot number tags and transported to the campus greenhouse for curing. The greenhouse was set to ambient humidity and 75 to 85°F. Onions were placed in one layer in onion sacks to cure in the greenhouse for about one month.

Onion Yield Data Collection

Once onions were finished curing, data was collected on quality and size (Figure 6). Onions were separated by marketable and cull. USDA size standards were used to develop a grading system (U.S. Department of Agriculture, 2014). A ruler with wood blocks was used to create a caliper for sizing onions. Marketable onions were weighed, counted, and separated into four size categories: packer (one and a half to two-inch diameter), medium (two to three-inch diameter), large (three to four-inch diameter), and colossal (diameter greater than four inches). Unmarketable onions were weighed, counted, and the following cull categories were noted: insect damage, disease and rot, less than one inch diameter, misshapen, and green leaf.

Figure 6. Onions curing in in SDSU campus greenhouse on August 28, 2023. (Hannah Voye photo)

Data Analysis

Analysis of variance (ANOVA) and means separation was conducted using PROC GLIMMIX procedure in SAS (Version 9.4; SAS Institute, Cary, NC) to determine the fixed effects of cultivar and tarp treatment on marketable and unmarketable onion count and weight as well as weed height, count, and weight. Interactions between tarp and cultivar response variables were also tested. Block and all interactions with block were random factors in analyses. Means were separated according to Fisher's protected least significant difference test ($P \leq 0.05$) using the "lsmeans" function.

Results

Weed Pressure at Time of Tarp Removal

At tarp removal there was a difference in weed growth among tarping treatments (Table 3). Broadleaf weight in all tarping treatments was less than broadleaf weight of the control treatment ($p \leq 0.0001$). The control and six-week clear tarp treatment plots had the highest grass weight averages, followed by two-week clear and four-week clear. All black and white tarp treatments showed very low grass weights when compared to the clear and control treatments ($p = 0.004$). The same trend showed up in broadleaf height ($p = 0.002$) and grass height ($p = 0.007$). Broadleaf counts were highest in the control treatment followed by the clear tarp treatments ($p \leq 0.0001$). Grass counts were highest in the two-week clear treatment, closely followed by the six-week clear and the control treatment ($p = 0.002$).

Weed Pressure During the Growing Season

For weed data collected during the growing season, there were not many differences in weed pressure among tarp treatments. A few differences were seen in data collected through August 1. The first growing season data collection event on June 12 (Figure 7) showed that there was a difference in broadleaf count per acre between tarp treatments ($p = 0.03$). The 6-week clear had an average broadleaf count of weeds per acre that was 67% less than the control and 74% less than the 4-week black tarp (see Figure 7). On the August 1 data collection event, there was a difference in broadleaf height among tarp treatments ($p = 0.04$). Weed height was similar among the control and all tarp treatments, except for the 4-week white tarp treatment, which had shorter weeds (Figure 8).

Table 3. Broadleaf and grass weight (lb/acre), count (per square foot), and average height (in.) for treatment plots at tarp removal on May 30, 2023 before onion planting.

Tarp	Week	Broadleaf weeds			Grass weeds		
		wt. (lb/acre)	no. of weeds/ square foot	height (in.)	wt. (lb/acre)	no. of weeds/ square foot	height (in.)
None	None	559.6 a	103 a	2.0 ab	280.8 a	49 a	4.7 a
Clear	2	77.1 b	76 b	1.1 bc	242.7 ab	58 a	1.6 c
Clear	4	44.3 b	40 c	1.0 cd	53.5 bc	28 ab	1.5 cd
Clear	6	117.8 b	35 c	2.3 a	283.1 a	52 a	3.2 b
White	2	0.0 b	0 d	0.0 d	0.0 c	0 b	0.0 e
White	4	65.3 b	1 d	0.8 cd	0.0 c	0 b	0.0 e
White	6	65.7 b	1 d	0.9 cd	1.2 c	3 b	0.4 de
Black	2	71.4 b	1 d	0.7 cd	0.0 c	0 b	0.0 e
Black	4	25.0 b	1 d	0.3 cd	0.0 c	0 b	0.0 e
Black	6	2.1 b	1 d	0.2 cd	0.0 c	0 b	0.0 e
P-value	--	<0.0001	<0.0001	0.0007	0.0042	0.0019	<0.0001

The ten different treatment plots were as follows: a control plot with no tarp applied, three black color tarped plots with tarps applied 6, 4, and 2 weeks before removal, three white color tarped plots with tarps placed for 6, 4, and 2 weeks before tarp removal, and three seperate clear tarped plots with tarps placed for 6, 4, and 2 weeks before tarp removal. White and black tarps were secured using sandbags. Clear tarps were secured with sandbags and burrying the edges.

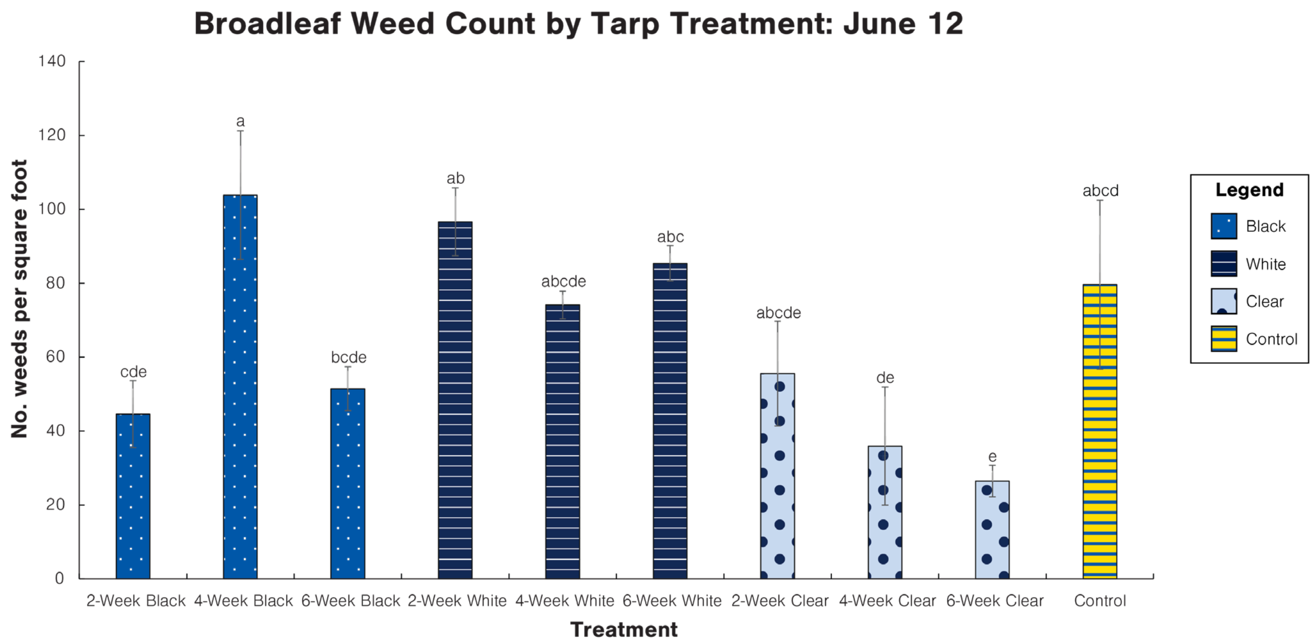

Figure 7. Differences in broadleaf weed count per square foot among tarp treatments. Weed counts were collected within onion rows using two 25-by-25-centimeter quadrats. Data was collected on June 12, approximately two weeks after tarp removal and onion planting.

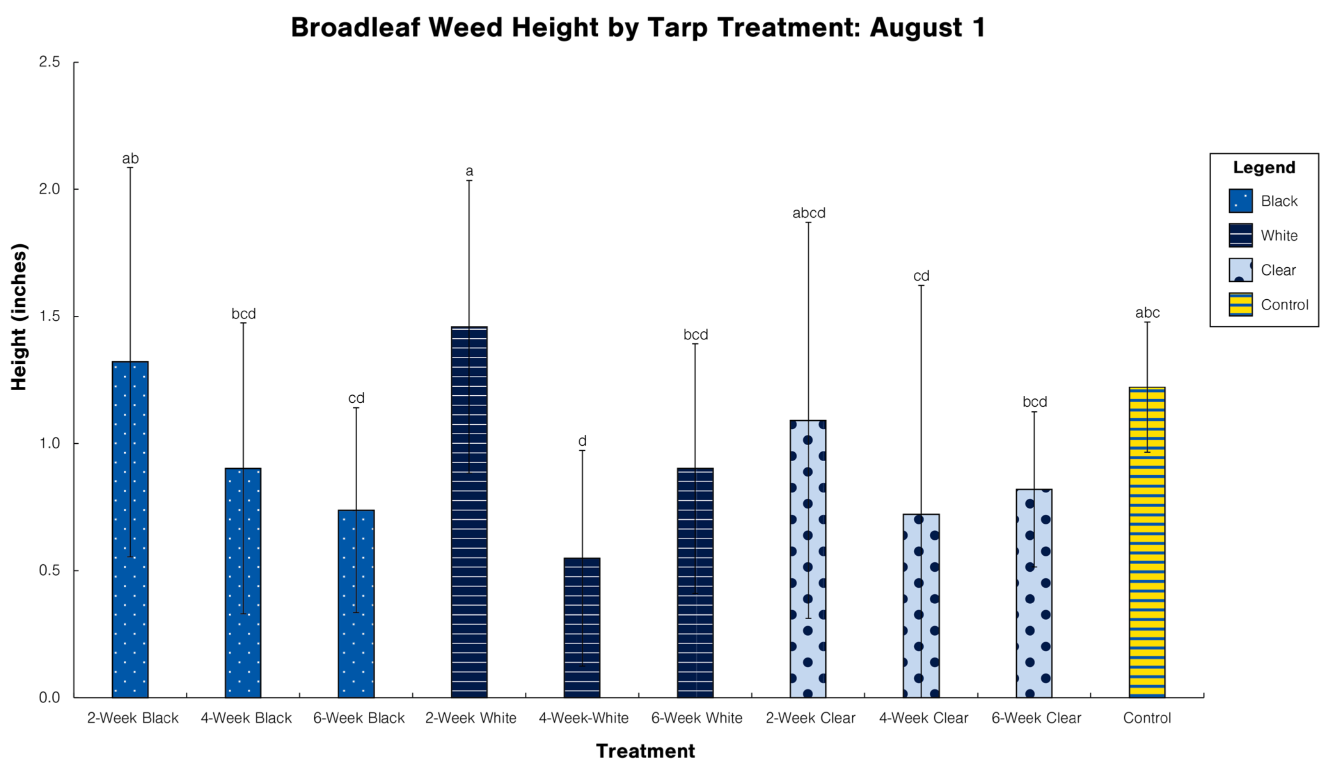

Figure 8. Differences in broadleaf weed height (inches) among tarp treatments. Data were collected by measuring the average of three random heights within two 25-by-25-centimeter quadrats within onion rows in each treatment plot. Weed height was measured on August 1, 2023, which was approximately eight weeks after tarp removal and onion planting.

Onion Yield

Patterson outyielded Candy by a large margin (Table 4). In a bed of 48 onion transplants, Patterson averaged 36 marketable and 10 unmarketable onions; Candy averaged 19 marketable and 28 unmarketable ($p = 0.02$). Most onions were marked as cull due to size being too small (less than one inch). For each 15 square foot onion bed, there was an average marketable yield weight of 13.7 pounds for Patterson and 6.2 pounds for Candy ($p = 0.02$). There was no significant difference between cultivars for cull weight. Tarping treatments had no effect on yield (data not shown).

Table 4. Patterson and Candy marketable and cull onion yield by weight (lbs) and number of onions per 48 onions planted in each 15 square foot cultivar bed.

Cultivar	Marketable		Cull	
	wt. (lb)	no. of onions	wt. (lb)	no. of onions
Patterson	13.7 a	36 a	3.2 a	10 b
Candy	6.2 b	19 b	9.1 a	28 a
P-value	0.02	0.02	0.05	0.02

Discussion

The results from year one support the idea that soil tarping can reduce weed pressure as compared to no management. However, there was no data that showed an increase in onion yield with the use of soil tarping. This could be due to the fact that all treatment plots were cultivated bi-weekly throughout the growing season, so there was less impact of weed pressure on onion yield. More differences with onion yield may have been seen between tarp treatments if no other weed management (e.g. bi-weekly cultivation) was used.

There was an obvious difference in weed pressure between treatments at tarp removal. The clear treatments showed high weed pressure, but less than the control. This could be due to clear treatments germinating high amounts of weed seedlings and then many of the seedlings dying due to high temperatures beneath the tarp. Only living weeds were counted at tarp removal, so it may be useful to count dead weeds as well as living weeds for next year's data collection. This would provide a clearer idea of how many weed seeds germinated beneath the clear tarp, whether they died or not. Both the white and black tarps had minimal to no weeds present at removal of the tarp, which supports the idea of the lack of light reducing germination.

The first growing season data collection event on June 12 showed the six-week clear tarp to have a much lower broadleaf count (67% less) than the treatment with no tarp applied. This could support the idea that solarizing the plot for 6 weeks reduced the weed seed bank of broadleaf weeds, so fewer seedlings came up in this treatment as the season progressed. Data collected on August 5 showed a difference in average height between the four-week and two-week white tarps. More research is needed to understand why white tarps at different timings could result in different average weed heights.

While there was no difference in onion yield due to tarp treatment, there was a difference in yield between Candy and Patterson cultivars. While Candy onions matured earlier than Patterson, they were still harvested at the same time and cured for the same amount of time. Patterson onions are good storage onions that last much longer than Candy due to their strong papery outside layers and thin necks. Candy onions do not last as long in storage. They are sweeter onions with a weaker paper coating, so they are more attractive to insects. If Candy was harvested earlier and left in curing conditions for less time, there may have been less yield counted as cull. Adjustments will be made for year two to handle each cultivar separately according to their needs.

Conclusion

From the first year of data, there is evidence that tarping can reduce weed pressure early in the season before planting. However, other weed management practices must be used along with tarping to maintain a viable yield of onions.

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