Early Season Soil Solarization and Occultation Impacts on Weed Pressure and Onion Yield in Eastern South Dakota: Year 2 (2024) Results

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Introduction

Tarping is a weed management practice used by farmers across the United States and around the world. 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 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 also 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 during the 2024 growing season, year two of the study of the effects of soil tarping on weed pressure and onion yield. Field location soil type was Barnes silty clay loam (Soil Survey, Natural Resources Conservation Service, United States Department of Agriculture 2024). Soil tests taken six inches deep at the beginning of the season contained between 2% to 4% of soil organic matter.

Three types of tarps were evaluated: black silage tarps, white silage tarps, and clear greenhouse plastic along with a control (bare ground) treatment plot. 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 24-feet by 100-feet blocks with ten 24-feet by 10-feet treatment plots within each block.

Soil Tarping

Opaque silage tarps with one side black and one side white were used for occultation treatments. Clear greenhouse plastic (UV resistant six mil, Farm Plastic Supply, Addison, IL) was used for solarization treatments. All tarps were purchased from Farm Plastic Supply and cut into 24-feet by 10-feet rectangles. These tarps were used in the tarping study for the 2023 field season, washed, and reused in 2024. Tarps were laid on soil to cover treatment plots on April 5, April 19, and May 2. Each tarp type covered the soil for durations of roughly six, four, and two weeks prior to tarp removal on May 14. Black side up and white side up tarps were secured with twenty-five to thirty 15-pound sandbags. Clear tarps were secured with sandbags as well as burying the edges.

Weed count, height, biomass, and type of weed were collected at tarp removal. This was done by randomly throwing three 50-centimeter by 50-centimeter PVC quadrats into each treatment plot. Weeds within each 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.

After data collection, clear tarp and control treatment plots were tilled using a 655 iMatch AutoHitch rotary tiller to clear out germinated weeds before planting. These treatments were tilled lightly at a two-and-a-half-inch depth to avoid bringing 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 minimal weeds in these treatment plots.

Planting Onions

Onion *(Allium cepa)* cultivars Barolo, Patterson, and Candy were seeded in 128-cell trays in the South Dakota State University campus greenhouse on February 29. Greenhouse temperatures were set 68°F to 74°F for daytime and 64°F to 70°F for nighttime, and 400-watt high pressure sodium lights were used from 7:00 a.m. to 6:00 p.m. each day. Onions were watered on an as needed basis. Onion seeds began germinating March 6. Once onions reached about two inches in height, they were fertigated with Nature's Source Organic Plant Food 3-1-1 on an at-need basis. On May 9, onions were placed outdoors in a holding area to acclimate before planting into treatment plots.

To prepare field plots for onions, three pounds of Multi-K GG KNO_3 granular fertilizer was hand-broadcast within each 250-square foot onion bed, based on pre-season soil tests and nutrient recommendations for onions from the 2024 Midwest Vegetable Production Guide. To loosen soil for transplanting and evenly distribute fertilizer, a BCS 749 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 6-inches by 9-inches apart to fill 2.5-feet by 10-feet beds. The same was done for Candy onions. Two rows of Barolo onions spaced 6-inches by 9-inches were each 1.25-feet wide, and a 3-feet-wide walkway was left on the edges of the plots. Two lines of drip tape were laid for each four-row test cultivar and one line for each two-row guard row. Onions were transplanted by hand on May 16.

Onion Irrigation and Fertilization

Onions were irrigated weekly as needed, with a rainfall equivalent target rate of one inch per week. Nature's Source 10-4-3 fertilizer was distributed through two fertigation applications midseason at a rate of 102 gallons per acre. There was a total rainfall of 12.7 inches June through August (South Dakota Mesonet, South Dakota State University 2024). Precipitation occurred on 31 days during these three months, with the greatest amount occurring on July 31 at 4.13 inches.

Growing Season Data Collection and Cultivation

During the growing season, weed growth was measured bi-weekly (June 3, June 19, July 1, July 18, July 31, and August 8), followed by a mix of stirrup hoe and hand weeding. Two 25-centimeter by 25-centimeter square PVC 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. After each data collection event, cultivation of the center eight feet of each bed was timed.

Observations were noted on insect pressure and weed species throughout the growing season. Insects observed in plots included ladybugs, bees, lacewings, and thrips. Thrip damage was noted on onion leaves July 18. By July 25 thrip pressure had become very high (Figure 1). Overhead irrigation was used to discourage thrip activity. This management strategy was minimally effective as the overhead irrigation was light and brief. A violent and heavy rain event on the evening of July 31, however, greatly reduced thrip pressure.

Onion guard rows and data rows were sprayed with Sevin to prevent thrip populations from increasing again. Six ounces of Sevin were mixed with 1.5 gallons water in a backpack sprayer to cover the entire 3000 square foot area of onion beds. Throughout the growing season, weeds found in the plots were noted (Table 1). The most prevalent weeds were Canada thistle which is a cool season perennial, as well as crabgrass and Venice mallow which are both warm season annuals.

Figure 1. Onion Thrip Pressure in SDSU Specialty Crop Field on July 25, 2024. Photo courtesy: Hannah Voye.

Table 1. Perennial, biennial, and annual weeds noted in SDSU Specialty Crop Field, Brookings, SD research plots during the 2024 growing season. Thistle, crabgrass, and venice mallow were most frequently noted.

Perennial weeds

Broadleaf

- Broadleaf plantain, *Plantago major*
- Canada thistle, *Cirsium arvense*
- Common milkweed, *Asclepias syrianca*
- Common yellow wood sorrel, *Oxalis stricta*
- Curly dock, *Rumex crispus*
- Dandelion, *Taraxacum offinale*
- Field bindweed, *Convolvulus arvensis*
- Hedge bindweed, *Calystegia sepium*
- Perennial sowthistle, *Sonchus arvensis*

Grass

- Foxtail barley, *Hordeum jubatum*
- Quackgrass, *Elymus repens*

Annual weeds

Broadleaf

- Common lambsquarter, *Chenopodium album L.*
- Field pennycress, *Thlaspi arvense*
- Ladysthumb, *Persicaria maculosa*
- Prostrate knotweed, *Polygonum aviculare L.*
- Purselane, *Portulaca oleracea*
- Redroot pigweed, *Amaranthus retroflexus L.*
- Shepherd's Purse, *Capsella bursa-pastoris*
- Venice mallow, *Hibiscus trionum L.*
- Waterhemp, *Amaranthus tuberculatus*

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*

Onion Harvest and Curing

Onions were harvested on August 27, 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 per cultivar in each 15 square foot treatment bed. Onions were bagged with corresponding plot number tags and transported to a high tunnel for curing. Many Candy onions had minimal healthy foliage at harvest due to thrip damage from earlier in the season, and some had completely rotted leaves from disease thriving on thrip-wounded leaves. Diseased onions were separated from healthy onions at harvest. The high tunnel sides were left open to allow for natural air flow through the tunnel and closed when high winds or rain were anticipated. Onions were hung in netted onion bags from high tunnel trusses using tomato twine and left to cure for about one month (Figure 2). Watch Dog humidity and temperature sensors placed in the high tunnel recorded a max temperature of 104°F and max RH of 99%. The minimum temperature reached was 30°F and minimum RH was 21%. The average temperature over the month the onions were in the tunnel was 66°F, while RH was 64%.

Figure 2. Onions curing in in SDSU Specialty Crop Field High Tunnel in September 2024. Photo courtesy: Hannah Voye.

Onion Yield Data Collection

Once onions were finished curing, yield data was collected October 2 through 7. Onions were separated into marketable and culled categories. 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 (1.5-inch to 2-inch diameter), medium (2-inch to 3-inch diameter), large (3-inch to 4-inch diameter), and colossal (diameter greater than 4 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.

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, weight, and cultivation time. 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 were visible differences among treatments (Figures 3, 4, 5, and 6). There was a difference in weed counts but not biomass among tarping treatments. The 4-week clear treatment had the highest broadleaf weed count at an average of 11 weeds per square foot and was different from the 4-week black tarp which averaged one weed per square foot ($p=0.030$). No tarp treatments were different from the control for broadleaf weed counts (Table 2). The 4-week clear treatment had the highest pressure for grass weeds, at an average of 63 weeds per square foot, significantly more than the control treatment which had only 22 grass weeds per square foot ($p=0.001$). The 6-week black tarps averaged zero weeds.

Figure 3. Control plot with no tarp in SDSU Specialty Crop Field on May 14, 2024. Photo courtesy: Hannah Voye.

Figure 4. 6-week white tarp plot in SDSU Specialty Crop Field on May 14, 2024. Photo courtesy: Hannah Voye.

Figure 5. 6-week black tarp plot in SDSU Specialty Crop Field on May 14, 2024. Photo courtesy: Hannah Voye.

Figure 6. 6-week clear tarped plot in SDSU Specialty Crop Field on May 14, 2024. Photo courtesy: Hannah Voye.

Table 2. Broadleaf and grass weight, count, and height for treatment plots at tarp removal on May 14, 2024. The ten treatment plots were: a control plot with no tarp applied, black tarp plots with tarps applied 6, 4, or 2 weeks before removal, white tarp plots with tarps placed for 6, 4, or 2 weeks before tarp removal, and clear plastic tarped plots with tarps placed for 6, 4, or 2 weeks before tarp removal. White and black tarps were secured using sandbags. Clear tarps were secured with sandbags and burying the edges. Within each column, means followed by the same letter are not significantly different. ANOVA and means seperation was conducted using PROC GLIMMIX procedure in SAS. Means were seperated according to Fisher’s protected least significant difference test ($P \leq 0.05$) using the “lsmeans” function.

Tarp	Week	Broadleaf weeds			Grass weeds		
		wt. (lb/acre)	no. of weeds/ square foot	height (inches)	wt. (lb/acre)	no. of weeds/ square foot	height (inches)
None	None	429.71	4 abc	3.60	1344.04	22 bc	8.55 a
Clear	2	267.68	10 a	1.75	230.51	43 ab	5.01 bcd
Clear	4	254.24	11 a	3.01	771.63	63 a	6.26 abc
Clear	6	162.12	8 a	2.33	718.11	49 ab	7.47 ab
White	2	142.76	4 acb	3.76	692.86	28 bc	4.39 cde
White	4	44.60	2 bc	2.68	133.81	5 c	2.55 def
White	6	62.44	1 bc	4.59	28.34	2 c	2.42 def
Black	2	139.76	1 bc	2.55	200.74	5 c	5.09 bcd
Black	4	29.82	1 c	2.22	63.93	3 c	1.89 ef
Black	6	28.28	1 bc	1.37	4.46	0 c	0.14 f
P-value		0.0567	0.0298	0.4125	0.0524	0.0014	<0.0001

Weed Pressure During the Growing Season

Differences were seen during the growing season for grass weed pressure among tarp treatments. On June 3, all clear treatments showed a lower average grass count than the control treatment (p=0.005). The control averaged 73 grass weeds per square foot while the 2-week clear averaged 28 weeds per square foot (Figure 7). Roughly two weeks later, on June 19, all clear treatments still showed lower grass counts than the control (p=0.003). Clear 2-week averaged only 9 weeds per square foot while the control averaged 29 weeds per square foot. On July 1, all clear treatments had lower grass counts than the control (p=0.011). The control averaged 35 grass weeds per square foot while 2-week clear averaged 13 grass weeds per square foot. The 2-week clear and 6-week clear treatments showed lower grass weights than the control on this date as well (p=0.018). Clear 6-week averaged 98 pounds of grass biomass per acre while the control averaged 240 pounds per acre (Figure 8). Differences were seen for amount of time used to weed each treatment plot on June 3, however, no differences were seen for any remaining data collection events. On June 3, the 6-week and 2-week white plots took longer to weed than the 6-week clear, but not the control (p=0.018). It took an average of 27 minutes for one person to cultivate the 6-week white, 22 minutes to cultivate the control, and 20 minutes to cultivate the 6-week clear (Table 3).

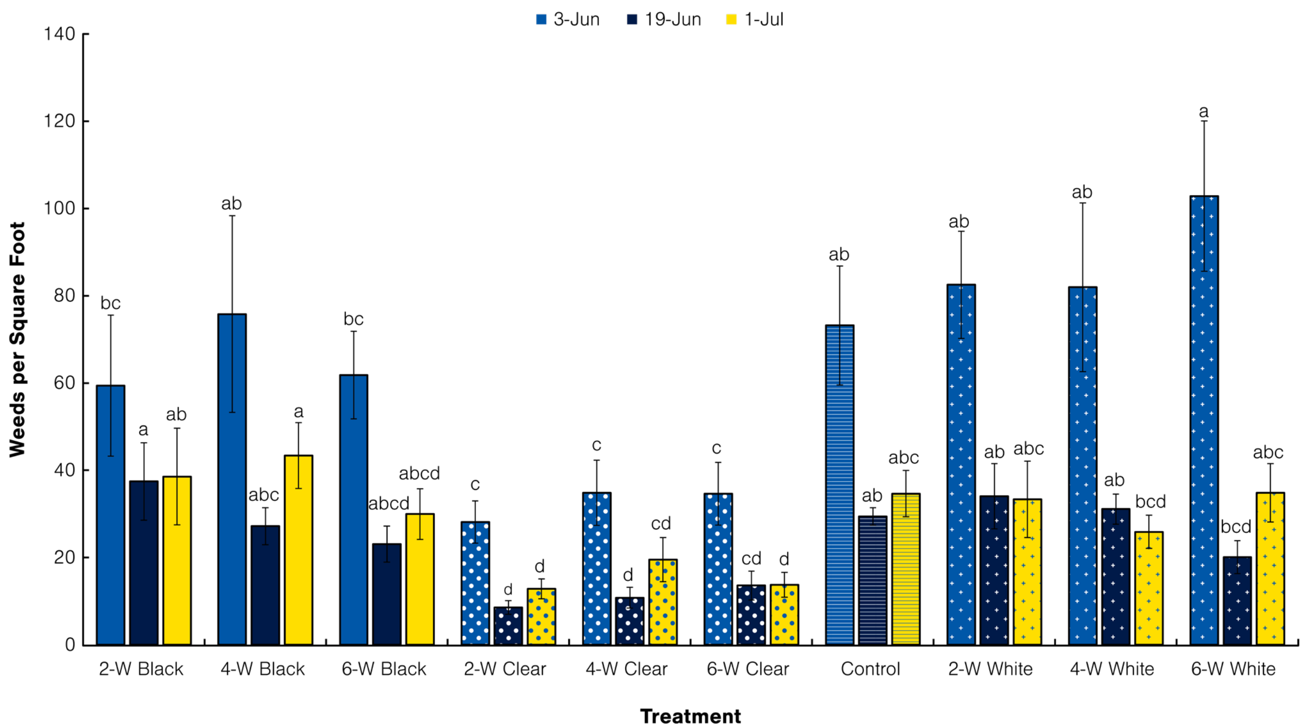

Figure 7. Differences in grass weed count per hectare among tarp treatments. Weed counts collected within onion rows using two 25 by 25-centimeter quadrats. Data were collected on June 3, June 19, and July 1.

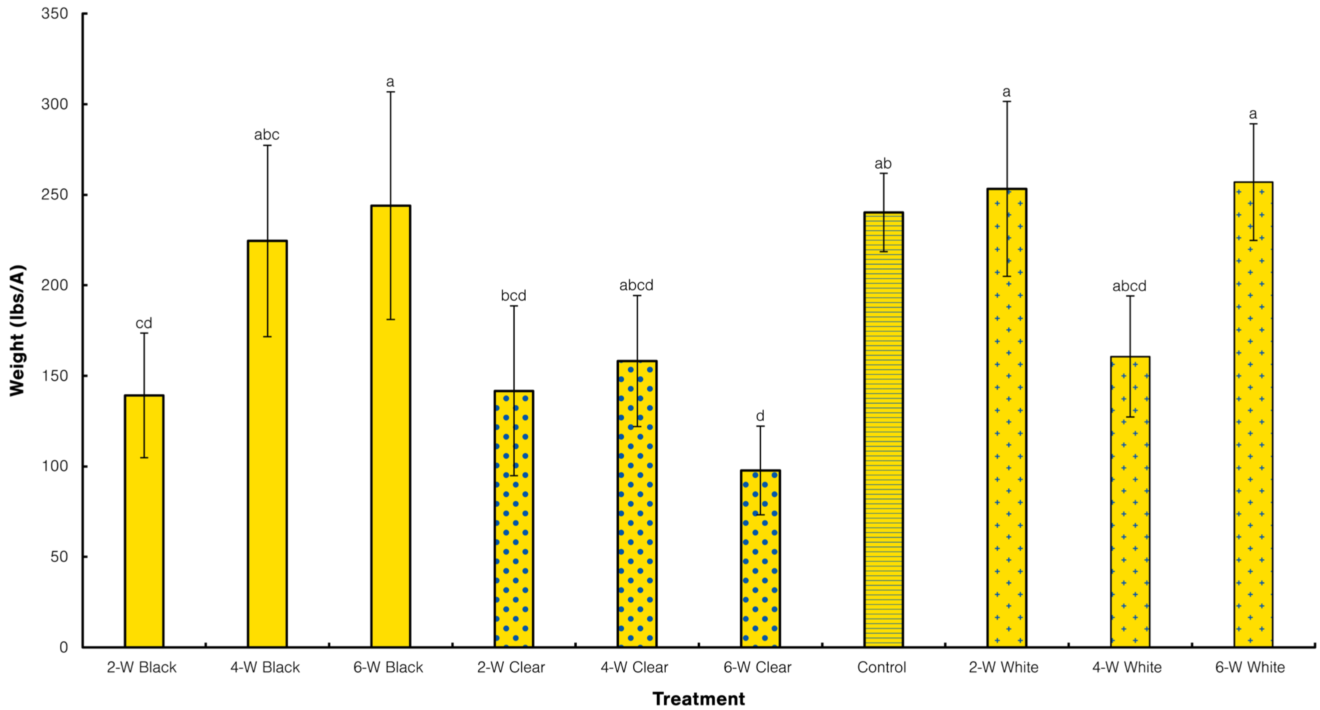

Figure 8. Differences in grass weed dry biomass weight among tarp treatments. Data were collected within onion rows using two 25 by 25-centimeter quadrats on July 1.

Table 3. Average amount of time in minutes for one person to weed each 8 feet by 2.5 feet onion bed treatment using a mixture of stir up hoes and hand weeding. This data was collected on June 3, 2024. No differences were seen in cultivation time for any of the data collection events after June 3.

Tarp treatment	Minutes/1 person
6-W Clear	20 b
4-W Black	21 b
2-W Black	21 b
2-W Clear	21 b
6-W Black	22 b
Control	22 b
4-W Clear	22 b
4-W White	23 b
2-W White	27 a
6-W White	27 a
P-value	0.0187

Onion Yield

Tarping treatments had no impact on onion yield, however, there was a difference in yield due to cultivar. Patterson outyielded Candy by marketable count, but not marketable weight (Table 4). In a bed of 48 onion transplants, Patterson averaged 35 marketable while Candy averaged 31 marketable ($p = 0.016$). There was no difference in cull count or weight for onion cultivars. Most onions were marked as cull due to disease or rot. There was no significant difference between cultivars for cull weight. Patterson yielded higher count ($p=0.008$) and weight ($p=0.008$) for medium onions while Candy yielded higher large count ($p=0.010$) and weight ($p=0.010$) and higher colossal count ($p=0.043$) and weight ($p=0.044$). There was no difference between cultivars for any cull categories aside from green leaf ($p=0.022$). There was an average of 1.08 Candy onions with green leaves after curing while Patterson had an average of 0.18.

Table 4. October 2024 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.

Total Marketable and Cull Count and Weights

Cultivar	Marketable		Cull	
	Count	Weight (lb)	Count	Weight (lb)
Candy	31 b	14.4	16	7.1
Patterson	35 a	10.7	11	3.7
P-value	**0.0159**	0.0861	0.0941	0.0811

Marketable Size Counts

Cultivar	Small	Medium	Large	Colossal
Candy	2	13 a	15 a	0.5 a
Patterson	3	30 b	2 b	0 b
P-value	0.0794	**0.0076**	**0.0101**	**0.0426**

Marketable Size Weights (lb)

Cultivar	Small	Medium	Large	Colossal
Candy	0.2	4.6 b	9.1 a	0.5 a
Patterson	0.4	9.3 a	1.0 b	0.0 b
P-value	0.0903	**0.0082**	**0.0103**	**0.0441**

Discussion

Consistent with year one, the results from year two support the idea that soil tarping can reduce weed pressure as compared to no management. There was no data that showed an increase in onion yield with the use of soil tarping for 2023 or 2024 growing seasons. This could be because in both years all treatment plots were cultivated bi-weekly throughout the growing season, so there was less impact of weed pressure on onion yield. Cultivation timing data only showed differences between treatments up to two weeks after tarp removal. More differences with onion yield may have been seen between tarp treatments if no 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 higher weed counts, but lower weights than the control. This supports the idea that clear treatments germinated more, but smaller weed seedlings before tarp removal. In the 2023 season, minimal weed pressure was noted in both white and black tarps at removal of the tarp. For the 2024 season, however, the treatment area contained high amounts of perennial Canada thistle, which was not as easily prevented using occultation. Roughly six weeks into the growing season, the clear tarp treatments still showed less grass weed counts for biweekly weed data collection. This is different from 2023 results, when differences were seen in broadleaf counts instead of grass counts during the growing season.

While there was no difference in onion yield due to tarp treatment, there was a difference in yield between Candy and Patterson cultivars. Candy produced a higher amount of large and colossal onions. The thick, papery skin surrounding the Patterson onion bulb may have played a role in protecting the Patterson onions from disease damage, allowing it to produce a higher amount of marketable onions than the minimally skinned Candy onions. Despite high thrip damage to onion leaves, onion bulbs had minimal insect damage. The main reason for unmarketable onions for 2024 was disease and rot. This may have been due to the high amounts of rain received as well as extreme temperature and moisture fluctuations during high tunnel curing.

Conclusion

From year two of data, there is evidence that tarping can reduce weed pressure. While fewer weeds were noted in occultation treatments at tarp removal, perennial weeds like Canada thistle and dandelions survived early spring occultation. Solarized treatments showed reduced weed pressure into the growing season, however, other weed management practices still needed to be used along with tarping to maintain a viable yield of onions.

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