Broccolini Performance in Three Established Clover Living Mulches in Eastern South Dakota: Year Two Results

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Introduction

Many vegetable production systems rely on tillage to manage weeds that threaten cash crop yields. This heavy reliance on tillage is detrimental to the health of the soil and increases the likelihood of soil erosion from wind and rain. To reduce in-row weed pressure, farmers often use a single-use plastic mulch that is thrown away after one season. The use of a perennial living mulch can help reduce the tillage requirements by tolerating mowing because of their low growing point and dense canopy which competes with weeds. The use of a clover living mulch has the added benefit of fixing atmospheric nitrogen and preventing wind and water erosion. However, the use of a living mulch can cause a reduction in yield since the clover can compete with the cash crop for light, water, and nutrients (Bruce, 2022). Reuseable woven fabric is an alternative to single-use plastic mulch and has advantages in reducing the plastic waste produced each year. Brassica is an important family in vegetable production systems, but recent heat waves have caused crops like broccoli to bolt and become unmarketable. A new crop called broccolini could replace broccoli demand and hold up to the heat.

Broccolini

Broccolini *(Brassica oleracea)* may be able to fill the demand for broccoli and allow farmers to diversify their cash crops. Broccolini is a lesser-known vegetable crop that has gained popularity in recent years. Broccolini is a cross between European broccoli, which is what most people in the United States think of as broccoli, and Chinese broccoli, also known as gai lan or Chinese kale. Broccolini goes by names such as mini broccoli, sprouting broccoli, aspabroc, baby broccoli, and tender stem broccoli. Many of these names give insight into why broccolini has become popular. Broccolini has a long tender stem that does not need to be trimmed and has a mild and sweet flavor in comparison to broccoli, which makes it ideal for cooking and reduces preparation work (Miles, 2024). An advantage of broccolini is its ability to continuously produce side shoots that can be harvested throughout the season. Unlike European broccoli, broccolini is grown for its' side shoots rather than the apical floret. This allows producers to grow the plants for longer periods of time and have more opportunities to profit and harvest in contrast to one harvest in the case of European broccoli.

Research Objective

Field research was conducted over the months of July to October of 2024 at the Specialty Crop Research Field in Brookings, South Dakota. The objective of this study was to determine the impact of three established clover species, used as living mulch, on weed suppression, crop growth, and broccolini yield.

Material and methods

Research Treatments and Plot Design

The clover cultivars used for living mulch were 'Domino' white clover (WC) (Trifolium repens), 'Aberlasting' white x kura clover (KC) (T. repens x ambiguum), and 'Dynamite' red clover (RC) (Trifolium pratense). The

fourth treatment was a bare ground (BG) control. Clover cultivars were established in 2023 (Barnes, 2023). The clover living mulch whole plot was replicated in four blocks. Within each clover plot, there were four randomized soil management treatments: tilled (T), no-tilled (NT), tilled with fabric (TF), no-tilled with fabric (NTF). These four management options were chosen to determine how soil health and broccolini performance is affected by in-row management strategies.

Broccolini Cultivar Description

Three cultivars were included in the study. 'Melody' has large, rounded leaves with a small green floret and side shoots that closely resembles Chinese broccoli. 'BC1611' has long wavy leaves with a green floret that resembles small European broccoli heads and long slender side shoots. 'Burgundy' has long wavy leaves with large dark purple apical floret head and long slender side shoots (Figure 1).

Figure 1. Broccolini plants before harvesting. 'Melody' (left), 'BC1611' (center), 'Burgundy' (right).

Clover Management and Soil Preparation Prior to Planting

Clover plots were mowed on May 6, May 29, July 1, July 26, and September 13. T and TF subplots were tilled with two passes with a BCS 749 walk-behind tiller (30 inches wide) to a depth of 3 inches at the beginning of the season before the fabric was installed in the plots. Stirrup hoes (Johnny's Selected Seeds) were used in T and TF subplots throughout the season to control weeds with dates corresponding with mowing events. NT and NTF were hand weeded to remove all plants other than clover and cash crops on dates corresponding with mowing events. The black woven fabric was 3 feet by 12 feet with holes that had been burned prior to installation with a butane can torch (Barnes, 2023).

Broccolini Planting

Broccolini was seeded in 50-cell trays on June 17 in a greenhouse at the SDSU campus and placed on heating pads to aid in germination. Once germinated, heating pads were removed and broccolini was fertigated at 250 parts per million (ppm) 10-4-3 Nature's Source liquid fertilizer weekly. Broccolini transplants were moved to an outdoor, shaded holding area on July 15 to harden off before being planted.

Broccolini was transplanted into the field on July 24 and 25. Each clover x soil management x broccolini cultivar sub-sub plot included five plants that were planted in 18-inch staggered double rows with 12-inch in-row spacing. Drip tape irrigation was installed prior to planting and used throughout the season for watering and fertigation. The drip tape had an emitter spacing of 8 inches and a flow rate of 0.20 gallons per hour at 8 PSI. Two lines of drip tap ran the entire length of the four subplots and were spaced approximately 16 inches apart on each bed.

Once planted, broccolini was watered using a garden hose with breaker nozzle to settle the soil while drip irrigation was also run for approximately two hours. All broccolini rows were covered with ProtekNet pulled over five feet tall nine-gauge galvanized wire secured with sandbag to prevent damage from deer and insects. Broccolini was fertilized using Nature's Source 10-4-3 at 250 ppm through a Dosatron fertilizer injector on July 27, August 12, and September 17.

Clover Growth and Weed Suppression Assessment and Management

Clover biomass was assessed seven times in the whole plot (pathways between cash crops) and five times within the cash crop rows (soil management

treatments. A 25 by 25 cm square PVC quadrat was randomly tossed three times in the whole plot and two times in the in-row management subplots to determine plant height and biomass of clover and weeds. If clover plants were found in the T and TF managements, it would be considered a weed since no plants other than cash crops should be growing after tillage events. Three random clover plants and weeds were measured from the base to the leaf tip to determine plant height. Weeds and clover plants were then cut as close to the ground as possible and placed in separate labeled paper bags. The paper bags were then put in a dryer for at least 48 hours at 140 degrees Fahrenheit (60 degrees Celsius) before determining biomass dry weight to the nearest 0.1g. After biomass collection in the field, subplots are weeded by hand in the NT and NTF plots and mechanical with stirrup hoes in T and TF plots. The whole plot clover pathways were mowed at four inches after every biomass collection and weed whipped as needed.

Broccolini Harvest and Data Collection

Broccolini was harvested eight times: August 29, September 3, September 10, September 17, September 23, September 30, October 7, and October 15. Apical shoots were cut with harvest knives 2-3 nodes below the floret bunch and lateral shoots were cut at the leaf axis or above woody plant shoots. Because of the lack of United States Department of Agriculture (USDA) standards for marketability of broccolini, standards for European broccoli heads were modified and used (USDA Broccoli for Processing Grades and Standards). A marketable floret, equivalent to a U.S. 1, does not have any sepals that have begun to split or open to reveal the petals within and can have a puffy appearance (Figure 2). Having a puffy appearance is considered nonmarketable according to USDA standards for European broccoli. An open floret is a floret with one or more buds that have opened to reveal the petal or completely blossomed, but the internodes of the floret have not begun to elongate (Figure 3). An open floret is equivalent to U.S. 2 since it is still edible. A non-marketable floret is any floret bolted (Figure 4) (which is defined as open flower buds with elongated internodes and wood stem texture) has biological damage from insects or animals, frost damage, or disease damage.

Figure 2. Three marketable shoots of ‘Melody’ broccolini. Photo Courtesy of: Connor Ruen

Figure 3. Three open floret shoots of ‘Melody’ broccolini. Photo Courtesy of: Connor Ruen

Figure 4. Three bolted shoots of ‘Melody’ broccolini. Photo Courtesy of: Connor Ruen

Results

Whole Plot Clover and Weed Biomass

The total clover biomass accumulated over the 2024 growing season showed that WC treatment had the greatest amount of biomass produced at 13347 Kg per ha but was not different from KC and RC treatment (Table 1). The weed biomass accumulated total was reduced by KC, RC, and WC treatments when compared to the BG treatment. Average clover height of RC was significantly taller than KC and WC. RC, on average, was 7 cm taller than WC and 9 cm taller than KC. The average weed height was not significant, but the trend showed that RC living mulch had the tallest weeds at 9 cm on average followed by BG treatment with 7 cm on average.

Table 1. Clover and weed whole plot height and biomass accumulation collected from alleyways between broccolini rows during the 2024 growing season at the specialty Crop Research Field, Brookings, SD. BG= Bare ground, KC= Kura Clover, WC= White Clover, RC= Red Clover. Values followed by the same letter within a column are not different from each other based on Fisher's protected least significant difference test (α = 0.05).

Clover Treatment	Plant Biomass (Kg/ha)		Plant Height (cm)	
	Clover	Weed	Clover	Weed
BG	0 A	1650 A	0 D	7
KC	12801 B	215 B	19 C	4
RC	11596 B	865 B	28 A	9
WC	13347 B	305 B	21 B	5
p-values	<0.0001	0.0043	<0.0001	0.0602

In-Row Plot Clover and Weed Biomass

In-row clover biomass was only measured in NT and NTF treatments. NT in-row management increased the plant height of KC, RC, and WC (Table 2). Weed height was reduced in NTF and TF sub-plots in the BG treatment. There were no differences in weed height based on in-row management of the KC Treatment. There were differences in in-row biomass within KC, RC, and WC treatments with NT management accumulating a greater amount of clover biomass over the season. There was no difference in weed biomass accumulated over the season from in-row treatments in BG. KC and WC treatments had a greater amount of weed biomass accumulated over the season in the T and TF managements. RC treatment had a greater amount of weed biomass accumulated over the season in NTF, T and TF treatments.

Table 2. Clover and weed in-row plot height and biomass accumulation collected from alleyways between broccolini rows during the 2024 growing season at the specialty Crop Research Field, Brookings, SD. TF= Tilled Fabric, T= Tilled no Fabric, NTF= No-till Fabric, NT= No-till No Fabric. Values followed by the same letter within a column and cover crop treatment are not different from each other based on Fisher's protected least significant difference test (α = 0.05).

Clover Treatment	Plant Height (cm)		Plant Biomass (Kg/ha)	
	Clover	Weed	Clover	Weed
BG				
NT	0	12 A	0	788
NTF	0	7 B	0	433
T	0	11 A	0	713
TF	0	8 B	0	605
p-values		0.0256		0.0648
KC				
NT	22 A	7	2118.9 A	202 B
NTF	17 B	7	1034.6 B	170 B
T	0 C	13	0.0 C	758 A
TF	0 C	11	0.0C	763 A
p-values	<0.0001	0.1925	<0.0001	0.0008
RC				
NT	31 A	12	1786 A	157 B
NTF	4 B	9	291 B	415 A
T	0 B	12	0 B	519 A
TF	0 B	6	0 B	157 A
p-values	<0.0001	0.0752	0.0004	0.196
WC				
NT	25 A	2 C	2633 A	128 B
NTF	19 B	10 B	867 B	325 B
T	0 C	14 A	0 C	672 A
TF	0 C	10 B	0 C	690 A
p-values	<0.0001	<0.0001	<0.0001	0.0062

Harvest

There were no interactions between broccolini variety by clover by management which is why harvest data was analyzed within each broccolini variety. There were differences in the number of 'Melody' marketable shoots per plant in WC treatment with NT having less shoots per plant compared to T and TF (Figure 5). Management did not impact shoot number for 'Melody' in the BG, KC, and RC. There were differences in the number of 'Melody' marketable shoot weight per plant in WC treatment with NT having less shoot weight per plant compared to T and TF (Figure 6). Management did not impact shoot weight for 'Melody' in the BG, KC, and RC. There were differences in the number of 'BC1611' marketable shoots per plant in RC treatment with NT having less shoots per plant compared to NTF, T, and TF (Figure 7). Management did not impact shoot number for 'BC1611' in the BG, KC, and WC. There were differences in the number of 'BC1611' marketable weight per plant in RC treatment with NT having less shoots per plant compared to NTF (Figure 8). Management did not impact shoot weight for 'BC1611' in the BG, KC, and WC. There were no differences in clover or in-row management in 'Burgundy' marketable shoots and weight per plant (Figure 9 & 10).

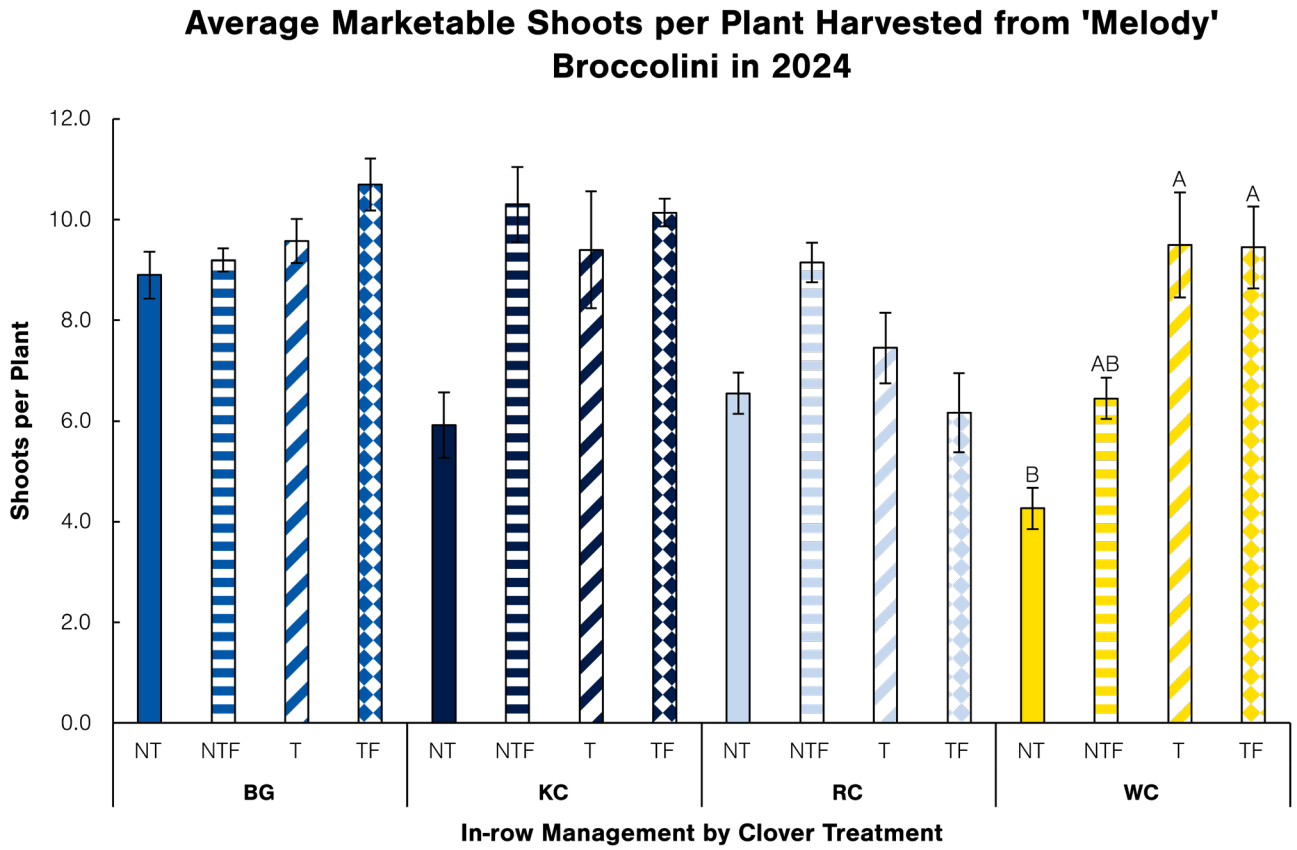

Figure 5. Marketable shoot yield responds per plant of 'Melody' broccolini from in-row management and clover treatments. BG= Bare ground, KC= Kura Clover, WC= White Clover, RC= Red Clover. TF= Tilled Fabric, T= Tilled no Fabric, NTF= No-till Fabric, NT= No-till No Fabric. Clover cultivar and management treatment used affected. Mean separations are affected within each clover treatment, BG ($p = 0.6572$), KC ($p = 0.1595$) RC ($p = 0.5852$), and WC ($p = 0.0283$). Bars with the same letter within a cover crop treatment are not different from each other based on Fisher's protected least significant difference test ($\alpha = 0.05$).

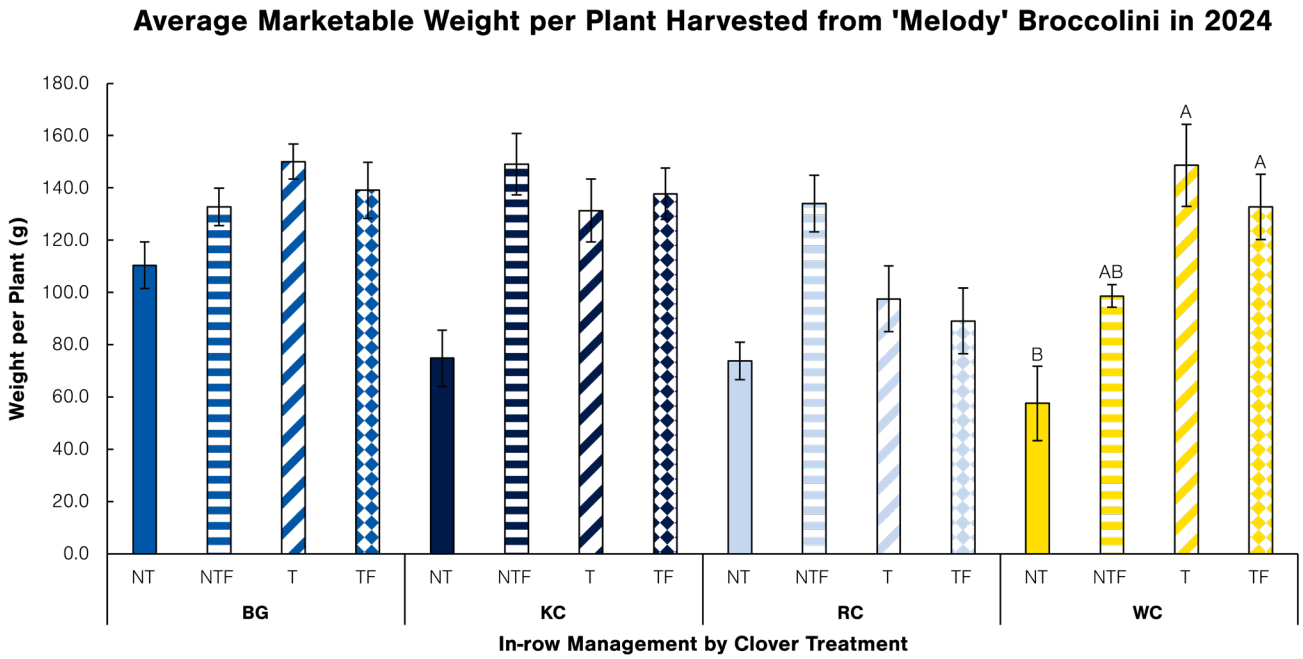

Figure 6. Marketable weight yield responds per plant of 'Melody' broccolini from in-row management and clover treatments. BG= Bare ground, KC= Kura Clover, WC= White Clover, RC= Red Clover. TF= Tilled Fabric, T= Tilled no Fabric, NTF= No-till Fabric, NT= No-till No Fabric. Clover cultivar and management treatment used affected. Mean separations are affected within each clover treatment, BG (p = 0.3312), KC (p = 0.0985) RC (p = 0.4077), and WC (p = 0.0214). Bars with the same letter within a cover crop treatment are not different from each other based on Fisher's protected least significant difference test (α = 0.05).

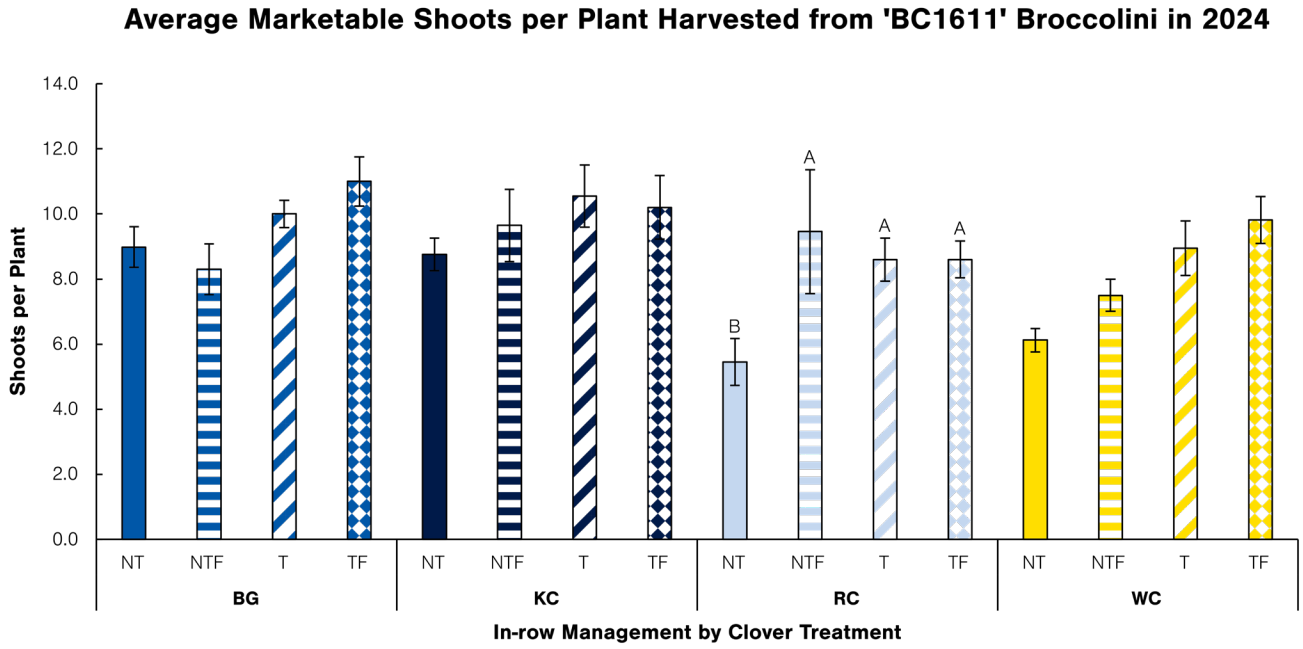

Figure 7. Marketable shoot yield responds per plant of 'BC1611' broccolini from in-row management and clover treatments. BG= Bare ground, KC= Kura Clover, WC= White Clover, RC= Red Clover. TF= Tilled Fabric, T= Tilled no Fabric, NTF= No-till Fabric, NT= No-till No Fabric. Clover cultivar and management treatment used affected. Mean separations are affected within each clover treatment, BG (p = 0.3164), KC (p = 0.9562) RC (p = 0.0738), and WC (p = 0.3838). Bars with the same letter within a cover crop treatment are not different from each other based on Fisher's protected least significant difference test (α = 0.05).

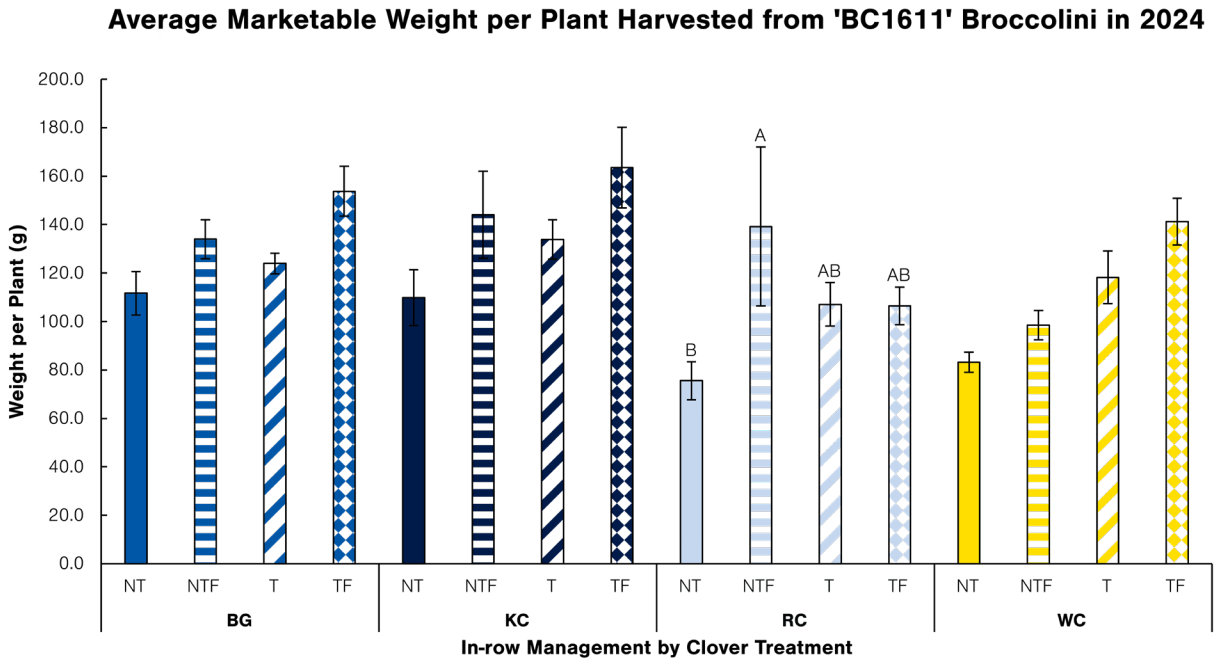

Figure 8. Marketable weight yield responds per plant of 'BC1611' broccolini from in-row management and clover treatments. BG= Bare ground, KC= Kura Clover, WC= White Clover, RC= Red Clover. TF= Tilled Fabric, T= Tilled no Fabric, NTF= No-till Fabric, NT= No-till No Fabric. Clover cultivar and management treatment used affected. Mean separations are affected within each clover treatment, BG (p = 0.4672), KC (p = 0.7926) RC (p = 0.0363), and WC (p = 0.1837). Bars with the same letter within a cover crop treatment are not different from each other based on Fisher's protected least significant difference test (α = 0.05).

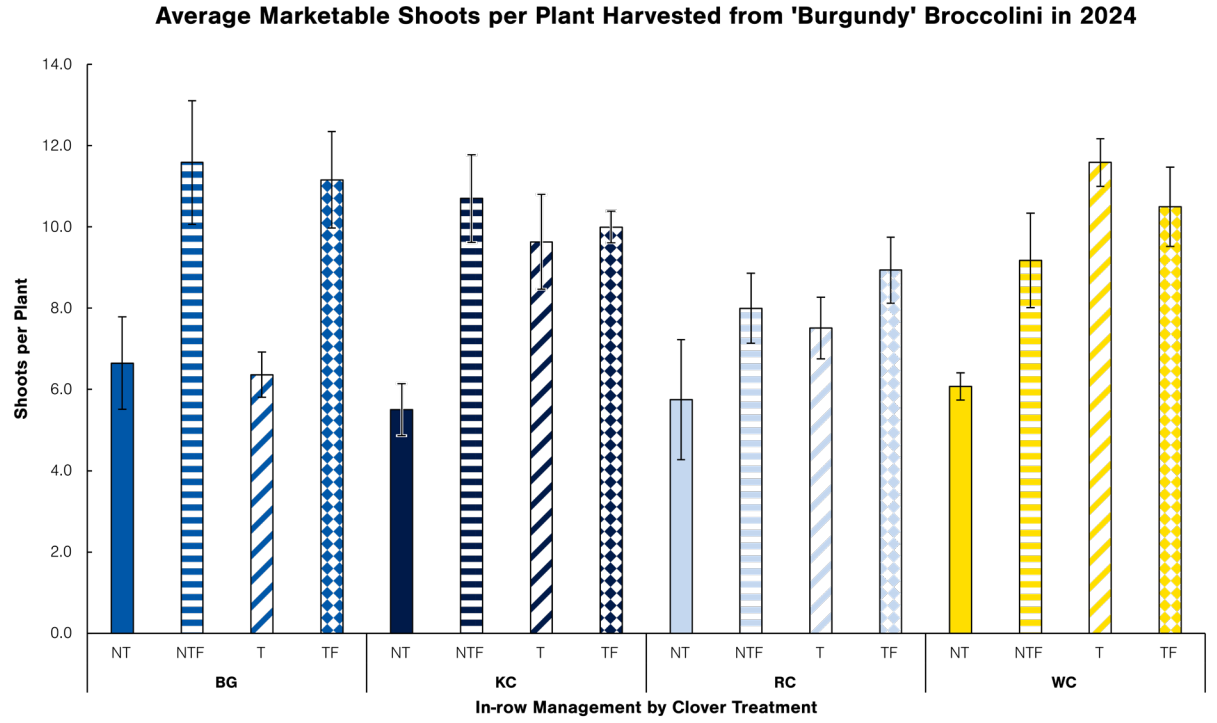

Figure 9. Marketable shoot yield responds per plant of 'Burgundy' broccolini from in-row management and clover treatments. BG= Bare ground, KC= Kura Clover, WC= White Clover, RC= Red Clover. TF= Tilled Fabric, T= Tilled no Fabric, NTF= No-till Fabric, NT= No-till No Fabric. Clover cultivar and management treatment used affected. Mean separations are affected within each clover treatment, BG (p = 0.1631), KC (p = 0.3175) RC (p = 0.6105), and WC (p = 0.2208). Bars with the same letter within a cover crop treatment are not different from each other based on Fisher's protected least significant difference test (α = 0.05).

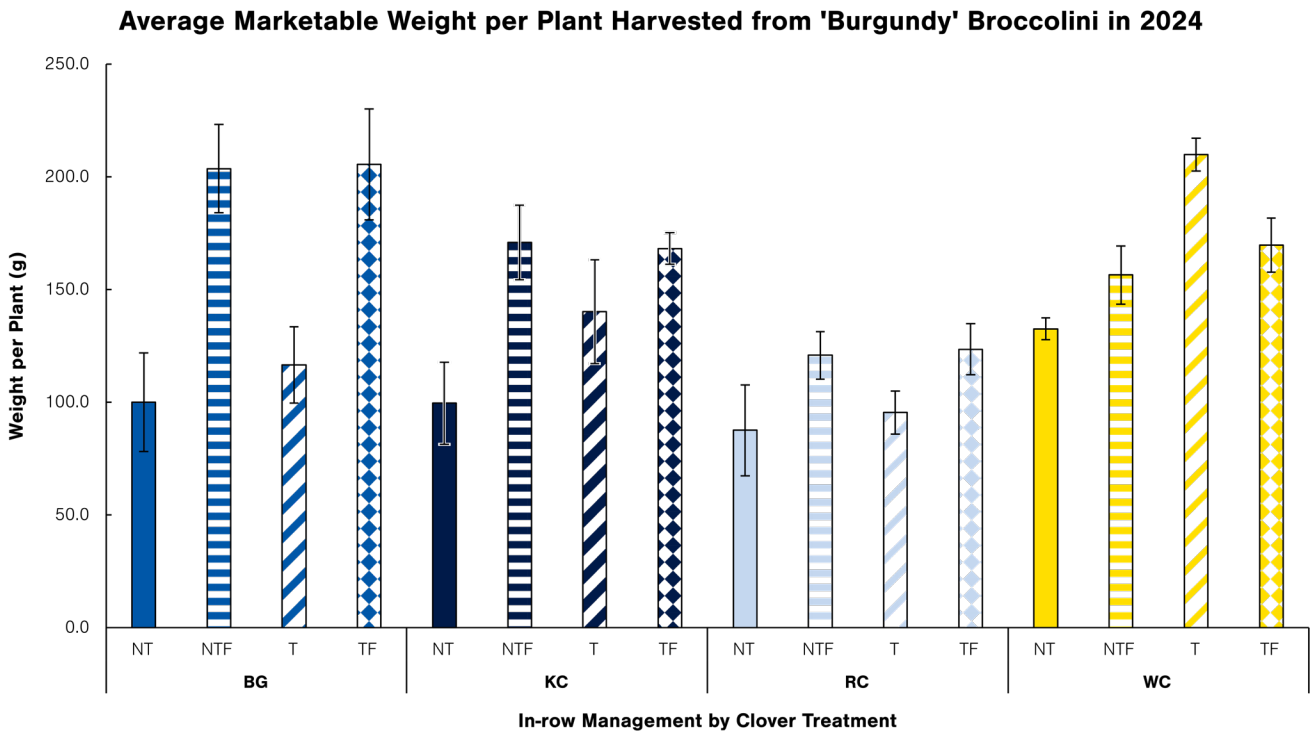

Figure 10. Marketable weight yield responds per plant of 'Burgundy' broccolini from in-row management and clover treatments. BG= Bare ground, KC= Kura Clover, WC= White Clover, RC= Red Clover. TF= Tilled Fabric, T= Tilled no Fabric, NTF= No-till Fabric, NT= No-till No Fabric. Clover cultivar and management treatment used affected. Mean separations are affected within each clover treatment, BG ($p = 0.1277$), KC ($p = 0.2147$) RC ($p = 0.5853$), and WC ($p = 0.1904$). Bars with the same letter within a cover crop treatment are not different from each other based on Fisher's protected least significant difference test ($\alpha = 0.05$).

Discussion

Whole Plot Biomass

This research demonstrates that clover living mulch can significantly reduce the weed pressure in the pathways in broccolini production which reduces the need for tillage and labor while improving soil health. In the 2024 growing season, all three whole plot clover treatments accumulated over 11,000 kilograms of biomass per hectare which is nearly double the biomass needed to reduce weed pressure by 50% (Table 1) (Pittman, 2020). Clover height had no correlation to biomass as RC was taller than both KC and WC but there was no difference in the biomass produced. All three whole plot clover treatments reduced the weed biomass compared to the BG treatment. RC reduced the weed biomass by half compared to BG but still had three times as much weed biomass than WC and four times as biomass as KC. Weed height was not different in clover treatments but RC on average had the tallest weeds which can be beneficial as the weeds spend more energy growing tall rather than branching and forming more seeds. Early season precipitation likely helped increase the clover biomass accumulation in 2024 compared to the 2023 growing season which was very droughty for most of the summer (Ruen, 2024).

In-Row Biomass

In-row plant biomass and height did not have clover in the BG whole plot and in the in-row T and TF treatments since clover in this area would be considered a weed since it was not intended to grow there. NT clover height in all KC, RC, and WC treatments were taller than all other in-row treatments (Table 2). This can be seen as detrimental since the clover will be directly competing with the broccolini for water, light, and nutrients (Bruce, 2022). NT and T treatments in BG had taller weeds than NTF and TF since the woven fabric limited the light that weeds could receive. T treatment in WC had taller weeds than TF, NT and NTF while NT had shorter weeds than T, TF, and NTF. NT in all three clover treatments there was more clover biomass than all other in-row treatments since there was not woven fabric to limit light to clover. The ratio of clover biomass in NT to NTF was much higher in RC since RC is upright growing and doesn't spread to replace itself like KC and WC. T and TF in KC and WC clover treatments there was a greater amount of weed biomass than NT and NTF. This was likely because of the competition with the clover in NT and woven fabric in NTF.

Harvest

'Melody' was the first variety to be harvested this year and continued to produce shoots for a total of eight weeks. 'Melody' would produce side shoots while the apical shoot was still maturing which may cause the apical shoot to decrease in size and weight (Figure 2). 'Melody' stems still stayed tender and snapped cleanly even when bolted which may make it tolerable to eat even after bolting. 'BC1611' was the second variety to be harvested for a total of seven weeks. 'BC1611' displayed much more apical dominance and would not produce side shoots until after harvesting the apical shoot. 'BC1611' consistently produced long slender shoots making it very desirable from a marketability standpoint. 'Burgundy' was the latest maturing variety and was harvested for only four weeks. 'Burgundy' produces a large cluster of shoots like European broccoli but slightly more open. The open form of the head makes for easy separation of individual shoots to prepare them. After the initial harvest of the apical shoots or head, there is a delay in the next flush of shoots compared to 'Melody' and 'BC1611.' 'Burgundy shoots are quick to become woody, even when the florets have not opened. 'Burgundy has a wonderful purple color which requires sunlight to form. Being shaded by leaves will occasionally cause them to become a mottled purple and green color (Figure 11). The yield impacts of clover living mulch in the NT clover treatments show a trend of yield reduction that is very troublesome. However, in a previous study at SCF on broccoli showed a yield of nearly zero in while the broccolini has been resilient enough to still produce through the stresses caused by the clover (Barnes, 2023). This prospect shows that broccolini may be a better option for producers to ensure a harvestable crop compared to broccoli.

Figure 11. 'Burgundy' broccolini that was shaded by leaves causing it to have a purple and green mottled color. Photo Courtesy of: Connor Ruen

Conclusion

Living mulch is an investment of time and energy that requires help getting started but once established, the long-term benefits can outweigh the initial cost. The clover pathways will reduce the need for tillage but still require timely mowing to maintain its condition and reduce weeding. The continuous cover on the soil improves soil health and provides habitat for many beneficial organisms essential for a healthy ecosystem. Broccolini is a new variety of Brassica that can help farmers spread the risk that comes with single harvest crops like European broccoli. Broccolini takes more time to harvest and some skill to know where and when to cut shoots, so it takes some time to experiment with what works for your farm. There is a large array of cultivars that can be used to attract customers to this new crop and fill the niche in the community. Protecting the yield of cash crops is essential to make the tradeoffs of using a living mulch system worthwhile to reap the benefits of living mulch systems.

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