Mow and Cover:

Cover Crop Management Using No-till Practices in a Market Garden

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Abstract

No-till cover crop management is a suitable way to prepare soil for planting vegetable crops and has been widely adopted by large scale farmers in both organic and conventional agriculture. These practices used together can benefit soil health, help reduce weed pressure and ultimately increase the sustainability of vegetable crop production, especially in organic systems. Cover cropping is practiced alongside no-till in large-scale field crop production but the two haven't often been practiced together in a market garden production system. This experiment was conducted in the Garden City Land in Richmond B.C during the summer of 2022 with the purpose of observing if conservation tillage practices could be paired with cover cropping in a market garden mixed vegetable production context. This experiment was conducted using an oat/pea cover crop that was terminated using three different tillage methods and paired with three different mulches after cabbages were planted. The tillage practices implemented to terminate the cover crop were mowing, mowing and covering with silage tarp, and mowing and tilling. The mulches were straw, composted mushroom manure and no mulch. Data was collected to observe ease of planting, management time, weed cover and biomass as well as harvest yield.

Introduction

There are a vast number of benefits associated with the use of cover crops and no till management in crop production. Andrew Mefferd states that "No-till is as much about climate change as it is about soil health as it is about farm profitability." and that "no-till growing practices are a way to improve all three" (2019). However, the adoption of these methods and research surrounding them is usually concerning large-scale field crop production. There is a need for research, and room for these methods to be adopted by small-scale organic growers as the benefits to soil health and weed suppression are present. Elliot Coleman highlights the room for research in this area saying that "while the general concept is workable, it's the specifics that need refining" and that "the idea is worth serious consideration. But it has to be done in a way that is more efficient rather than more complicated for the grower or it won't happen" (2018). The objective of this study was to evaluate cover crop termination, weed pressure, and labour use in organic cabbage grown with various combinations of tillage and mulch.

Cover cropping and No Till

Cover crops such as vetches, grains and legumes have been used for a long time to add value to farmers' soils (Wayman et al. 2015). Cover crops allow soil to be covered and harvest sunlight at times when cash crops aren't being produced, and in doing so provide nitrogen and other nutrients to the soil, provide structure to the soil through root systems and reduce soil erosion (Lounsbury et al. 2020). Originally cover crops were used as green manures that were tilled into the soil to provide excess organic matter and nutrients, however "the newest, most conspicuous management practice for using cover crops is in no-tillage or reduced tillage farming systems" (Lu et al. 2000).

No-till or reduced soil disturbance also has benefits for soil health by increasing water holding capacity, aggregate stability and providing an environment for biological life in the soil to thrive (Blevins et al. 1984, Chen et al. 2018). In reduced tillage or no-till systems, cover crops are terminated using methods such as flail-mowing or a roller crimper in organic systems, or using herbicides in conventional agriculture systems (Carrera et al. 2004). In colder climates, clear and black plastic tarps have also been used successfully to aid the termination of cover crops and help with weed suppression (Lounsbury et al. 2020). Once the cover crop is terminated the residue is utilized as a mulch that can "suppress weeds, reduce soil erosion, and maintain better soil moisture" (Lu et al. 2000). Some studies show however that using no-till and cover cropping can lead to both yield reduction and yield increase depending on different factors and crops as well as varied success in weed suppression (Robb et al. 2019). Implementing these techniques "has remained challenging, especially in organic vegetable systems, because of highly variable results" (Lounsbury et al. 2020). These mixed results show that more research and experiments need to be done in differing environments with different production systems and crops.

Weed Suppression

It has long been known that tilling practices bring up weed seeds and allow weed seed germination (Grundy et al. 1999). Organic growers have long battled weed pressure due to cultivation and the absence of the use of pesticides. "Weeds reduce yields by competing for nutrients, water, space and sunlight and are potentially responsible for 32 percent of crop losses worldwide" (Robačer et al. 2016). Different techniques such as flame weeding, solarization, cultivating a stale seed bed and finally hand-weeding are techniques that are often used to manage weeds (Rasmussen and Ascard 1995, Coleman 2018). Weeds are often suppressed in a no-till system by using the terminated cover crop as a mulch, however if a cover crop is poorly established there may not be enough biomass to act as sufficient weed suppression (Robb et al. 2019).

Other forms of mulch are often used in organic vegetable production, such as black plastic mulch or paper mulch. However these forms of mulch come with their own issues, plastic mulch is usually single use as the holes made for planting lead to quick deterioration, whereas paper mulches decompose into the soil but have varying success (Larking 2020). Organic mulches such as straw or wood products are also used. These products are often readily available and don't have a large environmental footprint. However, the issues related to organic mulch are well summarized by Bucki and Siwek when they state that "a factor that hinders widespread use of organic mulches is the feasibility of delivering them to the field, and evenly distribute them therein. In addition, many of these mulches decompose quickly, which requires systematic replenishment" (2019) Cover cropping in a no-till system offers some potential solutions to the issue of weed pressure by being a source of mulch that also helps to "lower external farm inputs and…minimize the use of non-renewable resources"(Robačer et al. 2016). However, the transition to a no-till system often entails an increase of weed pressure as the use of tilling is often what helps farmers get ahead of the weeds and cover crops that might have troubles establishing in these environments. The addition of organic mulches to supplement the biomass missing from a poorly established cover crop for systems in transition could be a way to manage weed pressure but the added labor involved with organic mulches needs to be considered.

Cover cropping and no till in market Gardens

The question arises, how can small-scale organic growers manage cover crops using no-till practices to reduce their labor without seeing a decrease in yield or having to invest in expensive equipment. This will allow farmers to gain the benefits of both cover crops and no-till soil management leading to overall healthier soils and more sustainable production systems. Many small-scale organic farmers are implementing reduced tillage practices in their systems already. Some methods include using walk behind tractors with flail mowers and silage or landscape tarp to terminate crops or cover crops. However, the sentiment is still often that no-till is a great concept in general but is restrictive and somewhat impractical in market gardens (Fortier 2014). It is with the words of real-life market gardeners in mind that this experiment has been designed to use and synthesize methods and tools already known by most small-scale vegetable producers to implement no-till techniques into cover cropped market garden systems. This study aims to combine scientific knowledge with tested techniques and to apply them on a scale that will provide useful information to market-gardeners in their contexts.

Summary of Literature Reviewed

This experiment has been based on the following studies and the conclusions they have made about cover crops, no-till, tarping, and mulch:

Cover crops

Conclusions made by Robačer et al. show that cover crops help reduce the environmental footprint of a farm, lowering external inputs. Additionally, cover crops reduce soil erosion and nutrient leaching (2016). Wayman et al. and their conclusion describe that each selection of cover crops comes with its own benefits, ranging from its effectiveness as a weed suppression, its ability to put on biomass and be an adequate mulch material and its ability to provide nitrogen to the soil (2015).

Tillage

Conclusions made by Robačer et al. show that a reduction of tillage saves on fossil fuel use because of reduce intensive tractor usage and reduces weed seed germination through less disturbance (2016). Robb et al. further conclude that no-till requires less labor input when compared to conventional tillage to establish a vegetable crop. Additionally, they conclude that although weed pressure was greater in the first year using no-till that the weeds were slower to establish then in conventional tillage and didn't compete as strongly with the vegetable crop

(2019). And finally, conclusions from Farmaha et al. show that the use of no-till along with cover crops can improve soil health but that the soil health benefits are often variable in short term implementation (2021).

Mulch and tarping

Robačer et al. concludes that residue left on the soil surface by the growth and termination of cover crops can act as a mulch and help reduce weed pressure (2016). Conclusions from Bucki and Siwek state that mulching has benefits on soil health and vegetable crop yield as well as the ability to create a microclimate within the field (2019). Finally, Larking's comments on the environmental pitfalls of plastic mulches inform the benefits of organic mulches (2020). Conclusions from Lounsbury et al. regarding the use of tarps discuss their ability to help in the termination of a variety of cover crop in colder climates, and the acknowledgement that a roller-crimper isn't always an available method of terminating cover crops for small-scale vegetable producers (2020). Methods of tarping using silage tarps described by Jean-Martin Fortier show the ability of tarps to reduce weed pressure before planting without soil disturbance (2014).

All these studies have informed the design of this experiment. The methods of terminating a cover crop using a flail mower and tarping methods are covered in a variety of different research and on farm implementation. Conclusions of these studies have been synthesized with methods and sentiments from market garden vegetable producers such as Jean-Martin Fortier, Elliot Coleman, and many growers represented by Adnrew Mefferd in order to experiment with techniques that acknowledge the needs of small-scale vegetable producers and their desires to implement more sustainable farming practices (2014, 2018, 2019).

Materials Methods

Field site

This experiment was conducted on Garden City Lands on the KPU Farm in Richmond B.C. The KPU farm sits on mineral soil that has been deposited on the west end of LuLu Island peat bog. The experiment was conducted on “market garden plot A” in the market garden section of KPU farm. According to a soil analysis done in 2021, this plot had an adequate amount of most nutrients with a boron deficiency, marginal amounts of nitrogen and manganese and an excess of sulfur. The soil was a loamy sand with the mineral portion being made up of 75% sand, 22% silt and 2.7 %clay. The soil in this plot had an organic matter content of 2.3% which is low compared to other parts of the farm. The field was managed according to organic standards for four years and has been farmed in a mixed-vegetable production system with different vegetables and cover crops being rotated since production began. The system has been managed mostly using a BCS rototiller. This field was planted with a mixed cover crop of oats and peas in April in preparation for this experiment.

Figure 1 An aerial photo of the KPU Farm in Richmond with the intended experimental plot marked.

Hypotheses

There were three hypotheses for this experiment, one specifically regarding tillage, the second mulch and the third regarding an interaction between the two. The first null hypothesis and hypothesis were as follows:

Null hypothesis 1: The tillage practice used to manage a cover crop has no effect on ease of planting of the field, yield of crop or weed pressure.

Hypothesis 1: No-till methods can be used to manage cover crops and prepare fields for vegetable as effectively as tillage management.

The second null hypotheses and hypothesis were as follows:

Null hypothesis 2: The presence or absence of a mulch has no effect on the crop yield or weed pressure of a vegetable crop.

Hypothesis 2: Mulching can be used to suppress weeds, reduce weed pressure and increase crop yield in vegetable crop production.

Finally, the third null hypothesis and hypothesis were:

Null hypothesis 3: There is no interaction between tillage practice and mulch treatment when managing cover crops and planting a vegetable crop.

Hypothesis 3: The use of mulch is required to manage weed pressure and produce a yield comparable to conventional methods when using no-till methods to manage cover crops

Experimental design

This experiment was set up as a randomized complete block split-plot factorial design with three replicates, each replicate being it's own block. Blocking was done to account for variation in the field (fig.2). Each block contained three plots which were randomly assigned to have their cover crop terminated using one of three tillage treatments: mow only, mow and cover, and mow and till. Every plot was then split into three sub-plots which each had twelve four-week-old tiara cabbage seedlings transplanted into them. Each sub-plot within every plot received one of three different mulches assigned randomly to no mulch, composted mushroom manure mulch, or straw mulch. All randomization was done using the randomizer module in Jamovi. The dependent variable in this study were ease of planting; management time required for planting, mulching, and weeding; weed cover and biomass; and cabbage yield.

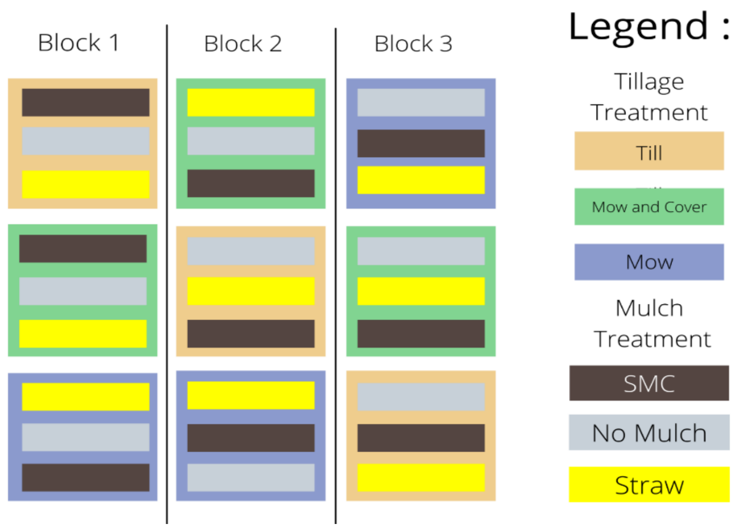

Figure 2 A randomized complete block split plot design for the experiment. Each tillage treatment (plot) occurs randomly assigned in each block. Every tillage treatment is randomly assigned each of the three mulch treatments (sub- plots). Resulting in a total of 9 plots and 27 sub plots.

Mow and till

The mow and till method of terminating the cover crop was the control for this experiment and is the method that is used regularly on the KPU Farm. This tillage method is the highest impact method when it comes to soil disturbance and is used to incorporate the cover crop into the soil. The mow and till method was done by first mowing the plots with the flail mower attachment on the BSC walk-behind tractor and then tilling the plots using the rototiller attachment on the BSC walk-behind tractor. The preparation for these beds were also done five days before transplanting cabbage seedlings.

Mow and cover

The plots that were determined to be mowed and tarped were mowed with a flail mower attached to a BCS walk-behind tractor. After mowing the plots were covered with a uv-treated polyethylene tarp (silage tarp) to allow for termination of the regrowth of the oat/pea cover crop as well as creating a stale seedbed by allowing weed seeds to germinate and then terminate due to lack of sunlight. This process was done 18 days before transplanting of the cabbage.

Mow only

The mow only method was done using a flail mower attached to a BSC walk-behind tractor and a string trimmer to cut anything left behind by the flail mower. The mowing of these plots was done five days before transplanting cabbage seedlings.

Mulch

The three mulch methods that will be used are straw mulch, composted mushroom manure, and no mulch. The mulches are intended to help with weed suppression as well to ensure the decomposition and smothering of the cover crop. Straw was chosen as it is is a traditionally used mulch. Composted mushroom manure is a mulch that is readily available and sourced locally and has been used on the KPU farm before. The mulch will be applied at a depth of about 6-10 cm and applied in a way where the transplanted seedlings are not covered but able to peek through. If the mulch decomposes quickly, it will be reapplied to the system as needed. The irrigation will be placed under the mulch. The KPU farm does not generally use mulch and no mulch will be the control.

Planting

On May 11th, 2022 700 tiara cabbage seeds were seeded into peat soil blocks made by the soil blocker multi 20 in the geo-dome at KPU farm. On May 26th a 1.5 m buffer zone was tilled around the entire experimental plot to eliminate as much edge effect as possible form the experiment. On June 1st the buffer strip was planted with two rows of transplants. The field within the buffer was divided into three 1.2m wide and 20m long rows with a walkway in between each row. Each row made up a block and was separated into three plots, walkways were also left between each plot within the row. Each plot was then divided into three sub-plots, for a total of 9 plots in the field and 27 sub-plots. On June 13th each sub-plot was planted individually with twelve cabbages at a 42cm between seedlings. Each plot received a total of 36 cabbage seedlings. Transplant holes were dug either by hand or with a small hand trowel depending on the difficulty of planting. Before planting each transplant hole received approximately 60g of feather meal as fertilizer. Once the seedlings were planted two lines of drip-tape were placed running the entire length of each block, for a total of 6 drip lines for the experimental field. If mulch was determined to be added to the sub-plot, then mulch was spread around the transplants.

In the two weeks following transplanting it was observed that many seedlings were dying. It is suspected that this was due to over fertilization with feather meal or an improper incorporation of feather meal with the soil. The seedlings that died were replaced with seedlings from the buffer strip.

Data Collection

Ease of planting

During planting, ease of planting was determined qualitatively by how much effort was required to dig a hole to plant a seedling. The ease of planting was determined on a scale of 1-5 with 1 being very easy planting and 5 being unplantable. 2 was easy planting with some difficulty planting with hands, 3 was moderately difficult where a hand trowel was necessary, and 4 was difficult where there was resistance in planting even with a hand trowel.

Management time

Planting time was recorded using a stopwatch separately for each sub-plot. Time started as the first hole was dug and stopped after the last seedling for the sub-plot was planted. Mulching time was recorded using a stopwatch, separately for each sub-plot. The time of transportation of the mulch to each sub-plot was not recorded. Time was recorded for distributing the mulch material around the seedlings in each sub-plot. Weeding time was recorded for each subplot three times throughout the growth of the cabbage at one week intervals, on June 21st, 29th, and July 6th. After July 6th the cabbages were large enough to have canopy closure and weeding wasn't necessary.

Weed cover and biomass

Weed cover was determined using an app (Canopeo) that is designed to determine the percentage of ground cover through processing images of crops. To determine weed cover removed, a top-down picture was taken before and after weeding to determine the percent ground cover in each instance. The percent ground cover after weeding was subtracted from the percent ground cover before weeding and the resulting number was used as the "% ground cover removed". Weed biomass was determined after the cabbages were harvested. The weeds present under the canopy of the cabbage were harvested on the east half of each sub-plot. The weeds were then immediately weighed to determine fresh biomass.

Yield

The cabbages were harvested on two separate days one week apart. On July 21^{st} the cabbages that were mature and firm were harvested and weighed. On July 27^{th} the remained of the cabbages were harvested and weighed. Harvest weight was recorded for each sub-plot individually.

Statistical Analysis

The data from this experiment was analyzed using the GAMLj module of the Jamovi interface for R to run a Mixed-Model analysis. The Model used for this design was $y \sim x1 + x2 + x1*x2 + (1 | plot) + (1 | block)$. The dependent variables in the analysis were, ease of planting, time spent planting, time spent mulching, time spent mulching and planting, time spent weeding (LN transformed to achieve normal distribution), time spent planting, mulching, and weeding, ground cover removed (LN transformed to achieve normal distribution), final weigh of weeds (LN +1.5 transformed to achieve normal distribution) and yield. The fixed factors in the analysis were tillage treatment and mulch treatment. The cluster variables were Plot and Block. If a p-value less than 0.05 was determined for either fixed factor or for an interaction between the fixed factors, then a Bonferroni post hoc test was conducted. Significant differences were then noted if the Bonferroni P-value was less than 0.05.

Results

Significant treatment effects were found within ease of planting, among the tillage treatments; within time spent mulching, for which only mulch treatment was considered; among mulch treatments, tillage treatments and an interaction between the two for time spent weeding; within time spent overall, among tillage treatments; total ground cover removed, among mulch and tillage treatments; and for final weight of weeds, among mulch treatments. There were no significant treatment effects found among the dependent variables time spent planting, or yield.

Ease of planting

The plots that were tilled were significantly easier to plant ($p<0.05$) than both no-till treatments. The mow and cover plots were easier to plant than the plots that were mowed but not covered (fig. 3).

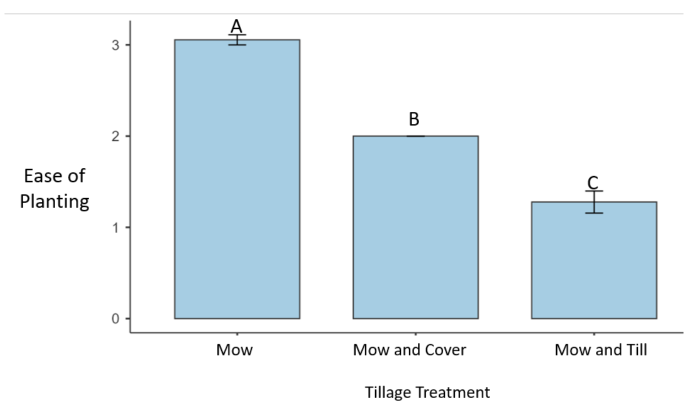

Figure 3 Ease of planting (1 easiest, 3 more difficult) measured over different tillage treatments. Bars labelled with different letters differ significantly ($p< 0.05$). Error bars denote standard deviation.

Time spent mulching

The composted mushroom manure took significantly longer ($p<0.05$) to spread than the straw mulch. The treatments with no mulch clearly took no time to mulch (fig. 4)

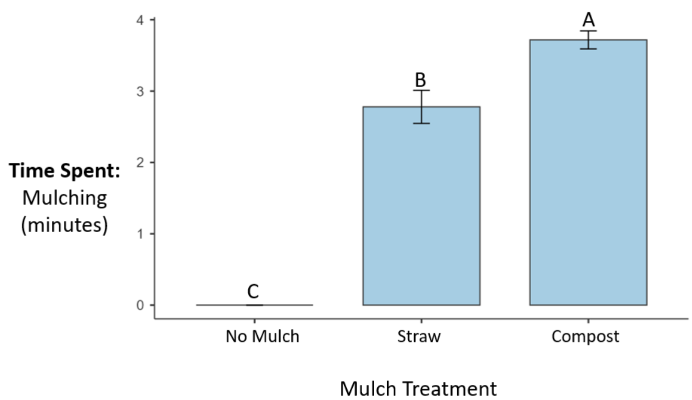

Figure 4 Time spent mulching measured for different mulch treatments. Bars labelled with different letters differ significantly ($p< 0.05$). Error bars denote standard deviation.

Time spent weeding

There was significantly less time spent weeding on the mow and cover plots compared to mow only and tilled plots. Furthermore, there was less time spent on the tilled plots compared to the mowed plots. Additionally, there was significantly less time weeding on the sub-plots that were mulched with either compost or straw as compared to the plots that weren't mulched. There were also many significant interactions between mulch and tillage treatments. All mowed treatments no matter their mulch took the longest to weed. Mowed and covered treatments mulched with compost or straw took the least amount of time to weed. Tilled treatments with straw weren't significantly different in time spent weeding than all the mowed and covered treatments and the tilled treatments with compost mulch or no mulch (Fig. 5).

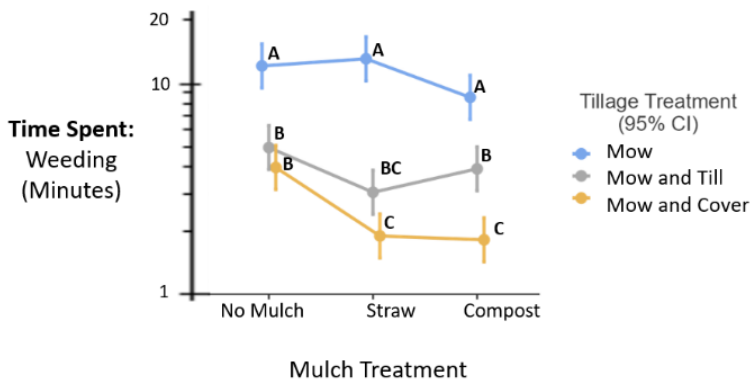

Figure 5 Time spent weeding measured for mulch and tillage treatments. Points labelled with the same letters do not differ significantly ($p < 0.05$). Error bars denote 95% Confidence interval.

Time spent planting, mulching, and weeding

There was significantly more time spent overall in the plots where the cover crop was only mowed as compared to the plots where the cover crop was mowed and covered or tilled into the soil (Fig. 6). Most of this significance came from the time spent weeding, as there was no significance between tillage treatments regarding mulching or planting.

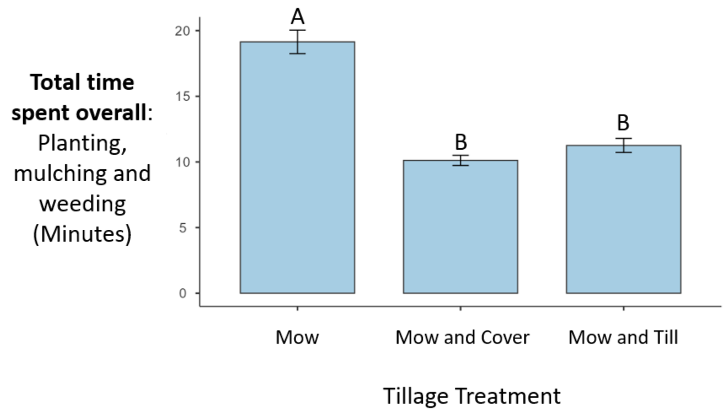

Figure 6 Time spent overall measured for different tillage treatments. Bars labelled with the same letters did not differ significantly ($p < 0.05$). Error bars denote standard deviation.

Ground cover removed

There were significant treatment effects observed both among mulch treatments (fig. 7) and tillage treatments (fig. 8) for ground cover removed. Sub-plots without mulch had significantly more ground cover removed during the growing season and the mow only plots had significantly more ground cover removed than the other two tillage methods. Although both treatment effects showed significant results among treatments, there was no significant interaction observed.

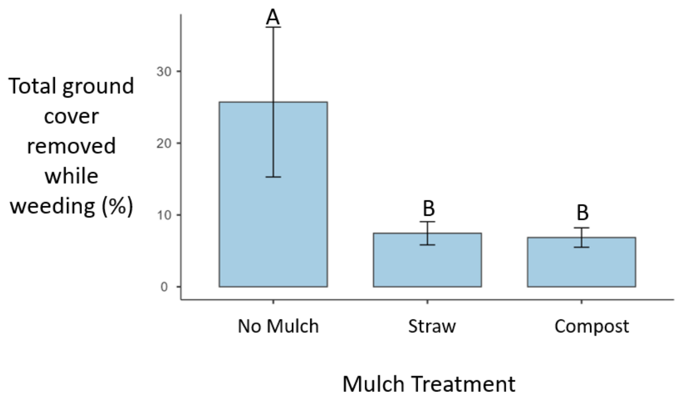

Figure 7 Total weed ground cover removed across different mulch treatments. Bars labelled with the same letters did not differ significantly ($p < 0.05$). Error bars denote standard deviation.

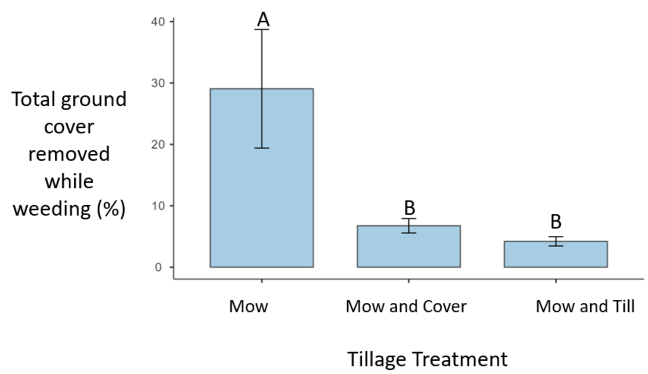

Figure 8 Total weed ground cover removed across different tillage treatments. Bars labelled with the same letters did not differ significantly ($p < 0.05$). Error bars denote standard deviation.

Final weight of weeds

There were significantly more weeds present in the plots without mulch at the end of the season as compared to plots with either straw mulch or compost mulch (Fig 9).

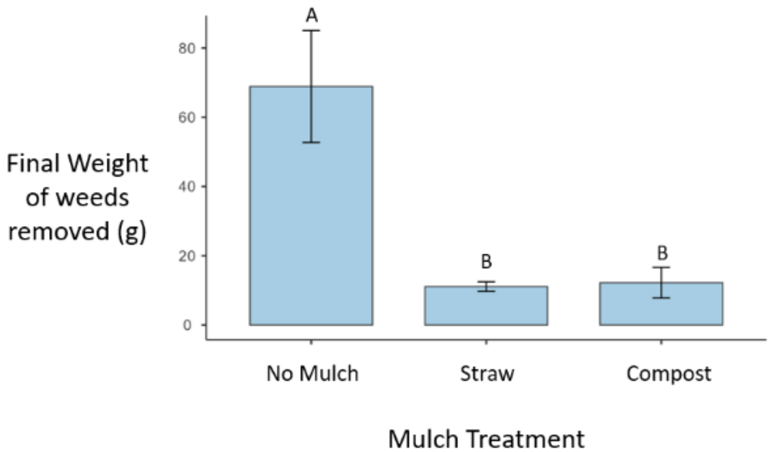

Figure 9 Weight of weeds removed at harvest (g) measured for each mulch treatment. Bars labelled with the same letters did not differ significantly ($p < 0.05$). Error bars denote standard deviation.

Discussion

Hypotheses

There was not entirely enough evidence to reject the first null hypothesis that the tillage practice used to manage a cover crop has no effect on ease of planting, yield of crop or weed pressure. Regarding yield of crop and weed pressure this null hypothesis was rejected, but not regarding ease of planting as there was significant treatment effects among tillage methods regarding ease of planting. The second null hypothesis was also only partially rejected. Mulching had no effect on crop yield, therefore the aspect of the null hypothesis that stated mulch has no effect on crop yield was rejected. The rest of the null hypothesis that stated that mulch or its absence has no effect on weed pressure was rejected. The third null hypothesis was rejected because there was an interaction between tillage practice and mulching and mulching was a factor that significantly reduced weeding pressure on mow and covered plots as compared to mow and till plots.

Ease of planting

Although the tilled plots are easiest to plant, the mowed and covered plots did not make planting much more difficult when a hand trowel was used. The remnant of the cover crop roots in the mow only plots made planting most difficult, but planting was still very manageable. Overall, there was no significant difference in time spent planting between the tillage methods which highlights that the qualitative analysis for ease of planting may have resulted in data that conflated the difficulty of planting. This is especially true between mow and cover and mow and till. Although mow and cover was more difficult to plant than mow and till, from a management perspective it was not more difficult to a degree that it hindered the transplanting in any way, which was reflected by the lack of significance in differences between planting time between the methods.

Mulch

Mulch proved to be important in the efficacy of weed suppression in the mow and cover treatments. The plots with no mulch had a greater coverage of weeds removed both during the growing season as well as after harvest. Regarding management time and weed suppression, there was no significant difference between straw and composted mushroom manure but from a logistical perspective, it was easier to weed the compost than the straw and would also likely be easier to weed compost if using mechanized methods. The mulches were spread after planting and the spreading may have gone quicker if it was done before planting as spreading mulch around transplants proved to be tedious. Although mulching added management time, the time addition was not significant in this study. The introduction of mulch does however add another step in management and logistics and these factors should be considered.

In further experiments it would be worth implementing a crimp and cover method. Crimping and tarping the cover crop would reduce the need for transporting mulch material to the field, which Bucki and Siwek state is a large logistical hindrance of using organic mulches in crop production (2019). A crimped cover crop would decompose much slower than the mowed cover crop and could itself act as a mulch. It is to be noted that managing a cover crop with no-till methods slows down the availability of nitrogen sourced from the cover crop and must be accounted for and planned into the soil fertility management (Stecker 1993). The concern voiced by Robb et al. does however remain that in order to use a cover crop as mulch there needs to be enough biomass produced by said cover crop (2019). In the case of poorly established cover crops there would be a lack of mulch material which could result in increased weed pressure. Having the option to add mulch to a no-till system would be a way to supplement ground cover in the case of poorly established cover crops.

Mow and cover

Tarping was an important step in cover crop termination for the no-till methods. Plots that were not tarped after mowing were the hardest to plant because of the presence of non-terminated cover crop. Non-tarped plots also had significantly more weed pressure due to regrowth of cover crop and sprouting weeds from a lack of creating a stale seed bed. Management time for mow and cover in this experiment did not exceed the time spent on the tillage treatment which doesn't fully align with remarks made by Robb that state labour requirements in no-till are less than conventional tillage (2019). However, through refining the methods and adding mechanization there is potential to reduce management time among mow and cover even further. Additionally, it is expected that the benefits of no-till are to be variable in the short term (Farmaha et al. 2021). As these no-till methods are consistently applied over time improved soil tilth will have the potential to develop to allow easier planting, weed population dynamics will change and the full benefits of no-till will be reflected in reduced management time.

Applications and further experimentation

The results of this study highlight that there are promising efficient no-till methods that satisfy concerns voiced by growers such as Coleman for methods that don't complicate growing practices (2018). Farmers producing vegetables on a small scale might benefit from implementing no-till methods such as mow and cover. Although there may be potential added task of mulchingk the trade-off could be less time weeding and better soil health in the long-run (Blevins et al. 1984, Chen et al. 2018). Additionally, even though a new step of management is added in a mow and cover system, the overall labour investment did not differ significantly from the conventional tillage practice.

Further study would be to expand the study to have more replicates and fewer treatments. Having a greater number of vegetables present in every replicate would provide more robust yield data and expanding the study would allow for mechanized weeding to be done. To further mechanize the experiment, mulching with composted mushroom manure could be done using a manure spreader, plants or seeds could then be planted into furrows and the mulch could later be pushed around established plants. Additionally, to collect weed pressure data and crop yield, weeding could be done for all plots only when the plots with the least amount of weeds are in need of weeding. This way a clearer picture of the impact of weed presence on crop yield would be observed.

Problems

Many cabbage seedlings had to be replaced in the first few weeks after transplanting because of a deterioration of the roots, potentially due to over-fertilization or poor incorporation of the fertilizer into the soil. Yield data had no significant results but may have been affected by this, regardless.

Conclusion

Mow and cover as a no-till method for managing cover crops is an effective way to reduce tillage. When this method of no-till management is paired with mulch it can reduce weed pressure and reduce overall time spent weeding without increasing labour or decreasing crop yield.

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Appendix 1

Model results and post hoc tests for significant results

SMC= Spent mushroom compost also referred to as composted mushroom manure in the paper.

Ease of Planting

Model Results

Ease of Planting

Fixed Effect Omnibus tests

	F	Num df	Den df	p
Mulch Treatment	6.09e−30	2	12.00	1.000
Tillage Treatment	55.500	2	6.00	< .001
Mulch Treatment ✻ Tillage Treatment	0.857	4	12.00	0.517

Note. Satterthwaite method for degrees of freedom

Post Hoc Tests

Ease of Planting

Post Hoc Comparisons - Tillage Treatment

Comparison							
Tillage Treatment		Tillage Treatment	Difference	SE	t	df	$p_{bonferroni}$
Mow	-	Mow and Cover	1.056	0.170	6.22	4.00	0.010
Mow	-	Till	1.778	0.170	10.47	4.00	0.001
Mow and Cover	-	Till	0.722	0.170	4.26	4.00	0.039

Time Spent Mulching

Model Results

Time Spent Mulching

Fixed Effect Omnibus tests

	F	Num df	Den df	p
Mulch Treatment	172.434	2	12.00	< .001
Tillage Treatment	0.376	2	6.00	0.701
Mulch Treatment ✻ Tillage Treatment	0.391	4	12.00	0.811

Note. Satterthwaite method for degrees of freedom

Post Hoc Tests

Time spent mulching

Post Hoc Comparisons - Mulch Treatment

Comparison							
Mulch Treatment		Mulch Treatment	Difference	SE	t	df	$p_{bonferroni}$
No mulch	-	SMC	−3.718	0.208	−17.86	12.0	< .001
No mulch	-	Straw	−2.779	0.208	−13.35	12.0	< .001
Straw	-	SMC	−0.939	0.208	−4.51	12.0	0.002

Time Spent Overall

Model Results

Time Spent Overall

Fixed Effect Omnibus tests

	F	Num df	Den df	p
Tillage Treatment	74.62	2	6.00	< .001
Mulch Treatment	3.70	2	12.00	0.056
Tillage Treatment ✻ Mulch Treatment	2.72	4	12.00	0.080

Note. Satterthwaite method for degrees of freedom

Post Hoc Tests

Time Spent Overall

Post Hoc Comparisons - Tillage Treatment

Comparison							
Tillage Treatment		Tillage Treatment	Difference	SE	t	df	$p_{bonferroni}$
Mow	-	Mow and Cover	9.02	0.805	11.21	4.00	0.001
Mow	-	Till	7.89	0.805	9.80	4.00	0.002
Mow and Cover	-	Till	−1.14	0.805	−1.41	4.00	0.692

Ground Cover Removed

Model Results

Ground Cover Removed

Fixed Effect Omnibus tests

	F	Num df	Den df	p
Mulch Treatment	5.63	2	12.00	0.019
Tillage Treatment	17.24	2	6.00	0.003
Mulch Treatment ✻ Tillage Treatment	1.71	4	12.00	0.213

Note. Satterthwaite method for degrees of freedom

Post Hoc Tests

Ground Cover Removed

Post Hoc Comparisons - Tillage Treatment

Comparison							
Tillage Treatment		Tillage Treatment	Difference	SE	t	df	$p_{bonferroni}$
mow	-	mow and cover	1.256	0.296	4.24	4.00	0.040
mow	-	till	1.670	0.296	5.64	4.00	0.015
mow and cover	-	till	0.414	0.296	1.40	4.00	0.705

Post Hoc Comparisons - Mulch Treatment

Comparison							
Mulch Treatment		Mulch Treatment	Difference	SE	t	df	$p_{bonferroni}$
No mulch	-	SMC	0.82980	0.284	2.9176	12.0	0.039
No mulch	-	Straw	0.82301	0.284	2.8937	12.0	0.040
Straw	-	SMC	0.00679	0.284	0.0239	12.0	1.000

Final Weight of Weeds

Model Results

Final Weight of Weeds

Fixed Effect Omnibus tests

	F	Num df	Den df	p
Mulch Treatment	19.731	2	12.00	< .001
Tillage Treatment	1.466	2	4.00	0.333
Mulch Treatment ✻ Tillage Treatment	0.641	4	12.00	0.644

Note. Satterthwaite method for degrees of freedom

Post Hoc Tests

Final Weight of Weeds

Post Hoc Comparisons - Mulch Treatment

Comparison							
Mulch Treatment		Mulch Treatment	Difference	SE	t	df	$p_{bonferroni}$
No mulch	-	SMC	1.805	0.309	5.842	12.0	< .001
No mulch	-	Straw	1.520	0.309	4.921	12.0	0.001
Straw	-	SMC	0.285	0.309	0.921	12.0	1.000

Time Spent Weeding

Model Results

Time Spent Weeding

Fixed Effect Omnibus tests

	F	Num df	Den df	p
Tillage Treatment	146.74	2	16.0	< .001
Mulch Treatment	14.40	2	16.0	< .001
Tillage Treatment ✻ Mulch Treatment	5.06	4	16.0	0.008

Note. Satterthwaite method for degrees of freedom

Post Hoc Tests

Time Spent Weeding

Post Hoc Comparisons - Tillage Treatment ✻ Mulch Treatment

Comparison									
Tillage Treatment	**Mulch Treatment**		**Tillage Treatment**	**Mulch Treatment**	**Difference**	**SE**	**t**	**df**	**$p_{bonferroni}$**
Mow	No mulch	-	Mow	SMC	0.3602	0.166	2.1677	12.0	1.000
Mow	No mulch	-	Mow	Straw	-0.0817	0.166	-0.4914	12.0	1.000
Mow	No mulch	-	Mow and Cover	No mulch	1.1636	0.166	7.0030	15.4	< .001
Mow	No mulch	-	Mow and Cover	SMC	1.9926	0.166	11.9920	15.4	< .001
Mow	No mulch	-	Mow and Cover	Straw	1.9489	0.166	11.7293	15.4	< .001
Mow	No mulch	-	Till	No mulch	0.9355	0.166	5.6302	15.4	0.002
Mow	No mulch	-	Till	SMC	1.1792	0.166	7.0967	15.4	< .001
Mow	No mulch	-	Till	Straw	1.4482	0.166	8.7156	15.4	< .001
Mow	SMC	-	Mow and Cover	SMC	1.6324	0.166	9.8243	15.4	< .001
Mow	SMC	-	Till	SMC	0.8190	0.166	4.9290	15.4	0.006
Mow	Straw	-	Mow	SMC	0.4418	0.166	2.6592	12.0	0.750
Mow	Straw	-	Mow and Cover	SMC	2.0742	0.166	12.4834	15.4	< .001
Mow	Straw	-	Mow and Cover	Straw	2.0306	0.166	12.2208	15.4	< .001
Mow	Straw	-	Till	SMC	1.2608	0.166	7.5881	15.4	< .001
Mow	Straw	-	Till	Straw	1.5298	0.166	9.2070	15.4	< .001
Mow and Cover	No mulch	-	Mow	SMC	-0.8034	0.166	-4.8353	15.4	0.007
Mow and Cover	No mulch	-	Mow	Straw	-1.2453	0.166	-7.4944	15.4	< .001
Mow and Cover	No mulch	-	Mow and Cover	SMC	0.8290	0.166	4.9890	12.0	0.011
Mow and Cover	No mulch	-	Mow and Cover	Straw	0.7853	0.166	4.7263	12.0	0.018
Mow and Cover	No mulch	-	Till	SMC	0.0156	0.166	0.0937	15.4	1.000
Mow and Cover	No mulch	-	Till	Straw	0.2846	0.166	1.7126	15.4	1.000

Post Hoc Comparisons - Tillage Treatment ✻ Mulch Treatment

Comparison									
Tillage Treatment	Mulch Treatment		Tillage Treatment	Mulch Treatment	Difference	SE	t	df	$p_{bonferroni}$
Mow and Cover	Straw	-	Mow	SMC	-1.5887	0.166	-9.5616	15.4	< .001
Mow and Cover	Straw	-	Mow and Cover	SMC	0.0436	0.166	0.2627	12.0	1.000
Mow and Cover	Straw	-	Till	SMC	-0.7697	0.166	-4.6326	15.4	0.011
Till	No mulch	-	Mow	SMC	-0.5753	0.166	-3.4625	15.4	0.121
Till	No mulch	-	Mow	Straw	-1.0172	0.166	-6.1217	15.4	< .001
Till	No mulch	-	Mow and Cover	No mulch	0.2281	0.166	1.3728	15.4	1.000
Till	No mulch	-	Mow and Cover	SMC	1.0571	0.166	6.3618	15.4	< .001
Till	No mulch	-	Mow and Cover	Straw	1.0134	0.166	6.0991	15.4	< .001
Till	No mulch	-	Till	SMC	0.2437	0.166	1.4665	12.0	1.000
Till	No mulch	-	Till	Straw	0.5127	0.166	3.0853	12.0	0.340
Till	SMC	-	Mow and Cover	SMC	0.8134	0.166	4.8953	15.4	0.006
Till	Straw	-	Mow	SMC	-1.0880	0.166	-6.5478	15.4	< .001
Till	Straw	-	Mow and Cover	SMC	0.5444	0.166	3.2764	15.4	0.178
Till	Straw	-	Mow and Cover	Straw	0.5008	0.166	3.0138	15.4	0.306
Till	Straw	-	Till	SMC	-0.2690	0.166	-1.6189	12.0	1.000

Post Hoc Comparisons - Tillage Treatment

Comparison							
Tillage Treatment		Tillage Treatment	Difference	SE	t	df	$p_{bonferroni}$
Mow	-	Mow and Cover	1.609	0.0959	16.77	4.00	< .001
Mow	-	Till	1.095	0.0959	11.41	4.00	0.001
Till	-	Mow and Cover	0.514	0.0959	5.36	4.00	0.018

Post Hoc Comparisons - Mulch Treatment

Comparison							
Mulch Treatment		**Mulch Treatment**	**Difference**	**SE**	**t**	**df**	**$p_{bonferroni}$**
No mulch	-	SMC	0.4776	0.0959	4.979	12.0	< .001
No mulch	-	Straw	0.4054	0.0959	4.226	12.0	0.004
Straw	-	SMC	0.0722	0.0959	0.752	12.0	1.000

Appendix 2 Field dimensions and planting details

- Field Area: 8.5m x 21m = 178.5m²
- Plot area: 1.5m x 6 m = 9m²
- Sub-plot Area: 1.5m x 2m = 3m²
- Row spacing: 45 cm
- In row spacing: 45 cm
- Plants per row in the treatment area: 2 m length/ 0.45 m plant spacing = 4.4 plants. Will do 4 plants @ 0.45m plant spacing = 1.8m (allows for buffer between treatments)
- Number of rows in treatment area: 1.5m width/ 0.45m row spacing = 3.333 rows. 3 rows
- Number of plants in treatment area: 4 plants * 3 rows = 12 plants.
- Number of plants for treatment areas = 12* 27 = 324
- Buffer: Long edges 21m x 2 =42m , Short edges 6.5m x 2 = 13m total: 55m/ 0.45m = 122 plants *2 rows = 244 plants
- Total number of plants 324 + 244 = 568

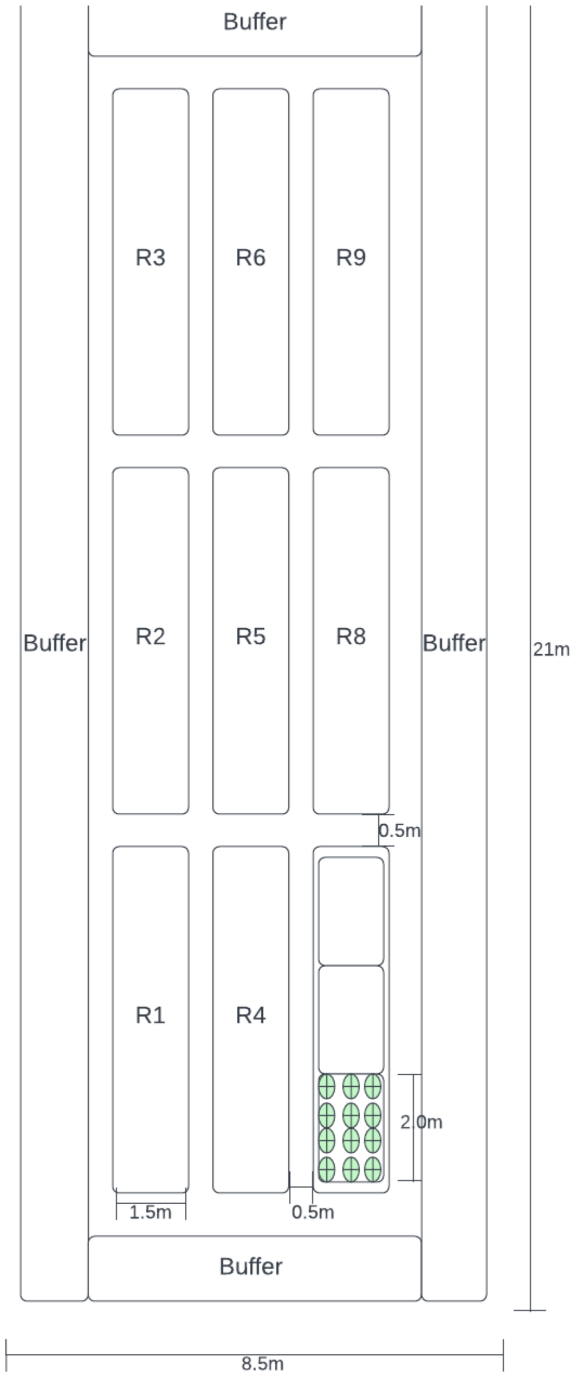

Fig. 1. The dimensional layout of the experimental plots. Each "R" is a tillage treatment plot which is 1.5m x 6m. Every plot is divided into three sub plots each with a different mulch treatment which are 1.5m x 2m. The total field area is 8.5m x 21m.
