Effects of Different Living Mulches on Weed Control and Biodiversity of Ground Beetles in a High-density Apple Orchard

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Abstract

In the organic fruit-growing industry, in-row living mulches have been used to enhance soil health and reduce weed coverage to achieve more effective orchard floor management. What is yet to be determined is which type(s) of living mulch is more effective as compared to other mulches, and more specifically, in Canada. This experiment was conducted on the Garden City land in Richmond, BC, Canada, during the summer of 2023. Using a randomized complete block design, this study aims to evaluate the effects of three different types of living mulch on suppressing weed growth and increasing biodiversity in ground beetles (Carabidea) in a high-density organic apple orchard. Results showed that although living mulch has an overall effect on suppressing weed coverage, Alyssum was the only one that showed a significant difference in weed coverage as compared to the control plot. However, the study failed to find significant results for the relationship between living mulch and increasing biodiversity of ground beetles.

Keywords: living mulch, weed suppression, biodiversity, ground beetles, Randomized Complete Block Design.

Objective:

Evaluate the influence of living mulches on weed suppression and ground beetle biodiversity in a high-density apple orchard.

Introduction:

One of the most important goals for all fruit farms worldwide is to increase yield while maintaining relatively lower costs. Many studies have been carried out to identify innovative ways to increase fruit tree yield. For instance, higher crop load was found to be associated with higher yield in apple orchards (Atay et al. 2021); A special irrigation method called 'Deficit Irrigation' was also found to have a positive impact on increasing yield among trees that have high tolerance for drought (Tong et al. 2022).

Orchard floor management, as an organic solution to achieve this common goal, has been one of the most popular topics in the research field. Orchard floor management is a system that aims to create optimal conditions for organic fruit tree growth and production by improving soil fertility, suppressing weed growth, and minimizing biotic and abiotic stressors (Skroch and Shribbs 1986). Living mulch can help achieve effective orchard floor management. Bhaskar et al. (2021) state that using living mulches can enhance the biodiversity of the agroecosystem, often leading to better weed management, and both perennial and annual species can be selected if they do not compete with the main crop for resources such as light and nutrition. Living mulch is also a more sustainable alternative to manage the in-row orchard floor compared to conventional practices such as replacing nondegradable plastic mulch or bare soil achieved through chemical use (Wang et al. 2022). Several species, including legumes and perennial herbs, have been evaluated for suitability for planting as living mulches. According to (Basinger & Hill, 2021), clover, an annualgrowing legume, is ideal for soil nitrogen fixing and reduce greatly weed abundance. Its low-growing habits also won't interfere with the growth of apple trees.

This specific research aims to compare the effect of three different types of living mulch on suppressing weed coverage and increasing biodiversity in organic apple orchards.

There are two sets of hypotheses in this experiment.

1) Null Hypothesis: Different living mulches do not have a significant effect on suppressing weed coverage in a high-density apple orchard.

   Alternative hypothesis: Different living mulches have a significant effect on suppressing weed coverage in a high-density apple orchard.

2) Null Hypothesis: Different living mulches do not affect the biodiversity of ground beetles in a high-density apple orchard.

   Alternative hypothesis: Different living mulches affect the biodiversity of ground beetles in a high-density apple orchard.

The significance of this experiment lies in its potential implications for orchard management practices in Canada. Canada has a long history of cultivating apples. With its unique weather and soil conditions, Canadian fruit growers have a strong need to understand which type of living mulch can lead to the most effective orchard floor management results. Shall we find significant results from this experiment, the findings can help growers choose more effective living mulch to help reduce weed growth, decrease labor costs, and reduce reliance on herbicides. The right type of living mulch might also be able to attract more beneficial insects like ground beetles and reduce pests that could damage the apple trees, benefiting both orchard management and environmental sustainability.

Materials and Methods

Experiment site

This experiment is conducted at the orchard on the east field of Kwantlen Polytechnic University's farm, located in the Garden City land, Richmond, BC, Canada (the red line on the figure below). The orchard was built in early 2023, and the poles were installed in April. Sixty apple trees were planted on April 24th and 26th, 2023. It consists of 4 varieties (Gala, Empire, Sunrise, Fuji), 15 trees per variety in an 80-meter row at 1.25-meter spacing.

Figure 1. *Satellite map of KPU farm in Richmond, BC*

Experimental design

This experiment used a Randomized Complete Block Design (RCBD) with four replicates and five treatments. The three types of living mulches studied in this experiment are Alyssum (*Lobularia maritima*), Micro clover (*Trifolium repens var.*) and 'Tip Top Alaska mixe' Nasturtium. (*Tropaeolum majus.*). Bark mulch and bare soil were included as control plots. The 80-meter row was separated into 20 individual plots, with each treatment plot measuring 2 meters by 2 meters in size.

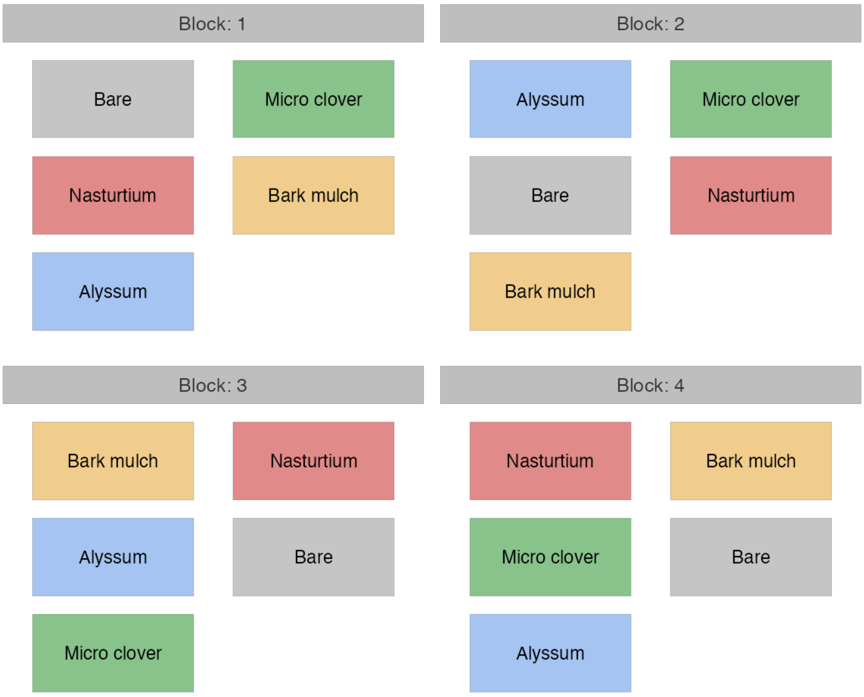

Figure 2. *Randomized Complete Block Design of the experiment. It consists of four replications and five treatments.*

Plot management

Before seeded, plot beds were tilled by BCS attached power harrow for preparation. Regularly hand-weed or implicate tools like weed wackers in the following weeks. All the treatment seeds are purchased from West Coast Seed. Seeds were broadcasted evenly on June 28th into designated plots; on the same day, bark mulch was put down at 3-4 cm depth. Two irrigation lines were pre-buried on each side of the apple trees, but the plots relied on hand watering during this study.

Data Collection

Weed coverage and ground cover percentages were collected using Canopeo on August 4th. It is an app used to measure the percentage of canopy cover of vegetation for every plot by taking downward-facing pictures before and after weeding.

Ground beetles were caught in pitfall traps on September 22nd, October 12th and October 26th. Beetles were stored in the freezer on the KPU farm and later used to calculate the species' biodiversity with the Shannon-Wiener index.

$$\text{Shannon Index (H)} = - \sum_{i=1}^{s} p_i \ln p_i$$

Statistically Analysis

Data collected from the experiment was analyzed using the ANOVA and mixed model in Jamovi.

Results

Statistical analysis has revealed a significant difference in the early-stage weed coverage among different treatments ($p \leq 0.05$), with the Alyssum and Bark mulch plots showing particularly distinctive results compared to the control group (i.e. Bare plots). The average weed coverage in the Alyssum plot is 20.9%, and 27% in the Bark mulch plot. Results showed significant differences in weed coverage between Alyssum plots and the control plots ($M_{Alyssum} = 20.9\%$; $M_{Bare} = 63.5\%$; $p_{tukey} < 0.05$). Significant differences were also observed between Bark mulch plots and the control plots ($M_{Barck\ mulch} = 27.0\%$; $M_{bare} = 63.5\%$; $p_{tukey} < 0.05$). Other treatments did not show a significant result compared to the control plots (Figure 3). (See Appendix 1)

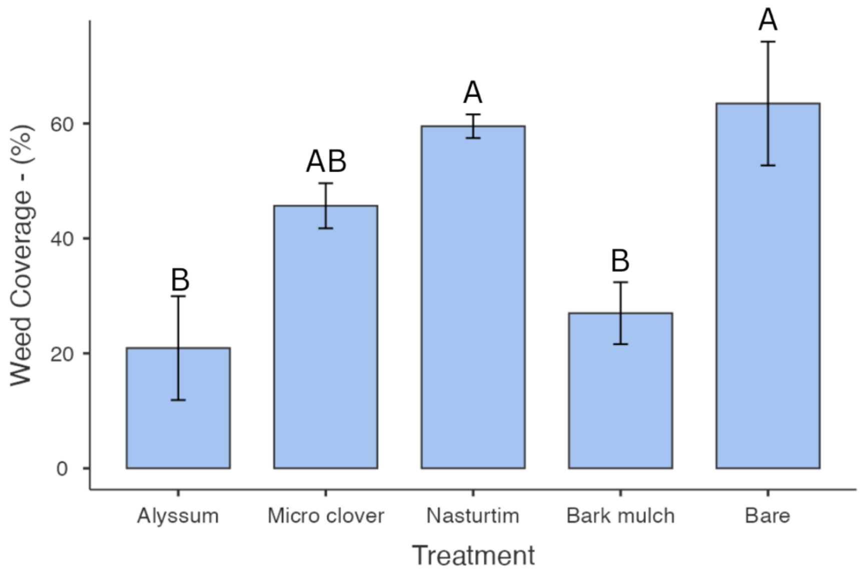

Figure 3. *The early stage of weed coverage in different treatment plots. Treatments have significant effects on weed coverage ($p \leq 0.05$). Error bars denote standard error.*

Results showed no significant differences in the quantity of ground beetles across different treatments (Figure 4). (See Appendix 1)

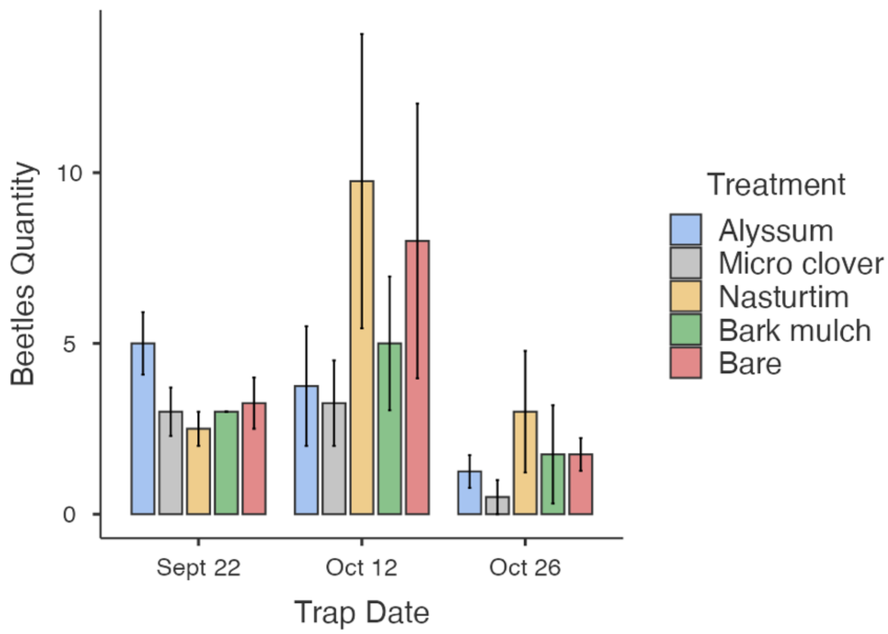

Figure 4. *The total number of ground beetles trapped in different treatment plots on various dates. There is no significant difference among treatment plots ($p < 0.05$). Error bars denote standard error.*

Six types of ground beetles (*Carabidae*) were found in the experimental site (figure 5).

Figure 5. *Types of ground beetles (Carabidae) found in the experimental site.*

Results showed no significant differences in the biodiversity of ground beetles across different treatments (Figure 6). (See Appendix 1)

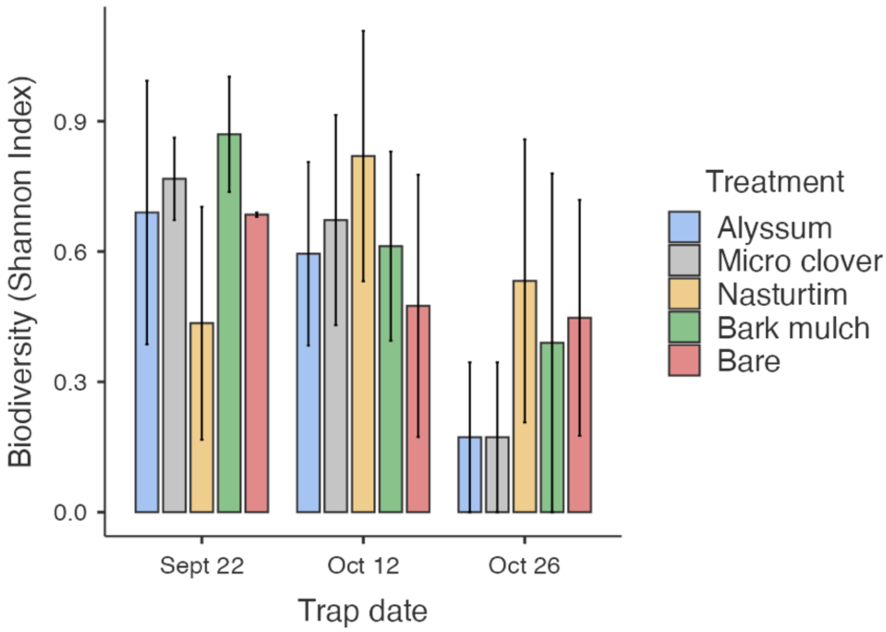

Figure 6. The biodiversity of ground beetles trapped in different treatment plots on various dates. Different treatment plots have no significant difference ($p < 0.05$). Error bars denote the standard error.

Results showed a significant difference in biodiversity between different trap dates ($p<0.05$) (Figure 7). (See Appendix 1)

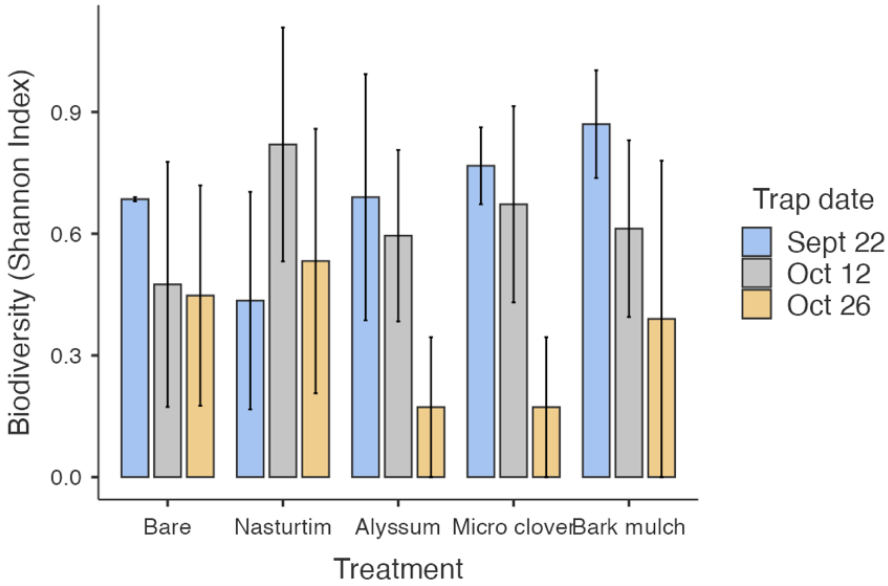

Figure 7. The biodiversity of ground beetles trapped in different treatment plots on various dates. Different tarp dates have a significant difference ($p < 0.05$). Error bars denote the standard error.

Discussion

Hypothesis 1

Planting living mulch in plots has a significant effect on suppressing weed coverage. The probability of observing the obtained results due to chance is less or equal to 0.05; therefore, the null hypothesis is rejected. Some treatments have a more significant effect than others when it comes to suppressing weed coverage.

Hypothesis 2

The existence of different living mulches failed to show any significant effect on biodiversity; thus, we failed to reject the null hypothesis. Even though the results showed a significant difference in biodiversity on different trap dates, this is probably due to the weather difference between the two trap dates, which should be considered an uncontrolled confounding variable.

Problems

There are several reasons behind the failure to obtain significant results. First, when hand-watering the plots without having a proper irrigation system, the water supply might vary in each plot. This unbalanced watering method might have influenced the seed germination rate and the growth of living mulches. One of the treatments, nasturtium, was germinating unexpectedly slow and might be the reason it does not help suppressing weed in the early stage. To mitigate this, future experiments could consider using more precise irrigation methods, such as using sprinklers that cover certain areas or setting up pre-buried drip lines or other automated irrigation systems to ensure equal water distribution to all plots.

Secondly, incomplete data collection can impact the accuracy of the result. When looking at weed coverage, the original plan was to take another measurement when all the living mulch had been fully established. However, the first frost strike knocked down all the nasturtiums on Nov 26. Only the data taken in June can be used for analysis. Even though there is still a significant effect of weed suppression on each treatment, the lack of data sets might be unpersuasive. Therefore, a more comprehensive data collection plan should be devised for future experiments to ensure the reliability of the result.

Moreover, this study has a relatively small sample size, which might limit the statistical power. In future research, a bigger sample size or larger plots will enhance the statistical power and more likely to reject the null hypothesis.

Further study

Implementing regular monitoring of experimental plots & irrigation systems, precise watering volume control, and collection data time is crucial for future studies. In addition, data collection should be carried out under similar weather conditions to minimize the influence of weather variability on results. These enhancements will contribute to future studies' reliability and scientific validity for better operation orchard floor management.

Conclusion

Establishing living mulches in a high-density apple orchard can effectively suppress weeds in the early stage. Alyssum and bark mulch are two treatments that stand out the most. Different living mulch types had no significant effect on ground beetle biodiversity.

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Appendix 1

Weed Coverage

ANOVA - Weed Coverage

	Sum of Squares	df	Mean Square	F	p
Treatment	0.433	4	0.1082	7.32	0.005
Residuals	0.148	10	0.0148		

Post Hoc Comparisons - Treatment

Comparison								
Treatment		Treatment	Mean Difference	SE	df	t	p_{tukey}	Cohen's d
Alyssum	-	Micro clover	-0.2477	0.0993	10.0	-2.495	0.168	-2.037
	-	Nasturtim	-0.3861	0.0993	10.0	-3.889	0.020	-3.175
	-	Bark mulch	-0.0607	0.0993	10.0	-0.612	0.970	-0.499
	-	Bare	-0.4256	0.0993	10.0	-4.287	0.011	-3.500
Micro clover	-	Nasturtim	-0.1384	0.0993	10.0	-1.394	0.644	-1.138
	-	Bark mulch	0.1869	0.0993	10.0	1.883	0.384	1.537
	-	Bare	-0.1779	0.0993	10.0	-1.792	0.428	-1.463
Nasturtim	-	Bark mulch	0.3253	0.0993	10.0	3.277	0.051	2.676
	-	Bare	-0.0395	0.0993	10.0	-0.398	0.994	-0.325
Bark mulch	-	Bare	-0.3649	0.0993	10.0	-3.675	0.028	-3.001

Note. Comparisons are based on estimated marginal means

Descriptives

	Treatment	N	Missing	Mean	Median	SD	Minimum	Maximum
Weed Coverage - (%)	Alyssum	3	1	20.9	17.5	15.66	7.22	38.0
	Micro clover	3	1	45.7	44.4	6.79	39.61	53.0
	Nasturtim	3	1	59.5	58.9	3.56	56.30	63.3
	Bark mulch	3	1	27.0	26.8	9.34	17.77	36.4
	Bare	3	1	63.5	58.5	18.65	47.83	84.1

Ground beetles' quantity

ANOVA - Ground Beetle quantity

	Sum of Squares	df	Mean Square	F	p
Treatment	171	4	42.7	0.731	0.585
Residuals	876	15	58.4		

Fixed Effect Omnibus tests

	F	Num df	Den df	p
Treatment	0.852	4	12.0	0.519
Trap Date	11.495	2	30.0	< .001
Treatment ✻ Trap Date	0.999	8	30.0	0.457

Note. Satterthwaite method for degrees of freedom

Post Hoc Tests

Post Hoc Comparisons - Trap Date

Comparison							
Trap Date		**Trap Date**	**Difference**	**SE**	**t**	**df**	**$p_{bonferroni}$**
Oct 12	-	Oct 26	0.925	0.194	4.78	30.0	< .001
Sept 22	-	Oct 12	-0.391	0.194	-2.02	30.0	0.158
Sept 22	-	Oct 26	0.534	0.194	2.76	30.0	0.029

Ground beetles' biodiversity

ANOVA - Biodiversity (Shannon Index)

	Sum of Squares	df	Mean Square	F	p
Treatment	0.143	4	0.0357	0.175	0.950
Replicant	0.958	3	0.3193	1.565	0.215
Trap date	1.389	2	0.6943	3.403	0.044
Treatment ✻ Trap date	0.953	8	0.1191	0.584	0.784
Replicant ✻ Trap date	2.583	6	0.4304	2.109	0.076

ANOVA - Biodiversity (Shannon Index)

	Sum of Squares	**df**	**Mean Square**	**F**	**p**
Residuals	7.346	36	0.2041		

Fixed Effect Omnibus tests

	F	**Num df**	**Den df**	**p**
Treatment	0.151	4	42.0	0.961
Trap date	2.937	2	42.0	0.064
Treatment ✻ Trap date	0.504	8	42.0	0.846

Note. Satterthwaite method for degrees of freedom