Weed Suppression Through Three Mulches (Subterranean Clover, Coffee Grounds, Newspaper/straw mix) on a Swiss Beet Chard Crop

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Abstract Studies have addressed the possibility of suppressing weeds through mulches by observing biomass measurements (dry weight) and density sampling. This study tests the effectiveness of three mulches (newspaper with straw mix, used coffee bean grounds and subterranean clover) in suppressing weeds for a silver beet chard crop. 16 outdoor subplots were divided into equal sizes and the three mulches were randomly assigned to 4 plots each. Silver beet chard was also planted to make the study more complete. The weeds were allowed to grow for a period of approximately 5 months. A density sampling was then taken in each plot. The weeds (including roots) were then pulled and dried in an oven. The biomass was weighed, recorded and combined with the density sampling results. Results show a greater degree of suppression for the plots with mulches in general. Specifically, the newspaper and straw mix suppress the weeds the greatest, for it blocks almost all incoming light. Light appears to be the greatest factor in promoting weed growth. Mulches that effectively block sunlight are the most successful. This conclusion is important for those in search of a mulch to control weeds, especially with a silver beet chard crop

Introduction

Weeds [any plant that is objectionable or interferes with the activities and welfare of man (Zimdahl 1993)] have been a problem in agriculture as far back as the inception of agrarian societies (Baloch 1993). Weeds require control, as they are harmful in three main respects. They lower yields of crop plants through competition, they increase agricultural costs and they reduce the health of animals, by competing with grazing crops (Zimdahl 1999). Weed competition with agricultural crops is of particular importance because they compete with crop plants for nutrients, water and light (Zimdahl 1999) and sometimes interfere with crop growth by releasing toxic substances in the rhizosphere (Rice 1984). In addition, weeds may also serve as alternative hosts for insect pests (Cheema 2000). In 1992, losses due to weeds in the USA and Canada were estimated at $4.1 billion (Bridges 1992).

The main method of weed control is by herbicide use (Hopkins 1994) which involve risks such as: contamination of ground and surface water, herbicide residues that may impact human and animal health, and the harming of already endangered plant species (Jordan 1996). Due to the adverse effects of herbicides on people and the environment, development of alternative methods of control are necessary (Kasasian1971).

Mulching is a relatively novel approach to weed suppression and control (Akobundu, 1980). Mulching works by excluding light and preventing shoot growth (Zimdahl 1999). Mulch is used most in high-value crops grown on small areas and in crops where mulch can be laid mechanically (Zimdahl 1999). Mulches are also used in greenhouses, where plants grow on a soil floor (Zimdahl 1999).

Several different materials have been used for mulching, including straw, hay, manure, paper, coffee beans, compost and black plastic (C. Vasilikiotis, 2000, personal communication). Living mulches such as clovers have also been used (Vrabel *et al*. 1980). To date, experiments on the relative effectiveness of mulches have not been extensive.

Pallett and Haleba (1995) evaluated use of chopped paper in a perennial nursery crop over two seasons. Their work showed that paper was an effective mulch that provided weed control for the seasons. The main drawback was the cost and application of the paper mulch, which will not be evaluated in this study. Enache and Ilnicki (1992) showed that subterranean clover has been shown to effectively reduce weed biomass in corn, sweet-corn and soybeans. Subterranean clover was the most promising cover crop in cucumbers and peppers in Georgia and contributed

to effective management of diseases, nematodes, and insects. (Phatak, *et al*. 1991). To date, no published scientific study has been done to compare the suppression capabilities of different mulches on a single crop.

The objective of this paper is to discover which mulch (coffee beans, subterranean clover or shredded- newspaper) is most effective at suppressing all weeds on a silver beet chard crop. The study assumes that all weeds compete with the crop, and thus all weeds should be pulled and considered as a whole, rather than individually identified (Schonbeck 1998). The measurement of weed biomass is the method that will be used. Specifically, this method is similar to one used by both Schonbeck, Browne, Deziel and DeGregorio (1991) and M.W. Schonbeck (1998) for weeds measurement. In addition, a density sampling method will also be used (J. Remais, 2001, personal communication). This study will include the use of a control (no mulch), too also see the relative effectiveness of the mulches as compared to none at all. This will serve as a secondary objective. The hypothesis is that the mulch in general will suppress weed growth more effectively than the control and that the clover will suppress weeds the most. This follows from conclusions drawn in past studies, in which authors were enthusiastic about the potential of clovers.

Similarities arise from other studies mainly in the mulch selected. Paper and subterranean clover have already proven to be effective players in weed management. No study has been done on the effectiveness of coffee bean grounds as mulch. In addition, silver beet chard has yet to be tested with these particular mulches. Previous studies have focused on corn, sweet-corn, soybeans, peppers and cucumbers.

Methods

Objective The objective of this project is to discover the effectiveness of three mulches (newspaper with straw mix, used coffee bean grounds and subterranean clover) on weed suppression for a silver beet chard crop. Weed biomass and density sampling will be used to determine the effectiveness of the mulches.

Study Site The study site is a section of land located at the Gill tract (Albany, California), operated by the University of California, Berkeley. The tract is home to many agro-ecology experiments. The climate in Albany is one of long dry summers and short wet winters. The temperature is fairly mild throughout the year (C. Vasilikiotis, 2000, personal communication).

The section of land for the experiment is located in the southeast portion of the tract where the soil within the section is uniform, as is the slope. Shading is uniform also, except on the northeast corner of the section, where shading from a eucalyptus tree may occur. Before tillage, the soil was covered (limited coverage) with a wild grass that has been incorporated into the soil matter. The land was not irrigated before tillage, however, rain has kept the soil moist.

Procedure The area was tilled on the 15th of November 2000. The experimental section measures 20x 7 meters. The section was divided into 16 equal rectangular plots, each measuring 2.5X3.5 meters (a walking path measuring 1/3 of a meter was also created down the center of the plot). The first four subplots on the South end were assigned 1st, 2nd, 3rd and 4th in a non-random fashion. This is to achieve even spacing and eliminate possible microclimate effects (Orr, 2000, personal communication). An Excel random generator determined the mulches place in these four plots. This process continued three more times until all plots were accounted for (Table 1).

1= Clover 2= Newspaper/Straw Mix 3=No Mulch 4 =Coffee Grounds

1	4
2	3
4	1
2	3
3	2
4	1
1	2
4	3

Table 1. Plot at the Gill Tract, Albany

Subterranean Clover The subterranean clover was obtained from the Stockton seed company (Stockton, California). In order to avoid competition for resources (i.e. water, nutrients, etc.) the clover will be planted before the silver beet chard. Once the clover reaches a size in which it will not compete with the chard for resources (approximately 10 cm), the seeds of the chard will be planted. During the clover growth period, all weeds will be pulled until all the mulches are laid down (C. Vasilikiotis, 2000, personal communication). On November 18th, 2000, the clover was planted. The clover seeds were distributed evenly over the 4 plots by hand. The plots were then

tilled lightly, to cover the seeds by a very thin layer of soil. Boards were then placed over the plots, and lightly stepped on, to compress the soil slightly to reduce dispersion through wind. The plots were than irrigated (see irrigation section below) manually (Ilnicki and Enache, 1992) (C. Vasilikiotis, 2000, personal communication).

Coffee grounds The used coffee grounds were obtained from various shops and cafés around the Berkeley and Oakland area (Café Estrada, Café Milano, Pete's Coffee & Tea, Starbucks etc.). Their composition was therefore a mix of many varieties. On November 28th, 2000, the grounds were poured over the plots, and evened to produce a uniform covering. Enough grounds were used to produce a 3 cm thick covering in each plot, which was necessary in case of loss from wind (C. Vasilikiotis, 2000, personal communication).

Newspaper/straw The newspapers were obtained from the Berkeley City recycling center (2nd and Gilman, Berkeley) on November 5th, 2000. Only unused newspapers were obtained. 2 layers of newspapers were laid down over each of the four plots completely (Pallett and Haleba, 1995). Each plot was then covered with one bail of straw, distributed evenly over the plot, to prevent dispersion through wind (C. Vasilikiotis, 2000, personal communication).

Control These plots were left un-mulched.

Silver beet chard Silver beet chard was ordered from the Peaceful Valley Seed Company. The seeds were allowed to germinate until they were approximately 4-5 cm in height. They were planted in early March in 24 holes measuring from 10 to 12 centimeters wide in each subplot.

Irrigation Irrigation of the plot was done manually by way of hose and nozzle. The nozzle is the Waterwand (by Alaska), and simulates a moderate rainfall. Each plot was irrigated evenly with three passes at maximum water pressure. The total irrigation time for each plot amounts to approximately 2 minutes. The time of watering varied upon the author and his associate's (J. Gawronski) schedule. It was usually between 11 A.M. and 5 P.M.. Irrigation took place once every 3 days. If heavy rains came, the watering frequency was reduced accordingly (C. Vasilikiotis, 2000, personal communication).

Density Sampling A legitimate technique for conducting a density sample on weeds could not be found. Thus, the methods were adopted through personal communication. Three measurement lines were placed equidistantly apart within each sub-plot. They were labeled 1,2,3 respectively. A square frame measuring 30cm^2 was used as a transect (C. Vasilikiotis, 2001, personal communication). Both the measurement line, and where on the line the transect was to

be placed, was selected randomly. Two samples were taken from each subplot, in which each weed root was counted and recorded (C. Vasilikiotis, 2000, personal communication). The numbers from each of these two samples was then combined. This procedure occurred for all 16 subplots.

Biomass Sampling All weeds were pulled during the final week of April, 2001. The experiment calls for a measurement of all weeds. Therefore, weeds were not identified, as it is unnecessary for the question this study is attempting to answer. The sampling procedure is modeled after work done by Shonebeck, Browne, Deziel and DeGregorio (1991).

Newspaper/Straw In April 2001, the straw and newspaper was removed. All weeds growing were pulled by hand. This includes both the root and stem. The extraction of the root required digging with a hoe in some instances. The weeds were placed in a bag labeled newspaper/mulch, plot 1 etc..

Coffee Grounds In April 2001, the weeds in the coffee ground plots were extracted in a method similar to above. The coffee ground was not completely dug up, as many weeds were strong enough to shoot up through the grounds.

Subterranean Clover Same procedure as above, however care was taken not to also pull the clover.

Control Same procedure as above.

The weeds were washed in a sink to remove all soil and coffee residues (Barbara, 2000, personal communication). The weeds were then placed in the Oxford Tract oven for 72 hours at approximately 55^{o}-70^{o} C (Shonbeck, Browne, Deziel and DeGregorio (1991). The weeds were removed from the oven and weighed on a scale. Values were recorded in g/m^2.

Statistical Techniques A comparison of the weed weight and density was analyzed through the Analyse-it (Microsoft) statistical program. This program contains the basic tests needed to determine significance. Specifically, a one-way ANOVA was used because there are four treatments and one factor (mulch type) that are being compared. The weed count from each subplot sampling was multiplied by the total weight of the biomass from the subplot (J. Remais, 2001, personal communication) and divided by 100. These numbers served as the final data.

Results

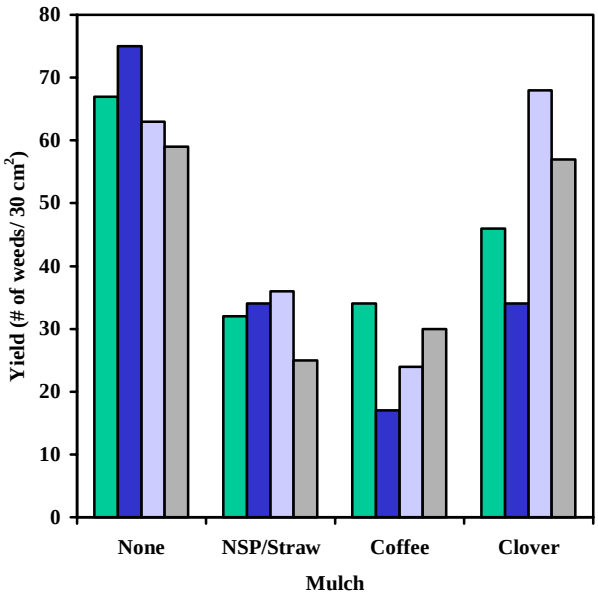
The weed density results showed that the coffee ground plots possessed the least total weed count (Graph 1). Increasing in count, this was followed by the newspaper/straw mix, clover and un-mulched sub-plots (Graph 1).

The biomass weighing produced slightly different results. The lowest weight of weeds were found in the newspaper/straw mix, followed by the coffee grounds, clover and un-mulched sub-plots (Graph 2).

When the data was combined (sampling data multiplied by biomass), the newspaper/straw mix possessed the lowest total and individual numbers (Graph 3).

As a whole, the mulched plots contained a significantly lower amount of weeds versus the control (One way ANOVA, $P < .0001$, Table 2).

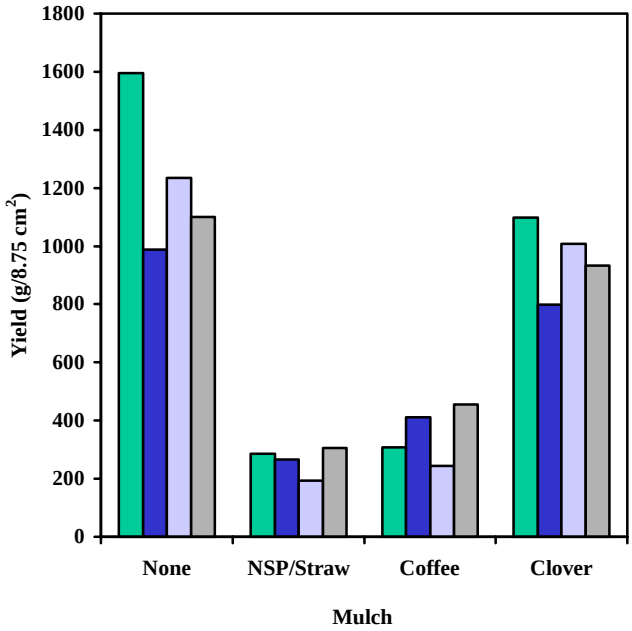
Individually, the newspaper/straw mix appears to be the most effective at suppressing the weeds, when compared against solely the control (Tukey Contrast, $P < .0001$, Table 2, Graph 3).



Graph 1. Effect of Mulches on Density

This was followed by the coffee grounds (Tukey Contrast, $P < .0001$, Table 2, Graph 3) and the clover (Tukey Contrast, $P < .0001$, Table 2, Graph 3).

When the mulches were compared against each other, only the newspaper/straw mix subplots and coffee ground subplots did not produce a statistically significant difference in the amount of weeds within each (Tukey Contrast, Table 2).



Graph 2. Effect of Mulch on Weed Biomass

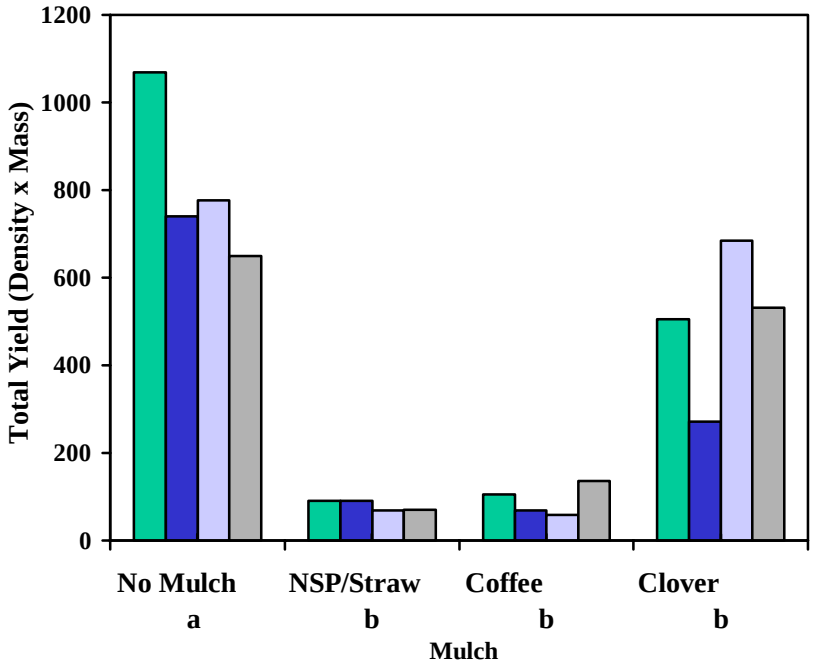


Table 3. Effect of Mulch on Weed Biomass and Density

n=16

SSq	DF	MSq	F	p
1476730.000	3	492243.333	31.05	<0.0001
190240.000	12	15853.333		
1666970.000	15			

Tukey				
Difference	95% CI		p	
406.000	141.673	to 670.327		(significant)
416.500	152.173	to 680.827		(significant)
-310.500	-574.827	to -46.173		(significant)
10.500	-253.827	to 274.827		
-716.500	-980.827	to -452.173		(significant)
-727.000	-991.327	to -462.673		(significant)

Table 2. 1 – way ANOVA. Effects of Mulches on Weed Biomass and Density

Discussion

From the data, the newspaper/straw mix is the most effective in suppressing the weeds, followed by the coffee grounds and the clover.

These results suggest two main points. First, the mulches as a whole were expected to reduce the weeds significantly, and indeed this occurred. Second, in comparing individual mulches, the clover does not appear to be as effective as originally predicated from past studies (Enache & Ilnicki 1992, Vrabel *et al*. 1980). However, it still does reduce the weeds enough to make it statistically significant when compared to the control alone.

Straw and newspaper mix shows the greatest potential to reduce weed counts, from the combined biomass and density results. Most past studies have used these mulches independently. However Schonbeck (1998) showed that using both (2 layers of newspaper covered by

approximately 6 inches of hay) is twice as effective in suppressing weeds than when used separately. Coffee ground mulch also has potential to reduce weeds from both the combined biomass and density results. No published study has tested the use of coffee grounds on mulches, so a comparison cannot be made. Thus, the mulches that provided a more "complete" covering appear to be blocking weed growth.

Possible explanations for these results may be found by understanding exactly how a mulch works. Mulching works by excluding light and physically preventing shoot growth (Zimdahl 1999). Both the coffee ground and newspaper/straw mix fit this weed-suppressing characteristic. In support of this, Shonbeck (1998) conducted experiments in which a complete blocker of light, black plastic mulch, proved to be more effective than newspaper/hay mix in reducing the weed amounts. Therefore it appears that the ability to block sunlight provides for a more clearer explanation of the results. The clover can only partially block light, and it definitely does not physically impede the stronger weed shoot. The benefit of using clover (or any other living mulch) however, is increased erosion control, reduced runoff, improved filtration, soil moisture retention, improved soil tilth and nutrient enhancement (Teasdale 1996).

The differences found between the coffee grounds and the paper/straw mixture can be explained only by speculation. The coffee ground is similar to soil in being soft. Weeds shoots are able to break through the layering. For the newspaper/ straw mix, a physical barrier was established that prevented weed shoots from successfully growing in additional to the greater blockage of light.

The coffee ground mulch may have other characteristics that help to keep the weeds suppressed, however. In addition to blocking light, coffee residues may possibly be seeping into the soil to lower pH, which can further inhibit weed growth. Reigosa (1999) showed that certain weeds do not grow well in acidic soils. However, further tests are necessary to see if there are truly allelopathic effects occurring.

Despite attempts at a legitimate controlled experiment, bias in the experiment may also have affected the results. Despite preventive measures, some mulch was blown into other subplots by the wind. Another bias may have been the additional shading effect of a large eucalyptus tree near the northeast corner of the plot, lowering the yield of the coffee mulch subplot close to it. In addition, seeds may have not been evenly dispersed in the plot to begin with. Another dilemma arose when some of the clover was occasionally mistaken for weeds and pulled. This will

decrease the projected effectiveness of the clover by increasing the biomass. Finally, additional human error (i.e. uneven watering, taking incorrect measurements from the weighing scale etc.) may have also biased the results of the experiment by either falsely increasing or decreasing the yield.

The implications of the results are useful mainly to farmers involved in small-scale vegetable productions. Mulches can be expensive, hard to find in great mass and time consuming in laying down (Schonbeck 1980). Further studies in the amount of labor involved in laying each of the respective mulches is necessary. Essentially, a cost-benefit analysis is necessary to see if the mulches are truly a "better" alternative to herbicides.

In conclusion, newspaper and straw mix appear to be excellent mulches, especially when used with vegetable crops like swiss beet chard. In addition, newspaper and straw mix is also effective, and the labor needed to lay the mulch is less than in coffee grounds. The need for many bales of hay for straw can become costly, however. Coffee grounds can also be utilized to suppress weeds. A bonus is that it can often be obtained in large amounts for free. The main drawback is the labor needed to collect the grounds. Subterranean clover is not as effective, but it still does suppress the weeds significantly. It is the least labor intensive of the three mulches and the seeds are inexpensive. In addition, it enriches the soil with nutrients.

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