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EVALUATING THE EFFECT OF WOODCHIPS ON SOIL MATRIC POTENTIAL, TEMPERATURE, WEED BIOMASS, AND YIELD OF SELECTED CROPS

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Abstract

Organic mulches are very popular for weed control in sustainable agricultural systems where the application of synthetic herbicides is restricted. A study was conducted to evaluate the effectiveness of organic mulch in controlling weeds, enhancing soil matric potential, and soil temperature. Blended hardwood mulch was applied to the soil surface at a thickness of 10 cm. The experimental design was laid out as a completely randomized design with two treatments, viz., mulch and no-mulch, replicated 5 times. Data were collected during the growing period for weed biomass, soil matric potential, soil temperature, and yield of selected crops. Results from a two-way ANOVA revealed that the mulch treatments significantly ($p \leq 0.50$) reduced weed biomass, and soil temperature while increasing the soil matric potential and yields of okra, tomatoes, squash, and basil. It was concluded that the use of organic mulch was beneficial for weed control and increasing crop yield.

Keywords: Organic Mulches, Weed Control, Soil Matric Potential, Soil Temperature

Introduction

Weeds are those unwanted plant species growing in an ordinary environment (Ahmad et al., 2016). They present a challenge to farmers or gardeners as they compete with crops for light, water, soil nutrients, pollinators, and space. One of the major constraints in organic crop production systems is weed control, a view that is commonly held by farmers, advisors, researchers, and even policymakers (Liebman and Davis, 2009; Penfold et al., 1995; Stonehouse et al., 1996; Clark et al., 1998; Turner et al., 2007). Concern over weed control is often cited by farmers as one of the major obstacles to conversion from conventional to organic farming (Beveridge and Naylor, 1999; Walz, 1999; Kristiansen et al., 2007). It is estimated that weed control can account for 30-50% of production costs on small, intensely managed farms (Kristiansen et al., 2007).

Farmers practicing conventional forms of crop production have more tools at their disposal to address weed control than organic farmers. Some of the methods of weed control available to organic vegetable growers include cover cropping, the use of organic herbicides, mechanical weed removal, soil solarization, and mulching. Cover cropping suppresses weeds through direct competition but some also provide allelopathic weed control (Haramoto and Gakkandt, 2004). Winter cover crops such as hairy vetch and crimson clover are established to compete with other plants that would otherwise become weeds during the growing season. Although important as a strategy to control weeds, cover cropping often requires several seasons before it can become effective.

Organic herbicides kill weeds that have emerged but often have no residual activity on those emerging subsequently. This makes them of limited use considering that they are only effective in controlling weeds when they are small and tender, but they are less effective on older plants (Lanini, 2010). Soil tillage remains one of the most important weed control strategies and although it can be quite effective at eliminating weed species, it can be very costly due to the many hours involved and expenses incurred in purchasing and maintaining the equipment needed. Tillage is also associated with a significant loss of soil organic matter and hence soil structure. According to Zheng et al. (2018), soil tillage can affect the stability and formation of soil aggregates by disrupting soil structure and weakening soil aggregates, causing them to be susceptible to decay.

Soil solarization is a weed control method involving a process of hydrothermal disinfestation and other physical and biological changes in soil (Stapleton and DeVay, 1986). It involves placing a clear plastic film over moist soil during periods of high air temperature, usually for 1-2 months to reduce or eradicate a number of soil pathogens and weeds (Stapleton and DeVay, 1986). However, soil solarization often reduces the growth of soil microflora which are beneficial to plant growth. The objective of the study was to evaluate the effectiveness of the application of chipped wood (organic) mulch on weed control plus additional benefits in soil including matric potential and temperature, and consequently its effect on yield for selected crops.

Literature Review

Mulching is a common weed control strategy that prevents weed growth and development by cutting off sunlight. Several materials can be used for mulching including plastic, fabric, and organic materials such as cardboard, straw, and wood chips. A study by Olkowski et al. (1981) showed that wood chip mulch can be effectively used to significantly reduce weed stands. According to Chalfer-Scott (2007), the advantages of using wood chips versus plastic mulch include improved soil structure, enhanced gas transfer, enhanced water infiltration and retention, prevention of erosion and compaction, provision of nutrients, suppression of pathogens and pests, enhanced beneficial organisms, increased biodiversity, neutralization of pollutants, reduction of economic loss, more visually appealing produce, and ease of application. Uwah and Iwo (2011) found that the application of organic mulch on coastal plain soils of southeastern Nigeria resulted in between 6 and 11 times less weed infestation compared to non-mulched control plots. Furthermore, the grain yield of corn was more than double that of the non-mulched control plots.

Ferguson et al. (2008) evaluated wood chip mulches from southern redcedar (*Juniperus silicicola*) and southern magnolia (*Magnolia grandiflora*) for their effectiveness in weed control in nursery containers. They found that wood chips from both southern redcedar and southern magnolia were as effective as a mixture in suppressing weed growth in nursery containers. Rathinasabapathi et al. (2005) evaluated the allelopathic potential of wood chips for weed suppression in horticultural production systems in the Southern US. Their research revealed that the growth of Florida beggarweed was significantly reduced by red cedar wood chips, and this was attributed to the allelopathic effect. According to Mia et al. (2020), wood chip mulch is suggested where the materials are available on or near the farm, and where there is a lower incidence of perennial weeds.

Soil matric potential measures how tightly or loosely water is held by the soil particles and has been a useful way to describe water status in a soil-plant system (Whalley, 2013). It is often measured using tensiometers or gypsum blocks and can be determined in various pressure units including cm of water, kPa, or Centibars. It is measured as negative pressure, hence the value of zero is the upper limit, presenting soil in saturated conditions, while the more negative the number the dryer the soil is. Organic mulches can alter the value of soil matric potential due to their impact on soil evapotranspiration. By covering the soil surface, mulching prevents water loss by evaporation, making it more available in the soil and hence lowering the soil matric potential. Research by Kader et al. (2017) found that seasonal soil moisture content under mulching treatments was the highest for straw and least for bare soil. The mulch acted as a buffer against extreme fluctuations in soil moisture.

Soil temperature, which is often measured using a soil temperature probe, plays a direct role in crop growth as it influences many physiological processes such as seed germination, growth rate, water uptake, and nutrient absorption, among other processes. Soil temperature is proportional to the intensity or amount of solar radiation absorbed by the soil surface directly, thus, covering it with a mulch can cause the soil temperature to be maintained at a relatively lower value compared to that of uncovered soil. Kader et al. (2017) found that mulching treatments, compared to the control lowered soil temperature by 2 °C at 5 cm depth and by 0.5 °C at 15 and 25 cm depths. In addition, the organic mulch served as an insulator, protecting the surface soil from large temperature fluctuations.

Materials and Methods

Study Location

The study site was at the Neighborly Affiliations for Naturally Idealized Health (NANIH) Farm and Garden, Inc. located in Richmond, VA, on latitude 37°31'26.8"N and longitude 77°19'19.7"W. The farm was founded in 2013 with the objective of growing various vegetables, fruits, herbs, and flowers. The operation includes both annual and perennial plants and uses organic production practices. While not certified organic, the farm markets itself as an ecologically friendly, local permaculture farm, and follows organic standards as laid out by the National Organic Program.

Experimental Design

The experimental design was a completely randomized design with two mulch treatments and control, replicated 5 times. Thus, a total of ten experimental plots, each measuring approximately 1.22 m by 15.20 m or 18.54 m^2 were established. The treatments were shredded hardwood bark applied at a depth of 0.10 m and control (no mulch). All plots were rain-fed with no supplemental irrigation. The soil matric water potential was measured using gypsum blocks installed at a depth of 0 - 0.10 m and connected to a data logger. The soil temperature was measured using a soil temperature probe inserted at a depth of 0 - 0.10 m. Each of these parameters was recorded on a weekly basis.

Multiple vegetables and herbs were planted including tomatoes, basil, onions, zinnias, okra, kale, melons, cucumbers, and summer squash. Harvestable and marketable yields for each of these crops were recorded at harvest time for each experimental plot. Weed infestation was determined by monitoring the population density and identification of the species. This was accomplished by assigning visual scores of observed weed coverage on a scale of 0 (no weeds) to 10 (the entire plot covered by weeds). In addition, weed samples were collected on a 1.33 m^2 sample area (quadrat) of each plot, stored in a cooler, and eventually transported to a laboratory where the weight of weed biomass was recorded. Weed identification was also done to determine the most abundant weed species in each plot. Although the original timeline was to conduct the project from March to October to coincide with the spring and summer growing seasons, the project timeline was thrown off by wet weather which delayed the delivery of mulch materials. Thus, the mulch was laid from May through June and the first weed sample was collected at the beginning of July.

Each of the mulch-treatment plots was assigned a number from 1-10. In all cases, the control plot was situated next to the treated plot with the same vegetable, herb, or flower being grown. To enable for random sampling, plot numbers were typed on cards that were then inserted into a cardboard box. The box was then shaken, followed by picking the cards at random. The number on the card was then matched on a corresponding plot map. A sample from the chosen area was taken by placing the quadrat over the sample area and picking all the weeds present in the framed area. The samples were taken on a weekly basis for 12 weeks.

Results and Discussion

The most dominant weed species at the research site were: broadleaf plantain (*Plantago major*), chickweed (*Stellaria media*), annual bluegrass (*Poa annua*), Crabgrass (*Digitaria sanguinalis*), Johnsongrass (*Sorghum halepense*), yellow foxtail (*Setaria glauca*), and southern crabgrass (*Digitaria ciliaris*). For each of the research plots, the average weed mass (g) was significantly lower ($p \leq 0.5$) for the plots treated with organic mulch compared to the control plots (Figure 1). For those treated with mulch, the weed biomass ranged from a minimum of 19 g/m^2 to a maximum of 245 g/m^2, with an average of 137 g/m^2. For the control plots, the weed biomass ranged from a minimum of 116 g/m^2 to a maximum of 459 g/m^2, with an average of 286 g/m^2. These results clearly revealed the potential benefits of the addition of the organic mulch in reducing the weed biomass.

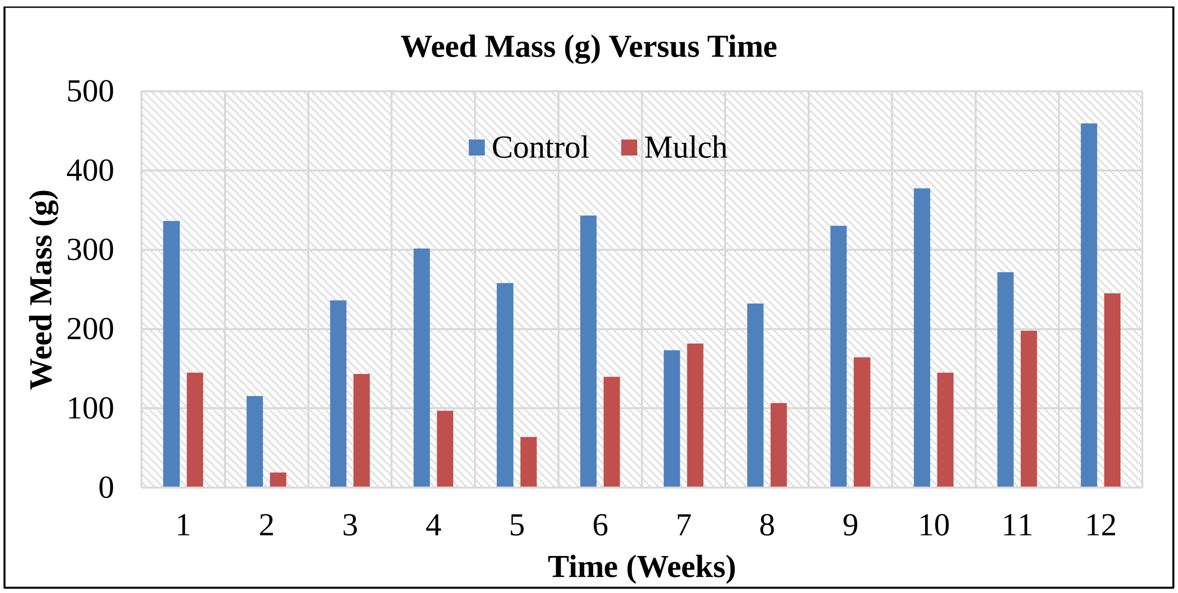

Figure 1. Average Weed Mass for the Control vs those Plots Treated with Mulch

The visual assessment of the experimental plots showed that those with organic mulch had observable weed suppression compared to the control plots (Figure 2). During the experimental period, the observed average weed coverage was 26.5% for the plots that were treated with mulch, compared to 67.2% for the control plots, meaning the organic mulch reduced weed infestation by about 40%. These results were comparable to findings by Skroch et al. (1992) who report that organic mulches reduced total weed counts by 50% compared to control plots. However, our results for weed suppression were relatively lower than those reported by Massa et al. (2019), which showed organic mulches reduced the presence of weeds by roughly 70% on average. It should be noted, however, that Massa *et al.* (2019) applied a hydro-compacting organic mulch composed of organic fibers and biodegradable glue, which makes the product adhesive and persistent on the substrate surface.

Figure 2. Visual Assessment of the Weed Growth on the Mulch and Control Plots

Soil matric potential values were significantly ($p \leq 0.5$) higher for the plots treated with organic mulch compared to the control plots. These ranged from 0 to -10 kPa, with an average of -1.5 kPa for the mulch-treated plots, and from -6.5 to -10 kPa, with an average of -8.0 kPa, for the control plots (Figure 3). For both the mulch-treated and the control plots, it is apparent that the matric potential values were greater than those of soil at field capacity, which is reported as -33 kPa according to Rai (2017). This observation can be explained by the presence of hydric soil at the experimental site. A hydric soil is that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part of the soil (Soil Survey Staff, 1999). It was notable that during the experimental period the soil held sufficient water to support crop production without the necessity of supplemental irrigation. However, Létourneau et al. (2015) reported that maintaining the soil matric potential lower than −9 kPa, as in the case of the lower matric potential range for the control plots, could induce stress in plants.

The temperature was significantly ($p \leq 0.5$) lower for the plots treated with organic mulch compared to the control plots during weeks 2-4. The mean temperature for the mulch-treated plots was 26.7 °C compared to 30.1 °C for the control plots. During weeks 13-15, the mean temperature for the mulch-treated plots was 22.3 °C compared to 23.4 °C for the control. However, the temperature was comparable (mean = 25.2 °C) for both the treatment and control during the rest of the experimental period (Figure 4). During the experimental period, it is apparent that the mean temperature of the mulch-treated plots was very close to the optimum temperature range for okra, which according to Benchasri (2012) is 20-30°C. It should however be noted that for the tomato plants, the optimum temperature is reported to be 30 °C according to Went (1953), which would be closer to that of the control plots.

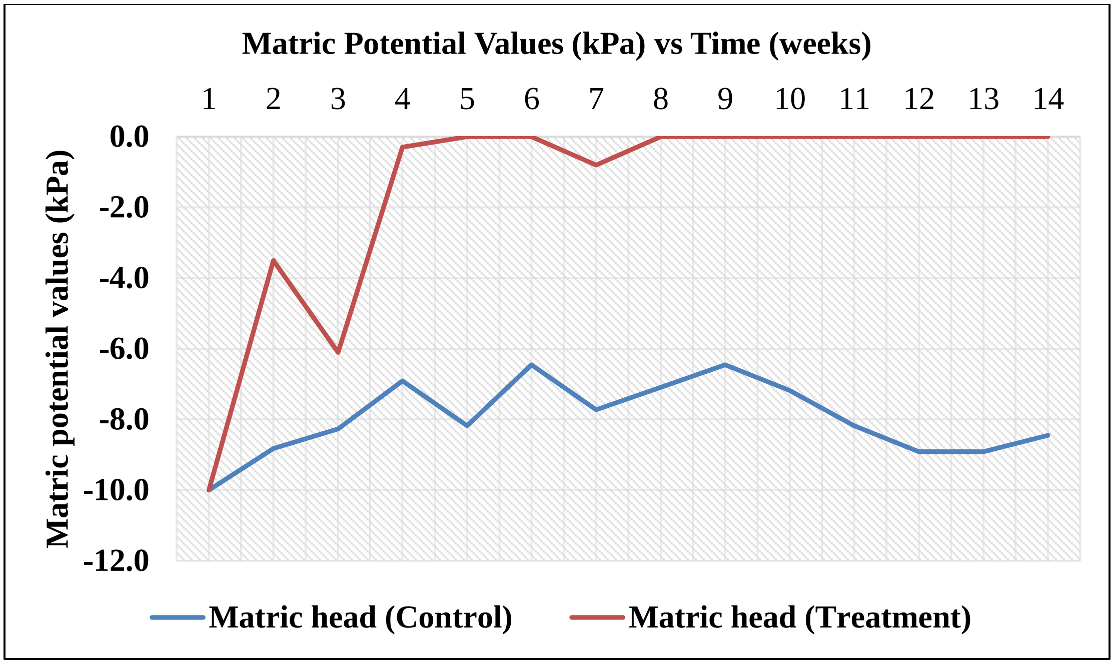

Figure 3. Matric Potential Values for the Control Plots vs those Treated with an Organic Mulch

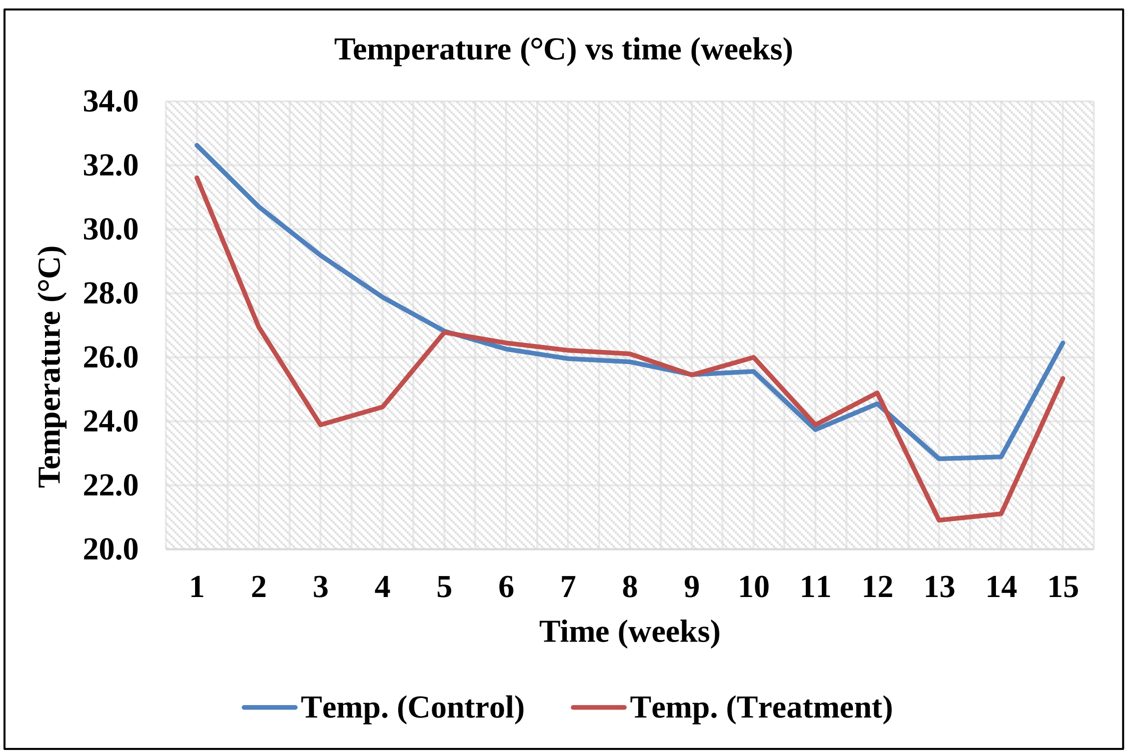

Figure 4. Temperature of the control plots vs those treated an organic mulch

The yield results for one of the test crops (okra) revealed the impact of applying the mulch treatment (Figure 5). The average okra yield was 5.88 Kg for the mulch-treated plots, and this was significantly ($p \leq 0.5$) higher compared to that of the control plots which was 4.98 Kg. It is apparent that the greatest impact of the mulch treatment was observed later in the season, at the 11th week of the study, compared to the beginning, as okra was being harvested weekly during the experimental period.

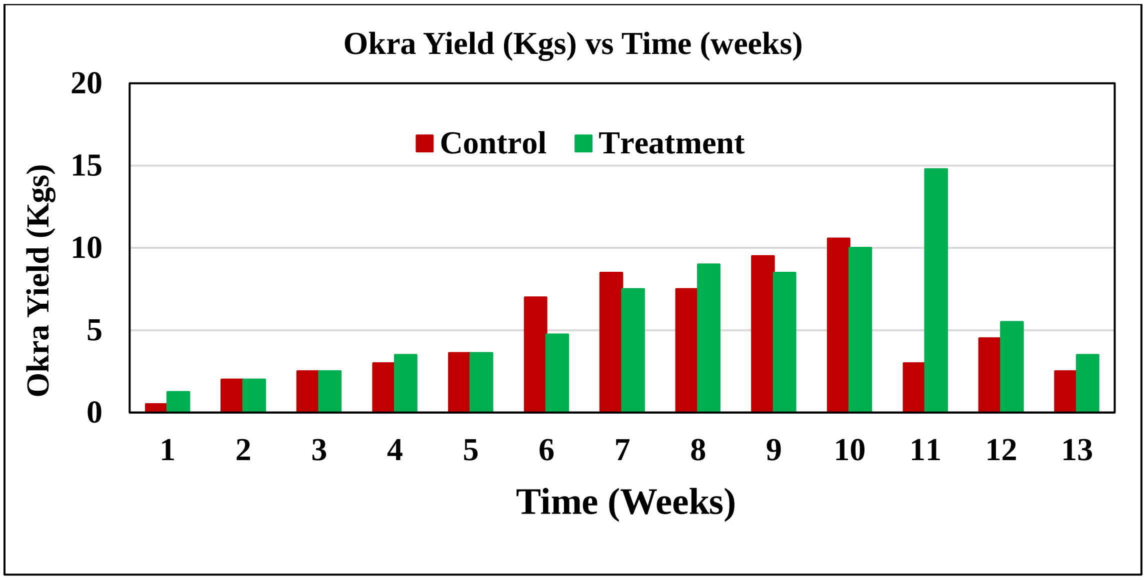

Figure 5. Average okra yield for the control vs plots treated with organic mulch

Using correlation coefficient, we compared our results of weed mass (g) for the mulch-treated plots with the visual weed index, determined as % weeds cover (Figure 6). The results revealed that there was a high correlation (r = 0.82) between the yield mass and the visual index (%), albeit with two outlier values. These results suggest that the visual index, a relatively easier method for determining weed infestation, can be used reliably in lieu of determining the weed biomass, which is relatively cumbersome and time-consuming.

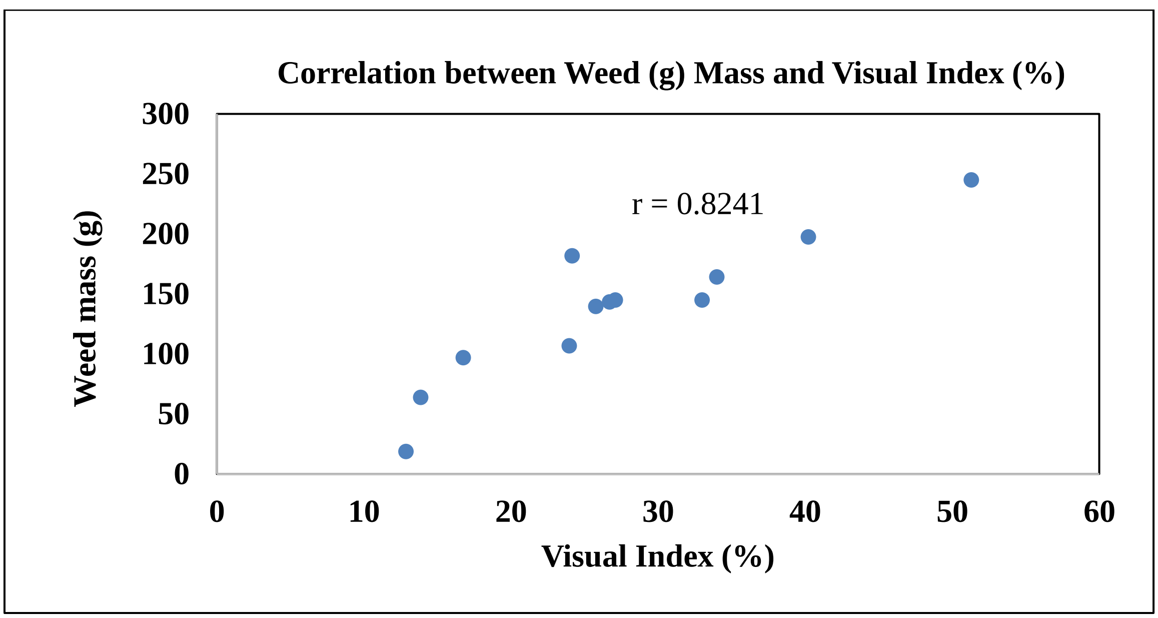

Figure 6. Correlation between the Weed Mass and Visual Index

The results for the weed index versus time showed that there was nearly a linear increase for both the control (R^2 = 0.8896) and mulch-treated plots (R^2 = 0.8649) (Figure 7). It is apparent that in both cases, weed proliferation continued with time indicating that the application of

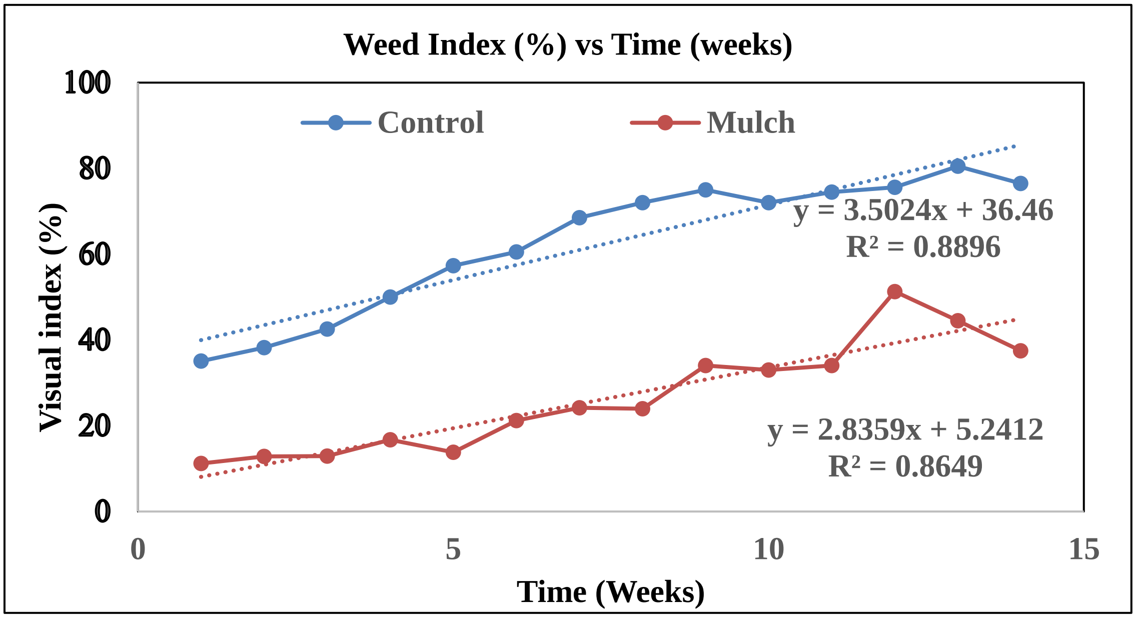

Figure 7. Regression of the Weed Visual Index over Time for the Mulch-Treated and Control Plots

mulch did not eradicate, but only served to suppress weeds. However, there was a significant reduction in % weed, by a factor of 1.3 as revealed by the gradient of 3.5 for the control plots compared to 2.8 for the mulch-treated plots.

Conclusion

Based on the results obtained from this experiment, it is notable that the addition of organic mulch suppressed weeds, which is a significant constraint in sustainable and organic systems. The organic much also increased soil matric potential, meaning that the plants grown in mulch-treated plots would experience a minimal risk of drought stress. The application of organic mulch also lowered the soil surface temperature, which can be of benefit to those plants that are not heat tolerant. Most importantly, the addition of organic mulch minimized weed infestation, and reduced competition for resources (nutrients, water, and space) with the cultivated crops leading to enhanced yields as observed during this research trial. The researchers recommend further studies on organic mulch application for different soil textural classes, varying the mulch thickness and timing of mulch application.

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