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The Effect of Three Different Mulches on Weed Presence, Soil Characteristics, and Zinnia Growth

Anmar Muttaleb

The Effect of Three Different Mulches on Weed Presence, Soil Characteristics, and Zinnia Growth

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By Anmar Abdulmohsin Muttaleb

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DATE APPROVED: ____________________________.

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Thesis Advisor

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Member, Thesis Committee

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Member, Thesis Committee

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Member, Thesis Committee

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Collegiate/School Graduate Coordinator

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Dean of the College/School

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University Graduate Coordinator

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Provost

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Abstract

Organic and inorganic mulching helps to control weeds. Mulching helps cultivated plants to grow by inhibiting the growth of weeds, retaining soil moisture, and regulating the temperature of soil. The objective of this study was to determine the effects of different organic mulches on weed presence, soil characteristics, and growth of *Zinnia elegans*. The mulches used in studying *Zinnia elegans* were wheat straw, non-shredded *Miscanthus* (*M.* × *giganteus*), and shredded *Miscanthus* (*M.* × *giganteus*) mulch. A Randomized Complete Block Design (RCBD) was used in the study, with different quantitative methods were used to collect data. ANOVA tests were utilized to statistically analyze data. The research found that shredded *Miscanthus* × *giganteus* was the most appropriate because it inhibited weed growth by depriving the weeds of sunlight required in seed germination and growth. The results of the study also showed a statistically significant difference between mulch treatments and the control, on *Zinnia elegans* growth. Non-shredded *Miscanthus* (*M.* × *giganteus*) together with wheat straw produced the highest macronutrient and micronutrient levels in the soil. Also, non-shredded *Miscanthus* (*M.* × *giganteus*) mulch stimulated *Zinnia elegans* growth by providing micro- and micronutrients and led to an increase in the stem diameter, length, flower sets, and the formation of flower buds. The conclusion of the study also indicated non-shredded *Miscanthus* (*M.* × *giganteus*) is a preferred alternative to wheat straw for gardeners. The limitations of this study included the possibility of different climatic conditions influencing various outcomes, the controlled setting as not representative of a real-life setting, and a generalization of results despite the study dealing with one type of plant.

Table of Contents

List of Tables

Tables of Figures

CHAPTER 1:

Introduction

Introduction

One of the most critical agronomic concerns is weed control. Particularly on organic farms, weed control can be done with other means than herbicides. Similarly, controlling weeds using herbicides is not encouraged in home gardens and landscape yards where children and other individuals often interact with the plants (Chalker-Scott, 2007). Alternative methods of weed control, such as mulching, are often used in place of herbicides. Mulching is a popular weed control method that has been used successfully in many countries (Amoghein, Tobeh, Gholipouri, Jamaati-e-Somarin, & Ghasemi, 2013). Both organic mulches and inorganic mulches are used, although the former is widely used in cropping systems because of its success in keeping weeds under control and reducing the need for soil tillage, as there are less weeds. Since temperature and soil moisture affect weed seed germination, mulch preserves soil moisture, maintaining higher levels of moisture as compared to soil without mulch (Teame, Tsegay, & Abrha, 2017). Mulches spread on soil surfaces lower average soil temperature during the hot season, thus keeping the temperature in the regular range during the growing season (Blazewicz-Wozniak, 2010; Forge, Hogue, Neilsen, & Nielsen, 2003).

Mulching is a vital part of good landscape management. In ornamental landscapes, mulching can be both decorative and functional. Mulching not only helps to shield the plant roots from frost, intense heat, and nutrient loss, but also aids in stabilizing the ecology by protecting the plants from stress, strain, and shock from various internal and external factors. The are many benefits of mulching, which include suppressing weed growth, maintaining soil moisture, preventing loss of soil water through evaporation, and buffering soil temperature (Ji & Unger, 2001). Mulches can also prevent traffic-, water-, and wind-induced compaction and erosion (Sinkeviciene, Jodaugiene, Pupaliene, & Urboniene, 2009). Lastly, mulches can increase crop production because they improve the soil quality by enhancing the physical and chemical properties of soil, which in turn enriches the biological activities of the soil. Therefore, mulching in ornamental or urban landscapes betters the soil quality and thus the growth of the plant (Marble, Koeser, Hasing, McClean, & Chandler, 2017). The mulches used in ornamental landscapes can be organic or inorganic materials. Organic materials include leaves, bark, or straw, whereas inorganic materials include polyethylene film, pebbles, and gravel. (Silva-Filho, et al., 2014). In general, mulches can provide aesthetically pleasing yet functional effects in ornamental landscapes.

Zinnia is an annual flowering plant that belongs to the *Asteraceae* family. Its Latin name is *Zinnia elegans* and its common name is Zinnia. This name is derived from a botany professor known as Johann Gottfried Zinn. There are about 20 species in the Zinnia genus, but only ten of these are suitable for the ornamental gardens (Carter & Grieve, 2010). The most popular species used in ornamental gardens is the *Z. elegans*. Other species that have received a lot of interest as ornamental plants include *Zinnia tenuifolia* and *Zinnia grandiflora*. *Z. elegans* is native to North America, found especially in Mexico. *Z. elegans*s are adapted to the hot, dry landscapes found in Mexico, and their flowers flourish most when subjected to full sun exposure (Chalker-Scott, 2007). They are also found in South America and have spread to many parts of the world, including Europe.

Z. elegans plants are renowned for their single, long-stemmed flowers that are available in many colors and hues. The variations in color include lilac, purple, pink, rose, red, white, orange, yellow, and multi-colored. These colors are attractive to butterflies, bees, and other pollinators. *Z. elegans* plant varieties come in both giant and miniature that range from around one foot to slightly over 3 ft. (91.4 cm) tall. They grow quickly, spreading up to around 2.5 ft. (76.2 cm) and reaching 2ft. (60.9 cm) in height, and they will adapt to various garden settings. In their country of origin, Mexico, they are grown and sold commercially as cut flowers and bedding plants. They are also economically important crops in the United States (Carter & Grieve, 2010).

Mulching is multifunctional as it is capable of controlling the nutrient level, absorbency, temperature and water level of the soil (Petrikovszki, Körösi, Nagy, Simon &Zalai, 2016). There are some basic requirements for mulch so that its use can deliver the effective results in agriculture. Mulch to satisfactorily destroy weeds sprouting in the soil underneath the mulch and creating a root structure. Mulch should also help conserve soil moister and improve nutrient obtainability as well regulate soil temperature (Manzello, Suzuki, Kagiya, Suzuki and Hayashi, 2014).

Various types of organic mulches have different effects on weed control, plant growth, and soil properties (Jodaugiene, Pupaliene, Urboniene, Pranckietis, & Pranckietiene, 2006). This study was carried out to determine the effects of different organic mulches on weed presence, *Z. elegans* growth, and soil properties. The organic materials that will be investigated in the study include wheat straw mulch, non-shredded

Miscanthus (non-shredded *M.* × *giganteus* mulch), and shredded *Miscanthus* (shredded *M.* × *giganteus* mulch). The plant under study is *Z. elegans*.

Statement of the Problem

Organic mulches have numerous benefits and add nutritional value to the soil through decomposition. Consumers have many options when choosing which organic mulch to use. Various mulches have differing effects on the soil, plant health, and weed control. This study evaluates the effects of three organic mulches on plant growth, soil properties, and weed suppression in a *Z. elegans* genus, as compared with non-mulched soil control

Purpose of the Study

This study will be carried out to determine the effects of different organic mulches on weed presence, *Z. elegans* growth, and soil characteristics. The study focused on the effect of mulch on plant vegetation, flower set, length and diameter of the stem, and date of formation of floral buds. In terms of soil properties, the study focused on how the mulches influence the general soil elements, such as phosphorus, potassium, calcium, magnesium, zinc, and soil pH.

Research Questions

1. What is the effect of the three different mulches on weed presence?
2. How does mulching affect the properties of the soil?
3. What is the effect of the three different mulches on *Z. elegans* growth?

Basic Assumptions of the Study

Some assumptions were made during the experiment. Some of these assumptions are that all three mulches will not be contain weed seeds before they are applied, repeated mulching due to decomposition will not be required during the experiment period, and all three mulches will suppress weeds. In addition to the three different mulches will improve plant growth and soil properties.

Hypotheses

H_{01}: There will be no difference in weed presence between the four treatments.

H_{R1}: There will be a difference in weed presence between the four treatments.

H_{02}: There will be no difference in soil properties between the four treatments.

H_{R2}: There will be a difference in soil properties between the four treatments.

H_{03}: There will be no difference in *Z. elegans* growth between the four treatments.

H_{R3}: There will be a difference in *Z. elegans* growth between the four treatments.

Delimitations of the Study

The study was conducted from June 2017 until December 2017 in Murray, Kentucky.

The following are delimitations of the study:

1. The study was limited to the same treatments throughout all replications.
2. The study was limited to three different mulches treatments (wheat straw, non-shredded *M.* × *giganteus*, and shredded *M.* × *giganteus*).
3. The study was limited to one variety of Z. elegans.

Limitations of the Study

There are several limitations in this study, which might affect the outcome. The first shortcoming was that it was not possible to determine the quantity of micro- and macronutrients in the mulches because chemical analyses of the mulches were not undertaken. The second limitation is a probability that nutrient uptake and release varies depending on the weather patterns, which is a variable that was not explored in the present research so, is that it is not clear whether different climatic conditions would achieve similar results as found in this study. Another limitation is that, since this experiment is controlled, it will likely not fully represent a real-life situation. Finally, this study is only dealing with one type of plant, so the results of different plant species in the four mulches could vary. In addition, this study is limited to the soil type(s) in the plot area.

Significance of the Study

The study aimed to determine the effect of varying mulches on the *Z. elegans* growth throughout the plant's growing cycle. The results of the experiment may help gardeners to understand the best mulch to apply and the positive impact that it will have on the plant. Having used four different methods of treatment in quantifying the effects of the mulches, the results may help to identify which mulch is the most useful for weed control. Analyzing the impact on the different factors studied was also done to provide advice to farmers regarding the optimum time to apply varying types of mulches (Mark, 2015). The research was conducted to analyze the effects of mulches on soil properties to identify the best mulch to enhance soil properties. Also, the research was conducted in order to analyze the effects of the weed population on the growth of the *Z. elegans* plant. This was completed in order to understand the amount of mulch that should be applied and the expected outcome of this application on the plant.

Definition of Terms

1. **Mulch**: Mulch refers to any material that is spread over the soil surface as a covering. It can be either organic or inorganic.

2. **Organic Mulch**: Organic mulch refers to a mulch material that readily decomposes over time, such as leaves, straw, hay, shredded bark, etc. (Rodale Inc., 2017).
3. **Inorganic Mulch**: Inorganic mulch is different from organic mulch because it is made up of inert materials that cannot decompose over time. Examples include gravels, plastic sheeting, rocks, etc. (Qin, Hu, & Oenema, 2015).
4. **Weed Control**: Weed control refers to the process of preventing growth or spread of unwanted plants. This can be done using various methods that can be classified as chemical, mechanical, and manual.
5. **Ornamental Garden/Landscape**: An ornamental garden is cultivated land intended for decorative purposes, or lands that are designed for aesthetic pleasure.
6. **Ornamental Plants**: Ornamental plants are grown for aesthetic pleasure in landscape design projects and gardens.
7. **Zinnia**: *Z. elegans* refers to an ornamental plant that belongs to the *Asteraceae* family.
8. **Soil Properties**: Soil properties refer to soil color, chemistry, porosity, structure, and texture, which are determined by the composition of soil elements, such as air, water, organic matter, and mineral particles (Ni, Song, Zhang, Yang, & Wang, 2016).

Chapter 2

Review of Relevant Literature

Introduction

Weed management is one of most expensive processes in nursery manufacturing. However, this is necessary as weeds can reduce the value of crops (Campiglia, Mancinelli, Radicetti, & Caporali, 2010). Different methods were used in the past for weed control. For instance, herbicides serve as the main tool in weed control. However, there is a disadvantage of using these herbicides, as they cannot be used in every production situation (Altland & Lanthier, 2007). Also, there is a huge labor cost associated with this method of weed control along with an inferior production quality (Amoroso, Frangi, Piatti, Piatti, & Ferrini, 2010). For this reason, there is a need for alternatives to herbicides, which can be in the form of mulches.

Moreover, weeds in a *Z. elegans* bed ought to be controlled because they reduce the quality and quantity of flowers. If the flowers are grown to be harvested, the presence of weeds increases the time needed to harvest and increases labor costs. Hence, there is a need for mulching to control weeds and restrict soil splash on flowers and foliage from irrigation and rain (Singh, 2006). *Z. elegans* is also one of the multispecies plants used in ornamental landscapes because they produce seeds and flowers within one to two months after sowing (Sas-Paszt et al., 2014). *Z. elegans* provides an attractive visual display because the flowers bloom periodically throughout the summer.

Nonetheless, the ornamental gardens become unattractive after the flowering season, which necessitates regeneration of the landscape. This is one of the main reasons to use organic or inorganic mulch. For instance, gravel, pebbles, and stones are used in ornamental landscapes as a part of the garden design to make it more attractive (Duppong et al., 2004).

Mulching helps to improve the quality of soil, preserves the nutrients, protects them from environmental and external stress factors, and thus produces an overall healthier plant. It provides protection from animals as well (Maggard, Will, Hennessey, McKinley & Cole, 2012). Furthermore, mulching also helps to reduce the amount of fertilizer and pesticide applications, which are often harmful to the environment. However, the choice of appropriate mulch according to the environment, location, and weather is of great significance as it impacts the overall efficiency and cost of the mulching mechanism (Chalker-Scott, 2007). Mulching is one of the most important components of gardening as it not only helps in protecting the plant roots from frosting, intense heat, and nutrient loss, but also in stabilizing the ecology by defending the plants from stress, strain, and shock from various internal and external factors (Chakraborty et al., 2010). Mulching is a useful agricultural technique that is used by gardeners in many climatic zones. In this procedure, the soil is covered with organic or human-made material. The mulch can completely cover the beds or be used to fill in the space between the plant rows.

Literature Review

Mulching is important when maintaining the sustainability and suitability of soil (Mulumba & Lal 2008). Mulching is of great importance, as the equilibrium level of the soil's organic matter depends on the balance between input through plant residues and other biosolids and output through decomposition, erosion, and leaching (Mulumba & Lal, 2008). Mulching also helps in reducing the impact of crop and plant residues that can create fungal infections, molding, and other pest infestations of the plants. Observations have also revealed that mulching increases the porosity, drainage, and water capacity of the soil to keep the plants hydrated and protected in arid and dry climates. Moreover, it provides protection from winter frosts as well (Gill, McSorley, & Branham, 2011).

Mulches are an integral part of landscaping and farming because they have aesthetic, economic, and environmental advantages. Mulching is important in establishing the growth of trees for restoration purposes, requiring minimal care. In urban gardening and landscaping, minimal care is a requirement because of various reasons, such as variety in the aesthetic of gardens (Chalker-Scott 2007). A layer of mulch makes it possible for the soil to retain its structure and prevent the formation of a crust (Kasirajan & Ngouajio, 2012). Also, mulch prevents the soil from being washed away by water, allows the soil to retain moisture, and inhibits the growth of weeds. Mulch significantly reduces the necessity of irrigation and limits the need for loosening (Sultana, Kashem, & Mollah, 2015).

Moreover, covering of the soil surface with a layer of organic or inorganic materials, known as mulching, is used to reduce the evaporation of moisture, preserve the soil structure, and reduce sharp fluctuations in upper layer soil temperatures. Most mulching agents suppress the growth of weeds, and some slow the development of pests and diseases. There is also an aesthetic function to mulch, as plants that are placed in mulch made from bark, cones, and small pebbles look more attractive (Rajablariani, Hassankhan & Rafezi, 2012). Organic mulch has more advantages than inorganic mulch. One of these is that the soil structure improves, allowing the root system to develop better. Consequently, plants are provided with more nutrients. Under the mulch layer, no soil crust is formed. Mulch protects plants from erosion by surface runoff of water and reduces spraying during watering, which aids in the development of fruits and berries (Medina et al., 2009).

Types of Mulches

There is a wide assortment of mulch types accessible, which can be separated into two substantial gatherings: organic and inorganic. Organic mulches incorporate such things as hardwood chips, straw, grass clippings and pounded clears out. Inorganic mulches include black plastic films, landscape fabric, plastic sheeting, rock, and gravel etc.

Inorganic mulches. Most types of mulches are used to prevent weed growth and. Also, they do not decompose quickly. These include black plastic films, landscape fabric, plastic sheeting, rock, and gravel etc. These materials are placed on gardening beds to hold in soil dampness, thus shielding plants from drying out rapidly (Bananuka, Rubaihayo & Zake, 2012).

One of the inorganic mulches is black plastic film. This mulch increases the soil temperature by 1.5-2 C (Subrahmaniyan & Zhou, 2008). This is an important factor for the unstable mid-range climate, in which the summer is typically short. Also, film mulching reduces the evaporation of moisture, making the soil cooler on hot days. Thus, the black plastic film allows plants to better grow in the heat, in the cold, and in times of drought. This film prevents the growth of weeds in the soil (Kasirajan & Ngouajio, 2012). Also, it can be used for mulching squash and cucumber. It will protect the plants from weeds and reduce the frequency of watering. It has been shown that plants such as strawberry bushes, covered with a film, are more likely to yield high fruit content (Maggard et al., 2012).

Although there are many positive aspects to film mulch, such as how it can be removed at any point (Gill et al., 2011), there are also some disadvantages. For example, the soil under the black film can overheat and thus serve as a breeding ground for numerous insects, which can be damaging to plants. Unlike organic mulches, film mulch does not decompose, which is important for soil fertility. This factor makes many individuals first mulch beds with humus and cover with various non-woven materials, such as black film (Bananuka et al., 2000).

Another type or inorganic mulch is pebbles they do not rot and so are used on decorative flowerbeds. As they do not rot from year to year, it is difficult to add new plants as the pebbles must be moved. Therefore, it is burdensome to plant new crops, as the pebbles must be shifted and rearranged (Maggard et al., 2012). Moreover, each pebble is partially embedded into the soil, which can make it difficult to cultivate the land.

Organic mulches. Organic mulches are important for the plant and the soil itself. The mulches act as manure on decomposition, which provide the plant with nutrients. These nutrients are necessary for the soil itself and for the plants. The mulches also reduce the rate of weed seed germination, as the mulches do not provide necessary conditions for weed seed germination (Kołota & Katarzyna, 2013). The lack of sunlight to the weeds due to the mulch physically hinders the emergence of the weeds, thus preventing their growth. The mulches have a positive effect on the crop, as they enhance its growth and conserve the soil moisture. In some instances, they modify the soil temperature. To maximize the positive effects of mulch, it is necessary to know what type of mulch to use and the amount of mulch to use in planting.

One type of organic mulch to use is mowed grass. However, if the grass has been treated with herbicides, it cannot be used as mulch (Elhindi, El-Hendawy, Abdel-Salam, Elgorban, & Ahmed, 2016). Freshly mowed grass is rich in nitrogen and other substances necessary for plant growth. Mulch from grass promotes the enrichment of sandy soil with organic substances. In a temperate and cold climate, grass mulch is applied to thermophilic crops. Grass cuttings have a beneficial effect on the quantity and quality of the crop (Bananuka et al., 2000).

Moreover, straw can also be used as organic mulch. Strawberry bushes mulched with straw have four times higher of a berry yield (Medina et al., 2009). Furthermore, straw also preserves carrots, potatoes, and parsnips left in the ground for the winter, as it does not allow the soil to freeze and prevents soil compaction, which facilitates harvesting. Bulbs of winter garlic grow more efficiently under a layer of straw mulch. They are mulched in the autumn when the bulbs take root, and the straw is left until harvesting. Because of the straw covering, the quantity of weeds in the area is reduced by 30% (Subrahmaniyan & Zhou, 2008).

Moreover, another type of organic mulch is compost. Compost provides plants with materials necessary for growth. Live microbes of compost destroy soil pathogens, so composting mulches prevent the development of plant diseases. Two to three centimeters of compost on the surface of the soil protects plants against diseases more efficiently than any patented chemical fungicide (Gill et al., 2011).

Additionally, for mulching flowerbeds of perennial flowers, wood chips can be used. Mulch from wood chips suppresses weeds, protects the soil from overheating, and retains water. The chips are durable, and it takes at least a year for them to rot completely. Mulch from wood chips is ideal for tracks and is optimal for areas where the soil is rarely treated or dug (Duong, Penfold & Marschner, 2012).

Furthermore, another type of organic mulch that can be used is the needles of coniferous plants. Using needles of coniferous plants for mulch, even with a layer of 7.5 cm, does not lead to a change in the acidity of the soil. One example of a plant that is very responsive to the mulching of coniferous plant needles is coniferous forest raspberry, as its yield is increased by twofold when this type of mulch is used (Medina et al., 2009). By regulating moisture levels in the soil, straw mulch prevents the development of petal rot in tomato plants and protects them from anthracnose, leaf spotting, and early decay. This is because it acts as a barrier between fruit and pathogenic microbes in the soil (Campiglia et al., 2010). Mulching potatoes with a layer of straw 8-10 cm thick allows for the eradication of the Colorado potato beetle, as straw helps reduce soil temperature and makes it difficult for adult beetles to move. Potatoes are mulched with straw when leaves appear on the top of the plants. The yield of potatoes in the areas mulched with straw is 40% higher (Rajablariani et al., 2012).

Covering of the Soil Surface with a Layer of Organic or Inorganic Materials

Mulching can reduce the amount of watering needed and virtually eliminate loosening. With the use of mulch, weeds do not penetrate through the layer of mulch more than five centimeters.

Organic materials are converted into nutrients during decay. This increases the amount of humus and, accordingly, the fertility of the soil (Haapala, Palonen, Korpela, & Ahokas, 2014). Therefore, organic mulch is considered to be the most useful. However, when some types of mulch are rotting, nitrogen is taken from the soil and used in the process of decay. This occurs mainly in the rotting of sawdust, small chips, and bark. This lack of nitrogen has a negative effect on the development of the plant (Duong et al., 2012). Therefore, when mulching the soil with sawdust and other similar materials, it is necessary to layer the soil with manure, feces, or urea infusion.

Sawdust mulch contains tannins. When tannins are released into the soil, they restrict the development of plants. Therefore, sawdust should not be used when mulching gardens. However, the bark can be used for mulching coniferous plants. Tannins do not have a negative effect on coniferous plants, and they serve to acidify the soil, which is helpful for the growth of coniferous plants (Sharan, Kumar & Singh, 2013). Since coniferous plants grow slowly, the need for fertilizers is low. Also, when fertilizing the conifers once a year, they are provided with apt nutrition through bark mulching.

Mowed grass, hay, straw, and uprooted weeds are ideal mulch for row-spacing in gardens and with trees. The roots of trees are moderately deep, so they cannot be harmed by the microflora operating on the surface (Wei et al., 2015). As for gardens, they should be located in open, sunny place. This is so the grass clippings placed on the garden dry quickly, preventing them from decomposing at a fast pace. This process takes place more intensively in autumn when the rainy season begins. By this time, the plants in the garden are decaying and the residual materials are transformed into fertilizer for the upcoming season. Mulch is also beneficial in autumn and winter as it shelters the plant roots from frost (Haapala, Palonen, Tamminen, & Ahokas, 2015).

Moreover, manure compost is considered one of the best mulches. It is very nutritious for plants. Also, it is loose and does not form a crust on the surface. However, the manure is dark and therefore absorbs the light. This property of compost is beneficial for heat-loving plants. Under the trees, in addition to compost, it is useful to apply sludge. In addition to having almost the same beneficial properties as mulch, sludge protects the soil from erosion and preserves nutrients. The most important component of this is to choose plants that can withstand the shadow of the tree crown (Elhindi et al., 2016).

Summary of Literature Review

Mulching performs many functions within soil, although some mulches do not contain any nutrients and thus are not able to form humus (Kasirajan & Ngouajio, 2012). For example, gravel, crushed stone, and expanded clay are used as mulch but do not contain any nutrients. Of these, the expanded clay decomposes. After a few years, the clay breaks up into small pieces. Black film for mulching retains moisture efficiently and constrains the growth of weeds. However, this method hampers irrigation, which may be vital to the growth of the plant. To water, it is necessary to manually insert a hose in each slit in the film or to install a system that allows for a trickling of watering, which can be expensive and labor intensive. Moreover, slugs may gather under the film and damage the plant (Chakraborty et al., 2010). Overall, the biggest drawback of black film is that it can cause overheating of the soil in a particularly hot climate. With frequent heating, the film oxidizes and decomposes faster. Because of this, the film may not be suitable to be used in the next year. In contrast, organic mulches decompose after some time and contribute to soil wellbeing. This can be extremely useful, particularly if your dirt is lacking in nutrients. Mulch lessens winter damage and assists with weed control. Some mulch types, for example, cypresses or pine wood chips, perform exceptionally well in regard to the repulsion of ticks, gnats, and bugs (Bananuka et al., 2000).

Lastly, the best mulch for gardeners is reliant on various factors, such as the garden atmosphere, the type of soil and type of plants, individual inclination, and the spending plan. If the gardener is interested in enhancing dirt ripeness, they should select organic mulch that fulfills these requirements. Nursery workers wishing to keep their patio nurseries organic ought to be cautious as some of mulches may be contaminated with weed seeds.

Chapter 3

Materials and Methods

Methodology

The Information included in this chapter provides a detailed explanation of the steps used to execute the study and analyze the data focus on the use of the three different mulches to determine their effect on the number of flowers, length and diameter of the stem, and the date of formation of floral buds. The methodology is divided into the following sections: research design, subject selection, data collection procedures, data analysis procedures, and budget and time schedule.

Design

The experimental research design was Randomized Complete Block Design (RCBD). The main purpose of using this experimental design for the study was to obtain a numerical evaluation of the topic under study, which includes information regarding the effect of three different mulches on weed presence, soil characteristics, and *Z. elegans* growth. The data from the field experiment was examined to see the impact of three different organic mulches on weed presence, soil characteristics, and *Z. elegans* growth.

The Randomized Complete Block Design (RCBD) was used with three types of mulching materials. These included wheat straw, non-shredded *M.* × *giganteus*, and shredded *M.* × *giganteus*. Also, one design was completed without mulch to serve as a control. The complete randomized block design involved the use of six duplicates of each treatment arranged randomly in two columns, and eight rows are already set up. The experimental area had 24 plots, and each plot had an area of 8 ft. (2.44 m width) by 11 ft. (3.35 m length). The spacing between blocks and plots was kept at 4.92 ft. (1.5 m) and 1 ft. (0.30 m), respectively. Each experimental plot had 10 plants in one line in the middle of the plot. The spacing between plants was kept at 1 ft. (30.48 cm). Site preparation was done before the planting of *Z. elegans* and application of mulching. During site preparation, all plots were ploughed to remove all weeds with the use of the local plough. Then, the bed was cleaned, smoothed and leveled.

The experiment was designed to have 24 plots having treatments (T) as:

T1: Control (no mulch application).

T2: Wheat straw mulch of 2-in. (5.08 cm thickness).

T3: Non-shredded *M.* × *giganteus* mulch of 2-in. (5.08cm thickness).

T4: Shredded *M.* × *giganteus* mulch of 2-in. (5.08 cm thickness).

Mulches were applied on the research plots before 30 days of transplanting *Z. elegans* seedling. Wheat straw, non-shredded *M.* × *giganteus*, and shredded *M.* × *giganteus* were obtained from the Murray State University West Farm in Murray, Kentucky.

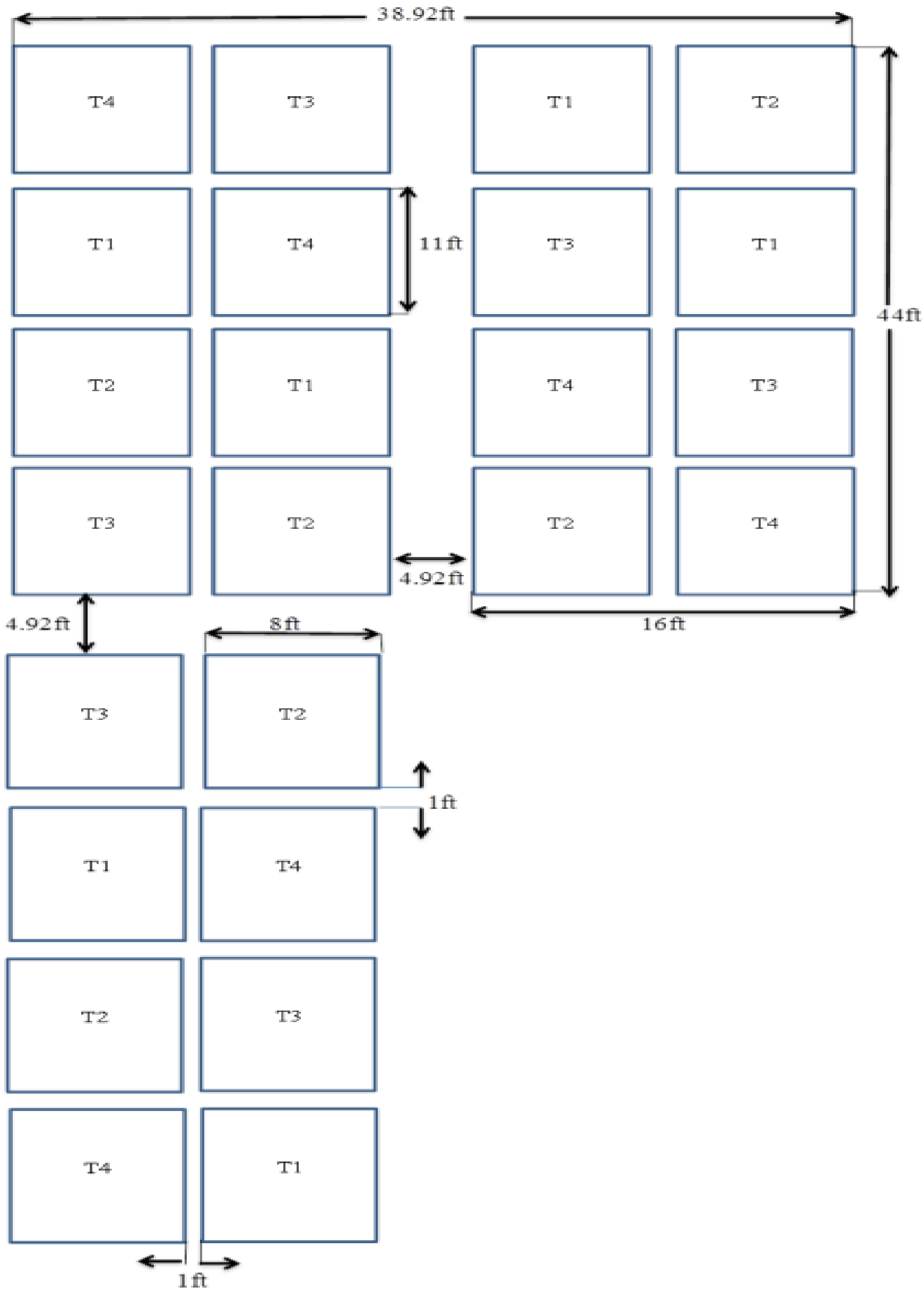

Figure 1. Layout of experimental plots

Figure 2. Layout of field before mulching

Figure 3. Layout of field after mulching

Variables

In this study, the dependent variables were weeds, 32 soil samples, and *Z. elegans*. The independent variables were three different types of mulches, including wheat straw mulch, non-shredded *M.* × *giganteus* mulch, and shredded *M.* × *giganteus*. Each variable was statistically analyzed to see if there was a relationship between the dependent variables and the independent variables.

Description of the Study Area

The study area was in Murray, Kentucky in the United States of America. Geographically, the plot was situated at 36°36′34″N 88°18′56″W (36.609494, −88.315656), which is 7 miles (11 km) north of the Tennessee border. Benton is 19 miles (31 km) to the north, and Mayfield is 24 miles (39 km) to the northwest. Murray has a humid, subtropical climate and four distinct seasons. The warmest month of the year is July, with an average high temperature of 90 °F (32 °C). The coldest month is January, with an average high temperature of 45 °F (7.2 °C).

The field experiment was conducted from July 2017 to November 2017 at an ornamental garden at a public university in Murray State University. The area is characterized as moist and sunny, and the topography is flat. Generally, the soil types are suitable for agricultural activities.

Sampling Procedure

The sampling procedure used for the study was experimental in nature. The experiment was carried out from July to November 2017 at an ornamental garden at a public university in Murray, Kentucky. The soil samples were collected in two different depths before and after the application of mulch measured at a depth of 0 - 2.95 in. (0 -

7.5 cm) and 2.95 -5.90 in. (7.5 - 15 cm), respectively. The soil samples taken at different depths were mixed into two composite samples to obtain a total of 32 soil samples, 16 soil samples before and16 soil samples after mulching, which were then sent to Kentucky university soil testing laboratory for routine soil testing.

The experiment was established in a split-plot design with 24 treatment plots, which were 11 ft. by 8 ft. each. The plots were set up using four treatment mulches: T1 = no mulch (control), T2 = wheat straw mulch, T3 = non-shredded *M.* × *giganteus* mulch and T4 = shredded *M.* × *giganteus*. The wheat straw, non-shredded *M.* × *giganteus* mulch, and Shredded *M.* × *giganteus* were obtained from the Murray State University West Farm in Murray, Kentucky. Mulch was applied to plots at 2 in. (5.08 cm deep) in all mulch applied treatment areas. *Z. elegans* seeds were started in 128-cell plug trays in peat moss.

The three 128-cell seedling starter trays were kept on a heater bed for 14 days at a temperature of 75°F (21.1 °C) to help the seeds germinate faster. After 14 days, the sprouted seedlings were transferred to another four 72 flats inside the greenhouse for 28 days. After 28 days, the *Z. elegans* seedlings were transplanted to the ornamental garden at Murray State University. 10 seedlings were placed in each bed at a spacing of 1ft (30.48cm). An irrigation system was established for watering the treatment plots by a water sprayer.

Instrument Selection

The instrument selection was used in the study to achieve the results of the study. To calculate the weed value in experimental design, the ERDAS Imagine image processing software program (version 16) was used to analyze the pictures that were taken from DJI drone (Dà-Jiāng Innovations) Phantom 4 Pro. To analyze the soil samples were taken from the plots before and after mulching, the glass electrode in 1:1 soil: water for pH, use of Sikora buffer for Buffer pH, Mehlich III extraction for nutrients was used for routine soil test at Kentucky university soil testing laboratory. To measure the length and the diameter of the stem, measuring tape and caliper was used; physical counting was used for date of formation when flowers were almost fully in bloom. All the variables were recorded in checklists and Microsoft Excel (version 2010) was used to analyze the data.

Validity and Reliability

For the statistical validity of experimental research design, each treatment ought to be replicated as in this case in this study. On the other hand, reliability will be enhanced by how consistently a repeated measure ANOVA calculates the characteristics being tested. Validity and reliability of this instrument was established in previous studies. According to Ni, Song, Zhang, Yang, and Wang (2016), soil characteristics are affected differently by different mulching treatments. This is consistent with other previous studies, which suggest that different mulches affect soil characteristics differently (Iles & Dosmann, 1999; Gleason & Iles, 1998; Singh, Gupta, Prasad, & Mohan, 1988). Ni, Song, Zhang, Yang, and Wang (2016) also indicate that different types of mulches do not affect some soil properties, such as pH and bulk density. Nonetheless, Sinkeviciene, Judaugiene, Pupaliene, and Urboniene (2009) indicate that the effect of different mulching treatments on soil properties and weed control differ a lot. Some types of mulches are considered better choice than others.

The growth of plants is also affected by different types of mulches, as indicated by previous studies. Chlorophyll, soluble sugar, root activity, trunk diameter and plant height are all affected differently by various types of mulches (Ni, Song, Zhang, Yang, & Wang, 2016). A study by Duppong et al. (2004) indicated different Catnip plant growth in various treatments. Some treatments provided better growth than others. Therefore, the growth of *Z. elegans* is affected differently by different treatment. Regarding weed control, previous studies have indicated that the effect of organic mulches on weed control is similar. According to Kosterna (2014), all types of organic mulches reduce weed emergence. In other words, organic mulches, irrespective of their type, lead to a decrease in the mass and number of weeds at the beginning of growing period of plants. However, the amount of mulch used matters, as different amounts of mulch used yields different effect (Kosterna, 2014). These results of previous studies suggest that the instrument used in this study will provide reliable and valid results.

Data Collection Procedure

Data collection is a crucial stage in research. In this study, a drone was used to measure the percentage of weeds after four months of weed germination and growth in the treatment plots. To measure the soil characteristics, two soil samples at different depths were taken from the plot before and after mulching. The collected soil samples were sent soil testing laboratory at the University of Kentucky to determine general soil composition and pH level of the soils.

A measuring tape was used to measure the length of the stem after five months of growth, while the number of flowers was measured by physical counting. An electronic Caliper was used to measure the width of the stem, while the formation of floral buds was measured by the difference between the date of planting and date of first formation of buds for every *Z. elegans* plant that was planted. All the data were collected and analyzed by appropriate statistical tools.

Data Analysis

All data was subjected to analysis through variance (ANOVA) tests, and the means were compared using treatment's t-tests by using Microsoft Excel version 2010. A repeated measures ANOVA test was performed for soil characteristics, the number of weeds, plant height, and trunk diameter to analyze the effect of three different mulches. Differences were considered significant at $p < 0.05$. A line chart was used to compare the general elements of soil samples before and after the mulching process.

Budget

The budget for this study was $1,250.00 and is broken down in the table below. The recommended funds were sufficient for the completion of the project

Z. elegans seeds	Cost: $20.00
Mulches (wheat straw, non-shredded *M.* × *giganteus, and* shredded *M.* × *giganteus)*	Cost: $100.00
Soil sample test	Cost: $100.00
Statistical Analysis	Cost: $1000.00

Time Schedule

This study was conducted over a five-month period. The first month of the study involved planting the *Z. elegans* seed and nurturing these in the greenhouse. Statistical analyses were used to conduct the study during the next four months. Statistical analyses were completed over the remaining two months, and the results of the study are presented here.

Chapter 4

Results

Introduction

This study aimed to determine whether the use of specific mulch treatments would enhance *Z. elegans* growth and soil properties while suppressing weeds. To determine how much different mulches affect the soil, a general soil test was used for the soil samples before and after mulching at two different depths. The first depth was 2.95 in. (7.5 cm) and the second depth was 5.90 in. (15 cm). The results included levels of zinc, phosphorus, potassium, calcium, Magnesium, zinc elements and the soil pH. The mulches used include wheat straw, non-shredded *M.* × *giganteus*, and on shredded *M.* × *giganteus.*

The result of Mulching on Weed Presence

Table 1, shown below, all plant had between 5388 cm^2 and 96542 cm^2 of weed cover.

The average plot area covered in weeds was 51,799.83 cm^2.

Table 1

Descriptive Statistics for Weed presence by Mulches

	N	*M*	*SD*	*Mdn*	*Min*	*Max*
T1	6	76,656.17	35,142.43	90,697.50	53,88	96,542
T2	6	45,703.17	10,423.19	49,244.00	29,356	58,171
T3	6	50,680.67	18,516.58	51,873.00	24,348	75,115
T4	6	34,159.33	11,282.13	34,563.00	16,466	46,435
Overall	24	51,799.83	25,429.87	47,633.00	5,388	96,542

Note. T1 = Control (no mulch), T2= Wheat straw, T3= Non-shredded *M.* × *giganteus*, T4= Shredded *M.* × *giganteus.*

The results of the ANOVA were statistically significant $F(3, 236) = 22.12$, $p < 0.05$. The ANOVA yielded a large effect size ($\eta^2 = 0.39$). Researchers ran post hoc analysis on the data. Independent t-tests were used to examine differences between groups. As such, the Bonferroni correction factor was used to adjust the alpha level for potential type one error. The alpha level for the post hoc tests was set at .05. Three of the four groups were not statistically different. Only control (T1) and shredded *M.* × *giganteus* (T4) were statistically different.

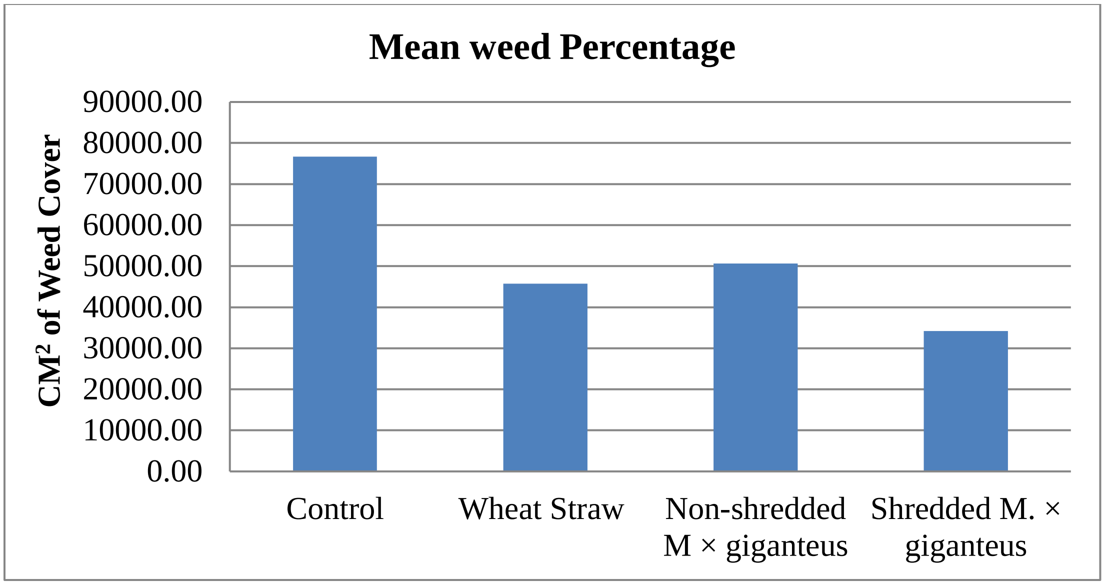

Figure 4. The average for weed presence by mulches

The Result of Mulching on Zinc at the First Depth

The line chart in figure 5 shows soil zinc level for each treatment before and after mulching at 2.95 in. (7.5 cm depth). The rate of zinc disintegration and uptake in the soil from the wheat straw (T2) increased at an increased rate 0.37% making it the most effective or highest contributor to soil zinc. This curve is steeper than the shredded *M.* × *giganteus*' contribution to the soil. The latter's curve is less stepper than the wheat straw making it the second contributor to the soil zinc at an increased rate 0.27%. The level of soil zinc increased in non-shredded *M.* × *giganteus* (T3) at rate 0.01%. Control (T1) had the decreased at rate 0.25% after the mulching process.

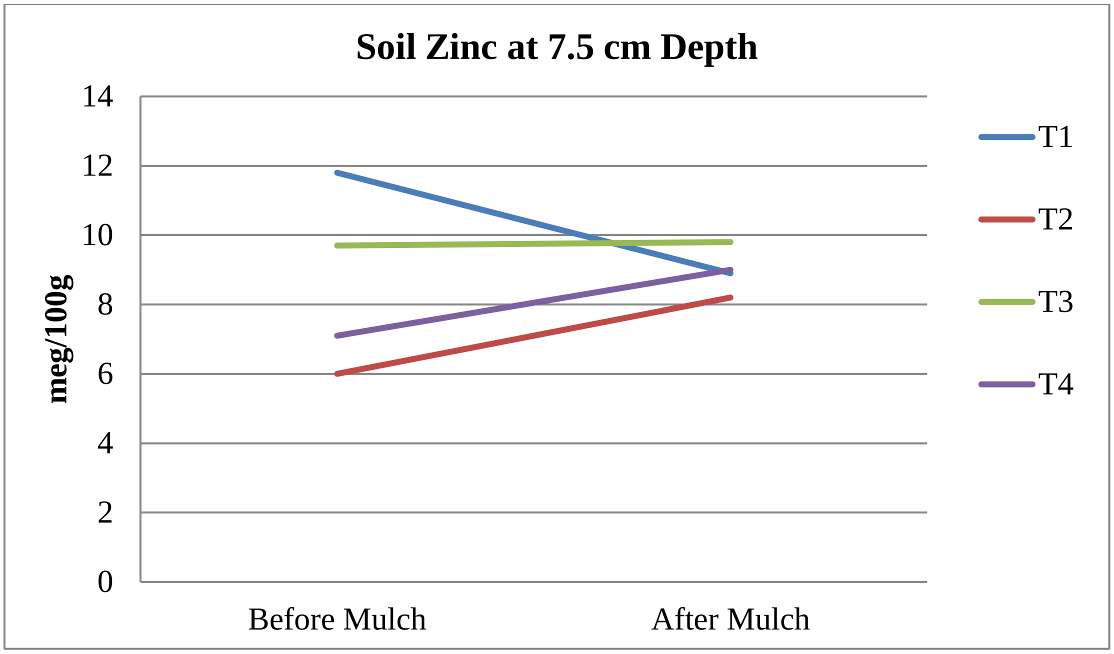

Figure 5. The effect of mulching on soil zinc at 2.95 in. (7.5 cm depth)

The Result of Mulching on Zinc at the Second Depth

The line chart in figure 6 shows zinc levels in the soil for each treatment before and after mulching at 5.90 in. (15 cm depth). Non-shredded *M.* × *giganteus* (T3) treatment decreased rate 0.12% making it the most disaffected to soil zinc. This curve is steeper than the wheat straw contribution to the soil. The latter's curve is less stepper than the non-shredded *M.* × *giganteus* making it the second disaffected to the soil zinc at rate 0.11%. %. Shredded *M.* × *giganteus* (T4) was the third disaffected of zinc to the soil after the mulching process at an increased rate 0.10%. The level of soil zinc decreased at rate 0.03% in control (T1).

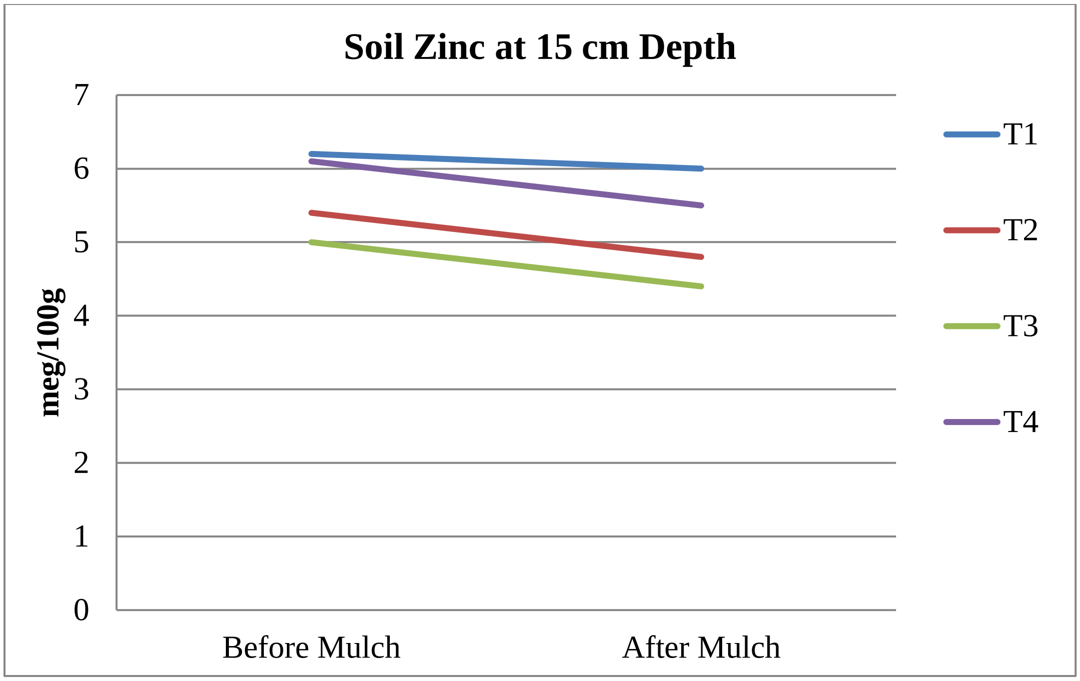

Figure 6. The effect of mulching on soil zinc at 5.90 in. (15 cm depth)

The Result of Mulching on Phosphorus at the First Depth

The line chart in figure 7 shows soil phosphorus levels for each treatment before and after mulching at 2.95 in. (7.5 cm depth). The rate of phosphorus disintegration and uptake in the soil from the non-shredded *M.* × *giganteus* (T3) treatment increased at a rate 0.67 %, making it the most effective at increasing phosphorus levels in the soil. This curve is steeper than that of the wheat straw mulch. The wheat straw's curve is less steep than the non-shredded *M.* × *giganteus*' curve, making it the second most effective at increasing phosphorus in the soil at 0.43 %. Shredded *M.* × *giganteus* (T4) was the third most effective at increasing phosphorus in the soil at a rate 0.06 %. Moreover, the level of phosphorus in the soil decreased at rate of 0.01 % in the control (T1).

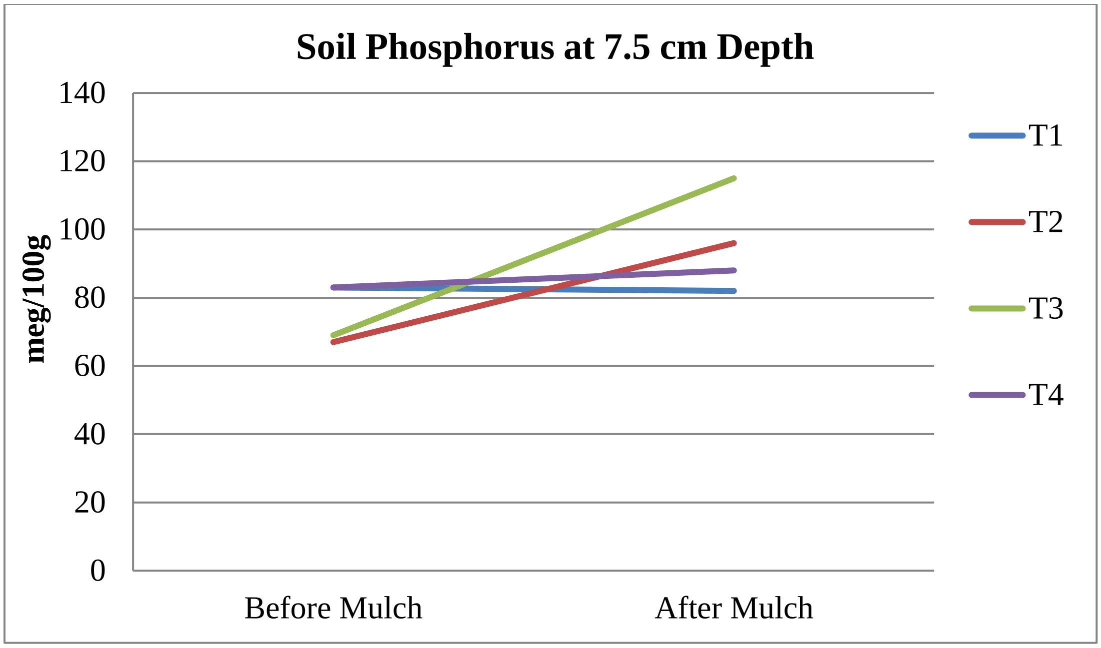

Figure 7. The effect of mulching on soil phosphorus at 2.95 in. (7.5 cm depth)

The Result of Mulching on Phosphorus at the Second Depth

The line chart in figure 8 shows soil phosphorus level for each treatment before and after mulching at 5.90 in. (15 cm depth). The rate of phosphorus disintegration and uptake in the soil from the wheat straw (T2) increased at a rate of 0.26 %, making it the most effective at increasing phosphorus levels in the soil. This curve is steeper than that of the non-shredded *M.* × *giganteus*. The latter's curve is less steep than that of the non-shredded *M.* × *giganteus*, making it the most effective at increasing phosphorous levels in the soil at a rate of 0.03 %. Furthermore, there were decreases in the amount of phosphorus in the soil in both the control (T1) and the shredded *M.* × *giganteus* (T4). The control (T1) had the steepest decline at a rate of 0.30 %, whereas shredded *M.* × *giganteus* (T4) had the second steepest decline at a rate of 0.13 % in the soil after the mulching process.

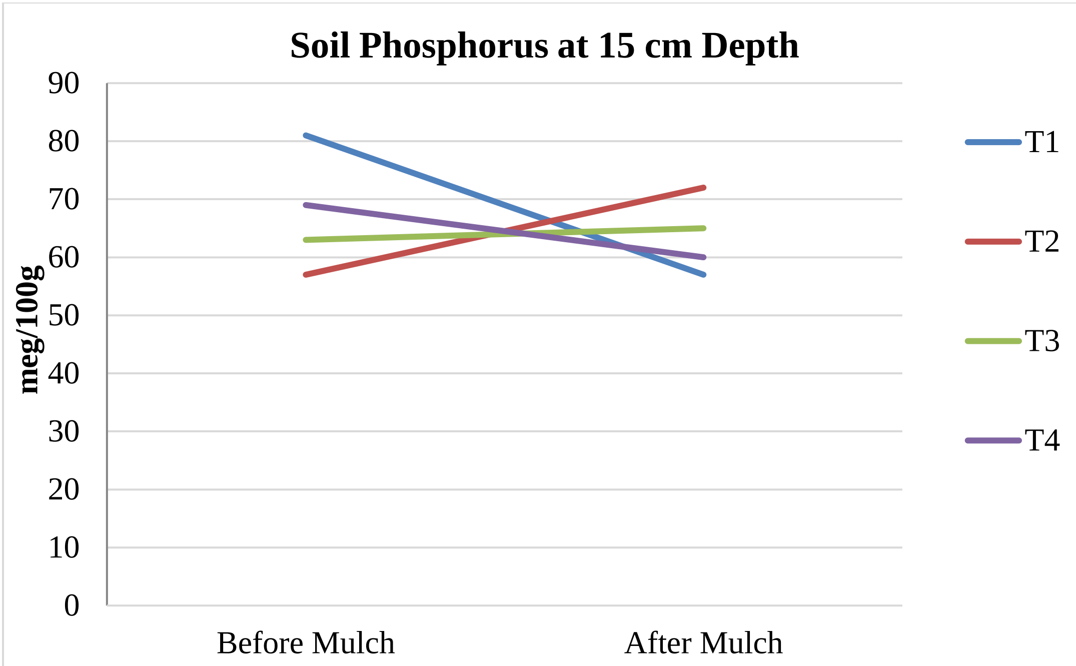

Figure 8. The effect of mulching on soil Phosphorus at 5.90 in. (15 cm depth)

The Result of Mulching on Potassium at the First Depth

The line chart in figure 9 shows soil potassium levels for each treatment before and after mulching at 2.95 in. (7.5 cm depth). The rate of potassium disintegration and uptake in the soil from the wheat straw (T2) increased at a rate of 0.32 %, making it the most effective at increasing potassium levels in the soil. This curve is steeper than that of the shredded *M.* × *giganteus* (T4). The latter's curve is less steep than that of the wheat straw, making it the second most effective at increasing potassium levels in the soil at a rate of 0.16 %. The control (T1) was the third most effective at increasing potassium levels in the soil a rate of 0.10 %. Non-shredded *M.* × *giganteus* (T3) was the fourth most effective at increasing potassium levels in the soil at a rate of 0.06 %.

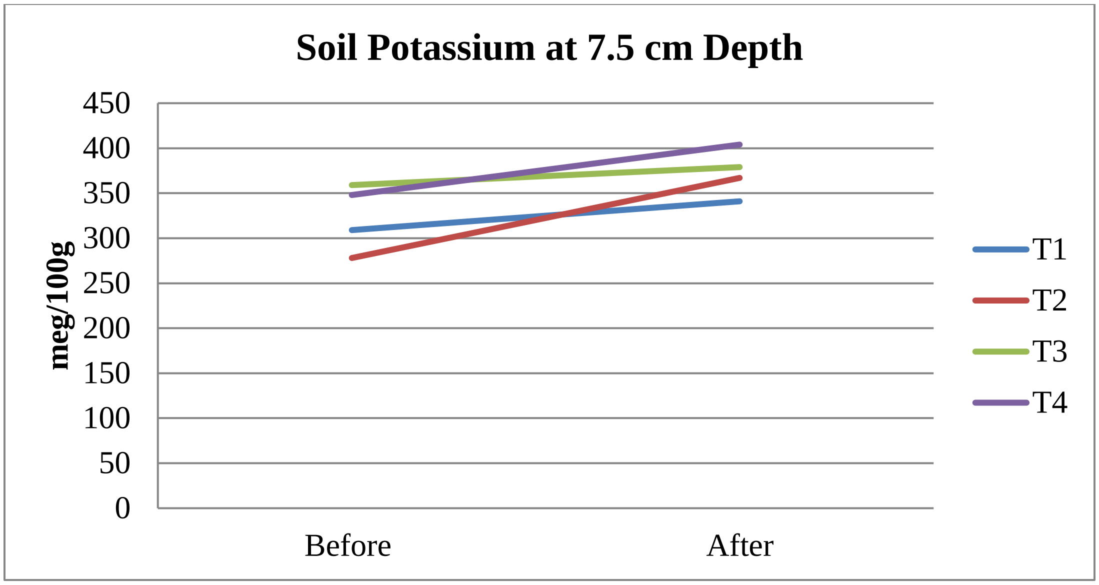

Figure 9. The effect of mulching on soil potassium at 2.95 in. (7.5 cm depth)

The Result of Mulching on Potassium at the Second Depth

The line chart in figure 10 shows soil potassium levels for each treatment before and after mulching at 5.90 in. (15 cm depth). The rate of potassium disintegration and uptake in the soil from the shredded *M.* × *giganteus* (T4) increased at a rate of 0.52 %, making it the most effective at increasing potassium levels in the soil. This curve is steeper than that of the wheat straw. The wheat straw's curve is less steep than that of the shredded *M.* × *giganteus*, making it the second most effective at increasing potassium levels in the soil at a rate of 0.16 %. Non shredded *M.* × *giganteus (T3)* was the third most effective at increasing potassium levels in the soil at a rate of 0.04 %. However, the control (T1) had a decrease in the rate of potassium in the soil at a declining rate of 0.20 %.

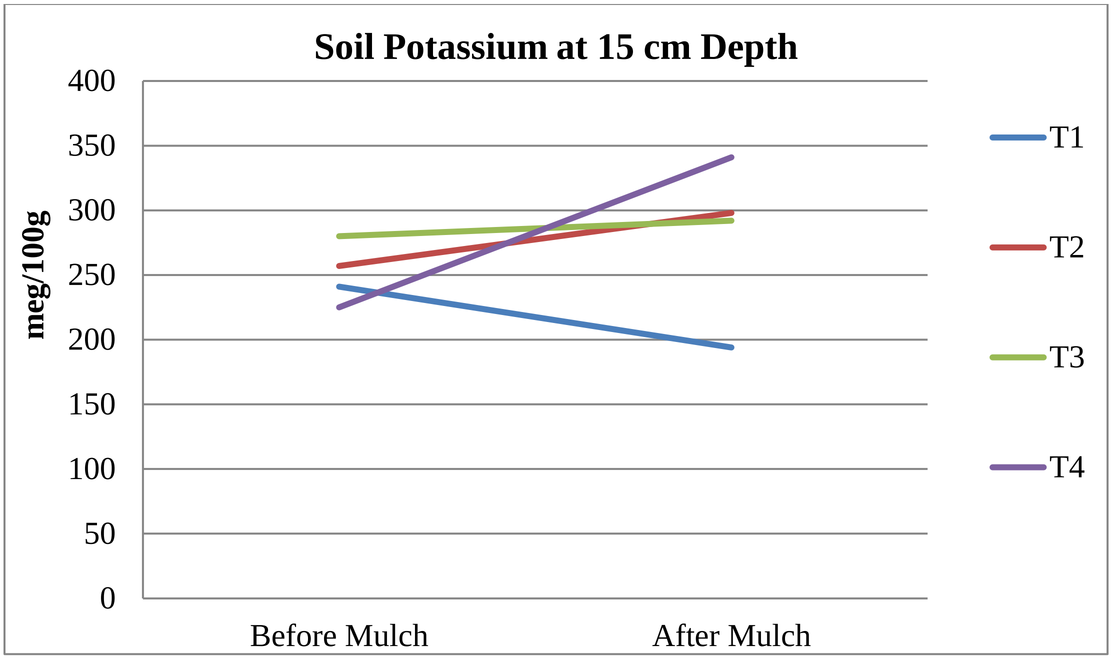

Figure 10. The effect of mulching on soil potassium at 5.90 in. (15 cm depth)

The Result of Mulching on Magnesium at the First Depth

The line chart in figure 11 shows soil magnesium levels for each treatment before and after mulching at 2.95 in. (7.5 cm depth). The rate of magnesium disintegration and uptake in the soil from the wheat straw (T2) increased at a rate of 0.23 %, making it the most effective at increasing magnesium levels in the soil. This curve is steeper than that of the non-shredded *M.* × *giganteus.* The latter's curve is less steep than that of the wheat straw, making it the second most effective at increasing zinc levels in the soil at a rate of 0.10 %. The shredded *M.* × *giganteus* (T4) was the third most effective at increasing magnesium levels in the soil after the mulching process at a rate of 0.05 %. In contrast, the levels of magnesium in the soil decreased at a rate of 0.07% in the control (T1).

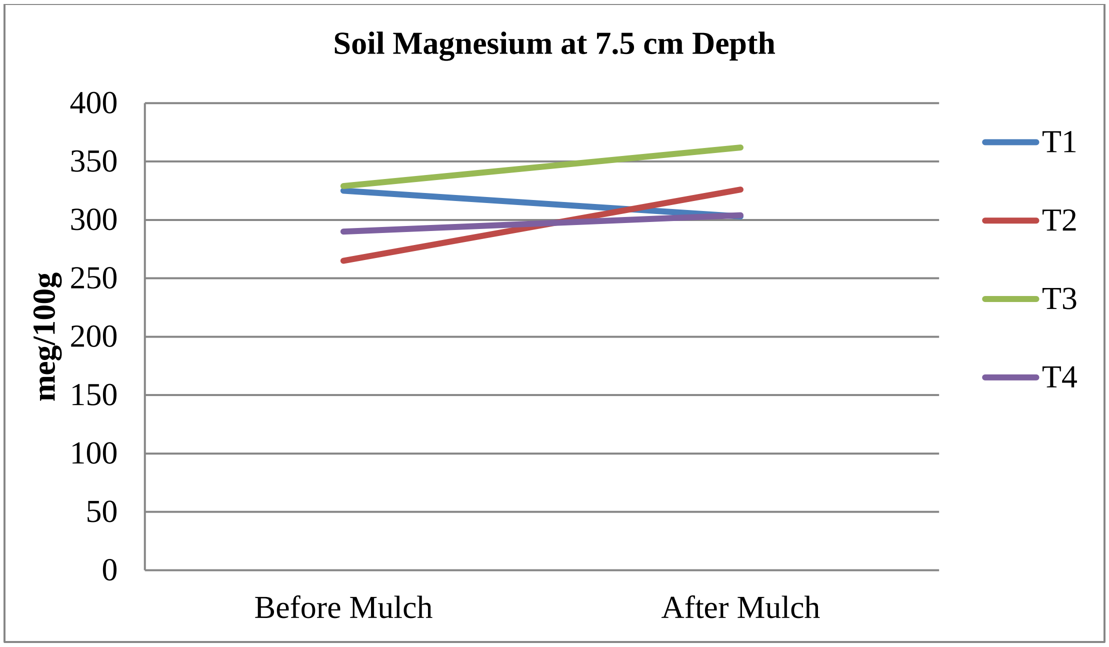

Figure 11. The effect of mulching on soil magnesium at 2.95 in. (7.5 cm depth)

The Result of Mulching on Magnesium at the Second Depth

The line chart in figure 12 shows the magnesium levels in the soil for each treatment before and after mulching at 5.90 in. (15 cm depth). The level of magnesium disintegration and uptake in the soil from the non-shredded *M.* × *giganteus* (T3) increased at a rate of 0.20 %, making it the most effective at increasing magnesium levels in the soil. In contrast, the rest of the treatments decreased the levels of magnesium in the soil magnesium. The highest decrease in the levels of magnesium in the soil was in the control (T1), which declined at a rate of 0.26 %. The shredded *M.* × *giganteus* (T4) had the second steepest decrease of magnesium in the soil at a rate of 0.21 %. The wheat straw (T2) had the third steepest decrease in the levels of magnesium in the soil at a rate of 0.01 % after the mulching process.

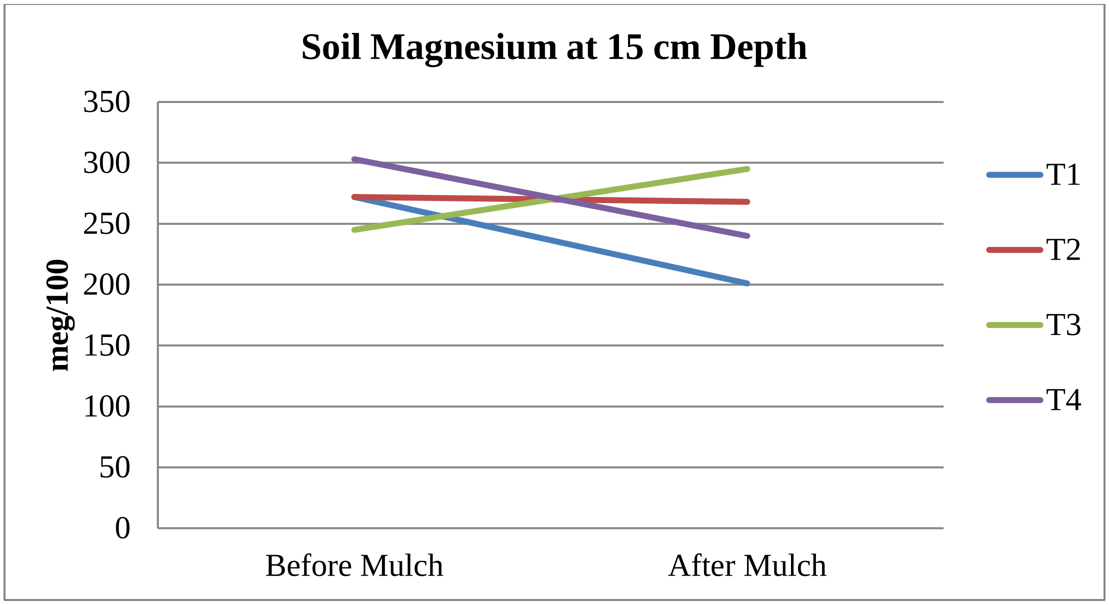

Figure 12. The effect of mulching on soil magnesium at 5.90 in. (15 cm depth)

The Result of Mulching on Calcium at the First Depth

The line chart in figure 13 shows soil calcium levels for each treatment before and after mulching at 2.95 in. (7.5 cm depth). The rate of calcium disintegration and uptake in the soil from the non-shredded *M.* × *giganteus* (T3) increased at a rate of 0.15 %, making it the most effective at increasing calcium levels in the soil. This curve is steeper than that of the wheat straw (T2). The latter's curve is less steep than that of the non-shredded *M.* × *giganteus*, making it the second most effective at increasing calcium levels in the soil at a rate of 0.11 %. The shredded *M.* × *giganteus* (T4) was the third most effective at increasing calcium levels in the soil after the mulching process at a rate 0.09 %. The control (T1) was the least effective at increasing calcium levels in the soil at a rate of 0.05 %.

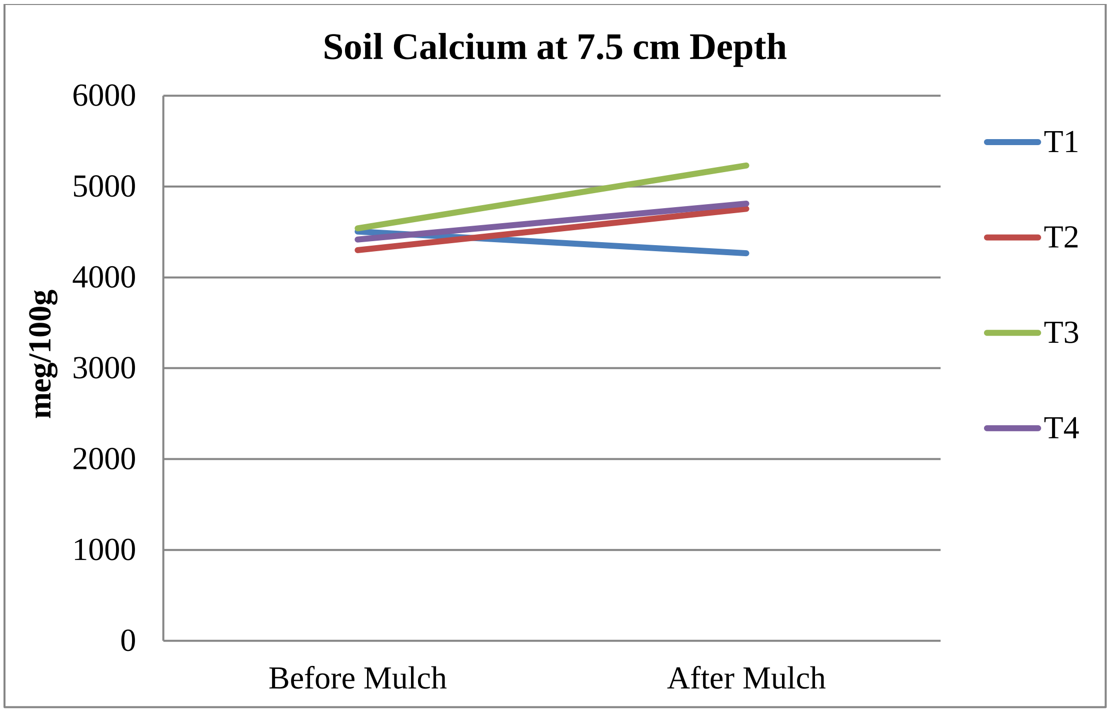

Figure 13. The effect of mulching on soil calcium at 2.95 in. (7.5 cm depth

The Result of Mulching on Calcium at the Second Depth

The line chart in figure 14 shows the calcium levels in the soil for each treatment before and after mulching at 5.90 in. (15 cm depth). The rate of calcium disintegration and uptake in the soil from the non-shredded *M.* × *giganteus* (T3) increased at a rate of 0.18 %, making it the most effective at increasing calcium levels in the soil. Wheat straw (T2) was the second most effective at increasing calcium levels in the soil at a rate of 0.01 %. Moreover, there were decreases in the levels of calcium in the soil in the control (T3) and the shredded *M.* × *giganteus* (T4). The control (T1) had the highest decline of calcium levels at a decreasing rate of 0.20 %, whereas the shredded *M.* × *giganteus* (T4) had the second highest decline of calcium levels at a decreasing rate of 0.12 % in the soil after the mulching process.

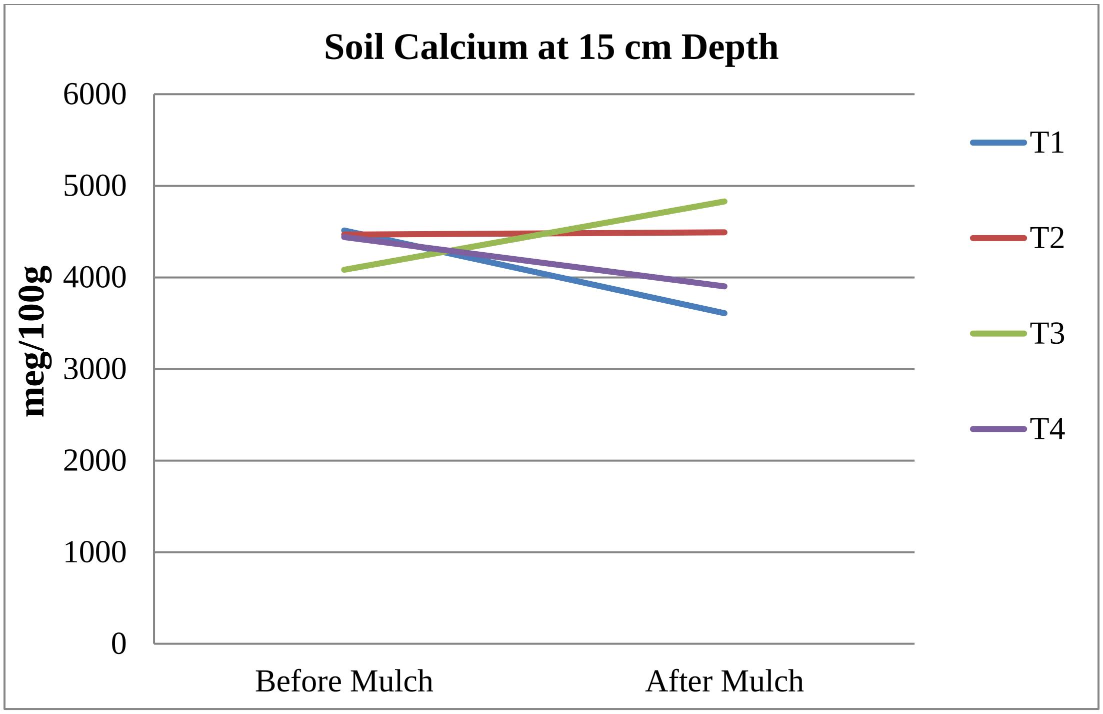

Figure 14. The effect of mulching on soil calcium at 5.90 in. (15 cm depth)

The Result of Mulching on Power of hydrogen (pH) at the First Depth

The line chart in figure 15 shows soil pH levels for each treatment before and after mulching at 2.95 in. (7.5 cm depth). The rate of soil pH uptake in the soil from the non-shredded *M.* × *giganteus* (T3) increased at a rate of 0.03 %, making it the most effective at increasing pH levels in the soil. The wheat straw (T2) was the second most effective at increasing pH levels in the soil after the mulching process at a rate of 0.02 %. Moreover, the control (T1) had the highest decline of soil pH at a rate of 0.04 %. The shredded *M.* × *giganteus* (T4) had the second highest decline in the soil pH at a rate of 0.02 %.

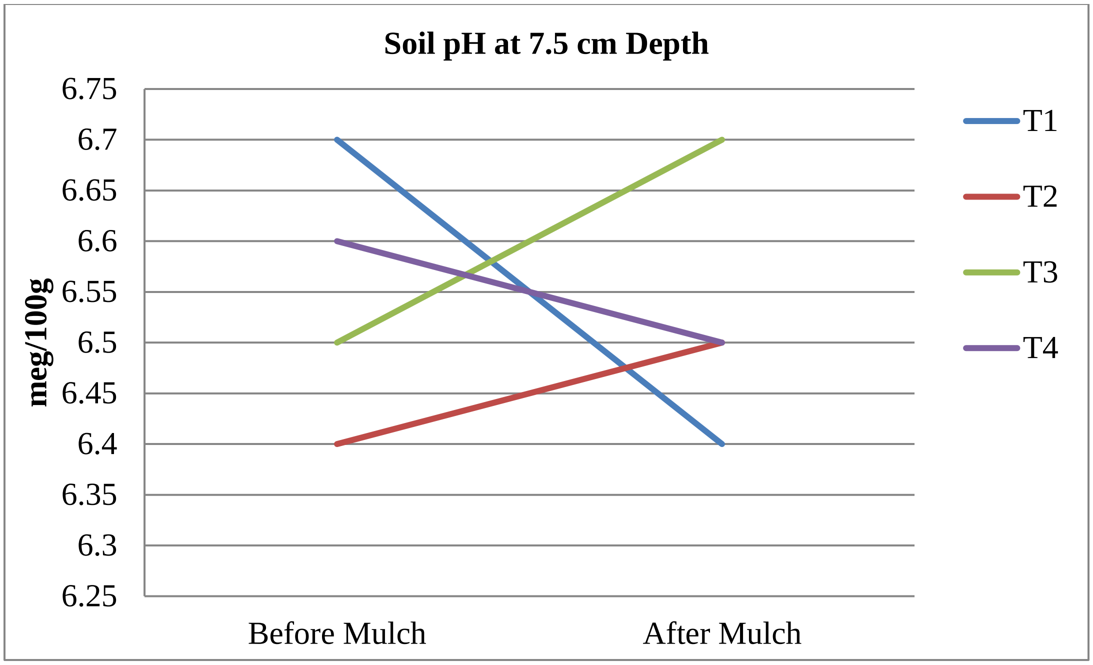

Figure 15. The effect of mulching on soil pH at 2.95 in. (7.5 cm depth)

The Result of Mulching on Power of hydrogen (pH) at the Second Depth

The line chart in figure 16 shows soil pH levels for each treatment before and after mulching at 5.90 in. (15 cm depth). The rate of soil pH uptake from the control (T1) and the wheat straw (T2) had the highest rate of decrease in soil pH at a rate of 0.03 %. The shredded *M.* × *giganteus* (T4) had the second highest rate of decrease at a rate of 0.02 %, while the non-shredded *M.* × *giganteus* (T3) had no effect on the soil pH after the mulching process.

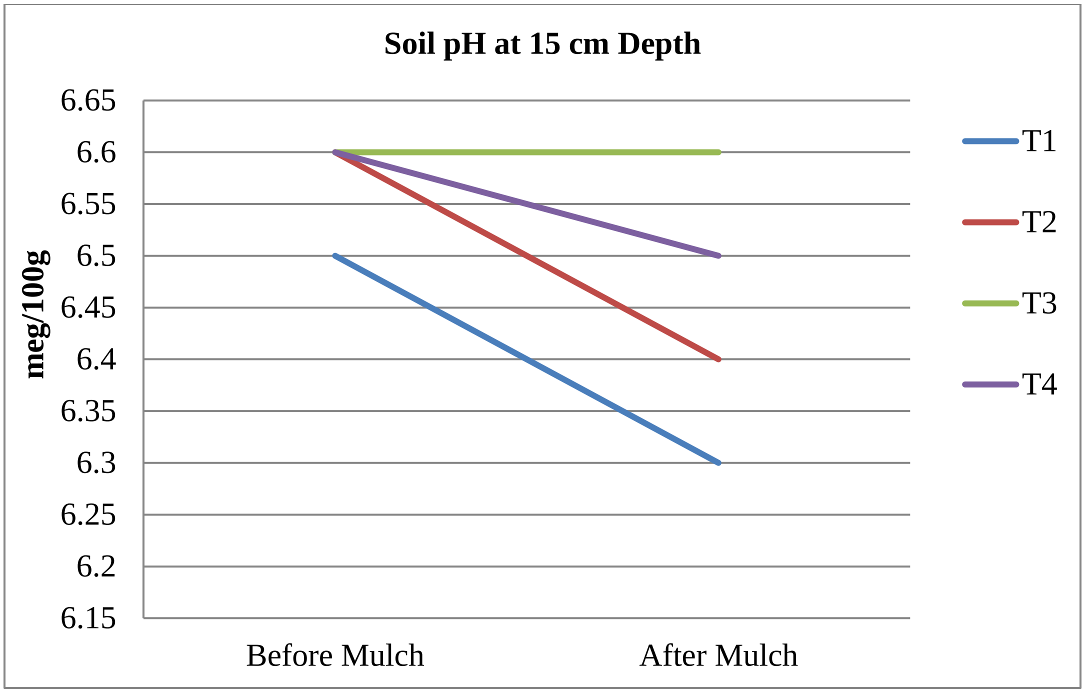

Figure 16. The effect of mulching on soil pH at 5.90 in. (15 cm depth)

The Result of Mulching on Date of Formation in *Z. elegans*

Table 2, shown below, all plant had between 47 and 86 days.

The average number of the date of formation was 68.91 days.

Table 2

Descriptive Statistics for Date of Formation in Z. elegans by Mulches

	n	*M*	*SD*	*Med*	*Min*	*Max*
T1	60	71.67	6.65	72	48	86
T2	60	66.55	7.79	69	48	77
T3	60	66.00	6.75	67	47	76
T4	60	71.42	6.45	73	48	79
Overall	420	68.91	7.38	71	47	86

Note. T1 = No mulch, T2= Wheat straw, T3= Non-shredded *M.* × *giganteus*, T4= Shredded *M.* × *giganteus*.

The results of the ANOVA were statistically significant $F(3, 236) = 11.63$, $p < .001$. The ANOVA yielded a large effect size (η^2 =0.21). Researchers ran post hoc analysis on the data. Independent t-tests were used to examine differences between groups. As such, the Bonferroni correction factor was used to adjust the alpha level for potential Type One error. The alpha level for the post hoc tests was set at .05. All the treatments were statistically different except all the treatments were statistically different except control (T1) was not statistically different compared to (T3) shredded *M.* × *giganteus* (T4). Also, wheat straw (T2) was not statistically different compared non-shredded *M.* × *giganteus* (T3).

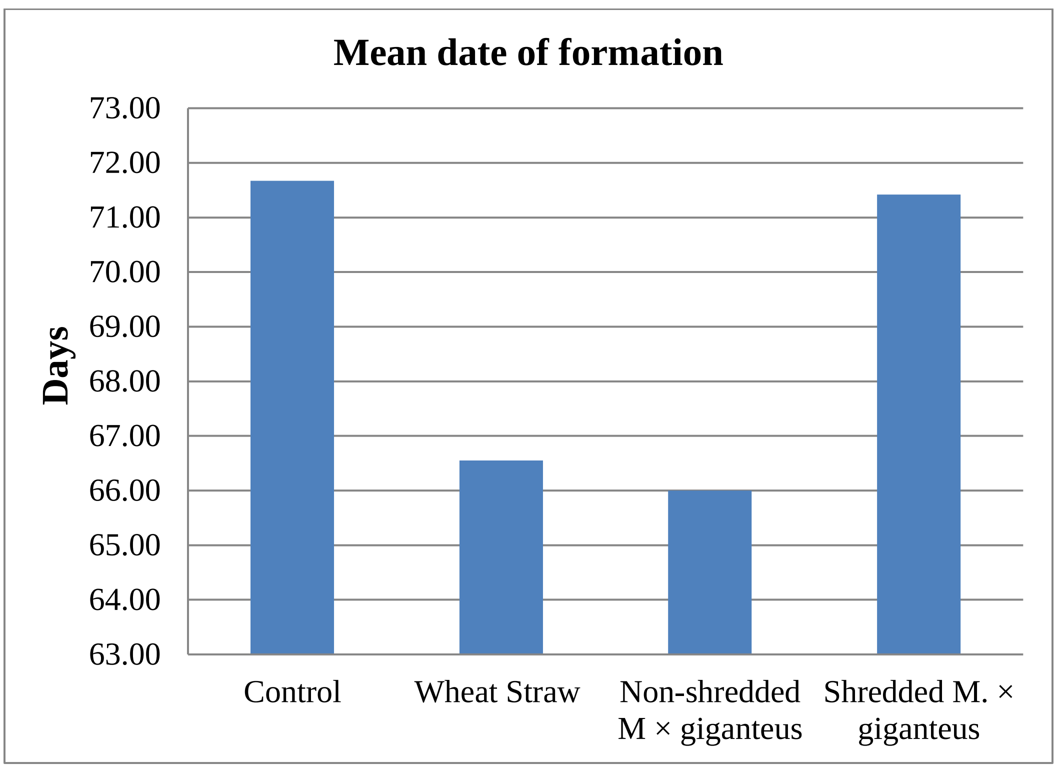

Figure 17. The effect of mulches on date of formation in *Z. elegans*

The Result of Mulching on Stem Length in *Z. elegans*

Table 3, shown below, all plant had between 14 in (35.56 cm) and 54 in (137.16 cm) length.

The average number of the stem length was 34.30 in (87.12 cm).

Table 3

Descriptive Statistics for Length of the Stem in Z. elegans by Mulches

	n	*M*	*SD*	*Mdn*	*Min*	*Max*
T1	60	32.63	4.85	33.00	15	43
T2	60	32.50	6.00	32.50	14	47
T3	60	39.58	6.86	38.00	28	54
T4	60	32.47	5.32	30.50	23	45
Overall	240	34.30	6.53	34.00	14	54

Note. T1 = No mulch, T2= Wheat straw, T3= Non-shredded *M.* × *giganteus*, T4= Shredded *M.* × *giganteus*.

The results of the ANOVA were statistically significant $F(3, 236) = 22.12$, $p < .001$. The ANOVA yielded a large effect size ($\eta^2 = 0.22$). Researchers ran post hoc analysis on the data. Independent t-tests were used to examine differences between groups. As such, the Bonferroni correction factor was used to adjust the alpha level for potential Type One error. The alpha level for the post hoc tests was set at .05. All the treatments were statistically different except control (T1) was not statistically different compared to wheat straw (T2) and shredded *M.* × *giganteus* (T4). Also, wheat straw (T2) was not statistically different compared to shredded *M.* × *giganteus* (T4).

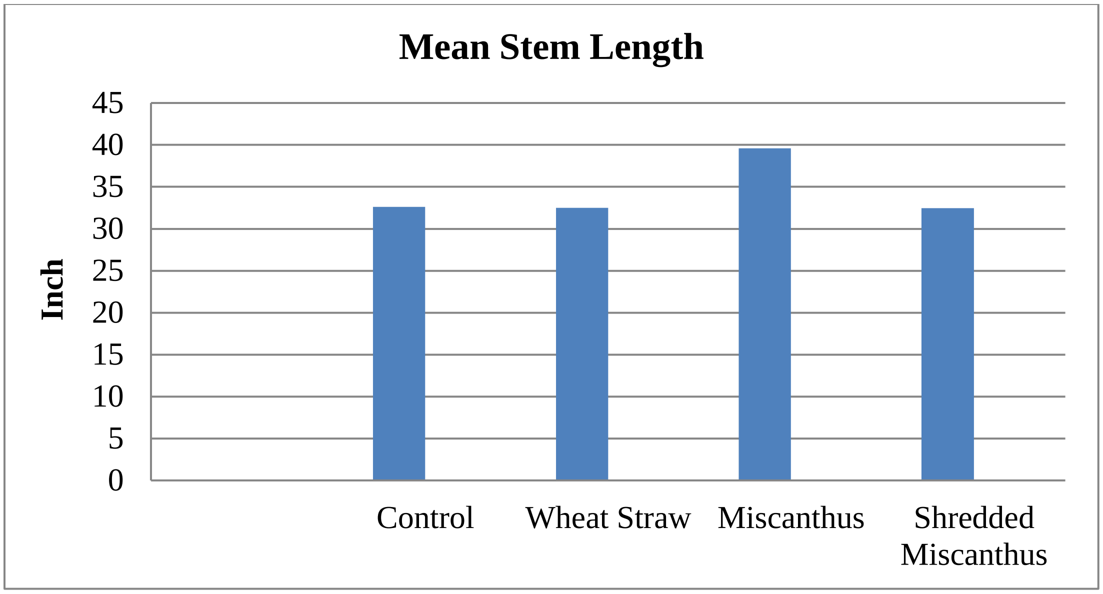

Figure 18. The effect of mulches on stem length in *Z. elegans*

The Result of Mulching on Stem Diameter in *Z. elegans*

Table 4, shown below, all plant had between 0.15 in (0.38 cm) and 0.54 in (1.37 cm) stem diameter.

The average number of the diameter was 0.31 in (0.78 cm).

Table 4

Descriptive Statistics for Stem Diameter in Z. elegans by Mulches

	n	*M*	*SD*	*Med*	*Min*	*Max*
T1	60	0.25	0.05	0.26	0.15	0.41
T2	60	0.32	0.07	0.31	0.19	0.50
T3	60	0.35	0.10	0.34	0.18	0.54
T4	60	0.32	0.08	0.32	0.19	0.54
Overall	240	0.31	0.08	0.31	0.15	0.54

Note. T1 = No mulch, T2= Wheat straw, T3= Non-shredded *M.* × *giganteus*, T4= Shredded *M.* × *giganteus*.

The results of the ANOVA were statistically significant $F(3, 236) = 17.07$, $p < .05$. The ANOVA yielded a large effect size (η^2 =0.18). Researchers ran post hoc analysis on the data. Independent t-tests were used to examine differences between groups. As such, the Bonferroni correction factor was used to adjust the alpha level for potential Type One error. The alpha level for the post hoc tests was set at .05. Control (T1) was statistically different compared to wheat straw (T2), non-shredded *M.* × *giganteus* (T3) and shredded *M.* × *giganteus* (T4). Three of the four groups were not statistically different.

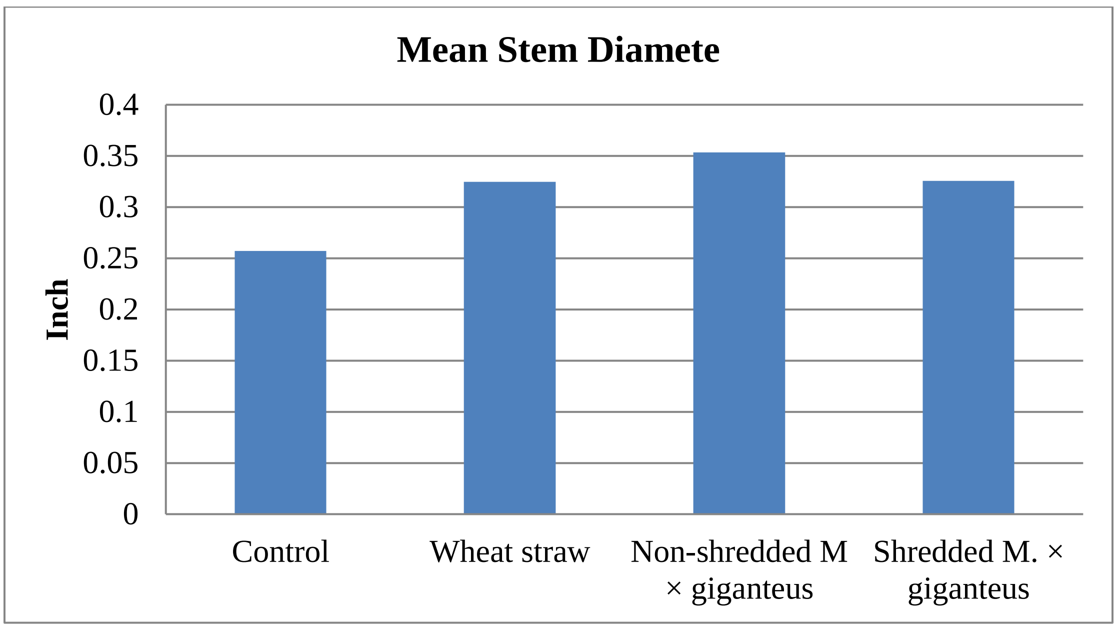

Figure19. The effect of mulches on stem diameter in *Z. elegans*

The Result of Mulching on Flower Set in *Z. elegans*

Table 5, shown below, all plant had between 1 and 28 flowers. The average number of the flower was 6.09 flowers.

Table 5

Descriptive Statistics for flower Set in Z. elegans by Mulches

	N	*M*	*SD*	*Med*	*Min*	*Max*
T1	60	3.47	1.57	3.00	1	11
T2	60	6.00	2.83	5.00	1	14
T3	60	8.82	5.61	8.00	1	28
T4	60	6.08	3.66	5.00	1	19
Overall	420	6.09	4.15	5.00	1	28

Note. T1 = No mulch, T2= Wheat straw, T3= Non-shredded *M.* × *giganteus*, T4= Shredded *M.* × *giganteus*.

The results of the ANOVA were statistically significant $F(3, 236) = 20.70$, $p < .001$. The ANOVA yielded a large effect size (η^2 =0.21). Researchers ran post hoc analysis on the data. Independent t-tests were used to examine differences between groups. As such, the Bonferroni correction factor was used to adjust the alpha level for potential Type One error. The alpha level for the post hoc tests was set at .05. Three of the four groups were statistically different. Wheat straw (T2) and non-shredded *M.* × *giganteus* (T3) were not statistically different.

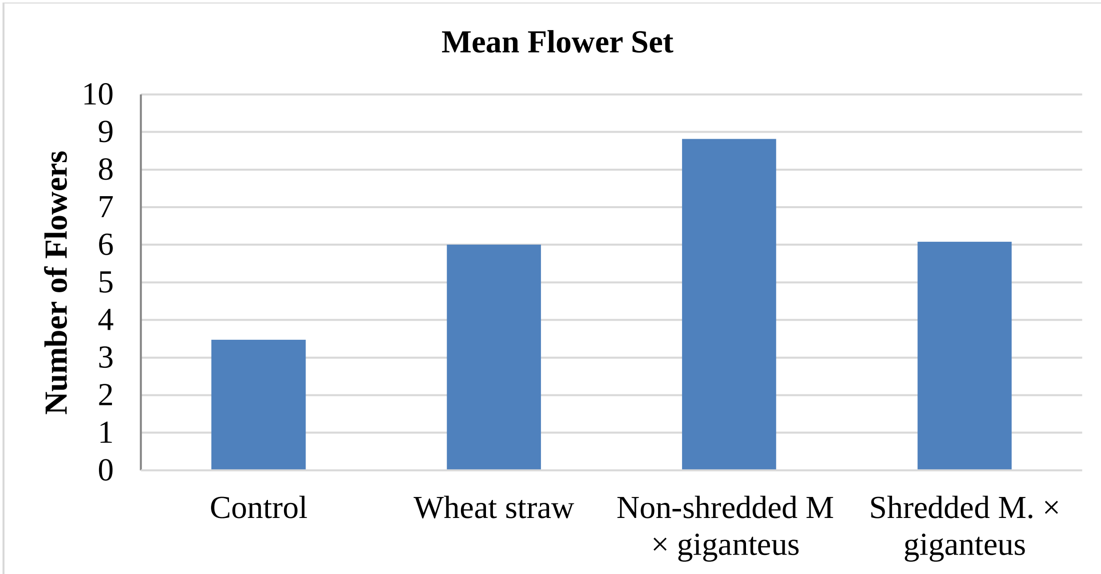

Figure 20. The effect of mulches on flower set in *Z. elegans*

Chapter 5

Discussion and Recommendation

Introduction

The core objective of this chapter is to discuss the empirical outcomes and the statistical analyses derived from the mulching experiment and to provide recommendations for future studies. The discussion section is divided into weed presence, soil characteristics, and *Z. elegans* growth. The soil characteristics section outlines experimental outcomes for essential micro- and macronutrients, namely zinc, magnesium, calcium, phosphorus, and potassium at 2.95 in. (7.5 cm) and 5.90 in. (15 cm) depths. The impact of soil mulch on the pH and weed population is reviewed; it was hypothesized that weed presence would vary depending on the mulch treatment. Also, the effect of three different mulches on soil properties, it was hypothesized that the soil properties would be affected by mulching. Furthermore, the effect of mulching on *Z. elegans* growth, it was hypothesized that *Z. elegans* growth would be affected by the type of mulch. The suitability of the mulch for *Z. elegans* growth was based on the stem length and diameter, flower set, and date of formation. The ability of the mulches to suppress weed development is highlighted, as weeds increase the competition for soil nutrients. (Teasdale & Mohler 2000) noted that the suitability of the mulch on plant growth was dependent on the ability of the young plant shoots to germinate, despite the obstruction from the mulch.

Impact of Mulching on Weed Presence

Findings from this investigation support the data presented in the literature review, showing that organic mulches help to control weeds (Díaz-Pérez et al., 2012). The study's findings presented in Table 1 and Figure 4 show that the control treatment (T1) had the highest mean weeds cover (76656.17 cm^2), which was expected as no mulch was applied. In contrast, shredded *M.* × *giganteus* had the lowest mean of weeds cover (34159.33 cm^2), making it the most effective at controlling weeds. From ANOVA, there was a statistical difference between treatment one, which was the control, and treatment 4, which was the shredded *M.* × *giganteus*. Then single factor to the *p*-value was $p < 0.05$, which was considered significant. This justifies the rejection of *H*01 hypothesis, as there was a difference in the weed emergence among the four treatments. Furthermore, a t-test showed that there was significance between the different treatments. Non-shredded *M.* × *giganteus* (T3) had the highest weed mean (50680.67 cm2), making it the least favorable. A t-test comparing the control (T1) and non-shredded *M.* × *giganteus* (T3) showed no statistical significance, which means that there was still weed emergence after the application of this mulch. This could suggest that the mulch was previously contaminated with weed seeds prior to its application. Wheat straw mulch comes in second to the shredded *M.* × *giganteus.* There was no statistical significance, which means it was not as effective in the controlling of weeds. This result is similar to the findings by Doring et al. (2005), who stated that straw mulch did not wield a significant effect in preventing weed emergence. However, the findings are limited, as the experiment was carried out in a controlled environment and it may not be possible to replicate the same conditions in a real-life situation. Additionally, the researcher is preview to the idea that different climatic conditions could result in different outcomes.

The Effect of Mulching on Zinc

According to the experimental outcomes, each type of mulch, including shredded *M.* × *giganteus*, wheat straw, and non-shredded *M.* × *giganteus*, had varying impacts on the availability of zinc micronutrients in the soil. At a depth of 2.95 in. (7.5 cm), wheat straw mulch had the highest zinc concentration, followed by the shredded *M.* × *giganteus*, the control, and non-shredded *M.* × *giganteus*. These outcomes were presented in Figure 5, 6 and. The findings derived from the study were consistent with observations made by Chen et al. (2017). A large decrease in the zinc concentration was noted at a depth of 5.90 in. (15 cm) in the non-shredded *M.* × *giganteus* and the wheat straw. The application of non-shredded *M.* × *giganteus* showed the third decrease in zinc concentration, followed by the control. The varying concentrations of zinc were attributed to the decomposition of the organic mulch.

According to Chen and fellow researchers, the lower availability of zinc in shredded *M.* × *giganteus*, non-shredded *M.* × *giganteus* mulch, and wheat straw at 5.90 in. (15 cm) depths was attributed to the formation of zinc complexes in soils that had the highest soil moisture content. It was postulated that the low zinc concentration was attributed to higher temperatures in the soil. This proposition was developed through previous experiments which established that the concentration of leached zinc was lower at higher temperatures (Dillon, 2017). Moreover, most of the zinc was available in the plant’s leaves rather than the stems (Nsanganwimana et al., 2016).

(Dillon 2017). Moreover, most of the zinc was available in the plant's leaves rather than the stems (Nsanganwimana et al., 2016).

The Effect of Mulching on Phosphorous

The application of non-shredded *M.* × *giganteus* resulted in an elevation in the level of phosphorous content by 0.67 %, as depicted in Figures 7 and 8. The soil samples with non-shredded *M.* × *giganteus* collected at the 2.95 in. (7.5 cm) depth recorded the highest increase in the phosphorous content at 0.67 %. The wheat straw had the second highest increase of phosphorous at 0.43 %, while the shredded *M.* × *giganteus* showed the lowest increase in phosphorous. A decline in the phosphorous content was observed in the control. Samples collected at 5.90 in. (15 cm) depths yielded the following results; the highest increase in the phosphorous concentration was noted in the wheat straw mulch, followed by the non-shredded *M.* × *giganteus* mulch. A decrease in the phosphorous content was seen in the control and the shredded *M.* × *giganteus* samples. It can be argued that the non-shredded *M.* × *giganteus* was readily disintegrated by microbes and quickly absorbed instill the soil, releasing phosphorus, unlike its counterpart shredded *M.* × *giganteus*. This finding is in line with those of Teasdale & Mohler (2000), who theorized that mulch properties play a role in the overall effectiveness of the mulch. The control treatment (T1) showed a gradual decrease of phosphorus in the soil throughout the experiment, although this was not a large decrease. This is logical, as the growing plants, including the weeds, used the available phosphorous that was previously in the soil.

All plants require phosphorous because it mediates protein synthesis and the proliferation of new cells, which is important for root growth and maturity. Based on plant growth considerations, it was postulated that non-shredded *M.* × *giganteus* is the ideal mulch type for young *Z. elegans* plants with less advanced root systems. Additionally, it was hypothesized that wheat straw was appropriate for older plants with elongated roots

The Effect of Mulching on Potassium

The findings presented in Figure 9 and 10 indicated that the largest increase in the potassium levels was established following the application of the wheat straw mulch and shredded *M.* × *giganteus* at the 2.95 in. (7.5 cm) depth. The control and non-shredded *M.* × *giganteus* mulch had the lowest concentration of potassium. This pattern was sustained at 5.90 in. (15 cm) depth, as shredded *M.* × *giganteus* resulted in a 0.52 % increase in potassium, also wheat straw resulted in a 0.16 % increase in potassium. The decline in the potassium levels with an increase in soil depth was in line with experimental outcomes reported by Wei et al. (2015). According to Wei et al (2015), the suppression of the potassium content was attributed to the variations in soil mineralization at various soil depths. Potassium is an essential macronutrient because it contributes to flower development in the *Z. elegans* plants. This observation was based on findings reported by Shah, Ali, Shah, & Abid (2014).

The Effect of Mulching on Magnesium

The experiments indicated that applying wheat straw to the soil resulted in a 0.23 % increase in the concentration of magnesium at a depth of 2.95 in. (7.5 cm). The second highest increase was seen in the application of non-shredded *M.* × *giganteus* soils, followed by shredded *M.* × *giganteus* at 0.05 %. One of the probable explanations for the high nutrient content in the wheat straw was that wheat straw increases the instantaneous availability of nutrients, which can then, either absorbed by the plants or leached into the soil. At 5.90 in. (15 cm) depth, non-shredded *M.* × *giganteus* had the highest increase in magnesium concentration at 0.20 %, while shredded *M.* × *giganteus* and wheat straw resulted in a 0.21 % and 0.01 % decline, respectively. The variations in the magnesium concentration were presented in Figure 11 and 12.

Moreover, the magnesium concentration in the control and wheat straw mulches showed a decline in the nutrient concentration. Therefore, based on the experiment, wheat straw was efficient at shallow depths, while non-shredded *M.* × *giganteus* was most useful at deeper depths. Apart from mulching, Carter & Grieve (2010) noted that the level of magnesium in deeper depths was influenced by the competition with calcium. According to the study, an increase in the magnesium concentration was associated with the suppression of calcium levels because both nutrients have similar chemical properties. Besides, the mineral content in the irrigation water.

The Effect of Mulching on Calcium

In contrast to the previous experimental observations at 2.95 in. (7.5 cm) depth, non-shredded *M.* × *giganteus* mulch (T3) showed the most significant increase in calcium at 0.15 %. This was closely followed by wheat straw and shredded *M.* × *giganteus* at 0.11 % and 0.9 %, respectively. This is illustrated in Figure 13. Similar observations were made at a depth of 5.90 in. (15 cm) (Figure 14), in which a 0.18 % increase in calcium concentration was reported in the soil with non-shredded *M.* × *giganteus*, followed by wheat straw at 0.1 %. In contrast, shredded *M.* × *giganteus* resulted in a 0.12 % decrease in soil calcium. The disparities in the soil concentrations were attributed to the interaction between various factors, including leaching and the ability of the soil to preserve the nutrient content. For example, clay soils have a greater nutrient and water holding capacity compared to sand due to broader surface areas (Curell, 2011).

The Effect of Mulching on Power of Hydrogen (pH)

The variation in soil pH at 2.95 in. (7.5 cm) and 5.90 in. (15 cm) depth was depicted in Figure 15 and 16. The pH was an essential determinant of soil nutrients because extreme acidic and basic pH conditions were unfavorable for plant growth. At a depth of 2.95 in. (7.5 cm), the pH was lowered in the control at 04 % and shredded *M.* × *giganteus* at 0.02 % samples. In contrast, wheat straw and non-shredded *M.* × *giganteus* resulted in an increase in pH. Similar observations were made in the 5.90 in. (15 cm) depth, with the exception being for the control, in which no change in the pH was noted. A decline in the pH was observed after the application of shredded *M.* × *giganteus* mulch at the 5.90 in. (15 cm) depth. In a study by Riaz et al. (2008), *Z. elegans* plants exhibited healthy growth at a pH of 8. In this study, shredded *M.* × *giganteus*, non-shredded *M.* × *giganteus*, and wheat straw resulted in a marginal increase in the soil pH. Similar patterns were observed in both 7.5 and 5.90 in. (15 cm) depths. Based on the pH changes, the three mulch types did not contribute to a considerable variation in the soil pH and therefore were suitable for plant growth.

Impact of the Mulches on Zinnia Growth

Weed control was a critical factor in the selection of soil mulch types to suppress the competition for nutrients. A study by Teasdale & Mohler established that mulches suppressed weed emergence (2000). According to the data in Table 2 and Figure 17, the mean date of formation of buds for *Z. elegans* plants was 71.67 average days in the control (T1) making it the longest. Bud formation was shorter in the rest of the treatments. Non-shredded *M.* × *giganteus* (T3), was the shortest average number of days

(66.00). The p-value for this factor was significant ($p < 0.01$). Furthermore, a t-test showed that there was significance between the different treatments. This indicates that the presence of mulch significantly contributed to accelerating the formation of flower buds.

Figure 18 and table 3 discussed stem length. Lengths of 39.58 in (101 cm), 32.47 in (82.47 cm), and 32.50 in (82.55 cm) were reported in *Z. elegans* plants grown using non-shredded *M.* × *giganteus*, shredded *M.* × *giganteus*, and wheat straw, respectively. The p-value for this factor was significant ($p < 0.01$). Furthermore, a t-test showed that there was significance between the different treatments. This indicates that the presence of mulch significantly contributed to increasing stem length in *Z. elegans*.

According to the data in Table 4 and Figure 19, *Z. elegans* plants grown in soils containing non-shredded *M.* × *giganteus* mulch had the largest stem diameter 0.35 in. (0.88 cm), which is a predictor of nutrient availability. The application of shredded *M.* × *giganteus* and wheat straw resulted in the second highest stem diameters at 0.32 in. (0.81 cm), whereas the plants in the control had the smallest stem diameters 0.25 in. (0.63 cm) perhaps due to the absence of micro- and macronutrients in the mulches. The p-value for this factor was significant ($p < 0.05$). Furthermore, a t-test showed that there was significance between the control (T1) treatment and the other treatments. This indicates that the presence of mulches significantly contributed to increasing stem diameter in *Z. elegans*.

According to the findings depicted in Figure 20 and Table 5, applying non-shredded *M.* × *giganteus* to the soil resulted in the greatest flower set. For instance, *Z.*

elegans plants grown in soils that were covered with non-shredded *M.* × *giganteus* mulch had an average of 8.82 flowers. Soils that were covered with shredded *M*. x *giganteus* mulch and wheat straw averaged 6.08 and 6 flower, respectively. The p-value for this factor was significant ($p < 0.01$). Furthermore, a t-test showed that there was significance between the different treatments.

Based on the results of the study, it appears that the vigor of the plants may have been improved by the decomposition of mulch. Non-shredded *M.* × *giganteus* (T3) was significantly different from the other two mulches and the control, related to stem diameter, stem length, the length of time to form flower buds, and flower set.

The outcomes reported by Nsanganwimana et al. (2016). After the experiments, the best outcomes were noted in soils containing *M*. × *giganteus* were consistent with this study's mulching effects on *Z. elegans* experimental outcomes. Moreover, the concentration of soil nitrates was elevated following the application of selected mulches, such as *T. incarnatum* (Teasdale & Mohler, 2000). Nitrates are critical to plant growth because they facilitate protein synthesis.

Hypotheses

Based on the study's outcomes, the first alternative hypothesis H_{R1} was validated because there was a notable variation in weed presence. This claim was reached based on the data depicted in Table 1. The variations in the micro- and macronutrients in soils that were covered with non-shredded *M.* × *giganteus*, wheat straw, and shredded *M.* × *giganteus* validated the second alternative hypothesis H_{R2}, considering that the changes were substantial as illustrated in Figure 5 to 16. Similarly, it was established that the third alternative hypothesis H_{R3} was justified because the p-value was $p < 0.05$, which was considered significant, as there was a difference in *Z. elegans* growth following the application of various mulches.

Conclusion

The results of the study showed a statistically significant difference between mulch treatments and the control (no mulch) on *Z. elegans* growth and weeds presence. Shredded *M.* × *giganteus* was most efficient in suppressing the population of weeds. Thus, if weed control is the primary goal, shredded *M.* × *giganteus* is the most appropriate because it inhibited weed growth by depriving the weeds of sunlight required in seed germination and growth. Mixed outcomes were reported after the use of the three mulches. For instance, the calcium, magnesium, and phosphorus content was elevated by non-shredded *M.* × *giganteus* mulch. In contrast, shredded *M.* × *giganteus* decreased the magnesium concentration at 5.90 in. (15 cm). Non-shredded *M.* × *giganteus* and wheat straw were found to contain the largest proportions of macro- and micronutrients at the 2.95 in. (7.5cm) and 5.90 in. (15 cm) depths. All mulches had an insignificant impact on the soil pH.

Each type of mulch investigated had benefits and limitations. Wheat straw and non-shredded *M.* × *giganteus* are recommended in the early phases of the *Z. elegans* plant growth. This is because young plants require phosphorous and potassium for early root and leaf development, whereas older plants require macronutrients for flower development. The non-shredded *M.* × *giganteus* mulch stimulated plant growth by providing micro- and micronutrients and led to an increase in the stem diameter, length, flower sets, and the formation of flower buds.

Based on the findings of this experiment, non-shredded *M.* × *giganteus* is a preferred alternative to wheat straw. The findings derived from the mulch experiments have significant implications for gardeners, given that non-shredded *M.* × *giganteus* has the potential to supplement synthetic fertilizers.

Recommendations

The recommendations are the study's limitations, research gaps, and the body of literature presented. The first recommendation is that additional studies are needed to ascertain the efficiency of the mulches used in this study applied at different thicknesses (surpassing two inches). The second recommendation is that future experiments should be carried out during Spring to demonstrate the role of weather on nutrient uptake and micro- and macronutrient retention in the soil. The third recommendation is that further studies should determine the correlation between the incorporation of mulches and weed presence, given that the current statistical analyses indicated that $p < 0.05$. Fourthly, apart from *Z. elegans*, other plants should also be investigated to in relation to mulches. Lastly, I would recommend increasing the size of the study by taking more than 32 soil samples and test soil's nitrogen.

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