EFFECTS OF ORGANIC MULCH ON YIELD AND SELECTED PESTS OF ORGANICALLY GROWN TOMATO (*Solanum lycopersicum* L.) AND SWEET PEPPER (*Capsicum annuum* L.)

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EXTENDED ABSTRACT

The objectives of this study were (i) to determine the effects of Mexican weeping pine (*Pinus patula* Schelde. ex Schltdl and Cham) and wild lemon grass (*Cymbopogon spp.)* mulches and time of their application on yield and quality of organically grown tomato (*Solanum lycopersicum* L.) and sweet pepper (*Capsicum annuum* L.), (ii) to investigate the effect of pine and wild lemon grass mulch on pests and beneficial arthropods under organic production of tomato and sweet pepper, and (iii) to examine the decomposition rate and chemical products of pine and wild lemon grass. Tomato cv. 'Tanya' and sweet pepper cv. 'California Wonder' were grown organically at Lushoto and Ubiri wards in Lushoto district, Tanga region, North-Eastern Tanzania. The experiment was laid out in a Randomised Complete Block Design (RCBD) with three replications and repeated for three seasons. The treatments were pine mulch applied 3 days after transplanting (PI), and 21 days after transplanting (PA), grass mulch applied 3 days after transplanting (GI), and 21 days after transplanting (GA) and two unmulched controls weeded and unweeded. Dry pine and wild lemon grass materials were used in compost making, each mixed with forest soil, cow manure, green grass and water. Laboratory analysis was done later on at Sokoine University of Agriculture (SUA) Soil Science laboratories to determine the chemical composition of the composts. Data collected included the number of leaves per plant, plant height, fruit yield, number of fruits per plant, fruit size, marketable and unmarketable fruit weight. Beneficial arthropods were also collected using pitfall traps for the three seasons. In each treatment and location, data on numbers and dry weight of weeds, disease incidences and insect pests were also collected. The time taken for compost to mature and their chemical composition in the period of three and twelve months of composting were recorded. The analysed parameters included organic carbon (OC), total Nitrogen (TN), phosphorus (P), potassium (K), copper (Cu), zinc (Zn), iron

(Fe), and manganese (Mn). Data were subjected to Analysis of Variance (ANOVA) at $P \leq 0.05$ and where applicable *Post Hoc*. Tukey's (HSD) test was used to compare means. Data analysis was done using R Statistical Package (AGRICOLAE Version 1.2.1). Results showed that both types of mulch had positive influence on yield and quality components regardless of the time of mulch application. Among the three seasons, the highest yields were obtained during the wet and cold season (April – August, 2013). Mulching with either pine or wild lemon grass did not affect the number of trapped arthropods while across the seasons, numbers of arthropods increased significantly ($P \leq 0.05$). In weed control, results revealed that pine and wild lemon grass mulch had similar ($P \leq 0.05$) effect as weeding. Laboratory analysis of compost containing pine and wild lemon grass containing compost showed significant changes in OC, TN, Na, Fe and Mn between three and twelve months of composting. In conclusion, application of both pine and wild lemon grass mulch brings higher yields of tomato and sweet pepper than hand weeded practice. Both types of mulch lasted throughout the production period without need replenishment. Types of mulch and time of application did not have a significant influence on yield, weed control, insect and disease attacks instead the presence of mulch reduced numbers of weeds, increased numbers of beneficial arthropods, yield and quality of tomato and sweet pepper. Pine and wild lemon grass containing compost released nutrients as early as three months after heaping. It is therefore recommended, that pine and wild lemon grass can be used as organic mulch three to 21 days after transplanting tomato and sweet pepper seedlings but using pine and wild lemon grass containing compost requires further investigation. It is further recommended for future scholars to also focus on studying beneficial arthropods and their relationship with insect pests where pine and wild lemon grass are used as mulch.

DECLARATION

I, LILIAN SHECHAMBO, do hereby declare to the Senate of Sokoine University of Agriculture that, this thesis is my own original work, done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

Lilian Shechambo — Date

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Above declaration is confirmed:

Prof. K. P. Sibuga — Date

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DEDICATION

This work is dedicated to my father and best friend who departed us at the very beginning of this work, the Late Dr. Fanuel Christopher Mazunde Shechambo. I will always love him.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

Cu	Copper
DANIDA	Danish International Development Agency
FAO	Food and Agriculture Organisation
Fe	Iron
K	Potassium
LSD	Least significant difference
m.a.s.l	metres above sea level
Mn	Manganese
OC	Organic Carbon
OC	Organic Carbon
P	Phosphorus
ProGrOV	Productivity and Growth in Organic Value-chains
SUA	Sokoine University of Agriculture
TN	Total Nitrogen
TN	Total Nitrogen
TOAM	Tanzania Organic Agriculture Movement (TOAM)
UMADEP	Uluguru Mountains Agriculture Development Project
USDA	United States Department of Agriculture
WAT	Weeks After transplanting
Zn	zinc

CHAPTER ONE

1.0 General Introduction

Vegetables are important sources of nutrients required to supplement daily dietary needs of the human body. Varying proportions of vitamins, provitamins, dietary minerals, fibers, carbohydrates and little amounts of proteins and fats are contained in vegetables (Whitaker, 2001). Tomato (*Solanum lycopersicum* L.) and sweet pepper (*Capsicum annuum* L.*)* in particular contain large proportions of vitamins A and C (USDA, 2005). The deficiency of vitamin A leads to night blindness disorder while the deficiency of vitamin C leads scurvy disorder in human beings (Dowling and Wald, 1958, Pimentel, 2003). Moreover, tomato and sweet pepper are sources of income for many households in Tanzania through provision of formal, informal and self employment to growers, traders, researchers and other allied workers. The world tomato and sweet pepper productions are estimated at 163.96 and 31.13 million tonnes harvested from 4.72 and 1.93 million hectares of land, respectively. In Tanzania, annual tomato production is estimated to be 423 323 harvested from 34 713 hectares of land, while annual sweet pepper production is estimated to be 14 000 tonnes harvested from 500 hectares of land (FAO, 2013).

Tomato and sweet pepper are cultivated by using conventional as well as organic methods. According to Jackson *et al*. (1998) and Cohen and Yuval (2000), ecological, toxicological and environmental shortcomings concerning synthetic pesticide and fertilizer residues in food and the environment have raised some restrictions on the use of the conventional agricultural produce. Pest management, however, poses a big challenge even in organic production systems. There are several abiotic and biotic factors that lead to low tomato and sweet pepper yield. These include pests such as weeds, insects and diseases (Tumwine *et al*., 2002). Pest problems can be severe as yield losses of nearly

100% are reported to be common when the crops are infested by high levels of diseases, weeds and insects, either singly or in combination (UMADEP, 2003).

Weeds affect crop production not only by competing with crops for nutrients, moisture and light but also by acting as alternate hosts of insect pests and diseases (Agbogidi and Okonmah, 2011; Thomas *et al*., 2005). Some weeds possess vegetative structures which make them very difficult to control. These structures include tubers in *Cyperus spp.*, stolons in *Cynodon spp.*, rhizomes in *Imperata spp.*, bulbs in *Oxalis spp.* and stem parts in *Commelina spps*. Varieties of pests are in existence and these include all organisms which in one way or the other contribute to yield reduction and poor quality of crop produce. Some insect pests such as the American bollworm [*Helicoverpa armigera* (Hübner)] are reported to account for more than half of the tomato fruit damages in Tanzania (Maerere *et al*., 2010). Tomato and sweet pepper are also susceptible to physiological disorders like fruit cracking and blossom end rot and a wide range of weeds, insect pests, nematodes and a variety of viral, fungal and bacterial diseases (Grubben and Mohamed, 2004).

Organic farming benefits the ecosystem by increasing species diversity, population density and biodiversity fitness (Gabriel *et al*., 2006). This increase in biodiversity is argued to increase ecosystem services including pest control by increasing the population of natural enemies of insect pests. However, the degree to which natural enemy diversity enhances the efficacy of pest management services, the effects of pest-enemy interactions through cultural management practices, field size, crop composition, pattern and even the surrounding vegetation is not clear (Altieri and Nicholls, 1999). Integration of all possible cultural and preventive practices against pests and other production challenges is highly encouraged in organic production systems. Mulching is among the cultural practices allowed in organic production systems. It is highly emphasized for its role of suppressing weeds, conserving soil moisture, providing nutrients upon decomposition, conserving natural enemies of insect pests by providing them with a suitable habitat, moisture, protection and alternative prey (Cortesero *et al*., 2000). Organic mulch in particular enhances the presence of predators like beetles and spiders (Diver *et al*., 1999).

Lushoto district in North-Eastern Tanzania is one of the areas in which organic production of many vegetables including tomato and sweet pepper takes place. Farmers commonly use star grass, banana leaves, bean plants and pods and other crop residues as mulch. However, several challenges have been associated with the use of these common organic types of mulch such as an increase in labour cost in terms of time and money because most of these mulches require frequent replenishment, scarcity in that most of them are also used as animal feed (Wickama *et al*., 2006) and seasonal availability which does not guarantee a year-through supply of mulch. Challenges associated with such commonly used mulches in Lushoto district have diverged attention towards alternative organic mulches such as tree leaves and non-animal feeding grasses.

A study involving tomato and sweet pepper organic vegetables mulched with pine (*Pinus patula* Schelde. ex Schltdl and Cham) and wild sunflower (*Tithonia diversifolia* (Hemsl.) A. Gray) was recently done in Lushoto district, Tanzania. The results from this study revealed that the use of pine mulch at 15cm layer thickness increased yields while lowering weed and insect pest infestations (Saria, 2014). Wild lemon grass is among the locally available mulch material which has not received research attention. It’s suitability as mulch and effect to crops and soil are yet to be revealed. Pine litter and wild lemon grass have been considered as the potential alternative organic mulches because they are not used as animal feed and they are available throughout the year in Lushoto district (Shechambo *et al*., 2015). Hence, further investigation on the durability of these organic mulch is necessary as most other commonly used organic mulch materials and plant residues require frequent replenishment due to their fast decomposition.

Despite of all the known advantages of applying organic mulch in various production systems, it is equally worth to note that such amendments have impact on soil properties as well. Organic mulch applied to cover the soil surface affects soil physical, biological and chemical properties. On the contrary, the rate of decomposition of organic matter on the soil surface is controlled by environmental conditions, soil microbial activities and the chemical composition of organic matter (Vitousek *et al*., 1994). Several studies have concentrated on the effect of using organic mulch on physical and biological properties of soil. Jobbagy and Jackson (2000) reported on the influence of soil texture on the rate of mineralization of soil organic matter stating the association of fine textured soils with high contents of organic matter and low rates of mineralization relative to coarse textured soils. Friedel *et al*. (2001) reported the functions of soil microbes as transient nutrient sink responsible for releasing nutrients from organic matter for use by plants.

The effects of organic mulches on soil chemical properties are perhaps one of the most important areas to focus because chemical composition of the mulches determines their quality as food for decomposer organisms (Swift *et al*., 1979). Several studies revealed the influence of organic mulches to nitrogen (N) availability in the soil through leaching and decomposition (Lambers *et al*., 1998; Aerts and Chapin, 2000). Most reports have shown no effect of organic mulch on soil pH [Stinson *et al*. (1990); Greenly and Rakow (1995)]. Iles and Dosman (1999) and De Vleeschauwer *et al*. (1980), reported the varying effects of organic mulch on soil temperature and moisture availability.

The inconsistent results reporting negative, positive or no effect reaction of organic mulch on soil properties is based on the fact that specific results are based on the type of organic mulch in question (Vitousek *et al.*, 1994; Greenly and Rakow, 1995; Aerts and Chapin, 2000). Thus, this particular study determined the effects of pine and wild lemon grass mulch on yield and quality of organically grown tomato and sweet pepper, pests and beneficial arthropods. The study also assessed the chemical composition of pine and wild lemon grass used as organic mulch, their decomposition rate and their mineral composition.

1.1 Objectives

1.1.1 Overall objective

To establish weed and insect pests management techniques for use in organic production of tomato and sweet pepper.

1.1.2 Specific objectives

i. To determine the effects of pine and wild lemon grass mulch on yield and quality of organically grown tomato and sweet pepper.
ii. To evaluate the effects of pine and wild lemon grass mulch on insect pests and beneficial insects under organic production of tomato and sweet pepper
iii. To determine the decomposition rate and nutrient release of pine and wild lemon grass compost.

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CHAPTER TWO

SWEET PEPPER YIELD RESPONSES TO ORGANIC MULCHES IN LUSHOTO, NORTH-EASTERN TANZANIA

Abstract

Mexican weeping pine (*Pinus patula* Schelde. ex Schltdl and Cham) and wild lemon grass (*Cymbopogon spp.*) were used as mulch in organic production of sweet pepper (*Capsicum annuum* L.) to evaluate the effect of type of mulch, time of application and influence of seasons on yield. The study was conducted in Lushoto and Ubiri wards, Lushoto district, North-Eastern Tanzania. The experiment was laid out in the Randomised Complete Block Design (RCBD) with three replications. The treatments were pine mulch applied 3 days after transplanting (PI), and 21 days after transplanting (PA), grass mulch applied 3 days after transplanting (GI), and 21 days after transplanting (GA) and two unmulched controls weeded (CI) and unweeded (CA). Data was collected on the number of leaves per plant, plant height, total yield, marketable and unmarketable fruit weight. Data was analyzed using R Statistical Package (AGRICOLAE Version 1.2.1). The *Post Hoc* Tukey's test was used to compare means. Results showed that both types of mulch had positive influence on yield with no significant differences ($P<0.05$) on yields recorded in mulched and weeded tretments. Plant height and number of leaves per plant recorded at 13 weeks after transplanting (WAT), fruit size and marketable fruit weight were higher in mulch treated plots regardless of the time of mulch application. Results also revealed that among the three seasons of growing sweet pepper, the highest yields were obtained during the wet and cold season (April – August, 2013).

Key words: Mulching effect, organic production

2.1 Introduction

Sweet pepper (*Capsicum annuum* L.) is among important vegetables grown in Lushoto district, North-Eastern Tanzania. Production of sweet pepper is, however, not optimal due to both biotic and abiotic factors. Both qualitative and quantitative yields are consequently low. Evidences from research reveal the importance of mulch in agriculture based on the roles it performs to improve crop yields and soils. Such roles include suppressing weeds by blocking light through forming a physical barrier, regulating soil temperature, conserving natural enemies of insect pests, control of soil erosion, moisture conservation and keeping agricultural produce clean and safe from soil impurities (Cortesero *et al*., 2000; Iftikhar *et al*., 2011; Schonbeck and Evanylo, 1998; Nkansah *et al*., 2003).

Higher yields of mulched capsicum were previously reported in works done by Vos and Sumarni (1997); Norman *et al*. (2011); Manuel *et al*. (2000); Thakur *et al*. (2000) and Venkanna (2008). One of the methods developed to conserve soils and improve crop productivity is the use of mulch to enhance soil and crop growth environment. Organic mulch in addition to the above, also add soil nutrients after decomposition, improving soil fertility and productivity (Awodun and Ojeniyi, 1999, Mulumba and Lal, 2008). Organic mulch directly affects soil physical, biological and chemical properties on application. Moreover, the rate of decomposition of organic matter on the soil surface is controlled by environmental conditions, soil microbial activities and the chemical composition of organic matter (Vitousek *et al*., 1994).

Farmers in Lushoto, use mainly crop residues as mulch (Wickama *et al*., 2006) to improve production and yield. However, such mulch only become available seasonally especially after harvest, they also require frequent replenishment due to their fast decomposition and in many cases they are used as animal feed therefore becoming unavailable as mulch. Saria (2014) reported that sweet pepper organic vegetables mulched with pine (*Pinus patula* Schelde. ex Schltdl and Cham) and wild sunflower (*Tithonia diversifolia* (Hemsl.) A. Gray) increased yield, lowered weed and insect pest infestations. Wild lemon grass is among the locally available mulch material which has not been previously studied in Lushoto. Pine litter and wild lemon grass could be potential alternative organic mulches because they are not used as animal feed and they are also available throughout the year in Lushoto district. This research, investigates the effect of mulching using pine and wild lemon grass, and time of mulch application on yield, yield components and quality of sweet pepper.

2.2 Materials and Methods

2.2.1 Description of the study area

The study was done in Lushoto district, Tanga region, Tanzania, located in the West Usambara mountains situated between 38º 10’ and 38º 36’ East and 4º 24’ and 5º 00’ South at an altitude of between 800-2300 m above sea level (m.a.s.l.) The area receives bimodal rainfall pattern with short rains from October to December and long rains from March to June. Annual rainfall ranges from 600 to 1200 mm, while temperature ranges from 16 - 30ºC (Fig. 2.1). The dominant soil type is latosols (Shemdoe, 2011). The experimental sites were Lushoto (38° 17’ 24’’ East and 4° 47’ 55’’ South) with an altitude of 1500 m. a.s.l. located at Lushoto town-forest area and Ubiri (38° 21’ 59’’ East and 4° 50’ 29’’ South) with an altitude of 1218 m. a.s.l. located at Ubiri village along Mombo-Lushoto road.

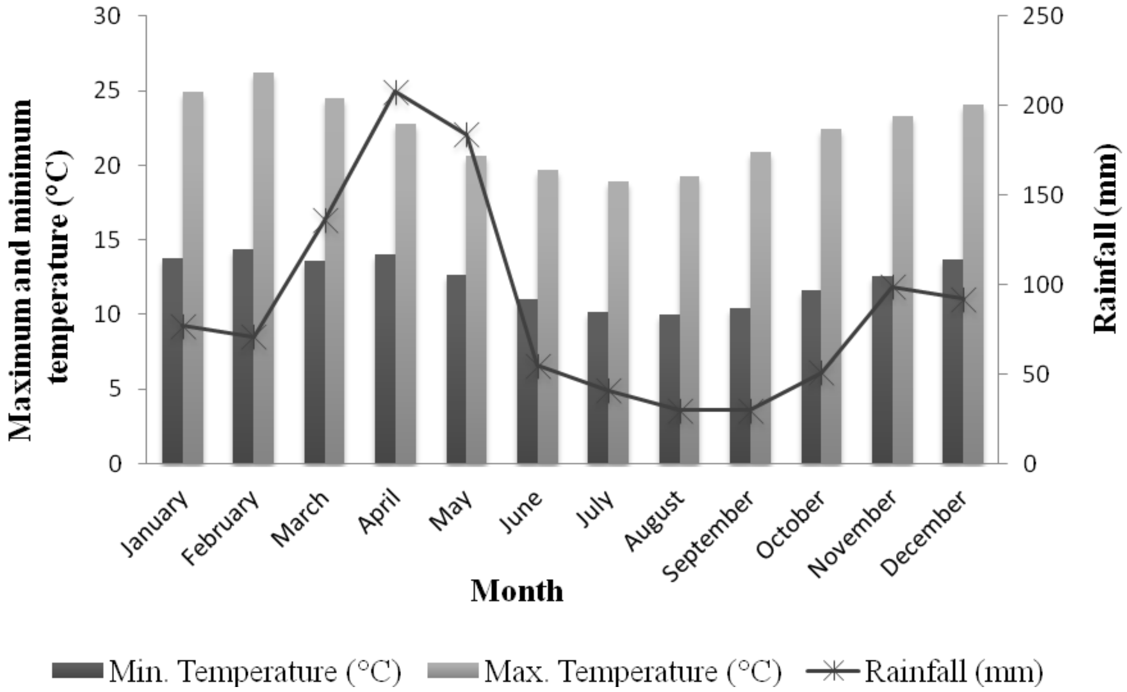


Figure 2.1: The thirty year (1982-2012) average weather condition in Lushoto district.

2.2.2 Weather conditions recorded during the study period

During the study period, Lushoto district experienced lowest rainfall in June, 2013 and heaviest rainfall in April, 2015 (Fig. 2.2). Temperature records showed a peak in January and March, 2015 while lowest temperatures were recorded in June, 2013. Relative humidity ranged between 85 to 90 percent. The year 2014 is not included in the chart because the experiments done in that year were not successful therefore pushing the experiments to the year 2015.

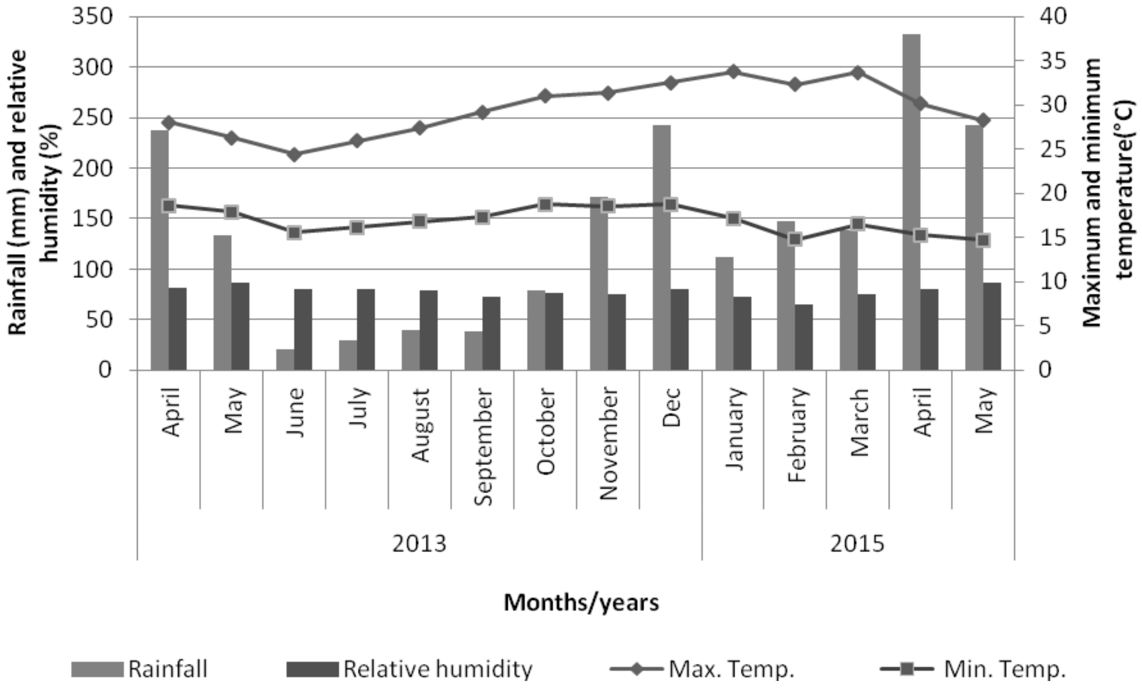


Figure 2.2: Rainfall, relative humidity, maximum and minimum temperature parameters for Lushoto during the study period.

2.2.3 Land, seedling preparation and transplanting

Seeds of sweet pepper variety California Wonder were sown on prepared seed beds located near the main fields on each site. Sweet pepper seeds were sown in February, 2013, July, 2013 and November, 2014 for season 1, 2 and 3, respectively. The germinated sweet pepper seedlings were reared for eight weeks at the nursery before transplanting.

The land for the experiment was prepared by clearing all weeds, hoeing and raking. Field layout was done towards the end of seedling rearing before transplanting. Plots measuring 3m x 3m were prepared by using a hand hoe and was followed by transplanting of sweet pepper seedling at the spacing of 40 x 40 cm.

Field management activities included irrigating by tap water (at Lushoto site) and by furrow irrigation (at Ubiri site). Another activity included application of organic compost ERTHFOOD$_{TM}$ (1.5-0.5-0.5) applied at 500g per planting hole, one day before transplanting. This was later supplemented by a seven-day fermented solution of cow urine (20 litres), cow dung (50 kg) and water (200 litres) applied as an organic manure top dressing solution at 0.5 litres per plant. A local biopesticide (mwarobaini) made from a mixture of Neem (*Azadirachta indica* A. Juss.) seeds in dried, ground and sieved form (0.5 kg), together with sour milk (0.5 litres), ashes (0.5 kg), banana male bud (1 piece) and kerosene (0.25 litres) and 15 litres of water was applied.

Pine mulch was collected under pine trees in the pine forest near Lushoto experimental site while wild lemon grass was collected from the rocks on the mountains at Kizara village near Ubiri experimental site. Pine mulch was in dry form and did not require chopping due to its needle-like shape while wild lemon grass leaves were dried for three weeks and were chopped before use. Weather data for Lushoto district were obtained from Tanzania Meteorological Authority.

Sweet pepper was grown for three seasons. Season 1 from April to August, 2013. These months are usually accompanied with long rains followed by cold temperatures just right after the end of the long rains (normally this is the off-season) (Fig. 2.1). Season 2 from September to December, 2013. These months are usually dry with warm temperatures gradually increasing towards the end of year (normally this is the on-season). Season 3 from January to May, 2015. These months are usually dry with warm temperatures and later on the long rains begin (this is normally the off-season as well) .

2.2.4 Experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with six treatments and three replications. The treatments were pine mulch applied 3 days after transplanting (PI), pine mulch applied after 21 days (PA), wild lemon grass mulch applied 3 days after transplanting (GI), wild lemon grass mulch applied after 21 days (GA), weeded (CI) control and unweeded (CA) control. The plot size was 9 m^2.

2.2.5 Data collection

Data on the number of leaves per plant were recorded four and eight weeks after transplanting (WAT). All full leaves were counted from all treatments. However, plants from guard rows in each plot were all excluded during leaf counting.

Plant height (in cm) was measured by using a tape measure four and eight weeks after transplanting. Plants in guard rows were also excluded during plant height recording.

During harvest (from 16 WAT), data on sweet pepper fruit size were collected on fruits with shoulder diameter ranging between 5 cm to 10 cm. Fruit shoulder diameter was measured by using a vernier caliper (Series 530-Standars model, Mitutoyo Bengatouch (Pty) Ltd Mobi). Fruit size categories were small, medium and large. Small fruits sized from 5 cm to 5.9 cm in shoulder diameter, medium fruits sized from 6 cm to 8.9 cm while large fruits sized from 9 cm and above.

Fruits were weighed (in kg) after each harvest by using a spring balance scale (Lineaeffe Brand 50 kg scale, Glasgow Angling Centre, UK), later, total harvest per season was calculated and converted to tons/ha. Yield data of marketable and unmarketable sweet pepper fruits were also collected. The criteria used to distinguish between marketable and non-marketable fruit were: 1) healthy versus damaged or diseased fruits, 2) fruit size whether small, medium or large fruits as described above.

2.2.6 Data analysis

All data obtained were subjected to Analysis of Variance (ANOVA) using R Statistical Package (AGRICOLAE Version 1.2.1). *Post Hoc* Tukey's (HSD) test was used to compare means at P = 0.05 level of significance.

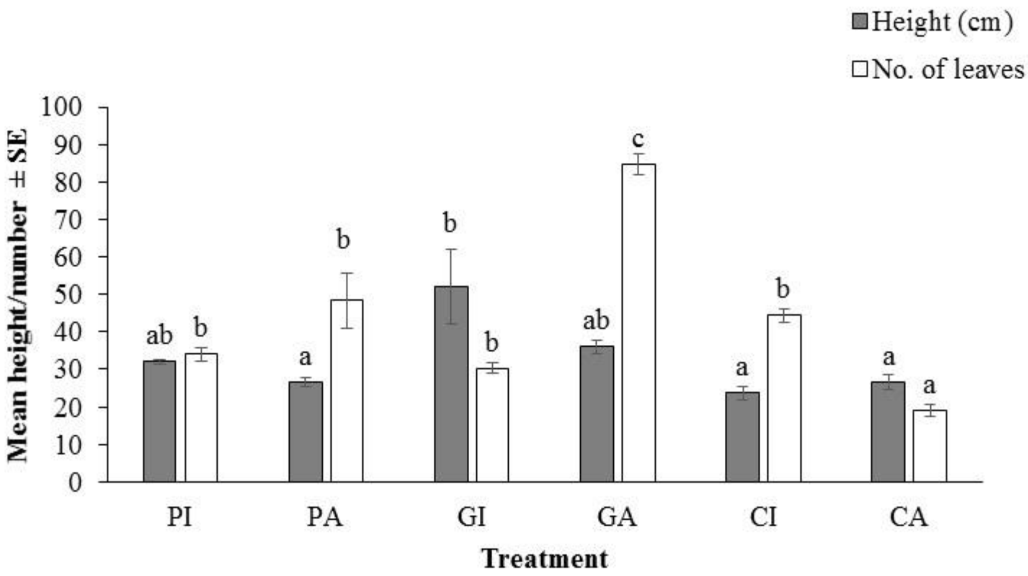
2.3 Results

2.3.1 Plant height

Results for mean plant heights in sweet pepper under various treatments are presented in Figure 2.3. The heights varied signifcantly among treatments ($F_{5, 12} = 4.40$, $P = 0.027$). *Post Hoc* (Tukey HSD) test showed that sweet pepper harvested from plots mulched with wild lemon grass applied three days after transplanting (GI) versus unweeded control (CA), weeded control (CI) and pine mulch applied 21 days after transplanting (PA). All other treatments had similar effects on sweet pepper heights.

2.3.2 Number of leaves

Number of sweet pepper leaves differed dignificantly among treatments ($F_{5, 12} = 26.455$, $P < 0.001$). *Post Hoc* (Tukey HSD) test showed that unweeded control (CA) plots had significantly lower yields compared to all other treatments (Fig. 2.3). Also sweet pepper plants in wild lemon grass mulch applied 21 days after transplanting (GA) plots had signficantly more leaves than those in pine mulch applied three days after transplanting (PI), pine mulch applied 21 days after transplanting (PA), wild lemon grass mulch applied three days after transplanting (GI) and weeded control (CI).



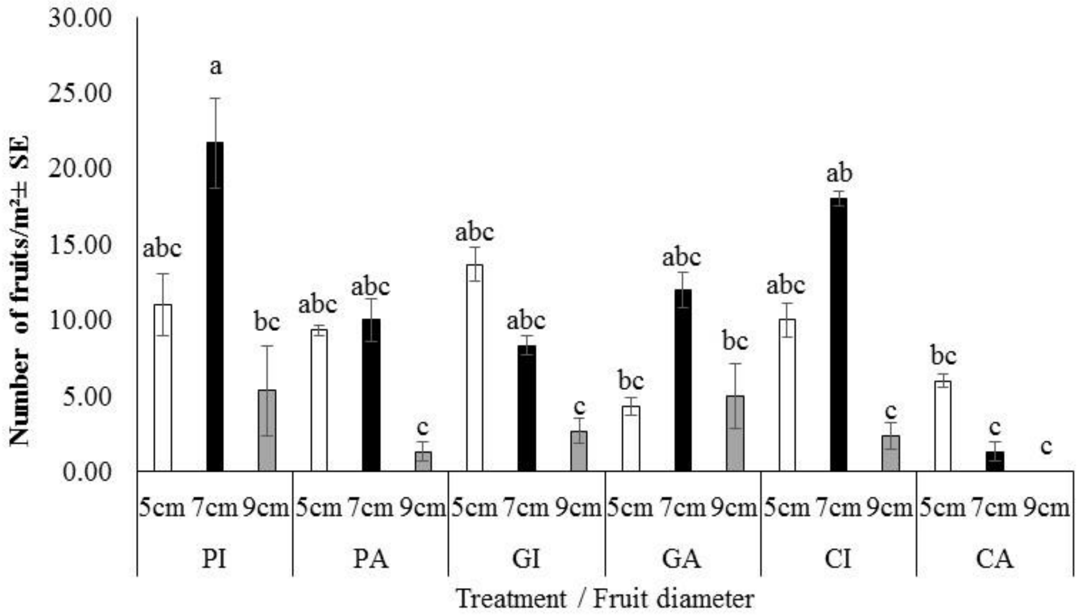
Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 2.3: Effect of mulch on plant height and number of leaves of sweet pepper plants.

2.3.3 Sweet pepper fruit sizes

Number of fruits of sweet pepper varied significantly with diameter ($F_{2, 36}$ = 90.95, P <0.001). Treatments significantly affected number of sweet pepper fruits ($F_{5, 36}$ = 55.63, P <0.001). The interaction between treatment and diameter were also significant ($F_{10, 36}$ = 186.82, P <0.001). *Post Hoc* (Tukey's HSD) showed that plots mulched with pine three days after transplanting had significantly higher number of large sized fruits compared to all other treatments (Fig. 2.4).



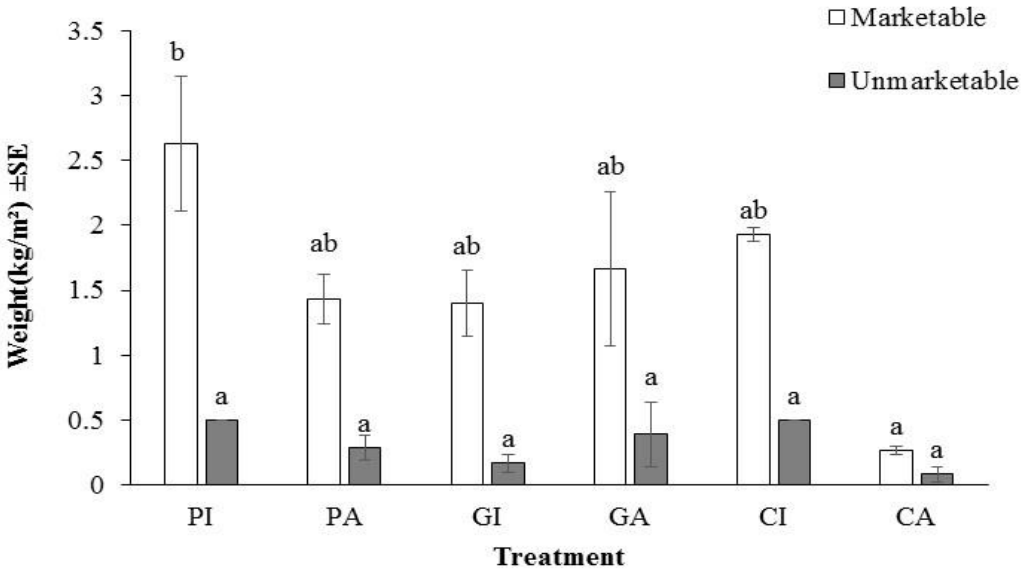
Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 2.4: Effects of type of mulch and time of mulch application on size of sweet pepper fruits.

2.3.4 Marketable and unmarketable sweet pepper fruit yield

Sweet pepper marketable yields differed significantly among treatments ($F_{5,\ 12} = 12.42$, $P < 0.001$). Significant diffferences were observed between control and all other treatments (Tukey's HSD). Treatments significantly affected umarketable sweet pepper yield ($F_{5,\ 12} = 8.03$, $P = 0.01$). Significant diffferences were observed between unweeded control and all other treatments (Tukey's HSD) (Fig. 2.5).



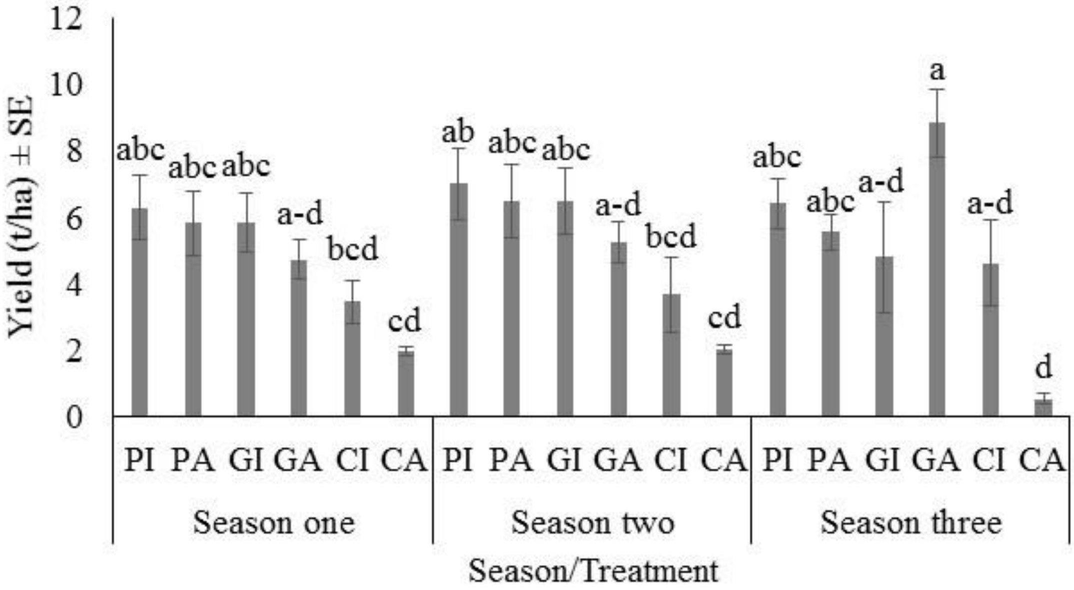
Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 2.5: Effect of type of mulch and time of application on marketable and unmarketable sampled sweet pepper fruit yield

2.3.5 Sweet pepper yield

Sweet pepper yields at Lushoto are presented in Fig. 2.6. Results showed that sweet pepper yields differed significantly among treatments ($F_{5, 36} = 13.65$, $P < 0.001$) but among seasons ($F_{2, 36} = 0.52$, $P < 0.59$). Effects of treatment x season were not statistically significant ($F_{10, 36} = 1.65$, $P = 0.13$). *Post Hoc* (Tukey's HSD) of main means showed that CA plots had significantly lower yields compared to all other treatments. Yields of sweet pepper from weeded control (CI) plots also differed significantly with yields from wild lemon grass mulched 21 days after transplanting (GA) and plots mulched with pine applied three days after transplanting (PI).

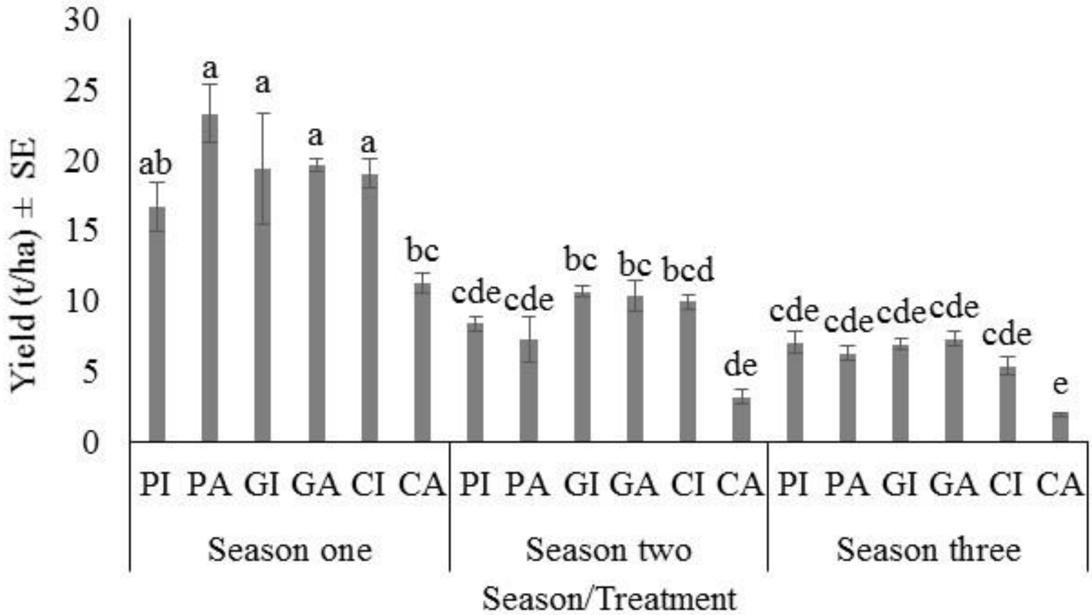


Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 2.6: Yield of sweet pepper fruits at Lushoto site

Figure 2.7 presents yields of sweet pepper at Ubiri. Results showed that Sweet pepper yields differed significantly among treatments ($F_{5, 36}$ = 36.52, P <0.001) as well as among seasons ($F_{2, 36}$ = 184.37, P <0.001). Effects of treatment x season were also significant ($F_{10, 36}$ = 3.35, P = 0.01). *Post Hoc* (Tukey's HSD) of main means showed that unweeded control (CA) plots had significantly lower yields compared to weeded control (CI), wild lemon grass mulched 21 days after transplanting (GA), wild lemon grass mulched applied 3 days after transplanting (GI), pine mulched 21 days after transplanting (PA) and pine mulched 3 days after transplanting (PI) plots.



Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 2.7: Sweet pepper fruit yield at Ubiri site

2.4 Discussion

All mulched treatments provided higher yields of sweet pepper. Yields in weeded treatments were statistically similar to yields in most mulched treatments (Fig. 2.6 and 2.7). Vos and Sumarni (1997), observed increased fruit weight of hot pepper with straw mulching compared to the control. Sawdust mulch recorded higher mean fruit weight of pepper than the control (Norman *et al*., 2011). They reported that fruit weight per plant in both grass mulched and unmulched plots in summer and winter produced no significant differences on growth and yield parameters of bell pepper. However, bell pepper grown using grass mulch produced higher total number of weight of fruits than those on unmulched plots (Manuel *et al*., 2000).

The total fresh weight of sweet pepper fruit per plant in the current study revealed that wild lemon grass mulch produced high yield compared to the unmulched control (Fig. 2.6 and 2.7). Previous studies have shown that bell pepper grown on grass mulch plots produced higher total number of fruits than those in unmulched plots both in summer and winter (Manuel *et al.,* 2000). The number of chilli fruits per plant differed significantly with glyricidia mulch and with crop residue mulch compared to no mulch (Venkanna, 2008). Mulch material used influenced the number of chilli fruits per plant. the highest fruit number per plant was recorded in sugarcane bagasse mulch followed by rice straw mulch and wheat straw mulch. Control recorded the lowest fruit number per plant (Iftikhar *et al*., 2011). Similary, in the current study, the highest mean number of sweet pepper fruits per plant was observed in wild lemon grass mulch plots over the control. Gollifer (1993) reported that application of organic mulch resulted in increased chilli dry fruit yield compared to the untreated control. Organic mulch had the highest fruit yield of bell pepper over control (Roe *et al*., 1994, Hassan *et al*., 1994). Vos and Sumarni (1997), observed an increased yield of hot pepper with straw mulching compared to control. Lantana leaves and grass mulches maintained higher growth and yield parameters in capsicum as compared to unmulched treatments, yield levels increased in plots mulched with lantana leaves and grass mulched plants over unmulched plants (Thakur *et al*., 2000).

Seasonal differences in sweet pepper yields observed in the current study could be attributed by temperature and moisture variations between seasons. Sweet pepper yields were high during wet cool season (April to August, 2013) than during hot dry season (September to December, 2013). Overall results also suggest that the use of pine and wild lemon grass mulch can reduce farmers' time spent on weeding. Mulch prevents light from reaching the soil surface hence, reducing chances of weed germination. Farmers can thus use the saved time from weeding for doing other economic activities and improve their income and livelihood.

This study has shown that plant growth, as represented by number of leaves and plant height was not affected by the type of mulch used. All plants attained average height with varying number of leaves per plant (Fig. 2.5). Plant height responses to mulch showing a similar trend was also reported by Ossom and Matsenjwa (2007) in a dry bean study done in Swaziland. Mulching in sweet pepper also had positive effects on growth. Sweet pepper fruit size was also not affected by the type of mulch used, pine and wild lemon grass. Such findings were also reflected by the fruit size.The quantities of small, medium and large sized fruits were also significantly different (Fig. 2.6). Number of leaves per plant were low in control plots compared to other treatments. This observation shows that mulched plants were in good condition as weeded plants therefore suggesting that mulching with pine and wild lemon grass increased the number of leaves and fruit yield (Fig. 2.5).

Marketable and unmarketable fruit weight harvested from mulched and weeded plots were also not significantly different between the two treatments. However, Adeniyan *et al*. (2008) reported the increase in establishment and tuber weight in yams mulched with organic weeded materials.

2.5 Conclusion and Recommendations

Employing organic mulch in sweet pepper production increased yield of sweet pepper. Presence of mulch also increased fruit size and market quality and quantity of marketable yield. This study recommeds the use of pine or wild lemon grass as mulch in sweet pepper production in Lushoto. Further study on the effects of decaying pine and wild lemon grass on soil properties is recommended.

2.6 Acknowledgements

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CHAPTER THREE

TOMATO YIELD RESPONSES TO ALTERNATIVE ORGANIC MULCHES IN LUSHOTO, NORTH-EASTERN TANZANIA

Abstract

Mexican weeping pine (*Pinus patula* Schelde. ex Schltdl and Cham) and wild lemon grass (*Cymbopogon spp.*) were used as mulch in organic production of tomato (*Solanum lycopersicum* L.) to evaluate the effect of type of mulch, time of applying mulch and influence of seasons on yield. The study was conducted in Lushoto and Ubiri wards, Lushoto district, North-Eastern Tanzania. The experiment was laid out in a Randomised Complete Block Design (RCBD) with three replications. The treatments were pine mulch applied 3 days after transplanting (PI) and 21 days after transplanting (PA), wild lemon grass mulch applied 3 days after transplanting (GI) and 21 days after transplanting (GA) and two unmulched controls weeded and unweeded. Data were collected on number of leaves per plant, plant height, yields, marketable and unmarketable fruit weight. Data were analyzed using R Statistical Package (AGRICOLAE Version 1.2.1). *Post hoc* Tukey's (HSD) Test was used for mean separation. Results showed that both types of mulch had positive influence on yield with no significant ($p<0.05$) differences in yields recorded in mulched and weeded tretments. Other production and quality components such as plant height and number of leaves per plant recorded at 13WAT, fruit size and marketable fruit weight were increased with mulch regardless of the time of mulch application. Results also revealed that among the three seasons of growing tomato, the highest yields were obtained during the wet and cold season (April - August).

Key words: Mulching effect, organic mulch, organic production, tomato.

3.1 Introduction

Tomato (*Solanum lycopersicum* L.) is among the important vegetables grown in Lushoto district in North-Eastern Tanzania. The crop is important for food and nutrition securty of local populations. Tomato production and yield are affected by various biotic and abiotic factors including pests and diseases. Various weed species affect tomato production through competition for resources. The use of mulch in tomato production has been reported to increase tomato yield (Schonbeck and Evanylo, 1998; Nkansah *et al*., 2003;. Awodoyin *et al*., 2007; Ojeniyi *et al*., 2007; Chakraborthy and Sadhu 1994; Alvaro *et al*., 2010).

Mulch suppress weeds, regulate siol temperature, conserve natural enemies of insect pests, control soil erosion and conserve moisture. Organic mulch add nutrients into the soil after decomposition, helping to improve soil quality and productivity Organic mulch directly affects soil physical, biological and chemical properties when applied. Moreover, the rate of decomposition of organic matter on the soil surface is controlled by environmental conditions, soil microbial activities and the chemical composition of organic matter (Cortesero *et al*., 2000; Awodun and Ojeniyi, 1999; Mulumba and Lal, 2008; Vitousek *et al*., 1994; Brown and Tworkoski 2003; Arancon *et al*. 2006; Arancon *et al*., 2006; Acharya and Sharma 1994; Cadavid *et al*., 1998).

Farmers in Lushoto District commonly use star grass, banana leaves, bean plants and pods and other crop residues as mulch. Such mulching materials become unavailable when they are used as animal feed (Wickama *et al*., 2006) or when the crops are not on season. The crop residue mulch are also easily decomposed requiring frequent replenishment. This called for a search for alternative mulching materials. A study involving tomato mulched with Pine (*Pinus patula* Schelde. ex Schltdl and Cham) and wild sunflower

(*Tithonia diversifolia* (Hemsl.) A. Gray) was done at Soni and Lushoto wards, Lushoto district, respectively. The results from the study revealed that the use of pine mulch at 15cm layer thickness increased yields while lowering weed and insect pest infestations (Saria, 2014). Wild lemon grass is among the locally available mulching material which has not received research attention. Its suitability as mulch and its effect on crops and soil are yet to be revealed. Pine litter and wild lemon grass could be the potential alternative organic mulching materials because they are not used as animal feed and they are also available throughout the year in Lushoto district. This paper, investigated the effect of pine and wild lemon grass mulching material, mulch thickness and time of mulch application on yield, yield components and quality of tomato.

3.2 Materials and Methods

3.2.1 Description of the study area

The study was done in Lushoto district, Tanga region, Tanzania, located in the West Usambara mountains between 38º 10’ and 38º 36’ East and 4º 24’ and 5º 00’ South at an altitude of between 800-2300 m above sea level. The area receives a bimodal pattern of rainfall with short rains from October to December and long rains from March to June. Annual rainfall ranges from 600 to 1200 mm while temperature ranges from 16 - 30ºC (fig. 2.1). The soils are generally latosols (Shemdoe, 2011). The experimental sites were Lushoto (38° 17’ 24’’ East and 4° 47’ 55’’ South) with an altitude of 1500m. a.s.l. located at Lushoto town-forest area and Ubiri (38° 21’ 59’’ East and 4° 50’ 29’’ South) with an altitude of 1218m. a.s.l. located at Ubiri village along Mombo-Lushoto road.

3.2.2 Weather conditions during the study period

The weather conditions recorded during the study period are shown in fig. 2.2. Lushoto district experienced the heaviest rainfall in April, 2015 and the lowest rainfall records in

June, 2013. Temperature records show a peak in January and March, 2015 while the lowest temperatures were recorded in June, 2013. Relative humidity parameters showed an average value of 85 to 90 percent.

3.2.3 Land, seedling preparation and transplanting of tomato

Seeds of tomato variety Tanya were sown on prepared seed beds located near the experimental main fields on each site. Seeds for the first season were sown in February, 2013, seeds for the second season were sown in July, 2013 while seeds for the third season were sown in November, 2014. The emerged seedlings were raised for eight weeks in the nursery before they were transplanted to the main field. Field layout was done towards the end of seedling rearing before transplanting. Plots measuring $9m^2$ each were prepared for transplanting. Tomato seedlings were then transplanted at the inter-row and intra-row spacing of 50cm x 50cm.

After transplanting, management activities included irrigation by tap water (at Lushoto site) and by furrow water (at Ubiri site). Organic compost $ERTHFOOD_{TM}$ (1.5-0.5-0.5) was used at the quantity of 500g per planting hole, applied one day before tomato seedlings were transplanted. A seven-day soaked solution of cow urine (20 litres), cow dung (50 kg) and water (200 litres) applied as an organic manure top dressing solution at 0.5 litres per plant were used as supplemens. A local biopesticide, ‘mwarobaini’ was used for insect pest control. The local biopesticide was a mixture of seeds of Neem plant (*Azadirachta indica* A. Juss.) in dried, ground and sieved form (0.5 kg), together with sour milk (0.5 litres), ashes (0.5 kg), banana male bud (1 piece) and kerosene (0.25 litres) in 15 litres of water. Pine mulch was collected under pine trees in the pine forest near Lushoto experimental site while wild lemon grass was collected from the rocks on the mountains at Kizara village near Ubiri experimental site, along the Mombo-Lushoto road.

Pine mulch was in dry form and did not require chopping due to its needle-like shape while wild lemon grass leaves were dried for three weeks and were chopped before use.

3.2.4 Experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with six treatments and three replications. The treatments were pine mulch applied 3 days after transplanting (PI) and 21 days after transplanting (PA), wild lemon grass mulch applied 3 days after transplanting (GI) and 21 days after transplanting (GA), weeded and unweeded (controls). The size of each plot was $9m^2$. Tomato was grown for three seasons from April to August, 2013 (wet and cold period - normally this is the off-season), September to December, 2013 (dry and hot period – the on-season) and January to May, 2015 (dry, hot and rainy period – the off-season).

3.2.5 Data collection and analysis

Data on the number of leaves per plant and plant height (cm) measured using a tape, were collected at 13WAT. Fruits were weighed (in kg) after each harvest, the total harvest per season was calculated and converted to tons/ha. Data for fruit size were collected and yields of marketable and unmarketable tomato fruits were also measured. The criteria used to distinguish between marketable and non-marketable fruit were: 1) healthy versus damaged or diseased fruits, 2) fruit size whether medium (≥ 5cm in diameter) and large fruits (≥ 7cm in diameter) versus small fruits (< 5cm in diameter). All data were subjected to Analysis of Variance (ANOVA) using R Statistical Package (AGRICOLAE Version 1.2.1). *Post Hoc* Tukey (HSD) test was used to compare means at P = 0.05 level of significance.

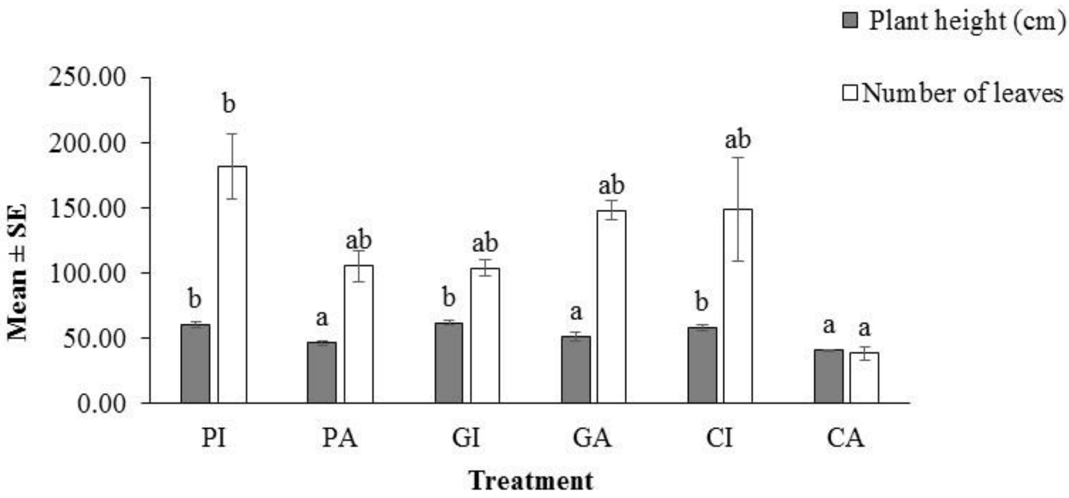
3.3 Results

3.3.1 Plant height

Figure 3.1 presents mean heights of tomato under various treatments. Results showed that tomato heights varied significantly among treatments ($F_{5, 12}$ = 14.55, P = 0.001). *Post Hoc* (Tukey HSD) test showed significant differences between unweede control (CA) versus, weeded control (CI), wild lemon grass mulch applied three days after transplanting (GI) and pine mulch applied three days after transplanting (PI). Also differences were observed between pine mulch applied 21 days after transplanting (PA) versus wild lemon grass mulch applied three days after transplanting (GI), pine mulch applied three days after transplanting (PI) and weeded control (CI).

3.3.2 Number of leaves

Number of tomato leaves differed significantly among treatments ($F_{5, 12}$ = 4.09, P = 0.02). *Post Hoc* (Tukey HSD) test showed that unweeded control (CA) plots had significantly lower yields compared to number of leaves recorded in plots mulched with pine three days after transplanting. The rest of the treatments were statistically similar in number of leaves recorded (Fig. 3.1).



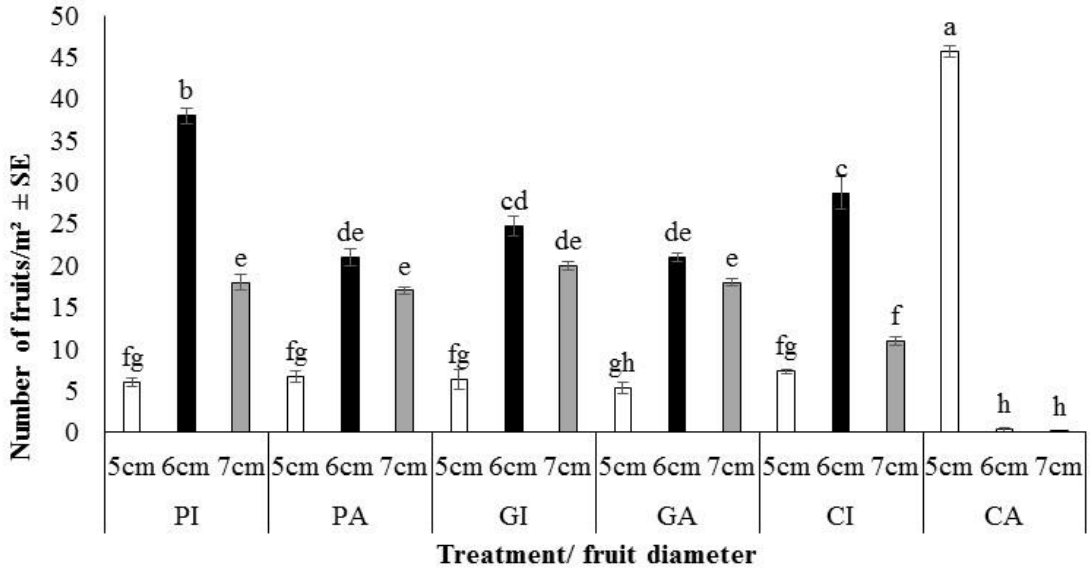
Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 3.1: Effect of mulch on plant height and number of leaves in tomato plants.

3.3.3 Number and size of tomato fruits

Tomato fruit sizes ranged from ≤5cm to ≥7cm and the highest number of fruits were medium sized (Fig. 3.2). Number of fruits of sweet pepper varied significantly with diameter ($F_{2, 36}$ = 90.95, P <0.001). Treatments significantly affected number of sweet pepper fruits ($F_{5, 36}$ = 55.63, P <0.001). The interaction between treatment and diamter were also significant ($F_{10, 36}$ = 186.82, P <0.001). *Post Hoc* (Tukey's HSD) showed that unweeded control (CA) had significantly higher number of small sized fruits compared to all other treatments (Fig. 3.2).



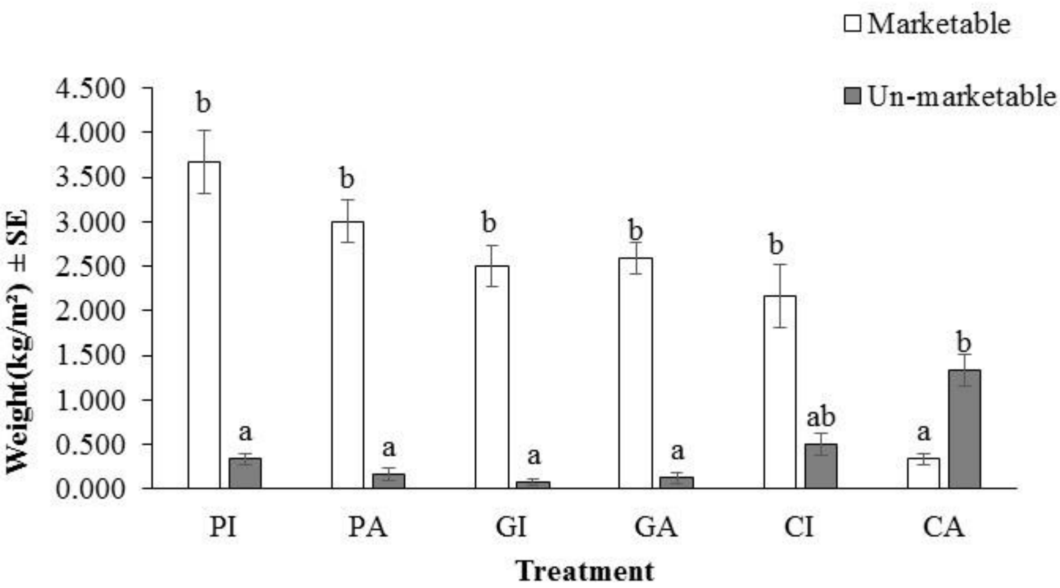
Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 3.2: Effect of type of mulch and time of mulch application on size of tomato fruits

3.3.4 Marketable and unmarketable fruit yield

Marketable fruits were clean, undamaged, unbruised and of acceptable size according local market qualities (with shoulder diameter of not less than 5cm) while unmarketable fruits were mostly insect damaged, bruised, diseased or too small in size (with fruit shoulder diameter of less than 5cm). Tomato marketable yields differed significantly among treatments ($F_{5,\ 12}$ = 12.42, P < 0.001). Significant diffferences were observed between control and all other treatments (Tukey's HSD). Treatments also significantly affected umarketable tomato yield ($F_{5,\ 12}$ = 8.03, P = 0.01). Significant diffferences were also observed between control and all other treatments (Tukey's HSD) (Fig. 3.3).



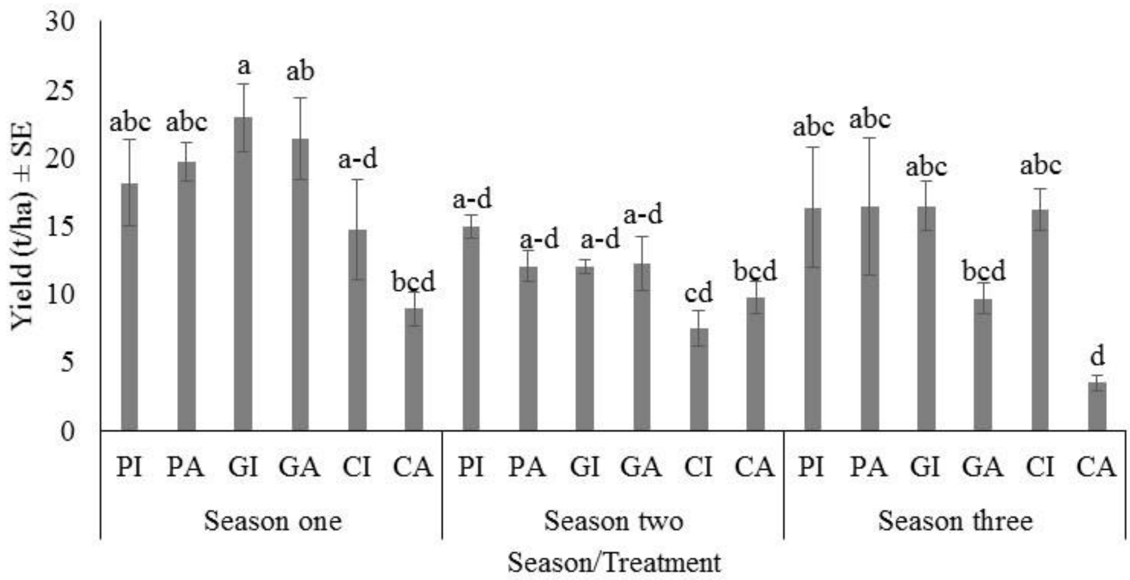
Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 3.3: Effect of type and time of mulch application on marketable and unmarketable tomato fruit yields

3.3.5 Tomato yield

Results of tomato yield are presented in Fig. 3.4. At Lushoto, treatments significantly affected tomato yield ($F_{5, 36}$ = 6.85, P <0.001). Yield varied significantly among seasons ($F_{2, 36}$ = 10.74, P <0.001). The effects of treatment x season were not significant ($F_{10, 36}$ = 1.97, P = 0.07). *Post Hoc* (Tukey's HSD) of main means showed that unweeded control (CA) plots had significantly lowest yields compared to all other treatments. The effects of other treatments were not significantly different.

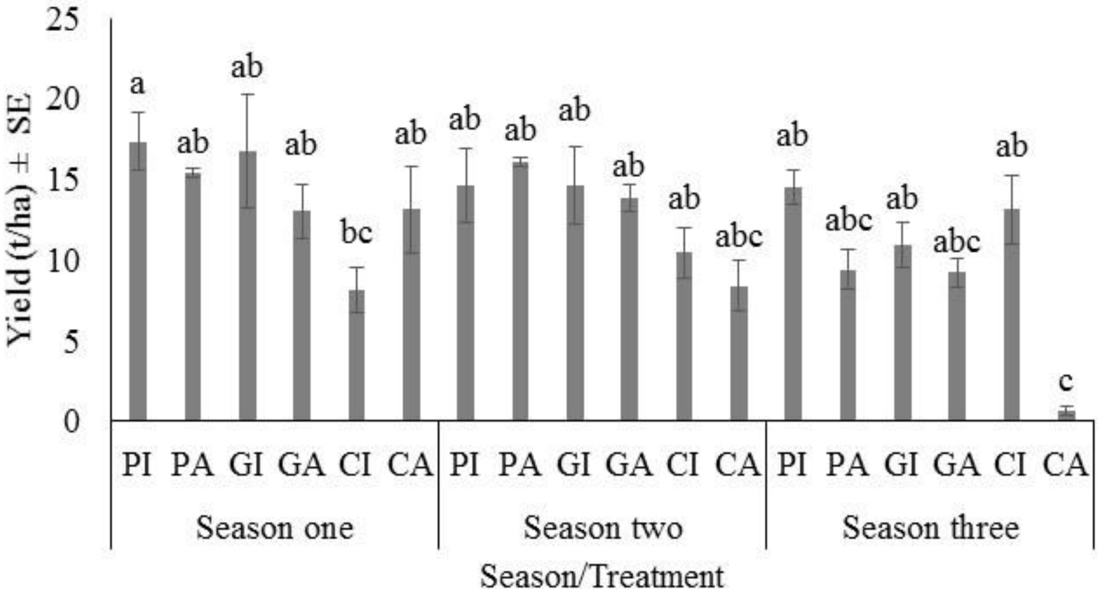


Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 3.4: Effect of mulch on tomato fruit yield at Lushoto site in season one to three

At Ubiri site, tomato yields (Fig. 3.5) were also significantly affected treatments ($F_{5,\ 36}$ = 8.84, P <0.001) as well as by season ($F_{2,\ 36}$ = 10.70, P <0.001) and treatment x season ($F_{10,\ 36}$ = 3.19, P = 0.04). Post Hoc (Tukey HSD) pairwise comparison of means showed unweeded control (CA) plots had significantly lower yields compared to wild lemon grass mulch applied 21 days after transplanting (GA), wild lemon grass mulch applied three days after transplanting (GI), pine mulch applied three days ater transplanting PI and 21 days after transplanting (PA). Differences in yield between pine mulch applied three days after transplanting (PI) and weeded control (CI) were also significant.



Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 3.5: Effect of mulch on tomato fruit yield at Ubiri site in season one to three

3.4 Discussion

3.4.1 Effect of type of organic mulch and time of mulch application on plant growth

Growth of tomato plants as represented by the number of leaves and plant height, was not affected by the type of mulch used in the study. Tomato plants in plots mulched with pine and wild lemon grass three days after transplanting were the tallest, followed by plants in plots mulched with pine 21 days after transplanting. The shortest tomato plants were found in unweeded control plots (Fig. 3.1). The number of leaves per tomato plant was also higher in all mulched and weeded control plots. The lowest number of leaves per plant was found in unweeded control plots. Plant height responses to mulch showing a similar trend was also reported by Ossom and Matsenjwa (2007) in a dry bean study done in Swaziland. The poor performance of unweeded control was likely caused high competition for resources between the crop and weeds. Similar results were also reported by Zimdahl (2012). Results of tomato fruit sizes were also not affected by the type of mulch used, that is pine and wild lemon grass (Fig. 3.2). The type of mulch and time of mulch application did not affect marketable and unmarketable fruit weight harvested between mulched and weeded plots. Adeniyan *et al*. (2008) also reported an increase in establishment and tuber weight in yams mulched with organic weed materials.

The number of leaves per plant, fruit number according to size and marketable as well as unmarketable fruits were significantly higher ($P \leq 0.05$) in unweeded control than in other treatments. All treatments except unweeded control were dominated by medium sized and marketable fruits. These results indicate that mulched and weeded plants were not statistically different in performance suggesting that additions of pine and wild lemon grass mulch are potential agronomic practices for use by farmers in tomato production in Lushoto. The results also indicate that using pine and wild lemon grass as organic mulch was superior to hand weeding. Moreover, pine leaves are known for their ability to last long and to possess high amounts of Nitrogen (N) (Singh, 1982) while grasses have been reported to possess high amounts of P (Sinkeviciene *et al*., 2009).

The present study showed higher yields of mulched than in unweeded tomato plots. Mulch has been reported to affect plant growth and yield in various ways, by improving nutrient status of the soil (Cadavid *et al*., 1998), soil biology (Brown and Tworkoski 2003; Arancon *et al*., 2006), increasing soil moisture (Barzegar *et al*., 2002), temperature moderation (Treder *et al*., 2004) improving root growth (Acharya and Sharma, 1994) and suppression of weeds. The use of mulch also significantly improves plant growth and yieldwater retention of the soil (Barzegar *et al*. 2002), which is widely reported to increase yield and growth (Autio *et al*., 1991; Kotzé and Joubert, 1992). Schonbeck and Evanylo (1998) reported that mulch treatments apparently affected early tomato yield by influencing soil temperature regime, but affected later yields by modifying soil moisture levels.

Hochmuth *et al*. (2001), reported further that the main objectives of mulching are weed control, soil moisture conservation and modification of temperature. Mulching effectively manipulates crop growing environment leading to increased yield and improved product quality by suppressing weed growth, ameliorating soil temperature, conserving soil moisture, reducing soil erosion, improving soil structure and enhancing organic matter content (OparaNadi, 1993; Hochmuth *et al*., 2001; Awodoyin and Ogunyemi, 2005).

According to Dilipkumar *et al*. (1990), under rain fed situations mulching increased tomato yield over no mulching. Tomato yields were higher in organically mulched plots than the unmulched control. Akintoye *et al*. (2005) studied live mulches and reported that the cucumber mulching material produced higher number of tomato fruits per plant, and that yield was significantly greater than the yield produced from herbicide treated plots,emphasizing the potential of organic mulch in tomato production The potential of organic mulch has also been demonstrated in other crops.

On the contrary, the pumpkin live mulch treatment was a poor treatment combination as it had a deleterious effect on tomato yield, but it controlled weeds more effectively than other live mulch crops. Schonbeck and Evanylo (1998) reported that early tomato yields were generally the highest with black plastic mulch and lowest in organic mulch, with paper mulch producing intermediate results. Alvaro *et al*. (2010) reported that the highest tomato yield was obtained when black polythene followed by paper, manual weeding, biodegradable plastic, and rice straw and was used. High yields of tomato were also reported with rice husk mulch (Nkansah *et al*., 2003), grass mulch (Awodoyin *et al*., 2007), wild sunflower leaves (Liasu and Abdul, 2007). Other reports include cocoa husks (Ojeniyi *et al*., 2007), straw mulch (Gandhi and Bains, 2006), water hyacinth mulch (Chakraborthy and Sadhu (1994).

Reports on use of mulches on yield of other crops are also positive. Yordanova and Gerasimova (2016) reported that yields increased 8–10 times when beetroot was grown with mulches, compared with non weeded plots. In comparison with weeded plots, the beetroot yield was higher by 7.8–9.3 % on the plots mulched with barley straw mulch during the 2 years of the experiment; the plots mulched with spent muchroom compost showed a yield increase of 22.8 % but only for the first year. In another study, Duppong *et al*. (2004) reported that catnip (*Nepeta cataria* L.) yield was significantly higher in the flax straw mat than all other treatments in 2001. According Johnson *et al*. (2004) melon yields were higher in plots with straw at planting (in which weeds were suppressed).

The effect of season on tomato yield was also observed at both Lushoto and Ubiri sites differences in tomato yields between season 1, 2 and 3 are clearly observed at both sites. Season 1 was characterized by the long rains from late March to the end of May followed by cold temperatures form June to August. The probable cause for the highest yields in season 1 and the lowest yields in season 2 and 3 was perhaps due to slow plant growth due to low temperature and the ability to utilize soil moisture and nutrients from the decomposing pine leaves and wild lemon grass mulch. soil and from pine and grass mulch. In season 2, (September to December, 2013) temperatures were higher and it was dry, thus contributing to low tomato yields.

Overall results also suggest that the use of pine and wild lemon grass mulch can help to reduce farmers' time that could be spent on weeding. Mulch has been reported to block light from reaching the soil surface, hence reducing chances of weed germination. Farmers can use the saved time for doing other economic activities and improve their income and livelihood.

3.5 Conclusion and Recommendations

Pine and wild lemon grass mulches resulted into higher yield and yield componets of tomato. Moreover, the presence of mulch resulted into yields of tomato with good quality due to its protection against soil pests as mulch acted as a barrier. Pine or wild lemon grasses should be used by farmers as mulching materials in tomato fields.

2.6 Acknowledgements

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CHAPTER FOUR

PREVALENCE OF WEEDS AND INSECT PESTS IN ORGANIC PRODUCTION OF MULCHED TOMATO (*Solanum lycopersicum* L.) AND SWEET PEPPER (*Capsicum annuum* L.)

Abstract

A study was conducted in Lushoto district, North-Eastern Tanzania to evaluate the effects of organic mulch and time of application on weed, insect pests and diseases of organically grown tomato (*Solanum lycopersicum* L.) and sweet pepper (*Capsicum annuum* L.). The experiment was laid as a Randomised Complete Block Design (RCBD) with three replications. The treatments included time of application of pine and wild lemon grass mulch which were compared to weeded and unweeded controls. Data on weeds were collected at 3 and 7 weeks after tomato and sweet pepper transplanting. Data on insect pests were collected on all above ground parts of the plants and recorded once in every two weeks. Data on diseases were collected by identifying and counting the number of diseased plants once in every two weeks. Data were analysed using R Statistical Package (AGRICOLAE Version 1.2.1). *Post Hoc*. Tukey's (HSD) test was used to compare means. Results indicated that mulch types significantly affected weed counts and weed dry matter weights in tomato at Lushoto ($P<0.01$) and Ubiri ($P<0.001$). The effects of mulch type on bacterial wilt and late blight diseases in tomato were not similar. Effects of mulch types on numbers of insect pests were also not statistically different. It can be concluded that pine and wild lemon grass have the ability to control weeds with similar effectiveness as weeding. Therefore both pine and wild lemon grass mulch are recommended for use.

Keywords: organic mulch, weeds, diseases and insect pests

4.1 Introduction

Pest problems in agriculture are as old as agriculture itself. Despite the natural and artificial control measures, pests are reported to account for an average of 30 - 50% of yield losses in agriculture (Oerke *et al*., 1994). Artificial methods of pest control which are based on the use of synthetic materials are restricted due to their ecological, toxicological and environmental shortcomings to the ecosystem (Cohen and Yuval, 2000) bringing about a preference to natural means of pest control and promotion of organic agriculture. Organic production systems benefit the ecosystem by allowing an increase in plant species diversity, population density and biodiversity fitness (Gabriel *et al*., 2006). This increase in biodiversity is argued to increase ecosystem services which include pest control by increasing the population of natural enemies of insect pests (Drinkwater *et al*., 1995; Wyss *et al*., 1995; Hesler *et al*., 1993).

The use of organic mulch in crop production in many cases suppresses weeds, adds organic matter upon decomposition, conserves moisture and provides suitable habitats for natural enemies of insect pests (Cortesero *et al*., 2000). A number studies exist that show the effects of mulch in suppressing weeds (Amoroso *et al*., 2007; 2009; Chong 2003; Ramakrishna *et al*., 2006; Gerasimova, 2016; Dupong *et al*., 2004; Anzalone *et al*., 2010). A few studies however, exist on the effects of mulch on diseases (Gleason *et al*., 2001; Rajasri *et al*., 2011) as well as on insect pests (Johnson *et al*., 2004). Literature on the use mulch to supress pests in Tanzania is scarce. Farmers generally rely on pesticides to control pests in tomato and sweet pepper, but they have negative effects on the environment and consumer health. Labour costs associated with pesticides use are high and their use is restricted in organic farming systems. Therefore, there is a need for finding alternative safe methods to control tomato and sweet pepper pests.

Lushoto district, North-Eastern Tanzania, is a prime area for organic production of vegetables with tomato and sweet pepper being the key crops (Jordan Gama, TOAM, personal communication). Some common mulching materials used in Lushoto to supress weeds include star grass, elephant grass, wild sunflower, banana leaves, bean pods, maize cobs and other crop residues. The challenges with such types of mulching materials include increased cost of labour since they require frequent replenishment, seasonal availability which does not guarantee a year-through accessibility and multiple use for instance as animal feed (Wickama *et al*., 2006). Challenges associated with such commonly used mulching materials in Lushoto district, have diverged attention of users towards alternative organic mulch. Pine litter and wild lemon grass have been considered as the potential alternative organic mulch that can be used in organic production of tomato in Lushoto district.

Preliminary information on the usefulness of pine as mulch in Lushoto, Tanzania indicated that pine mulch at 15cm layer thickness led to high yields and lower levels of weed and insect pest infestations when compared to another type of organic mulch (Saria, 2014). However, information specifically focusing on the effect of type of mulch and time of application of organic mulch on weeds and insect pests population and diseases is lacking. In this study, Mexican weeping pine (*Pinus patula* Schelde. ex Schltdl and Cham) and wild lemon grass (*Cymbopogon spp*.) were used as mulch in organic production of tomato (*Solanum lycopersicum* L.) and sweet pepper (*Capsicum annuum* L.) to evaluate if different types of mulch applied at different times in organically grown tomato and sweet pepper may have any influence on weeds, insect pests and diseases incidences.

4.2 Materials and Methods

4.2.1 Description of study area and materials

The study was done in Lushoto district, Tanga region, in the North-Eastern Tanzania. The district is located in the West Usambara Mountains, lying between 38º 10’ and 38º 36’ East and 4º 24’ and 5º 00’ South. The altitude in Lushoto is between 800-2300 m a.s. l. The rainfall pattern is bimodal with the short rains from October to December and the long rains from March to June. Annual rainfall ranges from 600 to 1200 mm while temperature ranges from 16 - 30º C (Fig. 2.1 and 2.2). The soils are generally latosols (Shemdoe, 2011). The experimental sites were Lushoto (38° 17’ 24’’ East and 4° 47’ 55’’ South) with an altitude of 1500m. a.s.l located at Lushoto town-forest area and Ubiri (38° 21’ 59’’ East and 4° 50’ 29’’ South) with an altitude of 1218m. a.s.l. located at Ubiri village along Mombo-Lushoto road.

4.2.2 Nursery and field establishment

Tomato variety Tanya and sweet pepper variety California Wonder were grown for three seasons from April 2013 to May 2015. The first season (season 1) began in April 2013 and ended in September 2013 while the second season (season 2) began in August 2013 and ended in December 2013. Season 3 began in January to May, 2015. Season 1 experienced wet and cold weather, season 2 experienced dry and hot weather while season 3 experienced dry, hot and then rainy months in January-February, 2015 and March-May, 2015, respectively.

Management activities included the use of organic compost [ERTHFOOD$_{TM}$ (1.5-0.5-0.5)] at the quantity of 500g per hole applied one day before tomato seedlings were transplanted as soil amendment material. This was later supplemented with a seven day soaked solution of cow urine (20 litres), cow dung (50 kg) and water (200 litres) as top dressing organic manure applied at 0.5 litres per plant. The seeds of neem (*Azadirachta indica* A. Juss.) in dried, ground and sieved form (0.5 kg), sour milk (0.5 litres), ashes (0.5 kg), banana flower (1 piece) and kerosene (0.25 litres) all mixed in 15 litres of water, were used to prepare a local biopesticide. This mixture was applied against aphids in season 1 and against thrips in season 2. This biopesticide was also used against fungal and bacterial diseases. All crops were irrigated by tap water (at Lushoto) and by furrow water (at Ubiri).

Organic mulch used was dried pine needles and dried wild lemon grass. Pine needles were collected under pine trees located in the pine forest near Lushoto experimental site while wild lemon grass was collected from the rocks on top of the mountains at Kizara village located along the Mombo-Lushoto road. Pine mulch was in dry form and did not require chopping due to its needle-like shape while wild lemon grass was in fresh form hence required about three weeks of drying before being chopped and used. The experimental plots measured 3 m x 3 m in length and width, respectively. Plant spacing for tomato was 50 x 50 cm while spacing for sweet pepper was 40 x 40 cm.

4.2.3 Experimental design

The experiment was laid down as a Randomized Complete Block Design (RCBD) with six treatments and was replicated three times. The treatments were pine mulch applied 3 days after transplanting (PI), pine mulch applied 21 days after transplanting (PA), wild lemon grass mulch applied 3 days after transplanting (GI), wild lemon grass mulch applied 21 days after transplanting (GA), weeded control (CI) and unweeded control (CA).

4.2.4 Data collection

Determination of dominant weeds was done by using Berger-Parker Index of Dominance (1970). Weeds were counted inside the pre - established quadrants in the middle of each plot and separated into grass, sedges and broadleaves and the number of each weed type was recorded. Weed counts were done 3 and 7 weeks after transplanting. Weeds were then cut at ground level after each count, and oven dried at 70°C for 72 hours to obtain weed dry weight data per square meter. Further, an investigation was conducted to determine the effect of pine and wild lemon grass mulch on height, weight and diameter of reproductive structures the most dominant weed in tomato and sweet pepper. The incidence of diseases and insect pests was determined at an interval of two weeks. Plants were inspected on all above-ground parts such as stem, branches and leaves for insect pest counts and recorded. Diseased plants were also counted and data was recorded. The diseases were confirmed by using methods put forward by Kaaya *et al*., 2003.

4.2.5 Data analysis

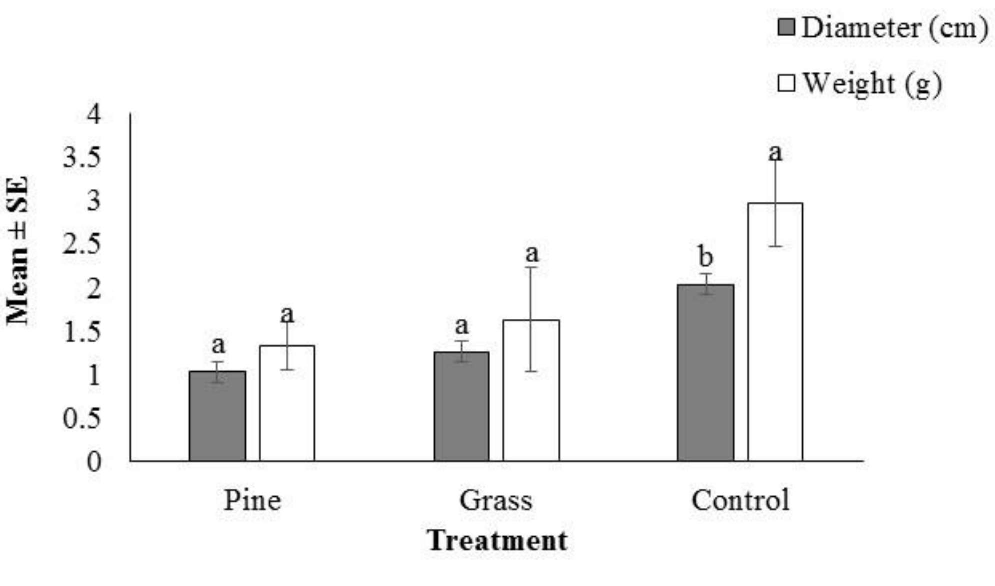
All the collected data were subjected to Analysis of Variance (ANOVA) using R Statistical Package (AGRICOLAE Version 1.2.1). *Post Hoc* Tukey's (HSD) test was used to compare means at P = 0.05 level of significance.

4.3 Results

4.3.1 Effect of organic mulch on the incidences of weeds in tomato and sweet pepper

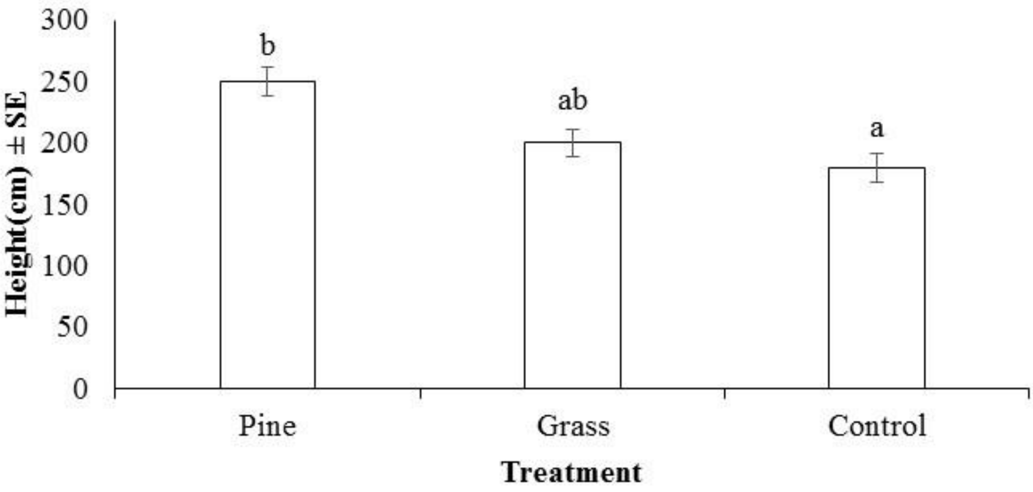
4.3.1.1 Effect of organic mulch on weed species

Data indicate that dominant weeds included *Oxalis latifolia* (42%), *Commelina benghalensis* (22%), *Cynodon dactylon* (18%) and *Cyperus spp* (10%) and other weeds (8%). The effect of pine and wild lemon grass on the most dominant weeds (*O. latifolia*) are shown in Fig. 4.1 and 4.2. *Oxalis latifolia* was observed to grow aggressively even on mulched plots. The diameter of *O. latifolia* bulb differed significantly among treatments ($F_{2, 6}$ = 12.96, P <0.01). *O. latifolia* from control plots had significantly bigger diameter than those from other treatments. *O. latifolia* from pine mulch had the lowest mean diameter. In addition, the height of *O. latifolia* was also significantly affected by mulching ($F_{2, 6}$ = 9.75, P <0.01). *O. latifolia* from pine mulched plots were significantly taller than those from weeded control plots. However, weight of *O. latifolia* was not significantly affected by treatments ($F_{2, 6}$ = 2.24, P = 0.18). Generally, *O. latifolia* from control plots had higher weight and bigger diameter than those treated with mulch (Fig. 4.1).



Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey’s (HSD) test.

Figure 4.1: Effects of type of mulch on bulbil axis diameter and weight of *Oxalis latifolia* weed in tomato and sweet pepper grown in Lushoto.

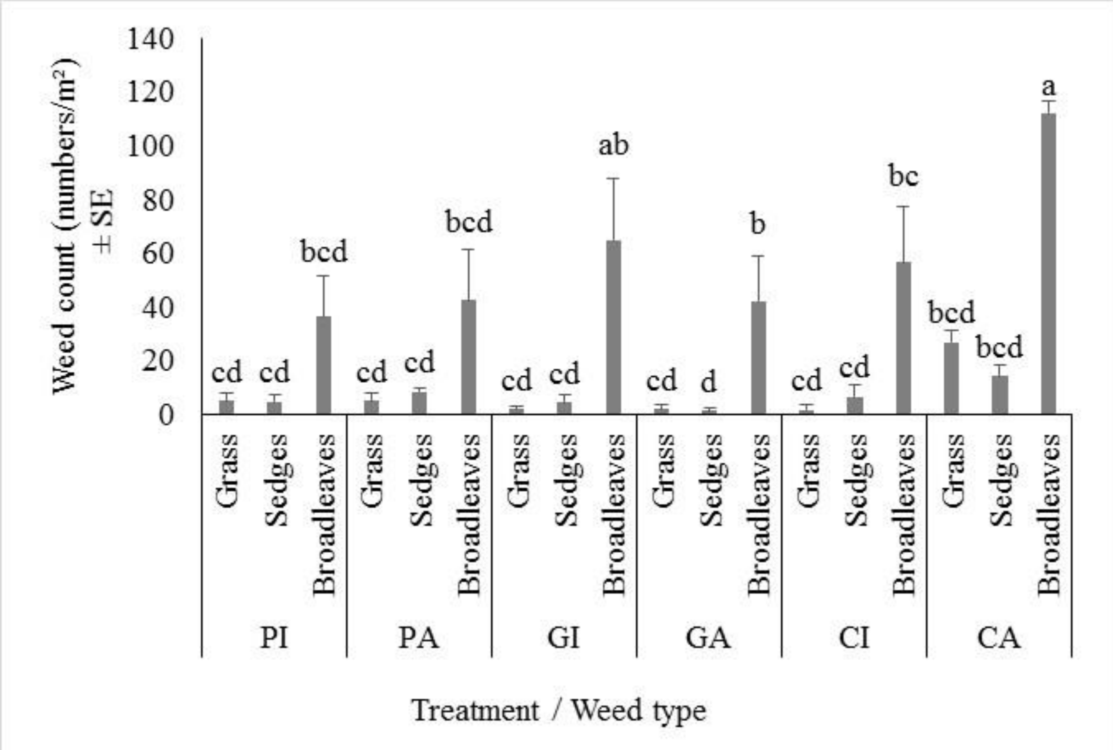


Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Figure 4.2: Effect of type of mulch on height (mm) of Oxalis latifolia weeds in tomato and sweet pepper rown in Lushoto.

4.3.1.2 Weed counts in tomato plots

Results of total weed counts in tomato plots are presented in Figure 4.3. At Lushoto, mulching significantly affected weed counts ($F_{5, 36}$ = 5.07, P <0.01). Weed counts varied significantly among weed types ($F_{2, 36}$ = 50.19, P <0.001). The effects of treatment x weed interaction were not significant ($F_{10, 36}$ = 1.61, P = 0.14). *Post Hoc* (Tukey's HSD) of main means showed that unweeded control (CA) plots had highest weed counts compared to all other treatments. Similarly, the number of broadleaved weeds were significantly higher than narrow leaved weeds (grasses and sedges) (Fig. 4.3).

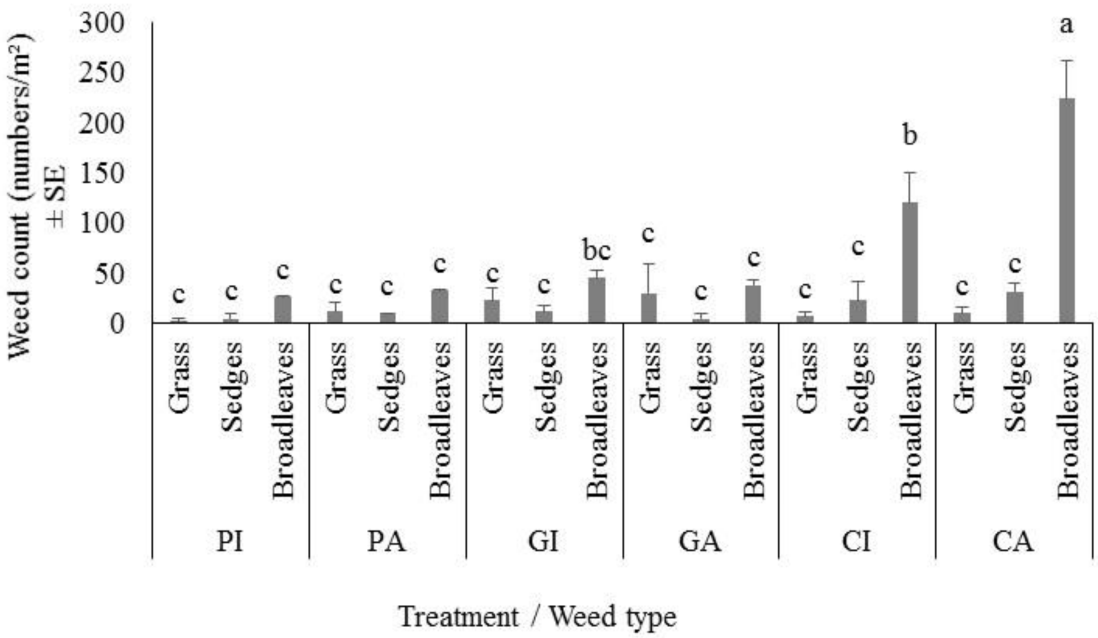


Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 4.3: Effect of the type of mulch and time of application on weed type and numbers in tomato at Lushoto site

Figure 4.4 shows mean weed counts in tomato fields at Ubiri. Mulching significantly affected weed counts ($F_{5, 36}$ = 10.53, P <0.001). Weed counts varied significantly among weed types ($F_{2, 36}$ = 38.18, P <0.001). The effects of treatment x weed interaction were also not significant ($F_{10, 36}$ = 8.16, P = 0.14). Results of *Post Hoc* (Tukey's HSD) showed significantly higher number of weeds in unweeded control (CA) compared to all other treatments. The interactions between unweeded control (CA) x broadleaves, were significantly higher than other treatments followed by weeded control (CI) x broadleaves. All other interactions were not significantly different from each others.



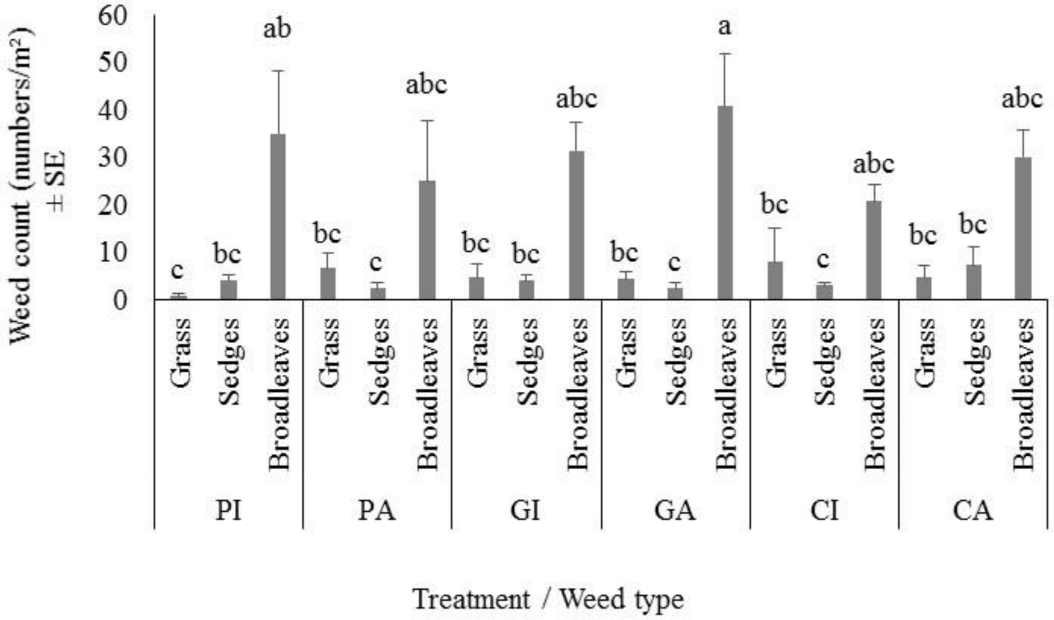
Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 4.4: Effect of the type of mulch and time of application on weed type and numbers in tomato at Ubiri site

4.3.1.3 Weed counts in sweet pepper plots

Figure 4.5 shows the mean weed counts in sweet pepper plots at Lushoto. Treatments did not significantly affect weed counts ($F_{5, 36}$ = 0.299, P = 0.91). However, weed counts varied significantly among weed types ($F_{2, 36}$ = 38.72, P <0.001). The effects of treatment x weed interaction were not significant ($F_{10, 36}$ = 0.70, P = 0.71). *Post Hoc* (Tukey's HSD) of main means showed that number of broadleaved weeds were significantly higher than grasses and sedges. However, mean number sedges and grasses did not differ significantly.

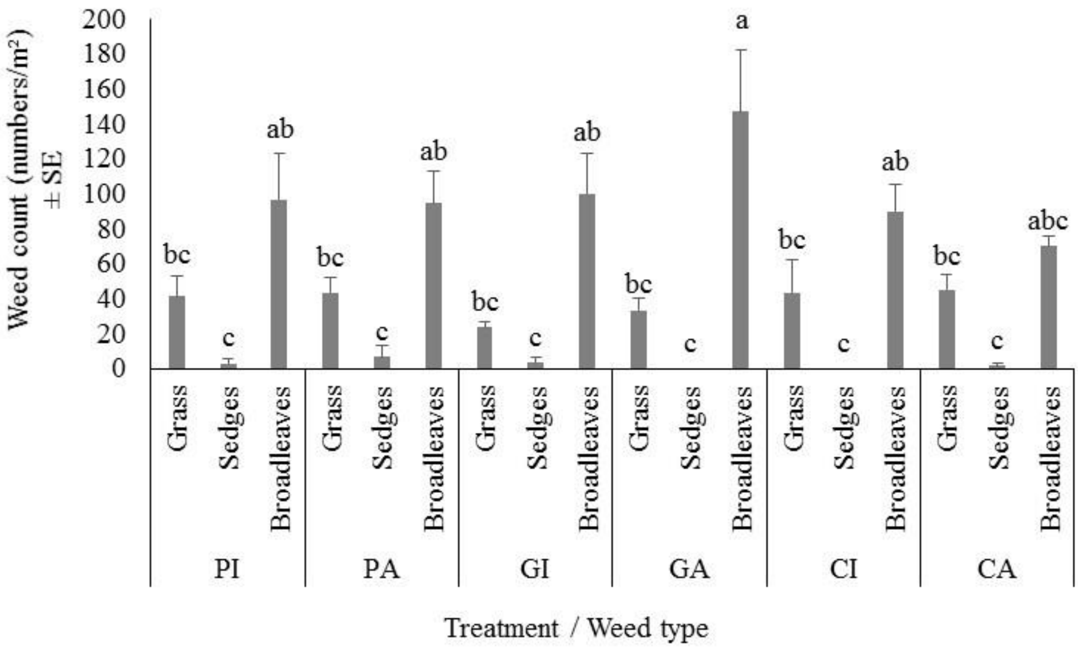


Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 4.5: Effect of the type of mulch and time of application on weed type and number in sweet pepper grown at Lushoto site

Figure 4.6 shows the mean weed counts in sweet pepper plots at Ubiri site. Treatments significantly affected weed counts ($F_{5,\ 36}$ = 0.76, P <0.59). Weed counts varied significantly among weed types ($F_{2,\ 36}$ = 68.70, P <0.001). The effects of treatment x weed interaction was not significant ($F_{10,\ 36}$ = 1.33, P = 0.25). *Post Hoc* (Tukey's HSD) of main means showed that number of broad leaves were significantly higher than other weed types. Mean number of grasses was significantly higher than sedges. However, mean number sedges and grasses did not differ significantly.



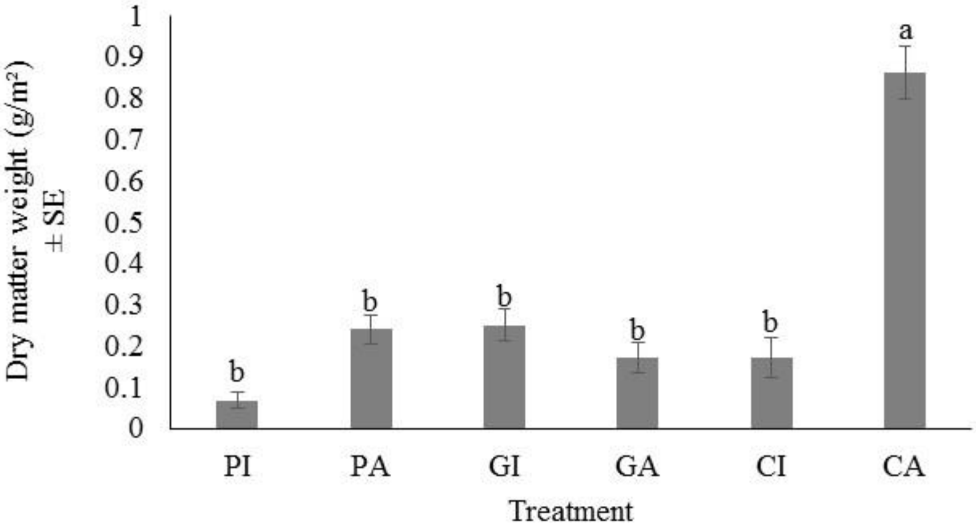
Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 4.6: Effects of type of mulch and time of application on weed types and numbers in sweet pepper at Ubiri site

4.3.1.4 Weed dry matter weight in tomato plots

Figure 4.7 show mean dry matter weight of weeds harvested from tomato plots at Lushoto. Mulching significantly affected weed dry matter weight counts ($F_{5, 12}$ = 45.27, P <0.001). Weeds harvested from unweeded control (CA) plots had significantly higher dry matter weight compared to all mulched and weeded treatments. Results (Tukey's HSD) further showed that, all the mulched and weeded treatments did not differ significantly in weed dry matter weight. Lowest dry matter weight was recorded from pine mulched three days after transplanting (PI) plots in tomato (Fig. 4.7).

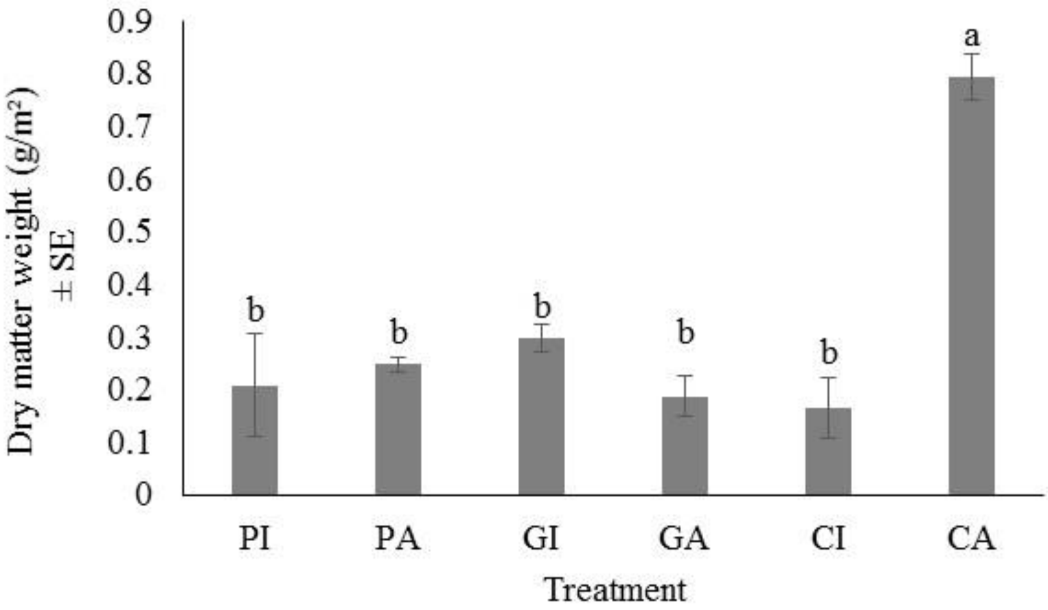


Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 4.7: Effects of type of mulch and time of application on weed dry weight of tomato at Lushoto site

The mean dry matter weight of weeds harvested from tomato plots at Ubiri site treated with different types of mulch are summarized in Figure 4.8. Treatments significantly affected weed dry matter weight counts ($F_{5, 12}$ = 19.92, P <0.001). Weeds harvested from unweeded control CA plots had significantly higher dry matter weight compared to all mulched and weeded treatments. Results (Tukey's HSD) further showed that, mulched and weeded treatments did not differ significantly in weed dry matter weight. The lowest dry matter weight was recorded from weeded control (CI) plots (Fig. 4.8).



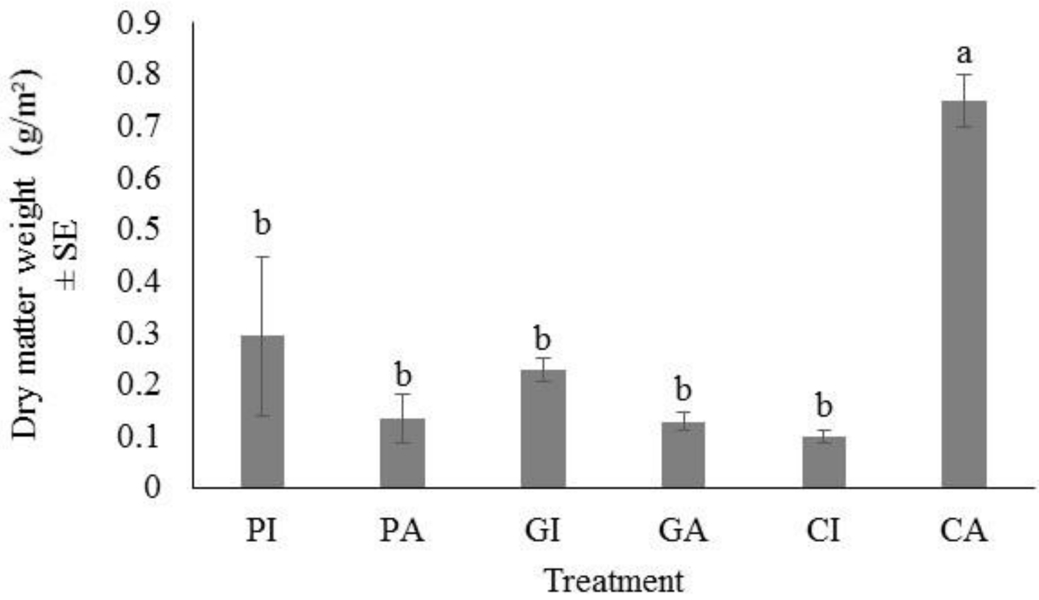
Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 4.8: Effects of type of mulch and time of application on weed dry matter weight of tomato at Ubiri site

4.3.1.5 Weed dry matter weight in sweet pepper plots

Figure 4.9 shows the mean dry matter weight of weeds harvested from sweet pepper plots treated with various organic amendments at Lushoto site. Treatments significantly affected weed dry matter weight ($F_{5,\ 12}$ = 12.17, P <0.001). Weeds harvested from unweeded control (CA) plots had significantly higher dry matter weight compared to all mulched and weeded treatments. Results (Tukey's HSD) further showed that, mulched and weeded treatments did not differ significantly in weed dry matter weight. The lowest dry matter weight was recorded in from weeded control (CI) plots (Fig. 4.9).

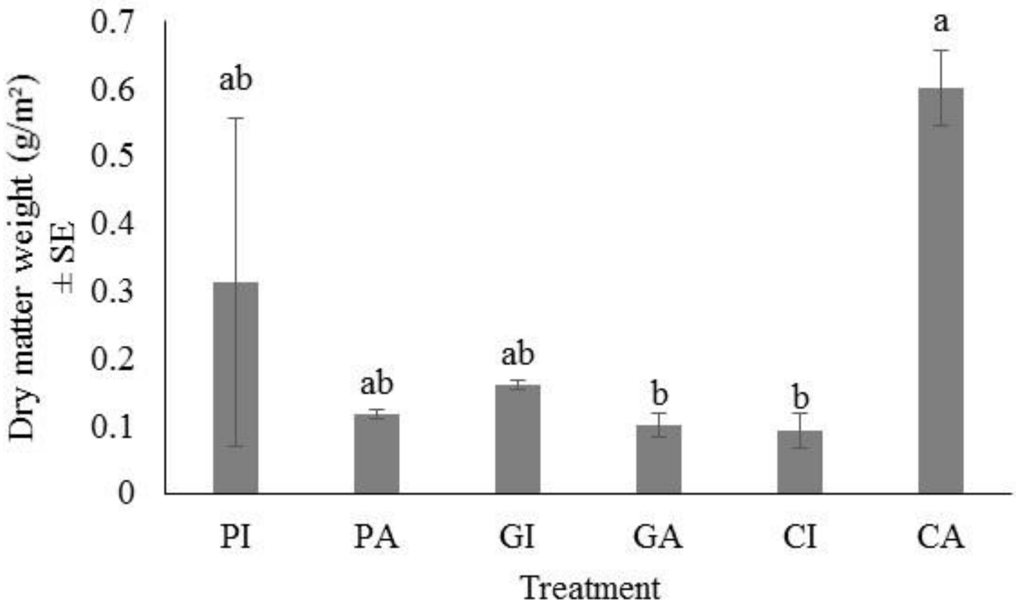


Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 4.9: Effects of type of mulch and time of application on weed dry matter weight of sweet pepper at Lushoto

Figure 4.10 show mean dry matter weight of weeds harvested from weet pepper plots at Ubiri site. Treatments significantly affected weed dry matter weight counts ($F_{5, 12} = 3.74$, $P < 0.05$). Weeds harvested from unweeded control (CA), pine mulched three days after transplanting (PI) and wild lemon grass mulched three days after transplanting (GI) plots had significantly higher weight compared to wild lemon grass mulches 21 days after transplanting (GA) and weeded control (CI) plots (Tukey's HSD). The differences in weed dry matter weight between wild lemon grass mulch applied 21 days after transplanting (GA) and weeded control CI were not significant. Similarly differences among unweeded control (CA), pine mulch applied three days after transplanting (PI), wild lemon grass applied three days after transplanting (GI) and pine mulch applied 21 days after transplanting (PA) were not significant.



Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

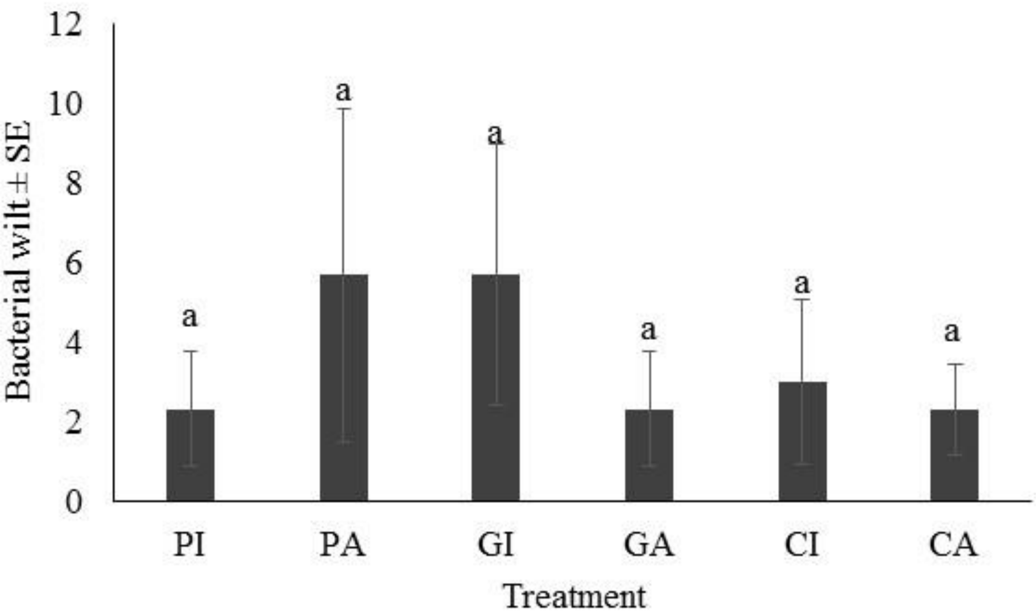
Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 4.10: Effects of type of mulch and time of application on weed dry matter weight of sweet pepper at Ubiri site

4.3.2 Diseases

4.3.2.1 Incidences of bacterial wilt disease

Results of the effects of pine and wild lemon grass mulch on incidence of bacterial wilt disease are presented in Figure 4.11 Bacterial wilt disease incidence was highest in pine mulch plots applied 21 days after transplanting (PA) followed by wild lemon grass mulch plots applied three days after transplanting (GI). Furthermore, wild lemon grass mulch applied 21 days after transplanting (GA) and pine mulch applied three days after transplanting (PI) plots had lowest incidences. ANOVA results showed non significant differences in incidences of bacterial wilt ($F_{5, 12} = 0.36$, $P < 0.87$) among treatments.



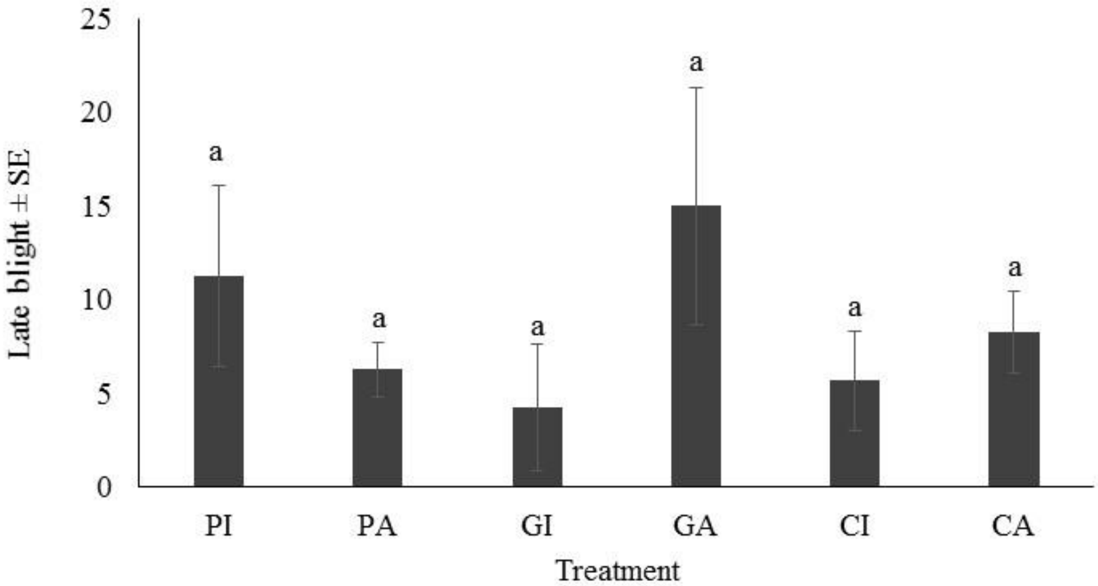
Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 4.11: The effect of the type of mulch and time of application on the incidence of bacterial wilt disease in tomato grown at Lushoto and Ubiri sites

4.3.2.2 The incidences of late blight disease

Data on the incidence of late blight disease in tomato are presented in Fig. 4.12. Late blight disease incidence was highest in pine mulch applied 21 days after transplanting (PA) plots followed by wild lemon grass mulch applied three days after transplantin (GI) plots. Furthermore, wild lemon grass mulch applied 21 days after transplanting (GA) and pine mulch applied three days after transplanting (PI) plots had the lowest incidences. ANOVA results showed that differences in incidences of bacterial wilt were not significant ($F_{5, 12}$ = 1.058, P < 0.42) among treatments.



Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI = Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

Figure 4.12: Effect of the type of mulch and time of application on the incidence of late blight disease in tomato grown at Lushoto and Ubiri sites

4.3.3 Incidence of insect pests in tomato

4.3.3.1 Incidence of aphids

Aphids were recorded occasionally in all plots and could not warrant further analysis. Total number of aphids recorded in tomato plants was 45 and 126 in Lushoto and Ubiri, respectively. Generally, aphids were more abundant in wild lemon grass mulch applied 21 days after transplanting (GA) plots at both Lushoto and Ubiri locations (Table 4.1).

Table 4.1: Aphid incidences in tomato at Lushoto and Ubiri sites

Treatment	Lushoto		Ubiri	
	Mean	SE	Mean	SE
PI	0	0	12	12
PA	0.33	0.33	0	0
GI	2	2	0	0
GA	2.67	2.67	13.33	13.33
CI	10	10	16.67	16.67
CA	0	0	0	0

Key: PI= Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA= Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control.

4.3.3.2 Incidence of thrips

Results showed that thrips were also a problem and were more abundant in weeded control (CI), pine mulch applied 21 days after transplanting (PA) and wild lemon grass mulch applied three days after transplanting (GI) plots at Lushoto, but were more abundant in pine mulch applied three days after tranplanting (PI) and pine mulch applied 21 days after transplantin (PA) plots at Ubiri (Table 4.2).

Table 4.2: Thrips incidences in tomato at Lushoto and Ubiri sites

Treatment	Lushoto		Ubiri	
	Mean	SE	Mean	SE
PI	3.33	1.67	7.67	0.33
PA	6	0	7.33	3.71
GI	6	1.15	6	3.46
GA	5	2.51	9	1
CI	8	4.36	7	4.36
CA	5.67	2.85	10	2.31

Key: PI= Pine mulch applied 3 days after transplanting; PA=Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA=Unweeded control.

4.4 Discussion

The current study evaluated the effects of organc mulch on supressing pest population in tomato and sweet pepper at Lushoto and Ubiri locations. Generally, pine and wild lemon grass mulch had significant reduction on weed counts and weed dry matter weight. According to previous research (Amoroso *et al.*, 2007, 2009; Chong, 2003), mulching materials can be successfully used as an alternative to chemical weed control. The mulching materials tested by Amoroso *et al*. (2010) provided a similar results on weed control. A review by Chalker-Scott (2007) proposed mulching as an effective means for landscape weed control. Nearly all mulches reduce light, which will stress existing weeds and prevent the germination of many weed species, especially those with small seeds (Chalker-Scott, 2007). Certain organic mulches, especially woodchips, may control weeds chemically through the leaching of allelopathic chemicals naturally occurring in the wood.

In this study, results have shown that mulching tomato and sweet pepper plots with pine leaves and wild lemon grass significantly reduced weed number, bulb diameter and height of *Oxalis latifolia* (Fig. 4.1 to 4.6). Dry matter weight was also significantly reduced. In the current study, results also indicate that mulching tomato and sweet pepper using pine leaves and wild lemon grass was very effective in reducing weed infestation (Fig. 4.3 to 4.10). Previous studies reported effects of different mulch types in supressing weeds in different crops. Ramakrishna *et al*. (2006) studied the effect of three mulching materials (polythene, rice straw and chemical) on weed infestation, soil temperature, soil moisture and pod yield were studied. They found that polythene and straw mulch were effective in suppressing the weed infestation. In another study Yordanva and Gerasimova (2016) determined the effect of barley straw mulch and mulch from spent mushroom compost, compared with non-mulched but weeded control plot and non-mulched and non-weeded control plot. They found that that mulching with barley straw mulch and mulch from spent mushroom compost significantly reduced weeds, especially cockspur *(Echinochloa crus-galli* L.), red finger-grass *(Digitaria sanguinalis* (L.) Scop.), common amaranth *(Amaranthus retroflexus* L.) and gallant soldier *(Galinsoga parviflora* Cav).

Results of the present study also showed effects of organic mulch in reducing bacterial wilt and and late blight diseases in tomato. Straw mulch has been reported to slow down the spread of disease in cultivation, such as *Colletotrichum acutatum* J.H. Simmonds in strawberry production (Gleason *et al*., 2001); however, the mechanisms of disease reduction have not been well documented. Rajasri *et al*. (2011) reported that UV reflective mulch and paddy husk mulch were superior treatments and they reduced disease incidence and also increased the total marketable tomato fruit yield. Hence, these cultural methods when combined with other management practices help in containing the disease through vector control.

Results on the effects of mulch on supressing insect pests were not very clear in the present study. Some studies reported effects of mulches on insect pests populations. According to Johnson *et al*. (2004) potatoes with straw at planting had fewer potato leafhoppers, *Empoasca fabae* (Harris) (and less associated plant damage) and more colonizing Colorado potato beetle (*Leptinotarsa decemlineata* Say), adults than the other treatments. Subsequent Colorado potato beetle egg mass and larval numbers, however, were not higher in this treatment. The few pests observed in the watermelon plots were not affected by the straw treatments. They recommended that, for potatoes, straw may be useful to control weeds and enhance predator numbers, but insect pests may still require control. In melons, straw should be used only if the crop is planted after the soil is sufficiently warm.

4.5 Conclusion and Recommendation

4.5.1 Conclusion

This study revealed that pine leaves and wild lemon grass can be used effectively as mulch in organic production systems in Lushoto district. Availability of both mulching materials throughout the year in Lushoto is an added advantage for use. Theses mulching materials sgnificantly reduced weed type and number in both tomato and sweet pepper plots. The dry matter weight of weeds from tomato and sweet pepper treated with pine leaves and wild lemon grass was significantly reduced at both Lushoto and Ubiri locations. In addition, the incidences of bacterial wilt and late blight diseases were also significantly reduced in tomato plots treated with pine and wild lemon grass, indicating that such material are useful in reducing disease in tomato production. However, such organic treatment had no sinificant effects in reducing insect pests, especially thrips and aphids.

4.5.2 Recommendations

It is recommended that a special attention should be paid on aggressive weeds which may grow and multiply under the mulch depending only on parts which have access to light on the mulch. For best results, these weeds can be pulled away as soon as they show up. Another recommendation based on this study is the inability of pine and wild lemon grass mulch to control insect pests therefore necessitating growers to be prepared for insect pest control by employing organically accepted methods. Since the studied types of mulch did not affect disease attack to tomato and sweet pepper crops, it is recommended that organically accepted methods of controlling diseases be adhered to at all times.

4.6 Acknowledgement

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CHAPTER FIVE

DECOMPOSITION AND MINERALIZATION OF COMPOSTING PINE AND WILD LEMON GRASS IN LUSHOTO DISTRICT NORTH-EASTERN TANZANIA

Abstract

An investigation was done to study the decomposition rate and nutrient release of composting pine and wild lemon grass in Lushoto district, Tanga, Tanzania. The treatments were compost heaps containing a mixture of organic materials composed mainly with pine, wild lemon grass and a control (compost heap with neither pine nor wild lemon grass included). The experiment was laid out in a Randomized Complete Block design and was replicated three times. Samples from each compost pile were drawn for laboratory analysis at the Department of Soil and Geological Sciences of Sokoine University of Agriculture, 3 and 12 months from the date of compost heap establishment. Macro and micronutrients selected for the study were OC, TN, P, K, Cu, Zn, Fe, and Mn. Data analysis was done by using R Statistical Package (AGRICOLAE Version 1.2.1). *Post hoc* Tukey's (HSD) test was used for mean separation. Results show that composting duration significantly ($p<0.05$) affected OC, K, Cu, Zn, Mn and Fe contents while total N and extractable P were not significantly ($p>0.05$) affected. Compost type significantly ($p<0.05$) affected contents of OC, total N, Mn and Fe contents while extractable P, K, Cu and Zn were not significantly ($p>0.05$) affected. Moreover, C:N ratio of the composts was significantly ($p<0.05$) affected by both compost duration and compost type. Pine and wild lemon grass can be used as compost materials that can be adopted in organic cultivation of vegetables in Lushoto district.

Key words: Pine compost, wild lemon grass compost, organic compost, decomposition rate.

5.1 Introduction

Composting may be considered to be a viable alternative for disposal of organic materials from various waste streams but in organic agriculture it is a valuable ammendment for soils. Compost itself, is an organic matter source with a unique ability to improve the chemical, physical and biological characteristics of soils (Cooperband, 2002). Some of the advantages of adding compost in to the soil include an increase in soil fertility, water holding capacity, and Cation Exchange Capacity (CEC). Other advantages include lowering of bulk density, fostering of beneficial microorganisms, pH stabilization and faster water infiltration rate due to enhanced soil aggregation (Drinkwater *et al*., 1995; Stamatiadis *et al*., 1999). Compost addition improves water retention in sandy soils and promotes soil structure in clayey soils (Cooperband, 2002). It has also been shown that microbial activity and biomass is higher in fields with organic amendments than fields with convetional ferlizers (Drikwater *et al*., 1995).

Returning crop residues to the soil improves soil quality and productivity through favourable effects on soil properties (Lal and Stewart, 1995). Organic mulch on the soil surface has long been known to contribute to the soil nutrient pool upon decomposition (Cortesero *et al*., 2000). The application of organic mulch as a soil cover is very effective in improving the quality of soil and increasing crop yield, especially in organic farming (Awodun and Ojeniyi, 1999, Mulumba and Lal, 2008). Moreover, organic mulch applied to cover the soil surface also affects soil physical, biological and chemical properties. Jobbagy and Jackson (2000) report on the influence of soil texture on the rate of mineralization of soil organic matter stating the association of fine textured soils with high contents of organic matter and low rates of mineralization relative to coarse textured soils. According to Friedel *et al*. (2001) soil microbes act as transient nutrient sink responsible for releasing nutrients from organic matter for use by plants.

Although the use of organic soil ammendments has been associated with desirable soil properties, other reports have documented some inconsistent results. Iles and Dosman (1999) and De Vleeschauwer *et al*. (1980) reported on the varying effects of organic mulch on soil temperature and water availability. Studies reveal about the influence of organic mulches on nitrogen (N) availability in the soil through leaching and decomposition (Lambers *et al*., 1998; Aerts and Chapin, 2000). Total carbon in soil is considered as one of the most important properties of soils because of its impact on ecosystem sustainability, affecting other physical, chemical and biological characteristics of soils (Reeves, 1997). Some reports have shown no effect of organic mulch on soil pH under 15 types of mulch after six months of application (Stinson *et al*., 1990); Greenly and Rakow (1995). The negative, positive or no effect reactions of organic mulch on soil properties is based on the fact that specific results on the effects of organic materials on soils are based on the type of organic material in question (Vitousek *et al*., 1994; Greenly and Rakow, 1995; Aerts and Chapin, 2000).

In many areas compost making comprise of the type of organic materials available locally. The materials used are expected to be easily accessible, cheap but rich in nutrient contents. Plant residues and some local grasses could be made availabe after harvest in most cases. However, most commonly used organic materials like common grass like star grass, guinea grass and other materials like banana leaves, bean pods and other crop residues possess some limitations. These limitations include having multiple uses like being used as wrapping materials during transport of delicate crop produce like fresh vegetables, being used as animal feed (Wickama *et al*., 2006) and their seasonal availability which does not guarantee a year-through supply. These limitations necessitates to look for alternative organic compost materials. Studies done in Lushoto disrtrict, North-Eastern Tanzania have reported on the potential of pine (*Pinus patula*

Schelde. ex Schltdl and Cham) and wild lemon grass (*Cymbopogon spp.*) to replace such organic materials due to their year-through availability and their unsuitability as animal feed (Saria, 2014, Shechambo *et al*., 2015).

The rate of decomposition of organic matter on the soil surface is controlled by environmental conditions, soil microbial activities and the chemical composition of organic matter (Vitousek *et al*., 1994). The decomposition of organic mulches has influence on their replacement during the crop cycle and nutrient property of the soil. There is limited information on the rate of decomposition and nutrients released from pine and wild lemon grass organic materials. In this work, the rate of decomposition and mineralization of composted pine and wild lemon grass materials was determined.

5.2 Materials and Methods

5.2.1 Description of the study area

The study was done in Lushoto District, Tanga Region, in the northeastern Tanzania. The district is located in the West Usambara Mountains, lying between 4 º 24’ and 5 º 00’ South and 38º 10’ and 38º 36’East. The altitude in Lushoto is between 800-2300 m above sea level. The rainfall received is of bimodal pattern with the short rains from October to December and the long rains from March to June. Annual rainfall ranges from 600 to 1200 mm while temperature ranges from 16 - 30º C. The soils are generally latosols (Shemdoe, 2011) . The experimental site was Lushoto (4° 47’ 55’’ South and 38° 17’ 24’’ East) with an altitude of about 1500 m. a.s.l located at forest area in Lushoto Municipality.

5.2.2 Methods

Organic materials used were dried pine needles and dried wild lemon grass. Pine needles were collected under pine trees located in the pine forest near Lushoto experimental site while wild lemon grass was collected from the rocks on the mountains at Kizara village also located along the main road from Mombo to Lushoto. Pine needles were in dry form and did require chopping while wild lemon grass was in fresh form. The fresh materials were sun-dried for three weeks before being chopped and used. Other materials used in the compost heaps were forest soil, decayed cow manure, annual and perennial unflowered weeds in dry and fresh forms and star grass (*Cynodon dactylon* L. Pers.) in dry form (for control heaps).

Composting process involved thorough mixing of either pine, wild lemon grass or star grass materials (30 kg/m^3) as treatments, mixed with annual and perennial unflowered weeds (20 kg/$m^{3)}$, decayed cow manure (60 kg/m^3) and forest soil (60 kg/m^3) and 100 litres of water (Table 4.1). These materials were arranged in layers to make a 1 m x 1 m x 1 m cube for each pile. During piling, each layer was sprinkled with 20 l of water before the next layer was put making a total quantity of 100 l for each heap. The layers were 10 cm in depth. The compost heaps received water at an interval of three days. Three piles of each compost (replicates) were made.

Table 5.1: Compost materials

Material	Weight/ Volume /m^3 heap
Dry pine leaves/wild lemon grass/star grass	30 kg
Mixed annual and perrenial unflowered weeds	20 kg
Decayed cow manure	60 kg
Forest soil	60 kg
Water	100 litres

5.2.3 Data collection and analysis

Nine compost samples were taken from the heaps for laboratory analysis to study the chemical compositions after three and twelve months of composting. Analysis for all samples included pH in water (except for plant samples), organic carbon (OC), total nitrogen (TN), extractable phosphorous (P), exchangeable copper (Cu), zinc (Zn), extractable iron (Fe), potassium (K) and manganese (Mn).

Total nitrogen was analysed by using Micro-kjeldahl method, extractable phosphorus was analysed by using Bray I method, Organic carbon was analysed by wet digestion method (by using hydrogen sulphide and potassium dichromate), exchangeable cation (K^+) were analysed by using ammonium acetate method and micronutrients (Cu, Zn, Fe, Mn) were analysed by using diethylenetriamine pentacetic acid (DTPA) method (Moberg, 2000).

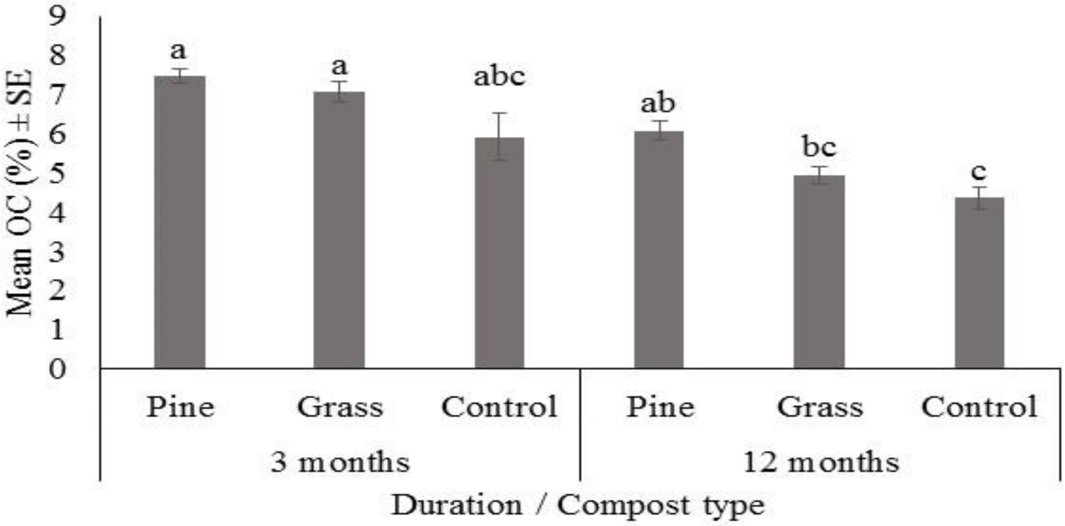
All data were later subjected to two way Analysis of Variance (ANOVA) ($P \leq 0.05$) using R Statistical Package (AGRICOLAE Version 1.2.1). *Post Hoc* Tukey's (HSD) test was used to compare means at $P = 0.05$ level of significance.

5.3 Results

5.3.1 Effects of type of compost and duration on macronutrients

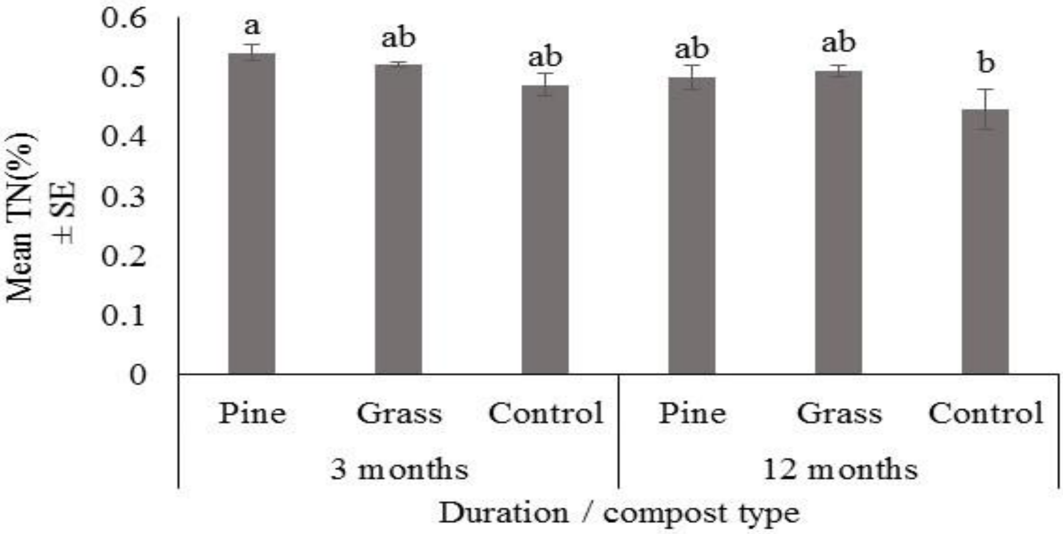
Results showed that mean macronutrients contents varied with duration of composting as well as with type of compost (Fig. 5.1 to 5.4). Highest contents of Organic Carbon (OC) and Total Nitrogen (TN) were obtained after 3 months of composting pine containing heaps (Fig. 5.1 and 5.2). The content of extractable Phosphorus (P) was highest in grass containing heaps composted for 12 months (Fig. 5.3) while the highest content of Potassium (K) was obtained from pine containing heaps composted for 3 months (Fig. 5.4). Organic Carbon (OC) decreased from 7.47 to 4.36 % across all experimental units while Potassium (K) decreased from 3.34 to 0.13 cmol/kg. Phosphorus (P) ranged from 32.76 to 52.82 cmol/kg while Total Nitrogen (TN) decreased from 0.54 to 0.45 mg/kg.

Compost duration significantly affected Organic Carbon (OC) ($F_{1, 12} = 38.93$, $p<0.0001$) and Potassium (K) ($F_{1, 12} = 48.94$, $p<0.0001$). On the contrary compost duration did not significantly affect Total Nitrogen (TN) ($F_{1, 12} = 4.59$, $p = 0.05$) and extractable Phosphorus (P) ($F_{1, 12} = 3.76$, $p<0.07$). Compost type significantly affected Organic Carbon (OC) ($F_{1, 12} = 12.19$, $p<0.01$), and Total Nitrogen (TN) ($F_{2, 12} = 5.24$, $p< 0.05$). However, compost type did not significantly affect extractable Phosphorus (P) ($F_{2, 12} = 0.70$, $p<0.52$) and Potassium (K) ($F_{2, 12} = 0.26$, $p= 0.77$) contents. The interaction between compost type and duration did not significantly affect Organic Carbon (OC) ($F_{2, 12} = 0.66$, $p = 0.53$), Total Nitrogen (TN) ($F_{2, 12} = 0.29$, $p= 0.75$) extractable Phosphorus (P) ($F_{2, 12} = 0.76$, $p= 0.48$), and Potassium (K) ($F_{2, 12} = 1.26$, $p= 0.32$).



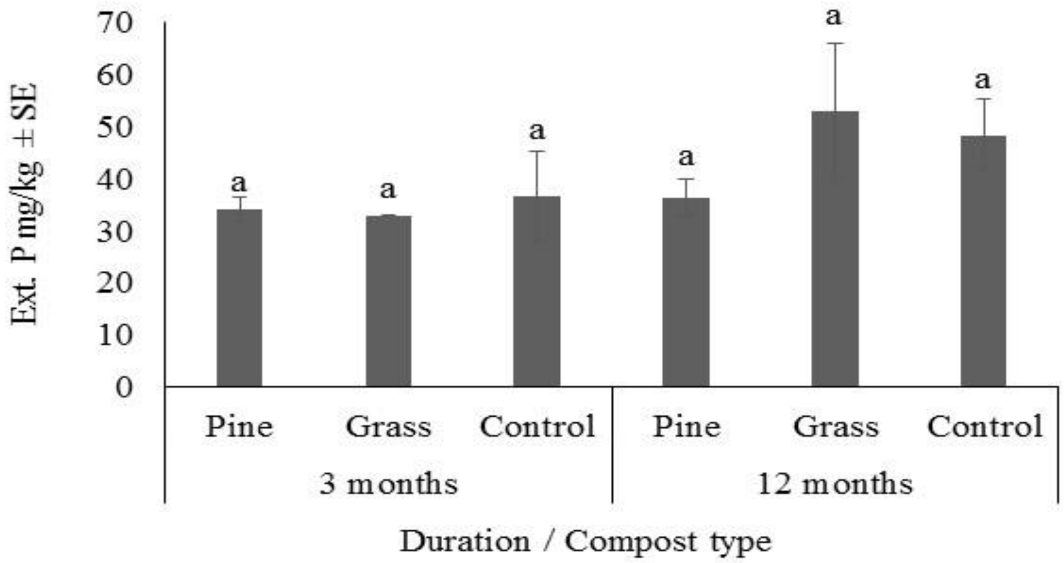
Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Figure 5.1: Effects of type of compost and duration of composting on Organic Carbon (OC) contents.



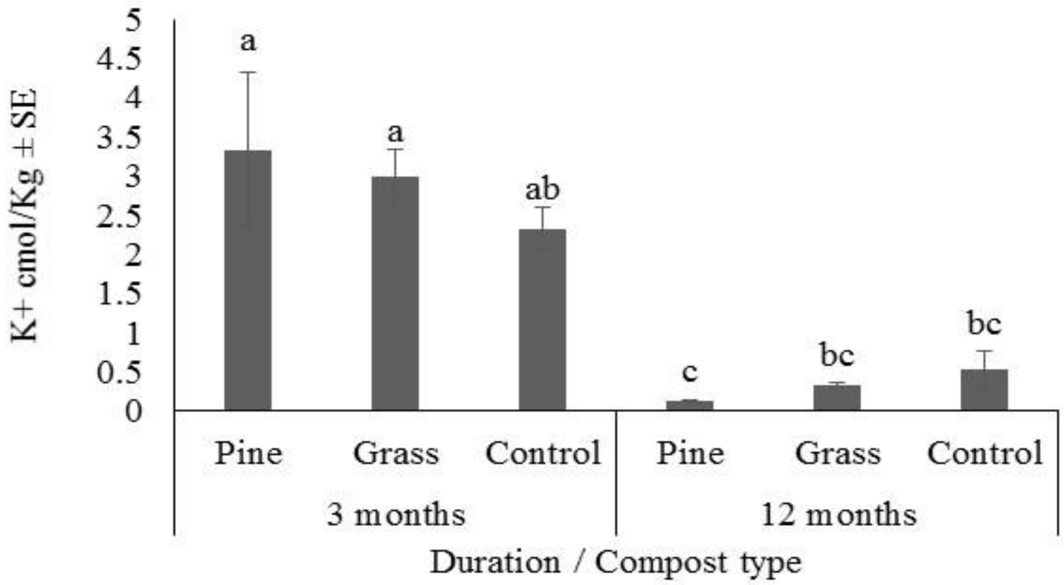
Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Figure 5.2: Effects of compost type and duration of composting on Total Nitrogen (TN) contents



Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Figure 5.3: Effects of compost type and duration of composting on Extractable Phosphorus (P) contents



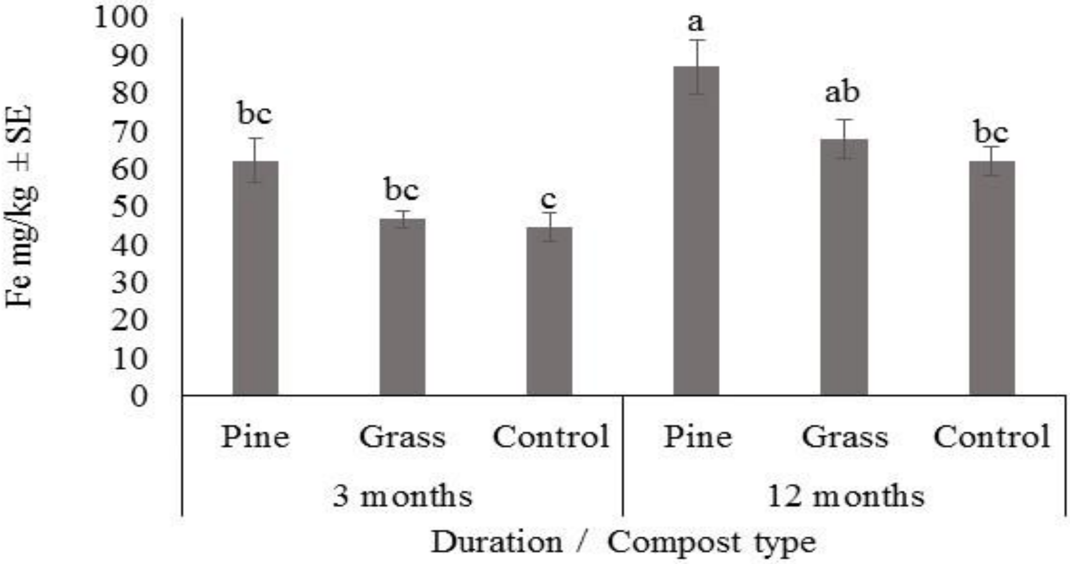
Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Figure 5.4: Effects of compost type and duration of composting of on Potassium (K+) contents

5.3.2 Effects of compost type and duration on micronutrients

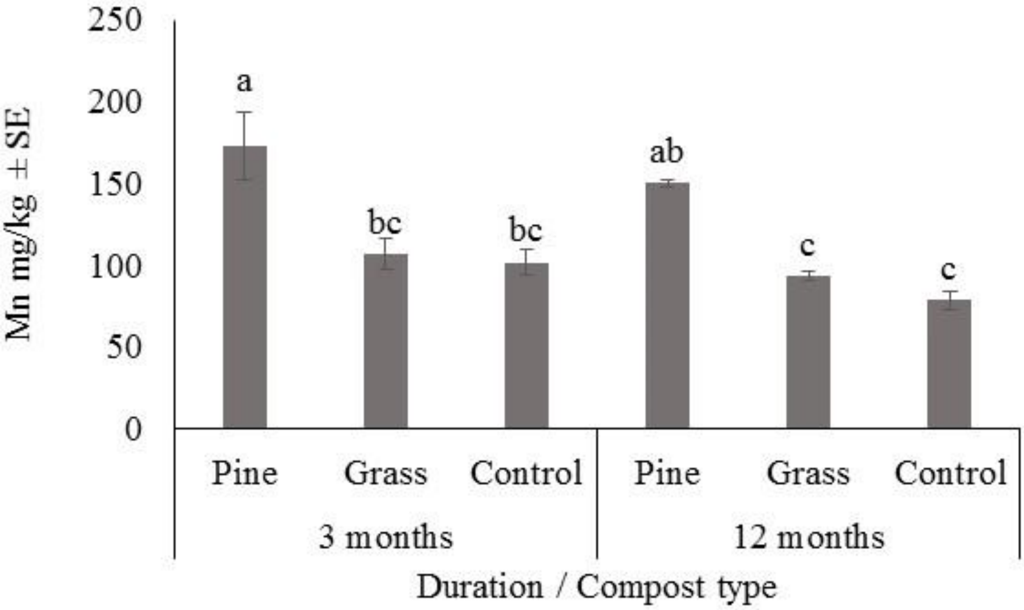
Results showed that mean micronutrients contents varied with duration of composting as well as with type of compost (Fig. 4.5 to 4.8). The highest content of extractable Iron (Fe) was obtained from pine containing heaps composted for 12 months. Highest contents of Copper (Cu) were obtained in pine, wild lemon grass and control heaps composted for three months. The content of Zinc (Zn) was highest in pine containing heaps composted for three months while the highest content of Manganese (Mn) was maintained in both three and 12 months of composting pine containing materials. Copper (Cu) contents decreased from 4.61 to 3.88 mg/kg across all experimental units while Zinc (Zn) contents decresaed from 9.91 to 0.65 mg/kg. Contents of Iron (Fe) ranged from 44.48 to 86.89 mg/kg while Manganese (Mn) contents decreased from 172.7 to 78.7 mg/kg.

Composting duration significantly affected Copper (Cu) ($F_{1, 12} = 65.57$, $p < 0.0001$)**,** Zinc **(**Zn) ($F_{1, 12} = 105.01$, $p < 0.0001$), Manganese (Mn) ($F_{1, 12} = 5.60$, $p < 0.05$) and Iron (Fe) ($F_{1, 12} = 22.79$, $p < 0.0001$). Compost type significantly affected Manganese (Mn) ($F_{2, 12} = 28.68$, $p < 0.0001$)**,** Iron **(**Fe) ($F_{2, 12} = 10.66$, $p < 0.005$) but not Copper (Cu) ($F_{2, 12} = 3.52$, $p < 0.06$) and Zinc (Zn) ($F_{2, 12} = 1.96$, $p < 0.18$). Composting duration x compost type interaction significantly affected Zinc (Zn) ($F_{2, 12} = 5.49$, $p < 0.05$) but not Copper (Cu) ($F_{2, 12} = 3.67$, $p = 0.06$), Manganese (Mn) ($F_{2, 12} = 0.15$, $p = 0.86$) and Iron (Fe) ($F_{2, 12} = 0.27$, $p = 0.77$).



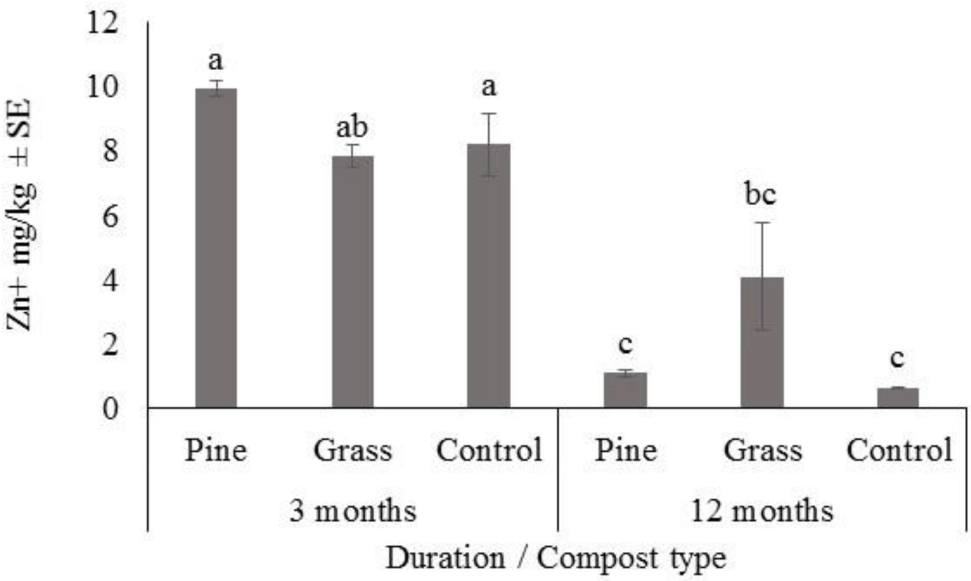
Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Figure 5.5: Effects of compost type and composting duration on Iron (Fe) contents.



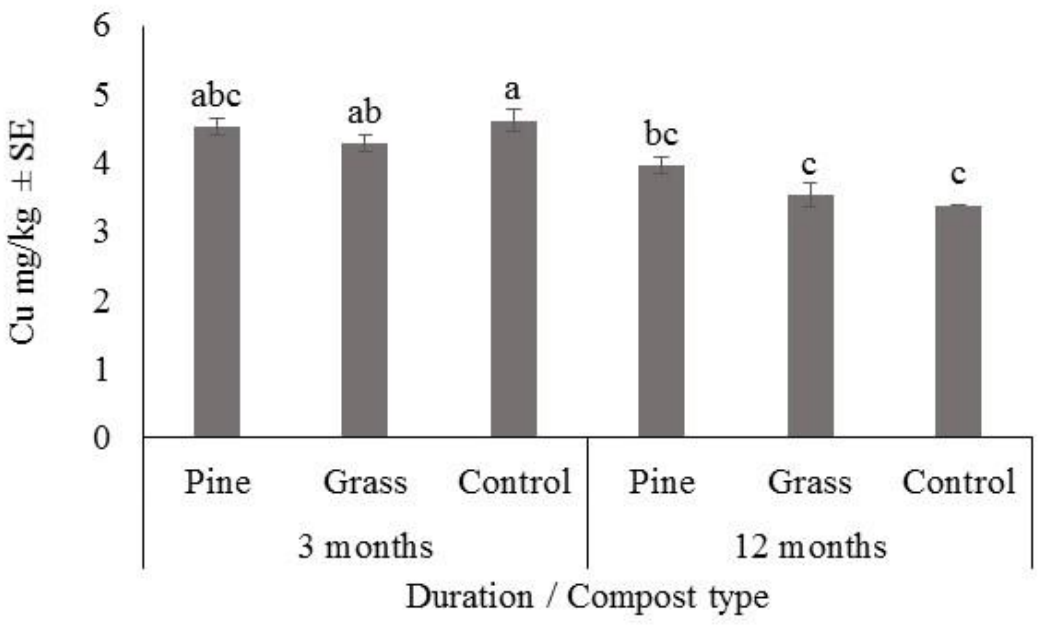
Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Figure 5.6: Effects of compost type and composting duration on Manganese (Mn) contents



Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Figure 5.7: Effects of compost type and composting duration compost on Zinc (Zn+) contents

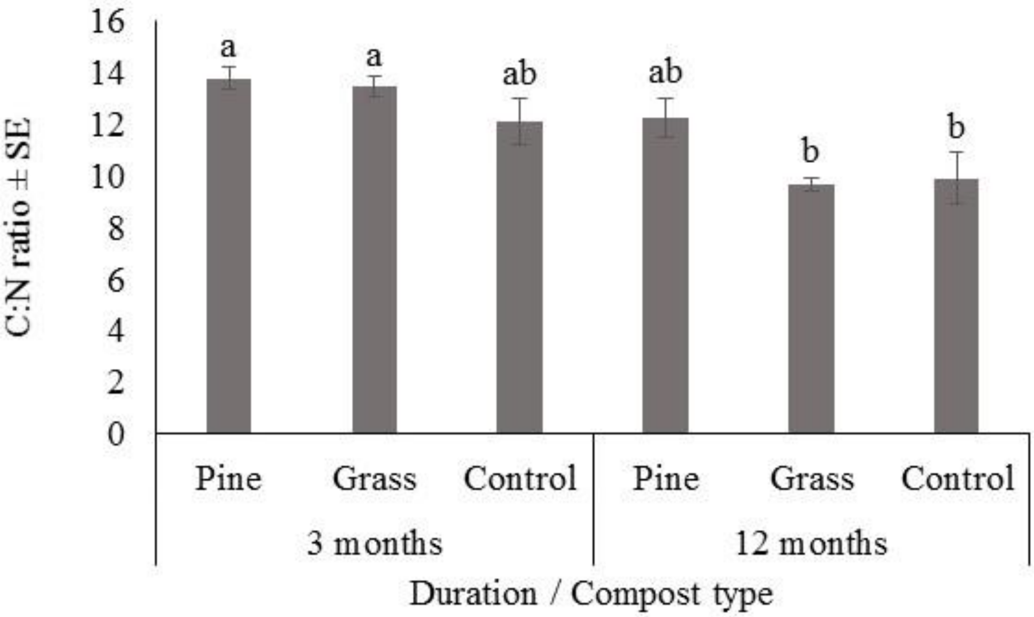


Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Figure 5.8: Effects of composting time and on Copper (Cu) contents.

5.3.3 Effects of compost type and duration on C:N ratio

Composting duration significantly affected C:N ratio ($F_{1,\ 12}$ = 20.69, p <0.0001**)**. Likewise, compost type significantly affected C:N ratio ($F_{2,\ 12}$ = 4.59, p <0.05) but the effects of compost duration x type were not significant ($F_{2,\ 12}$ = 1.40, p = 0.28). The highest mean C:N ratio was recorded in pine containing heaps composted for 3 months, while the lowest mean C:N ratio was recorded in wild lemon grass piles composted for 12 months. C:N ratio ranged between 13.77 and 9.66 across all experimental units.



Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Figure 5.9: Effect of compost type and composting duration on C:N ratio.

5.4 Discussions

The present study revealed that compost type and duration of composting significantly effected C:N ratio levels (Fig. 5.9). The study further showed that that the rate of decomposition of pine was the slowest, followed by wild lemon grass and lastly control.

A study by Awodun and Odeniyi (1999) reported that that type of organic materials influenced biotic activities and increased fertility through decomposition. C:N ratio has profound effects on N availability to plants. The rate and extent of nitrogen immobilization are related to the biochemical composition of the compost. A study by Prescott (2005) showed that N quantities from organic materials with narrow C:N ratios of less than 20:1 became quickly available to growing plants. The same was expected for all composts used in this study because the mean C:N ratios recorded did not exceed 13.77. It is inferred that addition of organic matter into the soil with C:N ratios of less than 30:1 released more N which supported microbial growth and increased the availability of N for plants. On the contrary, a high C/N ratio in compost will promote nitrogen immobilization. The immobilized nitrogen will be available to plants after the microorganisms die and the nitrogen is released. In this study, the C:N ratio of pine, and wild lemon grass gave promising results only after three months, and this indicated that the materials were of high quality which could be used to release nutrients and improve plant nutrition. This is useful information because the types of crops grown by farmers differ in maturation time.

Pine and wild lemon grass compost contributed significant amounts of macro and micro nutrients needed by plants. Results showed that compost duration had significant effects on macronutrients like Organic Carbon (OC) and Potassium (K) while compost type had significant effects on Organic Carbon (OC) and Total Nitrogen (TN). Phosphorus (P) contents were neither affected by compost duration nor compost type while Potassium (K) contents were also not affected by compost type. Total Nitrogen (TN) contents were not affected by duration of composting. Micronutrients like Copper (Cu), Zinc (Zn). Iron (Fe) and Manganese (Mn) were all affected by duration of composting. Type of compost affected Manganese (Mn) and Iron (Fe) only leaving Copper (Cu) and Zinc (Zn) unaffected. Most essential nutrients in compost are in organic forms and are released slowly thus less subject to leaching (compared to inorganic fertilisers).

Several studies reported increased N and C content from added composts. Leifield *et al*., 2002; Whalen *et al*., 2008; Mylavarapu and Zinati, 2009 reported highest contents of Total Carbon in pine containing after being composted for 12 months. According to Reeves (1997) Total Carbon in soils is considered as one of the most important properties of soils because of its impact on ecosystem sustainability, affecting other physical, chemical and biological characteristics of soil. According to Shiralipour *et al*. (1992) organic reported that matter content of composted municipal solid waste improved soil physical and chemical properties and enhanced biological activities. However, most agricultural benefits of compost application to soils are derived from improved physical properties related to the increased organic matter content rather than its value as a fertilizer (Shiralipour *et al*., 1992).

A study by Doran *et al*. (2003) found similar contents of N, P, K and Mg in compost and in farmyard manure. The study also reported optimal levels of Nitrogen, phosphorus and potassium contents of leaves in all applications except control, and Ca, Mg, Fe, Zn, Mn, Cu contents in all applications. Courtney and Mullen (2008) tested sewage sludge and bark compost a mulching materials in a vineyard. Both compost mulches increased organic matter content, available phosphorous and exchangeable potassium. According to Al-Bataina *et al*. (2016) crop and vegetable production is usually coupled with the use of nitrogen-rich fertilizers that result in high nitrogen release to soil (up to 150 kg N ha^{-1}).

Organic amendments to soils are advantageous to soils by providing mostly micronutrients that are seldom applied by farmers (Bulluck III *et. al*., 2001). Composts provide a stabilized form of organic matter that improves the physical properties of soils by increasing nutrient and water holding capacity (Farrell and Jones, 2009), total pore space, aggregate stability, erosion resistance, temperature insulation and decreasing apparent soil density (Shiralipour *et al.*, 1992). Application of compost improves the chemical properties by increasing pH (in acid soils), electrical conductivity, cation exchange capacity, and soil nutrient content. Courtney and Mullen (2008) reported that application of organic materials increased organic status of the soil and nutrient content.

5.5 Conclusions and Recommendations

It can be concluded that the decomposition of pine is slower than that of wild lemon grass materials implying that pine can last longer to support crop growth without a need for frequent replenishment when used as mulch. Levels of C:N ratio recorded after three months of composting pine and wild lemon grass materials also ensures that Nitrogen is made available for plant use. Macro and micro nutrients present in both pine and wild lemon grass materials at three and twelve months of composting assures the availability of nutrients to support crop growth, development and for improving soil fertlity.

It is recommended that pine and wild lemon grass materials be used as compost materials. Moreover, more alternative sources of compost should be explored in the study area. Different ratios of the composted materials should also be tested.

5.6 Acknowledgements

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CHAPTER SIX

EFFECT OF ORGANIC MULCH ON ABUNDANCE OF BENEFICIAL ARTHROPODS IN MULCHED TOMATO (*Solanum lycopersicum* L.) AND SWEET PEPPER (*Capsicum annuum* L.).

Abstract

A study was conducted in Lushoto district, Tanzania to evaluate the effect of organic mulch on abundance and population of beneficial arthropods in organic production of tomato (*Solanum lycopersicum* L.) and sweet pepper (*Capsicum annuum* L.). The experiment was laid as a Randomised Complete Block Design (RCBD) with three replications. The treatments included two times of applying mulch between 3 and 21 days after seedlings were transplanted. Beneficial arthropods were collected by the use of pitfall traps. Data on the number of arthropods collected based on the treatments were recorded in each crop, season and location. Data analysis was done by using R Statistical Package (AGRICOLAE Version 1.2.1). *Post Hoc* Tukey's (HSD) test was used to compare means at P = 0.05 level of significance. Results showed that arthropods responded differently to treatments across different seasons and crops in the locations. Mulching with either pine or wild lemon grass in a season did not affect significantly ($p>0.05$) the numbers of trapped arthropods suggesting that other factors may be responsible for their change while across the seasons, numbers of arthropods changed tremendously. The time of mulch application also did not affect numbers of beneficial arthropods significantly ($p>0.05$).

Keywords: beneficial arthropods, organic mulch, tomato, sweet pepper, pitfall traps

6.1 Introduction

Pest problems in agriculture are as old as agriculture itself. Despite of the natural and artificial measures taken since then, pests are reported to account for an average of 30%-50% of yield losses in agriculture (Oerke *et al*., 1994). Artificial methods which are based on the use of synthetic materials are restricted due to their ecological, toxicological and environmental shortcomings to the ecosystem (Cohen and Yuval, 2000) bringing about a preference to natural means of pest control and promotion of organic agriculture. Organic production systems benefit the ecosystem by allowing an increase in plant species diversity, population density and biodiversity fitness (Gabriel *et al*., 2006). This increase in biodiversity is argued to increase ecosystem services which include pest control by increasing the population of natural enemies of insect pests (Drinkwater *et al*., 1995; Wyss *et al*., 1995; Hesler *et al*., 1993).

Pest and predator associations have been the subject of research in various ecological studies and have unveiled information on occurrence, abundance, diversity and variations due to topographical, geographical and weather conditions (Landis *et al*., 2000; Juen *et al*., 2003). Insect pests and their predators are known to be active on the soil surface in agricultural fields. Studies have indicated the presence of a number of plant pests and some arthropods which feed on plant insect pests and therefore considered to be beneficial (Hill, 1994; Pedigo and Rice, 2009). Among the available natural enemies of insect pests, predatory arthropods are highly acknowledged for their contribution in reducing numbers of insect pests saving crops from substantial losses in yield. Gangurde (2007) revealed higher populations of insect pests and predators present in non-insecticide treated rice fields compared to insecticide-treated fields with most of the predators belonging to the order Coleoptera (beetles), Orthoptera (grasshoppers), Odonata (dragonflies), Hemiptera (plant bugs) and Araneae (spiders). Other predatory arthropods studied include ants (Formicidae), tiger beetles (Cicindelidae) and rave beetles (Staphylinidae) (Gill *et al*., 2011).

The use of organic mulch in crop production in many cases is of advantage to natural enemies of pests as it provides shelter for predatory insects (Johnson *et al*., 2004). Apart from other advantages, mulch also suppresses weeds, adds organic matter upon decomposition, conserves moisture and provides suitable habitats for natural enemies of insect pests (Cortesero *et al*., 2000). Organic mulch in particular is reported to enhance the presence of predators like beetles and spiders (Diver *et al*., 1999). A recent study revealed that numbers of fire ants, rove beetles and carabid beetles increased when killed cover crops were used as mulch in the production of sweet potatoes (*Ipomoea batatas* L. Lam.) by Jackson and Harrison, 2012. Maerere *et al*. (2010) also reported about the preference of lady bird beetles to mulched tomato plots than unmulched plots when dried Bermuda grass (*Cynodon dactylon* L. Pers) was used as mulch.

Lushoto district, in North-EasternTanzania, is a prime area for organic vegetable production of various vegetables with tomato and sweet pepper being the key crops (Jordan Gama, TOAM, personal communication). Farmers commonly rely on the use of star grass, banana leaves, bean plants and pods and other crop residues as mulch. However, several challenges have been associated with the use of these common organic types of mulching materials. The challenges include: an increased labour cost in terms of time and money as most of these mulches require frequent replenishment, scarce availability of these mulches as most of them are also used as animal feed (Wickama *et al*., 2006), and seasonal availability of the mulch which does not guarantee a year-through access to mulch. Such challenges diverged attention towards looking for alternative organic mulches. In this work, pine litter and wild lemon grass have been considered as the potential alternative organic mulch that can be used in organic production of tomato in Lushoto district.

Saria (2014) informs about the usefulness of pine as mulch in Lushoto, Tanzania indicating that pine mulch at 15cm layer thickness led to high yields compared to another type of organic mulch. In another study, both pine and wild lemon grass were used as mulch materials in organic production of tomato in Lushoto (Shechambo *et al*., 2015). However studies focusing specifically on the influence of pine and wild lemon grass mulch on population of beneficial arthropods are not available. In the present study, Mexican weeping pine (*Pinus patula* Schelde. ex Schltdl and Cham) and wild lemon grass (*Cymbopogon spp*.) were used as mulch in organic production of tomato (*Solanum lycopersicum* L.) and sweet pepper (*Capsicum annuum* L.) to determine the effects of type of mulch and time of application on the abundance of predatory arthropods.

6.2 Materials and Methods

6.2.1 Description of study area and materials

The study was done in Lushoto district, Tanga region, in the North-Eastern Tanzania. The district is located in the West Usambara Mountains, lying between 38º 10’ and 38º 36’ East and 4º 24’ and 5º 00’ South. The altitude in Lushoto is between 800-2300 m a.s. l. The rainfall received is in bimodal pattern with the short rains from October to December and the long rains from March to June. Annual rainfall ranges from 600 to 1200 mm while temperature ranges from 16 - 30º C. The soils are generally latosols (Shemdoe, 2011). The experimental sites were Lushoto (38° 17’ 24’’ East and 4° 47’ 55’’ South) with an altitude of 1500m. a.s.l located at Lushoto town-forest area and Ubiri (38° 21’ 59’’ East and 4° 50’ 29’’ South) with an altitude of 1218m. a.s.l. located at Ubiri village along Mombo-Lushoto road.

6.2.2 Crop establishment, management and trapping of beneficial arthropods

Tomato variety Tanya and sweet pepper variety California Wonder were grown for three seasons from April 2013 to May 2015. The first season (season 1) began in April 2013 and ended in September 2013 while the second season (season 2) began in August 2013 and ended in December 2013. Season 3 began in January to May, 2015. Season 1 experienced wet and cold weather, season 2 experienced dry and hot weather while season 3 experienced dry, hot and then rainy months in January-February, 2015 and March-May, 2015, respectively.

Management activities included the use of organic compost [ERTHFOOD$_{TM}$ (1.5-0.5-0.5)] at the quantity of 500g per hole applied one day before tomato seedlings were transplanted as soil amendment material. This was later supplemented with a seven day soaked solution of cow urine (20 litres), cow dung (50 kg) and water (200 litres) as top dressing organic manure applied at 0.5 litres per plant. The seeds of *Azadirachta indica* A. Juss. in dried, ground and sieved form (0.5 kg), sour milk (0.5 litres), ashes (0.5 kg), banana flower (1 piece) and kerosene (0.25 litres) all mixed in 15 litres of water, were used to prepare a local biopesticide. This mixture was applied against aphid in season 1 and against thrips outbreak in season 2. This biopesticide was also used against fungal and bacterial diseases. All crops were irrigated by tap water (at Lushoto) and by furrow water (at Ubiri).

Organic mulch used was dried pine litter and dried wild lemon grass. Pine leaves were collected under pine trees located in the pine forest near Lushoto experimental site while wild lemon grass was collected from the mountain rocks at Kizara village near Ubiri site. Pine mulch was in dry form and did not require chopping due to its needle-like shape while wild lemon grass was in fresh form hence required about three weeks to dry before being chopped and used. The mulch depth was 15cm. Pitfall traps were employed to collect beneficial arthropods in all the 3 vegetable growing seasons in both locations. The experimental plots measured 9m^2 (3m in width x 3m in length) and in each plot four pitfall traps were arranged at the middle quadrant of the plot. Each trap was filled with three quarter-full of slightly soapy-water resulting from a mixture of 2gm of domestic powdered detergent in 20l of water. For each set up, traps were emptied after 48 hours.

Plate 6.1: Pitfall traps used for trapping beneficial arthropods (left). Collection of beneficial arthropods after 48 hours of trapping (right)

6.2.3 Experimental design

The experiment was laid as a Randomized Complete Block Design (RCBD) with six treatments and was replicated three times. The treatments were pine mulch applied 3 days after transplanting (PI), pine mulch applied after 21 days (PA), wild lemon grass mulch applied 3 days after transplanting (GI), wild lemon grass mulch applied after 21 days (GA), weeded control (CI) and unweeded control (CA).

6.2.4 Data collection and analysis

Arthropods were collected in May and July (2013) in season1, in October and December (2013) in season 2 and in February and March (2015) in season 3. The collected arthropods were kept in ethanol diluted to 70% and taken to the Laboratory at Sokoine University of Agriculture, in Morogoro for identification, counting and preservation of the predatory arthropods. Data on the numbers of arthropods caught per square meter in pine mulched, grass mulched, weeded and unweeded control plots were collected. Data on numbers of beneficial arthropods collected in each season were compiled from individual catches made within each season. All these data were later subjected to Analysis of Variance (ANOVA) using R Statistical Package (AGRICOLAE Version 1.2.1). *Post Hoc* Tukey's (HSD) test was used to compare means at P = 0.05 level of significance.

6.3 Results

6.3.1 Arthropod composition

A total of 4 397 individual arthropods were collected from pitfall traps at both Lushoto and Ubiri sites in Season 1 (April-September, 2013), season 2 (August-December, 2013) and Season 3 (January-May, 2015). Out of the total number of arthropods collected, 990 arthropods were collected in season 1 alone while 2 074 and 1333 arthropods were collected in each of seasons 2 and 3, respectively. Based on number of arthropods per crop, 2 303 arthropods were collected in tomato alone while 2094 arthropods were collected in sweet pepper alone. In terms of location, 1733 arthropods were collected at Lushoto site while 2 664 arthropods were collected at Ubiri site.

In the total collection of individual arthropods, predators were 4 001 (91%) individuals, while herbivores (pests) and omnivores were 220 (5%) and 176 (4%), respectively.

The arthropods were classified up to family level. Classification revealed that predators belong to 5 orders and 13 families which are order Araneae (families Lycosidae, Pisauridae and Salticidae), order Coleoptera (families Carabidae and Coccinelidae), Order Hymenoptera (families Formicidae, Apidae, Anthrophoridae, Sphecidae, Tenthredinidae and Vespidae, order Acarina (family Phytoseeidae) and order Hemiptera (family Ruduviidae). Herbivores (pests) belong to 6 orders and 10 families which are order Coleoptera (families Pyrichoriidae, Chrysomelidae, Curculionidae, Tenebrionidae and Scarabaeidae), order Homoptera (families Aphididae and Cicadellidae), order Lepidoptera (family Noctuidae), order Orthoptera (family Gryllidae), order Hemiptera (family Berytidae), order Acarina (family Tetranychidae). Omnivores belong to 4 orders and 8 families which are order Hymenoptera (families Halictidae, Tenthredinidae and Vespidae), order Coleoptera (families Tenebrionidae and Carabidae), order Diptera (families Cecidomidae and Drosophilidae), order Orthoptera (family Blattelidae).

However, since the study focused on beneficial arthropods (predators), only predator families with more than 200 individual members were considered for analysis because their population in the traps was more consistent compared to arthropods caught in smaller numbers whose trapping could be considered to be accidental. The selected families were Lycosidae (order Araneae), Carabidae (order Coleoptera) and Formicidae (order Hymenoptera) (Table 6.1).

Table 6.1: Arthropod composition by treatments for tomato and sweet pepper crops at Lushoto and Ubiri sites

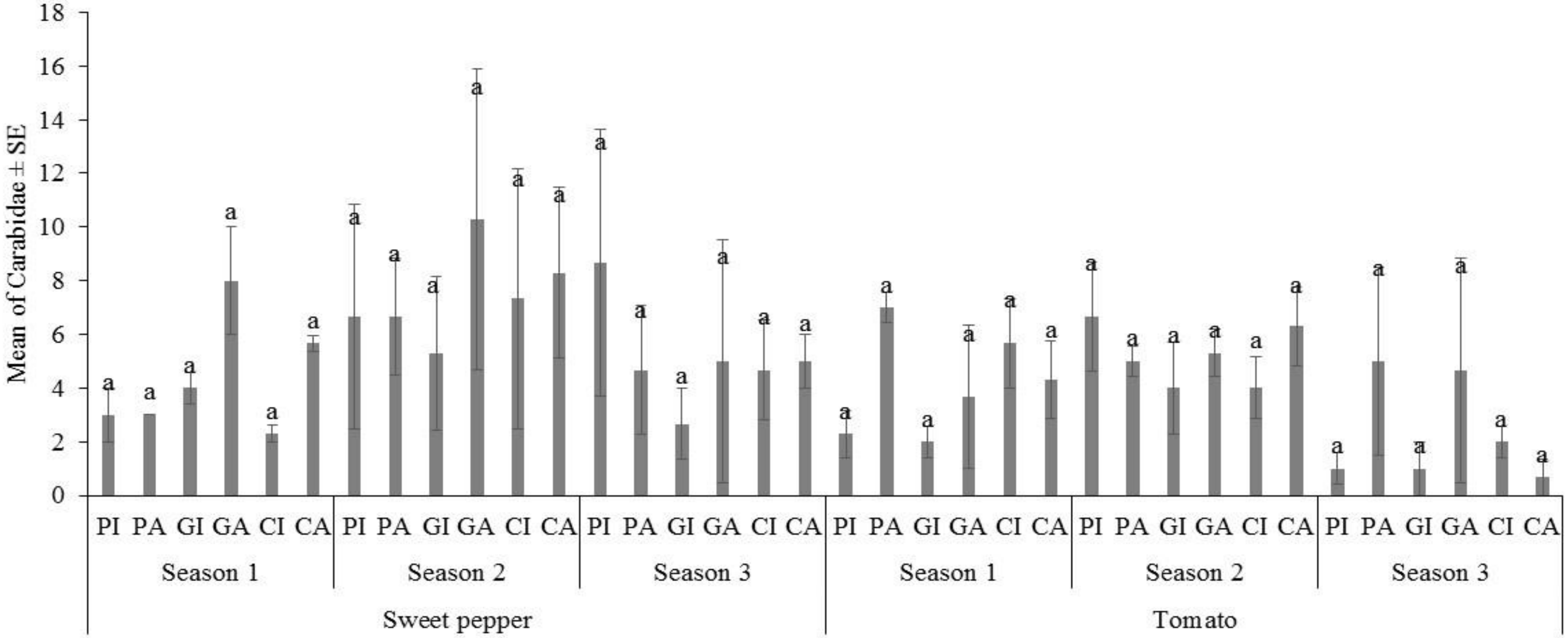
Location	Crop	Treatment	Lycosidae	Carabidae	Formicidae	Others	Total	%
Lushoto	Spepper	C	45	57	10	17	129	1.025
		GA	71	70	4	13	158	1.255
		GI	116	102	8	24	250	1.986
		PA	159	142	13	44	358	2.844
		PI	212	192	17	65	486	3.862
		W	251	233	21	88	593	4.712
	Tomato	C	42	34	10	28	114	0.905
		GA	46	41	14	10	111	0.882
		GI	105	62	29	23	219	1.74
		PA	156	107	38	50	351	2.789
		PI	223	136	61	70	490	3.893
		W	260	170	64	86	580	4.609
Ubiri	S pepper	C	25	4	204	4	237	1.883
		GA	28	13	251	2	294	2.336
		GI	60	26	377	7	470	3.734
		PA	91	36	492	12	631	5.014
		PI	136	40	691	12	879	6.985
		W	162	53	921	17	1153	9.162
	Tomato	C	23	4	358	17	402	3.194
		GA	41	14	252	15	322	2.558
		GI	72	23	499	23	617	4.903
		PA	95	33	762	26	916	7.279
		PI	141	40	1022	28	1231	9.782
		W	161	47	1348	37	1593	12.67
Total			**2721**	**1679**	**7466**	**718**	**12584**	**99.982**
%			**21.62**	**13.34**	**59.33**	**5.71**	**100**	

6.3.2 Abundance of beneficial arthropods

Results of abundance of beneficial arthropods at Lushoto are presented in Figures 6.1, 6.2 and 6.3. Crops significantly affected abundance of Carabaidae ($F_{1, 72}$ = 4.37 , P < 0.04). Season significantly affected abundance of carabaidae ($F_{2, 72}$ = 3.77, P < 0.03). Furthermore, abundance of carabaidae was not significantly affected by treatments ($F_{5, 72}$ = 1.0, P < 0.42). The effects of crop x season ($F_{2, 72}$ = 0.92, P < 0.40); treatment x crop ($F_{5, 72}$ = 0.58, P < 0.71); season x treatment ($F_{10, 72}$ = 0.26, P < 0.98) were not significant. The effects of treatment x season x crop were not significant ($F_{10, 72}$ = 0.63, P < 0.78).

Results further showed that crops significantly affected abundance of Formicidae ($F_{1, 72}$ = 17.12 , P < 0.001). Season significantly affected abundance of Formicidae ($F_{2, 72}$ = 17.56, P < 0.001). Furthermore, abundance of Formicidae was significantly affected by treatments ($F_{5, 72}$ = 2.6, P < 0.05). The effects of crop x season ($F_{2, 72}$ = 7.79, P < 0.001); treatment x crop ($F_{5, 72}$ = 2.92, P < 0.05); season x treatment ($F_{10, 72}$ = 2.23, P < 0.05) were also significant. The effects of treatment x season x crop were similarly significant ($F_{10, 72}$ = 3.52, P < 0.00).

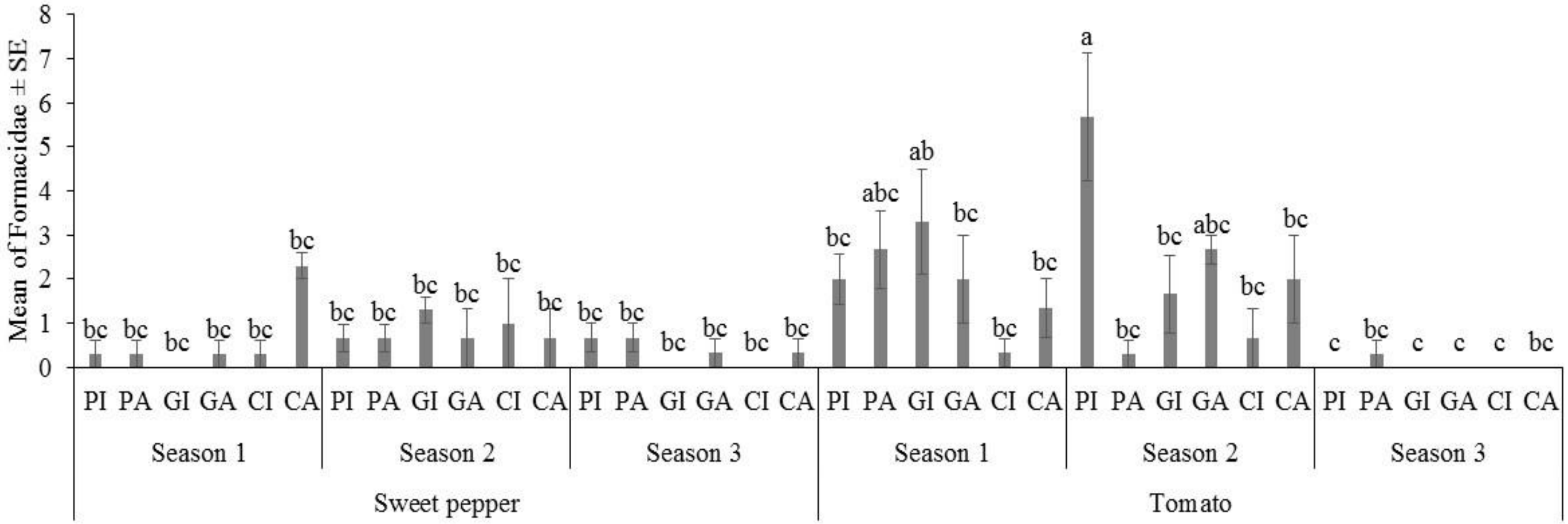
The abundance of Lycosidae did not differ significantly among crops ($F_{1, 72}$ = 0.38, P = 0.37). Season significantly affected abundance of Lycosidae ($F_{2, 72}$ = 53.98, P < 0.001). Furthermore, abundance of carabaidae was significantly affected by treatments ($F_{5, 72}$ = 3.9, P < 0.01). The effects of crop x season ($F_{2, 72}$ = 5.52, P < 0.01) and season x treatment ($F_{10, 72}$ = 2.27, P < 0.05) were also significant. However the effect of treatment x crop ($F_{5, 72}$ = 1.72, P < 0.14) was not significant. The effects of treatment x season x crop were not significant ($F_{10, 72}$ = 1.14, P < 0.34).



Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI= Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA= Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA= Unweeded control. Season 1: April to September, 2013; Season 2: August to December, 2013; Season 3: January to May, 2015

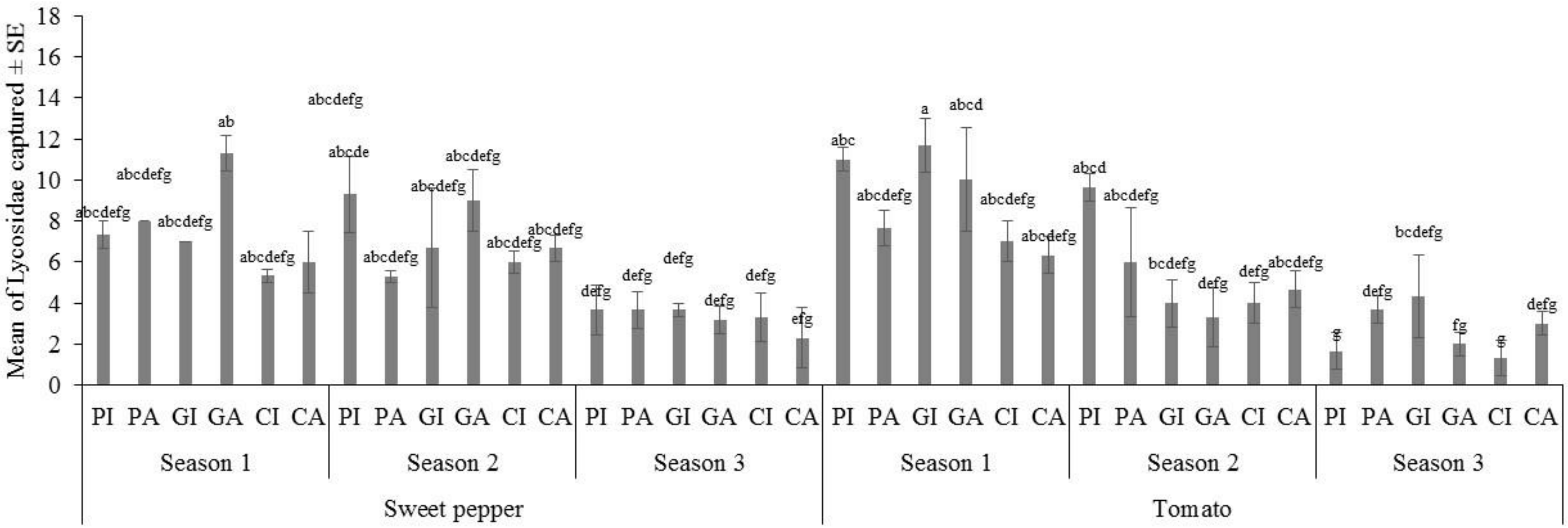
Figure 6.1: Effect of pine and wild lemon grass mulch on number of predatory Carabidae collected at Lushoto site



Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI= Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA=Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA=Unweeded control. Season 1: April to September, 2013; Season 2: August to December, 2013; Season 3: January to May, 2015

Figure 6.2: Effect of pine and wild lemon grass mulch on number of predatory Formicidae collected at Lushoto site



Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

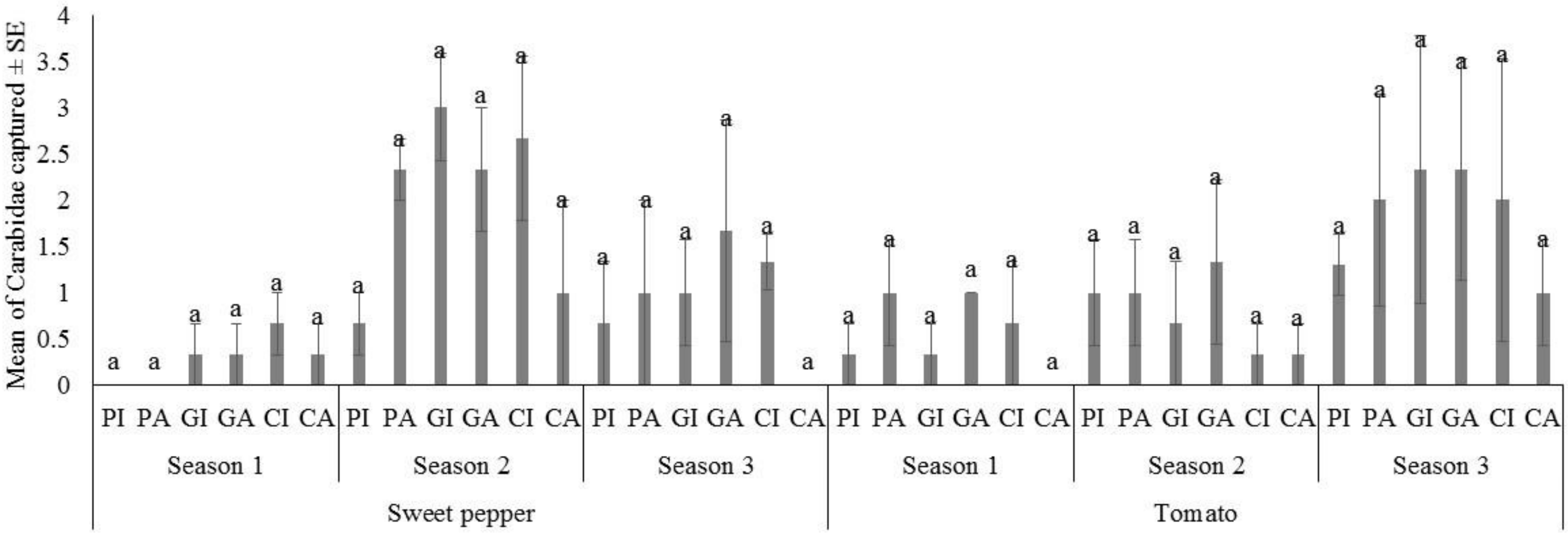
Key: PI= Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA= Wild lemon grass mulch applied 21 days after transplanting; CI= Weeded control; CA: Unweeded control. Season 1: April to September, 2013; Season 2: August to December, 2013; Season 3: January to May, 2015

Figure 6.3: Effect of pine and wild lemon grass mulch on number of Lycosidae collected at Lushoto site

Figures 6.4, 6.5 and 6.6 show abundance of beneficial arthropods at Ubiri. Crops did not significantly affect abundance of Carabaidae ($F_{1, 72} = 0.006$, $P < 0.93$). Season significantly affected abundance of carabaidae ($F_{2, 72} = 37.85$, $P < 0.001$). Furthermore, abundance of carabaidae was not significantly affected by treatments ($F_{5, 72} = 2.11$, $P < 0.73$). The effects of crop x season ($F_{2, 72} = 7.35$, $P < 0.01$) was also significant. However treatment x crop ($F_{5, 72} = 0.42$, $P < 0.83$); season x treatment ($F_{10, 72} = 0.21$, $P < 0.99$) were not significant. The effects of treatment x season x crop were also not significant ($F_{10, 72} = 0.49$, $P < 0.88$).

Results further showed that crops significantly affected abundance of Formicidae ($F_{1, 72} = 8.63$, $P < 0.01$). Season significantly affected abundance of Formicidae ($F_{2, 72} = 38.17$, $P < 0.001$). Furthermore, abundance of Formicidae was not significantly affected by treatments ($F_{5, 72} = 1.02$, $P < 0.40$). The effects of crop x season ($F_{2, 72} = 3.41$, $P < 0.05$) were also significant; treatment x crop ($F_{5, 72} = 0.31$, $P < 0.97$); season x treatment ($F_{10, 72} = 0.31$, $P < 0.97$) were not significant. The effects of treatment x season x crop were also not significant ($F_{10, 72} = 1.22$, $P < 0.288$).

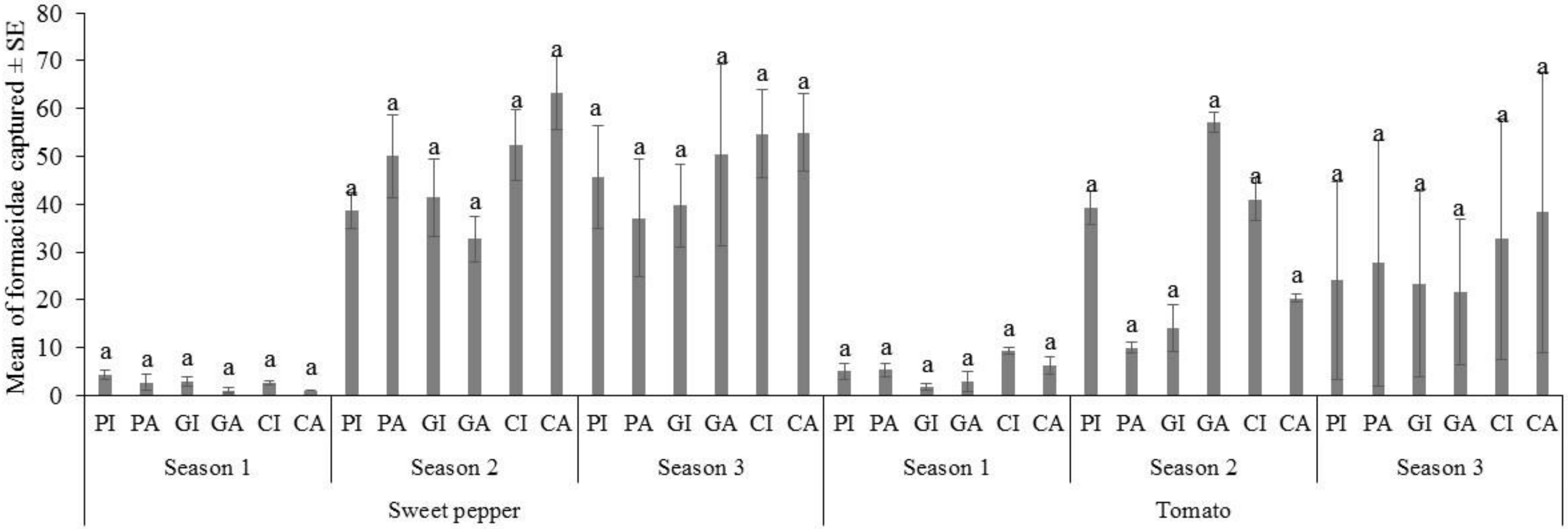
The abundance of Lycosidae did not differ significantly among crops ($F_{1, 72} = 0.10$, $P = 0.74$). Season significantly affected abundance of Lycosiadae ($F_{2, 72} = 7.77$, $P < 0.001$). Furthermore, abundance of Lycosidae was not significantly affected by treatments ($F_{5, 72} = 1.62$, $P < 0.16$). The effects of crop x season were significant (F2, 72 = 4.64, $P = 0.01$). However, effects of crop x treatment ($F_{10, 72} = 0.22$, $P < 0.94$) and season x treatment ($F_{5, 72} = 0.20$, $P < 0.99$) were not significant. The effects of treatment x season x crop were also not significant ($F_{10, 72} = 1.14$, $P < 0.34$).



Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI= Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA= Wild lemon grass mulch applied 21 days after transplanting; CI=Weeded control; CA= Unweeded control. Season 1: April to September, 2013; Season 2: August to December, 2013; Season 3: January to May, 2015

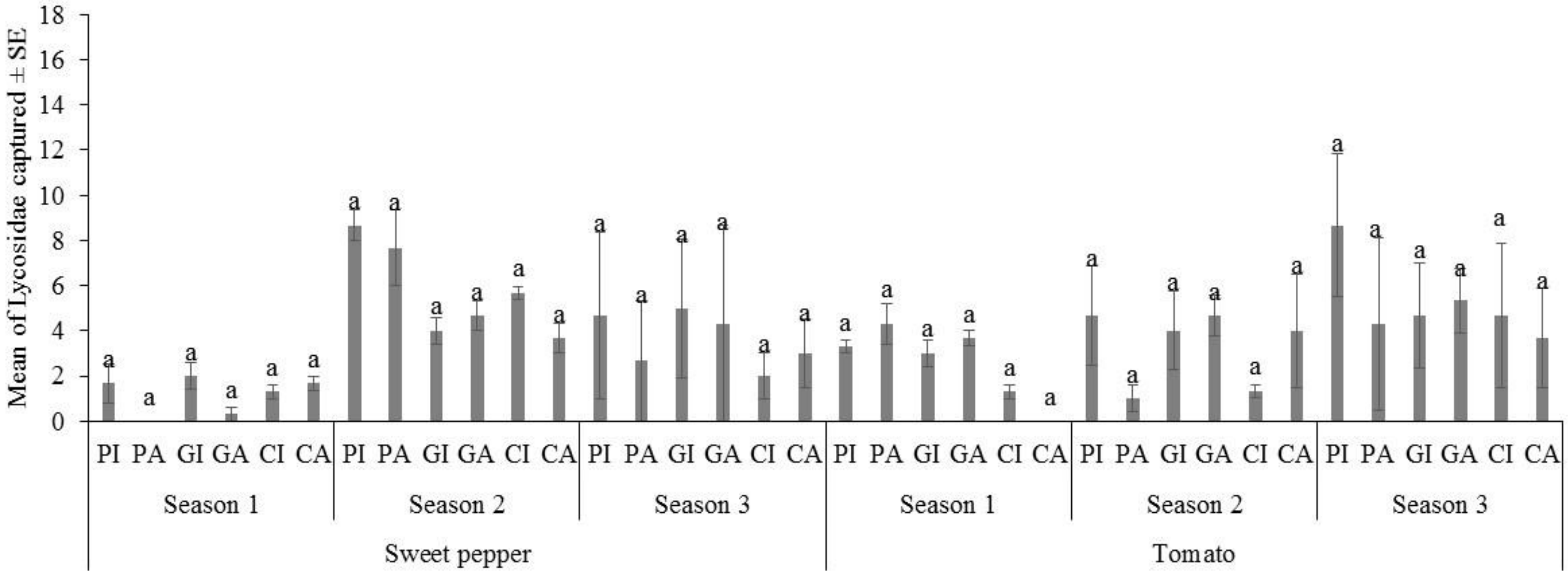
Figure 6.4: Effect of pine and wild lemon grass mulch on number of predatory Carabidae collected at Ubiri site



Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI= Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA= Wild lemon grass mulch applied 21 days after transplanting; CI=Weeded control; CA= Unweeded control. Season 1: April to September, 2013; Season 2: August to December, 2013; Season 3: January to May, 2015

Figure 6.5: Effect of pine and wild lemon grass mulch on number of predatory Formicidae collected at Ubiri site



Mean values with the same letter(s) are not significantly different at P=0.05 according to Tukey's (HSD) test.

Key: PI= Pine mulch applied 3 days after transplanting; PA= Pine mulch applied 21 days after transplanting; GI= Wild lemon grass mulch applied 3 days after transplanting; GA= Wild lemon grass mulch applied 21 days after transplanting; CI=Weeded control; CA= Unweeded control. Season 1: April to September, 2013; Season 2: August to December, 2013; Season 3: January to May, 2015

Figure 6.6: Effect of pine and wild lemon grass mulch on number of Lycosidae collected at Ubiri site

6.4 Discussions

The presence of mulch had a positive impact on the population of beneficial arthropods. The numbers of arthropods collected in mulched plots suggests that, pine and wild lemon grass mulch did not repel beneficial arthropods. The higher population of beneficial arthropods in mulched plots was possibly due to creation of good micro-climate which was condusive for spiders by offering refuge, cool and with high humidity during hot and dry seasons as compared to unmulched treatments. Johnson *et al*. (2004) argued that plant mulches can be an effective way to provide shelter for predatory insects. This situation was also reported by Rypstra *et al*. (1999).

The time at which mulch was introduced in plots also had an influence on the numbers of beneficial arthropods. Application of mulch three days after transplanting of tomato seedlings attracted more arthropods than application of mulch 21 days after transplanting. In this experiment, when pine and grass mulch which was introduced at three days after transplanting of tomato and sweet pepper ended up with higher numbers of arthropods were found compared to when 21 days were applied after tomato and sweet pepper seedlings were transplanted. The increase in numbers of arthropods in plots which received mulch early was probably due to creation of micro habitat in the particular plots which offered more conducive environment for the predators to survive. Mulching is also reported to provide alternative prey to natural enemies of insect pests (Cortesero *et al.*, 2000).

Lushoto district is normally characterized by long rains and average temperatures in the months of April and May while months of June to August are usually characterized by dry conditions and low temperatures. The numbers of spider catches were higher during the rainy months than during the cold and dry months. This observation suggests that spiders (Araneae) do not thrive well in cold conditions as the majority of spiders have a little resistance to low temperatures (Kirchner, 1987). Rainfall however, is argued to possibly kill substantial numbers of early instars of spiders (Wise, 1993). This argument explains the reason behind the low numbers of spiders right after the rains ended in the month of May and the high numbers of spiders caught at the beginning of the rainy season suggesting a population build up in the dry months.

The larger numbers of beetles and ants appeared towards the end of season 2 which is characterized by short rains and high temperatures. The presence of larger numbers of these arthropods at that time implies that they multiply when dry conditions prevail. This observation supports previous findings which report about the preference of ants and beetles to dry conditions and high temperatures (Janzen, 1973; Thiele, 1977 and Basu, 1997).

6.5 Conclusion and Recommendation

Overall, this study reveals that pine needles and wild lemon grass can be used effectively as organic mulch due to their ability to attract high numbers of beneficial arthropods which are the natural means of pest control. Availability of both mulches throughout the year in Lushoto is another added advantage. Based on this study, it is recommended that the most suitable time of applying mulch in tomato and sweet pepper is three days after transplanting because the mulch becomes available long enough to harbor good numbers of beneficial arthropods hence increasing the chances of pest control. Never the less, in all seasons studied in this work are recommended as the best for mulch application and for attracting larger numbers of beneficial arthropods. Large numbers of spiders and fair numbers of beetles occur during the wet and cold season while larger numbers of ants dominate the dry and hot seasons.

6.6 Acknowledgement

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CHAPTER SEVEN

7.0 General Discussions

This study reports the success of pine and wild lemon grass as mulch materials with the ability to suppress weeds, harbouring beneficial arthropods, supporting yield and quality of tomato and sweet pepper. It also repots the success of the organic materials as compost ingredients with important addition of slowly released macro and micronutrients.

Results of the present work showed that yield of of tomato and sweet pepper varied with seasons. Yields were were highest in season one (April to August, 2013) and were 4-5 tons less in season two (September to December, 2013) and season three (January to May, 2015). Highest yields were also obtained in all mulched treatments. Tomato and sweet pepper yields from plots with pine and wild lemon grass mulch applied 21 days after transplanting (PA and GA) were also similar with weeded treatments. Yields in control plots were the lowest. In all three seasons, tomato yields were higher at Lushoto site while sweet pepper yields were higher at Ubiri site. The differences in yield between the two sites is associated with weather conditions.

It was observed in this study that yield was similar between weeded and mulched plots. However, about 40 percent of what was harvested in weeded plots of both tomato and sweet pepper crops did not attain market qualities where fruits were either small sized or physiologically damaged. These damages could not be controlled because of the nature of weeded plots. For instance, fruits which were in contact with soil were easily affected by soil borne pests. On the other hand, mulch became a barrier between plants and soil which prevented damages caused by soil borne pests.

Results of this study showed that mulching controlled weeds similar to normal weeding practices. Weeds were controlled equally between the two types of mulches, pine and wild lemon grass. According to Milberg *et al.* (2000) ecological reactions to previous management practices, soil characteristics of the site, climatic and weather changes affected weed populations. Mulching alone was not enough to control all weeds effectively. Successful weed control in tomato and sweet pepper organic production requires a combination of strategies. Negative effects of mulch on weeds was previously reported (For example Amoroso *et al*., 2007; 2009; Chong 2003; Ramakrishna *et al*., 2006; Duppong *et al*., 2004; Anzalone *et al*., 2010). The use of organic mulch in crop production in many cases suppresses weeds, adds organic matter upon decomposition, conserves moisture and provides suitable habitats for natural enemies of insect pests (Cortesero *et al*., 2000). Studies on effects mulch on diseases are however limited (for example Gleason *et al*., 2001; Rajasri *et al*., 2011) as well as on insect pests (Johnson *et al*., 2004).

This study further showed that mulch also affected numbers of beneficial arthropods. The numbers of beneficial arthropods (predators) however, were different between mulched and unmulched plots implying that mulch application on crops create a good environment for predatots to find habitats and eventually control insect pests. Such observations were reported by Johnson *et al*., 2004 who observed higher numbers of predators in straw mulched potatoes and watermelons and Teasdale *et al*., 2004 who observed less numbers of Colorado potato beetles in tomato mulched with hairy vetch.

The contribution of pine and wild lemon grass mulch to high tomato and sweet pepper yield can be due to weed reduction, creation of conducive environment and nutrients availability upon decomposition. Use of mulches in tomato production is known to increase yield as reported in capsicum (Schonbeck and Evanylo, 1998; Nkansah *et al*., 2003;. Awodoyin *et al*., 2007; Ojeniyi *et al*., 2007; Chakraborthy and Sadhu 1994; Alvaro *et al*., 2010). Higher yields of mulched capsicum were previously reported (for example Vos and Sumarni, 1997; Norman *et al*., 2011; Manuel *et al*., 2000; Thakur *et al*., 2000; Venkanna, 2008). Weed suppression due to addition of organic mulch is evidenced to contribute substantial quantities in yield. According to Schonbeck and Evanylo (1998) an increase in yield as a result of reduced crop-weed competition due to weed suppression by organic mulching. Other works by Nkansah *et al.* (2003), report that grass straw, rice straw, rice husk and saw dust mulches significantly reduced fresh weed weight. They also stated that grass straw mulch significantly reduced fresh weed weight while the highest fresh weed weight was observed in the control. According to Norman *et al.* (2011), dry grass and sawdust mulches suppressed weed growth significantly.

This study showed that compost type affected levels of macro and micro nutrients. Levels of OC and Mn were higher in pine and wild lemon grass composts than in the control. However, levels of N, P, K,Fe, Zn and Cu did not significantly vary between composts. Furthermore, C:N ratio values were higher in pine conataining heaps compost for three months than in wild lemon and control composts. Levels of OC and K increased with time. On the contrary, levels of extractable P decreased with time in wild lemon grass heaps. Leifield *et al*. (2002), Whalen *et al*. (2008) and Mylavarapu and Zinati (2009) reported increased N and C content from added composts. Likewise Dambreville *et al*. (2006) reported increased N, P and other nutrients by added composts. Doran *et al*. (2003) found similar contents of N, P, K and Mg in compost and in farmyard manure. Courtney and Mullen (2008) found that compost mulches increased organic matter content, available phosphorous and exchangeable potassium. According to Drinkwater *et al*. (1995) the use of organic soil ammendments is associated with desirable properties including higher plant available water holding capacity, cation exchange capacity and beneficial microorganisms. Composting is a useful way of transforming organic wastes into a valuable ammendments for soil with benefits such as stabilizing pH, faster water infiltration rate due to soil aggregation (Stamadiatis *et al.,* 1999).

Actions of various organic mulch on soil physical and biological properties have been studied (Jobbagy and Jackson, 2000; Friedel *et al*., 2001), it was important to study chemical properties of pine and wild lemon grass compost because impact of an individual organic material could be different. Adding compost in to the soil improves soil fertility, water holding capacity, and Cation Exchange Capacity (CEC). Other advantages include lowering of bulk density, fostering of beneficial microorganisms, pH stabilization and faster water infiltration rate due to enhanced soil aggregation (Drinkwater *et al*., 1995; Stamatiadis *et al*.,1999; Cooperband, 2002) and microbial activity (Drikwater *et al*., 1995). According to Friedel *et al*. (2001) soil microbes act as transient nutrient sink responsible for releasing nutrients from organic matter for use by plants. Consequently use of composts increases soil and crop productivity (Lal and Stewart, 1995).

Research findings in this study reported that the numbers of insect pests were similar in all treatments while the abundance of beneficial arthropods was higher in all mulched plots. With this observation, lowest numbers of insect pests in mulched plots were expected. However, that was not the case. The reason behind this observation could be the alternative feed that can be carried by the decaying organic mulch. The observed insect pests aphids and thrips were located on the upper parts of the plant. This suggests that the beneficial arthropods which usually find shelter within the organic mulch on the lower parts of plants could feed on alternative prey that were found within the mulch.

Feber *et al*., 1998 and Pfiffner and Luka, 2003 support this idea by reporting about higher abundance of spiders (lycosidae) and beetles (carabidae) being supported by the richer understorey vegetation which provided not only a greater structural complexity but also a suitable microclimate with greater abundance of plant food for prey species.

Although the prepared compost containing pine and wild lemon grass materials was not used back to grow tomato and sweet pepper in this study, the released nutrients from the composts give promising results. The compost containg important nutrients that are required in growth and development of the grown vegetables. Between three and twelve months of composting as evidenced in the analysis results nitrogen, phosphorus and potassium macronutrients and iron, manganese, zinc and copper micronutrients were released. This is important because tomato and sweet pepper need nutrient sources that are well balanced in macro and micronutrients (Grubben and Mohamed, 2004; UNCTAD, 2003). The compost nutrient results can also be used to estimate tomato and sweet pepper additional nutrient requirements when such composts are used. Results of nutrient analysis of pine and wild lemon grass containing composts give an important indicator of what was released from pine and wild lemon grass when they were used as mulch and their anticipated effects on soil chemical properties. Tejada and Gonzales (2003) and Mulumba and Lal, 2008 support this idea by stating that the residues of organic matter have a profound effect on soils.

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CHAPTER EIGHT

8.0 Conclusions and Recommendations

8.1 Conclusions

The findings in this study show that pine and wild lemon grass mulch increase yield and quality of sweet pepper and tomato. The presence of mulch helps in preventing a direct contact between vegetable fruits and the soil hence protecting fruits from damages and diseases as they attain maturity and ripening.

Seasons affect yield of both tomato and sweet pepper. The months of April to August are the best time for growing tomato and sweet pepper vegetables at Lushoto and Ubiri. Moreover, tomato grow best at Lushoto site while sweet pepper grow best at Ubiri.

Pine and wild lemon grass mulch supress weed types, number and dry weight effectively in both tomato and sweet pepper. The time of mulch application between 3 and 21 days both in pine and wild lemon grass does not have an affect on weed contol. Pine and wild lemon grass mulch controlls weeds in the same manner as the when normal weeding is done.

Presence or absence of pine and wild lemon grass mulch as used in this study does not have a significant influence on either bacterial wilt and late blight disease incidences or on number of aphids and thrips insect pests.

Pine containing compost takes the longest time to ripen than wild lemon grass containing compost and the control. The of decomposition is slow, hence pine containing compost can be used well in crops that take long to mature or when it is applied on growing vegetables which take a short time a farmer can be sure that it will support growth throughout crop life. Wild lemon grass containing compost took longer to decompose than control, thus it can support support vegetable growth throughout as well. Laboratory analysis showed pine containing compost released high amounts of organic carbon, iron and manganese while wild lemon grass containing compost released high amounts of sodium.

Pine and wild lemon grass mulch also attracts high numbers of predatory Lycosidae, Carabidae and Formicidae. However, in this work that the population of beneficial arthropods is not influenced by the type of mulch used and the time of application.

8.2 Recommendations

i. It is recommended to use dry pine and wild lemon grass mulch to increase yield of both tomato and sweet pepper.

ii. It is also recommded to use dry pine and wild lemon grass mulch for weed control.

iii. It is further recommended that for dry pine and wild lemon grass mulch be complemented with hand pulling of weeds to achieve optimal control of troublesome weeds such as *Oxalis latifolia*, *Commelina benghalensis*, *Cynodon dactylon*, *Cyperus rotundus*, *Galinsoga parviflora* and *Bidens pilosa* as observed in this study.

iv. Farmers should use pine and wild lemon grass compost for nutrient increase in the soil.

v. Further studies on beneficial organisms is recommended in order to find out if the predators found in the mulch really feed on insect pests.