EFFECT OF SELECTED ORGANIC MULCHES ON SOIL PROPERTIES, GROWTH AND YIELD OF AMARANTHUS IN KILIFI COUNTY

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DECLARATION

Declaration by Student

I hereby declare that this is my original work and has not been presented in this or any other University for the award of a degree.

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Approval by Supervisors

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DEDICATION

This thesis is dedicated to Almighty God and to my wife Christine Mkambe and my two sons; Jason Ngala and Jayden Kai.

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ABSTRACT

Amaranthus is an indigenous vegetable which acts as a source of nutrition and income within Kilifi County. However, soil moisture stress due to unpredictable rains within the area is the major constraint to Agricultural production in the region. A study was carried out in Pwani University farm and Jaribuni secondary school farm to evaluate the effect of selected organic mulches on soil properties, growth and yield of amaranthus in Kilifi County. The experiment was laid out in randomized complete block design with three replications. The study was conducted from June 2nd 2018 to October 4th 2018. The selected organic mulches included; seaweed, neem leaves, cashew nut leaves, wood shavings and a control (no mulch). Data collected included; total nitrogen, exchangeable phosphorus, potassium, calcium and Magnesium, plant height, leaf length, leaf width, stem girth, number of branches, leaf number, chlorophyll content, leaf dry weight, soil temperature, soil moisture content and days to 50% flowering. Seaweeds increased soil pH in Jaribuni Secondary and Pwani University by 5.1% and 5.0%, respectively. Na content by 11% in both sites and Mn content by 113% in both sites. In Jaribuni Secondary and Pwani University, leaf number by 43% and 62% and chlorophyll content by 90% and 98% respectively. Seaweeds without amaranthus increased phosphorus in both sites by 90% and 100% in Jaribuni Secondary and Pwani University, respectively. Neem leaves and seaweeds mulches increased leaf area by 30% to 46%, stem girth by 32% to 40%, number of branches by 41% to 61%. Neem leaves mulch increased plant height by 70% to 76%, soil temp by 88% to 99%, fresh weight by 25% to 35% and dry matter by 8.4% to 8.5%. Neem leaves without amaranthus increased K by 23% and 25%, Mg content by 6% to 8% and Cu by 26 to 53%. Wood shavings with amaranthus increased Ca content by 23% and organic carbon by 8.3% and 10% in Jaribuni Secondary and Pwani University respectively. Cashew nut leaves lowered soil pH in both sites by 10.8% and 7.7%. Cashew nut leaves with amaranthus and seaweeds with amaranthus lowered the potassium in both sites by 40 % and 41%. Control without amaranthus had the highest Fe and Zn content. A clear indication that effects of mulches depends on the mulching material.

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ACRONYMS AND ABBREVIATION

ANOVA **-** Analysis of variance

FAO - Food and Agriculture Organization of United Nations.

GLM - General linear model

LSD - Least significant difference

OM - Organic Mulch

RCBD - Randomized Complete Block Design

SAS - Statistical analyses variance

UNEP - United Nation Environment Programme

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Agricultural productivity growth is vital for stimulating growth in other sectors of the economy (Chege, 2017). Currently, agricultural productivity growth in Sub-Saharan Africa lags behind that of other regions, it is well below that which is required to achieve food security and poverty eradication goals (Sasson, 2012). In the 21st century, agriculture continues to be a fundamental instrument for sustainable development, poverty reduction and enhanced food security in developing countries (Diao *et al*., 2010). It is also below that which is required to achieve food security and development goals. The Agricultural sector accounts for 65% of the export earnings, and provides employment, income and food security needs for more than 80% of the Kenyan population. It also contributes to improving nutrition through production of safe, diverse and nutrient dense foods (Chepkoech *et al*., 2018). The sector is also the main driver of the non-agricultural economy including manufacturing, providing inputs and markets for non-agricultural operations such as building and construction, transportation, tourism, education and other social services (Chege, 2017). In coastal Kenya, especially Kilifi County, amaranthus is one of the most produced vegetable for both commercial and consumption purposes, though this vegetable is grown by many farmers across the County, production remain relatively low (Chepkoech *et al*., 2018).

Kilifi County lies along the Kenyan coast. It is one among the five coastal Counties namely: Mombasa, Kwale, Kilifi, Tana-River and Lamu. The economic activities within the County are: farming, fishing, tourism, and mining among others. Crops commonly grown are; maize, cowpeas, cassava, coconut, cashew nut, mangoes, green grams and amaranthus. Soil degradation, erratic and low unreliable rainfall are the major constraints of crop production in Kilifi County. The County experiences high temperatures ranging from 23 °C to 30 °C (Ocholla *et al*., 2013). In most cases, the rains do not sustain the crop to maturity while in other cases; the rains are low, creating little moisture, which escape due to the hot temperatures experienced in the region. The ever rising population has contributed to sub-division of land to uneconomically small units. The reduction of fallow periods and continuous cultivation has led to depletion of soil nutrients, environmental degradation and declining yields. Pests and diseases are other major causes of reducing productivity in the coastal region (Ocholla *et al.,* 2013). The hot temperatures and high humidity creates an environment, which is favorable for multiplication of most pests and disease. Weeds are also another problem that affects crop production in the region. The weeds suppress growth of the vegetable and also reduce the quality of the produce (Rarieya & Fortune, 2010).

The high temperatures experienced in Kilifi means that there is high rates of evaporation and thus mulching is beneficial in reducing soil water loss. Additionally, studies have shown that uncontrolled weeds reduce yield by about 40% in maize, 31-70% in groundnuts, 75% in cayenne pepper and 84% in upland rice (Ghanizadeh *et al*., 2014). Apart from reducing the yield, weeds contaminate farm products reducing their market value. Controlling weeds require a lot of investment in labor, consequently increasing the cost of production. To increase vegetable production, many applications including mulching are applied in different environmental conditions. Mulching vegetables can increase productivity, promote early maturity, reduce evaporation from the soil surface, modify temperatures, prevent weed growth, protect soil structure, reduce insect infestation and reduce cost of production (Ekinci & Dursun, 2009). This study will evaluate the effect of four different types of organic mulches including; seaweed, wood shaving, neem leaves and cashew nut leaves on soil properties, growth and yield of amaranthus in Kilifi County.

1.2 Problem Statement

Kilifi County is located in the coconut-cassava agro-ecological zone, coastal low land zone 3 (CL3) which is characterized by low erratic rains and relatively high temperatures and humid environment. Most agricultural soils within the region range from plannosols, luvisols and arenosols to cambisols. Most soils are sand textured having been derived from varying sedimentary rocks of various properties such as consolidated sand, silt and clay limestone geology. Amaranthus is one among the vegetables that is widely grown and does well within the region. The full potential of this crop has however, never been achieved. Its production is mainly limited by low soil fertility, soil moisture and nutrient retention capacity and poor soil temperature regulation leading to poor organic matter decomposition, mineralization and biota population within the soils (Godfray *et al*., 2010). Amaranthus crop is a traditional indicator of soil fertility. It thrives well only in well aerated, fertile soils (Brady *et al*., 2008). Soil moisture acts as a solvent for all chemical reactions. These conditions are essential for dissolving and uptake of all nutrients by plants. Most farmers growing amaranth in the region depend on irrigation for their production activities. Irrigation efficiency within the area is also limited by prevailing high transpiration and evaporative rates. There is therefore need for improved soil moisture management methods for improved mineralization rate, biota activity and nutrient supply leading to improved amaranth production.

1.3 Justification of the Study

According to Jordan *et al*. (2010), mulches play an important role in sustainable vegetable production. Depending on the type and placement method, they can be used for soil moisture retention, soil nutrient retention, soil biota regulation, weed management, soil degradation management as well as provision of plant nutrients. Mulch also protects soil from environmental factors such as sun, wind, rain and human agricultural practices, which causes compaction, nutrient loss and erosion. It also helps in reducing the effects of evaporation and regulates soil temperature around the root region for optimal crop growth, thereby enhancing the quality and yield (Boxem *et al*., 1988). Mulch limits weed growth, since weeds require light to germinate and grow, mulch cuts off light from penetrating into the soil and as a result weed growth is hindered (Anzalone *et al*., 2010). In the long run, organic mulches increases soil fertility and soil structure. As organic mulches decompose, the nutrient stored within the mulch is released for the use of the plants and micro-organisms. The organic mulch encourages earthworms that are essential in improving soil structure and nutrient cycling. Additionally, some types of organic mulch such as ceder bark have natural oils that act as soil repellants (Montenegro *et al*., 2013). The fact that Kilifi is a water scarce region, with soils that are sandy leading to poor moisture and nutrient retention capacity, poor temperature regulation and poor soil biota population. Mulching can be the best practice which can aid in the improvement of water and nutrient uptake by plants leading to improved yields with use of optimal irrigation water. Different researchers have recommended various locally available organic mulching materials (Li & Liu, 2003). These materials include: neem leaves, seaweed, cashew nut leaves and wood shavings. The efficiency of some of these mulching materials has been tested in various parts of the world and the country under different cropping systems. Limited research has however been documented within the Kenyan coast which have varied soil and environmental properties. There is therefore need to evaluate the effects of this mulching materials on soil properties and on growth and yield of amaranth crop within Coastal cambisols.

1.4 Objectives of the Study

1.4.1 Broad Objective

To enhance soil properties, growth and yield of amaranthus using selected organic mulches in Kilifi County.

1.4.2 Specific Objectives

i. To determine the effect of selected organic mulches on soil properties during production of amaranthus in Kilifi County.

ii. To determine the effect of selected organic mulches on growth of amaranthus in Kilifi County

iii. To determine the effect of selected organic mulches on yield of amaranthus in Kilifi County.

1.4.3 Null hypotheses of the Study

i. There is no effect of selected organic mulches on soil properties during production of amaranthus in Kilifi County.

ii. There is no effect of selected organic mulches on growth of amaranthus in Kilifi County

iii. There is no effect of selected organic mulches on yield of amaranthus in Kilifi County.

CHAPTER TWO

LITERATURE REVIEW

2.1 Amaranthus Crop

Amaranthus, collectively known as Amaranths or pigweed, is the domesticated species of the genus *Amaranthus* (family *Amaranthaceae*). It is one of the oldest food crops in the world (Hoidal *et al*., 2019). It originated from America, where it is common in the Caribbean region and from southern Mexico to northern South America, India and Nepal. There are approximately 60 species of Amaranthus widespread throughout the humid lowland tropics that occurs in the wild as weed (Kyambo, 2014). The cultivated type may have been developed from the weedy ancestor in tropical Asia and is found in several African countries, where it was introduced by immigrants (Tindall *et al.,* 1991). *Amaranthus dubius* is a protected weed used as a pot herb in many African countries, and it possibly occurs in all African lowland areas. It is cultivated in West Africa, Central Africa and East Africa especially Kenya and Uganda (Khan *et al.,* 2002). Amaranthus is a multipurpose crop whose leaves and grains are tasty and of high nutritional value. It can also be cultivated as an ornamental plant (Das, 2016). The genus *Amaranthus* has received considerable attention in many countries because of the high nutritional value of some species that are important sources of food, either as vegetable or grain (Jimoh *et al*., 2018).

The main use of *Amaranthus dubius* is as a cooked leaf vegetable. The product is dark green and tender but its taste is somewhat neutral. Most communities in Kenya harvest the leaves of *Amaranthus* for cooking or combined with other vegetable such as nightshades (*Solanum* spp) to make it more palatable (Kyambo, 2014). The leaves easily become soft after five to ten minutes cooking in lightly salted water. Amaranth leaves in general are recommended as a good food with medicinal properties for young children, lactating mothers and for patients with fever, haemorrhage, anaemia, constipation or kidney complaints. In Tanzania the whole plant is used as a medicine against stomach aches (Jimoh *et al*., 2018). Amaranthus species are ranked as major crops that are underexploited among tropical plants with promising economic returns (Jimoh *et al*., 2018).

In Kenyan rural areas, amaranth is known as a traditional vegetable which can grow in open fields. It exhibits the highest diversity of species exploited as traditional vegetables (Tittonel & Giller, 2013). Amaranthus is mostly grown for its edible leaves which are a regular food component of most local community diets in the country. The production of vegetable amaranth has increased over the last few years in response to the growing urban vegetable demand (Islam *et al.*, 2011). Vegetable amaranth is found in many supermarkets and green grocers stores in the urban centers of Kenya. More than 90% of the supply of the vegetables to these outlets is normally from farms that are within the environs of the urban center (Njeru, 2018). Changing consumer demand especially in urban settlement added interest in nutritious vegetables such as amaranthus (Alemayehu *et al*., 2014). Kilifi County experiences extreme climatic conditions of hot day temperatures, amaranthus are a drought tolerant crop which meets food needs of individuals (Alemayehu *et al*., 2014).

2.2 Types of organic Mulches

Mulching material is any covering material including either organic or inorganic applied on the soil surface to reduce evaporation losses. This material may be grown and maintained in place, or any material grown and modified before placement or any material processed or manufactured and transported before placement (Irshad *et al*., 2016). Covering the ground with mulch saves water by preventing surface evaporation (Snyder *et al*., 2015). The layer can also greatly reduce or eliminate weed propagation, which will also result in higher water use efficiency. Wheat straw, grass clippings and leaf debris are fairly abundant byproducts. Many farmers generate these mulching materials and currently spend resources to dispose of them.

Mulching using these selected mulch types is a cost effective practice which would conserve water, moderate soil temperature, reduce waste and improve the soil health (Snyder *et al*., 2015). There are two types of mulches namely; organic mulches and inorganic mulches. Organic mulch material includes grass, straw, dry leaves, bark, saw dust and compost. These have capacity to ease degradation as it attract insects, slugs and cutworms that eat them and it help to degrade rapidly and it add some amount of organic matter and nutrient in soil (Irshad *et al*., 2016).

Inorganic mulch materials include gravel, pebbles and crushed stones: These materials are used successful for dry land fruit crops. Small rock or stone layer of 3 to 4 cm place on soil surface to provide good weed control, reduced evaporation and facilitate infiltration of rain water into the soil (Zribi *et al*., 2015). But they reflect solar radiation and can create a very hot soil environment during summer.

Limitations of organic mulching include; keeping the soil too moist, restricting oxygen in the root zone on poorly drained soils. When mulch is applied close to or in contact with the stem, it traps moisture creating an environment conducive to development of diseases and pests. Certain types of mulches such as hay and straw contain seeds that may become weeds (Zribi *et al*., 2015).

Mulching is done differently depending on what kinds of plants are in the bed and what is to be accomplished with the mulch. Therefore, vegetable garden mulching will differ from mulching around perennials and an entirely different strategy can be used to actually build soil with mulch materials. Mulch can be spread over an entire garden bed, or place it in concentrated rings around plants that require a boost of nutrients or some extra protection (Irshad *et al*., 2016).

2.3 Importance of organic mulch on Crop Production

Since the late 1930s, mulching has been used for environmental modification of forests, agriculture lands, and urban landscapes (Chalker-Scott, 2007). They play an important role in the modification of soil physical, chemical and biological properties (Magdoff, 1996). The resultant healthy soils are able to support good crop growth leading to improved yields. Mulch protects the soil from environmental factors such as wind, sun, rain and human agricultural practices, which causes compaction, nutrient loss and erosion. A thick layer of mulch is essential in suppressing weeds and maintaining favorable soil temperatures (Kosterna, 2014). Recent studies have shown increased soil organic carbon mineralization under plastic mulch being offset by higher root biomass production, providing a neutral effect on soil health while enhancing crop production. Mulch slows down rain drops and protects the soil from the impact of the rain drop, while allowing moisture through to reach the soil and the plant roots (Yamanaka *et al*., 2004). Excessive tillage activities in conventional agriculture and gardening leave the top soil vulnerable to being blown away by wind.

Mulch plays an essential role in protecting the underlying soil, while at the same time releasing nutrients and humic-acids that help to repair damages done from too much tillage. Additionally, mulch reduces the effect of evaporation and buffers soil temperatures, thereby keeping the soil moist for optimal plant growth. Uneven moisture stresses the plant, reducing the yield and quality. The mulch also keeps the soil temperature lower. Roots that suffer with high temperatures reduce the plant’s ability to grow optimally (Khan *et al*., 2002).

2.4 Effects of Organic Mulch on Soil Physical Properties

Using mulch on top soil improves soil moisture conditions. Mulches benefit the crop by improving soil physical conditions such as improved structural stability in the top soil. Several types of mulch can lead to increased soil moisture content as a result of reduced evaporation from the soil surface compared to un-mulched soil. According to (Alharbi, 2017) mulch reduces the surface area available for evaporation, reducing the amount of water lost from the plant root region. The mulch shades the root region reducing evaporation from the soil surface which significantly affects crop water use efficiency. Surface evaporation accounts for 25 to 50% of total evapo-transpiration (Li & Liu, 2003). Mulching with crop by-products such as wheat straw increases water retention and prevents soil evaporation (Jordan *et al*., 2010). This also ensures even moisture distribution throughout the soil profile, which further improves water use. Organic mulches also improve water use efficiency indirectly. As the mulch decomposes, humus is added to the soil, which increases its water holding capacity (Awodoyin *et al*., 2010). On the other hand, the effect of mulching on soil temperatures depends on the type of the mulch. Heat storage in the mulch layer is small, but the available energy at a mulch site will be affected by the heat storage in the mulch layer (Alharbi, 2017). Several researchers have found that the mulch influenced on soil temperature (Arnold *et al*., 2005). Furthermore, mulch has an effect on soil bulk density. However, the impact of mulching on soil bulk density depends on the soil properties, type of mulch and climate. Some studies have explained that mulch reduces soil bulk density and others found that mulch has no effect on soil bulk density (Kar & Kumar, 2007). At the same time, a majority of the studies have found that mulch increases soil bulk density A mulch layer can reduce soil erosion by minimizing the impact of raindrops and water runoff (Yamanaka *et al*., 2004).

2.5 Effects of Organic Mulch on Soil Chemical Properties

Addition of organic mulch above the soil surface influences soil chemical properties and have an effect on the movement of some nutrients. For instance, studies by (Kar & Kumar, 2007), reported that application of mulch as low as 2.25 Mg/ha from crop residue reduces the loss of nitrates, nitrogen, potassium, magnesium and calcium. Besides, there are relationships between crops residue amount and soil organic matter in the soil surface. Studies by Jordan *et al*. (2010) showed that mulch increased the available potassium, phosphorous, and organic carbon, which have enhanced effect on crop growth and yield production. Organic mulches add organic matter and plant nutrients to soil upon decomposition. Thus they improve carbon sequestration. The volatilization and leaching loss of nitrogen is reduced under mulched conditions. During decomposition of organic mulches, soil mineral nitrogen is immobilized by microbes and thus its loss is minimized (Jordan *et al*., 2010). Cation-exchange capacity is substantially influenced by organic matter content in soils containing predominantly low-activity clays. Improvement in the cation-exchange capacity of soil improves the fertility status of these soils (Mohanty *et al*., 2015). Furthermore, decomposition of organic mulches adds organic acids to the soil resulting in low soil pH, which influences the bioavailability of many plant nutrients such as Fe, Mn, Zn, and Cu. Mulches also influence the availability of nutrients through their influence on physical conditions, hydrothermal regime and biological activity of the soil (Mohanty *et al*., 2015).

2.6 Effects of Organic Mulch on Soil Biological Properties

According to Pilipavicius (2015) mulch is also useful in weed control. Since many weeds require light to germinate mulch cuts off light from penetrating to the soil underneath, thereby limiting the weeds' ability to grow. Weeds also have a difficult time penetrating thick layers of mulch and those that are generally weak and easy to eliminate as they are loosely rooted. A mulch layer prevents weed seedling growth by inhibiting light penetration to the soil surface (Pilipavicius, 2015). Lower weed prevalence significantly improves water use efficiency. While it slowly decomposes, the nutrients stored within the mulch are released for the use of plants and micro-organisms. This slow release nutrient helps sustain plants in adverse conditions. The increased organic matter that is added to the soil helps improve soil structure. Mulch helps decrease the risk of disease and increase the quality of harvest. Foliage or fruits that touch the soil can become infested with diseases. The severity of certain diseases can also be reduced by mulching. For instance, applying mulch to the understory of wine grapes resulted in a 97% reduction in infestation by *Botrytis cinerea* compared to a bare ground treatment (Adekiya *et al*., 2019). This reduction in disease was significantly correlated with increased soil biological activity and elevated rates of vine debris decomposition. At the same time, organic mulch encourages earthworms to occupy the soil. Earthworms help improve soil structure and nutrient cycling.

2.7 Effects of Organic Mulch on Crop Growth and Yield

Mulching also has an effect on the quality of the produce. A study by Teame *et al*. (2017.), found out that oleic acid, which is one of the major characteristics of sesame oil increased significantly when mulch was applied. Different types of organic mulches have been found to increase crop growth and yield in groundnuts, sesame, soybean, sweet pepper and sunflower.

Plastic mulches offer many of the same benefits as organic mulches. In high value vegetable crop production, plastic mulches have shown to improve yields for many decades (Tittonel & Giller, 2013). The mulch covers the soil protecting the foliage or fruit from rot and the product is usually cleaner when harvested. Using certain types of mulches, such as cedar bark can be instrumental in deterring pests due to the fact that they have natural oils that act as soil repellants.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Site

The study was carried out in two different locations within Kilifi County from June 2nd 2018 to October 4th 2018. The first site was Pwani University farm, which is located at latitudes 3^{o}S and 4^{o}S and longitudes 39^{o}E and 40^{o}E while the second one was in Jaribuni Secondary latitudes 3^{o}S and 4^{o}S and longitudes 41^{o}E and 42^{o}E in Kauma location, Ganze Sub-county. The sites were chosen because they are areas where amaranthus are commonly grown. Both sites experience low, erratic and unevenly distributed annual rainfall ranging from 500-1000 mm, 23-30 °C temperature range and a mean relative humidity of 80% (Achiando *et al*., 2010). The soils in Pwani University farm are ferralic and dystric cambisols while soils in Jaribuni Secondary are dystric nitisols (Boxem *et al*., 1988).

3.2 Experimental Design

The experiment was laid down in a randomized complete block design with three replications. The treatments used were locally available mulching materials that included five treatments with amaranthus and five without amaranthus for purposes of analyzing soil fertility. The treatments were neem leaves mulch, seaweed mulch, cashew nut leaves mulch, wood shavings mulch and control with no mulch. The amaranthus was planted at a spacing of 30 cm × 15 cm in plots of 2m × 3m making a total of 133 plants per plot, which was equivalent to 222,222 plants per hectare. Each block had 10 plots with a spacing of 0.5m between the plots making a block size of 6.5 m by 12 m. The distance between one block to the other was 1m, giving a total experimental area of 258m^2 (21.5 m by 12 m)

3.3 Crop Management

Land was prepared by ploughing using a tractor then harrowing. Amaranthus seeds were initially sown in nursery bed. The seedlings were transplanted after 3 weeks at a spacing of 30 by 15 cm. At transplanting organic mulch was applied at the rate of 9 t/ha and a thickness of 5cm that provided adequate soil insulation (Diaz *et al*., 2005). Drip irrigation was carried out to supplement the rainfall thrice per week in the evening hours, as recommended by Chepkoech *et al*. (2018). Weeds were uprooted fortnightly. Thunder broad spectrum pesticide (Agrovet, Kilifi) was used to manage pests.

3.4 Data Collection

Soil chemical characteristics were determined at the beginning of the season before land preparation and after crop harvest in National Agricultural Research Labaratory - Kabete. At the beginning of the season, soil samples were taken randomly from twenty points using a soil auger at 30 cm soil depth in both sites. The samples were thoroughly mixed and a 1.0 kg composite sample for each planting site packed and taken to the laboratory for analysis. At the end of the experimental period, after harvesting, soil samples were randomly taken using soil auger from each experimental plot at 30 cm. The samples per plot were thoroughly mixed to form one composite sample for each plot. A composite sample of 1kg per plot was packed leading to 10 samples per site and 20 composite samples for both experimental sites. The composite samples were taken to the laboratory for chemical analysis. The soils were analyzed for total nitrogen , exchangeable phosphorus , potassium , calcium and Magnesium, following the procedures described by Okalebo *et al*. (2002).

Five plants were tagged in the middle four (4) rows in each plot and used for collection of all agronomic data. Plant height was evaluated by measuring the height of the tagged plants from the ground level to the end of terminal bud using meter rule. Leaf area of the whole sampled plants was determined by measuring the individual leaf length and width. Stem girth of the tagged plants was measured using electronic digital vernier caliper. Number of branches was determined by counting the number of branches per plant while number of leaves was determined by counting the number of leaves per plant. All the data was collected on weekly basis. Chlorophyll content was determined on weekly basis on the tagged plants by use of SPAD meter. Economic yield was evaluated by determining the dry weight of amaranthus. Soil moisture content was measured using gravimetric method while soil temperature was measured using infrared thermometer sensor on weekly basis. Days to 50% flowering was determined by counting the number of plants which had flowered.

3.5 Data Analysis

All data obtained were subjected to analysis of variance using general linear model (GLM) of SAS computer package. Means were separated using the least significant difference at 5% level of significance.

CHAPTER FOUR

RESULTS

4.1 Pre-Planting Soil Chemical Properties in Jaribuni Secondary and Pwani University

Initial soil analysis indicated that soil pH was slightly acidic with Pwani University being 5.2% higher than Jaribuni Secondary (Table 1). Total N soil N content was the same in both sites. P (40.0%), K (27.3%) and Mg (10.0%) content was higher in Jaribuni Secondary than Pwani university site, while Ca content was slightly higher by 33.3% in Pwani University than Jaribuni Secondary.

Table 1: Pre-plant soil results of Jaribuni Secondary and Pwani University study sites

		Mineral elements (g/kg)				
Study sites	Soil pH	N (%)	P (mg kg^{-1})	K (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})
Jaribuni Secondary	5.02	0.004	0.025	0.022	0.06	0.050
Pwani University	5.28	0.004	0.015	0.016	0.08	0.045

4.2 Effect of Organic Mulch on Soil Chemical and Physical Properties in Jaribuni Secondary and Pwani University.

4.2.1 Soil pH

Organic mulch had significant effects on soil pH. In Jaribuni Secondary, most of the soil treatments reduced the soil pH except seaweeds with and without amaranthus. The highest soil pH was in sea weeds with amaranthus with pH of 7.02 which was 5.1% higher than the control without amaranthus. While the pH, for seaweeds without amaranthus was 6.70 which was 0.3% higher than the control without amaranthus. The lowest soil pH was cashew nut leaves with amaranthus with 5.96 which was 10.8%

lower than the control without amaranthus. The second lowest was Neem leaves with amaranthus which had a pH of 6.17 which was 7.6% lower than the control without amaranthus.

In Pwani University all the treatments lowered the pH except seaweeds with and without amaranthus. The highest soil pH was on sea weeds with amaranthus with a pH of 5.85 which was 5.0% higher than the control without amaranthus. This was followed by seaweeds without amarathus with a pH of 5.58 which was 0.2% higher than the control without amaranthus. The lowest pH was in cashew nut leaves with amaranthus with a pH of 4.97 which was 7.7% lower than the control without amaranthus.

4.2.2 Total Nitrogen (N)

There was significant effect of treatments (wood shavings, neem leaves, cashew nut leaves and sea weeds) on Soil total N content due to organic mulching (Table 2). Most treatments increased soil total N in both sites. In Jaribuni Secondary, the highest total N was observed from wood shavings with amaranthus, neem leaves with amaranthus, neem leaves without amaranthus, cashew nut leaves with amaranthus with all having a soil total N of 0.5g/kg. This was 25% higher than the control without amaranthus. Wood shavings without amaranthus, cashew nut leaves without amaranthus, and seaweeds without amaranthus were not significantly different from the control without amaranthus. The lowest was seaweeds with amaranthus with a soil total N 0.03g/kg which is 25% lower than the control without amaranthus.

In Pwani University, the highest total N was observed from wood shavings with amaranthus, neem leaves with amaranthus, neem leaves without amaranthus, cashew nut leaves with amaranthus and sea weeds without amaranthus, with total N content of 0.04g/kg which was 33.3% higher than control without amaranthus. However, wood shavings without amaranthus, cashew nut leaves without amaranthus, sea weeds with amaranthus, control with amaranthus had no significant difference.

4.2.3 Total Organic Carbon

The use of organic mulching had significant effect on total organic carbon content (Table 2). In Jaribuni Secondary, the highest organic carbon content was observed on wood shavings with amaranthus Soil total organic carbon content of 0.26g/kg which was 8.33% higher when compared with control without amaranthus. Neem leaves with amaranthus, cashew nut leaves with amaranthus, sea weeds without amaranthus had no significant difference when compared with control without amaranthus, neem leaves without amaranthus with 0.23g/kg total organic carbon which was 4.17 % lower, and the lowest organic carbon content was observed from sea weeds with amaranthus of 0.21g/kg which was 12.5% lower when compared with control without amaranthus. Similarly, in Pwani University, the highest organic carbon content was also observed in wood shavings with amaranthus with 0.22g/kg total organic carbon content which was 10% when compared with control without amaranthus, followed by control with amaranthus and then neem leaves with amaranthus, cashew nut leaves with amaranthus, and sea weeds without

Table 2: Effect of organic mulch on soil pH and macro-elements (g/kg) during amaranth production in Jaribuni Secondary and Pwani University

Mulching	pH		N		OC		P		K		Ca		Mg	
	Jaribuni	Pwani	Jaribuni	Pwani	Jaribuni	Pwani	Jaribuni	Pwani	Jaribuni	Pwani	Jaribuni	Pwani	Jaribuni	Pwani
Wood shavings with amaranthus	6.22f	5.18f	0.05a	0.04a	0.26a	0.22a	7.50g	6.5g	0.18e	0.15e	1.60a	1.33a	0.45d	0.52d
Wood shavings without amaranthus	6.21g	5.18f	0.04b	0.03b	0.22e	0.18e	17.50c	15.2c	0.19d	0.16d	1.10d	0.92d	0.45d	0.52d
Neem leaves with amaranthus	6.17i	5.14h	0.05a	0.04a	0.24c	0.20c	12.50e	10.9e	0.21b	0.18b	0.90f	0.75f	0.43e	0.50e
Neem leaves without amaranthus	6.20h	5.17g	0.05a	0.04a	0.23d	0.19d	12.50e	10.9e	0.25a	0.21a	1.10d	0.92d	0.53a	0.61a
Cashewnut leaves with amaranthus	5.96j	4.97i	0.05a	0.04a	0.24c	0.20c	10.00f	8.7f	0.12g	0.10g	0.90f	0.75f	0.41g	0.47g
Cashewnut leaves without amaranthus	6.47e	5.39e	0.04b	0.03b	0.22e	0.18e	15.00d	13.0d	0.21b	0.18b	1.40b	1.17b	0.46c	0.53c
Sea weeds with amaranthus	7.02a	5.85a	0.03c	0.03b	0.21f	0.18e	15.00d	13.0d	0.12g	0.10g	1.10d	0.92d	0.42f	0.49f
Sea weeds without amaranthus	6.70b	5.58b	0.04b	0.04a	0.24c	0.20c	25.00a	21.7a	0.18e	0.15e	1.00e	0.83e	0.39h	0.45h
Control with amaranthus	6.49d	5.41d	0.05a	0.03b	0.25b	0.21b	22.50b	19.6b	0.16f	0.13f	1.10d	0.92d	0.53a	0.61a
Control without amaranthus	6.68c	5.57c	0.04b	0.03b	0.24c	0.20c	12.50e	10.9e	0.20c	0.17c	1.30c	1.08c	0.49b	0.57b

Means followed by the same letter within a column were not significantly different according to LSD test (5%).

amaranthus which were not significantly different and the lowest was from wood shavings without amaranthus, cashew nut leaves without amaranthus, and sea weeds with amaranthus all were 10% lower than the control without amaranthus.

4.2.4 Phosphorus (P)

Organic mulch had significant effects on soil P content (Table 2). Organic mulch increased soil P content except for wood shavings with amaranthus and cashew leaves with amaranthus. In Jaribuni Secondary, the highest P content was observed on sea weeds without amaranthus with soil P content of 25.00g/kg which was 100% higher compared with control without amaranthus. Control with amaranthus, wood shavings without amaranthus, cashew nut leaves without amaranthus, sea weeds with amaranthus showed significant difference compared with control without amaranthus. Neem leaves with amaranthus; neem leaves without amaranthus had no significant difference compared with control without amaranthus. Cashew nut leaves with amaranthus had soil P content of 10.00g/kg which was 20% lower than control without amaranthus, the least was wood shavings with amaranthus with Soil P content of 7.50g/kg which was 40% lower compared to control without amaranthus. In Pwani University, the highest P content was observed on sea weeds without amaranthus with soil P content of 21.7g/kg was 99.08% higher compared with control without amaranthus. Control with amaranthus, wood shavings without amaranthus, cashew nut leaves without amaranthus, sea weeds with amaranthus showed significant difference compared with control without amaranthus. Neem leaves with amaranthus; neem leaves without amaranthus had no significant difference compared with control without amaranthus. Cashew nut leaves with amaranthus had soil P content of 8.7g/kg which was 20.18% lower than control without amaranthus, the least was wood shavings with amaranthus with soil P content of 6.5g/kg was 40.37% lower compared to control without amaranthus.

4.2.5 Potassium (K)

Organic mulch significantly affected soil K content (Table 2). In Jaribuni Secondary, the highest K content was observed from neem leaves without amaranthus with soil P content of 0.25g/kg was 25% higher compared with control without amaranthus, followed by neem leaves with amaranthus and cashew nut leaves without amaranthus with both having soil K content of 0.21g/kg was 5% higher when compared with control without amaranthus. Wood shavings without amaranthus, wood shavings with amaranthus, sea weeds without amaranthus, control with amaranthus showed lower significant difference compared with control without amaranthus. Cashew nut leaves with amaranthus and sea weeds with amaranthus both had the lowest K content of 0.12g/kg was 40% lower compared with control without amaranthus. In Pwani University, the highest K content was observed from neem leaves without amaranthus with soil K content of 0.21g/kg was 23.5% higher compared with control without amaranthus, followed by neem leaves with amaranthus and cashew nut leaves without amaranthus with both having soil K content of 0.18g/kg was 5.9% higher compared with control without amaranthus. Wood shavings without amaranthus, wood shavings with amaranthus, sea weeds without amaranthus and control with amaranthus showed higher significant difference compared with control without amaranthus, while the lowest K content was from cashew nut leaves with amaranthus and sea weeds with amaranthus with soil K content of 0.10g/kg was 41.18% lower compared with control without amaranthus.

4.2.6 Calcium (Ca)

Soil Ca content was significantly affected by organic mulch (Table 2). Organic mulch reduced soil Ca content except for wood shavings with amaranthus and cashew nut leaves without amaranthus. In Jaribuni Secondary, the highest Ca content was observed from wood shavings with amaranthus with soil Ca content of 1.60g/kg was 23.08% higher compared with control without amaranthus. Cashew nut leaves without amaranthus with soil Ca content of 1.40g/kg was 7.69% higher compared with control without amaranthus. Neem leaves with amaranthus and cashew nut leaves with amaranthus both had the lowest Ca content of 0.90g/kg was 30.77% lower compared with control without amaranthus. In Pwani University, the highest Ca content was observed from wood shavings with amaranthus with soil Ca content of 1.33g/kg was 23.15% higher compared with control without amaranthus, cashew nut leaves without amaranthus with soil Ca content of 1.17g/kg was 8.33% higher compared with control without amaranthus. Neem leaves with amaranthus and cashew nut leaves with amaranthus both had the lowest Ca content of 0.75g/kg was 30.55% lower compared with control without amaranthus.

4.2.7 Magnesium (Mg)

Soil Mg content was influenced by use of organic mulch (Table 2). Organic mulch reduced soil Mg content except for neem leaves without amaranthus and control with amaranthus. In Jaribuni Secondary, the highest Mg content was observed from neem leaves without amaranthus and control with amaranthus, both having soil Mg content of 0.53g/kg was 8.2% higher compared with control without amaranthus, cashew nut leaves without amaranthus, wood shavings with amaranthus, wood shavings without amaranthus, neem leaves with amaranthus, sea weeds with amaranthus showed significant difference compared with control without amaranthus, while cashew nut leaves with amaranthus had the lowest Mg content of 0.39g/kg was 20.41% lower compared with control without amaranthus. In Pwani University, the highest Mg content was observed from neem leaves without amaranthus and control with amaranthus, both having soil Mg content of 0.61g/kg was 6.6% higher compared with control without amaranthus. Cashew nut leaves without amaranthus, wood shavings with amaranthus, wood shavings without amaranthus, neem leaves with amaranthus, sea weeds with amaranthus showed higher significant difference compared with control without amaranthus, cashew nut leaves with amaranthus had the lowest Mg content of 0.45g/kg was 21.05% lower compared with control without amaranthus.

4.2.8 Copper (Cu)

Soil Cu content was affected by use of organic mulch (Table 3). Organic mulch increased soil Cu content in the soil except for sea weeds without amaranthus. In Jaribuni Secondary, the highest Cu content was observed from neem leaves without amaranthus with soil Cu content of 0.23µg/kg was 53.33% higher compared with control without amaranthus. Cashew nut leaves without amaranthus had no significant difference compared with control without amaranthus, while the lowest Cu content was from sea weeds without amaranthus with soil Cu content of 0.14µg/kg was 6.67% lower compared with control without amaranthus. In Pwani University, the highest Cu content was observed in neem leaves without amaranthus with soil Cu content of 0.19µg/kg was 26.67% higher compared with control without amaranthus. Neem leaves with amaranthus, wood shavings with amaranthus, sea weeds with amaranthus, cashew nut leaves with amaranthus, control with amaranthus were higher compared with control without amaranthus, cashew nut leaves without amaranthus had no significant difference compared with control without amaranthus, while the lowest Cu content was from sea weeds without amaranthus with soil Cu content of 0.12µg/kg was 20% lower compared with control without amaranthus.

4.2.9 Iron (Fe)

Soil Fe content was significantly affected by the use of organic mulch (Table 3) below. Organic mulch reduced soil Fe content in the soil. In Jaribuni Secondary, the highest Fe content was from control without amaranthus with 12.61µg/kg soil Fe content which was 0% change compared to control without amaranthus, sea weeds with amaranthus was the least with soil Fe content of 12.28µg/kg was 2.62% lower compared with control without amaranthus.. In Pwani University, the highest Fe content was from control without amaranthus with soil Fe content of 10.51µg/kg was 0% change compared with control without amaranthus, lowest Fe content was from sea weeds with amaranthus with soil Fe content of 10.23µg/kg was 2.66% lower compared with control without amaranthus.

4.2.10 Zinc (Zn)

Soil Zn content was affected by use of organic mulch (Table 3). In Jaribuni Secondary, the highest Zn content was obtained from control with amaranthus with soil Zn of 14.10µg/kg was 56.67% higher compared with control without amaranthus, wood shavings with amaranthus, neem leaves without amaranthus, wood shavings without amaranthus were significantly higher compared with control without amaranthus. Sea weeds without amaranthus ,neem leaves with amaranthus , cashew nut leaves without amaranthus were lower compared with control without amaranthus, while the lowest Zn was obtained from cashew nut leaves with amaranthus with soil Zn of 8.00µg/kg was 11.11% lower compared with control without amaranthus.

In Pwani University, the highest Zn content was obtained from control with amaranthus with soil Zn of 11.75µg/kg was 47.22% higher compared with control without amaranthus. Wood shavings with amaranthus, neem leaves without amaranthus, cashew nut leaves without amaranthus, wood shavings without amaranthus, sea weeds without amaranthus, neem leaves with amaranthus, cashew nut leaves with amaranthus showed significant difference compared with control without amaranthus. While the lowest Zn was obtained from cashew nut leaves with amaranthus with soil Zn of 6.67µg/kg was 11.07% lower compared with control without amaranthus.

4.2.11 Sodium (Na)

Soil Na content was affected by organic mulch (Table 3). Organic mulch reduced soil Na content except for sea weeds without amaranthus. In Jaribuni Secondary, the highest Na content was obtained from sea weeds without amaranthus with soil Na content of 1.70µg/kg was 11.11% higher compared with control without amaranthus, cashew nut leaves without amaranthus, neem leaves without amaranthus, wood shavings without amaranthus, cashew nut leaves with amaranthus, sea weeds with amaranthus, control with amaranthus. Neem leaves with amaranthus showed significant difference compared with control without amaranthus. While the lowest Na content was from wood shavings with amaranthus with soil Na of 0.30µg/kg was 80.39% lower compared with control without amaranthus. In Pwani University, the highest Na content was obtained from sea weeds without amaranthus with soil Na content of 1.42µg/kg was 10.94% higher compared with control without amaranthus, cashew nut leaves without amaranthus, neem leaves without amaranthus, wood shavings without amaranthus. Cashew nut leaves with amaranthus , sea weeds with amaranthus, control with amaranthus, neem leaves with amaranthus showed significant difference compared with control without amaranthus, while the lowest Na content was from wood shavings with amaranthus with Soil Na of 0.25µg/kg was 80.47% lower compared with control without amaranthus.

4.2.12 Manganese (Mn)

Organic mulch had significant effect on Soil Mn (Table 3). Organic mulch increased soil Mn except for wood shavings with amaranthus and wood shavings without amaranthus. In Jaribuni Secondary, the highest Mn content was from sea weeds without amaranthus with soil Mn of 0.61µg/kg which was 112.9% higher compared with control without amaranthus. Cashew nut leaves without amaranthus, sea weeds with amaranthus, cashew nut leaves with amaranthus, control with amaranthus, neem leaves with amaranthus, neem leaves without amaranthus had significant difference compared with control without amaranthus. Wood shavings with amaranthus with 0.29µg/kg soil Mn content was 6.45% lower, wood shavings without amaranthus had the lowest Mn content of 0.24µg/kg which was 22.58% lower compared with control without amaranthus. In Pwani University, the

Table 3: Effect of organic mulch on soil micro-elements (μg/kg) under amaranth production in Jaribuni Secondary and Pwani University

Mulching	Cu		Fe		Zn		Na		Mn	
	Jaribuni	Pwani	Jaribuni	Pwani	Jaribuni	Pwani	Jaribuni	Pwani	Jaribuni	Pwani
Wood shavings with amaranthus	0.20c	0.17c	12.48e	10.40e	11.75b	9.79b	0.30i	0.25i	0.29g	0.24g
Wood shavings without amaranthus	0.12i	0.10i	12.54d	10.45d	9.05e	7.54e	1.36d	1.13d	0.24h	0.20h
Neem leaves with amaranthus	0.21b	0.18b	12.39g	10.33g	8.65h	7.21h	0.32h	0.27h	0.35d	0.29d
Neem leaves without amaranthus	0.23a	0.19a	12.56b	10.47b	10.05c	8.38c	1.36d	1.13d	0.34e	0.28e
Cashewnut leaves with amaranthus	0.18e	0.15e	12.45f	10.38f	8.00j	6.67j	0.55e	0.46e	0.38c	0.32c
Cashewnut leaves without amaranthus	0.15g	0.13g	12.55c	10.46c	8.50i	7.08i	1.40c	1.17c	0.40b	0.33b
Sea weeds with amaranthus	0.19d	0.16d	12.28h	10.23h	9.25d	7.71d	0.40f	0.33f	0.40b	0.33b
Sea weeds without amaranthus	0.14h	0.12h	12.51e	10.43e	8.85g	7.38g	1.70a	1.42a	0.66a	0.55a
Control with amaranthus	0.17f	0.14f	12.45f	10.38f	14.10a	11.75a	0.37g	0.31g	0.38c	0.32c
Control without amaranthus	0.15g	0.13g	12.61a	10.51a	9.00f	7.50f	1.53b	1.28b	0.31f	0.26f

Means followed by the same letter within a column were not significantly different according to LSD test (5%).

highest Mn content was from sea weeds without amaranthus with soil Mn content of 0.55µg/kg which was 111.54% higher compared with control without amaranthus. Cashew nut leaves without amaranthus, sea weeds with amaranthus, cashew nut leaves with amaranthus, control with amaranthus, neem leaves with amaranthus, neem leaves without amaranthus had significant difference compared with control without amaranthus. Wood shavings with amaranthus with soil Mn content of 0.24µg/kg was 7.69% lower, wood shavings without amaranthus had the lowest Mn content of 0.2µg/kg was 23.08% lower compared with control without amaranthus.

4.2.13 Soil Temperature

Soil temperature was significantly affected by organic mulch (Figure 1). In Jaribuni Secondary, neem leaves treatments had the highest soil temperature increase by 88.1%, followed by wood shavings (66.2%), sea weeds (57.3%) and cashew nut leaves (49.9%) which were not different from one another, when compared with the control but was not different from sea weeds. In Pwani University, neem leaves treatments had the highest soil temperature with a 98.9% increase, followed by wood shavings (69.2%), sea weeds (62.8%) and cashew nut leaves (58.4%) which were not significantly different from one another. Soil temperature in the control treatment was not different from sea weeds.

4.2.14 Soil Moisture

Soil moisture was significantly affected by organic mulch (Figure 2). In Jaribuni Secondary, control treatments had the highest soil moisture of 27.7%. This was followed by neem leaves and cashew nut leaves which were not different from each other with 24.9%

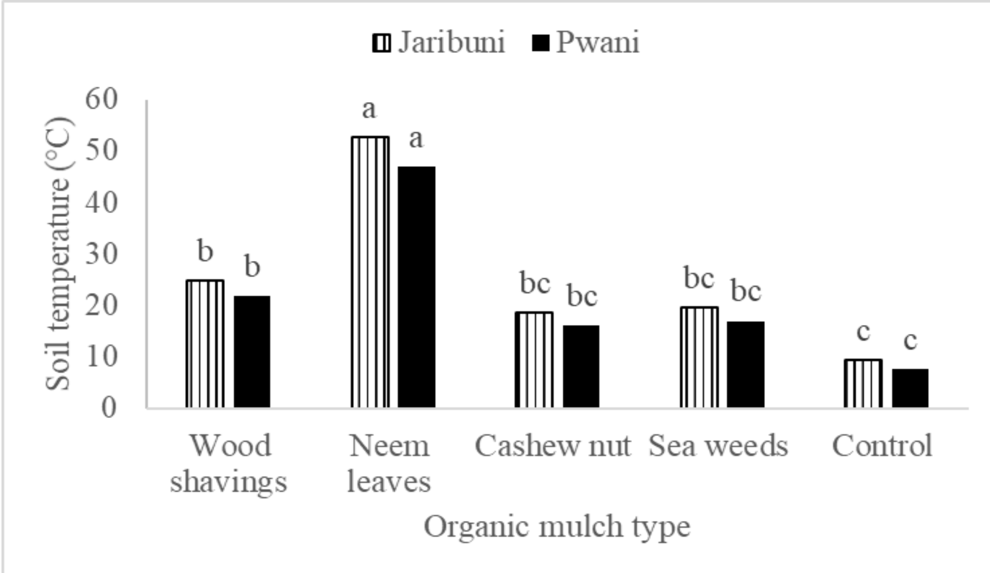

Figure 1: Effect of organic mulch on soil temperature during amaranthus production in Jaribuni Secondary and Pwani University. Means followed by the same letter within a site are not significantly different according to LSD test (5%).

and 24.7%, respectively. Wood shavings and sea weeds had the lowest soil moisture with 23.7% and 23.9%, respectively, which was not different from cashew nut leaves. In Pwani University, control treatments had the highest soil moisture with 20.6%. This was followed by neem leaves and cashew nut leaves which were not different from one another with 18.4% and 18.2%, respectively. Wood shavings and sea weeds had the lowest soil moisture with a mean of 17.6% and 17.5%, respectively, which was not different from cashew nut leaves.

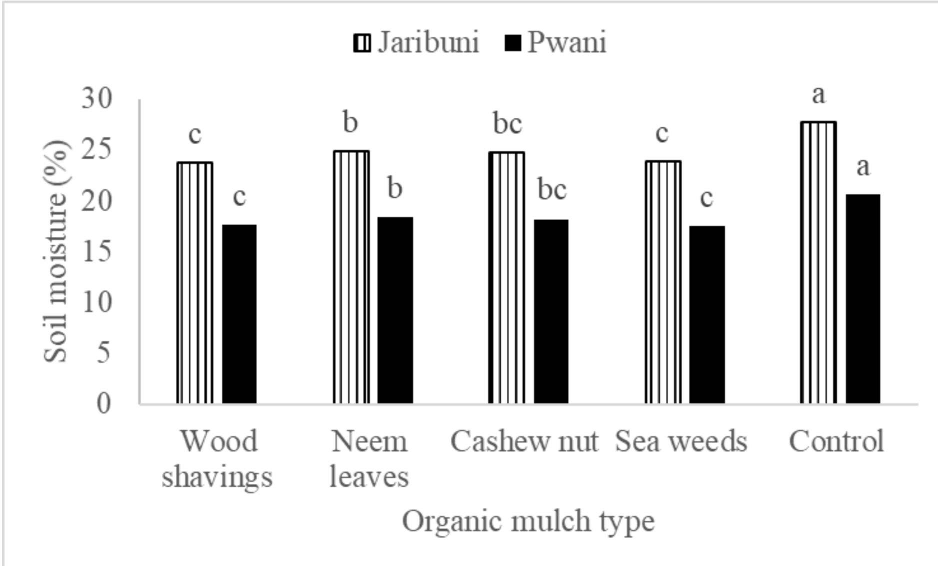

Figure 2: Effect of organic mulch on soil moisture during amaranthus production in Jaribuni Secondary and Pwani University. Means followed by the same letter within a site are not significantly different according to LSD test (5%).

4.3 Effect of Organic Mulch on Growth of Amaranthus in Jaribuni Secondary and Pwani University

4.3.1 Plant Height

Plant height of amaranthus was significantly affected by organic mulch (Table 4). In Jaribuni Secondary, neem leaves treatment had the tallest plant height with 69.7% when compared with the control. Sea weeds had a 43.5% increase in plant height compared to control but not significantly different from neem leaves. Cashew nut leaves treatment had a 31.3% increase in plant height but was not significantly different from sea weeds. Control treatment had the shortest height. In Pwani University, neem leaves treatment had the tallest plant height with 76.0% while sea weeds with 47.6% were not significantly different from neem leaves, compared with the control. Cashew nut leaves treatment which had a 34.2% increase in plant height compared to control, was not significantly different from sea weeds. Control treatment had the shortest amaranthus plant height.

4.3.2 Leaf Area

Leaf area of amaranthus was significantly affected by organic mulch (Table 4). In Jaribuni Secondary, neem leaves and sea weeds treatments had the highest leaf area with a 31.6% and 30.4% increase, respectively, compared with control. Cashew nut leaves and wood shavings had a leaf area of 8.9% increase when compared with the control. In Pwani University, neem leaves and sea weeds treatments had the highest leaf area with 45.7% and 43.5% increase, respectively, compared with the control. Cashew nut leaves and wood shavings had both 13% increase in leaf area compared with the control respectively.

4.3.3 Stem Girth

Stem girth of amaranthus was significantly affected by organic mulch (Table 4). In Jaribuni Secondary, neem leaves and sea weeds treatments had the largest stem girth with a mean of 35.1% and 31.6%, respectively. Cashew nut leaves, and wood shavings had the lowest stem girth with a mean of 8.8%, and 3.6% respectively, which was not different from the control treatment. In Pwani University, neem leaves and sea weeds treatments had the largest stem girth with an increase of 39.5% and 34.9%, respectively, compared with the control. Cashew nut leaves and wood shavings had the lowest stem girth with 9.3% and 4.6%, respectively, but showed no significant difference compared to control.

4.3.4 Branch Number

Branch number of amaranthus was significantly affected by organic mulch (Table 4). In Jaribuni Secondary, neem leaves and sea weeds treatments had the highest number of branches with an increase of 59.1% and 40.9%, respectively, compared with the control. Cashew nut leaves, wood shavings and the control treatments had the lowest number of branches. In Pwani University, neem leaves and sea weeds treatments had the highest number of branches with an increase of 68.8% and 43.8% respectively, compared with the control. Cashew nut leaves, wood shavings and the control treatments had the lowest number of branches.

4.3.5 Leaf Number

Leaf number of amaranthus was significantly affected by organic mulch (Table 4). In Jaribuni Secondary, sea weeds treatment had the highest number of leaves with an increase of 61.9%, while neem leaves with an increase of 42.9% were not significantly different from seaweeds, compared with the control. Cashew nut leaves treatment which had an increase of 23.8% was not significantly different from sea weeds, when compared with the control which had the lowest leaf number. In Pwani University, sea weeds treatment had the highest number of leaves with a 68.8%, while neem leaves with a 46.9% were not significantly different from seaweeds, compared with the control. Cashew nut leaves treatment which had a 28.1% was not significantly different from sea weeds which had 15.6% increase in leaf number when compared with the control.

4.3.6 Chlorophyll Content

Leaf chlorophyll content of amaranthus was significantly affected by organic mulch (Table 4). In Jaribuni Secondary, wood shavings treatments had the highest leaf chlorophyll content with a 90% increase when compared with the control treatment. This was followed by neem leaves, cashew nut leaves and sea weeds which were not different from one another with an increase of 54.1%, 35.3% and 32.4% respectively, when compared with the control treatment which was not different from sea weeds treatment. In Pwani University, wood shavings treatments had the highest leaf chlorophyll content with an increase of 98.6% compared with the control. This was followed by neem leaves, cashew nut leaves and seaweeds which were not different from one another with a 55.4%, 36.0% and 33.1% respectively, when compared with the control treatment which was not different from sea weeds treatment.

4.3.7 Days to 50 % Flowering

Flowering of amaranthus was significantly affected by organic mulch (Table 4). In Jaribuni Secondary, wood shaving had the highest number of days to 50% flowering with an increase of 155% when compared with the control. This was followed by sea weed, cashew nut leaves and neem leaves treatments with an increase of 122%, 105% and 98.8%, respectively, when compared with the control treatments which had the lowest days to 50% flowering. In Pwani University, wood shaving had the highest number of days to 50% flowering with an increase of 158% when compared with the control. This was followed by sea weed, cashew nut leaves and neem leaves treatments with an increase of 125%, 107.6%

Table 4: Effect of organic mulch type on growth of amaranthus in Jaribuni Secondary and Pwani University

	Plant height (cm)		Leaf area (cm^2)		Stem girth (mm)		Branch number (no./plant)		Leaf number (no./plant)		Chlorophyll content (CCI)		Days to 50% flowering	
	Jaribuni	Pwani	Jaribuni	Pwani	Jaribuni	Pwani	Jaribuni	Pwani	Jaribuni	Pwani	Jaribuni	Pwani	Jaribuni	Pwani
Wood shavings	38.4bc	30.0bc	8.6b	5.2b	5.9b	4.5b	2.5b	1.8b	4.8bc	3.7bc	35.2a	29.1a	28.9a	23.8a
Neem leaves	49.9a	39.6a	10.3a	6.6a	7.5a	5.8a	3.1a	2.3a	6.0ab	4.7ab	26.2b	21.6b	21.9b	18.0b
Cashew nut leaves	38.6bc	30.2bc	8.6b	5.2b	6.2b	4.7b	2.5b	1.8b	5.2bc	4.1bc	23.0b	18.9b	23.2b	19.1b
Sea weeds	42.2ab	33.2ab	10.4a	6.7a	7.7a	6.0a	3.5a	2.7a	6.8a	5.4a	22.5bc	18.5bc	25.1b	20.7b
Control	29.4c	22.5c	7.9b	4.6b	5.7b	4.3b	2.2b	1.6b	4.2c	3.2c	17.0c	13.9c	11.3c	9.2c
Mean	39.7	31.1	9.1	5.6	6.6	5.1	2.8	2.1	5.4	4.2	24.8	20.4	22.1	18.2
P value	0.0045	0.0032	0.0005	0.0004	0.0001	0.0001	<0.0001	<0.0001	0.0085	0.0003	<0.0001	<0.0001	<0.0001	<0.0001
$LSD_{0.05}$	9.5728	6.2456	1.1631	0.2458	0.8601	0.3	0.4242	0.1	1.4395	0.9	5.754	4.5	3.5731	2.7
CV (%)	20.1	14.7	10.6	8.4	10.9	8.7	12.8	10.4	22.3	18.3	19.4	15.9	13.5	11.0

Means followed by the same letter within a column were not significantly different according to LSD test (5%).

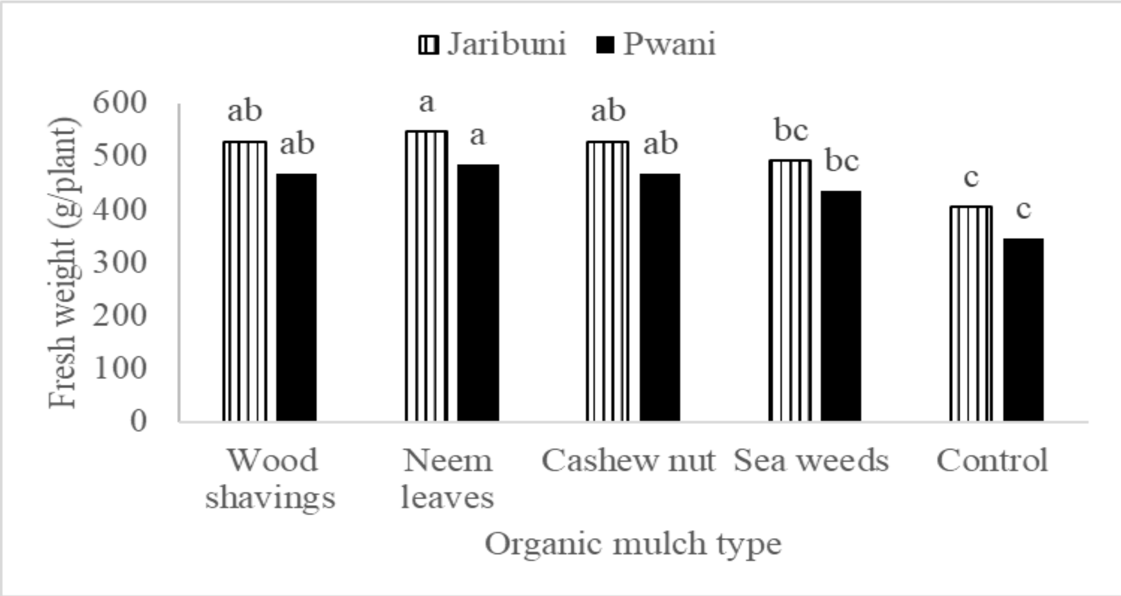

Figure 3: Effect of organic mulch on fresh weight during amaranthus production in Jaribuni Secondary and Pwani University. Means followed by the same letter within a site are not significantly different according to LSD test (5%).

and 96.7% respectively when compared with the control treatments which had the lowest days to 50% flowering.

4.4 Effect of Organic Mulch on Yield of Amaranthus in Jaribuni Secondary and Pwani University

4.4.1 Fresh weight

Fresh weight of amaranthus was affected by organic mulch (Figure 3). In Jaribuni Secondary, neem leaves with amaranthus had the highest fresh weight with a 35.2% increase, but not different from wood shavings with amaranthus (30.7%) and cashew nut leaves with amaranthus (30.7%) compared with the control with amaranthus. The lowest fresh weight content was obtained from control with amaranthus, which had no difference from sea weeds with amaranthus. In Pwani University, neem leaves with amaranthus was the highest with an increase of 25.5%, but not different from wood shavings with amaranthus (21.3%) and cashew nut leaves with amaranthus (21.4%). The lowest fresh weight content was obtained from control with amaranthus, which had no difference from sea weeds with amaranthus.

4.4.2 Dry Matter

Dry matter content of amaranthus was affected by organic mulch (Figure 4). In Jaribuni Secondary, neem leaves with amaranthus had the highest increase in dry matter by 8.4%, but not different from wood shavings with amaranthus (4.9%) and cashew nut leaves with amaranthus (4.9%) when compared with the control. Sea weeds with

amaranthus had the lowest dry matter content with a 2.4% reduction but had no difference with control treatment. In Pwani University, neem leaves with amaranthus was the highest dry matter with 8.6%, but not different from wood shavings with amaranthus and cashew nut leaves with amaranthus, when compared with the control. The lowest dry matter content was obtained from sea weeds with amaranthus with a 2.5% reduction, which had no difference from control with amaranthus.

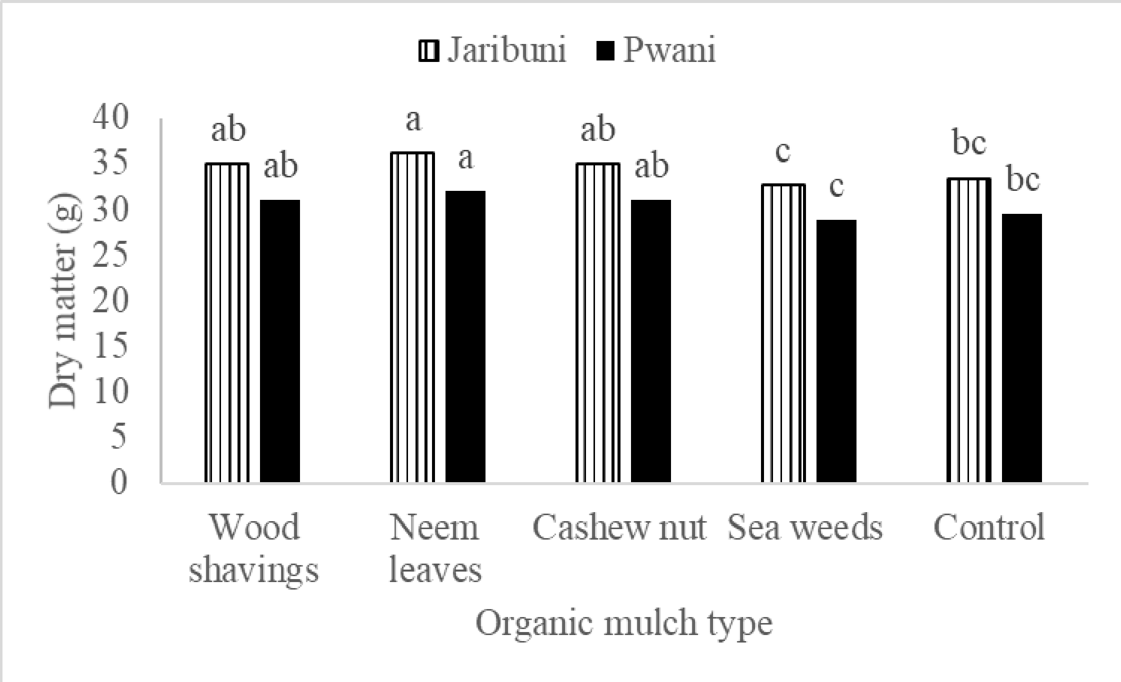

Figure 4: Effect of organic mulch on dry matter content during amaranthus production in Jaribuni Secondary and Pwani University. Means followed by the same letter within a site are not significantly different according to LSD test (5%).

CHAPTER FIVE

DISCUSSION

5.1 Effect of Organic Mulch on Soil Chemical and Physical Properties in Jaribuni Secondary and Pwani University

5.1.1 Soil pH

Most of the soil treatments (neem, cashew nut and wood shaving) reduced the soil pH except seaweeds with and without amaranthus in both sites. The highest soil pH was in seaweeds with amaranthus for both sites with Jaribuni Secondary and Pwani University having soil pH of 7.02 and 5.85 which was 5.1% and 5.0% higher than the control without amaranthus, respectively. These findings were in agreement with those of (Lopez-Mosquera & Pazos, 1997) who indicated that seaweed application to soil had effects similar to those of liming i.e. increased pH. Billeaud & Zajicek (1989), reported that mulching with four types of organic mulches such as screened pine bark, hardwood, cypress, and decorative pine bark nuggets significantly increased soil pH in a soil composed of fine sandy loam soil. (Iles & Dosmann, 1999) found that mulching with inorganic rocks such as river rock and lava rock and organic materials such as wood chips and shredded bark mulches remarkably increased soil pH in fine sandy loam soil. The elevated pH values possibly resulted from the soil pH buffering property as a result of the decomposing soil organic matter (Tisdale *et al*., 1993). The lowest soil pH in Jaribuni Secondary and Pwani University was in cashew nut leaves with amaranthus with 5.96 and 4.97 which was 10.8% and 7.7% lower than the control without amaranthus respectively. These findings were in agreement with Duryea *et al*. (1999) who found that pine bark mulches decrease soil pH. From this study effect of mulches on soil pH depended on the mulching material as well as soil composition and type.

5.1.2 Total Nitrogen

Most treatment increased soil total N in both sites. The highest total N in Jaribuni Secondary and Pwani University was observed from wood shavings with amaranthus, neem leaves with amaranthus, neem leaves without amaranthus, cashew nut leaves with amaranthus with all having a soil total N of 0.5g/kg and 0.4g/kg which was 25% and 33.3% higher than the control without amaranthus. Wood shaving without amaranthus, cashew nut leaves without amaranthus, and seaweeds without amaranthus were not significantly different from the control without amaranthus respectively. Organic mulches such as cashew nut leaves have been reported to decompose faster availing higher N to plants compared with other wood chips (Chalker-Scott, 2007). The lowest was seaweeds with amaranthus with a soil total N 0.03g/kg which is 25% lower than the control without amaranthus. Similar results were reported by Prakash *et al*. (2018) who observed that seaweeds had lower N content as a result of excessive leaching. According to Smith *et al*. (2010) mulching was highly beneficial in dry tropical areas; however, mulch materials varied with respect to improving soil physical characteristics and fertility (Jordan *et al*., 2010). This study showed that biological mulches contributed mineral N after decomposition.

5.1.3 Total Organic Carbon

The highest organic carbon content in Jaribuni Secondary and Pwani University was observed on wood shavings with amaranthus with a soil total organic carbon content of 0.26g/kg and 0.22g/kg which was 8.33% and 10% higher than the control without amaranthus respectively. Neem leaves with amaranthus, cashew nut leaves with amaranthus, seaweeds without amaranthus had no significant difference with control without amaranthus. Wood chips were reported to contain higher organic matter and easier for microorganisms to decompose compared with leafy mulches (Magdoff, 1996). The lowest organic carbon content was observed from seaweeds with amaranthus of 0.21g/kg which was 12.5% lower when compared with control without amaranthus. Seaweeds are reported to contain fewer nutrients and are difficult for microorganisms to decompose compared with grass mulch (Magdoff, 1996). Soil organic matter is derived from the decay of dead organisms and consists of organic (carbon-based) compounds (Brady & Weil, 2008). It positively contributes to tree and environmental health through its effects on soil physical, chemical, and biological properties (Magdoff, 1996). Previous studies have shown that organic materials increase soil organic matter by directly improving soil properties (Scharenbroch & Lloyd, 2006), increasing photosynthesis, and by having an impact on below ground C allocation (Scharenbroch *et al*., 2009).

5.1.4 Phosphorus

Organic mulch increased soil P content except for wood shavings with amaranthus and cashew nut leaves with amaranthus. In Jaribuni Secondary and Pwani University, the highest P content was observed on sea weeds without amaranthus with soil P content which was 99 to 100% higher compared with control without amaranthus. Control with amaranthus, wood shavings without amaranthus, cashew nut leaves without amaranthus, sea weeds with amaranthus showed significant difference compared with control without amaranthus. Neem leaves with amaranthus, neem leaves without amaranthus had no significant difference compared with control without amaranthus. (Possinger & Amador, 2016) observed higher content of P when seaweed was applied on maize. Cashew nut leaves with amaranthus had soil P content which was 20% lower than control without amaranthus; the least was wood shavings with amaranthus with soil P content of 7.50g/kg which was 40% lower compared to control without amaranthus. (Magdoff,1996) reported low soil P when cashew nut leaves was applied as a liquid fertilizer to beet root plants.

5.1.5 Potassium

In Jaribuni Secondary and Pwani University, the highest K content was observed from neem leaves without amaranthus with soil P content of 23% to 25% higher compared with control without amaranthus. Cashew nut leaves with amaranthus and sea weeds with amaranthus both had the lowest K content of 40% to 41% lower compared with control without amaranthus. Adekiya *et al*. (2019) observed that soil K was higher when neem leaves organic manure was applied in okra compared with cashew nut leaves. The high content of soil K in neem leaves could be attributed to its high nutrient profile particularly K which is released during decomposition (Chalker-Scott, 2007).

5.1.6 Calcium

Organic mulch reduced soil Ca content except for wood shavings with amaranthus and cashew but leaves without amaranthus. In Jaribuni Secondary and Pwani University, the highest Ca content was observed from wood shavings with amaranthus with soil Ca content of 23% higher compared with control without amaranthus. Wood chips were reported to contain higher Ca content compared with grass mulch (Tran, 2005). Neem leaves with amaranthus and cashew nut leaves with amaranthus both had the lowest Ca content of 31% lower compared with control without amaranthus. Neem leaves and cashew nut leaves are reported to have lower Ca content compared with wood shavings (Magdoff, 1996) probably contributing to low soil Ca content upon decomposition.

5.1.7 Magnesium

Most organic mulches reduced soil Mg content except for neem leaves without amaranthus and control with amaranthus. In Jaribuni Secondary and Pwani University, the highest Mg content was observed from neem leaves without amaranthus and control with amaranthus, both having soil Mg content of 6% to 8% higher compared with control without amaranthus.

Shayaa & Hussein (2019) observed higher soil Mg content when neem extract was applied on potatoes. The increase in soil Mg content was attributed to high Mg concentration on neem leaves which was released upon decomposition. (Aikpokpodion *et al*., 2009) observed that Mg content was significantly lower in cashew nut leaves contributing to its low soil Mg content.

5.1.8 Copper

Soil Cu content was affected by use of organic mulch. Most organic mulches increased soil Cu content in the soil except for sea weeds without amaranthus. In Jaribuni Secondary and Pwani University, the highest Cu content was observed from neem leaves without amaranthus with soil Cu content of 26 to 53% higher compared with control without amaranthus. These results were in agreement with Shayaa & Hussein (2019) who observed higher soil Cu content when neem extract was applied on potatoes. The lowest Cu content was from sea weeds without amaranthus with soil Cu content of 7 to 20% lower compared with control without amaranthus. The results were consistent with the findings of Prakash *et al*. (2018) who observed that seaweeds had lower Cu content as a result of low heavy metal content (Smith *et al*., 2010; Tindall *et al*., 1991).

5.1.9 Iron

Soil Fe content was significantly affected by the use of organic mulch. Most organic mulches reduced Soil Fe content in the soil. In Jaribuni Secondary and Pwani University, the highest Fe content was from control without amaranthus which was 2 to 12% higher compared to neem leaves without amaranthus. Similar results were observed by Shayaa & Hussein (2019) during production of potatoes. Sea weeds with amaranthus was the least with soil Fe content of 3% lower compared with control without amaranthus. Smith *et al*. (2010) observed that seaweeds had lower Fe content. This was attributed to low heavy metal content in sea weeds contributing to low soil Fe content after decomposition.

5.1.10 Zinc

Soil Zn content was affected by use of organic mulch. In Jaribuni Secondary and Pwani University, the highest Zn content was obtained from control with amaranthus with soil Zn of 47% to 57% higher compared with control without amaranthus. Results are in agreement with the findings of Shayaa & Hussein (2019) who observed that Zn content was significantly improved when forest soil was used to grow potatoes. The lowest Zn was obtained from cashew nut leaves with amaranthus with soil Zn 11% lower compared with control without amaranthus. Aikpokpodion *et al*. (2009) observed that Mg content was significantly lower in cashew nut leaves contributing to its low soil Zn content.

5.1.11 Sodium

The results are consistent with the findings of Prakash *et al*. (2018) who observed that seaweeds have higher content of soil Na attributed to its saline growing conditions. The lowest Na content was from wood shavings with amaranthus with soil Na of 80% lower compared with control without amaranthus. Wood chips were reported to result in lower soil Na content compared with leafy mulches (Magdoff, 1996). This could be attributed to lower Na content in wood shavings.

5.1.12 Manganese

Most organic mulch increased soil Mn except for wood shavings with amaranthus and wood shavings without amaranthus. In Jaribuni Secondary and Pwani University, the highest Mn content was from sea weeds without amaranthus with soil Mn of 113% higher compared with control without amaranthus. The results are in agreement with the findings of Prakash *et al*.

(2018) who observed that seaweeds have higher content of soil Mn attributed to high Mn content in seaweeds. Wood shavings without amaranthus had lowest Mn content of 23% lower compared with control without amaranthus. Wood sawdust were reported to result in lower soil Mn content compared with leafy mulches (Magdoff, 1996) attributed to lower Mn content in wood shavings.

5.1.13 Soil Temperature

In Jaribuni Secondary and Pwani University, neem leaves treatments had the highest soil temperature increase by 88 to 99% compared with the control which was the lowest. Similar results were observed by Kumar *et al.* (2014) who reported that mulches are known to increase the soil temperature since the sun's energy passes through the mulch and heats the air and soil beneath the mulch directly and then the heat is trapped by the 'greenhouse effect' (Kumar *et al.,* 2014). If topsoil temperature is excessive, mulching can reduce temperature for more optimal germination and root development. Mulch reduces water evaporation from soil and helps to maintain stable soil temperature (Kumar *et al.*, 2014). During organic mulch decomposition, heat is emitted contributing increase in soil temperature as observed in the study. Since organic mulches decompose under appropriate water and temperature levels, nutrients are released to the soil and become available for root uptake or microbial use (Chalker-Scott, 2007; Islam *et al.,* 2011).

5.1.14 Soil Moisture

In Jaribuni Secondary and Pwani University, control treatments had the highest soil moisture of 21 to 28% compared with wood shavings and sea weeds had the lowest soil moisture. These results are consistent with previous studies that suggested mulching with wood chips , and grass sequestered water and prevented water loss from the soil through evaporation (Sinkeviciene *et al*., 2009; Hartman *et al*., 2000; Ni *et al*., 2016). Organic mulches conserve water more effectively than inorganic ones (Kumar, *et al.*, 2014; Njeru, 2018). However, some studies show that living mulches might compete with plants for water and hence, mulched soils can show lower moisture content than bare soils, as observed in the study (Ni *et al*., 2016). These results may be influenced by the low precipitation at the study site.

5.2 Effect of Organic Mulch on Growth of Amaranthus in Jaribuni Secondary and Pwani University

5.2.1 Plant Height

In Jaribuni Secondary and Pwani University, neem leaves treatment had the tallest plant height with 70% to 76% when compared with the control which was the shortest plants. (Iles & Dosmann, 1999) found that tree height of red maple trees (*Acer rubrum* L.) were improved when mulching with neem leaves. This was attributed to the improved soil physical and chemical properties.

5.2.2 Leaf Area

In Jaribuni Secondary and Pwani University, neem leaves and sea weeds treatments had the highest leaf area 30% to 46% higher when compared with the control. (Holloway, 1992) also found that five herbaceous plant species grew better after sea weed mulch and neem leaf treatments than after other mulch treatments. The increase in leaf area could be attributed to the interaction between the increased soil water content and soil temperature.

5.2.3 Stem Girth

In Jaribuni Secondary and Pwani University, neem leaves and sea weeds treatments had the largest stem girth with a mean of 32 to 40% compared with the control which was the lowest. Ferrini *et al*. (2008) also found that mulching with neem leaves and seaweeds significantly improved trunk diameter of ornamental trees. This was attributed to the increase in physiological activities due to improved soil physico-chemical properties.

5.2.4 Branch Number

In Jaribuni Secondary and Pwani University, neem leaves and sea weeds treatments had the highest number of branches with an increase of 41% to 69% when compared with the control which had the fewest number of branches. Iles & Dosmann (1999) found that numbers of branches of red maple trees were improved remarkably when neem leaves and seaweed mulches attributed to enhanced soil temperature, moisture, and pH.

5.2.5 Leaf Number

Leaf number of amaranthus was significantly affected by organic mulches. In Jaribuni Secondary and Pwani University, sea weeds treatment had the highest number of leaves with an increase of 43% to 62% when compared with the control which had the fewest leaf number. Holloway (1992) also found that five woody plant species had more leaves following use of neem leaves and seaweeds as organic mulch, attributed to the high nutrient composition in the organic material which is released during decomposition.

5.2.6 Chlorophyll Content

In Jaribuni Secondary and Pwani University, seaweeds treatments had the highest leaf chlorophyll content with a 90% to 98% increase when compared with the control treatment which had the lowest chlorophyll content. Similar results were observed by Iles & Dosmann (1999) who found chlorophyll content of red maple trees were improved remarkably when seaweed was used as mulch. Jagadeesh *et al*. (2018) observed that green manures increased chlorophyll content of beet root leaves compared with farmyard and poultry manure. The increase in chlorophyll content may be attributed the high soil mineral content such as N, Mg, and Fe which plays significant role during chlorophyll synthesis upon decomposition of seaweeds.

5.2.7 Days to 50 % Flowering

In Jaribuni Secondary and Pwani University, wood shaving had the highest number of days to 50% flowering with an increase of 125% to 155% when compared with the control which had the fewest days to 50% flowering. Ferrini *et al*. (2008) also found that mulching with pine bark did not significantly affect the height or trunk diameter of ornamental trees. These results are in agreement with (Brady & Weil, 2008). Organic materials increase soil fertility directly improving vegetative growth of crops (Scharenbroch, 2006).

5.3 Effect of Organic Mulch on Yield of Amaranthus in Jaribuni Secondary and Pwani University

5.3.1 Fresh Weight

In Jaribuni Secondary and Pwani University, neem leaves with amaranthus had the highest fresh weight with a 25 to 35% increase compared with the control which had the lowest fresh weight. Ferrini *et al*. (2008) found that mulching neem leaves significantly improved fresh weight of ornamental trees. Previous studies have also shown that organic materials increase soil organic matter by directly improving soil properties (Scharenbroch, 2006), increasing photosynthesis, and by having an impact on above ground C allocation (Scharenbroch, 2009).

5.3.2 Dry Matter

Dry matter content of amaranthus was affected by organic mulches. In Jaribuni Secondary and Pwani University, neem leaves with amaranthus had the highest increase in dry matter by 8.4 to 8.6% when compared with the control which had the lowest dry matter. This finding was consistent with that of Khan *et al*. (2002), who suggested that neem mulch increased crop yield by improving soil physico-chemical properties

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Neem leaves mulches can be used to increase soil chemical and physical properties such as pH, soil temperature, potassium, magnesium and copper content. Growth characteristics such as plant height, leaf area, stem girth, number of branches, fresh weight and dry matter all of which contribute to growth and yield of amaranthus were enhanced by use of neem leaves mulches. Seaweeds mulches can also be used to increase soil chemical properties such as soil pH, sodium, manganese, phosphorus, leaf number, chlorophyll, leaf area, stem girth and number of branches which contribute to the growth of amaranths. Wood shavings mulches can be used to increase calcium content and organic carbon while cashew nut leaves mulches can be used to lower soil pH and potassium. A clear indication that effects of mulches depends on the mulching material. Control without amaranthus had the highest iron and zinc content this indicates that amaranthus uses iron and zinc in its growth.

6.2 Recommendation

Organic mulches such as neem leaves, seaweeds and wood shavings should be used to enhance growth and yield of amaranthus in the region. Similar work should be done to determine the effect of these organic mulches on cereals such as maize and sorghum; and legumes such as cowpeas and green grams in the region. There is need to study other organic mulches to increase the variety of organic mulches so that farmers can have variety of mulches to use depending on circumstances.

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APPENDICES

Appendix 1: Selected ANOVA Tables

1. Plant height

a. Jaribuni Secondary

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	696.2373333			
Block	2	68.8573333			
Mulching	4	553.9506667	138.4876667	15.09	0.0045
Error	8	73.4293333	9.1786667		

b. Pwani University

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	2628.124000			
Block	2	701.0920000			
Mulching	4	826.5906667	206.6476667	1.50	0.0032
Error	8	1100.441333	137.555167		

2. Leaf area

a. Jaribuni Secondary

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	17.99733333			
Block	2	2.83733333			
Mulching	4	7.09066667	1.77266667	1.76	0.0005
Error	8	8.06933333	1.00866667		

b. Pwani University

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	36.98400000			
Block	2	2.30400000			
Mulching	4	27.83066667	6.95766667	8.13	0.0004
Error	8	6.84933333	0.85616667		

3. Stem girth

a. Jaribuni Secondary

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	1.47337333			
Block	2	0.11457333			
Mulching	4	1.07870667	0.26967667	7.70	0.0001
Error	8	0.28009333	0.03501167		

b. Pwani University

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	7.73357333			
Block	2	0.25097333			
Mulching	4	6.29544000	1.57386000	10.61	0.0001
Error	8	1.18716000	0.14839500		

4. Branch number

a. Jaribuni Secondary

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	11.33333333			
Block	2	1.73333333			
Mulching	4	5.33333333	1.33333333	2.50	<0.0001
Error	8	4.26666667	0.53333333		

b. Pwani University

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	53.73333333			
Block	2	10.13333333			
Mulching	4	28.40000000	7.10000000	3.74	<0.0001
Error	8	15.20000000	1.90000000		

5. Leaf number

a. Jaribuni Secondary

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	335.3333333			
Block	2	78.5333333			
Mulching	4	200.0000000	50.0000000	7.04	0.0085
Error	8	56.8000000	7.1000000		

b. Pwani University

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	1448.400000			
Block	2	132.400000			
Mulching	4	1067.066667	266.766667	8.57	0.0003
Error	8	248.933333	31.116667		

6. Chlorophyll content

a. Jaribuni Secondary

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	87.96836000			
Block	2	30.75748000			
Mulching	4	24.54342667	6.13585667	1.50	<0.0001
Error	8	32.66745333	4.08343167		

b. Pwani University

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	50.89597333			
Block	2	1.72825333			
Mulching	4	30.82097333	7.70524333	3.36	<0.0001
Error	8	18.34674667	2.29334333		

7. Days to 50% flowering

a. Jaribuni Secondary

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	1234.400000			
Block	2	199.6000000			
Mulching	4	363.0666667	90.7666667	1.08	<0.0001
Error	8	671.733333	83.966667		

b. Pwani University

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	208.0000000			
Block	2	31.60000000			
Mulching	4	56.66666667	14.16666667	0.95	<0.0001
Error	8	119.7333333	14.9666667		

8. Dry matter

a. Jaribuni Secondary

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	1037.477133			
Block	2	36.3670533			
Mulching	4	783.7412000	195.9353000	7.21	0.0092
Error	8	217.368880	27.171110		

b. Pwani University

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	7699.176160			
Block	2	52.891480			
Mulching	4	7573.455427	1893.363857	207.98	<.0001
Error	8	72.829253	9.103657		

9. Soil temperature

a. Jaribuni Secondary

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	29.96769333			
Block	2	3.68921333			
Mulching	4	22.26682667	5.56670667	11.10	0.0024
Error	8	4.01165333	0.50145667		

b. Pwani University

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	54.04349333			
Block	2	1.82241333			
Mulching	4	44.14356000	11.03589000	10.93	0.0025
Error	8	8.07752000	1.00969000		

10. Soil moisture

a. Jaribuni Secondary

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	459.9713333			
Block	2	6.6664133			
Mulching	4	365.9155333	91.4788833	8.37	0.0058
Error	8	87.3893867	10.9236733		

b. Pwani University

Source	DF	SS	MS	Fvalue	Pvalue
Total	14	783.2887333			
Block	2	1.6860933			
Mulching	4	747.5196667	186.8799167	43.86	<.0001
Error	8	34.0829733	4.2603717		