KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

FACULTY OF RENEWABLE NATURAL RESOURCES

DEPARTMENT OF AGROFORESTRY

EFFECT OF *Moringa oleifera* AND *Leucaena leucocephala* BIOMASS ON THE GERMINATION AND EARLY GROWTH PERFORMANCE OF GUAVA (*Psidium guajava*)

NYAWUNU, Eli

MAY, 2015

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

FACULTY OF RENEWABLE NATURAL RESOURCES

DEPARTMENT OF AGROFORESTRY

EFFECT OF *Moringa oleifera* AND *Leucaena leucocephala* BIOMASS ON THE GERMINATION AND EARLY GROWTH PERFORMANCE OF GUAVA (*Psidium guajava*)

THIS THESIS SUBMITTED TO THE FACULTY OF RENEWABLE NATURAL RESOURCES KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF SCIENCE (BSc) DEGREE IN NATURAL RESOURCE MANAGEMENT

NYAWUNU, Eli

MAY, 2015

ABSTRACT

Tree crop farming in Ghana is constrained with low soil fertility, increasing cost and unavailability of inorganic fertilizers, and excessive soil erosion leading to low fruit production to meet the demands of fruit juice processing industries in Ghana. This study was conducted at the Faculty of Renewable Natural Resources (FRNR) Research Farm, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana to assess the effect of *M. oleifera* and *L. leucocephala* on the germination and early growth performance of guava. Using polypots, the study had four treatments in Completely Randomized Design (CRD) with four replicates. The treatments consisted of a control (no biomass), 4000 kg/ha equivalent of *M. oleifera*, 5000 kg/ha equivalent of *L. leucocephala*, and a mixture of 2000 kg/ha and 2500 kg/ha equivalent of *M. oleifera* and *L. leucocephala* respectively. Findings from the study revealed that, *M. oleifera* and *L. leucocephala* mixture recorded the highest germination, height, diameter, and number of leaves with mean values of 90 %, 6.80 cm, 1.43 mm and 13 respectively compared to the control. The control enhanced germination compared to sole *M. oleifera* and *L. leucocephala* treatments but performed poorly morphologically. The study concluded that, the combination of *M. oleifera* and *L. leucocephala* leaf biomass significantly stimulated germination, morphological growth of guava seedlings, and improved soil properties compared to sole *M. oleifera* and *L. leucocephala* leaf biomass treatments. The study recommends the combination of *M. oleifera* and *L. leucocephala* should be applied to soils to improve the early morphological growth in guava and possibly other tree crops. Further research should be carried out on varying combinations of the two leaf biomasses to determine the optimum quantity or combination for the best results.

ACKNOWLEDGEMENTS

I am very grateful to God for the good health and wellbeing that were necessary to complete this research. I wish to express my sincere gratitude to Dr. E.K. Dawoe, my project supervisor for the continuous encouragement, expertise, valuable guidance, and provision of all necessary facilities for the success of this research. I would like to express my profound appreciation to my parents Mr. Nyawunu Pierre and Mrs. Yiborku Mercy, my siblings Mawufemor, Peace, Mary and Faustina for the unceasing encouragement, support, and attention throughout my education. I would like to thank Mrs. Yiborku Beatrice, and Yiborku Albert, and the entire family for the encouragement, and support. Finally, to all who have lent their hand, directly and indirectly in this venture, I am very grateful.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

1.0 Introduction

1.1 Background of study

Guava is a large tropical evergreen shrub or small shade tree that grows up to 11 m tall; it is widely grown for its fruit in tropics. There are two most common varieties of guava: the red (*P. guajava. Pomifera*) and white (*P. guajava. Pyrifera*). Guava is preferred by fruit growers due to its wide adaptability, high productivity, high profitability, and higher returns per unit area with proper management (Orwa *et al*., 2009). Guava plant is considered as one of the most important tropical fruit trees in the world, enriching the diet of hundreds of millions of people with its special characteristic aroma, high medicinal and nutritive value (El-Bulk *et al*., 1997). However, the increasing cost, unavailability, and adverse side effects of inorganic fertilizers have resulted in low guava production (Davidson *et al*., 2012; Galloway *et al*., 2008). Currently, there are about two medium scale guava farms in Ghana (Agorsa, 2013). Considering the economy, energy, and environment, it is imperative that plant nutrients should be used effectively by adopting proper nutrient management system to ensure high yield, quality fruit production, and sustaining the available soil nutrient at the optimum level (Yadav, 1999). Study by Katiyar *et al*., (2012) have shown that, the use of organic materials as source of available nutrients to plants resulted in beneficial effects on growth, yield and quality of various fruit crops including guava. One of the factors required for optimum yield of crops is adequate nutrient in the soil and its proper management. According to Russel and Marsah (1997), organic materials are sustainable and relatively cheap materials of plant and animal origin that are incorporated into the soil before seeding to increase its productivity and crop yield. Green manure, compost and sewage sludge are some of the materials used as organic amendment. In view of this, it is imperative to include agroforestry tree species (*Moringa oleifera* and *Leuceana leucocephala*) noted for their soil nutrient improvement capabilities, nitrogen (N) and phosphorous (P) rich, cheap and sustainable source of plant nutrient into cropping systems to increase productivity, quality and profitability from low input cost. The continuous use of inorganic fertilizers as source of nutrient without the application of recommended proportion is also a problem, causing inefficiency, damage to the environment and in certain situations, harm the plants themselves and also human being who consume them (Shanker *et al.,* 2002).

1.2 Problem Statement and Justification

Tree crop farming is constrained by numerous pressing issues of which the low soil fertility, increasing cost and unavailability of inorganic fertilizers and excessive erosion (Phiri, 2010). This had led to production of guava to meet the ever increasing demands of fruit juice processing industries in Ghana causing them huge sums of money to air-lift millions of tons of fruits from the international market in order to stay in business (Abloh, 2013). Furthermore, the sole application of inorganic fertilizer is unsustainable and had led to ecosystem imbalance through loss of soil fertility from excessive erosion and leaching, surface and groundwater pollution from fertilizers and sediments, biodiversity loss, and low farm income from high production costs (Hooper *et al*. 2012). In view of this, there is an increasing awareness worldwide about alternative agricultural systems known as integrated plant nutrient management, which implies the maintenance or adjustment of soil fertility and plant nutrients supply for sustaining desired crop productivity through optimization of benefits from all possible sources of plant nutrients in an integrated manner (Ram *et al.,* 2007). There is the need to increase guava fruit production to meet the increasing demand of the fruit juice processing industries in Ghana with the integration of organic alternatives. Furthermore, the ecological and environmental concerns over the increase and indiscriminate use of inorganic fertilizers would be mitigated through integrated plant nutrient management as a more suitable means of meeting the Millennium Development Goals 1 and 7 thus, eradicating extreme poverty and hunger and ensuring environmental sustainability respectively. This had necessitated the search for organic alternatives to meet the nutrient requirement of tree crops especially for resource poor farmers. Moreover the research would provide information which would serve as a baseline for further research.

1.3 Aim and Objectives

1.3.1 Aim

The study aimed at assessing the effect of *Moringa oleifera and Leuceana leucocephala* biomass on the germination and early growth performance of Guava (P. *guajava*).

1.3.2 Objectives

The specific objectives of the study were:

i. To determine the comparative effect of *M. oleifera* and *L. leucocephala* biomass on the germination and early growth performance of *P. guajava*,

ii. To determine the effect of the combination of *M. oleifera* and *L. leucocephala* biomass on the germination and early growth of *P. guajava*, and

iii. To determine the effect of *M. oleifera* and *L. leucocephala* biomass on pH, organic carbon and total nitrogen content of the soil.

1.4 Hypothesis

The incorporation of *M. oleifera* and *L. leucocephala* mixed biomass has an effect on the germination and early morphological growth of guava.

CHAPTER TWO

2.0 Literature review

2.1 Origin and distribution of guava

Guava is native to and widely distributed in Southern Mexico and Central America and cultivated throughout the tropical and subtropical areas of Africa, South Asia, South East Asia, The Caribbean, North America, Australia, and New Zealand (Guava, 2014). In Asia, guava production is concentrated in Taiwan, China, the Philippines, Hawaii, Florida in United States, South Africa, Brazil, Dominica, and Cuba also have more production (T.G.P.M, 2011). Guava fruit is often referred to as the apple of the tropics probably as it is the only fruit that matches the high nutritive value of the more commercially important temperate fruit apple. From a horticulture perspective, it is one of the most common fruits grown commercially in India and is ranked next to mango, banana, and citrus fruits with respect to area and production (N.H.B., 2012). Matured-bearing trees can produce 40 kg of fruit every year. The recommended planting distance between plants is 4–6 m between rows. With this planting distance, one acre can be planted with 205 trees, with an estimated production of up to 7500 kg/year.

2.2 Botany/morphology of guava

Guava is a member of the Myrtaceae family, with about 133 genera and more than 3,800 species. Guava trees grow symmetrically dome-shaped with broad, spreading, low-branching canopy. The tree is shallow-rooted and of 3 to 11 m in height, branching close to the ground and of ten heavily suckering from the base of the trunk. The green to reddish-brown and smooth bark on older branches and trunk peels off in thin flakes. The four-angled young twigs of guava are easily distinguished. Guava leaves are opposite, short petiole, oval or oblong elliptic, somewhat irregular in outline, 2 - 6 inches long and 1 - 2 inches wide. The dull-green, stiff but leathery leaves have pronounced veins, and are slightly downy (fuzzy) on the underside. Crushed leaves are aromatic. Flowers are white and faintly fragrant, and are borne singly or in clusters in the leaf axils. They are 1 inch wide with 4 or 5 white petals. These petals are quickly shed, leaving a prominent tuft of perhaps 250 white stamens tipped with pale yellow anthers (T.G.P.M, 2011).

2.3 Environmental requirements

2.3.1 Climate

Guava can grow in both humid and dry tropical or subtropical climates. The guava requires an annual rainfall between 1000 - 2000 mm. The optimum temperature lies between 15 ^{o}C – 40 ^{o}C. However, best quality guava is obtained where low night temperature (10 ^{o}C) prevails during months and humidity of 70 to 90 %. It is recommended that, guava is cultivated below 800 m above sea. The plant requires adequate sunlight for photosynthesis and can tolerate high temperature and drought conditions and blown over by storm, but defoliation occurs during strong winds (Antunes and Sfakiotakis, 2000)

2.3.2 Soil

The guava seems indiscriminate as to soil, doing equally well on heavy clay, light sand, gravel, or on limestone; and tolerating a pH range from 4.5 to 9.4. It is somewhat salt-resistant. Good drainage is recommended but guavas are seen growing spontaneously on land with a high water table too wet for most other fruit trees (Hamilton and Seagrave-Smith, 1959). Good quality guavas are produced in river-basins. Maximum concentration of its feeding roots is available up to 25 cm soil depth. Guavas cannot tolerate frost. Good land preparation requires plowing and harrowing to facilitate good plant stand. High bed ding or mounds should be in place for the rainy season. Although guava may be tolerant to rather poor soil conditions, it responds well to good soils and climate, and surprisingly well to both organic and chemical fertilizers (Fielder *et al.,* 1936).

2.4 Agronomic practices

2.4.1 Seed propagation

According to Fuglie (1999), seeds require little or no pre-treatment prior to germination with viability rates for freshly extracted seeds reported to be up to 80 %, which reduces to about 50 percent after 12 months of storage. Considering the hard coat of the seeds, soaking of seeds in water for 12-24 hours or in hydrochloric acid for 3-5 minutes gives about 90 % germination. Seedlings can be raised in nursery or in polypots. Seed viability declines very quickly after extraction from fruits. The raising of the guava plants form seed is not desirable, since the seedling trees differ greatly from their mother plants. However for planting seedlings, seeds should be collected from the plants producing high quality fruits and high yield. Seeds can be sown directly or in seedbeds, and in a light soil mixture of 3 parts soil to 1 part sand (Church World Service, 2000). Germination occurs 5-12 days or even up to 30 days, depending on the age of the seed and the pre-treatment method used. About 1 year old seedlings become ready for grafting or budding. Seeds should be planted in flats of sandy soil and covered to a depth of about 0.25 inch (Ruehle, 1948).

2.4.2 Pruning

According to Singh *et al* (2001), the vegetative growth response of guava trees to pruning treatments varied with the month of operation and cultivar and observed that May was the best month for pruning, which resulted in shortening of shoot growth from 24.0-21.0 cm to 16.5-12.0 cm and May pruned trees produced maximum flowering shoots during July to September. According to Whiting *et al.,* (2005), soft pruning does not only contribute to the vegetative growth of guava but also enhance the development and enlargement of fruit as well as increase the number of fruit whereas moderate and intense pruning caused substantial yield reductions per tree (36.71 and 67 % reduction, respectively). Pruning is the most important operation in guava cultivation, because blooming always comes out from the new branch. A good tree-form (tree shape) is required to maintain the productivity of guava trees. According to T.G.P.M. (2011), Regular pruning keeps the sub-main branches. This type of pruning is always used in year-round production of fruit, medium pruning keeps the main branches; this type of pruning is used for off-season production to harvest the fruit in October to April, and heavy pruning is always used to renew an old field that is more than 10 years in production. The trees are pruned until the trunk does not have any branch left. Guava trees should be dwarfed for better field management. Defoliation not only reduces initial and final fruit set in guava trees, but also reduces yield through smaller fruit size rather than by a smaller fruit number (Tustin *et al*., 1997).

2.4.3 Fertilizer application

Guavas are fast growing heavy feeders and can greatly benefit from regular feeding. Apply fruit tree fertilizers monthly, and especially just before heavy pruning. Manure and fertilizer needs of guava plants vary with varieties, age of plant, soil fertility and management practices. Although, inorganic fertilizers are commonly used to make up nutrient deficiency, yet combined application of organic and inorganic manures proved better than their individual application (Muhamma *et al.*, 2000). Research conducted by Bashir *et al*, (2009) concluded that 40 kg FYM + one kg each of N-P2O5-K2O per plant (splitting N i.e. ½ kg before flowering in August add ½ kg after fruit setting in September) proved better for yield and fruit quality of winter guava crop. The combination of organic and inorganic fertilizer resulted in higher production of fruits than only organic or inorganic sources. The chemical fertilizers 18-18-18, 0-0-60, 60-0-0 (urea) and foliar fertilizers are always used in guava production. Additionally, organic fertilizers such as compost and liquid fertilizers are also important to improve the soil condition and helps complement fertilizer usage. There are two fertilizer applications practices: one for off season production and the other for year-round production (T.G.P.M., 2011).

2.4.4 Pest and diseases

Guava can be susceptible to a range of pests, such as dried fruit beetle, case moths, fruit sucking moths, leafhoppers, fruit flies and swarming beetles. One problem with Guavas is a ring barking grub which drills a hole into the trunk, feeding off the cambium layer and covering the hole with the dead wood. Control it by removing the debris layer and applying Pyrethrum (natural insecticide made from dried flower heads) down the hole (Berens *et al*., 2008; Orwa *et al.*, 2009).

2.5 Uses of the guava

2.5.1 Fruit

Guava fruits are valued as potential source of pectin, sugars, minerals, rich in vitamins A and C, carotene and contains high amount of dietary Fiber (Hassimotto *et al.*, 2005). As food, guava can be consumed fresh or cooked to produce mild flavor. Guava varieties have been developed for the industrial purposes and the following wide variety of products are available: canned fruit or mesocarps in sweet syrup, puree, cake, jams and jellies, juices and nectars, ice cream and yoghurts, and wine (Orwa *et al.*, 2009).

2.5.2 Seed

Guava seeds have been reported (Paniandy *et al.*, 2000) to contain 14 % oil to dry weight, with 15 % proteins and 13 % starch. Ten phenolic and flavonoid compounds including one new acylated flavonol glycoside were isolated. The structures of the new compound quercetin-3-O-β-D-(2''-O-galloylglucoside) - 4'-O-vinylpropionate and of the known compounds were elucidated.

2.5.3 Medicinal

All parts of *P. guajava*, including fruits, leaves, bark, and roots, have been found to be of great significance to life. Leaves, pulp and seeds are used to treat respiratory and gastrointestinal disorders, and as an antispasmodic, anti-inflammatory, as a cough sedative, anti-diarrheic, in the management of hypertension, obesity and in the control of diabetes mellitus. The seeds are used as antimicrobial, gastrointestinal, anti-allergic and anti-carcinogenic activity (Huang *et al*., 2011). Pharmacological studies conducted on *P. guajva* by Gutiérrez *et al.,* (2008) indicated its immense potential in the treatment of conditions such as diarrhoea, gastroenteritis and rotavirus enteritis, wounds, acne, dental plaque, malaria, allergies, coughs, diabetes, cardiovascular disorder, degenerative muscular diseases, inflammatory ailments including rheumatism and menstrual pain, liver diseases, cancer, and many more.

2.5.4 Other functions

Guava plant contributes to apiculture as its white fragrant flowers secrete nectar in excess all day attracting bees, which also collect juice from the damaged fruits. In India for instance, the blossoms occur in May and June. It also provides Fuel or energy which makes excellent firewood and charcoal because of its abundance, natural propagation, and classification as an undesirable weed. Moreover, it is a timber species, its light brown sapwood, brown or reddish heartwood; hard, moderately strong and durable. It is used for tool handle, fence posts and in carpentry and turnery. Tannin or dyestuff extracted from the leaves and bark may be used for dyeing and tanning. The plant contains an essential oil which volatiles with methylchavicol, persein and d-pinene (paraffin) is found in the leaf. Furthermore, they are widely cultivated as an ornamental fruit tree and also used for boundary or barrier or support for staking yams (Dioscorea spp.). Guava is noted to have performed very well when intercropped with fodder crops such as maize, sorghum and cowpeas. Tree growth reduction is very small. Finally, it had been identified as useful for bio-indication and as a bio-accumulator in India. It is sensitive to sulphur dioxide; sensitivity to injury based on chlorophyll destruction (Orwa *et al.*, 2009).

2.6 Organic matter decomposition

According to Stoffella *et al*. (1997), organic matter can serve as soil amendments to improve soil nutrient status. They provide a ready source of carbon and nitrogen for microorganisms in the soil, improve its structure, reduce erosion and lower the temperature at the soil surface and also aid in seed germination and increase its water holding capacity. Organic matter stabilizes soil pH**,** increase water holding capacity particularly in sandy soils and ultimately improve plant growth and yields (Roe *et al*., 1997). Litter decomposition is a fundamental biogeochemical process influencing rates of carbon and nutrient cycling in forest ecosystems (Perry *et al*, 2008). Global syntheses indicate that temperature is a primary factor controlling litter decay rates (Adair *et al.,* 2010). Temperature is a primary factor controlling leaf litter decomposition rates and the proportional change in litter decay rate due to a 10 ◦C increase in temperature is potentially because of the confounding effects of precipitation and soil moisture, which also exert a strong control on litter decay. Moreover, litter chemical composition, climate, nutrient availability, communities of soil organisms, and site-specific factors also influence decomposition (Salinas *et al.,* 2011). The maintenance of natural systems or soil fertility in tropical forest ecosystems is achieved by high and rapid circulation of nutrients through the fall, incorporation and decomposition of litter (Regina *et al*., 1999). Decomposition is a key process in the control of nutrient cycling and formation of soil organic matter (Berg and McClaugherty, 2002). Decomposition of leaf litter is also an integral and significant part of biochemical (i.e. intra system) nutrient cycling and food webs; this refers to both the physical and chemical breakdown of litter and the mineralization of nutrients (Terrell *et al*., 2001). Plant production depends on the recycling of nutrients within the system; recycling depends on the decomposition of organic matter and release of the nutrients it contains (Temel, 2003). Nutrient cycling is clearly related to decomposition. The availability of nutrients in a given soil is due in large part to the decay dynamics of the organic matter in that soil. In addition, the accumulation of organic matter in soil can greatly increase the cation exchange capacity, and have positive impacts on the nutrient holding capacity of that soil. Decomposition can influence the pH of soil; pH may be increased if plants pump basic cations up from the mineral soil to be released during the leaching and decay of litter. Soil pH can be lowered through the release of CO_2 and the formation of carbonic acid (Salinas *et al.*, 2011). Finally, during initial stages of decay, nutrients are immobilized and taken out of the general circulation for a while, thereby temporarily reducing nutrient availability.

2.7 Moringa oleifera

2.7.1 General description

The *Moringaceae* family has 12 species, with *Moringa oleifera* being the most widely known and utilized species. *Moringa oleifera*, a native to northern India (Panga, 2002) is a multipurpose tree species suitable for fuelwood, fodder, food, medicinal and improvement of soil fertility. These properties make the tree species a good candidate for intercropping systems (Follard and Sutherland, 1996). It is a member of Moringaceae family and a small deciduous tree with sparse foliage. It is an extremely fast growing tree with 5-15 m height, diameter of 20-40 cm, and grayish-green bark. It has 20-70 cm leaves with several tiny leaflets that drop when the leaf matures. The flowers (10-15 mm long) are generally yellowish white to pink, bisexual, and harbour insect-pollination characteristics e.g. large, showy, slightly scented, and zygomorphic (Gomaa and Pico, 2011).

The flowering season is from March to April and fruiting period last for up to 3 months. The fruit (pods) are initially light green, slim, and tender, eventually becoming dark green and firm up to 120 cm long. Fully matured, dried seeds are round or triangular shaped, the kernel surrounded by a lightly wooded shell with papery wings (Hegazy *et al*., 2008). *M. oleifera* can grow in all types of soil, from acid to alkaline and can tolerate up to 6 months of dry season reasonably well. It requires rainfall between 500 and 1500 mm per year. It is therefore useful for semi-arid areas. However, a prolonged period of stress caused by lack of water will result in loss of leaves (Nadir *et al*., 2006). The outstanding performance in survival and growth of *M. oleifera* both in a semi-arid and sub humid confirms the wide plasticity of this species as observed in other studies (Folkard and Sutherland, 1996; Manh *et al*., 2003)

2.7.2 Uses

Research by Mishra *et al*., (2011) indicated that, *M. oleifera* is a highly valued plant with multipurpose effects (biomass production, livestock fodder, green manure biogas, plant growth enhancer, medicines and biopesticides). It is considered as one of the world's most useful trees, as almost every part of the tree has an impressive effect of food, medication and industrial purposes (Moyo *et al*., 2011). Different parts of this plant contain a profile of important minerals, proteins, vitamins, β carotene, amino acids and various phenolics and provide a rich and rare combination of zeatin with several flavonoid pigments (Anwar *et al.*, 2007). Reports by, Fuglie (1999) stated that, the leaf extract of *M. oleifera* accelerated growth of young plants, strengthened plants, improved resistance to pests and diseases, increased leaf duration, increased number of roots, produced more and larger fruits and generally increased yield by 20 and 35 %. Several recent investigations were undertaken aiming to increase both the growth parameters measured as plant height, number of leaves, leaf area, fresh and dry weight, number of tillers, shoot vigor, root length, germination percentage and yield represented as fruit number and dry weight by foliar application of Moringa leaf extracts at different rates (Nouman *et al*., 2011; Phiri, 2010). It is a suitable tree for traditional agroforestry in the home because of its versatility (Nduwayezu *et al*., 2007). With rapid growth and large amount of biomass yield of high-protein content, *M. oleifera* trees are one of the best multipurpose tree (MPT) candidates for use in alley cropping systems. Traditionally, the species is grown in mixed multi-storey stands with food crops. *M. oleifera* has widespread use in agricultural industry and medicine. It can be used in livestock as a biocide. All parts of the *M. oleifera* tree are used in natural medicine (Smith and Eyzaguirre, 2007). The fruit, seeds, leaves, and flowers are consumed by humans as nutritious vegetables in some countries (*Aberra et al.*, 2011). Leaves from browse and fodder trees form major parts of livestock feed in the tropical countries (Woods *et al.*, 1994) and play a major role in improving dietary protein (Kaitho *et al.*, 1998)

2.7.3 Nutrient concentration

M. oleifera biomass was reported by Meena Devi *et al*, (2013) to contain 4.2 % of Nitrogen, 0.23 % of Phosphorus, and 2.36 % of Calcium which are essential plant nutrients for plant or crop growth and productivity. The maintenance of soil fertility involves the return to the soil of the nutrients removed from it by harvests, runoff, erosion, leaching, and other loss pathways from organic materials (Aune, 1993).

2.8 Leucaena leucocephala

2.8.1 General description

L. leucocephala is a perennial, non-climbing, erect, thornless shrub or small tree, 5–10 m (rarely 20 m) tall which belongs to the family Mimosaceae and well known species of the *Leucaena* genus. Fast-growing, with a trunk 5–50 cm in diameter, the bark on young branches is smooth, slash salmon pink, darker grey-brown and rougher with shallow, rusty orange-brown vertical fissures and deep red inner bark on older branches and bole (Hughes 1998a). This evergreen plant is deep rooted. It often has a combination of flowers, immature and mature pods all present on the tree at the same time. Trees can live from 20 years to more than 50 (Hughes, 2002). Leaves are bipinnate with 6-8 pairs of pinnae bearing 11-23 pairs of leaflets 8-16 mm long. The leaves are slightly asymmetric, linear-oblong to weakly elliptic, acute at tip, rounded, obtuse at base, glabrous except on margins. Leaves and leaflets fold up with heat, cold or lack of water. Flower heads 12-21 mm in diameter, 100-180 flowers per head, in groups of 2-6 in leaf axils, arising on actively growing young shoots, flowers white or pale cream-white. The inflorescence is a cream-coloured globular shape which produces a cluster offlat brown pod 13-18 mm long containing 15-30 seeds. According to Orwa *et al.* (2009), pods (minimum. 9) 11-19 cm long, (minimum. 13) 15-21 mm wide, (minimum. 3) 5-20 (maximum. 45) per flower head, linear-oblong, acute or rounded at apex, flat, 8-18 seeded, mid- to orange-brown, glabrous and slightly lustrous or densely covered in white velvety hairs, papery, opening along both margins. Seeds hard, dark brown with a hard, shining testa, 6.7-9.6 mm long, 4-6.3 mm wide, aligned transversely in pod.

2.8.2 Uses

L. leucocephala is an excellent protein source for cattle fodder, consumed browsed or harvested, mature or immature, green or dry. It is also used in land reclamation, erosion control, water conservation, dye production, reforestation and soil improvement programs, and is a good cover and green manure crop. The leaves, used as mulch around other crops, are said to significantly increase their yields. It has high nitrogen-fixing potential (100-300 kg N/ha/year), related to its abundant root nodulation (Agroforestry Database, 2009). *L. leucocephala* is one the highest quality and most palatable fodder trees of the tropics, often being described as the ‘alfalfa of the tropics’. The leaf quality compares favourably with alfalfa or lucerne in feed value except for its higher tannin content and mimosine toxicity to non-ruminant. Leaves have a high nutritive value (high palatability, digestibility, intake and crude-protein content), resulting in 70-100 % increase in animal live weight gain compared with feeding on pure grass pasture. Seeds yield about 25 % gum worthy of commercial investigation. Young pods are cooked as a vegetable and seeds are used as a substitute for coffee. Wood is hard and heavy and used for fuel or charcoal. Plants are used for shade for black pepper, coffee, cocoa, and for hedges (James, 1983). Its leaves and green fresh pods are used as vegetables by humans and are rich in carotene and ascorbic acid with a good profile of amino acids. The plant blooms almost throughout the year, providing constant forage or nectar to honey bees and also an excellent firewood species with a specific gravity of 0.45-0.55 and a high calorific value of 4600 cal/kg (Makkar and Becker, 1997).

2.8.3 Nutrient concentration

According to N.A.S (1977), *L. leucocephala* is noted for its atmospheric nitrogen fixing capability and nitrogen rich biomass which had had significant effect in the increment of plant or crop growth and productivity. *L. leucocephala* in partnership with rhizobium is capable of annually fixing more than 500 kg/N (200 metric tons/400 ha) and its biomass contains 2.2-3.8 % nitrogen (N), 0.2-0.4 % phosphorus (P), and 1.3-4.0 % Potassium (K) which agrees with (Frimpong, 2014).

CHAPTER THREE

3.0 Methodology

3.1 Study site

The research was conducted at the Faculty of Renewable Natural Resources (FRNR) Research Farm, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana. The site is situated on latitude 6.40 °N and 1.37 °W. The site falls under the Moist Semi-deciduous Forest Zone with mean annual rainfall ranging from 1500-2000 mm. The major rainy season starts in March and lasts till July which is followed by the minor rainy season which starts in September and ends in November. The daily average temperature is 25.6 °C, with the warmest average temperature of 33 °C in March and the lowest average temperature of 20 °C in January, February and December. The mean annual temperature and humidity are 26.5 °C and 67.5 % respectively. The soils in the site belong to the family Ferric Acrisols in the soil taxonomy. Ferric Acrisols are loamy sand, well drained but strongly acidic (Adu and Asiamah, 1992).

3.2 Experimental procedure

The experimental site was cleared using hoe, cutlass, and rake. Soil sample was obtained at the depth of 0-15 cm was tested for initial pH, organic carbon, and total available nitrogen (N) content. The guava seeds were obtained from Crop Research Institute, Fumesua, Ghana. *M. oleifera* and *L. leucocephala* biomass were collected from Faculty of Renewable Natural Resource Research farm, KNUST. Equal weight (3.5 kg) of soil was used in each polypots of 10 cm x 15 cm dimension. Fresh biomass of *M. oleifera* and

L. leucocephala biomass in varying proportions were applied on the different polypots in singles and combinations immediately they were weighed using electronic balance. The guava seeds were soaked in water for 24 hours to dissolve germination inhibitors and soften seed coat. Six seeds were sown per polypot a week after biomass incorporation. Watering was done regularly in the mornings using watering can followed by thinning out of seedlings to 3 seedlings per polypot in the fourth week. Soil samples from biomass amended soils (3 polypots) were bulked and tested to ascertain the final pH, organic carbon, and total nitrogen (N) content.

3.3 Experimental design and treatment

The research was laid in Completely Randomized Design (CRD) with four treatments replicated four times.

The treatments were as follows:

- T1= No biomass, (control)
- T2= 8 g (0.3 gN)/polypot *L. leucocephala* biomass, equivalent to 5000 kg/ha
- T3= 7 g *M. oleifera* biomass (0.3 gN)/polypot, equivalent to 4000 kg/ha
- T4= 3.5g (0.015 gN)/polypot *M. oleifera* biomass, equivalent to 2000 kg/ha + 4.0g (0.015 gN)/polypot *L. leucocephala* biomass, equivalent to 2500 kg/ha.

3.3.1 Calculation of biomass and nutrient quantities

Weight of soil per polypot = 3.5 kg

1 ha = 2000000 kg soil

Percentage nitrogen (N) in *M. oleifera* is 4.2 % according to Meena Devi *et al*, (2013) and *L. leucocephala* contains 3.86 %N according to Frimpong, (2014).

If 4000 kg/ha of *M. oleifera* = 2000000 kg soil, then 3.5 kg soil of pot would result in 40000 kg/ha × 3.5 kg/2000000 kg soil = 0.007 kg or (7 g) *M. oleifera*/polypot.

Amount of N supplied by 0.007 g *M. oleifera*/polypot was 0.29 gN≈ 0.3 gN from the calculation below:

If 100 kg *M. oleifera* = 4.2k gN, then 0.007 kg *M. oleifera* will supply (4.2 kgN × 0.007 kg/100 kg) × 1000 g = 0.29 gN ≈ 0.3 gN/polypot.

If 5000 kg/ha *L. leucocephala* = 2000000 kg soil, then 3.5 kg soil of pot would result in 50000 kg/ha × 3.5 kg/2000000 kg soil = 0.008 kg or 8 g *L. leucocephala*/polypot.

Amount of N supplied by 8 g *L. leucocephala* /polypot was 0.309 g ≈ 0.3 g from the calculation below:

If 100 kg *L. leucocephala* = 3.86k gN, then 0.008 kg *L. leucocephala* will supply (3.86 kgN × 0.008 kg/100 kg) × 1000 g = 0.309 gN ≈ 0.3 gN/polypot.

Table 3.1: Experimental layout

Replicate I	Replicate II	Replicate III	Replicate IV
T1	T3	T4	T2
T4	T1	T2	T3
T2	T4	T3	T1
T3	T2	T1	T4

3.4 Data collection and analysis

The percentage germination was calculated four weeks after germination using the formula: $\frac{number\ of\ sprouted\ seeds}{Total\ number\ of\ seeds} \times 100.$ Data was collected on height, stem diameter, and number of leaves at weekly intervals over 12 weeks. The diameter of seedling stems was obtained using a digital caliper, the height of seedlings using tape measure, and the number of leaves by counting. All statistical analysis was conducted using Genstat 12^{th} Edition software. Analysis of Variance (ANOVA) at $p \leq 0.05$ was used to determine the significance of treatments. Least Significance Difference (L.S.D.) was used to separate means and data was presented in tables and appropriate graphs.

CHAPTER FOUR

4.0 Results

4.1 Growth progression of guava

4.1.1 Growth progression of guava height over the twelve weeks

The growth progression of height (Figure 4.1) among various treatments was almost uniform from the first week to the twelfth week with T4 (*M .oleifera* and L. *leucocephala* mixed biomass) recording the highest progressive growth whilst T1 (control) recorded the least height. In contrary, T4 (*M .oleifera* and *L. leucocephala* mixed biomass) recorded a sharp increment between fifth and sixth week. In the case of the intermediates, T3 (*M .oleifera* biomass) higher compared to T2 *(L. leucocephala* biomass). However, minimal increment in height was observed with increasing number of weeks.

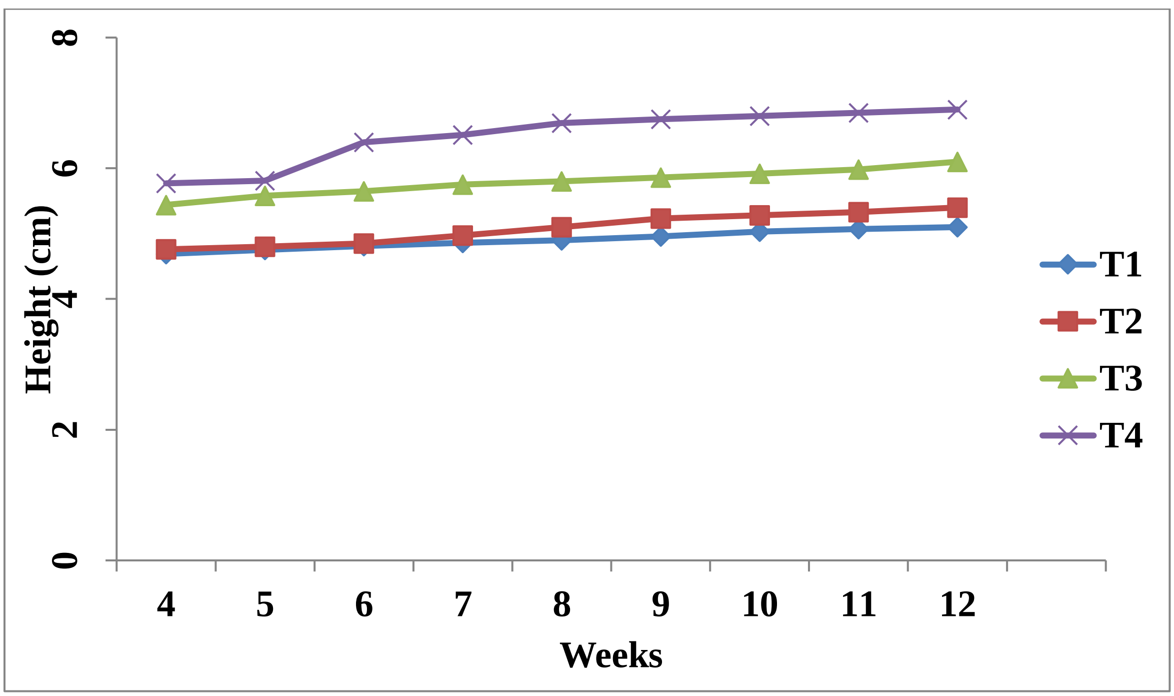

Figure 4.1: Effects of treatments on the height of guava plant over the 12th weeks of study period.

4.1.2 Growth progression of guava diameter over the twelve weeks

Growth progression of diameter was significant with steady growth trend observed across all treatment from the 4th to the 12th week with the exception of T4 (*M .oleifera* and *L. leucocephala* mixed biomass) recording a sharp growth from the forth to fifth week. The highest growth progression was observed in T4 (*M .oleifera* and *L. leucocephala* mixed biomass) and the least in T1 (control). T2 (*L. leucocephala* biomass treatments) and T3 (*M .oleifera* biomass) were intermediate but T3 (*M .oleifera* biomass) did better in terms of stem diameter growth compared to T2 (*L. leucocephala* biomass). Slow increment in diameter was observed with increasing number of weeks.

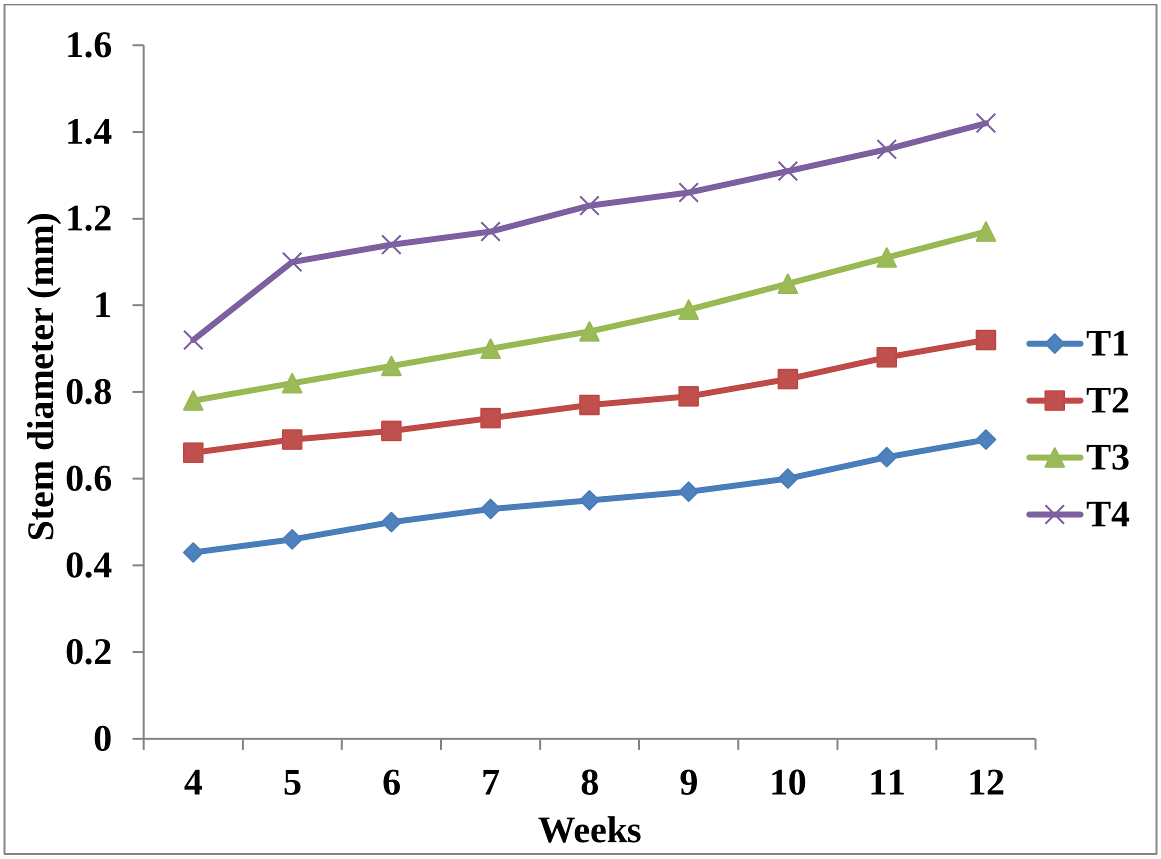

Figure 4.2: Effects of treatments on the stem diameter of guava plant over the 12th weeks of study period.

4.2 Germination and morphological growth responses

Data on mean germination percentage, growth in height and stem diameter, and number of leaves at the end of 12^{th} weeks after planting in response to the application of *L. leucocephala* and *M. oleifera* biomass are shown in table.

Table 4.1 Effects of treatments on growth parameters of guava plant at the end of the 12^{th} week.

Treatments	Germination %	Height (cm)	Diameter (mm)	Number of leaves
T1	72.5±2.53	5.15±0.065	0.69±0.006	4±0.489
T2	55±2.28	5.35±0.086	0.92±0.007	11±0.250
T3	70±2.38	6.10±0.041	1.17±0.006	7±0.707
T4	90±2.08	6.80±0.058	1.43±0.007	13±0.479
P-value	0.001	0.001	0.001	0.001
L.S.D.	7.240	0.198	0.0207	1.557

Values of germination percentage, height, stem diameter and number of guava leaves are mean (± standard error).

4.2.1 Germination percentage of guava seeds

Application of *L. leucocephala* and *M. oleifera* biomass significantly (P = 0.001) affected germination and the morphological growth of guava seedlings (Table 4.1). Mean germination percentage at the end of the 12^{th} week after planting ranges from 55±2.28 % for T2 (*L. leucocephala* biomass) to 90±2.08 % for T4 (*M .oleifera* and *L. leucocephala* mixed biomass).

4.2.2 Number of leaves of guava seedlings

Observation from Table 4.1 indicates that, treatments had significant effects (P = 0.001) on the number leaves of the guava seedlings. T1 (control) recorded the least mean number of leaves (4) compared to T4 (*M. oleifera* and *L. leucocephala* mixed biomass) that recorded the highest mean number of leaves (13). With regards to the intermediates, treatment T2 (*L. leucocephala* biomass) with 11 leaves did better compared to T3 (*M. oleifera* biomass) with 7 leaves.

4.2.3 Height of guava seedling

In the case of growth in height, differences were similarly highly significant (P = 0.001) at the end of the 12th week after planting. The highest mean height of 6.80±0.058 cm, was recorded in T4 (*M .oleifera* and *L. leucocephala* mixed biomass) whilst the lowest mean height of 5.15±0.065 cm, was seen in T1 (control). T2 (*L. leucocephala* biomass) and T3 (*M. oleifera* biomass) recorded 5.35±0.09 cm and 6.10±0.06 cm respectively as intermediate heights.

4.2.4 Stem diameter of guava seedling

Results of the study indicates that, treatments had significant effects (P = 0.001) on the stem diameter of guava seedlings. T4 (*M. oleifera* and *L. leucocephala* mixed biomass) had the highest growth in stem diameter (1.42±0.007 mm) with the lowest growth in stem diameter (0.69±0.006 mm) observed in T1 (control). The treatments with the intermediate mean growth in stem diameter were T2 (*L. leucocephala* biomass) and T3 (*M. oleifera* biomass) with 0.29±0.007 mm and 1.17±0.006 mm respectively as shown Table 4.1 above.

4.3 Initial and final soil analysis

Final soil analysis at the end of the 12th week of the experiment indicated in Table 4.2 showed that, *M. oleifera* and *L. leucocephala* biomass amended soils had increased pH from the initial 4.5 to 5.3, organic carbon from 4.53 to 5.2 % and total nitrogen from 0.34 to 0.41 % compared to the initial results.

Table 4.2: Initial and Final chemical composition of soil sample at the end of the 12th week

Soil parameter	Initial value	Final value
pH	4.50	5.30
Organic carbon %	4.53	5.20
Total Nitrogen %	0.34	0.41

CHAPTER FIVE

5.0 Discussion

5.1 Effects of treatments on the growth parameters of guava seedling

5.1.1 Percentage germination of guava seeds

Germination of guava seeds (Table 4.1) was significantly influenced (P = 0.001) by the application of *M. oleifera* and *L. leucocephala* biomass compared to T1 (control). T2 (*L. leucocephala* biomass) and T3 (*M. oleifera* biomass) reduced the percentage germination of the guava seeds. This could be as a result of the presence of allelochemicals in *M. oleifera* (Terpenoids and Monilactone) and *L. leucocephala* (Mimosine, flavonoids and hydroxycinnamic acids) in the leaf biomasses. These allelochemicals are known to inhibit the synthesis of growth hormones which in turn suppressed cell division, enlargement, and elongation. These findings agree with reports by Chou, (2010) and Phiri, (2010) who applied extracts of *M. oleifera* and *L. leucocephala* biomass respectively on cereal crops. The *M. oleifera* and *L. leucocephala* mixed biomass amended soils (T4) were found to have stimulated and enhanced the percentage germination of guava seeds. This might be due to the neutralizing effects of growth enhancers or hormones in *M. oleifera* (Zeatin) and *L. leucocephala* (auxin) leaf biomass invigorating or stimulating enzymic and embryonic reactions within the seeds. These findings are consistent with the reports of Katsaruware, (2013), Khan, (2011), and Phiri, (2010**)** in major cereals. Moreover, the seeds being soaked to dissolve germination inhibitors to break dormancy could have as well influenced the germination of the guava seeds which is consistent with findings by Fuglie (1999) in guava propagation.

5.1.2 Number of leaves of guava seedlings

The number of leaves was significantly affected by biomass application (Table 4.1). Guava seedlings under T2 (*L. leucocephala* biomass) and T4 (*M. oleifera* and *L. leucocephala* mixed biomass) had significantly more leaves compared to T1 (control) and T3 (*M. oleifera* biomass). This could be attributed to the fact that application of biomass improved soil physiochemical properties as a result of which seedlings on these soils grew better as depicted by the differences in number of leaves. Seedlings on biomass amended soils were possibly taking up and utilizing available nutrients especially nitrogen better compared to the control. Secondly, this could be due to the presence of growth hormones (Zeatin) in *M. oleifera, L. leucocephala* leaf biomass (auxin), and conducive environment inducing the development and retention ability of leaves in the guava seedlings compared to the control. These confirmed the findings by Khan, (2011) and Phiri, (2010), who found similar effects of treatments on some major cereals.

5.1.3 Height and stem diameter of guava seedling

The Height and stem diameter under the biomass amended soils showed statistically (Table 4.1) that, guava seedlings were significantly enhanced. There were no significant differences among the mean heights with the exception of T1 (control) and T4 (*M. oleifera* and *L. leucocephala* mixed biomass) that differ significantly. However, there were significant differences among the means stem diameters. Increased in plant height and stem diameter could be due to efficient utilization of available nitrogen or mineralized nutrients present in the decomposed leaf biomass of *M. oleifera* and *L. leucocephala*. Moreover, growth stimulators in *M. oleifera* and *L. leucocephala* biomass might have vigorously induced the vegetative development of the seedlings compared to the control. These growth stimulators are noted to have sped up cell division, enlargement and elongation in plants. Furthermore, increment in height and stem diameter could be as a result of *M. oleifera* and *L. leucocephala* biomass increasing or adjusting the soil pH and cation exchange capacity causing bound cation to be released for the uptake by the guava seedlings These findings are in agreement with reports by Culver *et al*., (2012) in tomato and Phiri, (2010) in cereals. However, these findings refute report by Moktar, (2012) that stunted heights were observed in mungbean with the application of *L. leucocephala* and *M. oleifera* biomass.

5.1.4 Final soil analysis

The improvement of soil physiochemical properties by the application of *M. oleifera* and *L. leucocephala* leaf biomass as indicated in Table 4.2 could be due the accumulation of organic matter in the soil which had greatly increased the cation exchange capacity, and had had positive impacts on the nutrient holding capacity of soil accounting for the increased total nitrogen content of the soil. The pH might have increased as the plants pumped basic cations up from the mineral soil to be released for their growth activities. Similar findings were reported by Perry *et al.*, (2008) who analyzed the effects of leaf litter decomposition on physiochemical properties of soil.

CHAPTER SIX

6.0 Conclusions and Recommendations

6.1 Conclusions

From the results of the study, the following conclusions could be made:

- Germination percentage of guava seeds were inhibited by *M. oleifera* and *L. leucocephala* leaf biomass singly applied.
- The combination of *M. oleifera* and *L. leucocephala* leaf biomass positively stimulated and enhanced percentage germination and morphological growth of guava seedlings.
- The final total nitrogen content and structure of the soil was improved with the application of *M. oleifera* and *L. leucocephala* leaf biomass compared to the initial total nitrogen content of the soil.

6.2 Recommendations

The research recommends that:

- *M. oleifera* and *L. leucocephala* leaf biomass should be applied to soils to improve the morphological growth growth in guava and possibly other tree crops.
- *M. oleifera* and *L. leucocephala* leaf biomass should be incorporated into nitrogen deficient soils to improve the total nitrogen content and soil structure.
- Further research should be carried out on varying combinations of the two leaf biomasses to determine the optimum combination for best results.

REFERENCES

Aberra, M., Workinesh, T. and Tegene, N. (2011). *Effects of feeding Moringa stenopetala leaf meal on nutrient intake and growth performance of Rhode Island Red chicks under tropical climate. Trop*. Subtrop. Agroecosyst. 14:485-492.

Abloh, E. (2013). *"Processing companies look offshore for fruits", Graphic Business*, 15 October 2013, p. 5.

Adair E.C., Hobbie S.E. and Hobbie R.K. (2010). *Single-pool exponential decomposition models: potential pitfalls in their use in ecological studies*. Ecology 91:1225–1236 DOI 10.1890/09-0430.1.

Adu, S. V. and Asiamah R. D. (1992). *Soils of the Ayensu-Densu Basin, Central, Eastern and Greater Accra Regions of Ghana*. Council for Scientific and Industrial Research (CSIR) – Soil Research Institute Memoir No. 9. 117 pp.

Agorsa, E. (2013). Personal Communication, December 20th.

Antunes, M.D.C. and Sfakiotakis, E.M. (2000). *Effect of high temperature stress on ethylene biosynthesis, respiration and ripening of 'Hayward' kiwifruit. Postharvest Biology and Technology*, v.20, p.251-259.

Anwar, F., Latif, S., Ashraf, M. and Gilani A.H. (2007). *Moringa oleifera: A food plant with multiple medicinal uses*. Phytother. Res. 21:17-25.

Aune, J.B. (1993). *Ecological and economical requirements for sustainable land use in sub Saharan Africa*. Forum Dev.Stud.2:211-219.

Bashir, M. A., Ahmad, M., Salik., M. R. and Awan, M. Z. (2009). *Manure and fertilizers effect on yield and fruit quality of guava (Psidium guajava L.)*. Journal of Agricultural Research (Lahore), 47(3), 247-251.

Berens, D.G., Farwig, N., Schaab, G. and Bohning-Gaese, K. (2008). *Exotic guava are foci of forest regeneration in Kenya farmland*. Biotopica. 40;1004-112

Berge, B and McClaugherty. (2002). *Plant litter decomposition humus*. Springer-verlag, New York. Black C. A (ed.) (1965). Methods of soil analysis. Agronomy No. 9, Part 2. America Society of Agronomy, Madison, Wisconsin.

Chou, C.H. (2010). *Role of allelopathy in sustainable agriculture: Use of allelochemicals as naturally occurring bio-agrochemicals*. Allelopath J 25:3–16

Church World Service, (2000). *Moringa oleifera the miracle tree*. Church World Service. Pp 3.

Cronk, Q.C.B., and Fuller, J.I. (1995). *Plant Invaders*. London: Chapman and Hall. 241 pp.

Culver, M., Fanuel, T., and Chiteka, A. Z. (2012). *Effect of Moringa extract on Growth and Yield of Tomato.* Greener Journal of Agricultural Sciences 2(5): 207-211

Davidson, E.A., David, M.B., Galloway, J.N., Goodale, C.L., Haeuber, R., Harrison, J.A., Howarth, R.W., Jaynes, D.B., Lowrance, R.R. and Nolan, B.T. (2012). *Excess nitrogen in the U.S. environment: trends, risks, and solutions*. ESA Issues Ecol 15:1–16.

El-Bulk, R.E., Babiker, E.F. and El-Tinay A.H. (1997). *Changes in chemical composition of guava fruits during development and ripening*. Food Chem. 59, 395-399.

Fielder, G., Clairandr, S.T. and Garner, J. (1936). *Vegetative Propagation of Tropical and Sub-tropical fruits*. Imp. Bu. Of Fruit Prod.Tech.Comi\,F.No.7.Imp. Bu. of Fruit Production, East Malllng, 67pp.

Folkard, G.K. and Sutherland, J.P., (1996). *Moringa oleifera: a tree and a litany of potential. Agroforestry Today*. p 5-8.

Frimpong, K.G. (2014), *Effect of organic and inorganic fertilizers and their combinations on the growth performance of spring onion* (*Allium fistulosum*), pp 32

Fuglei, L.J., (1999). *Moringa oleifera* - the miracle tree. Church World Service. Pp 1-5.

Galloway, J.N., Townsend, A.R., Erisman, J.W., Bekunda, M., Cai, Z.C., Freney, J.R., Martinelli, L.A., Seitzinger, S.P. and Sutton, M.A. (2008*). Transformation of the nitrogen cycle: recent trends, questions, and potential solutions*. Science 320(5878): 889–892.

Gangwar, K.S., Sharma, S.K. and Tomar, O.K. (2004). Indian Journal of Agronomy, 49(2): 84-88.

Gomaa, N.H. and Pico, X.F. (2011). *Seed germination, seedling traits, and seed bank of the tree Moringa peregrina (Moringaceae) in a hyper-arid environment.* Am. J. Bot. 98, 1024–1030.

Guava. (2014). *Encyclopedia Britannica Online***.** Retrieved 17 December, 2014, from http://www.britannica.com/EBchecked/topic/248073/guava.

Gutiérrez, R. M. P., Mitchell, S., and Solis, R. V. (2008). *Psidium guajava: A review of its traditional uses, phytochemistry and pharmacology.* Journal of Ethnopharmacology, 117(1), 1-27.

Hamilton, R. A. and Seagrave-Smith, H. (1959). *Growing Guava for Processing. University of Hawaii Cooperative Extension.* Available at: http://www.ctahr.hawaii.edu/oc/freepubs/pdf/EB1-63.pdf. [Accessed 15 December 14]

Hassimotto, N.M., Genovese, M.I. and Lajolo, F.M. (2005). *Antioxidant activity of dietary fruits, vegetables, and commercial frozen fruit pulps*. J. Agric. Food Chem., 53, 2928–2935.

Hegazya, A.K., Hammoudab, O., Lovett-Doustc, J. and Gomaa, N.H. (2008). *Population dynamics of Moringa peregrina along altitudinal gradient in the northwestern sector of the Red Sea.* J Arid Environ. 72, 1537–1551.

Hooper, D.U., Adair, E.C., Cardinale, B.J., Byrnes, J.E.K., Hungate, B.A., Matulich, K.L., Gonzalez, A., Duffy, J.E., Gamfeldt, L. and O'Connor, M.I. (2012). *A global synthesis reveals biodiversity loss as a major driver of ecosystem change*. Nature.doi:10.1038/nature11118.

Huang, C.S., Yin, M.C. and Chiu, L.C. (2011). *Antihyperglycemic and antioxidative potential of Psidium guajava fruit in streptozotocin-induced diabetic rats.* Food Chem Toxicol 49: 2189-2195.

Hugdes, C.E. (1998a). 'Leucaena: A Genetic Resources Handbook', Tropical Forestry Paper No. 37, Oxford Forestry Institute, Oxford, U.K.

Hughes, C.E. (2002). *Global Invasive Species Database, Invasive Species Specialist Group*, viewed 23 May 2002, http://www.issg.org/database/welcome.

James, A. Duke. (1983). *Handbook of Energy Crops.* unpublished.

Jiménez-Escrig, A., Rincón, M., Pulido, R. and Saura-Calixto, F. (2001). *Guava fruit (Psidium guajava L.) as a new source of antioxidant dietary fiber.* Journal of Agricultural Food Chemistry 49: 5489-5493.

Kaitho, R.J., Nsahlai, I.V., Williams, B.A., Umunna, N.N., Tamminga, S. and Van Bruchem, J. (1998). *Relationship between preference, rumen degradability, gas production and chemical composition of browses*. Agrofor. Syst. 39:129-144.

Katiyar, P.N., Tripathi, V.K., Sachan, R.K., Singh, J.P. and Chandra, R. (2012). *Integrated nutrient management affects the growth, flowering and fruiting of rejuvenated ber*. Hort. Flora. Res. Spectrum, 1 (1): 38-41.

Katsaruware, R.D.G.J. (2013). *The Effect of Agroforestry (Leucaena leucocephala) Tree Pruning's in Priming Media as a Nutrient Source in Early Crop Establishment for Maize (Zea mays) in Zimbabwe.* Greener Journal of Agricultural Sciences ISSN: 2276-7770 Vol. 3 (11), pp. 769-777.

Khan, M. (2011). *Seed germination and seedling growth of maize.* African J. of Agrcultural research. 6 (30): 63991-6396.

Kumari, R., Kaur, I. and Bhatnagar, A.K. (2011). *Effect of aqueous extract of Sargassum johnstonii setchell and gardner on growth, yield and quality of Lycopersicon esculentum* Mill. J Appl. Phycol. 23:623-633.

Makkar, H.P.S. and Becker, K. (1997). *Nutrients and antiquality factors in different morphological parts of the Moringa oleifera tree*. J. Agric. Sci., Cambridge 128: 311–332.

Manh L.H., Dung N.N.X. and Vo Tong, X. (2003). *Biomass production of some legumes in the hilly area of Thinh Bien District, An Giang Province. In: Proceedings of Final National Seminar Workshop on Sustainable Livestock Production on Local Feed Resources* (Editors: Reg Preston and Brian Ogle). HUAF-SAREC, Hue City, 25 – 28 March, 2003. Retrieved March, 2015, from http://www.mekarn.org/sarec03/manhcantho2.htm

Medina, M.L. and Pagano, F.G. (2003). *Characterization of Psidium guajava pulp "criolla roja"*. Revista de la Facultad de Agronom´ıa de La Universidad del Zulia, (LUZ) 20, 72–76.

Meena Devi, V.N., Ariharan, V.N. and Nagendra Prasad P. (2013). *Nutritive Value and Potential Uses of Leucaena Leucocephala as Biofuel – A Mini Review.* RJPBCS Volume 4 Issue 1 Page No. 515.

Mishra, G., Singh, P., Verma, R., Kumar, S., Srivastava, S., Jha, K.K. and Khosa, R.L. (2011). *Traditional uses, phytochemistry and pharmacological properties of Moringa oleifera plant*: An overview. Der Pharmacia Lettre. Scholar Res. Lib. 3(2):141-164.

Moktar, H., Giashuddin, M., Tofayel, A. and Noor, S.S. (2012). *Study on allelopathic effect of Moringa oleifera on the growth and productivity of mungbean*. Intl J Agri Crop Sci. Vol., 4 (15), 1122-1128.

Moyo, B., Masika, P.J, Hugo, A. and Muchenje, V. (2011). *Nutritional characterization of Moringa (Moringa oleifera Lam) leaves*. Afr. J. Biotechnol. 10(60):12925-12933.

Muhammad, F., Shakir, M.A. and Salik, M.R. (2000). *Effect of individual and combined application of organic and inorganic manures on the productivity of guava (Psidium guajava L.).* Pak. J. Biol. Sci. 3(9):1370-1371.

N.H.B. (2012*). Online statistical database of National Horticultural Board, Ministry of Agriculture, Govt. of India.* http://www.Indiastat.com /. (Accessed on 8th November, 2014).

Nadir, R.S., Stig, L. and Inger, L. (2006). *Biomass production and chemical composition of Moringa oleifera under different management regimes in Nicaragua Agroforestry Systems.* 66:231–242. DOI 10.1007/s10457-005-8847-y.

National Academy of Sciences (1977b). *Leucaena: promising forage and tree crop for the tropics.* Washington, DC.

Nduwayezu, J.B., Chamshama, S.A.O., Mugasha, A.G., Ngaga, Y.N., Khonga, E.B. and Chabo R.G. (2007). *Comparison in seed kennel sizes and early growth performance of different Moringa oleifera provenances in Southeast Botswana*. Discov. Innov.19: 52-58.

Nouman, W., Siddiqui, M.T., Basra, S.M.A. (2011). *Moringa oleifera leaf extract: An innovative priming tool for rangeland grass*. Turk. J. Agric. For. TUBITAK 35:1-11.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Simons, A. (2009). *Agroforestree Database:a tree reference and selection guide version 4.0* (http://www.worldagroforestry.org/af/treedb/)

Panga, J.T. (2002). *Effect of processing on nutritional quality of Moringa oleifera leaves and pods.* MSc. Dissertation, SUA, Tanzania. pp 81

Paniandy, J. C., Chane-Ming, J., Pieribattesti, J. C. (2000*). Chemical composition of the essential oil and headspace solid-phase microextraction of the guava fruit (Psidium guajava L.).* Journal of Essential Oil Research, 12, 2,153-158.

Perry, D.A., Oren, R. and Hart, S.C. (2008). *Forest ecosystems*. second edition. Baltimore, MD: Johns Hopkins University Press.

Pflugmacher, S. (2002). Possible allelopathic effects of cyanotoxins, with reference to microcystin-LR, in aquatic ecosystems. Environ Toxicol, 17: 407- 413

Phiri, C. (2010). *Influence of Moringa oleifera leaf extracts on germination and early seedling development of major cereals*. Agric. Biol. J.N Amer. 1(5):774-777.

Ram R.A., Bhriguvanshi, S.R. and Pathak, R.K. (2007). *Integrated plant nutrient management in guava cv*. Sardar. Proc. Ist IS on Guava Eds. Acta Hort. 73(5): 345-350.

Ramulu, P. and Rao, P.U. (2003). *Total, insoluble and soluble dietary fiber contents of Indian fruits*. Journal of Food Composition and Analysis 16: 677-685.

Regina, M., Wetrington B.D., Vana stru, F.F. and Aldi-De Vuono. (1999). *Litter and nutrient content in two Brazilian tropical Forest.* Revta brasil. Bot. 22: 1999.

Roe, N.E., Stofella, P.J. and Graetz, D.A. (1997). *Compost from various municipal waste feedstocks affects vegetable crops II. Growth, yield and fruit quality*. J. Am. Soc. Hortic. Sci., 122: 433-437.

Ruehle, G. D. (1948). *The common guava—a neglected fruit with a promising future. Economic botany*, *2*(3), 306-325.

Russel, A and Marsah, E.J. (1997). *Soil conditions for plant growth.* Longman group limited, 10th edition, London and New York pp 264-300.

Salinas N., Malhi Y., Meir P., Silman M., Roman Cuesta R. and Huaman J. (2011). *The sensitivity of tropical leaf litter decomposition to temperature: results from a large-scale leaf translocation experiment along an elevation gradient in Peruvian forests.* New Phytologist 189:967–977 DOI 10.1111/j.1469-8137.2010.03521.

Shanker, Uma., Pathak, R. A., Pathak, R, K., Ojha, C. M. and Shanker, U. (2002).*Effect of NPK on the yield and fruit quality of guava cv*. Sardar. Progressive Horticulture. 34(1):49-55.

Singh, G., Singh, A. K. and Rajan, S. (2001). *Influence of pruning date on fruit yield of guava (Psidium guajava L.) under subtropics. Jour. Appl. Hort*, *3*(1), 37-40.

Smith, F.I. and Eyzaguirre, P. (2007). *African leafy vegetables: Their role in the world health organisation's global fruit and vegetables initiative*. African J. Food Agric. Nutri. And Dev. 7 (3): 1-17.1

Stoffella, P.J., Roe, N.E., Ozores-Hampton, M. and Graetz, D.A. (1997). *Utilization of Organic Waste Composts in Vegetable Crop Production Systems*. In: Managing Soil Fertility for Intensive Vegetable Production Systems in Asia, Morris, R.A. (Ed.). Asian Vegetable Research and Development Center, Shanhua, Taiwan.

Taiwan Guava Production Manual. (2011). *Horticulture Crop Training and Demonstration Center*. first edition.

Temel, S. (2003). *Litter decomposition of Picea orientalis, Pinus sylvestrisand Castanea sativatrees crown in Artvin in relation to their iInitial title quality variables*. Turkey Agric. For. 27: 23–243.

Terrell, T., Baker I.J., Graeme Lockaby, B., William, H. C., Calvin E., Meier John, S.A. and Marianne, K.., Berke. (2001*). Leaf litter decomposition and nutrient dynamics in four southern forested flood plain communities.* Soil Soc. Am. J. 5: 1334–1347.

Tustin, D.S., Stanley, C.J., Adams, H.M., Barritt, B.H. and K.F. (1997). *Physiological and phonological responses of apple trees to artificial reduction of the growth period from harvest to leaf fall.* Acta Hort., 451: 383-404.

Whiting, M., Ophardt D., Lenahan O. and Elfving, D. (2005). *Managing sweet cherry crop load: new strategies for a new problem.* Compact Fruit Tree 38:52-58.

Woods, C.D., Tiwari, B., Plumb, V.E., Powell, C.J., Roberts, B.T., Sirimane, V.D.P., Rositer, J.T. and Gill, M. (1994). *Interspecies differences and variability with time of protein precipitation activity of extractable tannins, crude protein, ash and dry matter contents of leaves from 13 species of Nepalese fodder trees.* J. Chem. Ecol. 20:3149-3162.

Yadav, I. S. (1999). *An overview of nutrient management in horticultural crops.* Indian Hort. 43 (4): 4.

APPENDICES

Appendix 1.0 Analysis of variance: Effect of *moringa* and *leaucaena* biomass on germination percentage of guava seeds

Source of variation	Degree of freedom	Sum of squares	Mean square	F-ratio	Sig.
Treatment	3	2468.75	822.92	37.26	0.001
Residual	12	265.00	22.08		
Total	15	2733.75			

Appendix 2.0 Analysis of variance: Effect of *moringa* and *leaucaena* biomass on number of guava leaves

Source of variation	Degree of freedom	Sum of squares	Mean square	F-ratio	Sig.
Treatment	3	143.688	47.896	46.93	0.001
Residual	12	12.250	1.021		
Total	15	155.938			

Appendix 3.0 Analysis of variance: Effect of *moringa* and *leaucaena* biomass on height of guava seedlings

Source of variation	Degree of freedom	Sum of squares	Mean square	F-ratio	Sig.
Treatment	3	6.82000	2.2733	136.40	0.001
Residual	12	0.20000	0.01667		
Total	15	7.02000			

Appendix 4.0 Analysis of variance: Effect of *moringa* and *leaucaena* biomass on stem diameter of guava seedlings

Source of variation	Degree of freedom	Sum of squares	Mean square	F-ratio	Sig.
Treatment	3	1.2380687	0.4126896	2276.91	0.001
Residual	12	0.0021750	0.0001812		
Total	15	1.2402437			