THE POTENTIAL OF SEAGRASS LITTER AS ORGANIC FERTILIZER IN
KILIFI KENYA

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A thesis submitted in partial fulfilment of the requirements for the degree of
Master Environmental Science of Pwani University

March, 2017
DECLARATION

Student’s Declaration
This thesis is my original work and has not been presented wholly or partial for a Degree or any other award in this or any other University.

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Supervisors’ Declaration
We confirm that the work reported in this thesis was carried out by the candidate under our supervision as University supervisors.

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DEDICATION

I dedicate this thesis to God, my parents, Zachary and Jane Kimaru, siblings Kennedy and Sally Kimaru, my icons and support.
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ABSTRACT

Beach-cast seagrass litter deposits are common in many coastal areas with extended seagrass meadows. Seagrass litter abundance on the shoreline is a contentious issue on the aesthetics of the beaches and as an environmental hazard to beach revelers. To change this perception and view the seagrass litter as a potential asset, this study assessed the seagrass litter accumulation patterns at Mombasa, Kilifi and Malindi shorelines. Further, the efficacy of composted seagrass fertilizer products was evaluated using amaranth (*Amaranthus albus*) as a test vegetable. Beach-cast seagrass was collected, weighed and returned *insitu* at Kenyatta beach in Mombasa, Bofa beach in Kilifi and marine park area in Malindi. The weights were translated to T/ha. Two samples of seagrass, each weighing 500kg, were composted in separate chambers, one with saline composite while the other, with desalinated composite. The litter was composted for 4 months, sifted and packaged as organic fertilizer for field trials. The performance of the seagrass organic fertilizer was compared to farmyard manure and inorganic fertilizer (DAP) in the field trial. New leaf development, leaf size, height, dry matter and leaf yield of Amaranthus plant were used as growth parameters to assess the efficacy of seagrass organic fertilizer. Highest accumulation of seagrass litter was noticed in Kilifi at 72.4T/ha which was significantly different (P<0.005) from Malindi at 26.5T/ha and Mombasa at 24.75T/ha. There was no significant difference in litter accumulation between Malindi and Mombasa. After four (4) months of composting seagrass, the saline setup achieved 85% decomposition, while the desalinated setup decomposed at 75%. However, fertilizer from the saline setup performed better than the desalinated, farm yard manure and the control. Half rate application of the saline product produced better results compared to all the applied rates of the seagrass products. Three weeks after transplanting, it achieved an average of 25.3cm plant
height compared to control at 22.7cm, while commercial fertilizer recorded 29.6cm as a positive control. New leaf development recorded an average of 12.8, 12.3, 12.1 and 13.2 leaves for seagrass products, farm yard manure, control treatment and commercial fertilizer, respectively. Half rate application of the saline product achieved 16.9T/ha leaf yield which was higher than all applied rates of the seagrass products and farm yard manure. However, commercial fertilizer recorded 30T/ha which was significantly different from all the treatments. Half rate application at 30g/hill saline seagrass product performed better than full rate 60g/hill of the same, and all application rates of the desalinated product. These findings indicate that seagrass fertilizer products are a potential alternative source of plant nutrients that can complement the available inorganic fertilizers.
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# ABBREVIATIONS AND ACRONYM

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>CAN</td>
<td>Calcium Ammonium Nitrate</td>
</tr>
<tr>
<td>DAP/</td>
<td>Diammonium Phosphate</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization</td>
</tr>
<tr>
<td>FERT-DESAL</td>
<td>Desalinated Fertilizer</td>
</tr>
<tr>
<td>FERT-SAL</td>
<td>Saline Fertilizer</td>
</tr>
<tr>
<td>FYM</td>
<td>Farm Yard Manure</td>
</tr>
<tr>
<td>KEMFRI</td>
<td>Kenya Marine Fisheries Research Institute</td>
</tr>
<tr>
<td>NEMA</td>
<td>National Environment Management Authority</td>
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<tr>
<td>SOD</td>
<td>Superoxide Dismutase</td>
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CHAPTER ONE: INTRODUCTION

1.1 Background Information

Seagrasses are unique marine underwater flowering plants, with strap-like leaves or paired oval leaves. They grow in shallow coastal marine locations characterized by salty marshes and estuaries that have soft sand or muddy bottoms. They have extensive well-developed root system for anchorage, stopping them from being washed away by sea waves (Beena et al., 2015). Seagrasses are the most widespread coastal vegetation worldwide, protecting shorelines against erosion both in the middle and lower intertidal and subtidal zones (Slim et al., 1996). Seagrasses significantly contribute to the energy pathways, with diversity of organisms being involved in a complicated food interrelationship (Burrell & Schubel, 1977). The ability and efficiency of seagrasses in nutrient removal from marine waters and surface sediment makes it an important plant in the significant role of coastal water quality control (Patriquin, 2002). Seagrass meadows are among the most productive biological systems and are best known for their accumulation and stabilization of sediments from surrounding environment (Fry et al., 2013). Fishes, dugongs, ducks and sea urchins get direct food from fresh seagrasses while more often, epiphytic algae growing on the seagrasses act as food resource for most marine macro-invertebrates (Pinto and Punchihewa, 2006). Seagrass beds also provide shelter and nursery functions for juvenile stages of commercially important species in the fisheries (Irlandi, 2007).

A dense seagrass meadow may consist of more than 4000 plants/m$^2$, with a standing crop biomass of 1-2 kg/m$^2$ dry weight. Seagrasses act as nutrient pump due to their ability to absorb nutrients from sediments via roots and release nutrients through their leaves hence contribute to the poor waters of coral reefs (Hemminga et al., 1995). It has been established that there are about 60 seagrass species in 4 families and 12 genera.
Most biologists recognize four major families of seagrasses: the Zosteraceae, Hydrocharitaceae, Cymodoceae and the Posidoniaceae (Kuo et al., 2006).

Early uses of seagrass were limited to diet and medicine. Seagrass like many sea foods are high in Iodine, clinically known for goiter prevention, boosting metabolism, sterilizing agent, and good for breast and ovarian health, which is rare in many food crops (Jennifer & Townsend, 2003). Recent scientific research has found seagrass to be useful as an inorganic fertilizer. The University of Miami Marine Laboratory states that most seagrasses are excellent sources of major fertilizer elements such as Nitrogen, Phosphorous and Potassium as well as many elements required in minute quantities for normal plant growth such as auxin, cytokinin and gibberellins (Angie, 2008). The use of seagrass as manure dated back tens of centuries ago. There are records of this practice amongst the Romans, British, French, Japanese and Chinese (Hemminga et al., 1995). Seagrass farming has been undertaken in many countries to provide high quality manure for farm use (Jaliya, 2012). The Philippines is one of the world’s top seagrass producing countries, with several companies buying seagrass from farmers, composting it into manure and exporting it as organic fertilizer to other parts of the world (Sridhar, 2010).

1.2 Seagrass in Kenya

Kenya’s coastal region of bays, reefs and estuaries form important zones of productivity. The shallow coastal zones are colonized by marine angiosperm, referred to as seagrasses which superimpose the structural component on an otherwise bare muddy bottom. They serve as a habitat for small invertebrates and fishes (McMillan et al., 1997). Additionally, they shelter threatened species like the green turtle, hawk-bill turtle and the dugongs. Although seagrass extraordinarily display high degree of
phenotypic plasticity to changing environmental conditions, threats mainly from human
disturbance notably eutrophication, mechanical destruction of habitat and over fishing
affects them. Along the Kenyan coast, seagrass beds occur in patches sometimes
extending in creeks. About 14 species of seagrasses have been reported in the Kenyan
coast. These include; *Cymodocea rotunda*, *C. serrulata*, *Enhalus sacoroides*, *Halodule
uninervis*, *H. writii*, *H. alophilaminorm*, *H. ovalis*, *H. stipulacea*, *Syringodium filiforme*,
*Thalassia hemprichii*, *Thallassodendron testudinum*, *Thalassadendron ciliatum* and
*Syringodium isoetifolium* (De Wit, 1998). The following plates illustrate examples of
seagrasses:

Plate 1: a) *Syringodium filiforme*  b) *Thalassa testudinum*

*Source: http://uncw.edu/cms/bermuda2012/2012day05.html*

Ochieng (1999) conducted a quantitative assessment between 1995 and 1996, and
observed that an average total of 93,000 kg dry weight of beach cast material are
deposited along a 9.5 km stretch of beaches in northern coast of Mombasa. An average
of 88.18% of the beach cast dry weight consisted of seagrass material (88% leaves),
while the remainder was composed of the seagrass *Sargassum sp.* and *Ulva sp.* Due to
suitable substrate, *Thalassadendron ciliatum* constituted the major part (76%) of the
seagrass tissue on the beach followed by 15 % of *Syringodium isoetifolium* (Jokiel &
Morissey, 1993). Another study carried out sought to quantify and describe the
distribution of the seagrasses through satellite remote sensing along the Kenyan coast
using 10 sectors. It revealed that the extent of the algal vegetation in the area was 32
square kilometers (Dahdouh et al., 2004).
With their shallow sub littoral and intertidal existence, Kenya’s seagrasses are subjected to stress, imposed by the ever-growing use of the coastal zone and estuarine as an avenue of transport, receptacle of waste and source of recreational and aesthetic pleasure. A large part of Kenyan coast is characterized by white sandy beaches, which play a significant role to the tourism industry hence of importance to Kenya’s economy. To recreation and tourism sectors, accumulations of beach cast seagrass litter is often considered a nuisance due to its non-aesthetic quality. Despite the economic importance of these beaches, no previous detailed studies of alternative utilization of this substantial accumulation beach cast material have been done. Based on the identified problem of continuous accumulation of seagrass along Kenyan coast, this study aimed at experimenting on the viability of seagrass litter as a potential organic fertilizer to provide alternative fertilizer to conventional ones as beaches are cleaned of seagrass litter.

1.3 Statement of the Problem

Beach cast seagrass along the beach is an eye sore to tourists and beach revelers. As it decomposes, it becomes a source of foul smell whose litter degrades the aesthetic value of the beautiful white beaches. Beach management committees spend lots of resources and time cleaning up the beach cast litter which they finally bury. As it decomposes, it oozes humic acid which is a beneficial component to crops while some of the buried litter is washed back to the sea by the strong waves. This study therefore utilized beach cast seagrass to develop organic fertilizer as an alternative farm input to the current inorganic fertilizer.

1.4 The Objective of the study

The main objective of the study was to evaluate the potential of Seagrass as an organic fertilizer
1.5 Specific Objectives

The specific objectives of the study are:

i) To assess the seagrass distribution along the Kenyan North Coast shorelines

ii) To establish the nutrients levels of the seagrass fertilizer

iii) To evaluate the efficacy of seagrass organic fertilizer

1.6 Hypotheses

(i) H₀: The annual seagrass accumulation does not vary with seasons

(ii) H₀: Seagrass compost does not provide adequate nutrients for plant growth.

(iii) H₀: Seagrass composites does not compare to other fertilizers

1.7 Justification of the study

Intensive farming has tended to overuse inorganic fertilizers which lowers the soil pH, that creates acidic soils, breaks down soils physical structure, reduce water holding capacity, making soils more friable and vulnerable to erosion. Overuse of inorganic fertilizer, generally lowers soil fertility and pollutes ground water. However, application of organic fertilizer improves the soil structure, water holding capacity, and generally good soil health. Furthermore, the soils in the lower coastal region are naturally friable sandy loam soils characterized by low fertility

Accumulation of seagrass litter along the beach lines affects the beauty and aesthetic value of the beaches. White sandy beaches are a preference for many tourists and beach revelers. Based on these criteria, Diani Beach in Kwale County put Kenya on the world map after being voted among the top 25 beaches in the world in 2015 (https://www.tripadvisor.com). To achieve high quality beach standards, local beach management units in several counties, have developed beach cleaning programs where the seagrass litter is collected as waste and buried insitu along the beach lines. The litter
develops into humus which oozes as black streams against the white beach sand. This scenario therefore negates the purpose of removing and burying seagrass litter from the beach. Organic fertilizer made from seagrass have been found to provide a wide range of benefits that include a well-balanced nutrition, improved growth and development of crops, increased resistance to biotic and abiotic stress, soil conditioning and enhanced yields (Horizon, 2012). The composted fertilizers are easily absorbed by the plants and enhance effects of other farm inputs, stimulating metabolic processes which help the plant to explore leaf-locked nutrients (Schoorl & Visser, 1991). It also effectively improves soil conditions and absorption of nutrients from the soil (Taha et al., 2011). This study therefore proposed to assess seagrass as an alternative source of farm input.

1.8 Scope of the Study

Seagrass distribution

This study was aimed at experimenting on seagrass litter to develop fertilizer products and assess their efficacy on yield of Amaranths (Amaranthus albus). The study was limited to conditions affecting the shorelines of the North Coast of Kenya, with Mombasa, Kilifi and Malindi as sampling sites. The efficacy trials were limited to leafy vegetables with Amaranth as the test plant. All nutrient assays were conducted in government accredited laboratory. The farm trials were limited to conditions at Pwani University farm that represented the lower humid coastal region.
CHAPTER TWO: LITERATURE REVIEW

2.1 Seagrass botany

Seagrasses are grass-like flowering plants that live completely submerged in marine and estuarine waters. They are the most widespread coastal vegetation worldwide; the only flowering plants that can live underwater (Hartog & Den, 1990). They grow in shallow coastal marine locations, salt marshes and estuaries with soft and or muddy bottoms. They have erected elongate leaves and an extensive well developed root system (rhizome) for anchorage, stopping them from being washed away by sea waves (Beena et al., 2015).

They protect shorelines against erosion both in the middle and lower intertidal and subtidal zones (Slim et al., 1996). Seagrass meadows rank among the most productive biological systems of the oceans and are best known for their accumulation and stabilization of sediments from surrounding environment (McMillan et al., 1997). They produce a greater amount of organic matter and serve as a good substratum for a variety of epiphytic algae including diatoms and sessile fauna (Smith, 1991). Their ability to effectively remove nutrients from marine waters and surface sediments makes them an important plant in the coastal water quality control (Patriquin, 2002). Seagrass beds provide shelter and nursery functions for juvenile stages of commercially important species in the estuarine fisheries (Irlandi, 2007). They act as food resources for most marine macro-invertebrates with fishes, dugongs, ducks and sea urchins getting direct food from fresh seagrasses (Pinto & Punchihewa, 2006).

There are 12 genera and 58 species of seagrass available all over the world. The genera (Amphibolis, Heterozostera, Phyllospadix, Posidonia, Pseudanthenia and Zostera) are mostly restricted to temperate seas and the remaining seven genera (Cymodocea,
Enhalus, Halodule, Halophila, Syringodium, Thalassia and Thalassodendron) are distributed in tropical seas (Short & Coles, 2001). Most biologists recognize four major families of seagrasses: the Zosteraceae, Hydrocharitaceae, Cymodoceae and the Posidoniaceae (Kuo et al., 2006). Early uses of seagrass were limited to diet and medicine. Seagrass like many sea foods are high in Iodine, clinically known for goiter prevention, metabolic boost, sterilizing agent, and good for breast and ovarian health (Jennifer & Townsend, 2003). Recent scientific research has found seagrass to be useful as an organic fertilizer (Fry et al., 2013). The University of Miami Marine Laboratory states that most seagrass are excellent sources of the major fertilizer elements such as Nitrogen, Phosphorous and Potassium as well as many elements required in minute quantities for normal plant growth such as auxin, cytokinin and gibberellins (Angie, 2008). The use of seagrass as manure dated back tens of centuries ago, with records of this practice being amongst the Romans, British, French, Japanese and Chinese (Hemminga et al., 1995). Seagrass farming has been undertaken in many countries to provide high quality manure for farm use (Jaliya, 2012). The Philippines is one of the world’s top seagrass producing countries, with several companies buying seagrass from farmers, composting it into manure and exporting it as organic fertilizer to other parts of the world (Sridhar, 2010).

2.2 Seagrass biodiversity

Seagrasses are unique for being the only angiosperms adopted to marine life out of the several two to three hundred thousand species of flowering plants, (Hemminga and Buth, 2011). They are the only rooted organisms in the near shore region, that act as foundation for thousands of other taxa including vertebrate and invertebrate species, using the biome for shelter, foraging sites, spawning habitat, and nurseries (Preen et al., 1995). Seagrass ecosystems and other macro algal species strongly influences
sediment biogeochemistry, nutrient cycling, water-column oxygen profiles, water filtration capacity, primary and secondary production, carbon storage, support of higher trophic levels including commercially important species, and response to disturbance (Deegan, 2002). Seagrass protection therefore safeguards species richness, biodiversity, ecosystem structure, and many ecological processes. The loss of seagrasses alters the flow of organic matter, nutrient cycles, and food webs throughout coastal ecosystems which eventually leads to economic disasters including the collapse of fisheries, degradation of water quality and the decline of other living resources (De Jonge & De Jonge, 2002).

2.3 Threats to biodiversity of seagrass ecosystems

Seagrasses are subjected to stress imposed by the ever-growing use of the coastal zone (De Wit, 1998). The continuous demand of the coastal environment as producers of food, transportation avenues, receptacles of waste, living space and sources of recreational or aesthetic pleasure, has affected seagrass beds (De Wit, 1998). Stations with high density of hotels are more likely to have human activity that’s more detrimental towards seagrass growth and development. Motor boat propellers, anchors, esthetic activities like dredging and filling operations affects larger part of coastline than other activities. Construction of hotels or residential facilities at water front destroys seagrasses directly either by uprooting or burying them (Kemp et al., 2003). Large-scale upstream activities like deforestation or use of poor farming techniques near coastal regions results in silt discharges. This causes reduced penetration of light, thus impairing photosynthesis hence productivity of the seagrass beds and associated communities (Philip & Ernani, 2008). With global rising energy demands, seagrasses are the most susceptible communities through the crude oil spillage arising from petroleum transport by ship (McClanahan & Muthiga, 1999). City sewage effluents
drained in the shallow sub tidal ocean through underground pipes result in rise of nutrients levels (nitrates, nitrites and phosphates) and the accumulation of deposits on the leaf surfaces that may reduce the habitable area and structural complexity for phytal meiofauna leading to a decrease in abundance and diversity (Hamisi et al., 2004).

Fishermen’s foot and canoe pathways to the deep sea are continuous activities that are destructive to seagrasses, where they appear from a range 250- 500meters (Mohammed, 2000). Where motorboat density is high, the boat propeller and anchor cause disturbance to seagrasses by the cutting of leaves and shoots in shallow waters, uprooting of rhizomes leaving holes in seagrass beds (Short & Wyllie, 1996). Large volumes of detached seagrasses at the shores cause aesthetic disturbance to swimmers during high tides. Hoteliers clean large areas of intertidal seagrass beds which are deemed a nuisance to tourists.

Apart from these anthropogenic inputs, a number of environmental parameters are critical to whether seagrass will grow and persist (Armenteros et al., 2010). These include physical parameters that regulate the physiological activity of seagrasses (temperature, salinity, waves, currents, depth, substrate and day length), natural phenomena that limit the photosynthetic activity of the plants (light, nutrients, epiphytes and diseases), and those that inhibit access to available light for growth (nutrient and sediment loading). Various combinations of these parameters will permit, encourage or eliminate seagrass from a specific location (Philip & Ernani, 2008). The depth range of seagrass is usually controlled at its deepest edge by the availability of light for photosynthesis. Exposure to low tide wave action and associated turbidity, low salinity from fresh water inflow, determines seagrass species survival at the shallow edge. Seagrasses survive in the intertidal zone especially in sites sheltered from wave action or where there is entrapment of water at low tide, (e.g. reef platforms and tide
pools), protecting the seagrasses from exposure (to heat, drying) at low tide (Armenteros et al., 2010).

2.4 Seagrass-Coral-Mangrove interactions

Tropical seagrasses are important in their interactions with mangroves and coral reefs. All these systems exert a stabilizing effect on the environment, resulting in important physical and biological support for the other communities (United Nations Educational, Scientific and Cultural Organization, 2003). Barrier reefs maintain integrity of the coastlines by acting as buffer to dissipate wave energy before reaching seagrass beds and mangrove stands. Mangroves filter nutrients and sedimentation from land based runoff hence improving water quality before reaching seagrass (John, 2003). Seagrass further filters nutrients and sediments before discharge unto reefs hence improving the water quality. This symbiotic relationship between mangroves, corals and seagrasses harmoniously protects coastline from erosion and destructive energy from waves.

2.5 Empirical literature on seagrass fertilizer

Considerable evidence has been accumulated in recent years to support and identify the benefits associated with the use of seagrass extracts in crop production systems. Brown (2012) reports that replicated trials on tomato showed significant increases in yield 8%. Similar results were found for pepper weight yield 30% and fruit number 47% (Clark et al., 1999). Greenhouse results on fresh market tomatoes indicated an increase in overall yield by 14 and 49% (for recommended and double rate applications, respectively). Similar results were found for potatoes 6%, bananas 2.5%, grapes 31% and apples 7% (Clark et al., 1999). On a larger acreage, trials demonstrated significant increase in fruit firmness cherries 5-15%, apples 8%, peaches 5-13%, and grapes up to 23% (Ahmed & Shalaby, 2012).
2.6 **Effects of seagrass liquid fertilizer on plant growth**

A field experiment was conducted during the rainy season in India in 2006 to study the effects of foliar applications of different concentrations of seagrass extract on nutrient uptake, growth and yield of soybeans (Ahmed & Shalaby, 2012). The highest soybean yield was recorded with applications of 15% seagrass extract, followed by 12.5% seagrass extract that resulted in 57% and 46% increases respectively compared to the control. The maximum straw yield was also achieved with 15% seagrass extract application. Thus, under rain-fed soybean production, foliar applications of seagrass extracts could be a promising option for yield enhancement (Rathore et al., 2008).

Ahmed & Shalaby, (2012) conducted an experiment to investigate the effect of three seagrass extracts like red alga (*Asparagopsis* spp), red alga (*Gelidium pectinutum*), green alga compost and the commercial seagrass extract on cucumber hybrid Prince. Direct seeds were sown in May and plants sprayed with different seagrass extracts with or without compost application. Results showed that using seagrass extract of green alga, red alga or commercial seagrass extracts with compost is considered a suitable application to improved vegetative growth and yield of cucumber plants. Suwandana et al., (2011) investigated concentrations of heavy metals (Fe, Zn, Cu, Hg and Pb) and nutrients (N, P and K) in the seawater, seagrass (leaves and corms) and sediments of Banten bay in Indonesia and analyzed their spatial distribution patterns in the sediments. The results revealed that the concentrations of heavy metals and nutrients in the seawater samples from the sixteen stations were relatively low, with most concentrations being below the limits of detection (Immanuel & Sabramanian, 2009). In the sediments, all heavy metal concentrations were lower than those previously reported for Jakarta bay in Indonesia and Gokova bay in Turkey. Excluding total K, the mean concentrations of total P and N were also higher than those found in China and
Japan, respectively. With the exclusion of Pb, the concentrations of other elements in the seagrass were higher than concentrations found in Jakarta bay, Larymna bay (Turkey) and the Gulf of Mexico.

Immanuel & Sabramanian, (2009) conducted a study to investigate the influence of monthly field applications of seagrass extract. The liquid seagrass extracts from seagrass were prepared by hydrolyzing the material under pressure while this preparation may vary from species to species depending on the amount of dried material available. Foliar application (spraying) was done to ensure fast absorption of nutrients to plants hence quick rectification on nutrients deficiency (Zodape & Kawarkhe, 2008). However, multiple application of liquid is necessary to supply a sufficient quantity of the nutrients (Zodape & Kawarkhe, 2008). Once applied, foliar nutrients may be washed off by rains before the plants can absorb. This can be countered by using surfactants to increase the efficiency of penetration on leaf surface and the duration of the spray on the leaf be increased depending on the situation (Sridhar, 2010). In certain cases, application of high concentration of nutrients in foliar spray may cause severe leaf damage due to phyto-toxicity. To avoid this situation, repeated application of dilute formulation therefore is necessary to supply the plant nutrient requirement without damaging the foliage (Taha et al., 2011).

The study was successful in determining that seagrass extract contains high levels of nutrients that can replace organic fertilizers and can be used as a bio-stimulant in agriculture during a crop cycle (Immanuel & Sabramanian, 2009).

2.7 Amaranthus as a test plant

The proposed study intends to assess the impact of seagrass nutrients on Amaranthus (Amaranthus albus). Amaranthus grow in temperate and tropical climates and can be used as grains or vegetables (Grubben, 2004). Some of the most widely grown species
include *Amaranthus cruetus* and *Amaranthus meritus*. Amaranthus leaves, stems and the entire plant may be eaten raw or cooked as spinach. Most African countries use Amaranth as nutritious food in regard to treating those suffering from HIV/AIDS.

![Plate 2: Amaranthus plant](image)

Nutritious value of amaranth has been defined as excellent source of proteins with its maximum accumulation in the blossoming phase (Andini et al., 2013). Amaranth is highly recommended for its tenderness as vegetables and its high medical properties for the young and lactating mothers. It is also a food to people with anemia and kidney complications. Amaranth alone or mixed with nightshades is used as a vegetable and has been used for children, treating fever, stomach ache and for making potash (Asian Vegetable Research and Development Center, 2008). Although vegetable amaranth has drawn little researcher's attention, the vegetable has high mineral content including calcium, iron and phosphorous (Andini et al., 2013) than most vegetables. Its bitterness sometimes has made its use limited as many people would opt for other vegetables in the market. However, amaranth remains a nutritious vegetable plant termed as wild by many.

### 2.8 Ecological effects of seagrass litter

Abundant seagrass litter in many coastal ecosystems is part of detrital food webs. Seagrasses in temperate and warm temperate waters are a direct source of food for a
limited number of organisms, for example isopods, sea urchins, abalone and some fish species. Among seagrass species, Cycomoducea is an important macrophytic primary producer. This is due to its high productivity which significantly contributes to overall production of organic materials (Peduzzi & Herndl, 1999). Seagrass material can be incorporated directly by herbivores or omnivores via detritus by detritivores or indirectly via predation on the former species. Thus, small crustaceans incorporate seagrass carbon into their tissues and form an important part of the diet of fish species in tropical seagrass meadows (Lugendo et al., 2006). In countries where seagrass farming has been practiced, its considered a dominating form of mariculture because it is environmental friendly (Sievanen et al., 2005). It does not cause any major physical alteration of the environment and requires little or no input of fertilizer or medicine. It is therefore heavily promoted as an alternative sustainable aquaculture practice for local coastal communities (Johnston & Ólafsson, 1995).

2.9 Research gap

The easy though slow release of nutrients, as well as low nutrient content have contributed to limited use of organic fertilizers when compared to chemical fertilizers. Use of seagrasses as fertilizer products would open doors to embrace organic fertilizers as an alternative to inorganic fertilizers. Organic fertilizer products are known to play vital roles in soil fertility, crop productivity and production in agriculture as they are environmental friendly. However, they cannot at any cost replace chemical fertilizers that are indispensable for getting maximum crop yields (McKenzie & Campbell 2004). For maximum output from organic fertilizers, set quantities minimizing the use of chemical fertilizers can be used (Jaliya, 2012). This study would therefore lead to a solution not only to crop productivity but also improve drainage in poorly drained coastal soils.
CHAPTER THREE: MATERIALS AND METHODS

3.1 Assessment of seagrass litter distribution

The possible sites for seagrass accumulation were identified. For objective one (i), three beach fronts in the North Coast namely Kenyatta beach in Mombasa (WGS 1984 UTM Zone 37S, 580779.52 m E, 9557212.10 m), Bofa beach in Kilifi (WGS 1984 UTM Zone 37S, 599362.45 m E, 9604021.81 m S) and Malindi public beach near the Kenya marine protected area (WGS 1984 UTM Zone 37S625431.22 m E, 9640744.79 m S) were selected. Based on accumulation data in objective two (ii), Kilifi beach was selected for sea grass collection for the purpose of fertilizer development.

3.1.1 Study area

![Figure 1: Location of Kilifi, Malindi and Mombasa sampling shoreline.](image-url)
3.1.2 Seagrass Sampling

Monthly seagrass assessments in Malindi, Kilifi and Mombasa were concurrently done in the first week of January through December 2015. All the sites were observed on the same day and time to avoid disparities in the data.

A square metal quadrant of 1 x 1M was used as a sampling unit in the field. Each site was loosely divided into 10 stations. Through purposeful sampling, seagrass samples were collected from the middle beach position with assumption it was what was brought to the shore for that day.

Seagrass litter distribution was assessed at every 20 meters interval through a line transects along the beach; where the quadrant was thrown and all the seagrass litter in the quadrant collected and weighed *insitu*. Collection and sampling was done during the low tide after the water had resided and left deposits of seagrass litter along the beach front. All the plastics and other debris were removed before weighing the seagrass samples. The rest of the seagrass was returned to the sampled sites on the shoreline after each weigh.
3.1.3 Collection of Seagrass

Among the three sites Mombasa, Malindi and Kilifi, preliminary data indicated that Kilifi had the highest collection per year hence chosen for bulk processing. Samples were collected from Bofa beach Kilifi at Mwisho wa Lami site (WGS 1984 UTM Zone 37S, 599362.45 m E, 9604021.81 m S) and transferred to Pwani University garbage collection site for composting.

3.2 Composting seagrass into fertilizer

Constructed composting chambers sized (4 x 5 x 3M) were prepared to each host treatments of about 500Kg. One chamber composted saline seagrass (as collected from the sea) while the other desalinated seagrass, which was achieved by serially washing it with fresh water. The treatments were then labeled Treatment A and Treatment B, respectively.

3.2.1 Composting Saline seagrass (Treatment A)

The first layer of saline seagrass (Treatment A) was spread across the chamber up to 15 cm height. It was then evenly inoculated with EM (Effective Microorganism), diluted 20 times and partially buried using two inch layer of soil. The soil layer was used to speed up decomposition and hold down any odor that would emanate from the rotting seagrass. After applying the forest soil, more seagrass layers were added, sprayed with EM and covered with a layer of forest soil (Page 22: Picture 4 ). The above procedure was repeated 5 times to create six layers of seagrass for composting. The setup was then reinforced with wooden planks, watered and labeled (Page 19: Plate 4). To enhance composting the setup was watered weekly with 20 liters fresh water for two and half months.
3.2.2 Composting of desalinated seagrass (Treatment B)

3.2.3 Pre-run of desalination process

A pre-trial was first done using simple desalination procedure where five buckets, each with 20 liters capacity were filled with 10 liters of water (Page 22: Picture 2). One kilogram (1kg) of seagrass was filled in a netted sack, immersed in the first bucket for 5 minutes and the water allowed to drip off for 3 minutes. The immersion was repeated serially through five buckets filled with fresh tap water and the conductivity of the water in each bucket monitored after every immersion. Water in the fifth bucket was monitored and conductivity maintained at not more than 1000 micro siemens (µS). When salt reading hit the 1000µS mark, it was replaced with fresh water which was placed at the tail end (Page 22 Pictures 2).
Table 1: Conductivity readings for desalination process after 5 dipping in each bucket

<table>
<thead>
<tr>
<th>Buckets</th>
<th>Conductivity in Micro Siemens (µs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bucket 1</td>
<td>14330</td>
</tr>
<tr>
<td>Bucket 2</td>
<td>7160</td>
</tr>
<tr>
<td>Bucket 3</td>
<td>3270</td>
</tr>
<tr>
<td>Bucket 4</td>
<td>1867</td>
</tr>
<tr>
<td>Bucket 5</td>
<td>801</td>
</tr>
</tbody>
</table>

It was noted that each serial dipping lowered salt levels from the seagrass product by approximately a half the initial level. Conductivity was measured using a conductivity meter. It was noted that at least 5kgs of seagrass would pass through each bucket to attain the 1000µs in the 5th bucket.

Plate 5: Treatment B (Desalinated sample)

3.2.4 Actual desalinization

Five drums were filled with 100 liters clean fresh water and placed in a series. Five kilograms (5Kg) of seagrass litter was filled in a meshed sack and dipped serially in the five drum and the conductivity in drum number five monitored and recorded. The results were as follows:
Table 2: Conductivity readings in drum 5 after serial dipping

<table>
<thead>
<tr>
<th>5th drum reading After each dipping</th>
<th>Micro Siemens (μS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st dipping</td>
<td>380</td>
</tr>
<tr>
<td>2nd dipping</td>
<td>580</td>
</tr>
<tr>
<td>3rd dipping</td>
<td>677</td>
</tr>
<tr>
<td>4th dipping</td>
<td>713</td>
</tr>
<tr>
<td>5th dipping</td>
<td>760</td>
</tr>
<tr>
<td>6th dipping</td>
<td>861</td>
</tr>
<tr>
<td>7th dipping</td>
<td>950</td>
</tr>
</tbody>
</table>

It was noted that 5 kg of seagrass litter passed through the 5th drum at least 7 times before the conductivity levels hit 1000μs mark, hence needing replacement. This procedure was used as a template for the subsequent desalinating process. The desalinated seagrass product from the 5th drum was then spread in the composting chamber and partially buried as described in 3.2.1.

3.2.5 Assessing the rate of seagrass decomposition

1Kg of the seagrass compost was sampled monthly to assess the rate of decomposition. The fertilizer product was sieved through a 4.75mm standard soil sieve (because that could allow particles that could help the soils structure). Each month, the ratio of seagrass product that passed through the sieve, to that which did not was recorded and expressed as a percentage for a period of four (4) months. After the four months, seagrass fertilizer compost was ready and was transferred from the composting chambers to a shade, awaiting sieving process.

3.2.6 Preparation of fertilizer products

The seagrass product was passed through a mechanical sieve prepared with mesh wire (5.5 inch openings) supporting a coffee tray wires with 5mm openings. The product
was manually loaded onto the highest point of the sieve and allowed to trickle down by gravity. This movement separated the un-decomposed from the fully decomposed seagrass fertilizer product (Plate 6: Picture 5).

![Picture 1: Seagrass collection at Bofa beach, Kilifi](image1)

![Picture 2: Desalinization set up](image2)

![Picture 3: Conductivity check](image3)

![Picture 4: Inoculating with Effective Microorganisms (EM)](image4)

![Picture 5: Seagrass sieving](image5)

![Picture 6: Seagrass fertilizer products packaging](image6)

Plate 6: Summary of Seagrass fertilizer preparation process
3.3 Chemical analysis of fertilizer products

Samples of fertilizer products prepared from saline seagrass (FERT-SAL), and that from desalinated (FERT-DESAL) were sampled and taken for chemical analysis. The samples were digested in tubes with Sulphuric acid, Salicylic acid, Hydrogen peroxide (H₂O₂) and Selenium. The larger part of organic matter was oxidized by (H₂O₂) at relatively low temperature 1000°C (Kawamata et al., 2006). After expulsion of the excess H₂O₂ and evaporation of water, the digestion was completed by concentrated Sulphuric acid at elevated temperature (3300°C) under the influence of Selenium as a catalyst. Sodium and potassium were determined using a flame photometer, Phosphorus was determined calorimetrically on spectrophotometer; N-total was measured by distillation followed by titration. Other cations; Ca⁺, Mg⁺, Cu⁺, Zn⁺, Mn⁺ and Fe⁺ were evaluated using Atomic Absorption Spectrum AAS (Kawamata et al., 2006).

3.4 Field trials

3.4.1 Land Preparation

A total of 84 plots were laid out each measuring 2M x 3M, with a buffer zone of 0.5M between the plots and 1m between blocks. A complete randomized block design was adopted with three (3) blocks each having a complete set of treatments. Each treatment was replicated four times per block and completely randomized within the block as shown in Table 3.
Table 3: Layout of experimental design

<table>
<thead>
<tr>
<th>Block 3</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<td>T4</td>
<td>T7</td>
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<td>T2</td>
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<td>T7</td>
<td>T6</td>
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</tbody>
</table>

<table>
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<td>T4</td>
<td>T6</td>
<td>T1</td>
<td>T5</td>
<td>T4</td>
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<tr>
<td>T1</td>
<td>T5</td>
<td>T5</td>
<td>T7</td>
<td>T2</td>
<td>T3</td>
<td>T7</td>
</tr>
</tbody>
</table>
3.4.2 Seed bed preparation

A 5x1M seed bed was prepared. The soil was dug out, clods broken to fine tilth and raked to obtain a leveled surface. Lines about 10 cm apart were made across the seed bed and seeds sprinkled thinly along. The seeds were lightly covered with a thin film of soil and watered. A shed net (80%) was placed along the bed to avoid direct strong sunlight. The seedlings were transplanted to the main plots after three (3) weeks.

3.4.3 Treatments

The following seven treatment levels were adopted:
TI: Control: No fertilizer/ No manure

T2: DAP/CAN fertilizer

T3: Half rate (30g/hill) application of FERT-SAL

T4: Full rate (60g/hill) application of FERT-SAL

T5: Half rate (30g/hill) application of FERT-DESAL

T6: Full rate (60g/hill) application of FERT-DESAL

T7: Full rate (60g/hill) application FYM.

Farm yard manure (FYM), CAN/DAP fertilizer and Control were used as tests, against the saline and desalinated seagrass products.

3.4.4 Transplanting

Based on the 5T/Ha application rate for FYM manure, the 2x3M plots were applied with 3Kgs of fertilizer product. This translated to 60g per hill for spacing of 50x15cm for Amaranth vegetable. Full rate application was therefore pegged at 60g/hill while half rate at 30g/hill. The 2x3M plots were dug to a fine tilth and five rows marked out with 15 holes each row. The fertilizer was applied according to the treatment chart in Table: 3 and seedlings transplanted and watered in their respective plots.

3.5 Data collection and analysis

3.5.1 Plant growth parameters

Two weeks after transplanting, plants were marked prior to data collection. The following growth parameters were assessed: Number of new leaf development, size of the leaf, plant height and leaf size. In each plot, five plants were randomly selected from each of the three middle rows. Four (4) leaves were identified and marked with different colored rubber bands for easy of identification in subsequent data collections. Colored bands: yellow, blue, green and red were used, representing leaf 1 (L1), leaf 2
(L2), leaf 3 (L3) and leaf 4 (L4), respectively.

The bands were carefully inserted at the petiole of each selected leaf as shown in Plate 9. Data collection for leaf length (mm) and leaf width was done using a ruler, from the petiole to the apex of the leaf and recorded.

3.5.2 Number of new leaf development

Five plants were picked randomly from the inner three rows of each plot which were used to record all parameters assessed during data collection. Three days after planting, the number of leaves was counted from the base of the plant along the main stem to the last top leaf before the bud. The exercise was repeated after two weeks.

3.5.3 Yield data

Three weeks after transplanting, all plants in the plots except the guard rows were harvested by cutting the primary stalk 20 cm from the ground and weighed, to determine yield (Kg). This was followed by weeding to avoid weed competition. The guard rows were harvested later but were not included in the preparation of the production data. Harvesting was done after every three weeks and data recorded.
3.5.4 Dry matter evaluation
At the end of 3 months, dry weight was taken by randomly choosing five plants from the 15 marked plants per plot. The plants were pulled out, soil washed off, and the wet weight in grams recorded. The individual plants were then dried using an oven at 60°C for two days, cooled and weighed.

3.5.5 Data analysis
Analysis was done through general linear model using block as a random effect and treatment as a fixed effect. Data obtained from the field growth parameters were subjected to Analysis of variance (ANOVA) at 95% confidence level using GenStat Release 15.1 computer software where significant means separation was done by LSD. Means with a $P \leq 0.05$ were regarded as significantly different. Data obtained was presented in simple descriptive format of tables and graphs, where necessary. MS-excel version 2011 was used to prepare the bar charts and treads per treatments discussed.
CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Monthly seagrass litter distribution and accumulation

Results were observed and recorded showing monthly seagrass distribution pattern for a period of one year as presented in the chart below:

![Chart showing monthly distribution of seagrass litter between Kilifi, Malindi, and Mombasa](image)

Figure 2: Monthly distribution of seagrass litter between Kilifi, Malindi, and Mombasa

In Kilifi, beach-cast seagrass recorded high accumulation in June 138 t ha\(^{-1}\) and December 110 t ha\(^{-1}\). Highest accumulation in Malindi was recorded in July 90.3 t ha\(^{-1}\) and December at 99.5 t ha\(^{-1}\) while Mombasa had a different accumulation pattern compared to Malindi and Kilifi. The highest accumulation in Mombasa was recorded in July 102 t ha\(^{-1}\) and in May at 66.5 t ha\(^{-1}\). Generally high accumulation was noted in March, April and May with negligible accumulation from July through December. Kilifi however showed a bimodal pattern with peaks in June-July and November-December. June and July had similar accumulation pattern in all the three stations at 102 t ha\(^{-1}\) in Mombasa, 105.8 t ha\(^{-1}\) in Kilifi and 90.3 t ha\(^{-1}\) in Seagrass. Data on monthly seagrass accumulation across the three stations was tested for their variance using ANOVA tool and results tabulated as shown in Figure 3.
Highest mean accumulation of seagrass litter was noticed in Kilifi at an average of 72.4t ha⁻¹ which was significantly different compared to Malindi 26.5t ha⁻¹ (P<0.005) and Mombasa 24.75t ha⁻¹ (Figure 3). There was no significant difference in litter accumulation between Malindi and Mombasa which had P>0.005 (0.904). The monthly deposition of seagrass was correlated to the elevated turbidity of water, weather changes and natural events that contribute to detachment of the seagrass plants from the mother bed (Frankovich et al., 2009). However these effects also depend on the conditions of the rhizome and root system of the seagrass species. For example, Syringodium filiforme (dominant at the three sites) which has delicate rhizome and root system is easily uprooted and washed to the shore creating litter. This however is in contrast with Thalassia studinum population, which has robust rhizome and root system that remain unaffected (Dierssen et al., 2006).

The bimodal deposition of litter was closely related to the rain patterns observed in this region which experiences two rainy seasons occurring shortly after equinoxes and two dry seasons occurring during solstices (McClanahan, 2008). Due to wind direction and shape of Africa, the greatest amount of rainfall occurs during the S.E monsoon (March to October) when winds pass over the Indian Ocean (Krishnamurthy & Iii, 2003).
During the NE monsoon (October to March) the air mass passes over the drier Somali land mass and therefore coastal areas receive only a small rainfall peak (Bell, 2002). The SE monsoons characterized by high cloud cover, rain, decreased temperatures and light may have contributed to the low seagrass production from October to March along the three sites (Brakel, 2002). This is in contrast to NE monsoons when variables are reversed, where the changing winds slow the northerly water movement and eventually reverse their movement, forming counter current. These currents cause major down welling throughout the year, but are strongest during SE Monsoons, disturbing the seagrass cover along tropical coast, hence the much seagrass deposits (Bell, 2002).

4.2 Seagrass fertilizer products

The ratio of seagrass product that passed through the sieve, to that which did not was recorded and expressed as a percentage monthly for a period of four (4) months. Results were as tabulated below:

Table 4: Ratio of fertilizer products sieved through 4.75mm soil sieve

<table>
<thead>
<tr>
<th>Month</th>
<th>Above sieve Saline Treatment A (kg)</th>
<th>Below sieve Saline Treatment A (kg)</th>
<th>Above sieve Desalinated Treatment B (kg)</th>
<th>Below sieve Desalinated Treatment B (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st month</td>
<td>0.55</td>
<td>0.45</td>
<td>0.65</td>
<td>0.35</td>
</tr>
<tr>
<td>2nd month</td>
<td>0.40</td>
<td>0.60</td>
<td>0.55</td>
<td>0.45</td>
</tr>
<tr>
<td>3rd month</td>
<td>0.30</td>
<td>0.70</td>
<td>0.45</td>
<td>0.55</td>
</tr>
<tr>
<td>4th month</td>
<td>0.15</td>
<td>0.85</td>
<td>0.25</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Rate of decomposition 85% 75%

Results showed that after the first month of decomposition, 45% (0.45kg) of sample A (FERT-SAL Saline Fertilizer) and 35% (0.35kg) of sample B (FERT-DESAL Desalinated fertilizer) had fully decomposed and could pass through a 4.75mm mesh
sieve. In the second month, the rate of decomposition in sample A increased by 33% from 0.45kg to 0.6kg, while sample B increased by 28.5%, from 0.35kg to 0.45kgs. At the end of the forth month, the saline seagrass product had decomposed by 85% compared to 75% of the desalinated sample. This study showed that washing the litter reduced the rate of decomposition, which was contrary to the expectations. Washing probably eliminated some microbes that were necessary in the decomposition process.

4.3 Nutrient content in seagrass compost

Table 5 shows the nutrient composition of seagrass compost FERT-SAL and FERT-DESAL, compared to the recommended Farm Yard Manure. The seagrass compost was analyzed for its nutrient content after 120 days of composting.

Table 5: Seagrass bio-fertilizer nutrient analysis

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>FERT-SAL</th>
<th>FERT-DESAL</th>
<th>FYM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen %</td>
<td>1.75</td>
<td>1.05</td>
<td>1.2-1.8</td>
</tr>
<tr>
<td>Phosphorus %</td>
<td>0.36</td>
<td>0.28</td>
<td>0.4-0.6</td>
</tr>
<tr>
<td>Potassium %</td>
<td>0.62</td>
<td>0.15</td>
<td>1.1-1.9</td>
</tr>
<tr>
<td>Calcium %</td>
<td>23.8</td>
<td>20.2</td>
<td>0.5-1.1</td>
</tr>
<tr>
<td>Magnesium %</td>
<td>0.77</td>
<td>0.72</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Iron mg/kg</td>
<td>3448.00</td>
<td>613.00</td>
<td>1135-3515</td>
</tr>
<tr>
<td>Copper mg/kg</td>
<td>1.67</td>
<td>1.67</td>
<td>17-29</td>
</tr>
<tr>
<td>Manganese mg/kg</td>
<td>117</td>
<td>38.3</td>
<td>229-668</td>
</tr>
<tr>
<td>Zinc mg/kg</td>
<td>43.3</td>
<td>16.7</td>
<td>83-128</td>
</tr>
</tbody>
</table>

The seagrass fertilizer products prepared in this study had higher Nitrogen content (1.75%) compared to 1.2- 8.0 % of many documented organic fertilizers (Reddy, 2005). The FERT-DESAL had lower N content (1.05%) compared to the FERT-SAL (1.75) indicating that washing reduced the levels of nutrients concentrations in the final
products (Arrington et al., 2007). Phosphorus and Potassium levels in both seagrass products were lower than the documented standards that are 0.4-0.6% for phosphorus and 1.1-2.2% for Potassium (Beegle, 1997). However, the calcium levels recorded in the seagrass samples were higher 20.2-23.8% compared to 0.5-1.1 of documented levels in organic fertilizers. Among the micro-nutrients in the seagrass samples, Magnesium (Mg), iron (Fe), Copper (Cu), Manganese (Mn) and Zinc (Zn) were available in the standard range (0.5-1.0 mg/Kg). Fe was available in higher concentration 3448 mg/Kg in FERT-SAL but fairly low 613mg/Kg in FERT-DESAL compared to 1135-3515 mg/Kg documented for FYM. Copper, manganese and Zinc were lower than the standard levels for FYM (Beegle, 1997). Generally the seagrass sample products were more superior to farm yard manure based on nutrient content, with higher Nitrogen, Calcium, and Iron content.

The washing process reduced the salinity level of the seagrass samples. It is possible that the microbes involved in the decomposition of seagrass, rely on or are tolerant to high levels of Calcium and Sodium salts that were washed off in the desalinated samples. Substrates with high Nitrogen, Phosphorus, Calcium and Sodium content decomposes faster because they are associated with fast growth of the microbial populations (Berg & Martzner, 1997). These arguments provide an explanation for increase in decomposition rate with increasing nutrient concentration.

However, more studies need to be done to evaluate the carbon, nitrogen and phosphorus levels washed off during desalination process. The evaluated fertilizer samples show low levels of Nitrogen, Calcium and Phosphorus for the FERT-DESAL compared to the FERT-SAL.
4.4 Effects of composted sea grass litter on growth parameters of Amaranth

4.4.1 Plant height

Figure 4: Effects of composted sea grass litter on plant height

T1=Control, T2=DAP/CAN, T3=30g/hill saline seagrass compost, T4=60g/hill saline seagrass compost, T5= 30g/hill desalinated seagrass compost, T6=60g/hill desalinated seagrass compost and T7= 60g/hill farm yard manure

Amaranth plants treated with DAP/CAN elicited highest (29.6cm/plant) plant height compared to plants treated with composted sea grass litter and farm yard manure. Plants not provided with any compost (control) had minimum (22.9cm/plant) plant height, but not statistically significant to the height indicated by plants treated with 60g/hill saline seagrass compost. In relation to the negative control (no manure), saline sea grass compost at 30g/hill treatment significantly enhanced plant height by about 10% while the saline seagrass compost at 60g/hill resulted to about 4% plant height increase. Desalinated seagrass treatment at 30g/hill was superior to desalinated 60g/hill and farm yard manure. This was however statistically insignificant.

4.4.2 New leaf development

Leaf development was a significantly (P≤0.05) influenced by seagrass litter in the field experiment.
Table 6: Effects of Seagrass on new leaf development of leafy amaranth field experiment

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Leaf number</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>12.3&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>T2</td>
<td>13.2&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T3</td>
<td>12.9&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T4</td>
<td>12.8&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T5</td>
<td>12.5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>T6</td>
<td>12.6&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>T7</td>
<td>12.3&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

P value 0.02  
LSD 0.5  
CV 19.6%

Means followed by the same letter within the same column are not significantly different (P≤0.05)  
*Significant F values at P≤0.05

T1=No manure, T2=DAP/CAN, T3=30g/hill saline seagrass compost, T4=60g/hill saline seagrass compost, T5= 30g/hill desalinated seagrass compost, T6=60g/hill desalinated seagrass compost and T7= 60g/hill farm yard manure (FYM)

Plants provided with DAP/CAN treatment had maximum average of 13.2 number of leaves compared to all other treatments. This was however not statistically different from saline seagrass compost at 30g/hill and 60g/hill. The control (no manure added) and FYD had the least 12.3 number of leaves each. Saline seagrass manure had higher number of leaves compared to desalinated seagrass compost with half rate (30g/hill) being superior to the full rate (60g/hill). This was also the case with desalinated compost where half rate indicated higher leaf count than full rate.

### 4.4.3 Yield (Dry weight)

Yield in terms of dry weight was significantly (P≤0.05) influenced by seagrass litter compost addition (Figure 4.2).
Figure 4.2: Effects of composted seagrass litter on dry weight

T1=No manure, T2=DAP/CAN, T3=30g/hill saline seagrass compost, T4=60g/hill saline seagrass compost, T5=30g/hill desalinated seagrass compost, T6=60g/hill desalinated seagrass compost and T7=60g/hill farm yard manure.

Similar to the plant height and number of leaves, DAP/CAN treated plants showed maximum (81.8g) dry weight yield than other treatments. Plants not supplied with any nutrients (control) had the lowest dry weight yield. Composted seagrass litter; both the saline and desalinated products were not statistically significant, though saline compost at 30g/hill elicited higher yield compared to the full rate 60g/hill. Farm yard manure was neither better nor bad to seagrass litter compost as the dry weight yield accumulations were statistically at par.

The growth of vegetable amaranth was influenced by both organic and inorganic fertilizer provision compared to the control (Hartemink et al., 2000). It’s not surprising that more rapid growth of amaranth plants was realized with the use of inorganic nitrogenous fertilizers (DAP/CAN) compared to organic fertilizer both composted seagrass litter and farm yard manure. These results are in agreement with the findings of other workers Nyankangaet al., 2012, who observed that amaranth plants supplied with inorganic chemical fertilizers such as DAP as source of nutrients had better growth.
unlike those provided with organic farm yard manure. Similar results have been reported in other crops; vegetable cow pea (Yoganathan et al., 2012), Marigold et al., 2010) and broccoli (Kandil and Gad, 2009) where organic manure yield was more inferior to inorganic mineral fertilizers.

The improved plant growth and yield under inorganic fertilizer could be as a result of rapid release and availability of essential plants nutrients for instance nitrogen resulting to increased Nitrogen (N) uptake by plant roots. The stimulated N uptake could have prompted more vegetative growth in plant height and number of leaves hence increased plant yield. In the case of organic manure, release of nitrogen is much slower after mineralization hence reduced plant growth. These explanations are supported by the results of Pang & Letey, (2000), Hartemink et al. (2000) and Eghball et al. (2002) who observed that while nitrogen supplied by inorganic fertilizer was readily available, the nitrogen supplied by organic manure was released at a slow rate. Compared to mineral fertilizers, organic manure contains relatively smaller amounts of nutrients readily available for growth of plants (Edmeades, 2003). Furthermore, nutrient availability and release rates from organic fertilizers are affected by several factors, including application timing, microbial activity, soil temperature, soil moisture, substrate components, and the nature of the organic fertilizer (Rosen and Allan, 2007).

It’s interesting that the saline seagrass litter treatment performed better on plant height and yield than the desalinated seagrass litter. On washing the seagrass compost; this may have removed essential microbes involved in the decomposition of seagrass (Marschner, 1995). It is possible that the microbes involved in the decomposition of seagrass, rely on or are tolerant on the high levels of Calcium and Sodium salts that were washed off in the desalinated samples. Substrates with high Nitrogen, Phosphorus, Calcium and Sodium content decomposes faster because they are associated with fast
growth of the microbial populations (Berg, 1997). These arguments provide an explanation for increase in decomposition rate with increasing nutrient concentration.

Regarding the rate of composted seagrass litter; plant supplied with half rate (30g/hill) of both saline and desalinated compost indicated enhanced growth in plant height and dry weight, compared to full rate (60g/hill). This concurs with the findings of (Fain et al., 2008). Since there was no increase in yield when 60g/hill were used, it could be that higher rates of Nitrogen result in luxury Nitrogen uptake or loss of it through leaching (Maurao & Brito, 2001).
CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

Among the three sites along the Kenyan North Coast studied, Kilifi recorded an average of 72.42T/ha\(^{-1}\) compared to 26.5T/ha\(^{-1}\) and 24.75T/ha\(^{-1}\) for Malindi and Mombasa, respectively. The saline seagrass litter treatment decomposed faster than the desalinated. Incidentally, saline trials produced better quality fertilizer than the non-saline. However, desalination process is labor intensive and time consuming. It is therefore uneconomical to desalinate the seagrass before composting.

The high costs of chemical inorganic fertilizers frequently force small scale vegetable farmers to look for alternatives such as use of compost manure in crop production. In this research, compost was being used for the first time on the plots and it is possible that its rate of proper decomposition and mineralization was insufficient to release plant nutrients (Nitrogen) fast enough to meet the requirements of a rapid growing plant such as amaranth. It is possible that repeated use of composted seagrass litter on the same plot would be needed to verify this.

Seagrass biofertilizer can be applied as alternative manure, for it has enough nutrients content to support leafy vegetables. Efficacy trials of the seagrass fertilizer products indicated that FERT-SAL outperformed all the other treatments except those applied with commercial fertilizer. The use of seagrass litter at a higher dosage does not result in a notable yield in fact it leads to decrease; thus use of 60g/hill on amaranth is not economically valuable. Half rate application of FERT-SAL performed better than full rate of the same.
5.2 Recommendations

i. This study provides an alternative use of seagrass through fertilizer development. Youth groups through the County governments can be encouraged to pick up this venture to help clean-up the beach and improve agricultural productivity by using seagrass organic fertilizer.

ii. This study did not evaluate the dynamics of microbial population in the fertilizer products before and after application of the fertilizer into the soil. Further studies to assess the microbes involved in the decomposition of seagrass and how they affect vital microbes in the soils needs to be done.

iii. Any seagrass decomposition process should be done directly, without desalination.

iv. Half rate (30g/hill) application of FERT-SAL product is recommended for production of leafy vegetables.

v. It may be necessary to evaluate the effect of pre-washing (desalinating) the seagrass in as far as nutrient and microbial populations are concerned. It may give insight on the disparities noted between SAL-FERT and DESAL-FERT and the amount of nutrients lost in the process.

vi. Amaranth vegetable is a fast absorber of heavy metals that can be toxic if consumed in large quantities. It will be prudent to assess the quantities of heavy metal accumulated in this vegetable after applying this fertilizer.
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