INFLUENCE OF SPACING, TRELLIS/ STAKING AND PRUNING ON GROWTH AND YIELD OF VINE SPINACH (*Basella alba L)* IN WESTERN KENYA

BY

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DECLARATION

Declaration by the candidate

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DEDICATION

This thesis is dedicated to my wife Judith Masombo, my children, Joy Masombo, Sharon Masombo, Eric Bwabi and Ian Bwabi for their moral support, love and patience.

ABSTRACT

Basella alba L is a highly nutritious indigenous leafy vegetable besides medicinal benefits as compared to other leafy vegetables. Locally known as 'Enderema' in Luhya (Western Kenya) has the potential to alleviate malnutrition among communities in Western Kenya and beyond. However, production is limited by a number of factors, including competition for land area with other crops, lack of skills in preparation for consumption and storage, unavailability of seed and lack of appropriate husbandry practices. The potential yield for indigenous vegetable is 42 metric tons however the only 35 metric tons were attained in 2015. The specific objectives were to evaluate the effect of trellis, pruning and spacing on biomass production. To promote production, an experiment was conducted to evaluate trellis, spacing and pruning effect on biomass production. Three types of trellis and spacing and two types of pruning were evaluated. A one season experiment was laid in a Randomized Completely Block Design (RCBD) with three replicates in two sites in Busia and Bungoma counties. All plots were applied with Farm yard manure and Mavuno planting fertilizer (N P K Cao Mg S) after soil analysis. Data was collected and subjected to analysis of variance at ($P < 0.05$) using SAS Mixed linear model version 2012. The parameters measured included Plant height, Number of leaves, Number of branches at 88 Days After Transplanting (DAT). Analysis of variance indicate that trellising ($P \leq 0.05$) gave the highest plant height (54 cm), Number of leaves (34), Number of branches (25) and dry matter (28 tons/ha). AdoptIing trellis, pruning and spacing of 20 cm by 30 cm for higher *Basella alba* yields is recommended.

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ABBREVIATIONS, ACRONYMS AND SYMBOLS

AEZ	Agro –Ecological zone
ANOVA	Analysis of variance
CV	Co-efficiency of variance
DAT	Date after transplanting
DM	Dry matter
DF	Degree of freedom
FAO	Food and agriculture organization
LSD	Least Significant Difference
NS	Non-significant
RCBD	Randomized Complete Block Design
REP	Replicate
SAS	Statistical Analysis System
TRT	Treatment

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND INFORMATION

Basella alba belongs to the family *Basellaceae*, genus *basella* and species *alba*, It is native to tropical Asia, (Grubben and Denton 2004) and Africa as a whole. It is a fast growing indigenous leaf vegetable, which is cultivated both as perennial and annual crop for home gardens and as a cash crop. It is propagated by seed, root or long tip cuttings. The leaves are thick, semi, succulent heart –shaped, with a mild flavour and mucilaginous texture. It is a vigorous growing with climbing habit and does better with support when sprawling on the ground to keep the foliage clean (Palada and Chang ,2003). *Basella alba* does well in tropical and subtropical climate. However, it being perennial performs poorly due to insect pest and high temperature [Grrubben.1997]. *Basella alba* is highly nutritious compared to most indigenous leafy vegetables, available in western Kenya and East Africa. It is nutritionally rich in vitamin A, B, C, iron and calcium, (Grubben & Denton, 2004). The juice of leaves has been prescribed against constipation especially for children and pregnant women [Duke and Ayensu 1985]. Since it is a crop it plays a role in food and nutrition security particularly during the dry period, Maundu *etal.*, 1999. Research conducted in the glass house at Larenstein International Agricultural College (LIAC), Deventer. Showed that indigenous leafy vegetables have high nutritive value. They contain high levels of minerals especially calcium, Iron and Phosphorus. They also contain significant amounts of vitamins and proteins (Mnzava, 1997). In most cases the mineral and vitamin contents is equivalent to or higher than that found in popular exotic vegetables like cabbage. On average 100g of fresh vegetable contain levels of calcium, iron and vitamins that would provide 100% of the daily requirement and 40% for the proteins (Abukutsa-Onyango, 2007). Indigenous leafy vegetables are therefore a valuable source of nutrition in rural areas where they contribute substantially to protein, mineral and vitamin intake (Mnzava, 1997). They are compatible to use with starchy staples and represent cheap but quality nutrient source to the poor sector of the population in both urban and rural areas where malnutrition is widespread. Healthy people need a balanced diet consisting not just of starchy foods but also protein and micronutrient rich foods. A neglected crop such as *Basella alba* has a potential in alleviating malnutrition among certain vulnerable groups in the rural communities in Western Kenya but there is lack of agronomic practices such use of quality cuttings, spacing, pruning, staking/ trailis and fertilizers leading to reduced leaf yield.

Rop *et al*., (2012) showed that use of nitrogen fertilizer increases the growth, yield and quality of Indian Spinach. Also Abukutsa-onyango (2007), research on African leaf vegetables consumed in Western Kenya revealed that little research has been done on the propagation and management practices on Vine spinach. *Basella alba* can grow under conditions of moderate soil fertility but production is enhanced by application of fertlizers (Murwira and Kirchmann 1993). Nitrogen is an essential plant nutrient needed for vegetative growth and it is a major limiting nutrient for crop production (Pionke e*t al.*, 1990)

Indigenous vegetable production in Kenya has been on a declining trend (Ministry of Agricultural 2014, annual report). In Bungoma County in 2014 of the targeted 42 MT only 35 MT of indigenous vegetables were produced. There is scanty information of *Basella alba* production levels in western Kenya, and the current production is less the 1 MT per annum despite its nutritional and economic importance (MOA report 2015). The reasons for low production include poor trellis methods, poor agronomic management especially pruning, spacing as well propagation materials. The area under indigenous vegetables is also low compared to other vegetables, for instance only 500 hectares were allocated to indigenous vegetables of the total 14893 hectares under vegetables (Government of kenya 2008). Besides People often consider vegetables to be of limited importance, mainly because they are not aware of the nutritive value. This is a clear misconception because the human body needs major minerals like iron, calcium, phosphorus, magnesium as well as trace elements and vitamins that are essential for the health of the people, especially vitamins such as ß-carotene and ascorbic acid.

The nutrient content of these vegetables could be affected by several other factors like stage of growth, storage, cooking, processing and these factors need to be investigated if the nutritional potential is to be fully exploited. Loss of between 57% and 78% of

Vitamin C after 30 minutes of cooking has been reported. For the case of vitamin, A, there is low conversion rate of beta-carotene to retinol equivalent the form in which vitamin A is utilized in humans. In case of mineral nutrients such as calcium, iron and zinc the bioavailability is not assured as certain phyto chemicals like phytates bind them making them unavailable (Makokha and Ombwara, 2005).

Limited information available on the mode of preparation suggest that the presence of undesirable chemical compounds in these potential crops cannot be overruled. Most of the indigenous vegetables have been reported to contain anti-nutrient factors. Oxalates found in Amaranthaceae and Solanaceae vegetables may bind calcium and render it unavailable, Alkaloids found in the bitter types of Crotalaria and Solanum species may cause stomach-ache if eaten in excess, Spider plants contain phenolic compounds which bind proteins thereby reducing the nutritional value of the vegetable. The smell of spider plant caused by an acrid volatile oil has a high phenolic content and glucosinolates which interfere with iodine metabolism as occurs in Brassica carinata. These factors need to be investigated as some of the phenols can be anti-oxidants Due to the limitations mentioned above, successful commercial exploitation of African Indigenous Vegetables, need to be explored. Another area that could be exploited is phyto-chemicals or Nutraceuticals which are biologically active, non-nutrient compounds that provide health benefits. These phytochemicals help promote optimal health by lowering risk of occurrence of chronic diseases like cancer. Some of the phytochemicals are called antioxidants, scavenge for and bind free radicals that occur in the body these radicals could cause cancer and other ailments if left unchecked. Further investigation need to be done to elucidate the medicinal properties of these African indigenous vegetables.

Indigenous leafy vegetables have considerable potential as cash income earners, enabling the poorest people in the rural communities to earn a living (Onyango, 2007). Socio-economic survey on traditional vegetables conducted in various parts of Africa particularly in Central, Western and Eastern Africa (Abukutsa-Onyango, 2007; Schippers 2000) revealed that indigenous vegetables are important commodities in household food security. They provide employment opportunities and generate income for the rural population. There appears to be a high demand of indigenous vegetables in cities and major towns, making the intensive production in and around the towns and trading of the same important sources of household income for the urban poor and the unemployed. Over 70% of the traded vegetables in rural markets were indigenous vegetables while in bigger towns was about 10%. However, there was generally a poor marketing system in some of the countries. (Abukutsa-Onyango, 2002, Schippers, 2000)

Despite its nutritional and medicinal benefit,*Basella alba* is consumed at minimum rate due to low level of production as it is almost getting extinct in western Kenya Abukutsa-onyango(2007). Hence there is need to improve on the production so as to promote consumption, thereby preventing nutrient deficiency diseases, such as night blindness scurvy ,and rickets which are common in slums and rural areas.

Therefore, understanding the appropriate agronomic practices especially spacing, trailis and pruning would enhance productivity of *Basella alba* in Western Kenya.

Basella alba is well adapted to harsh climatic conditions and disease infestation and are easier to grow in comparison to other vegetables such as tomatoes and cabbages among others. Indigenous leafy vegetables can produce seed under tropical conditions unlike the exotic vegetables. They have a short growth period with most of them being vegetables ready for harvesting within 3-4 weeks, and respond very well to organic fertilizers. Most of them have an in built ability to withstand and tolerate some biotic and abiotic stresses. They can also flourish under sustainable and environmental friendly cropping conditions like intercropping and use of organics.

Furthermore, because most of them have not been intensively selected, they have wide genetic bases, which will be important in sourcing for new genotypes and/or genes for adaptation to climate change.

Trellis is an important agronomic management practice in the production of *Basella alba*. It reduces disease and pest infestation; ensure quality leaves, easy field activities i.e. pruning, spraying, weeding and fertilizer application among others. However, there is little information on methods of trellis and relative advantage of each on *Basella alba*. Farmers in Western Kenya just allow the crop to grow wildly. Therefore, there is need to establish the best and most economical method of trellis the crop in Western Kenya.

Research conducted elsewhere indicated trellis give optimum yield when constructed at 30 cm above the ground. The stake must also be stout and at least 2 meters tall (Lucas, 1988).

On the other hand, *Basella alba* requires pruning for optimum growth just like other vegetables such as tomatoes. In order to maximize the efficiency of photosynthesis and minimize the risk of disease, each tomato leaf must have plenty of room and be supported up off the ground. When a tomato plant lies on the ground, or when its growth is extremely dense, many of its leaves are forced into permanent shade, which greatly reduces the amount of sugar they produce. If a leaf uses more sugar than it makes, eventually it will yellow and drop off. A pruned and staked plant will produce larger fruit two to three weeks earlier than a prostrate one.

A properly pruned and supported single-stem tomato plant presents all of its leaves to the sun. Most of the sugar produced is directed to the developing fruit, since the only competition is a single growing tip. The result is large fruit that are steadily produced until frost. If more stems are allowed to develop, some of the precious sugar production is diverted from fruit to multiple growing tips. Fruit production, although slowed, never stops. The result is a nearly continuous supply of fruits throughout the season. In general, more stems means more but smaller fruits, which are produced increasingly later in the season. Therefore, *Basella alba* require pruning for healthy and vigourous growth due to less competition by branches.

Basella alba is a climbing vegetable and require support to avoid falling down. Stakng/ trellis direct the plant growth upwards, and supporting ties keep it there. Staking makes the plant upright which exposes leaf canopy to sunlight essential for photosynthesis and dry matter accumulation (Francis J.F, 2010).

Basella alba need to be given priority among other indigenous vegetables in Western Kenya due to its nutritional and medicinal attributes through enhancing its yield. This can be achieved through addressing yield limiting factors such as spacing, pruning and staking/ pruning. Therefore, the present study is to evaluate the influence of spacing, pruning and trellis on growth and yield of *Basella alba*.

1.2 STATEMENT OF PROBLEM

Indigenous vegetable production in Kenya has been on a declining trend (Ministry of Agricultural 2014, annual report). In Bungoma County in 2014 of the targeted 42 MT only 35 MT of indigenous vegetables were produced. There is scanty information of *Basella alba* production levels in western Kenya, and the current production is less the 1 MT against a yield potential of 25MT per annum despite its nutritional and economic importance (MOA report 2015). The reasons for low production include poor trellising methods, poor agronomic management especially pruning, spacing as well propagation materials. The area under indigenous vegetables is also low compared to other vegetables, for instance only 500 hectares were allocated to indigenous vegetables of the total 14893 hectares under vegetables (Annual report, MoA Bungoma county 2015). Besides People often consider vegetables to be of limited importance, mainly because they are not aware of the nutritive value. This is a clear misconception because the human body needs major minerals like iron, calcium, phosphorus, magnesium as well as trace elements and vitamins that are essential for the health of the people, especially vitamins such as ß-carotene and ascorbic acid.

1.3 JUSTIFICATION

Besalla alba can offer an opportunity to gap the existing nutritional, health, income and food security in Kabuchai and Bumala sub-counties in Bungoma and Busia counties when compared to other indigenous leafy vegetable grown in the region. This is because its hardy and most adaptable even in dry spell. It has high nutrition value compared to most common vegetables such kales i.e. rich in vitamin A, B, C, iron and calcium, (Grubben and Denton 2004). It is hardy, adaptable and can withstand harsh climatic conditions i.e. high temperature ranging 250 C-350 C and nourishes in silt-loamy and sandy soils. Most of the African Leafy vegetables are highly perishable with a shelf life of less than 24 hours at room temperature. This problem affects quality of the produce at the market and this problem can overcome by preservation and processing technologies. However, *Basella alba* being perennial would be suitable as it has longer shelf life. Despite the many advantages, African Leafy Vegetables have been neglected for a long time to the extent that some have become extinct and if this trend goes unchecked, there is a possibility that all could be lost. Promoting the production and utilization will ensure conservation by utilization, in which case if there is consumer demand of African Leafy Vegetables then production will be sustained to meet the demand and therefore avoid the threat to their extinction. Farmers in western Kenya currently grow *Basella alba* without considering spacing hardly stake nor prune. To fully exploit the genetic yield potential of this crop, farmers need to consider appropriate crop management practices such as trellis, spacing and pruning. Despite its nutritional and medicinal benefit, *Basella alba* is consumed at minimum rate due to low level of production as it is almost getting extinct in western Kenya Abukutsa-onyango, (2007). Hence there is need to improve on the production so as to promote consumption, thereby preventing nutrient deficiency diseases, such as night blindness scurvy, and rickets which are common in slums and rural areas. However, to maximize on growth and biomass yield farmers need to consider crop management practices trellis, spacing and pruning to more fully exploit the genetic potential of *Basella alba*.

1.4 OBJECTIVES

1.4.1 GENERAL

To evaluate of the effect of propagation methods on the yield of *Basella alba* in Kabuchai and Bumala sub-counties in Bungoma and Busia counties respectively.

1.4.1 SPECIFIC OBJECTIVES

a) To evaluate of the effect of various trellis methods on the plant height, number of leaves and branches and dry matter.

b) To establish of the effect of types of pruning on plant height, number of leaves and branches and dry matter.

c) To determine of the effect of levels of spacing on plant height, number of leaves and branches and dry matter.

d) To evaluate the effect of interaction of trellis, Pruning and spacing on plant height, number of leaves and branches and dry matter.

1.5 RESEARCH HYPOTHESES

a) Different types of trellis affect plant height, leaf and branch number biomass, fresh and dry leaf weight of *Basella alba*.

b) Pruning at different levels have an effect on the plant height, leaf and branch number biomass, fresh and dry leaf weight of *Basella alba*.

c) Different types of spacing affect plant height, leaf and branch number biomass, fresh and dry leaf weight of *Basella alba*.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin and importance

Basella alba is a popular tropical leafy-green vegetable commonly grown as backyard plant in the home gardens. It is a creeping vine, and its leaves feature glossy, broad, deep green, thick, and mucilaginous. Commonly found in the backyard gardens of many South Asian families, it is gaining popularity in some of the tropical and temperate climates of America, Australia and Europe for its succulent, nutritious greens, and tender stems (Grubben, 1997). The plant is a perennial vine and grown as annual or biennial pot-herb. It prefers hot humid climate and moist, fertile, well-drained soil to flourish (Grubben and Denton, 2004). Although, its seeds can be sown directly for planting, usually thick cuttings about the length of 20 cm are preferred for easy propagation, and fast growth. Being a vine, the plant requires trellising for its spread at a faster rate. It bears white or white-pink color tiny flowers depending upon the species and deep-purple to black color berries (Grubben and Denton, 2004).

Basella alba is very low in calories and fats (100 g of raw leaves provide just 19 calories). Nonetheless, it holds an incredibly good amount of vitamins, minerals, and antioxidants. Fresh leaves are rich sources of several vital carotenoid pigment anti-oxidants such as ß-carotene, lutein, zea-xanthin, (AVGRIS, 2OO5). These compounds help act as protective scavengers against oxygen-derived free radicals and reactive oxygen species (ROS) that play a healing role in aging and various disease processes. Leaves are a good source of non-starch polysaccharide, mucilage. In addition to regular fiber (roughage) that is found in the stem and leaves, mucilage facilitates in smooth digestion, bring reduction in cholesterol absorption, and help prevent bowel movement problems. Vine spinach leaves and stem are incredibly rich sources of vitamin A. Vitamin-A is required for maintaining healthy mucus membranes and skin, and essential for good eye-sight. Consumption of natural vegetables and fruits rich in vitamin-A, and flavonoids has been thought to offer protection from the lung and oral cavity cancers, (Grubben and Denton, 2004). .*Basella alba* too is an excellent source of iron. 100 g fresh leaves contain about 1.20 mg or 15% of daily intake of iron. Iron is an important trace element required by the human body for red blood cell (RBC's) production. Additionally, this element acts as a co-factor for oxidation-reduction enzyme, cytochrome-oxidase, during the cellular metabolism. Leaves are good sources of minerals like potassium (11% of RDA/100 g), manganese (32% of RDA/100 g), calcium, magnesium, and copper. Potassium is an important component of cell and body fluids that helps controlling heart rate and blood pressure. Manganese and copper are used by the body as a co-factor for the antioxidant enzyme, *superoxide dismutase.*

Like many other vegetables such as root tuber crops as well as spices, the growth and yield of *Basella alba* are influenced by different factors like sowing time, propagation methods, plant spacing, pruning and Trellis etc. The crop has received less attention of the researchers on its various aspects because normally it grows with less care or management practices. For that very few studies on growth yield and development of Indian spinach has been carried out in our country as well as in many other countries of the world. Never the less research related to the plant spacing pruning and trellis so far done in Kenya and other countries on leafy vegetable crop production including Indian spinach has been reviewed in this chapter under the following headings:

2.2 Time of Planting

Basella alba is grown best at onset of rainy season, although it can be grown throughout the year. When planted during onset of rains, it bears seeds and eventually dies. This can be counteracted by removing the flower buds and fruits as they appear or by digging out galls or watery nodules attached to the roots. This will make the degenerating plant have more buds and become more luxuriant again.

2.3 Propagation

Basella alba can be propagated by both seed and cuttings. While using seed, the seeds are sown at the beginning of the rains and also require a minimum temperature of 18-21^0 c in order to germinate. Pre-germination is done at 20^0 c by pre -soaking the seeds for 24 hours in warm water which shortens germination period within 10 to 21 days. Use of inorganic and organic manure enhance yield however the quality of The seedlings are pricked into individual pots of fairly rich compost for fast growth and then planted out in the main field. Cut off clean and disinfects a piece of the plant on healthy stem and place in a pot or a jar of water, this will stimulate growth within a week and can then be planted out (Lucas, 1988).

Lack of quality seed has been a major hindrance to sustainable production and utilization of indigenous vegetables. Some of the vegetables perpetuate themselves untended, they were harvested whenever they occurred and this system of seed procurement heavily depended on the soil borne seed pool and the ability of these species to reseed themselves (Abakutsa-Onyango, 2007) Seed production has for a long time virtually remained in the hands of farmers, although seed sale in markets was common.

For a very long time these vegetables were harvested from the wild, but as the pressure on land increased, they were domesticated and the need for quality seed set in. Normally Ba*sella alba* are grown as a subsistence crop and most farmers save their own seed from season to season, and sell surplus to other growers. The quality of such seeds is poor in terms of purity, viability and seed dormancy issues. There is need for production and supply of quality seed to increase yields and quantities produced to meet the unsatisfied market demands of priority indigenous vegetables especially in Western Kenya (Abakutsa-Onyango, 200). Indigenous vegetables have often been grown as intercrops with other vegetables or staples, however there has been hardly any technical information on optimal production and appropriate cropping systems. There has been lack of agronomic and preparation packages and access to technical information has been very limited, therefore extension workers have limited knowledge to advise indigenous vegetable growers. This necessitated research on development of optimal production packages for indigenous vegetables and recipe development.

2.4 CULTURAL PRACTICES

2.4.1 Fertilizer application

*Basell*a *alba* can grow under conditions of moderate soil fertility but production is enhanced with application of fertilizer (Murwira and Kirchmann, 1993). It requires some well-drained moisture-retentive soil rich in organic matter and a warm sunny sheltered position. It tolerates high rainfall and requires a pH in the range 4.3 to 7. Manure is essential as it may contain pathogens that may cause diseases (Olanrewaju, 2006). Inorganic fertilizer is based on the target yield and requires soil analysis to determine the soil nutrient status prior to fertilizer application. Rahman et al., (1985) also showed that fertilizer influence yield of Indian Spinach. He found out that highest dry matter yield was obtained when highest dose of nitrogen was applied. However, he found out that maximum number of shoots were produced from Nitrogen dose of 82.8 kg / ha. In another experiment by Rubeiz et *al.*, (1992), it showed that lack of response in Indian Spinach yield was due to sufficient levels of NO_3^- and available P in the untreated soil.

2.4.1.1 Effect of fertilizer on yield of *Basella alba*

Basella alba, as a leafy vegetable responds greatly to major essential elements like N, P and K in respect of its growth and yield (Thompson and Kelly, 1988). Generally, a large amount of nitrogen is required for the growth of the leaf and stem of *Basella alba* (Opena et al, 1988). It plays a vital role as a constituent of protein, nucleic acid and chlorophyll. It is also the most different element to manage in a fertilization system such that an adequate, but not excessive amount of nitrogen is available during the entire growing season (Anonymous, 1972). Nitrogen progressively increases the marketable yield (Obreza and Vavrina, 1993) but an adequate supply of nitrogen is essential for vegetative growth and desirable yield (Yoshizawa et al, 1981). Excessive application of nitrogen on the other hand is not only uneconomical but also induces physiological disorder.

2.4.2 Planting density

Plant spacing is an important factor which affects the growth and yield of Indian Spinach. Park *et al.,* (1993) conducted an experiment on plant spacing of Indian Spinach; from their finding it was clear that 30 cm by 30 cm was better than 15 cm by 15 cm or 45 cm by 45 cm in consideration of growth and yield of the crop. Similar results by Akinasoye *et al.,* (2008) showed that spacing of 25 cm by 25 cm produced the highest shoots whereas the highest dry matter yield were obtained at 20 cm by 20 cm. Abbasdokht *et al.,* (2003) conducted an experiment on Amaranth in Iran at spacing of (10, 20 and 40 m^{-1}). His results showed that the density with 40 plants m^{-1} gave minimum yield whereas 10 plants m^{-1} gave the highest single plant yield but the lowest yield was found when yield in hectare was considered.

From the reviews above it is apparent that plant spacing influences growth and yield of the crop however there is scanty information about plant density on *Basella alba* in Western Kenya. Therefore, the current study will be handy in providing such information to enhance yield of *Basella alba.*

2.4.3 Trellis

Basella alba is a climbing leafy vegetable and requires support to avoid falling down for optimum growth and yield just like other vegetables such as tomatoes The support methods can be trellis or staking depending on availability of stakes and economic implication. Trellis/ staking maximizes the efficiency of photosynthesis and minimize the risk of disease, for instance each tomato leaf must have plenty of room and be supported up off the ground. When a tomato plant lies on the ground, or when its growth is extremely dense, many of its leaves are forced into permanent shade, which greatly reduces the amount of sugar they produce. If a leaf uses more sugar than it makes, eventually it will turn yellow and drop off (Francis J.F, 2010). A properly supported single-stem tomato plant presents all of its leaves to the sun. Most of the sugar produced is directed to the developing fruit, since the only competition is a single growing tip. The result is large fruit that are steadily produced.

Therefore, *Basella alba* require trellis/ staking for healthy and vigourous growth due to exposure to sunlight necessary for photosynthesis (Akunda *et al.*, 2001). Francis J.F, (2010) also observed that Staking/ trellis direct the plant growth upwards, and supporting ties keep it there. Staking makes the plant upright which exposes leaf canopy to sunlight essential for photosynthesis and dry matter accumulation

2.4.4 Pruning

Pruning of *Basella alba* involves cutting back the crop stem at intervals that promote growth and crop yield. It was noted that *Basella alba* grows widely unchecked resulting to varied and low biomass yield (AVDRC Report, 2005). However, it requires pruning for optimum growth just like other vegetables such as tomatoes, tea and coffee among others. For instance, a pruned tomato plant will produce larger fruit two to three weeks earlier than a prostrate one. A properly pruned single-stem tomato plant presents all of its leaves to the sun. Most of the sugar produced is directed to the developing fruit, since the only competition is a single growing tip. The result is large fruit that are steadily produced. If more stems are allowed to develop, some of the precious sugar production is diverted from fruit to multiple growing tips. Fruit production, although slowed, never stops. The result is a nearly continuous supply of fruits throughout the season. In general, more stems means more but smaller fruits, which are produced increasingly later in the season. Therefore, *Basella alba* require pruning for healthy and vigourous growth due to less competition by branches.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental sites

The study was conducted at two sites, namely Kabuchai and Bumala in Bungoma and Busia Counties. Kabuchai had had moderately fertile, homogeneous and gentle slope (Table 2) while Bumala had low phosphorus, P^H and Carbon (Table 2). The sites had similar cropping and past management history.

The sites represented the broad agro-ecological zones of Bungoma and Busia Counties. Kabuchai site had altitude of 1592 m above sea level with annual rainfall between 1200 - 1800 mm and mean temperature of 22^oC (Table 1) soils were sandy –clay on gentle sloping land, well drained. Bumala site had altitude of 1321 m above sea level. It receives between 1100 -12450 mm (Table 1) rainfall amounts with a mean temperature of 28^oC, soils were sandy loan on gentle land well drained.

Table 1: Selected characteristics of major agro-ecological conditions in the study sites

	Sites	
Characteristic	**Bumala**	**Kabuchai**
Altitude	1321 m	1592 m
Rainfall	1100-1450 mm	1200-1800 mm

Source: Jaetzold *et al.*, 2005

Table 2: Physical-chemical characteristics of top (0-20 cm) soil at the experimental sites

	Sites	
Characteristic	**Bumala**	**Kabuchai**
Total Nitrogen (%)	0.1048	0.445
Olsen P (Mg/ kg)	3.6	4.8
% C	1.32	2.05
P^H H_2O	4.8	6.13

3.2 Experimental Design

The experiment was factorial, laid out in a Randomized Complete Block Design (RCBD) with three replicates. The plot sizes were 4m x 3m. It consisted 18 treatments, the treatment combinations were 3 trellis, 3 levels of spacing and 2 levels pruning as described in 3.3 below. With a blanket application of farmyard manure in all plots at the rate of 270g per plot i.e. 2 tons/ha and Mavuno planting (NPK Cao Mg S) at the rate of 180 g per plot i.e. 20% elemental Phosphorus.

3.3 Treatments

The experiment consisted of eighteen (18) treatments. The treatments were:

1. Intra-row spacing of : (I_1) 15 cm, (I_2)- 20cm and (I_3)-25cm at inter-row of 30cm respectively.
2. Pruning: (P_1)- No Pruning   (P_2)- Double stem pruning
3. Trellis : (T_1)- No staking (T_2)- One stake per plant (T_3)-Trellising

Table 3: Treatment Structure

I_1 P_1 T_1	**I_2 P_1 T_1**	**I_3 P_1 T_1**
I_1 P_2 T_1	**I_2P_2 T_1**	**I_3 P_2 T_1**
I_1 P_1 T_2	**I_2 P_1 T_2**	**I_3 P_1 T_2**
I_1 P_2 T_2	**I_2 P_2 T_2**	**I_3 P2 T_2**
I_1 P_1 T_3	**I_2 P_1 T_3**	**I_3 P_1 T_3**
I_1 P_2 T_3	**I_2 P_2 T_3**	**I_3 P_2 T_3**

4m

3m

I1 P2 T3	I1 P2 T2	I1 P2 T1	I1 P1 T3	I1 P1 T2	I1 P1 T1
I2 P1 T1	I2 P1 T2	I2 P1 T3	I2 P2 T2	I2 P2 T3	I2P2 T1
I3 P1 T1	I3 P1 T2	I3 P1 T3	I3 P2 T1	I3 P2 T2	I3 P2 T3
I1 P1 T1	I1 P1 T2	I1 P1 T3	I1 P2 T1	I1 P2 T2	I1 P2 T3
I3 P1 T1	I3 P1 T2	I3 P1 T3	I3 P2 T1	I3 P2 T2	I3 P2 T3
I2 P1 T1	I2 P1 T2	I2 P1 T3	I2 P2 T2	I2 P2 T3	I2P2 T1
I2 P1 T1	I2 P1 T2	I2 P1 T3	I2 P2 T2	I2 P2 T3	I2P2 T1
I1 P1 T1	I1 P1 T2	I1 P1 T3	I1 P2 T1	I1 P2 T2	I1 P2 T3
I3 P1 T1	I3 P1 T2	I3 P1 T3	I3 P2 T1	I3 P2 T2	I3 P2 T3

Figure 1: Experimental layout

3.4 Trial Establishment and Management

3.4.1 Land preparation and planting

The fields were manually prepared using a hand hoe by casual labourer. Upon attaining a fine tilth, planting was done at onset of rains using clean disinfected cuttings. All plots received blanket rates of farm yard manure and Mavuno fertilizer. The farm yard manure (270 grams per plot) translating to 2 tons/ ha. Manure was incorporated while Mavuno fertilizer was mixed with soil in the hill at the rate of (1.4 grams) per hill before planting cuttings.

3.4.2 Trial management

Three (3) weeks after transplanting, plants were thinned to 1 plant per hill, thinning was done to reduce competition among plants for vital resources such as nutrients, light and water. The fields were manually weeded using a hand hoe to ensure that there was no competition from weeds. Appropriate pesticides were sprayed to control pests. Diseases were also scouted and controlled to ensure that variation is due to factors measured i.e. Spacing, Pruning, Trellis and their interactions.

3.5 Data collection

Data collected included: - Plant height, which was determined using a tape measure at 60, 74 and 88 days after transplanting.

Number of leaves by visual counting, at 60, 74 and 88 days after transplanting.

Number of branches by visual counting, at 60, 74 and 88 days after transplanting.

Above ground biomass samples (Fresh and dry weights) were taken from all plots by cutting the plants at the first node from the soil surface using a kitchen knife. Ten (10) Plants for biomass accumulation were randomly selected within the net area. Samples were then packed in a well labeled paper bag (17 cm by 29 cm by 30 cm), dried at 65 ^{0}C to constant weight and then weighed using an electronic balance (5000 g). This was done 88 days after transplanting.

3.6. Data analysis

Data collected was subjected to analysis of variance to determine the effects of trellising, pruning, Intra-row spacing and their interaction on Basella. *alba* agronomic and yield performance using mixed linear model (Mixed procedure SAS Institute 2012). The means were compared using Least Significance Difference (LSD).

THE MODEL OF THE EXPERIMENT

$$\mathbf{Y_{ijklm} = \mu + T_i + P_j + I_k + TP_{ij} + TI_{ik} + PI_{jk} + TPI_{ijk} + \varepsilon_{ijklmn}}$$

Where: μ=General mean

T_i= effect due to Ith Trellis

P_j= effect due to j^{th} Pruning

$I_{k =}$ effect due to k^{th} T Intra-row spacing

TP_{ij} = Effect due to interaction i^{th} Trellis and k^{th} Pruning

TI_{ik} = Effect due to interaction i^{th} Trellis and k^{th} Intra-row spacing

TP_{ij} = Effect due to interaction i^{th} Trellis and k^{th} Pruning

PI_{jk} = Effect due to interaction j^{th} Pruning and k^{th} Intra-row spacing

TPI_{ijk} = Effect due to interaction i^{th} Trellis * k^{th} Pruning*Intra-row spacing

$\varepsilon_{ijklmn=}$ Effect due to $ijkl^{th}$ Random error

CHAPTER FOUR

RESULTS

Effect of Trellis on mean plant height, number of leaves, Number branches and dry matter of *Basella alba* in Kabuchai and Bumala

Analysis of variance show that trellis significantly ($P \leq 0.05$) influenced plant height in Kabuchai and Bumala. At Kabuchai trellising gave the highest plant height (54 cm) which was not statistically ($P>0.05$) different from one stake per plant (52 cm) but both significantly ($P \leq 0.05$) differed from no staking (38 cm) (Table 4). A similar trend was shown in Bumala (Table 5).

Analysis of variance also showed that trellis significantly ($P \leq 0.05$) influenced number of leaves. Trellising gave the highest (32) while one stake per plant gave 31 although statistically similar and no staking recorded the lowest number of leaves (25) at Kabuchai (Table 4). In Bumala trellising and one stake per plant also statistically differed with no staking (Table 5). Number of branches and dry matter also showed similar trend as trellising resulted in highest branches and dry matter respectively in both Kabuchai and Bumala (Table 4 and 5).

Table 3: Effect of Trellis on mean plant height, number of leaves , branches and dry matter of *Basella alba* –Kabuchai

Trellis	**Mean Plant height (cm)**	**Mean number of leaves**	**Mean number of branches**	**Average DM ton/ha**
No trellis (T1)	38b	25b	14b	9c
Staking (T2)	52a	31a	17a	26b
Trellising (T3)	54a	32a	16a	28a
CV%	26.1	23.1	31	30
Lsd	10.1	3.2	1.6	0.42

Means with same letters in the column are not significantly different.

Table 4: Effect of Trellis on mean Plant height, Number of leaves and branches of *Basella alba*-Bumala

Trellis	**Mean Plant height (cm)**	**Mean number of leaves**	**Mean number of branches**	**Average DM ton/ha**
No trellis (T1)	35b	23b	11b	5c
Staking (T2)	48a	30a	13a	21b
Trellising (T3)	46a	27a	14a	24a
CV%	20.1	24.1	22.5	23.6
Lsd	5.2	3.5	1.8	1.2

Means with same letters in the column are not significantly different.

Effect of Pruning on mean plant height, number of leaves, Number branches and dry matter of *Basella alba* in Kabuchai and Bumula

Pruning significantly ($P \leq 0.05$) influenced plant height in both Kabuchai and Bumala. Double stem pruning gave highest mean plant height (52.7 cm) and (44.7 cm) in Kabuchai (Table 6) and 51.6 cm and 40.2 cm in Bumala (Table 7) respectively.

Analysis of variance also showed that numbers of leaves were significantly influenced by pruning. Double stem pruning (P2) recorded the highest number of leaves (26.5) at Kabuchai and (25.8) at Bumala and lowest number of leaves recorded at no pruning (P1) in both sites respectively.

A similar trend was observed on number of branches and dry matter in both Kabuchai and Bumala. Number of branches was highest ($P \leq 0.05$) at double stem pruning when compared to no pruning i.e.16.9 branches in Kabuchai at and 15.9 at Bumala while lowest number of branches recorded at no pruning i.e. 15.3 and 14.7 in Kabuchai and Bumala respectively. Pruning positively influenced dry matter with no pruning recording the lowest dry matter (5.7 tons/ha) at Kabuchai and 3.4 tons/ha at Bumala respectively. These were significantly ($P \leq 0.05$) different from double stem pruning as shown in Tables 6 and 7 respectively.

Table 5: Effect of Pruning on mean Plant height, Number of leaves and branches of *Basella alba*-Kabuchai

Pruning	Mean Plant height (cm)	Mean number of leaves	Mean number of branches	Average DM ton/ha
No pruning (P1)	44.7b	23.2b	15.3b	5.7b
Pruning (P2)	52.7a	26.5a	16.9a	11.5a
CV%	26.1	23.1	31	30
Lsd	2.16	1.96	0.88	0.42

Means with same letters in the column are not significantly different.

Table 6: Effect of Pruning on mean Plant height, Number of leaves and branches of *Basella alba*-Bumala

Pruning	Mean Plant height (cm)	Mean number of leaves	Mean number of branches	Average DM ton/ha
No pruning (P1)	40.2b	22.7b	14.7b	3.4b
Pruning (P2)	51.6a	25.8a	15.9a	9.3a
CV%	20.1	24.1	22.5	26
Lsd	6.7	2.1	0.52	2

Means with same letters in the column are not significantly different.

Effect of Intra-row spacing on mean plant height, number of leaves, Number branches and dry matter of *Basella alba* in Kabuchai and Bumala

Intra-row spacing significantly influenced ($P \geq 0.05$) plant height in both Kabuchai and Bumala as demonstrated in table 8 and 9 respectively. Intra-row spacing of 15 cm (I_1) recorded the highest plant height of 54 cm compared to 50 cm and 48 cm at intra-row spacing of 20 cm (I_2) and 25 cm (I_3) at Kabuchai (Table 8). A similar trend was also observed at Bumala (Table 9) where Intra-row spacing of 15 cm (I_1) recorded the highest plant height of 50 cm compared to 46 cm and 47 cm at intra-row spacing of 20 cm (I_2) and 25 cm (I_3) respectively. Number of leaves were also significantly ($P \geq 0.05$) influenced by intra-row spacing with intra-spacing of 15 cm (I_1) recording more leaves followed by intra-row spacing of 20 cm (I_2) and 25 cm (I_3) at both Kabuchai and Bumala (Tables 8 & 9).

Table 7: Effect of intra spacing on mean Plant height, Number of leaves and branches of *Basella alba*-Kabuchai

Intra spacing	Mean Plant height (cm)	Mean number of leaves	Mean number of branches	Average DM ton/ha
15 cm (I1)	54b	34b	13b	7.1c
20 cm (I2)	50a	30a	18a	28b
25 cm (I3)	48a	29a	16a	21a
CV%	26.1	23.1	31	25.7
Lsd	3.2	1.96	2.1	1.9

Means with same letters in the column are not significantly different.

Intra-row spacing significantly ($P \geq 0.05$) influenced number of branches in both Kabuchai and Bumala. In Kabuchai intra-row spacing of 15 cm (I_1) significantly differed intra-row spacing of 20 cm (I_2) and 25 cm (I_3) i.e. 13, 18 and 16 respectively.

However, intra-row spacing of 20 cm (I2) and 25 cm (I3) were not statistically different (Table 8). The same trend was observed at Bumala as shown in Table 9.

Table 9: Effect of intra spacing on mean Plant height, Number of leaves and brances of *Basella alba*-Bumala

Intra spacing	Mean Plant height (cm)	Mean number of leaves	Mean number of branches	Average DM ton/ha
15 cm (I1)	50b	32b	12.5b	5.3c
20 cm (I2)	46a	29a	16.5a	22.8b
25 cm (I3)	47a	27a	15.4a	20.6a
CV%	20.1	24.1	22.5	29.2
Lsd	2.91	2.2	2.7	1.2

Means with same letters in the column are not significantly different.

Intra-row spacing of 20 cm (I_2) yielded higher ($P \geq 0.05$) in terms of dry matter compared to Intra-row spacing of 15 cm (I_1) and Intra-row spacing of 25 cm (I_3) in both Kabuchai and Bumala (Table 8 and 9) respectively.

The highest yield on dry matter basis (28 ton/ha) were recorded from Intra-row spacing of 20 cm (I_2) while the lowest dry matter per hectare was recorded from Intra-row spacing of 15 cm (I_1) with 7.1 tons/ha, which was statistically different ($P \geq 0.05$) from Intra-row spacing of 25 cm (I_3) (21 tons/ ha) at Kabuchai.

In Bumala, analysis of variance also showed significant ($P \geq 0.05$) differences among intra-row spacing in relation to dry matter (Table 9). The highest dry matter (22.8 tons/ ha) was recorded from Intra-row spacing of 20 cm (I_2) which was statistically different ($P \geq 0.05$) from intra- row spacing of 15 cm (I_1) (5.3 tons/ha) and intra-row spacing of 25 cm (I_3) i.e. 20.6 tons/ha.

Effect of the Interaction between Trellis, Pruning and Intra-row spacing on mean plant height, number of leaves, Number branches and dry matter of *Basella alba* in Kabuchai and Bumala

Plant Height (mean cm)

Analysis of variation Figure 2 showed ($P \leq 0.05$) significant interaction of trellis, pruning and intra-row spacing. No staking interacting with no pruning and intra-row spacing of 25 cm (39 cm) recorded the lowest plant height while trellising interacting with double stem pruning and intra-spacing of 20 cm recorded the highest plant height (54 cm) at Kabuchai.

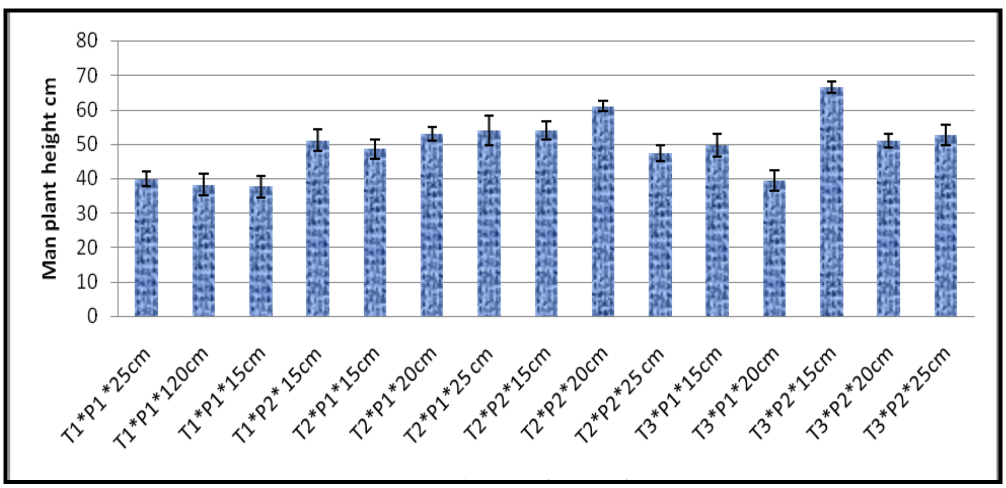

Figure 2: Effect of Interaction between Trellis, Pruning and Intra spacing on mean plant height of *Basella alba* - Kabuchai

A similar trend was observed in Bumala as the analysis of variance also showed positive interaction ($P \leq 0.05$) between training and pruning, training and intra-row spacing, intra-row spacing and pruning then training with pruning with intra-row spacing. The highest plant height recorded at trellising interacting with double stem pruning and intra-spacing of 20 cm recorded the highest plant height (5 cm) which was statistically similar to one stake per plant interacting with pruning and intra-spacing of 15 and 20 cm respectively Figure 4

Number of leaves and branches (mean)

The interaction between training and pruning, training and intra-row spacing, intra-row spacing and pruning was significant at P ≤ (0.05) Figure 3. The highest interaction (3 ways) i.e. was obtained at trellising with double stem pruning and intra- row spacing of 20 cm. However, this was not significantly different from one stake per plant (Figure 3)

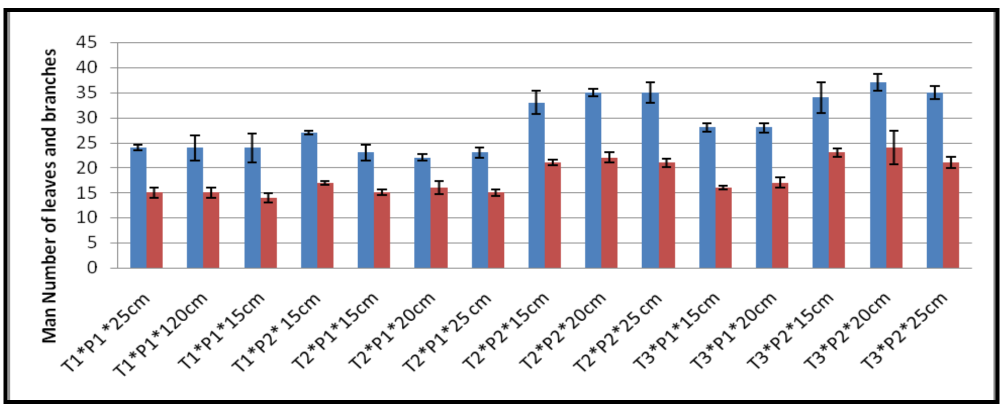

Figure 3: Effect of Interaction between training, pruning and Intra-row spacing on mean number of leaves and branches-Kabuchai

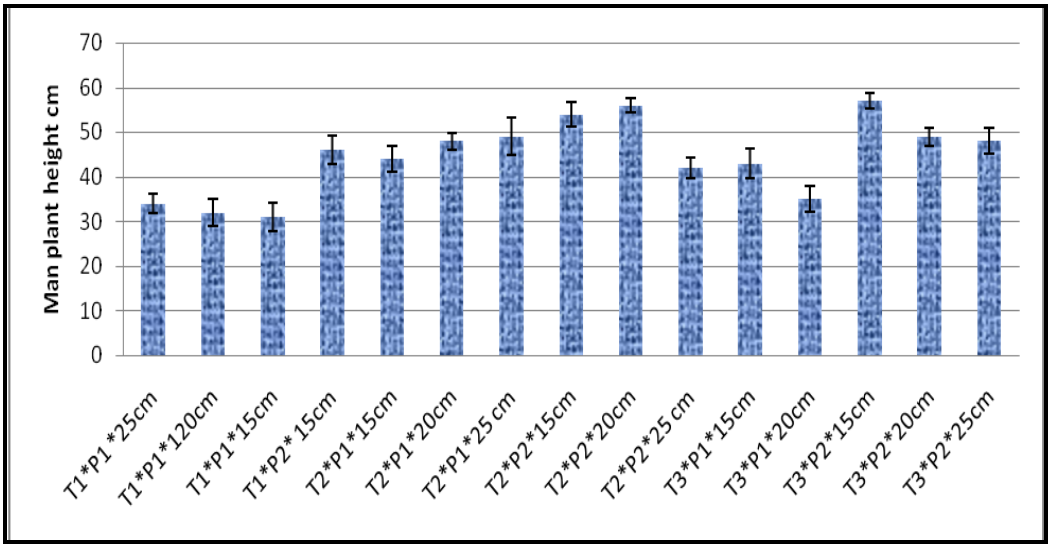

Figure 4: Effect of Interaction between trellis, pruning and Intra-row spacing on mean plant height –Bumala

Dry matter (tons/ha)

Analysis of variation showed significant interaction ($P \leq 0.05$) of trellis, pruning and intra-row spacing in Bumala Figure 5. No staking interacting with no pruning and intra-row spacing of 25 cm (3.4 tons/ha) recorded the lowest dry matter while trellising interacting with double stem pruning and intra-spacing of 20 cm recorded the highest dry matter (31 tons/ha) at Bumala. A similar trend was observed in Kabuchai as the analysis of variance also showed positive ($P \leq 0.05$) interaction between trellis and pruning, trellis and intra-row spacing, intra-row spacing and pruning then trellis with pruning with intra-row spacing. The highest dry matter was recorded at trellising interacting with double stem pruning and intra-spacing of 20 cm (33 tons/ha) which was statistically similar (P > 0.05) to one stake per plant interacting with pruning and intra-spacing of 15 and 20 cm respectively (Figure 5).

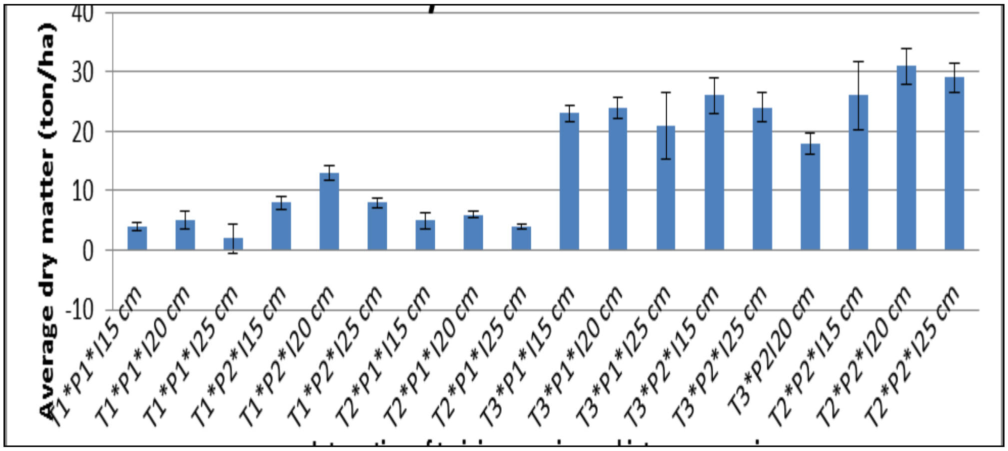

Figure 5: Effect of Interaction between trellis, pruning and Intra-row spacing on average dry matter in tons/ha-Bumala

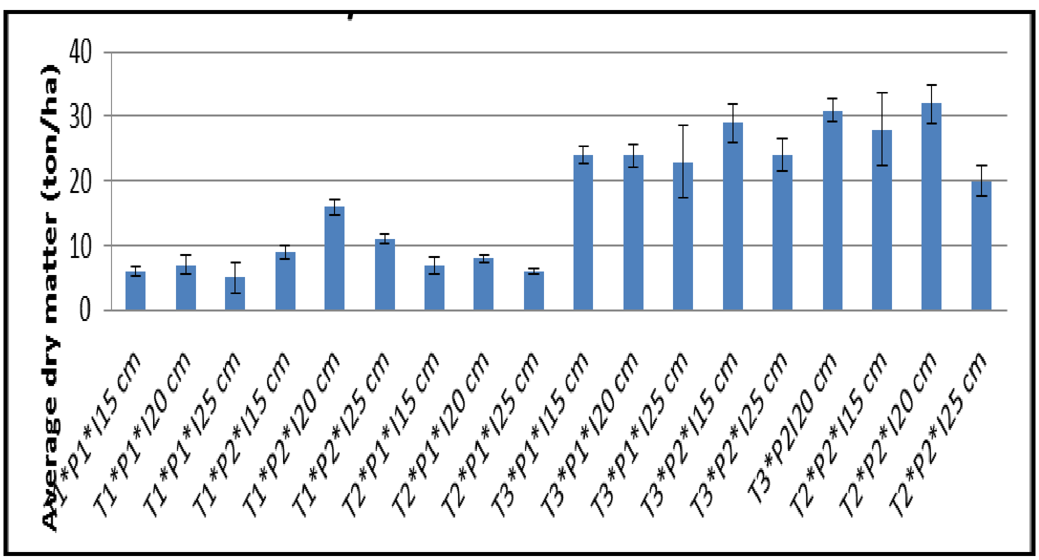

Figure 6: Effect of Interaction between trellis, pruning and Intra-row spacing on average dry matter in tons/ha- Kabuchai

CHAPTER FIVE

DISCUSSION

5.1 Plant height

Vine length per plant was significantly ($P \leq 0.05$) influenced by trellis, pruning and intra-row spacing as well as their interaction in both Bumala and Kabuchai. The longest vine length was recorded at trellising and one stake per plant and lowest at no staking, no pruning and intra- row spacing of 25 cm. On overall the longest vine was recorded at intra-row spacing of 15cm and 20cm interacting with pruning and trellising and or one stake per plant. Narrow spacing led to high plant density per unit area that encourages competition for vital resources especially light. It also leads to high interception of light for photosynthesis which directly relates to dry matter accumulation. Also trellis supported the plant and promoted epical growth. These findings are also in line with research done by Park *et al.*, (1993) whose results showed that highest vine length was found from closest spacing and lowest obtained from widest spacing.

5.2 Number of leaves

Number of leaves was significantly ($P \leq 0.05$) influenced by trellis, pruning and intra-row spacing as well as their interaction in both Bumala and Kabuchai. The number of leaves increased in treatments with trellises, double stem pruning and intra-row spacing of 20 cm. Interaction of trellises, double stem pruning and intra-row spacing 20 cm encouraged more branches that led to more leaves due to vegetative growth. Treatments with wider spacing (intra-row spacing of 25) gave the lowest number of leaves. This was attributed to low plant population which is a determinant of yield. The findings agree with research done by Khan A A., (2013). From his study in Bangladesh he found out that growth and yield of *Basella alba* largely depend upon the plant spacing and it was apparent that 40cm x 20cm spacing was more profitable as compared to other spacing. Also Park et al., (1993) reported that 24 cm by 24 cm was better than 15cm by 15 cm or 30 cm by 31cm in consideration of growth and yield of *Basella alba.*

5.3 Number of branches

Trellis, pruning and spacing had significant ($P \leq 0.05$) influence on the number of branches per plant in both sites. The highest number of branches per plant was recorded from treatments with trellises, double stem pruning and intra-row spacing of 20 cm. While no trellises, no pruning and intra-row spacing 15 gave the lowest number of branches per plant. The number of branches was more on treatments that were pruned because pruning (double stem pruning) encourages development of more buds and sprouting that eventually develop into branches. Spacing also influenced number of branches where wider intra-row spacing (25 cm) and medium spacing provided ambient environment and adequate resources such as sunlight, nutrients and water which are vital for vigorous branching. The finding is in agreement with Khan A A, (2013), who found out that number of branches of *Basella alba* was significantly influenced by different plant spacing. The highest Number of branches per plot was recorded from closest spacing (40 cm x 20 cm) and the lowest yield per plot was obtained from the widest spacing (40 cm x 40 cm).

5.4 Effect of Interaction of Trellis, Pruning and Intra-row spacing on Plant height, Number of leaves, Number of branches and Dry Matter of *Basella alba*.

Plant height, Number of leaves and Number of branches

Plant height, Number of leaves and Number of branches were significantly influenced by in interaction of Trellis, Pruning and Intra-row spacing in both Bumala and Kabuchai. The influence was higher at three way i.e. Trellis* Pruning* Intra-row spacing than two ways i.e. Trellis* Pruning or Trellis and Intra row spacing or Intra-row spacing and Pruning than singly. A combination of medium and or narrow spacing, trellising and double stem pruning encourages high plant density which enhances competition, while trellising supports the crop against logging and exposes it to light interception while pruning initiates buds which develops into branches. These combination encourages vines to grow taller compared to those without trellis, pruning and wider spacing. Akunda, (2001) findings revealed that high plant density leads to high interception of light for photosynthesis which directs relates to dry matter accumulation.

5.5 Dry Matter (tons/ha)

The yield of *Basella alba* expressed on dry matter basis in tons per hectare was significantly influenced by Trellis, Pruning and spacing and their interactions in both Bumala and Kabuchai. The highest yield was recorded where there was interaction of trellises, double stem pruning and intra-row spacing of 20 cm followed by followed by trellising, pruning and intra-row spacing of 25 cm and trellising, double stem pruning and intra-spacing of 15 cm. while the lowest yield was obtained from treatments with no trellises and no pruning and intra-row spacing of 15 and 25 cm respectively. Rahman *et al., (*1985) findings showed that spacing of (20 cm by 40 cm) gave the highest yield while the spacing of (40 by 40 cm) gave the lowest yields of green. Intra-row spacing of 20 cm with trellises and double stem pruning accommodates more plants per unit area and consequently increases yield per plot. Lesser number of plants per unit area caused less yield per plot in intra-row spacing of 25 cm. The increased yield at intra-row spacing of 20 cm could be attributed to the increased number of plants per unit area which compensated and resulted in higher yield. Park *et al.,* (1993) reported that 24 cm by 24 cm was better than 15 cm by 15 cm or 30cm by 31 cm by 31 cm in consideration of growth and yield of the crop. Akunda, (2001) noted that narrow spacing has advantage because plants achieve canopy closure more quickly and intercept more light throughout the growing season. Canopy development is a function of spacing, and environment. The relative equidistant plant distribution leads to increased leaf area development and greater light interception early in the season.

Double stem pruning encourages growth of more branches from sprouts that bear leaves which ultimately influences dry matter accumulation. Dry matter positively correlates with number of branches and leaves. Pruning increases cell division (mitotic activity) and enlargement resulting in many branches and leaves. Through photosynthesis there was accumulation of carbohydrates in the leaves thus increasing their weights (Basela and Mahaden, 2008). Combination of trellises, pruning and intra-row spacing of 20 cm not only had more branches and leaves but supporting the branches.

Through trellises and or one stake per plant led to more interception of light a resource for photosynthesis hence accumulation of more dry matter compared to those without trellis.

Treatments without staking or trellising and no pruning had low dry matter accumulation in general. These could be attributed to a number of factors including minimum exposure to light that essential for photosynthesis a function of dry matter accumulation, logging on the ground predisposes the plants to pests and diseases which limit plant development and productivity. Abiotic and biotic stresses can reduce yield of crops when not well managed for example, moisture stress has been documented to reduce the yield benefit from narrow row spacing in Kansas by more than 20% (Heitholt *et al.*, 2005).

Combined effect of Trellis, Spacing and Pruning for dry matter per plot varied significantly Appendix (5 and 6) the highest (32 ton/ ha) dry matter per plot was recorded from Trellising plus 20 cm intra-row spacing and double stem pruning, while no staking plus no pruning and wider spacing gave the lowest (3.4 tons/ha) yield per plot. A combination of medium and or narrow spacing, trellising and double stem pruning encourages high plant density which enhances competition, while trellising supports the crop against logging and exposes it to light interception while pruning initiates buds which develops into branches. These combination encourages vines to grow taller compared to those without trellis, pruning and wider spacing. Akunda, (2001) noted that narrow spacing has advantage because plants achieve canopy closer more quickly and intercept more light throughout the growing season. Canopy development is a function of growth and development. The relative equidistant plant distribution leads to increased leaf area development and create light interception early in the season.

Trellising seems to be the best option of staking *Basella alba when* compared to use of one stake per plant as it gives higher dry matter compared to the later. One stake per plant yields relatively lower than trellising because stakes often lodge due to wind and termite attack. This disturbs growth and more often causes injury to plants unlike string and poles. The string also environmentally friendly and it is also convenient and easy to implement.

Although the research was not comparing sites, Kabuchai seems to be performing well than Bumala and this could be attributed to favourable soil pH of 6.1 compared to lower pH of 4.8 in Bumala. The pH of 6 allows for easier absorption of nutrients especially Phosphorus and Nitrogen which are essential in root development and vegetative growth respectively (Okalebo *et al.,* 2003). Kabuchai also had reliable and well distributed rainfall which is necessary for dry matter accumulation and other metabolic activities.

CHAPTER SIX

CONCLUSION

To optimize *Basella alba* yields, proper combination of trellises, pruning and intra-row spacing must be adhered to. Trellis, Spacing and Pruning had a significant effect on plant height, number of leaves, number of branches and dry matter. Trellis enhances light interception that is necessary for photosynthesis, a determinant to dry matter accumulation. It also minimizes logging that predisposes the vines to pests and diseases among other yield limiting factors.

Interaction of trellising/ one stake per plant, double stem pruning and intra-row spacing of 20 cm greatly influenced growth and dry matter accumulation of *Basella alba*. This interaction allows for more plants per unit area with relatively adequate nutrients which enhances more branches and consequently number of leaves per plant components which determine dry matter accumulation. It also exposes the plant to light interception a component necessary for photosynthesis that influences dry matter. In contrast intra-spacing of 25 cm spacing without trellis and or pruning yields lowly because of low plants per unit area. Wider spacing results into low plant density which is a major determinant of yield.

From the findings of this research it is clear that growth and yield of *Basella alba is* a function of training, pruning and intra-row spacing in combination although training and intra-row spacing seems to influence more *Basella alba* performance than pruning.

Pruning enhances more sprouts that develop into branches and number of branches has a great influence on number of leaves which intercept photo-synthetically active radiation (PAR) hence photosynthesis and dry matter accumulation.

6.2 RECOMMENDATION

I. From agronomic point of view, it would be wise to adopt combination of trellising, double stem pruning and intra-row spacing of 20 cm for higher *Basella alba* yields.

II. From this study trellising, double stem pruning and intra-row spacing of 20 cm is recommended for adoption of for optimum dry matter yield.

6.3 WAY FORWARD

I. A study should be done on the most economical and appropriate trellis method to establish most economical viable and farmer and environmentally friendly.

II. A long term experiment on methods of trellis, pruning and spacing be conducted to ascertain the optimum Days After transplanting for dry matter accumulation.

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APPENDICES

Appendix I: Effect of Trellis, Pruning and Intra spacing on mean Plant height of *Basella alba* at Kabuchai

Source of variation	DF	Mean Square	F Value	Pr > F
Trellis	2	1633.64149	10.48	<.0001
Pruning	1	3062.1873	19.64	<.0001
Intra spacing	2	201.46778	1.29	0.0025
Replicate	2	244.02122	1.57	0.21
Interaction of trellis and Pruning	2	2918.52094	18.72	<.0001
Interaction of trellis and Intra spacing	4	2611.01134	16.75	<.0001
Interaction of pruning and Intra spacing	2	2861.01134	15.81	<.0001
Interaction of trellis* Pruning* Intra spacing	3	912.08658	5.85	0.0006
Error	35			
Total	53			
CV%	26.12 %			

Appendix II: Effect of Trellis, Pruning and Intra spacing on mean Plant height of *Basella alba* at Kabuchai

Source of variation	DF	Mean Square	F Value	Pr > F
Trellis	2	1533.64149	9.48	<.0001
Pruning	1	2662.1873	19.64	<.0001
Intra spacing	2	181.46778	2.29	0.0025
Replicate	2	144.02122	3.6	0.51
Interaction of trellis and Pruning	2	2318.52094	16.6	<.0001
Interaction of trellis and Intra spacing	4	2011.01134	14.6	<.0001
Interaction of pruning and Intra spacing	2	2761.01134	15.71	<.0001
Interaction of trellis* Pruning* Intra spacing	3	1012.08658	4.5	0.0009
Error	35			
Total	53			
CV%	26.12%			

Appendix III: Effect of Trellis, Pruning and Intra spacing on Mean Number of leaves of *Basella alba* at Kabuchai

Source of variation	DF	Mean Square	F Value	Pr > F
Trellis	2	411.865651	3.22	0.0406
Pruning	1	1048.863867	8.21	0.0043
Intra spacing	2	1239.219795	9.7	<.0001
Replicate	2	534.580305	4.18	0.0157
Interaction of trellis and Pruning	2	1485.436867	11.63	<.0001
Interaction of trellis and Intra spacing	4	396.756717	3.11	0.0152
Interaction of pruning and Intra spacing	2	455.01134	3.75	<.0001
Interaction of trellis* Pruning* Intra spacing	3	524.976366	4.11	0.0067
Error	35			
Total	53			
CV%	23.10%			

Appendix IV: Effect of Trellis, Pruning and Intra spacing on Mean Number of branches of *Basella alba* at Kabuchai

Source of variation	DF	Mean Square	F Value	Pr > F
Trellis	2	738.6181208	5.42	0.0047
Pruning	1	659.4767199	10.15	0.0015
Intra spacing	2	77.9089197	14.79	<.0001
Replicate	2	168.3111958	6.59	0.0015
Interaction of trellis and Pruning	2	7.7913831	0.3	0.7373
Interaction of trellis and Intra spacing	4	110.3474608	4.32	0.0019
Interaction of pruning and Intra spacing	2	114.655	4.12	0.00023
Interaction of trellis Pruning* Intra spacing	3	135.0066462	5.28	0.0014
Error	35			
Total	53			
CV%	31.00%			

Appendix V: Effect of Trellis, Pruning and Intra spacing on Mean Dry matter of *Basella alba* at Kabuchai

Source of Variation	DF	Mean Square	F Value	Pr > F
Trellis	2	151.1	25.5	< 0.001
Pruning	1	2228.7	376.8	< 0.001
Intra spacing	2	477.1	80.6	<.0001
Replicate	2	26.1	4.4	0.0125
Interaction of trellising and Pruning	2	126.1	21.3	<.0001
Interaction of trellisin and Intra spacing	4	43.9	7.4	0.09
Pruning and Intra-row spacing	2	168.3	28l.5	<.0001
Interaction of trellis* Pruning* Intra spacing	3	16.3	2.7	0.09
Error	37			
Total	53			
CV%	30.3			

Appendix VI: Effect of Trellis, Pruning and Intra spacing on Mean Dry matter of *Basella alba* at Bumala

Source of Variation	DF	Mean Square	F Value	Pr > F
Trellis	2	138.6181208	5.42	0.0047
Pruning	1	259.4767199	10.15	0.0015
Intra spacing	2	377.9089197	14.79	<.0001
Replicate	2	168.3111958	6.59	0.0015
Interaction of trellis and Pruning	2	7.7913831	0.3	0.7373
Interaction of trellis and Intra spacing	4	110.3474608	4.32	0.0019
Interaction of trellis* Pruning* Intra spacing	3	135.0066462	5.28	0.0014
Error	37			
Total	53			
CV%	23.2			