INFLUENCE OF AGRONOMIC PRACTICES ON SEED QUALITY AND LEAF YIELD OF JUTE MALLOW (*Corchorus olitorius*) IN THE NORTH RIFT REGION, KENYA

BY

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DECLARATION

Declaration by the Candidate

I declare that this thesis is my original work and has not been submitted for any academic award in any institution and shall not be produced in part or full, or in any format without prior written permission from the author and/or University of Eldoret.

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ABSTRACT

Production of Jute mallow (*Corchorus olitorius*) in Kenya has been low due to many reasons, some of them being poor production agronomic practices by farmers such as poorly spaced plants, incorrect fertilizer rates, incorrect seed harvesting stage and poor quality seeds. The result is that the yield has remained low, 2-4 tons/ha as compared to potential yield of 5-8 tons/ha. Observations from the Jute mallow growing areas showed that as much as 7 kg/ha instead of 5 kg/ha of seed is being used, which is required for a density of 250,000 plants/ha. This is 40% extra seed. The objective of this study was to discern effect of agronomic practices on seed quality and leaf yield of Jute mallow germplasm, in the North Rift region, Kenya. A seed collection from Kenya Seed Company, Iten, Eldoret, Kapsabet, Kitale and Kapenguria was done and information from the farmers collected using questionnaire and data analyzed using descriptive statistics. The collected seed germplasm were taken for seed quality tests on analytical purity, germination and vigour as per International Seed Testing Association. Pure seed sub-samples were then planted in green house and morphological characterization done and seed harvested and planted at two sites of Eldoret and Kitale over one season under three spacings (20 cm x 30 cm, 30 cm x 30 cm, 40 cm x 30 cm) and three fertilizer rates (0, 60, 120 kg/ha) treatments. Data was collected and analyzed using GENSTAT. Seed was then harvested at three different maturity stages of green, tan and black pod and seed taken to laboratory for quality tests on analytical purity, germination and vigour. The survey results showed 86% farmers growing Jute mallow for seed were of middle and old age and 98% were female. Only 14% farmers were trained on vegetable seed production and agronomy. Education level showed 54% had not attended school. Seed quality analysis showed 98% purity and 59% germination which is below quality standard of 60%. Morphological characterization results at green house showed two morphotypes based on colour (Green and Brown) and two based on height (Short and Tall). Plant height results showed morphotypes green short being 28.3 cm and morphotypes brown short at 29.0 cm, while morphotypes green tall being 93.0 cm and brown tall at 84.0 cm. Pod count per plant was lowest on morphotypes green short with 14 pods and highest on green tall with 19 pods. Field results showed Jute mallow responded best to wider spacing of 40 cm x 30 cm and high fertilizer rates of 120 kg/ha on GLMT and BLMT morphotypes with plant height of 91.67 cm and 93.00 cm at site 1 and 2 respectively; highest number of branching of 8 and 9 branching per plant at site 1 and 2 respectively; highest pods of 23 and 24 pods per plant at site 1 and 2 respectively and highest leaf yield of 99.2 g and 96.3 g per plant respectively. Harvesting stage maximizing on quality seed attribute of germination were at tan stage on morphotype GLMT (94.5%) and BLMT (94.25%). It is concluded that most farmers have low education, are aged and not trained in Jute mallow seed and agronomic aspects, plant own saved seed or from neighbours where storage was in plastic containers. For high quality seed and leaf yield, it is recommended spacing of 40 cm x 30 cm coupled with higher fertilizer rates of 120 kg/ha be used and seed be harvested at tan stage.

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LIST OF ABBREVIATIONS, ACRONYMS AND SYMBOLS

ANOVA: Analysis of Variance.

BEMS: Brown Early Maturing Short

BLMT: Brown Late Maturing Tall

BP: Between Paper

CNG: Centre for Genetic Resources

DMTR: Duncan Multiple Range Test

DNA: deoxyribonucleic acid

E.C: Electrical Conductivity test

FAO: Food and Agriculture Organization

GEMS: Green Early Maturing Short

GENSTAT: General Statistical package

GLMT: Green Late Maturing Tall

GOK: Government of Kenya

HM: Harvest Maturity

IPGRI: International Plant Genetic Resources Institute

ISTA: International Seed Testing Association.

KALRO: Kenya Agriculture and Livestock Organization

KARI: Kenya Agricultural Research Institute.

LSD: Least Significant Difference

MOA: Ministry of Agriculture.

N: Nitrogen

PhD: Doctor of Philosophy

PM: Physiological Maturity

RCBD: Randomized Complete Block Design

Spp: Species:

SPSS: Statistical Package for Social Sciences

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CHAPTER ONE

INTRODUCTION

1.1 Background Information

Jute mallow (*Corchorus olitorius)* is noted for its important contribution to diet by supplying nutrients and rendering food more palatable (Grubben and Denton, 2004). *C. olitorius* is reported to be demulcent, deobstruent, diuretic, lactagogue, purgative, and tonic (Ayodele, 2005). It can meet major protein-calorific nutritional needs especially in children, sick, elderly and both expectant and lactating mothers in the rural areas (Smith and Eyzaguirre, 2007). Cooked leaves form a mucilaginous substance that has a slippery character that is highly appreciated especially in areas where people depend on rather coarse food such as millets and sorghum (Nekesa and Mesa, 2003). Jute mallow leaves are normally mixed with cowpeas to reduce their coarseness or to neutralize the bitter taste in *Crotalaria brevidens* (Abukutsa-Onyango, 2004). *Corchorus olitorius* is not usually eaten on its own but along other main meals as side dish. The dark green leaves have varying proportions of calcium, iron, carotene, vitamin C and proteins required for good health (Schippers, 2002).

Jute mallow is an important local leafy vegetable consumed in Kenya due to its contribution to a balanced diet especially in areas where animal protein is deficient (Abukutsa-Onyango, 2002). Increasing vegetable protein supply is easier and less expensive than boosting supply of animal protein (Mroso, 2003; Van Rensburg *et al*., 2004). The government has also been advocating for production and consumption of local vegetables in its strategy for food self sufficiency in the country (MOA, 2009). Vegetables are an integral part of obtaining nutritional security as they are a source of important nutrients essential for the good health (WHO, 2003; GOK, 2005). In

Kenya, there is ample production potential, not only to meet the growing demand for the domestic use requirement, but also produce surplus for export (MOA, 2010).

The crop is a folk remedy for aches and pains, dysentery, enteritis, fever, pectoral pains, and tumors (Keller, 2004). Ayurvedics use the leaves for ascites, pain, piles, and tumors (Okoegwale and Olumese, 2001, Furumoto *et al*., 2002). Elsewhere leaves are used for cystitis, dysuria, fever, and gonorrhea (Kokwaro, 1990). The cold infusion is said to restore appetite and strength. Despite the nutritional quality of this crop, its production is limited to the rainy season due to scarcity of water supply during off season (Makokha and Ombwana, 2002). *C. olitorius* is easily susceptible to moisture stress in easily drying up top soils owing to its shallow rooting depth, though can be solved by applying irrigation (Fasinmirin, 2001).

Taylor and Wepper (1990) reported that adequate watering as well as other inputs like fertilizer significantly increased crop, seed yield and storability of Jute mallow and that the amounts used are variable due to variation of nutrients in soil and its organic matter presence and so the farmer has to establish rates that are most economical for him or her. Yellowing or reduced leaf size before maturity is a sign that the plant needs more nutrients. Compound fertilizers or nitrogen fertilizer such as Calcium Ammonium Nitrate or Sulphate of Ammonia is applied at the rate of two and half teaspoonfuls per running meter. Alternatively foliar feed can be sprayed once every week (KARI, 2011, 2014).

Currently, there is no good quality seed of Jute mallow vegetable (Ndinya, 2005). Production of high quality seeds has not been practiced in African leafy vegetables (Abukutsa-Onyango, 2002). Farmers have been getting re-cycled planting seed of *Corchorus olitorius* every season from local markets and farms whose potential is not assured (Okongo, 2005). The leaf yield of crop has remained low, 2-4 tons/ha/annum as compared to expected yield of 5-8 tons per ha per annum (KARI, 2009), and major constraints has been non use of proper agronomic practices and poor quality seeds. Consequently, farmers use as much as 7 kg/ha instead of 5 kg/ha seed required for density of 250 000 plants/ha, which amounts to 40% extra seed (MOA, 2009).

Generally for many crops, the use of proper agronomic practices like spacing, fertilizer, right harvesting stage and good quality seed has helped to raise yields and consequently better post harvest handling of produce thereby stimulating interest in its farming (Amarjit, 1995). The combination of farming practices was found to have had an increase of 112% in cereals, 124% in potatoes and 142% in sugar beet in central Europe (Desai *et al*., 1997). Also in India good quality seed and use of fertilizer increased wheat production from 12 million tons to 31.3 million tons over a short period of ten years (Feistrizer *et al*., 1975). Jute mallow crop destined for seed production may either be left without cutting or cutback once at 20 cm above ground to stimulate lateral branching.

Plants need to be spaced at 50 x 50 cm and well fertilized to get a good seed yield (Berinyinyet *et al*., 1997). The stage at which capsules are collected is very important for quality seed. Fruit capsules left in field become dark brown or black and could get diseased or they could ripen and shatter their seeds. Leaving them for too long also reduces their germination capacity and result in a high percentage of seed dormancy (Nagel and Börner, 2010). Ideally, almost mature capsules should be picked by hand and left to dry on a sheet. Dried capsules are beaten lightly to release seed. The seed is cleaned and stored in sealed containers such as gourds and glass jar or similar containers (Almekinders and Louwaars, 1999; Groot *et al*., 2012).

Characterizations of different types of plant resources have been increasing in the last years. Studies have shown that a broad range of characterization have been applied on hundreds of plant species. These have followed theoretical basis for inferring genetic/morphological diversity for the purpose of both breeding and conservation strategies in their identification. Despite increased importance of characterization in plant resources, there is scarce information about analysis of this type of data (Beebe *et al.,* 2000). To fill such a gap of information, research like this being carried out on Jute mallow needs to be done. This will bring out the rationale behind morphological/genetic relationship among germplasm (within and between groups) and to identify accession, and also discuss the parameters for specific plants (Drossou *et al.,* 2004). To confirm morphological diversity, Genetic characterization can be used to check diversity within groups and may be either quantified for the whole group (parameters to use need to be chosen), or quantified and visualized for the relationships among individuals (Jakse *et al.,* 2001). Quantification parameters can be chosen depending on type of parameters chosen, reproduction mode and relatedness of individuals. Visualization is achieved by hierarchical and non-hierarchical methods. In genetic diversity between groups, quantification is done either by analysis of molecular variance (Excoffier *et al*., 1992), or Nei's parameters, or Wright's F-statistics (Goudet, 1995; Karp *et al*., 1997). Efficiency of accession identification can be evaluated by maximal probability of identical match by chance and number of resolved morphotypes (Krauss, 2000).

1.2 Statement of the Problem

Jute mallow production in Kenya, including North Rift region, is in most cases done without strict adherence to recommended agronomic practices by farmers thereby lowering quality and yields (MOA, 2009). To address this challenge in agricultural production high quality seed is required, among other factors for its sustainability and profitability. However seed production system of many indigenous vegetables including Jute mallow in North Rift region, Kenya is largely informal (Ndinya, 2005). Farmers often produce and store their own seed and distribute the seeds among themselves without knowing seed quality status in terms of purity, germination or vigour thereby lowering yields (Ngoze and Okoko, 2005). This situation has been thought to be due to many factors including inadequate knowledge of seed quality aspects (Okongo, 2005) necessitating the study of how Jute mallow seed is produced and handled by farmers up to marketing level.

In the North Rift region, Kenya, there are no known described improved morphotypes of Jute mallow apart from the local land races (Guo *et al*., 2007) making improvement of the vegetables a challenge. This is because there is no official breeding in place for the indigenous vegetables (Bhattacharjee *et al.,* 2000). Farmers in North Rift region, Kenya and other parts of the world grow landraces which differ in their morphology, are of low yield performance, and growth (Drossou *et al*., 2004) proliferating the scarcity of crop availability in the market. In order for Jute mallow to be increased in production to meet the current high demand of these vegetables, purification, selection and breeding of germplasm need be enhanced necessitating for characterization to provide current field germplasm information that can show which germplasm are high yielding to be used by farmer in production and for future breeding work and conservation strategies (Jackse *et al*., 2001).

In North Rift region most of the fruits of Jute mallow fruits do not ripen simultaneously, and fruits left to dry on the mother plant before harvesting face seed losses like deterioration due to weather, lodging and shattering through dehiscence thereby reducing quality (Schippers, 2002). These loses could be reduced by hand-picking seed pod at mature stage, followed by seed extraction and drying (Kamotho, 2005) necessitating research to find out harvesting stage of Jute mallow seed that maximizes seed quality aspects of analytical purity, germination, and seed vigour.

The quantity and quality of farm produced Jute mallow in the North Rift region is usually low and poor (KARI, 2009). Several reports indicate that the quantity and quality of farm produced Jute mallow many parts including Western, Nyanza and North rift is not always optimal (Schippers, 2002; Abukutsa-Onyango, 2005). Because of the high cost of fertilizers and chemicals and the low purchasing power of farmers, most farmers do not use them (Gisselquist and Harun-ar-Rashid, 1998). It is estimated that 90% of the Jute mallow farmers plant seeds that have been produced without adequate agronomic practices like spacing and right harvesting stage and may express poor germination, vigour, and storability (Muliokela, 1999). This leads to reduced seed quality for the progeny (Dornbos Jr. 1995), which could express a more variable emergence (Egli, 1998) leading to low yield, necessitating this study to find out the effect of spacing, fertilizer and harvesting stage on seed quality and leaf yield of Jute mallow.
Jute mallow production currently has been low and stands at 2-4 tons/ha per year as compared to expected 5-8 tons/ha per year (KARI, 2009). This is attributed to various agronomic practices. The use of correct agronomic practices like spacing, fertilizer, crop protection and harvesting stage for Jute mallow production helps to increase quality of crop, enhance storability and seed yield (Berinyinyet *et al.*, 1997). In the market, there is no high quality seed of the Jute mallow (*Corchorus olitorius*) vegetable from the breeders to farmers, and this has resulted to farmers getting re-cycled planting seed of the crop whose quality/ potential is not assured. There is also

presence of high produce wastage due to poor post harvest handling at farms and market. In the country, there is ample production potential not only to meet the growing demand for the domestic use requirement but also produce surplus for export, but the major constraint has been use of poor agronomic practices, post harvest handling and storage as well as poor quality seed. Farmers use as much as 7 kg/ha instead of 5 kg/ha of seed which is required for a density of 250 000 plants/ha (MOA, 2009), and it has been observed that farmers plant many seeds per hill thereby using 40% extra seed. Such has endevoured the Kenya Agricultural Research Institute (KARI) to focus her efforts on generation of appropriate strains of the vegetable in its' seed improvement programs to improve germplasm available in the country (KARI, 2009).

1.3 Justification

Jute mallow is both a food security crop and a commercial crop in the North Rift region. It is among popular indigenous vegetables whose leaves are used widely in Kenya, especially Western, Coast and Rift valley regions. This can be attributed to its nutritive value, its relative cheapness compared to exotic vegetables, its ease in cultivation and input requirement and its quick maturity among other factors. Its production offers job opportunities either directly or indirectly to a vast majority of people right from homes, through local markets up to the urban whole sale markets (Okongo, 2005).

Accurate characterization through phenotypic and genotypic methods is of interest both for the description, enhancement and protection of landrace materials and for the initiation of breeding programs (Guo *et al.,* 2007). Also further knowledge of germplasm diversity through genetic variation assessment has significant impact on the improvement of crop plant like Jute mallow (Drossou *et al.*, 2004). Seed quality information on the other hand is important for farmers as it is relevant to crop establishment, yield and profit (Okongo, 2005).

The government has also been advocating for production and consumption of local vegetables in its strategy for food self sufficiency in the country (MOA, 2009). Vegetables in Kenya are an integral part of obtaining income, nutritional and food security (Habwe *et al*., 2008) as they are a source of important nutrients essential for the good health (WHO, 2003). However, Jute mallow production has been low, 2-4 tons/ha per year in most parts of Kenya (Abukutsa-Onyango, 2003), North Rift included, adding to food in-security in Jute mallow growing areas. Low levels of Jute mallow production can be attributed to the use of low quality farm saved seeds as opposed to improved morphotypes, none/low level of fertilizer use, incorrect spacing and other agronomic practices like crop protection and weeding (Okongo, 2005). Fertilizers and manures provide nutrients to crops which grow vigourously and produce high yield and quality seed. A good crop destined for yield/seed production needs to be well spaced, weeded, crop protected and harvested at correct stages to get a good quality seed and increased yield (Schippers, 2002). Though so, such good production practices that maximizes on seed quality and yield needs to be researched for use by agricultural extension services especially for North Rift region, Kenya nessesitating for the research.

It is estimated that 80% of the seeds sown in developing countries, Kenya included, is farmer produced (Almekinders *et al.,* 1994). Among agricultural inputs, high quality seed and fertilizer and correct spacing has a great ability to increase on-farm productivity (Okot, 2002) and hasten storability thereby enhancing food security (Chadha *et al*., 2007) since it determines the upper limit on yield and therefore the potential of the other inputs (Beck *et al.,* 2003). Improved husbandry practices including the use of high quality seeds are capable of increasing Jute mallow production by over 70% (GOK, 2007). Under farmers' conditions, the national average Jute mallow yield is about 2-4 tons/ha/annum (MOA, 2010) as compared to the expected yield of 5-8 tons per ha per annum, while potential exists for increasing the yields to over the world's average of 8-12 tons per ha per annum (KARI, 2009). With the use of improved Jute mallow seed, fertilizer and good crop husbandry practices, yields can be improved (AVRDC, 2004). Feistrizer (1975) reported yield increases of up to 112 % in cereals in Central Europe through the use of improved seed and other agricultural inputs. Similar increases are possible with other crops such as Jute mallow.

It has been observed that poverty comes with malnutrition and poor health which can be addressed in part by consumption of the highly nutritious indigenous vegetables (GOK, 2007). Surveys conducted in Kenya show that 50% of the people live below poverty line and live on less than one dollar a day (AICAD, 2003). To try and solve this problem, improved production and sale of vegetables like Jute mallow can play an important role in improving rural livelihoods (Wallingo *et al*., 2001).

The stage at which capsules are collected is very important for the quality of the seed (Abukutsa-Onyango, 2007). Fruit capsules left in the field become dark brown or black and could get diseased or they could ripen and shatter their seeds (Almekinders and Louwaars, 1999). Leaving them for too long also reduces their germination capacity and result in a high percentage of dormancy (Ekpong, 2009). Ideally, Jute mallow mature capsules should be picked by hand and left to dry (Ngoze and Okoko, 2005) but there is a lapse that exists in right stage of picking pods to maximize seed attributes, necessitating for study on right seed harvesting stage.

1.4 General Objective

The overall objective of this study was to determine effect of agronomic practices on seed quality and leaf yield of Jute mallow germplasm, in the North Rift region, Kenya.

Specific objectives

1. To assess production and handling processes of Jute mallow by farmers in the North Rift region, Kenya.

2. To do morphological characterization on Jute mallow germplasm from the North Rift region, Kenya.

3. To determine effect of spacing and fertilizer application on seed quality and leaf yield of Jute mallow in the North Rift region, Kenya.

4. To determine harvesting stage in Jute mallow maximizing seed quality aspects of analytical purity, germination and seed vigour in the North Rift region, Kenya.

1.5 Hypotheses

H_o1: There are differences in production and handling processes of Jute mallow by farmers in the North Rift region, Kenya.

H_o2: Jute mallow germplasm differ morphologically in the North Rift region, Kenya.

H_o3: Spacing and fertilizer application has effect on seed quality and leaf yield of Jute mallow in the North Rift region, Kenya.

H_o4: Harvesting stages of Jute mallow has effect on seed quality in terms of analytical purity, germination, and seed vigour aspects in the North Rift region, Kenya.

CHAPTER TWO

LITERATURE REVIEW

2.1 Importance of indigenous vegetables

In Kenya, meals are usually considered complete with the inclusion of vegetables (Mroso, 2003). Vegetables are those plants which are consumed in relatively small quantities as a side- dish along the staple food and may be the leaves, roots or stems of herbaceous plants, although flowers, calyces, immature seeds or fruits may also be consumed as vegetables (Desai *et al*., 1997). Nutritionally vegetables are good sources of vitamins, proteins, minerals and fiber (FAO 2000; 2004). In Africa three major classes of vegetables are consumed (Raymond, 2000). Those gathered from the wild e.g. baobab leaves, black jack leaves (*Bidden pilosa*) and leaves of purslane (*Portulaca spp*); secondly the Indigenous vegetable which are often gathered, but are also cultivated e.g. *Amaranthus spp, Solanum nigram, Corchorus olitorius* and *Crotalaria bredivens,* and then the exotic/imported vegetable species which are cultivated e.g. cabbage, kales, spinach and cauliflower.

In many cases the first two are far more nutritious than the last category, and it is from this that government and health institutions have been encouraging continued consumption of them (Maundu, 1997). The nutritive qualities of the leaves, especially the proteins, vitamins and mineral contents and dietary fiber, have helped to avoid widespread levels of mulnutrition in many societies (Mroso, 2003). The origin of many vegetable crops can be traced to various parts of Europe as well as to Asia, Africa and South America (Abbass, 2000). In general terms, the range of latitude within which such vegetable crops are grown varies from 20 degrees north and south of the equator (Yousof *et al*., 2006).

Indigenous vegetables are popular in Kenya (Schippers, 2002). They are mainly grown in kitchen gardens for home consumption and little for the urban market (Abukutsa-Onyango, 2002). However they have been neglected in terms of research on agronomic recommendations, seed production and improvement (Ndinya, 2005). In most cases, they have been allowed to regenerate with onset of rains without a serious effort to plant new seed or even apply other cultural practices on them (Okongo, 2005). The local demand for the vegetables is still largely unmet and farmers have continued to use their own seed or purchase the scarce seed of unknown quality from the local market (K' Opondo *et al*., 2005).

These vegetables are advantageous in that they are fast growing, well adapted to a widerange of agro-ecological zones. In general terms, the range of latitude within which such vegetable crops are grown varies from 20 degrees north and south of the equator (Yousof *et al*., 2006). Also these vegetables are less susceptible to diseases and pests, more nutritious than the exotic vegetables and require little or no in-organic fertilizers (Abukutsa-Onyango, 2002). These vegetables fetch good prices in the market (Shiundu and Oniang'o, 2007). However when grown for commercial purpose the addition of inorganic fertilizers is important for improved yields and quality (Kipkosgei *et al*., 2003).

The expansion of production of these vegetables continues to be hampered by lack of a reliable source of planting materials and technical information (Ngoze and Okoko, 2005). There are many indigenous vegetables, but the commonly used ones in Kenya are *Solanum nigrum, Crotalaria brevidens, Corchorus olitorius, Cleome gynandra, and Amaranthus spp.*

2.2 Jute mallow (*Corchorus olitorius*)

2.2.1 Botanical Description

Jute Mallow is an herbaceous annual or short-lived perennial with upright stems of 1.0 - 1.5 m high with abundant fibers in the phloem tissue. The leaves are alternate, light green, linear, and deciduous. The petiole is 1.2 cm in length with the lamina being lanceolate and measures 20 cm long by 7 cm wide. The edge of leaf is serrated with tip acute that is generally ovate. The flowers are solitary or in cymes, normally yellow and small being in opposite to the leaves and measure 1 cm in diameter. The sepals are 5, narrow and measure 7-8 mm in length. The stamens are 10 with short styles and flattened stigma. The ovary is superior with 5-locular numerous ovules. Its fruits are long, cylindrical, 10 ridged, a beaked capsule, measuring 5-10 cm x 5-8 mm dehiscing by 5 values and with transverse septa between the seeds. There are 180-230 seeds per capsule. The seeds are pyramidal, measuring 1-2 mm in length, are dark grey –blue in colour. The weight of seeds is approximately 400-500 seeds/g (Schippers, 2002, Fondio and Grubben, 2004).

2.2.2 Diversity of Jute Mallow (*Corchorus olitorius*)

Jute Mallow belongs to the genus *Corchorus* and *Tiliaceae* family. Common names include long-fruited jute, Jute/Jews mallow, Bush okra, and West African sorrel. Its origin is probably South China, but now found growing wild and in parts of tropical Asia (India) and tropical Africa (Yousof *et al*., 2006). It has been naturalized in many tropical countries including Kenya. It is cultivated as vegetable in many tropical areas, including Egypt, Sudan, Kenya, tropical Asia (Malaysia), tropical Africa especially West Africa (Ghana, Nigeria, and Sierra Leone), South America and the Caribbean

(Desai *et al*., 1997). The local forms have been selected in many regions, many of these are dwarf, branching forms, growing to 50 cm in height, for instance in Nigeria, two main types have been described by Epenhuijsen (1974), *Amugbadu*- with large finely serrate leaves, growing to 180 cm in height*Oniyaya*- has broad leaves, coarsely serrate, growing to 150 cm in height, widely branched.

Jute mallow (*Corchorus olitorius*) is a nutritious leafy vegetable that prefers a warm, moist climate. Yields are usually low due to lack of improved morphotypes, poor seed quality and poor production practices, including improper fertilization and spacing of plants (Grubben and Denton 2004**)**.

Plate 1: Photo of Green morphotype (on left) and Brown morphotype (on right) of Jute mallow (Corchurus olitorious)

In Africa, few countries have given research priorities to the genetic improvement of Jute mallow, though Nigeria has tried to do research on locally available morphotypes and thus, a large number of local landraces have been characterized and improved (FAO, 1998). Fertilizer trials indicate that the crop does not respond favorably to high nitrogen application, which may be evidence of its adaptation to low nitrogen conditions (KARI, 2005).

Other studies have shown that higher leaf yields can be obtained with the application of fertilizer combined with spacing (Schippers, 2000). Jute mallow is a high quality leafy vegetable in market value (Shiundu and Oniang'o, 2007), consumers' preference and nutritional value (Abukutsa-Onyango, 2005). It is recommended that African leafy vegetable local cultivars be collected and tested for useful characteristics including adaptation to various environments and inputs, resistance to diseases and yield (Onyango *et al*., 2009).

Jute mallow is one of the leading leafy vegetables in many countries and much cultivated and traded though no statistical data on production or marketing are available (Schippers, 2002). International trade with neighboring countries occurs, but is not registered. The world Jute production (combined data from *Corchorus olitorius* and *Corchorus capsularis* L.) has been stable over the past 40 years (Khatun *et al*., 2002). In the period 1997–2001 it averaged 2.76 million tons per year (Khandakar and van der Vossen, 2003). India and Bangladesh together produced more than 90% of the total. Jute is a rain-fed crop with little need for fertilizer or pesticides (Bhattacharjee *et al*., 2000).

2.2.3 Jute mallow nutritional Content

Nutritionally, most indigenous vegetables including Jute mallow have not been assessed in depth for their nutritional contents, especially the many varied land races available across the world. Though so, some such as spider plant, amaranth and black night shade have been done though for comparison with exhotich vegetables like cabbage, spinach and kales (Taber, 2009). Some researches have shown that the indeginous vegetables contain higher amounts of phosphorus, zinc, (Yebpella *et al*., 2010) iodine, fluorine and vitamin B as compared to exotic vegetables (Ruibaihayo *et al*., 2002). Research has also shown the indeginous vegetables are nutritionally superior to exotic in many nutrients (Mibei *et al*., 2011). Though these local vegetables are very nutritious they have been neglected and exotic vegetable are consumed by many people in Kenya in large amounts which include; kales, spinach and cabbage (Adebooye *et al*., 2003; Adebooye *et al.*, 2005; Villa *et al*., 2005). This has led to 30% malnourishment of people in African countries (Raymond, 2000). This is supported by many world countries raising concern of poor health, including Kenya (GOK, 2005; WHO, 2003). In Kenya for example malnutrition has been found to be due to lack of these nutrients leading to high or increasing nutritional related diseases such as heart diseases, diabetes, hypertension, obesity, cancer, weak bones (Voster *et al*., 2007; Maundu, 2003). The leaves of Jute mallow are rich source of iron, protein, calcium, thiamin, riboflavin, niacin, foliate as shown in Table 1.

Table 1: Nutritional values of boiled Jute mallow (per 100 g edible portion)

Nutrients	**Amount**
Moisture (%)	80.4
Food energy (cal.)	43
Protein (g)	4.5
Fiber (g)	1.7
Total Carbohydrates (g)	7.6
Ash (g)	2.4
Calcium (mg)	266
Phosphorus (mg)	97
Iron (mg)	11.6
Sodium (mg)	12
Potassium (mg)	444
Vit. A (I.U.)	6,390
Thiamine (mg)	15
Riboflavin (mg)	28
Niacin (mg)	1.5
Ascorbic acid (mg)	95

Source: FAO 2004

Traditional leafy vegetable crops such as *Amaranthus*, *Corchorus* and *Cleome* are important sources of food and nutrients (Akubugwo *et al*., 2007). They have high nutritional value and contain significant levels of calcium; iron and vitamins A and *C. Amaranthus spp.* and *Corchorus olitorius* are also rich in protein quantity and fiber (IPGRI, 2000).

2.2.4 Jute mallow crop management

Seeds are sown by direct drilled on lines prepared beds, preferably at the beginning or the end of the wet season, and the seedlings thinned to leave plants at various spacings including a square spacing of 20-30 cm x 20-30 cm, depending on the vigour of the selection and use as vegetables or for seed. Alternatively, seeds may be sown in a seedbed and transplanted in rows 45-55 cm, between plants (AVRDC, 2004). Soaking of seeds in warm water before sowing may overcome erratic germination due to a dormancy factor. Approximately 5 kg/ha of seed is required for a density of 250 000 plants/ha, giving leaf yield varying from 5-8 t/ha per annum (MOA, 2009). Irrigation may be required during dry period to maintain an adequate level of soil moisture. Addition of complete fertilizer at planting and surface dressings of nitrogen stimulates leaf production once the plants become well established (Van Averbeke, 2007). But generally the vegetable grows well without inorganic fertilizer or farm-yard manure (Desai *et al*., 1997; Mc Donald, 1994).

2.2.5 Jute mallow (*Corchorus olitorius*) uses

Leaves and young shoots contain a high proportion of mucilage and are used as cooked vegetable, in a similar manner to spinach greens (Abukutsa-Onyango, 2002). The protein content of young leaves is approximately 1.5% while that of older leaves varies from 5% - 6%. Harvested leaves may be dried and stored for significant periods (Dessai *et al*., 1997). There is an increasing awareness of the value of leafy vegetables in contributing to a balanced diet, particularly in areas where animal protein is deficient (Abukutsa-Onyango, 2003). In addition to their iron content, leafy vegetables, like Jute mallow, contribute significant amounts of beta-carotene and ascorbic acid (Vitamin C), protein, minerals (particularly calcium) and carbohydrate (FAO, 2000, 2004). Maternal and infant mortality at childbirth have also been linked to lack of these nutrients. It is reported that one out of four women suffers from nutritional deficiency in Kenya (Maundu, 2003). The vegetable is nutritious and popular with expectant mothers since it stimulates more milk during breast feeding period (Nekesa and Mesa, 2003).

In Kenya the vegetable is popularly used to blend with other local vegetables like *Solanum nigrum, Crotalaria brevidens, Cleome gynandra, and Amaranthus spp.* They are also often added to soups and stews for they have high nutritional value and can be cooked without fat, hence popular with rural communities (Rubaihayo, 2003). However, if cooked only in water, leaves are usually hard and locally made sodium bicarbonate is used to soften it, (ash is distilled and distillate used to soften vegetable during cooking). Generally these vegetables can be fried or boiled and milk added to increase palatability (Maundu, 1997).

2.3 Jute mallow production and seed quality management

2.3.1 Jute mallow production in Africa

Little is known about the informal on-farm Jute mallow production systems prevalent in sub-Saharan Africa (SSA) (Irungu *et al.*, 2007). While the informal Jute mallow production sector is responsible for providing more than 90% of the farming inputs like fertilizer and seed used in most countries (Kenya included), the formal (commercial companies) account for 10% remainder, and only recently has it been recognized as the major system for seed supply in SSA (Gisselquist and Rusike, 1998). In particular, the majority of small-scale farmers in SSA use on-farm produced and saved seed (Muliokela, 1999), but unfortunately the quality of local seed is usually poor (Louwaars, 1994).

It is surprising, though, how many farmers actually sell the best produce and keep the worst for seed, the exact opposite of what should be done (Odhiambo and Oluoch, 2008). Such practices can only lead to a rapid decline in quality and productivity, and therefore low profits (Onim and Mwaniki, 2008). The reason as to why most of the seed obtained from the informal sector is of low quality is that many SSA farmers value the most 'adequate physical purity of seed' and reasonable germination percentages, while other seed quality parameters such as speed of emergence and vigour are considered less important (Wright *et al.*, 1994). The consequence is that on-farm vegetable crops are produced without strict adherence to quality production standards like ensuring optimal plant density, roguing, and maintenance of isolation distance, timely weed control, disease and pest control, fertilizer application, proper land preparation and proper storage system (Onyango *et al*., 2009). Any of above can contribute to low yield of crop if not attended to (AVRDC, 2004).

The cost of seed is a small proportion of total growing costs, yet the final crop is as dependent on seed quality in terms of yield and leaf product uniformity as on the cultural environment (Amarjit, 1995). The first step in crop improvement is a full assessment of the local crop and seed material. More often than not, local crop materials are not of excellent quality and have led to non acceptance by farmers and consumers (Bujulu and Matee, 2005). In crop and seed production, legislation governing all aspects of seed production is a basic requirement, and provision must be made for appropriate training, which most farmers producing own crop and seed lack

(Okongo, 2005). The lack of seed testing services locally at farmer's disposal is one of the major problems of farmer Jute mallow producers. When the above issues like correct fertilizer rates, optimum spacing, and correct seed harvesting stage are addressed, there is no doubt that there is vast scope for improving Jute mallow crop and seed industry (Habwe *et al.,* 2008). Using simple in-expensive equipment coupled with research can be employed to produce improved cultivars (Opabode and Adegbooye, 2005).

2.3.2 Jute mallow production in Kenya

Jute mallow production fundamentals

In Kenya, as in other sub-Saharan countries, food production per capita has been continually declining in the last decades of the twentieth century due to poor soil fertility, diseases, storage pests, and weeds (FAO, 1996, 1997). Other salient causes of low agricultural production are lack of adapted morphotypes, poor agronomic practices and lack of good quality seeds (Ochuodho *et al.*, 1999; Olaniyan, 2001) for use as planting material by farmers. Seed is an essential input in crop production and its genetic potential determines the upper limits of potential leaf and seed yield (Oyoko *et al*., 2003).

Good seed is fundamental to success in any crop production and especially for vegetables, where quality and uniformity of the leaf product are so important to consumers (KARI, 2014). No amount of good husbandry practices or expensive chemical inputs will overcome an initial handicap of poor seed (Ochuodho *et al.,* 1999). Kenya currently, tends to focus on a narrow band of crops for quality seeds, principally maize and wheat which is produced locally (MOA, 2013). The horticultural sector in Kenya has grown to be very important industry, however, crop management and seed quality has been a major problem (Abukutsa-Onyango 2002), as most horticultural seeds are not produced locally and most of the seed companies merely deal with the importation and distribution of horticultural seed (MOA, 2012). Similarly strategies such as plant breeding or crop selection and improvement through characterization can be rolled out for development of indigenous vegetable seeds, among others which contribute greatly to food security in the country have been given minimal attention (Habwe *et al*., 2008, Shiundu and Oniang'o, 2007). In order to attain national food security and better rural livelihoods for our farmers and Kenya as a whole, there is need for seed industry to research on these aforementioned issues of seed quality, leaf yield, by looking into fertilizer application, spacing and seed harvesting stage maximizing seed quality attributes of purity, germinationas well as seed vigour which this research is geared to trying to address.

Preparing the field for Jute mallow production

Jute mallow is a small seeded plant; therefore, thorough land preparation is required to promote good growth as suggested by Palada and Chang (2003). The field should be plouged, harrowed and rotor tilled. A plough or mechanical bed shaper is used to form beds. Raised beds are formed for planting 20 cm-high during the dry season and 30 cm- high during the wet season. The distance between furrows should be 150 cm (if furrows are used) or beds left un-furrowed and bed tops be about 90 cm wide. Seeds are then covered 0.5 cm depth. If seedlings are raised in trays, individual cells should be 3 cm wide and deep (size 100 cell trays are recommended). The trays can be filled with a potting mix that has good water-holding capacity and good drainage. Such potting mix include peat moss, commercial potting soil, or a potting mix prepared from soil, compost, rice hull, and vermiculite or sand (KARI, 2014). The non-sterile components can be used or a sterilized mixture that is autoclaved or baked at 150^{o} C for 2 hours. Two or three seeds are then sown per cell, 0.5 cm deep, and thin to one seedling when they have two true leaves (KARI, 2011).

In the seedbeds or cell trays, seedlings should be protected with fine-mesh nylon net or grown inside a greenhouse or screen house or if not available open field serves purpose (MOA, 2012). This provides shade and protects seedlings from rain and pests. The seedlings should be watered thoroughly as needed (moist, but not wet). The seedlings should be grown in shade, harden and gradually exposed to direct sunlight during the 4–5 days prior to transplanting. On the first day seedlings are exposed to direct sunlight for 3 hours and later increase the duration until they receive full sun throughout the fourth day.

Seedlings will be ready for transplanting three weeks after sowing or when transplants have five or six true leaves (Chadha and Oluoch, 2003). Seedlings produced in a seedbed should be gently removed with a trowel and planted bare-root. Those produced in trays are then lifted with their root balls intact and then transplanted. When setting plants into the field, optimum spacing varies depending on morphotype and harvest method (Hampton, 2000).

Planting of Jute mallow

Jute mallow is planted either by direct seeding or transplanting. Direct seeding is used when seed is in plenty; labor is limited and during the dry season and when flooding is not a problem. Planting is done at the beginning of the rainy season. When there is uniform distribution of rainfall, it can be planted anytime of the year. Direct seeding is also appropriate for once-over harvesting. Transplanting is preferable when there is limited supply of seed, plenty of labor, and during the wet season, when there is high risk of washing out of seeds due to heavy rains. Transplanting is often used for crops that are harvested multiple times. Seeds are drilled uniformly 10 cm to 13 cm apart in furrows or at the rate of 5-6 kg of seeds per hectare (MOA, 2013). For big scale planting and in open places, seeds are judiciously broadcast and lightly covered with fine soil by passing a wooden harrow (Abukutsa-Onyango, 2003).

The seed has a dormancy period and may take several months to germinate. Dormancy is broken by putting seeds in a cloth bag and steeping them in just-boiled water for 10 seconds and seeds allowed to dry overnight. Treated seeds should be sown quickly since they cannot be stored. Seeds are either broadcast or sown in rows. Seeding rates range from 0.5–5 g/m^2 or 5 kg/ha depending on viability and size of seed (MOA, 2009). Each 6 gram of seed contains about 500 seeds. Spread seeds uniformly over a well-prepared bed and cover lightly with a layer of compost or rice hull or soil. If grown in rows, space furrows 10 cm apart on the bed. Two or three seeds per hill is planted in hills spaced 5 cm apart, and seeds covered 0.5 cm deep (AVRDC, 2004). Seedlings may be thinned to one plant per hill when they have two to three true leaves. Transplanting reduces the amount of time the crop is in the field and secures a more uniform stand. There are two steps to transplanting seedling production in a nursery and setting plants into the field. Seedlings can be grown in a raised seedbed or in cell trays. If started in a seedbed, the soil should be partially sterilized by burning a 3-5 cm thick layer of rice straw or other dry organic matter on the bed (AVRDC, 2004; KARI, 2004).

Spacing of Jute mallow

Jute mallow species broadly exists by two cultivars i.e. narrow leaved and broad leaved. Direct seeding at a spacing of 45 cm between the rows and 15 cm within the plants has been adopted for both cultivars (Abukutsa-Onyango, 2007). Wider spacing's are used for tall cultivars with broad leaves, multiple branches, and harvested several times (Adebooye *et al.,* 2005). Narrower spacings are used for short and bushy cultivars and once-over harvesting. Rows are spaced 10 cm apart with 5–10 cm between plants within row (Sivakumar and Ponnusami, 2011). At transplanting it should be done in the late afternoon or on a cloudy day to minimize transplant shock. Make transplant in 10 cm holes and cover the roots with soil and lightly firm. Water plants immediately after transplanting to establish good root-to-soil contact (Berinyinyet *et al.,* 1997). The seedlings are then thinned two weeks later to a spacing of 30 cm x 30 cm. The experimental plots be kept weed free throughout the experimental period (Bhattacharjee *et al.,* 2000).

Fertilizer application on Jute mallow crop

Various literature give different views on African Leafy Vegetables (ALV), Jute mallow included concerning these crops growth effect to fertilizer application. Some researcher's urque that ALVs respond well to added fertilizer, especially nitrogen (Opiyo, 2006). Other researcher's reports indicate ALV's do not respond to high fertilizer application (Abukutsa-Onyango, 2007). Some still conclude that a combination of both inorganic and organic fertilizers improves yield and maintains soil fertility (Diaz *et al*., 2011). Although so, most researchers in essence still agree that the rate of fertilizer application depends on soil fertility, soil type, fertilizer recovery rate, and soil organic matter (Van Averbeke 2007). A soil test is highly recommended to determine the available N, P, and K (Jaetzold *et al*., 2011). The amount of applied fertilizer can be calculated based on target yield and adjusted for residual nutrients (Ashilenje *et al*., 2011). Fertilizer recommendations depend heavily on local conditions, so it's better to consult fertility management specialist for appropriate fertilizer rate (Juma, 2006). At planting well decomposed farm yard manure at the rate of 39 tons/ha or 50 kg/ha of DAP have given same yield (Kipkosgei *et al*., 2003) although Di-ammonium phosphate at the rate of 200 kg per hectare can be applied at planting (Van Averbeke *et al*., 2007).

Although African leafy vegetables can be considered as low management crops and can grow in poor soils, preliminary research results show that yield can be increased with fertilizer application (Mwangi and Mumbi, 2006). *Corchorus olitorius* productivity can be improved by fertilizer application, especially nitrogen (Rensburg *et al*., 2007). Nitrogen is also reported to influence the nutritional value (N, Ca and P content) (Habwe *et al*., 2010). Calcium and magnesium are reported to improve the development of fiber as well as yield and quality of *Corchorus olitorius*. *Cleome* also responds positively to increased soil fertility (Mauyo *et al*., 2008.). However, very high nitrogen applications will course succulent stems which reduce regeneration and this will be a disadvantage when plants are periodically harvested (Van Averbeke *et al*., 2007).

It is recommended that field trials be established to determine the effect of fertilizer (nitrogen, phosphorus and potassium) application on the indigenous vegetables' growth performance, yield, quality and nutritional value (Diaz *et al*., 2011). Pot trials can be utilized to identify nutrient deficiency symptoms on a morphotype of traditional leafy vegetable food crops. Soil sampling is done in the experimental plots before the seeds are planted to determine the soil nutrient status at the time the experiment commences (Hamayun *et al*., 2011). This can be done by soil samples being air dried and passed through a two millimeter sieve (Tan, 1996). The fraction which passes through the sieve is used to analyze total nitrogen, exchangeable cations, organic carbon, available P and pH using described analytical methods and available nitrogen analysis determined using fresh soils (Irungu *et al*., 1997).

Water management of Jute mallow

Jute mallow is sensitive to drought. Irrigating is critical after sowing or transplanting to ensure a good stand. In fields that are furrowed, irrigation is done every 10 days during the cool-dry season, and weekly during the hot-dry season (Fasinmirin, 2001). As a rule, plants should be irrigated if wilting occurs in midday. Irrigate thoroughly to develop a deep, healthy root system. Good drainage is essential for plant survival and growth. Provide drainage canals to facilitate quick drainage of excess water after heavy rains. Avoid over-irrigation since this leads to disease development and leaching of soil nutrients. Drip irrigation or micro-sprinkler irrigation is recommended in areas with limited water supply. If sprinkler irrigation must be used, avoid late evening irrigation to prevent foliar diseases (Fasinmirin 2001; Kamwaga *et al*., 2005).

Environmental conditions for growth and development of Jute mallow

Jute is cultivated over a wide range of environments. The plants grow well under hot, wet in the lowland tropics. It is also responds especially to warm, humid weather and is often grown near riverbanks and waste places. Cold weather and severe periods of drought can kill the crop. A loam or silty-loam soil and plenty of organic matter is ideal. It tolerates soil pH of 4.5 to 8.0, but more extreme pH conditions will reduce the availability of iron in the soil (Ndinya, 2005). Most cultivars are extremely tolerant to many soil conditions although alluvial, well-drained soils with adequate reserves of soil moisture are preferable (Schippers, 2002). Some cultivars are sensitive to excess water in the soil, particularly in the early stages of growth (Epenhuijsen, 1974).

Temperatures within the range of 22° C – 35° C are generally considered conducive to satisfactory growth and diurnal variation within this range may encourage leaf development. Short-day conditions are satisfactory for growth and development; some forms are sensitive to longer days and flowering may be adversely affected (Desai *et al*., 1997; Benjamin, 1990; Bewley and Black, 1994). Most selections are tolerant to high levels of rainfall but do not thrive in areas receiving less than 1000 mm per annum (Schippers, 2002). Well distributed rainfall throughout the growing season and a high relative humidity of 80-90%, is generally considered necessary for optimum growth. Elevations of less than 700 m are normally required for satisfactory growth and yields are likely to diminish above this (AVRDC, 2004; KARI, 2005).

Pests and Disease Management in Jute mallow

The foliage and shoot tips of Jute mallow are susceptible to damage by insects like grasshoppers, caterpillars, army-worms, flea beetles and spider mites. Nematodes (*Meloidogyne spp.*) cause stunting of plants. Pest damage is usually less severe in plantings that are well fertilized and rotated with other crops. Insect pests may be managed by covering beds with fine-mesh nylon netting. Pesticides are useful for controlling pests when they cause significant damage. It is advicable to choose a pesticide that targets the pest and avoid pesticides that kill beneficial organisms. Also use of pesticides that last only for a short period on crop when sprayed is recommended. To avoid exposing consumers to pesticide residues, follow instructions for time intervals between spraying and harvesting (KARI, 2014).

Only a few diseases affect Jute mallow. Damping-off caused by *Rhizoctonia*, *Pythium* or *Phytophthora spp.* occurs in seedbeds. These pathogens are managed through the use of raised beds, well-drained soils, and proper watering (Lazarovits *et al.*, 2000). Stemrot (*Sclerotium rolfsii*) is a common disease during the dry season, causing plants to wilt. Stem rot is managed by deep plowing, using raised beds, rotating crops, and allowing ample time for breakdown of green manure before planting (Nasreen and Ghaffar, 2010). The most serious disease is blight which may cause 100% crop failure when rains are heavy though control by spraying with fungicides has been tried, but unsuccessfully (Colla *et al*., 2012). The other, diseases observed are brown sport and rust during wet conditions but the crop is fairly tolerant to them, however, use of fungicides such as ridomil and antracol may help reduce them (Kamwaga *et al*., 2005).

Harvesting and Post- harvest handling of Jute mallow

Harvesting period of Jute mallow varies with the cultivar and plant type. They can be harvested in 20-45 days after emergence of the crop, 30-60 days after planting and may continue up to 160 days, depending on the cultivar and plant type, and on the prevailing weather conditions. The optimum stage for harvest in most types of Jute mallow could be fixed between 25-35 days after planting to get the highest yield as well as nutritious and palatable greens. Previous research conducted suggests that a plant density of 250 000 plants/ha can be practiced for increased yield can be 5-8 tons/ha per year (KARI, 2009), though currently farmers get between 2-4 tons/ha (MOA, 2009). Continuous cropping of Jute mallow may yield up even more marketable product per year if there is favorable weather (Mwangi and Mumbi, 2006). Both yield and quality of leaves are higher with more frequent cuttings (MOA, 2013).

Jute mallow yield can be increased significantly through improved seed, sowing practices and proper choice of cultivar/morphotype (Kamotho, 2005). Some cultivars are sensitive to short day length, causing them to bloom prematurely. These cultivars should be harvested 20-40 days after planting, just before pods develop (KARI, 2014). Plants may be harvested once or several times and over harvest can be adapted for quick growing morphotypes (Kamwaga *et al*., 2005). At times whole plants (20-30 cm tall) are pulled from soil with roots, washed and tied in bundles (Palada and Chang, 2003). With multiple harvests, young leaves and shoots are picked every two to three weeks and new side shoots will develop and harvesting can be repeated three or four times (MOA, 2009). Frequent harvesting delays flowering and prolongs the harvest period (KARI, 2011). Jute mallow wilts rapidly after harvest and therefore harvest be during the cooler time of day, such as early morning or late afternoon, and keep the produce cool and shaded (Buddhadeb, 2012). Since Jute mallow wilts rapidly, common practice in markets and shops is to sprinkle with water to keep its fresh appearance (MOA, 2012). Jute mallow vegetable can be kept fresh for some days by dipping its roots in water on a basin and sold in bunches or by weight (MOA, 2007).

Various factors, external and internal, determine seed quality and performance. It includes seed development, seed harvesting stage, seed size, weight and composition (Jing *et al*., 2000). Well developed, large seeds, and heavy seeds tend to germinate faster and produce large seedlings (Schipers, 2002). Seeds that are harvested when mature tend to be heavier in weight and emerge faster in field and so perform better under field conditions (Gabriel *et al*., 1997). Fruit development and maturation takes varying periods of 3-4 months in many indigenous vegetables including Jute mallow (Chweya and Eyzaquire, 1999). This has caused early matured pods to shatter especially Spider plant and Jute mallow through dehiscence calling for progressive seed harvesting as pods mature and turn tan/yellow (Mnzava and Chigumira, 2004).

2.3.3 Concept of crop and seed quality aspects of Jute mallow

Mature seed is the means by which the new crop individual is dispersed (grown/raised). The Physiological and biochemical features of the seed largely determine the success, with which the new crop individual is established, in terms of time, place and vigour of young seedlings (Tekrony and Egli, 1997). Of key importance to this success are the seeds effects to the environment and the food reserves it contains. This reserve sustains young plant in early stages of growth before it becomes an independent autotrophic organism, able to use light energy (Bewley and Black, 1994).

High quality seed plays a central role in all efforts to raise yield per unit area and achieve a higher income. Furthermore, seed is the key to optimum use of natural resources and according to its provenance and the breeding goal. Seed determines the requirements for inputs such as pesticides, fertilizer and agricultural technology (Franzern *et al.,* 1996).

One aspect of quality of particular importance to the seed buyer is genetic quality (K'Opondo *et al*., 2005). The seed is sold as being from a particular quality which the buyer expects will give certain results under the conditions where the seed is to be planted since there is a positive relationship between germination and seed quality (Basu, 1997).

2.3.4 Jute mallow seed production

Currently there is no quality seed production in process (KARI, 2014). As for seed production, leaf harvesting should be limited to assist more food storage in seeds (Kamotho, 2005). Most vegetables are self-pollinated with up to 10% out-breeding making it only have some variation between local selections and off-types which should be weeded out (Choudhury *et al*., 2007). The mature plant is threshed to extract the seed but care should be taken to harvest before significant seed loss occurs due to shattering (Fondio and Grubben, 2004). Locally, mature seed pods are usually harvested and dried in the shade for five days and one day in the sun (Epenhuijsen, 1974). The pods are then shelled and seeds winnowed (KARI, 2009) and farmers store clean seed after mixing it with five handfuls of ash per 5 kg tin of seed and store in guards, pots or tins (Abukutsa-Onyango, 2007).

2.3.5 Farm-saved-seed of Jute mallow (*Corchorus olitorius*)

In plant breeding the considerable work is assessing combinations of cultivars to ensure superiority in general agronomic terms and profitability in the final analysis (Habwe *et al*., 2008). Very clearly, the average small vegetable farmer has neither the time nor the expertise to mount full breeding program that goes with quality seed production process. That is why generally they have to purchase seed from commercial concerns. But for various reasons like high seed price, seed availability for purchase and lack of finances to do the purchasing, farmers prefer saving their own seed from their field crops and even sell to their neighbors, especially for vegetables. This keeping of seed from crop leftovers, usually refered to as farmers-saved-seed has resulted in plant degeneration leading to poor yield (Okongo, 2005). Processing of seeds includes harvesting, drying, dressing and cleaning, grading and seed treatment with fungicide. It needs careful application since they can have adverse effect on seed viability. Processing is a complex procedure involving a lot the machinery and need specialized persons to do the work and most farmers do not have.

To improve the quality of on-farm produced seed an understanding of traditional seed production systems is therefore essential and can be accomplished through participatory research and in-depth analysis of the present informal seed supply systems (Ngoze and Okoko, 2005). A robust crop generally is a basic tool for secured food security in any country; the principle means to secure crop yields in less favorable production areas and a medium for rapid rehabilitation of agriculture in cases of natural disaster. The use of good quality seeds combine with other inputs e.g. fertilizer to significantly increase yield levels, in cereals (112%), in potatoes (124%) and in sugar beet (142%) in central Europe. Also in India good quality crop seed increased wheat production from 12 million tons to 31.3 million tons over a short period of ten years (Feistrizer, 1975).

Agricultural production requires high crop quality among other factors for its sustainability and profitability. Seed quality is largely influenced by good crop production conditions, maturity during harvest and subsequent treatments. Seed lots must have high purity, viability and germination capacity for it to respond to good agricultural practices (Hampton, 2000). Low germination percentage, low germination rate and low vigour are often associated with low crop yields. Low germination can be due to genetic properties of certain crop cultivars, incomplete seed development on the plant, injuries during harvest, improper processing and storage, disease and ageing (Basra, 1997) and therefore need to be checked-up for high yields.

2.4 Testing for seed quality on Jute mallow

2.4.1 Importance and types of seed quality tests on Jute mallow

This is the science of evaluating seed quality for agricultural purposes. It is valuable in the evaluation of the planting quality of field crop and vegetable seeds, and also in determining the quality of crop, flower, and tree seeds (Mc Donald, 1994). Seed quality is usually a composite of several factors, all of which contribute to the desirability or planting value of seed.

Each aspect of seed quality may be the result of different testing procedure (Ellis *et al*., 1991). The most direct method of testing the quality of seed is germination test, as it gives reliable counts of germination, judged by the percentage emergence of healthy radicle in about 2-5 days. Other quick methods of testing seed quality include Tetrazolium tests for viability, electrical conductivity test for seed vigour and free fatty acid content test (Yousof *et al*., 2006). A number of tests of vegetable seed vigour have been suggested like Tetrazolium, Electrical conductivity (Vieira, 1994). Cool germination test is similar to standard germination test except that temperature of 18 degrees centigrade is used and percentage of normal seedlings (4 cm long) is determined after 6 and 7 days respectively (Krzyzanowski, 1999).

A simple test will show the true germination capacity and vigour of the stock and whether sowing rates need to be increased, so that correct plant populations are achieved (Carvalho and Nakagawa, 2000). There is little sense in sowing seed of low germination several times, in hope that some miracle will overcome a basic seed fault (Ochuodho *et al*., 1999). In practice, such marvels are rare and farming plans based on such hopes prove costly and frustrating.

All seed should therefore be tested before planting, especially home-produced and stored over sometime, like over a year, which may have been kept in less than ideal condition. Seed rates and treatments can then be adjusted on the tangible facts of a properly executed and interpreted seed test. In countries where farmers produce their own seed and or areas where seed testing services are absent, a farmer can test his own seed by placing seeds on a wet medium, such as cotton wool, newspaper or wet sand. In one or two weeks, depending on species he can obtain a reasonable estimate of the percentage of normal plants growing which translates to field situation (Ferreira and Borghetti, 2004).

2.4.2 Analytical purity test

The objective in making a seed purity analysis is to determine the mechanical quality of the sample and the percentage, by weight, of each component, and by inference the composition of the seed lot. To test the sample (which contains about 2500-3000 seeds) for analytical purity, it must be separated into three fractions: pure seed, seed of other species, and inert matter.

The quality seed is considered superior, if pure percentage of seed is above 98% and other species seeds and inert matter percentage as low as possible. The percentage of seeds of other species should be almost negligible, or nil (below 0.1%). From the sample submitted to laboratory, a working sample (weighted portion) is taken either by successive halving or random-cup method until the required weight is gotten as in table 2 below and transferred to a dark smooth surface for purity analysis (ISTA, 2004).

Table 2: Purity weights (recommended) of Jute mallow seed samples

	Crop	**Maximum weight of seed lot (kg)**	**Minimum sample weight**	
Common name	Scientific name		Submitted sample (g)	Working sample for purity (g)
Jute mallow	*Corchorus olitorius*	10,000	150	15

Source: ISTA, (2004)

The analyst then examines every seed and particle, dividing the sample into the said three fractions. After separation, each fraction is weighted and reported as a percentage of total weight.

2.4.3 Germination test

The number of seeds required as per ISTA (2004) is 400 seeds. Four replicates of 100 random seeds of Jute mallow are placed on individual Petri dishes lined with a wet filter paper. The Petri dish is regularly checked to ensure that the filter paper is kept moist throughout the experimental period. A daily count on the number of germinated seeds is recorded for five days as shown in table 3 below and then percentage germination calculated at the end of the experiment according to ISTA (2004) protocol.

Table 3: Requirements for testing of Jute mallow seeds

Crop	**Substrate**	**Temperature**	**Light**	**1st count**	**Final count**	**Breaking dormancy**
Corchorus olitorius	BP, TP	30^{0}C	-	3rd day	5th day	-

Source: ISTA, (2004): Where, BP = Between Paper and T.P = Top of paper

Germination tests shall be made with pure seeds taken from either the pure seed fraction of a purity test carried out or from representative fraction of the submitted-sample. The seeds shall receive no pre-treatment. The counting of seeds is done without discrimination as to size or appearance by hand or by aid of counting board or vacuum counter. The seeds, arranged in replicates, are tested under favorable moisture and temperature conditions in accordance with the methods prescribed by the ISTA (2004). The replicates are examined and counts made of the seedlings and seeds in the various categories required for reporting in ISTA (2004).

Proper spacing of seeds minimizes the contact of seedlings with each other during germination. The distance between seeds should not be less than 1 to 5 times the width or diameter of the seed to be tested or evaluation. A normal seedling show capacity for continued development into normal plants under favorable conditions, and possesses all essential structures when tested on artificial substrate. They include, well developed root system, intact hypocotyls and epicotyls. Abnormal seedlings include those damaged, deformed, and decayed. Check on hard, fresh un-germinated, dead seeds.

2.4.4 Seedling emergence (speed of emergence as vigour) test

The quality of seeds has profound influence on the economic production of agricultural crops of all species, vegetables included. Seedling emergence is the result of a large number of preceding processes, which occur against the often-hostile background of the seedbed environment. Under these circumstances, the chances of successful seedling emergence are greatly influenced by seed quality. If the quality of seed is low then emergence will be poor. Laboratory germination tests reveal differences in seed lot viability, which will inevitably result in differences in levels of seedling emergence (Benjamin, 1990). In general, the poorer – quality seeds will show symptoms such as low viability, reduced germination and emergence rates, poor tolerance to sub-optimal conditions, and low seedling growth (Mc Donald *et al*., 1987). Physiological seed treatment given to seeds generally act to improve seed performance directly by reducing the time to germination and seedling emergence, or indirectly by improving the seeds ability to cope with stresses such as limited water availability (Walters and Engels, 1998).

2.4.5 Seed vigour (Electrical conductivity (E.C) test

Seed vigour is the sum of all those properties of the seed that determine the level of activity and performance of a non-dormant seed or seed lot during germination and seedling emergence. A vigourous seed lot is one likely to succeed under a wide range of field conditions (ISTA, 2004), while non-vigourous ones are unlikely to produce a satisfactory stand under certain field conditions. A vigour test is however not a test for field effect per se since the field effect of a particular seed lot may more closely correlate with vigour test or the ordinary laboratory test, depending on the nature of the field conditions.

A vigour test, therefore, is an examination of seed under specific environmental conditions so as to provide means of detecting differences that are not discernible in an ordinary laboratory germination test. Direct vigour tests simulate pertinent unfavorable field conditions on a laboratory scale, and include: Brick Gravel, Paper Piercing and Accelerated Ageing Tests. Indirect vigour tests measure certain physiological attributes of seeds and include: seedling growth rate (germination speed), Tetrazolium (TZ) test, Leaching/ Electrical Conductivity (E.C) test, Enzyme and Respiration Test (ISTA, 2004).
In Electrical conductivity (E.C) Test, Measurement of electrical conductivity of leachates provides an assessment of extend of electrolyte leakage from plant tissues. Conductivity measurement is done on soak water in which bulk sample of seeds e.g. Pea, (*Pisum sativum)* has been steeped giving an estimate of seed vigour. Seed lots

that have high electrolyte leakage, that is, having high leachate conductivity, are considered as having low vigour, while those with low leakage (low conductivity) are considered high vigour. The conductivity test offers a vigour test for seeds (particularly for pea seeds), which relates to the field emergence potential of seed (ISTA, 2004).

Test of electrical conductivity (conductivity test) was used for first time in the year 1928 A.D. to explain high germination of pea in laboratory conditions and low germination in field conditions (ISTA, 2004). The phenomenon is explained by facts that in field conditions germinating seed releases substances such as saccharides and other electrolytes into soil, enhancing activity of soil fungi. The enhanced activity can negatively affect germination and seedling growth, especially in cold and wet conditions when germination is impeded already (Proberts, 1992). It was later established that integrity of cell membranes, determined by deteriorative biochemical changes or physical disruption, can be considered the fundamental cause of differences in seed vigour which are indirectly determined as electrolyte leakage during the conductivity test (Matos, 2009). The greater the speed with which the seed is able to re-establish its membrane integrity the lower the electrolyte leakage. Thus, electrolyte leakage measured from high vigour seeds are less than that measured from low vigour seeds.

Electrical conductivity is determined by various factors. Soil conductivity increases simultaneously with the increase of temperature, approximately 2% for each degree. Therefore, the strict control is required during the experiment. Conductivity depends on initial seed moisture. Higher conductivity with lower moisture could be result of cell wall damage caused by seed immersion. Analyzed seed (seed moisture 10-14%) is immersed into deionised water for 24 hours at 20° C. After that period the conductivity of the solution should be immediately measured with conductometre and obtained results put in the formula (ISTA, 2004):

$$\frac{\text{Conductivity reading } (\mu\ S\ cm^{-1}g^{-1} - \text{background reading}}{\text{Weight (g) of replicate}} = \text{conductivity } (\mu\ S\ cm^{-1}\ g^{-1})$$

If the calculated value is: < 25µ*S* / *cm/g* - seed has a high vigour, i.e. the seed is suitable for early sowing in unfavorable conditions; 25 – 29µ*S* / *cm/g* - seed can be used for early sowing with risk in unfavorable conditions; 30 – 43µ*S* / *cm/g* - seed is not suitable for early sowing especially in unfavorable conditions; > 43 µ*S* / *cm/g* - seed has a low vigour i.e.it is not suitable for sowing. Conductivity test allows a quick, objective vigour test that can be conducted easily in most seed testing laboratories with minimum expenditure for equipment and training of personnel. Conductivity tests have high correlations with field emergence, hence its wide use in seed vigour tests.

2.5. Characterization of Jute mallow germplasm

Characterization and evaluation approaches are varied and depends on what is being worked on. Characterizing of germplasm is an activity that is typically regarded as the responsibility of the gene bank curator, and involves determining the expression of highly heritable characters, ranging from morphological features to seed proteins and possibly including molecular markers (Mwai *et al*., 2005). Such characters also enable easy and quick discrimination among morphotypes and allow simple grouping of the germplasm, as well as a check on the trueness-to-type of homogeneous samples, frequently according to criteria used by breeders and other Germplasm users. Gene banks consider establishing close cooperation with plant breeders while characterizing germplasm, not only during the field and laboratory activities but also earlier to decide on which descriptors to use. In addition to or instead of a molecular analysis, their scoring also allows establishment of systematic relationships among germplasm and even crops, including their evolutionary relationships (Geleta and Viljoen, 2006).

Characterization facilitates utilization of collections, allows detection of misidentifications and indicates possible errors made during other gene bank operations (FAO, 1998). It also results in better insight in the composition of the collection and the coverage of genetic diversity. A proper characterization also makes an important contribution towards rationalizing management procedures, since it allows the curator to make well-informed decisions on where best to regenerate the material. Such will also allow identify possible duplicates, to group Germplasm germplasm and proposed a modified version of the traditional three-step linear model of conservation. Characterization also allows evaluation and use by promoting genetic enhancement and pre-breeding, relying on knowledge and activities of farmers as well as local breeders (FAO, 1996, 1997). The environment invariably influences the expression of traits used in the (preliminary) evaluation of Germplasm germplasm (Keding *et al*., 2007).

The most valued traits in crop improvement include yield, agronomic performance and stress resistances. It is obvious that an adequate evaluation of the collection represents an important prerequisite to effective use of the collection, as well as a major investment. The gene bank manager should take every opportunity to get the 74 IPGRI Handbooks for Gene banks No. 6, showing conserved material evaluated. The expression of important traits is increasingly being researched using molecular markers (Bhattarai, 2010). Since this activity is not regarded by all gene banks as a typical gene bank responsibility, but rather as a task for plant breeders and other users, close cooperation among all participants is essential to ensure useful application of results.

It is not always obvious which molecular technique should be used in addressing a specific Germplasm management question. International Plant Genetic Resources Institute (IPGRI) published a technical bulletin to provide curators with a guide for choosing the best and most cost-effective technique (Karp *et al.*, 1997). Centre for Genetic Resuorces, Netherlands (CGRN) offers an on-line update on this issue (www.cgn.wageningen-ur.nl/pgr/). In order to facilitate standardization of information obtained during characterization and evaluation, IPGRI coordinates the publication of Descriptor Lists in close cooperation with crop experts and gene bank curators. These are consensus lists of descriptors for individual species and written in universally understood language thereby contributing to a more efficient exchange of information and use of Germplasm. To date, 85 lists have been published (IPGRI, 2001).

At present most Germplasm breeders and conservationist believe that the larger the collection, the higher the degree of getting desirable characters to use in crop improvement (Brown, 1998). Currently there is no single technique which is best for measuring overall genetic diversity of a crop (Camacho and Liston, 2001). Thus it is difficult to determine the size of a collection necessary to represent diversity existing within a crop (Ng, and Padulosi, 1992).

As defined by Brown *et al.*, (2005), a core collection is a selected and limited set (5-20% of the total collection) of germplasm derived from an existing Germplasm collection chosen to represent the genetic spectrum in the whole collection (reserve collection) and including as much as possible of its diversity. Core collections are to address the issue of large Germplasm collections.The very size of some of these collections represents a daunting challenge for characterization and evaluation (Barcaccia *et al.,* 2003; Alvarez *et al*., 2006). This is the reason most crop plants have not been characterized including indigenous vegetables like Jute mallow. To address this problem, molecular techniques help simplify these tasks (Archak *et al.,* 2003; Cheng *et al.,* 2006).

Characterization consists of recording those parameters that are highly and less highly heritable (Bolibok *et al.,* 2005). They include plant height, leaf number, and number of branches, number of flowering plants per plot, leaf yield and seed yield (Branco *et al.,* 2007), or use of plant or its parts (Munsell, 1977). Non-destructive measurements are taken weekly commencing two weeks after planting and destructive measurements on leaf area and leaf yields is taken only twice just before onset of flowering (eight weeks after sowing) and one week later. Plant height is taken by selecting two and up to five plants per plot, tagging them and their heights measured using a ruler from the soil surface to the apical bud. Number of emerged leaves and number of branches per plant of the tagged plants is counted. The number of flowering plants per plot is counted and then the percentage of flowering plants in each plot determined. Leaf yield per plant is determined by harvesting two and up to five plants per pot and cutting off the edible parts, including leaves, young branches and shoots and weighed on a balance. Seeds are harvested when mature but before drying up and shattering, they are dried, threshed, winnowed and seed yield determined at 8% moisture content and the germination percentage of the seed lot is also determined.

When doing characterization it's important to note that morphological traits such as stem, petiole, and flower colour often have a high heritability (Geleta *et al.,*2006), and are helpful as descriptors (Choudhury *et al.,* 2007). Characterization can make use of more sophisticated tools such as *isozyme* and DNA analyses (Guo *et al.,* 2007). These analyses are being used by breeders and taxonomist to study genetic diversity with the aim of identifying differences and commonalities among living organisms. This type of characterization has gained much interest, and its potential application is considered, particularly in drawing linkage maps and identifying gene markers for selection purposes (Ng' and Padulosi, 1992). However such data are not available for most crops such as indigenous vegetables and many other domesticated crops, especially morphological data are unavailable or inadequate.

2.6 Gaps in knowledge

Currently there is little information known on botanical morphotypes or cultivars of Jute mallow in Kenya. Characterization of germplasm used in this study is based on their morphological traits as well as the assessment of the phenotypic variation through various techniques that will assist in the development of some cultivars through formal plant breeding.

Farmers in North Rift region and elsewhere in Kenya that grow Jute mallow tend to rely on their own-saved seed (Okeno *et al*., 2003). This is due to lack of improved types of Jute mallow. Although Kenya Seed Company is now selling seeds of a number of indigenous vegetables that include Jute mallow (Mnzava and Chigumira, 2004), the same are neither produced through any formal breeding programme nor under any certification scheme thereby needing more research to be done in this area of varietal production.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

There were four stages in this study. The first stage involved Germplasm collection from the North Rift region and taking the germplasm for seed quality analysis tests at the laboratory. The second stage of the experiment was planting Jute mallow germplasm at the green house and morphological characterization done.The third stage was taking resultant pure Jute mallow seed from green house experiments and planting in the field to discern their effect by spacing, fertilizer and various harvesting stages on seed quality and leaf yield. The fouth stage involved the seed harvested from field experiments and then taken to the laboratory for seed quality test.

3.1.1 Experimental sites

The overall study was in the North Rift Region (Figure 1) and planting carried out in two sites of KALRO Kitale and The University of Eldoret, Kenya. KALRO Kitale is situated in North Rift region between Mount Elgon and the Cherang'any hills, at latitude 1^{o} 02' North and longitude 35^{o} East and altitude of 1901 meters above sea level in Trans Nzoia County. The University of Eldoret is in North Rift region, situated at 0° 30' 51.3972" N and 35° 16' 11.2044" E and altitude of about 2140 m above sea level, it is 9 km North of Eldoret town in Uasin Gishu County.

Figure 1: Map of Kenya showing North Rift region.

3.2 Jute mallow production and handling assessment, seed collection and laboratory seed quality analysis

3.2.1 Introduction

Jute mallow plant material for use in the experiment were sourced in between January/April 2015 period from Kenya Seed Company Kitale and farmers from the North Rift region areas of Iten, Eldoret, Kapsabet, Kitale and Kapenguria with a questionnaire using stratified random sampling method with a population sample of 250. During data collection farmers were visited individually at random in their areas and asked about *Corchorus olitorius* vegetable. Their effects were recorded down for each individual farmer in the questionnaire (Appendix 1) and seed samples taken.

The seed samples were then well-labelled and taken to the seed laboratory at The University of Eldoret in the Department of Seed, Crop and Horticultural Sciences for seed quality tests and subsequent planting at the green house for morphological characterization and grouping of germplasm before planting in the field.

3.2.2 Seed collection and assessment of Jute mallow production and handling

Corchorus olitorius plant material was sourced during January/April period from North rift region by a questionnaire using stratified random sampling method with a population sample of 250. Information captured included; Age, Sex, Educationand Seed training of farmers. The objective was to asses the production status of Jute mallow by farmers in North Rift region, Kenya. The collected Jute mallow germplasm were then taken to seed testing laboratory at University of Eldoret to determine the seed quality status in terms of seed purity, germination and vigour. Data of seed survey and collection was analyzed using descriptive statistics.

3.2.3 Analytical purity test

The Jute mallow seeds were subjected to ISTA, (2004) sampling rules and analysis procedures. This included mixing seed well by passing through a seed divider several times and subsequently reconstituting them. The sub-samples got for each source were obtained by successively halving the sub-sample until working sample of 15 g weight was gotten as required by ISTA (2004) and labelled well and taken to seed laboratory. At the lab the seeds were placed on a purity work board, examined and separated into three purity portions of; pure seed, other seeds in sample e.g. grass seeds, other crop seeds and inert matter (dust, Soil). To determine purity, weights of each group were separated and their percentages worked out from their initial weight of each sample (15 g), and results analyzed as per ISTA (2004).

3.2.4 Germination test

In the germination test, four replicates of 100 random seeds were obtained from the pure seed sample using a vacuum seed counter (with counting plates counting 100 holes) and placed on moistened filter paper inside a Petri dish, ensuring the seeds are sufficiently spaced. They were then taken to the growth chamber machine set at 30^{o} C temperature. Seed germination was scored daily for 5 days, and evaluation of germinations done and recorded as follows: normal seedlings, abnormal seedlings, dead seeds according to ISTA (2004) regulations and procedures. The distance between seeds was ensured not to be less than 1 to 5 times the width or diameter of the seed tested. During evaluation, the normal seedlings were graded as, those seedlings that showed capacity for continued development into normal plants under favorable conditions, and possessed all essential structures when tested on artificial substrate. These essential structures included, well developed root system, intact hypocotyls and epicotyls. The abnormal seedlings included those damaged, deformed, and decayed. Also checked were hard, fresh un-germinated and dead seeds. The data from experiment on germination test was analyzed as per ISTA (2004).

3.2.5 Electrical conductivity (Seed vigour) test

The Electrical Conductivity test was done where 250 ml of distilled water was measured and put in 24 well labelled laboratory flasks and 100 Jute mallow seeds added to each and covered with aluminum foil to control dust. Two beakers containing distilled water of 250 ml each were also set as control and covered with aluminum foil. The flasks and beakers were then left on bench in the laboratory for 24 hrs at room temperature (20^o-23^o C). After 24 hours the contents of flasks were gently swirled for 10-15 seconds and conductivity (µ S $cm^{-1}g^{-1}$) of soak water measured and only stable reading on meter taken. In between measurements the dip cell was rinsed twice in distilled water and dried using clean dry paper towels. The conductivity of seed weight for each replicate was calculated after accounting for the background conductivity of the original water and the average of the four replicates provided the seed lot result. Thus for each replicate, conductivity was obtained as follows:

$$\frac{\text{Conductivity reading } (\mu \text{ S } cm^{-1}g^{-1} - \text{background reading}}{\text{Weight (g) of replicate}} = \text{conductivity } (\mu \text{ S } cm^{-1}\ g^{-1})$$

Electrical conductivity readings were taken by Handy lab LF schott conduct meter (serial No. 9902008 Schott Glaswerke Mainz, Made in Germany). The data from experiment on Electrical Conductivity test was analyzed as per ISTA (2004).

3.3 Green house experiments on characterization of Jute mallow

3.3.1Morphological characterization of Jute mallow

The objective of this study was to do morphological characterization on Jute mallow (*C.olitorius*) germplasm. The experiment was done at The University of Eldoret Biotechnology laboratory and the Seed, Crop and Horticultural Science green house. At the green house, boxes measuring 50 cm x 30 cm x 30 cm were filled with well mixed top naturally fertile well–drained, friable, sandy clay soil of Ferro - orthic acrisol with an average pH of 5.0 as according to Jaetzold *et al.,* (2006) and Jute mallow seed germplasm planted. The boxes were laid out using randomized complete block design with three blocks and three replications. Watering of planted Jute mallow germplasm was done appropriately ready for characterization.

3.3.2 Morphological traits data collection and analysis

During morphological trait data collection, five plants were sampled from net plot on which the following descriptors were measured or scored: a). Plant height; b). Number of pods per plant; c). Leaf petiole length; d). Leaf lamina (shape, length and width); e). Leaf serration (direction of serration): f). Leaf tip shape: g). Leaf colour: h). Flower; (shape, colour, number of sepals and its length and width): i). Fruit; (shape, length and width) and j) Seeds per pod.

3.4 Field experimental management and data collection of Jute mallow

3.4.1 Field experimental management

The objective of the study was to discern effect of agronomic practices on seed quality and leaf yield of Jute mallow germplasm. The Jute mallow experiment on spacing, fertilizer and harvesting treatments was conducted at two sites of The University of Eldoret farm and KALRO - Kitale farm over one season between May - November 2015. Before the start of experiment, soil sampling was done in both sites at the experimental plots before the Jute mallow seed samples were planted. This was to know the nutrient variation between the soils of the two sites at the time the experiment commenced. The soil samples were then taken to the soil laboratory where it was air dried and passed through a two millimeter sieve. The fraction which passes through the sieve was used to analyze total nitrogen, exchangeable cations, organic carbon, available P and pH using described analytical methods (Tan, 1996; Irungu *et al.*, 1997) and available nitrogen analysis determined using fresh soils. The soils were worked out to fine tilth as recommended for small seeds (MOA, 2013). Jute mallow seeds were then drilledwith nitrogenous fertilizer at the research N fertilizer treatment rates of 0, 60, and 120 kg/ ha, (Diaz *et al.*, 2011) in the field in well prepared demarcated seed beds at the experimental plots. Weeding was carried out in all plots in the sites simultaneously. The seedlings were then thinned two weeks later to the research spacing treatments of 20 x 30, 30 x 30 and 40 x 30 cm (Abukutsa-Onyango. 2005). The experimental plots were kept weed free and pests and diseases scouted throughout the experimental period. Harvesting was done at various research harvest stages of maturity, namely: Green (Physiological maturity), Tan (Harvest maturity) and Black (Overripe) stages and seed taken to laboratory for quality tests.

To discern the effect of treatments on plant growth, five plants in each plot were systematically sampled randomly (Gomez and Gomez, 1976), tagged and their heights, branching at main stem, pod count and leaf yield determined.

3.4.2 Field data collection of Jute mallow

a). Plant height: Plant height was measured in cm from ground level up to apex of youngest leaf (Maritim *et al*., 2009) on five sampled plants at harvesting.

b). Number of branching per plant: The total number of branches per plant was counted at harvesting on five sampled plants in the net plot.

c). Number of pods per plant: The total number of pods per plant was counted at harvesting on five sampled plants in the net plot.

d). Fresh leaf yield: Harvesting was done on five sampled fresh leafy plants before onset of flowering in season (Maritim *et al*., 2009) from the net plot area. The harvested plants were then put in paper bags and fresh weight in g taken using weighing scale for each plant immediately to avoid loss of moisture (Masinde *et al.,* 2010) and later converted to kg ha^{-1} for yield analysis.

3.4.3 Field experimental model

The linear model for field experiment used was as follows:

$Y_{ijklm} = \mu + R\alpha + M_i + L_j + M_iL_j + S_k + M_iL_jS_k + F_L + M_iL_jS_kF_L + H_m + M_iL_jS_kF_LH_m + \varepsilon_{ijklm}$ $i = 1\ldots4$; $j = 1...2$; $k = 1\ldots3$; $_L = 1\ldots3$; $m = 1\ldots3$

Where, μ is Grand mean; $R\alpha$ is replication effect; M_i is Jute mallow morphotype effect; L_j is the location effect; M_iL_j is interaction effect of the Jute mallow morphotype and the location; S_k is spacing effect; $M_iL_jS_k$ is interaction effect of the Jute mallow morphotype, the location, and spacing; F_L is the fertilizer effect; $M_iL_jS_k F_L$ is interaction effect of the Jute mallow morphotype, the location, spacing and the fertilizer; H_m is the Harvesting stage effect; $M_iL_jS_kF_LH_m$ is interaction effect of the Jute mallow morphotype, the location, spacing, fertilizer and harvesting stage while ε_{ijklm} is the residual effect error.

3.5 Seed quality test for seed harvested from field

The objective of the study was to discern effect of harvesting stages on seed quality of Jute mallow germplasm.The Jute mallow seed samples harvested from field on fertilizer and spacing experiments (from each treatment replicates in blocks) were mixed well and taken for seed quality tests attributes on purity, germination and seed vigour as per ISTA, (2004) at University of Eldoret seed testing laboratory.

3.6 Analysis of data from Jute mallow field experiments

The data on seed quality was analyzed as per ISTA (2004) and those from spacing and fertilizer experiments had Analysis of variance (ANOVA) done on plant growth (height, branching, pod count and leaf yield) to determine whether there was any significant difference between the treatments by using GENSTAT computer package analysis (12.2, 2010). The means were separated using DRMT or SED at $p<0.05$.

CHAPTER FOUR

PRODUCTION STATUS, HANDLING PROCESS AND SEED QUALTY OF JUTE MALLOW (*Corchorus olitorius*) IN THE NORTH RIFT REGION, KENYA

4.1 Abstract

Jute mallow (*Corchorus olitorius*) vegetable production in North Rift region is low due to many reasons, one of them being poor quality seeds. Yields of crop has remained low 2-4 tons/ha/annum compared to expected yield of 5-8 tons/ha/annum. Farmers use much as 7 kg/ha seed instead of 5 kg/ha which is recommended for a density of 250 000 plants/ha that is 40% extra seed. The objective of this study was to assess production status, handling process and examine seed quality of Jute mallow used by farmers at planting. A survey was conducted using a questionnaire in North Rift region areas of Iten, Eldoret, Kapsabet, Kitale, Kapenguria, and Kenya Seed Company with a questionnaire using stratified random sampling method with a population sample of 250. During data collection farmers were visited individually at random in their areas and asked about Jute mallow vegetable. Their effects were recorded down for each individual farmer. During data collection seed samples were simultaneously taken from them, well-labelled and taken to seed laboratory at The University of Eldoret for seed quality tests and analysis on purity, germination and vigour using International Seed Testing Association, (2004) procedures. The data from survey was analyzed using descriptive statistics. The survey results showed 86% of farmers growing Jute mallow for seed were middle and old age people of which 98% of them were female. Only 14% of the farmers were trained on vegetable seed production and agronomy. Education level analysis showed 54% of farmers had not attended school. Production practices of crop showed 65% of farmers use fertilizer, 75% of them harvest whole plant and 85% indicating seed maturity was at Tan stage. On handling process, 97% of the farmers extract seed from pods by beating with sticks with 85% of them storing seed in tins and plastic/synthetic polybags. Seed germination average for North Rift region was 59% with some of regions seed sources germinations such as Kapenguria (45%) and Kapsabet (43%) were below quality standard of 60%. It was concluded that most of the farmers have not been trained on aspects of Jute mallow seed production and agronomy, were of low level of education, were aged and genderwise majority were women. They get their seed for planting from own saved seed or neighbours where storage was in plastic/tins usually stored in the open. Most farmers do not use fertilizer, harvest whole plant and beat out seed from pods and dry seeds in direct sunlight. Though seed grown by farmers is of high analytical purity, they are of poor physiological quality in terms of germination and seed vigour. It's recommended that farmers be trained on improved methodologies of crop production, seed processing and proper post harvest handling of the seeds to improve or maintain seed quality.

4.2 Introduction

Jute mallow (*Corchorus olitorius*) vegetables are an integral part of obtaining nutritional security (Mibei *et al*., 2011). They are a source of important nutrients essential for the good health (WHO, 2003). Jute mallow is noted for its important contribution to diet by supplying nutrients and rendering food more palatable (Grubben and Denton, 2004). In Kenya, there is ample production potential of Jute mallow not only to meet the growing demand for domestic use requirement, but also produce surplus for export (K'Opondo *et al*., 2005).

C. olitorius is reported to be demulcent, deobstruent, diuretic, lactagogue, purgative, and tonic (Ayodele, 2005). It can meet major protein-calorific nutritional needs especially in children, sick, elderly and both expectant and lactating mothers in the rural areas (Smith and Eyzaguirre, 2007). Cooked leaves form a mucilaginous substance that has a character that is highly appreciated especially in areas where people depend on rather coarse food such as millets (Maundu, 1997). Jute mallow leaves are normally mixed with cowpeas to reduce their coarseness or to neutralize the bitter taste in *Crotalaria brevidens* (Abukutsa-Onyango, 2004).

There is no good quality seed of the vegetable crop from the breeders to the farmers (Ndinya, 2005). Production of high quality seeds has not been practiced in many of the African leafy vegetables (Abukutsa-Onyango, 2002). Farmers have been getting re-cycled planting seed of *Corchorus olitorius* every season from the local markets and farms whose potential is not assured (Okongo, 2005). The challenge facing Jute mallow is that yields of crop has remained low, 2-4 tons/ha/annum compared to expected yield of 5-8 tons per ha per annum (KARI, 2009), and the major constraints has been use of poor quality seeds which forces farmers to use as much as 7 kg/ha instead of 5 kg/ha of seed required for a density of 250 000 plants/ha, which amounts to 40% extra seed (MOA, 2009).

Use of good quality seed has helped to raise yields (Amarjit, 1995). Seeds with assured quality can be expected to respond to best agronomic practices and other inputs and increase yield as expected (Bhattacharjee *et al.*, 2000). For example in India good quality seed and use of fertilizer increased wheat production from 12 million tons to 31.3 million tons over a short period of ten years (Feistrizer, 1975).

Characterizations of different types of plant resources within and across germplasm have been increasing in the last years (Bhattarai *et al.,* 2010). These have followed theoretical basis for inferring genetic diversity for the purpose of both breeding and conservation strategies in their identification (Keding *et al*., 2007). Despite increased importance of characterization in plant resources; there is scarce information about analysis of this type of data (Beebe *et al.,* 2000). To fill such a gap of information, research needs to be done to identify diversity of germplasm and the descriptors for specific plant (Drossou *et al.,* 2004).

Surveys conducted in Kenya show that 50% of the people live below poverty line and live on less than one dollar a day (AICAD, 2003). To try and solve this problem, increased yields through improved production practices and quality crop for sale of vegetables like Jute mallow can play an important role in improving food security, health and general rural livelihoods (Fondio and Grubben, 2004).

4.3 Importance of Jute mallow

Jute mallow is not usually eaten on its own but along other main meals as side dish (Mibei *et al*., 2011). The dark green leaves have varying proportions of Calcium, Iron, carotene, vitamin C and proteins required for good health (Schippers, 2002). Research has also shown they are nutritionally superior to exotic in many nutrients as they contain higher amounts of phosphorus, zinc, iodine, fluorine and vitamin B (Yebpella *et al*., 2010). To avoid losing such useful micro-elements it would be best to boil the 'soup' for as short as possible or steaming produce would be much better (Chadha and Oluoch, 2003).

The crop is a folk remedy for aches and pains, dysentery, enteritis, fever, pectoral pains, and tumors (Keller, 2004). Ayurvedics use leaves for ascites, piles, tumors, cystitis, dysuria, fever, and gonorrhea (Kokwaro, 1990). The cold infusion is said to restore appetite and strength of user. These vegetables fetch good prices in market (Shiundu and Oniang'o, 2007). The expansion of production of these vegetables continues to be hampered by lack of a reliable source of planting materials and technical information (Ngoze and Okoko, 2005). The objective of study was to examine the seed quality of Jute mallow germplasm used by farmers at planting and evaluate their morphological diversity.

4.4 Materials and Methods

4.4.1 Survey and Jute mallow plant material collection.

A survey was conducted in North Rift region areas of Iten, Eldoret, Kapsabet, Kitale, Kapenguria and the Kenya Seed Company where farmers were asked about husbandry of the crop and seed samples simultaneously collected. A population of 25,000 and sample size of 250 farmers in the region was visited by use of stratified random sampling method individually at random in their areas and asked about *Corchorus olitorius* vegetable. Their effects were recorded down for each individual farmer in the questionnaire (Appendix 1) and seed samples taken. The information collected included; age, sex, education background, seed and crop agronomy training of each farmer. The seed were well-labelled and taken to University of Eldoret seed laboratory for quality tests on purity, germination and vigour as per ISTA, (2004) protocol.

4.4.2 Analitycal purity test as per ISTA, (2004)

Jute Mallow collected seeds sub-sample from each replicate of each seed source were mixed well by passing through a seed divider several times and subsequently reconstituting them. The sub-samples for each source were obtained by successively halving the sub-sample until sample of required weight was got. Working samples of 15 g were taken (ISTA, 2004). Weight was taken for each sample and recorded. The working samples were placed on a purity work board and examined for analytical purity by separating to groups of: pure seed, other seeds and inert matter. Weights of each group were separated and their percentages worked out from their initial weight of each sample (15 g) and results recorded.

4.4.3 Germination test as per ISTA (2004)

Four replicates of 100 random seeds were obtained from the pure seed sample using a vacuum seed counter (with 100 holes) and placed on moistened filter paper inside a Petri dish, ensuring the seeds were sufficiently spaced. Seeds were placed in growth chamber set at 30^{o} C temperature. Evaluation of germination was done with 1st count on 3rd day and last count on 5th day and recorded as follows: Normal and abnormal seedlings and dead seeds.

4.4.4 Electrical conductivity test (Seed vigour) test as per ISTA (2004)

The Electrical conductivity test was done using machine Handy lab LF Schott Conductometer serial No. 9902008 Schott Glaswerke Mainz, Made in Germany. Distilled water of 250 ml was measured and put in 24 well labelled flasks and covered with aluminum foil to control any contamination. Other 2 flasks of distilled water of 250 ml was each set aside as control and covered with aluminum foil. The flasks were put on bench for 24 hrs at room temperature (20-23^{o} C). Jute mallow seeds (100) were added to each of the 24 flasks and left to soak for 24 hours. The soaked seeds were then swirled gently for 10-15 seconds and conductivity ($\mu Scm^{-1}g^{-1}$) of soak water was measured upon meter showing constant reading. Between measurements, dip cell was rinsed twice in distilled water and dried using clean dry paper towels. The conductivity of seed weight for each replicate was calculated after accounting for the background conductivity (by subtracting E.C. reading of control water) of the original water and the average of the four replicates provided the seed lot result.

4.5. Results

4.5.1 Assesment of Jute mallow production status

The North Rift region where sampling was done included: Iten, Eldoret, Kapsabet, Kitale and Kapenguria. In these areas the data collected from the farmers were grouped according to their number of trainings attended and their education background and analysis done as percentages. This is necessary because training and education level of a farmer assist in keeping informed of quality seed production procedures and agronomic production requirements for quality plants and high yields. Also it assists farmers to practice record keeping on level of production i.e. whether producing on profit or loss.

4.5.2 Trainings of Farmers

From the number of training by farmers (Table 4), it is observed that few farmers (18%) of all the total farmers interviewed in North Rift region have under gone at least one training on vegetable seed production and agronomy. Eventhough 82% of the farmers are doing vegetable seed production, they have not attended any training in seed production and agronomy.

Table 4: Number of farmers training on vegetable seed production and agronomy in North Rift region

Area	Number of trainings received by farmer						
	Total no. of farmers	Zero (none)	One (agro)	Two(crop protection)	Three (seed)	Four and above (any)	Farmers trained (%)
Iten	50	44	4	1	1	0	12%
Eldoret	50	40	6	2	1	1	20%
Kapsabet	50	41	5	1	1	1	16%
Kitale	50	35	8	4	2	1	30%
Kapenguria	50	44	3	2	1	0	12%
North Rift region total	250	204	26	10	6	3	18%

The area with high farmer trainings were Kitale (30%) and Eldoret (20%), while the area with least trained farmers on vegetable seed production and agronomy were Iten and Kapenguria having 12% of its farmers trained. Over half of farmers (58%) had only at least one training on vegetable seed production and agronomy, while only 7% farmers had four or more trainings given to them in North Rift region. The farmers with two trainings were 22% and three number of training by farmers were 13% of all trained farmers on vegetable seed production and agronomy.

4.5.3 Education Levels of Farmers

Results of education levels (Table 5) show that most of the farmers (54%) have never attended School. This show that over half of the farmers doing Jute mallow seed production are illiterate i.e. cannot read and write, so cannot prepare or use farm records, but rely on their memories to store information.

Table 5: Education level (%) of farmers growing Jute Mallow in North Rift region

Area	Not Schooled	Primary Level	Secondary and Above
Iten	28	12	10
Eldoret	25	15	10
Kapsabet	27	12	11
Kitale	24	8	18
Kapenguria	30	13	7
Total	134	60	56
North Rift region mean	54%	24 %	22 %

Low level of education could be one of the hindrances to use of farm records in areas of North Rift region that was visited. This in turn could have contributed to low quality of seed production in the region by farmers, leading to decline in quality and productivity.

4.5.4 Age and Gender of Farmers

Results show that most of the farmers growing Jute mallow vegetable were people aged over 60 years accounting for over 47% of total farmers interviewed (Table 6). It was also noted that young people (13.6%) and middle aged people (39.2%) were doing Jute mallow farming.

Table 6: Age (years) of farmers dealing with Jute mallow in North Rift region

Location	**18-38 yrs (Young)**		**39-59 yrs (Middle)**		**60 and Over yrs (Old)**	
	Female	**Male**	**Female**	**Male**	**Female**	**Male**
Iten	5	0	19	0	26	0
Eldoret	8	0	21	2	19	0
Kapsabet	6	0	18	0	26	0
Kitale	11	0	21	1	17	0
Kapenguria	4	0	16	0	30	0
North Rift total	34	0	95	3	118	0

Results on gender showed that majority of Jute mallow producers were women except in areas like Eldoret and Kitale that had men present at middle age amounting to 1.2% in North Rift region (Table 6). When asked why, the answer given was that men from region shy away from vegetable farming considering vegetable production as women's work.

4.6 Crop Husbandry Practices

4.6.1 Fertilizer Use for Quality Crop

Results on fertilizer use show that 65% of the farmers do not use any fertilizer during production of Jute mallow. Those farmers who apply fertilizer at planting do not top dress as required for improve quality of seed and crop yield. The use of good agronomic practices not only increases yield but makes crop meet market quality requirements similarly enhancing seeds.

4.6.2 Indicators of Pod Maturity

Results on when to harvest seed showed majority of the farmers (85%) indicated that harvesting was done when pod has matured and turns from green colour to brown or tan colour. This indicates seed has reached harvest maturity. At such stage, seed development has peaked and moisture level is low and harvesting can be done without appreciable risk of mechanical damage to seed.

4.6.3 Seed Harvesting Method

Results showed the method of harvesting Jute mallow seed by farmers involves cutting the whole plant done by 75% of the farmers as opposed to 25% farmers who chose to hand pluck pods that have matured. The cutting of whole plant for seed was not appropriate as Jute mallow pods do not mature all at same time but from bottom of plant as upper part of plant continues to flower.

4.6.4 Seed Handling Process

Results on the method of Jute mallow seed extraction showed 97% farmers extracted their seed from pods by beating pods with sticks. This method causes mechanical damage to the seed, hence reducing the seed quality. During Jute mallow seed drying, it was observed that all the interviewed farmers (100%) dry their Jute mallow seed in direct sunlight as opposed to drying in shade for 4 days and only 1 day in sunlight. After selection and drying, most of farmers (85%) store their Jute mallow seeds in pots/tins (mostly of plastic/synthetic) in the open air/sun. Farmers had no predetermined number of years they saved Jute mallow seeds before renewal. Farmers had saved their seeds for many years with 73% of them had saved seed for 3 years and over. It also came out that farmers renew their seeds when unexpected happens, i.e. crop failure or very poor yields.

4.7 Laboratory results on seed quality as per ISTA, (2004)

4.7.1 Analytical Purity test results

From the purity analysis percentage (Table 7), it's evident that seed from Kenya Seed Company had the highest seed purity (99.6%), while Eldoret had the lowest purity (98.1%) among the six analyzed sources of Jute mallow seed. According to ISTA (2004), the quality of seed analysis is considered superior if purity percentage (pure seed) is above 98%.

Table 7: Purity (%) of Jute mallow seeds from various seed sources in North Rift

Source of seed	% Pure seed	% Other seed	% Inert matter
Kenya seed company	99.6	0.2	0.2
Kapsabet	99.5	0.1	0.4
Kitale	98.8	0.5	0.7
Kapenguria	98.7	0.3	1.0
Iten	98.2	0.8	1.0
Eldoret	98.1	0.7	1.2
North Rift region mean	98.8	0.4	0.8

From this analysis, it evident that all Jute mallow seed analyzed from the North Rift is of superior quality since their purity percentages are above 98% and need to be subjected to further tests to ascertain its seed quality. On other seeds purity analysis, results show Kapsabet (0.1%) having the lowest percentage of other seeds mixed in them, while Iten market (0.8%) was highest having mostly Brassica spp. seeds, mixed in it. The inert matter results showed Kenya Seed Company (0.2%) was lowest, while

Iten and Eldoret farms had the highest inert matter of 1.0% and 1.2% respectively, mostly being soil, dust and sand.

4.7.2 Germination test results

The germination results (Table 8) show that Jute mallow seed from Kenya Seed Company had the highest germination (86.25%) and while those from Kapsabet (43.00%) were the lowest. This means that Kenya Seed Company Jute mallow seed would do better in the field than all of the seeds from various sources analyzed. On average the regions germination results were lowered to 59.33% though some of its sources like Eldoret (66.75%) and Kenya Seed Company (86.25%) were high. Though so, North Rift regions' mean germination (59%) was below ISTA (2004) minimum germination standard of below 60%.

Table 8: Germination (%) results of seed from various seed sources in North Rift region

Source of seed	**% Normal seedling**	**% Abnormal seedling**	**% Dead seed**	**% radicle emergence of seedlings (speed of germination)**
Kenya Seed Company	86.25	2.00	11.75	88.25
Eldoret	66.75	5.00	28.25	71.75
Kitale	58.25	5.25	36.50	63.50
Iten	56.50	4.50	39.00	61.00
Kapenguria	45.25	3.75	51.00	49.00
Kapsabet	43.00	4.50	52.50	47.50
North Rift region Mean	59.33	4.17	36.50	63.50

Radicle emergence result from Kenya Seed Company (88.25%) was the highest in terms of seed vigour, while Kapsabet (47.50%) was the least. This means that seeds from Kenya Seed Company were best in terms of germination and radicle emergence compared to those from all the other sources. It's also observed that though radicle emergence of seeds from Eldoret and Kitale were high (71.75% and 63.50% respectively), germination percentage were reduced to Eldoret (66.75%) and Kitale

(58.25%). This was due to high number of abnormal seedlings of 5.00% (Eldoret) and 5.25% (Kitale) as per Table 8. This trend is observed in seed from other areas of North Rift region and would possibly show same results even if this seeds were planted on the soils in farm. This low radicle emergence can possibly contribute to low yields and quality if subjected to unfavorable field situation.

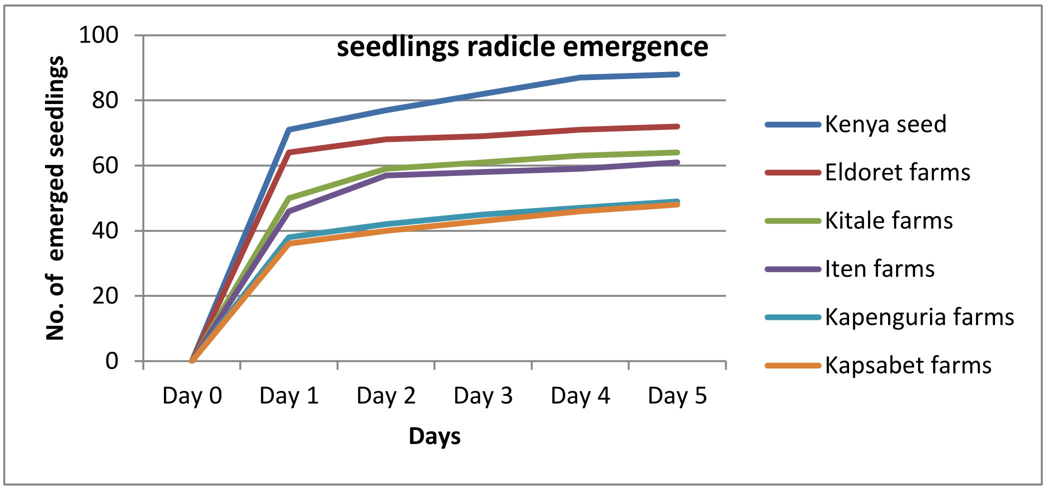

Figure 2: Germination rate (%) measured as radicle emergence of Jute mallow

From the results of percentage seedling radicle emergence (Figure 1, Table 8) it is observed that Jute mallow seed from Kenya Seed Company had highest vigour (88.25%). The lowest seed vigour seeds were from Kapsabet farms (47.50%). This emergence trend is expected to be seen in field if these seeds are planted actually on soils in farm. Results also show that on average over half of seed emerged on 1st day.

Results on abnormal seedling percentage showed the highest was from Kitale farms (5.25%) and lowest was from Kenya seed company (2.00%). Dead seeds were highest from Kapsabet farms (52.5%) and least was in observed in Kenya Seed Company (11.75%).

4.7.3 Electrical Conductivity (Seed Vigour) test results

The Electrical conductivity results (Table 9), show lowest seed leachet conductivity of 2.69 µScm^{-1}g^{-1} was from Kenya Seed Company meaning that the seeds were of high vigour.

Table 9: Electrical Conductivity (µScm-1g-1) of Jute mallow from North Rift region

Source of seed	Conductivity (µscm^{-1}g^{-1}) (Seed vigour)
Kenya Seed Company	2.69
Kitale farms	3.07
Eldoret farms	4.11
Iten farms	4.59
Kapenguria farms	5.10
Kapsabet farms	5.71
North Rift region Mean	4.21

The source with high leachate conductivity was from Kapsabet farms (5.71 µScm^{-1}g^{-1}) meaning the seeds were of low quality. In general seeds from North rift had low vigour and lead to low yield and quality of crop.

4.8 Discussion

Most of the farmers growing Jute mallow vegetable were middle and old people meaning that Jute mallow growing is not done by young generation as also observed by Abukutsa-Onyango, (2002) in her studies. Men did not engage in growing jute mallow crop in the region as outcome showed most were female, when asked why, the answer given was that men from the region shy away saying vegetable production was best women’s work. The reason why Jute mallow yield has remained low was that most farmers have not attended any training on vegetable seed production and agronomy and yet are producing Jute mallow crop and seed for farmers to use as seed material, concurring with MOA, (2013) concerning same.

Low level of education could be one of the hindrances to use of farm records tool to produce quality resembling crop and seeds in North Rift region, leading to decline in productivity and therefore profits, which concurs with what Ellis *et al*., (1991) put forward. Also in market there was non-acceptance by consumers of low quality produce, supporting what Weinberger and Msuya, (2004) also found out.

Though Jute mallow seeds from farmers were of superior quality (purity), germination was low meaning such seed should not be used as planting material as it is below the ISTA (2004) minimum seed quality standard of 60%. This is seen from the high percentage of dead seeds. The dead seeds could be result of: immature harvested seed, diseased seeds, arising from poor processing methods/storage conditions right from farms to markets.

4.9 Conclusion

It is concluded that;

1. Production status of Jute mallow showed most of the farmers in the North rift region have not been trained on aspects of Jute mallow seed production and agronomy, were illiterate as shown by low level of education, were aged and genderwise majority were women. They get their seed for planting from own saved seed or neighbors where storage was in plastic tins usually stored in the open. Most farmers do not use fertilizer, harvest whole plant and beat out seed from pods by sticks and dry seed in direct sunlight.

2. Jute mallow seed grown by farmers in the North Rift region are of high analytical purity but were of poor physiological quality and produced under poor agronomic practices as seen from the poor germination and high percentage of dead seeds. The dead seeds could be result of poor processing and storage conditions, immature harvested seed, diseased or over dried seeds.

4.10 Recommendations

1. Since many farmers have not been trained on many aspects of seed production, efforts should be made by the government of Kenya and other stakeholders of the seed sector e.g. Universities, KARI and KEPHIS to increase trainings to producers either formal or Informal to enhance production and proper handling and processing practices.
2. The recommended seed for use by farmers is from Kenya Seed Company as it showed high purity, germination, and vigour. The rest of seed lots from North Rift region should not be used as seed for it will lead to poor yields due to its low seed quality.
3. It’s recommended that since all Jute mallow seed were of high analytical purity, the seed be subjected to further tests to ascertain why their viability was low.

CHAPTER FIVE

MORPHOLOGICAL CHARACTERIZATION OF JUTE MALLOW (*Corchorus olitorius*) IN THE NORTH RIFT REGION, KENYA

5.1 Abstract

Jute mallow (*Corchorus olitorius*) is an important African leafy vegetable in Kenya including North Rift region. It is highly nutritious and source of revenue for the farmers producing it and traders who produce and sell the produce. The plant has medicinal value as well as other advantages like being resistant to pests, diseases and can tolerate and establish in poor soils. The challenge of unavailability of improved cultivars for planting has hampered farmers increasing crop productivity leading to underutilization of the vegetable. One of the ways of solving such hindrances is by doing genetic enhancement which needs assessment of morphological diversity. The objective of research was to do morphological characterization of Jute mallow. The seed germplasm were collected from five counties in Kenya and seed sample planted at green house and morphological traits picked. The descriptors used for morphological identity include colour of stem, flower, leaf, seed, shape of leaf, as well as height of plant. Leaf length and width, pod numbers and number of seeds. Analysis of variance (ANOVA) was done and means separated using least significant difference (LSD). Statistical package used was Genstat version 12. The outcome showed two morphotypes based on colour and two based on plant height as morphotype 1 and 2 – green short and green tall respectively and morphotype 3 and 4 (brown short and brown tall). It was concluded that the Jute mallow germplasm has varied morphotypes and recommended for breeders to do purification on germplasm to come up with high yielding morphotypes for farmers use at production process.

5.2 Introduction

Jute mallow is an important leafy vegetable in Kenya as a source of nutrients as well as revenue source for the farmers as well as traders (Abukutsa-Onyango, 2002). It can also be used to produce bast (soft) fibers that are used to weave Herssian or burlap bags and sacks (Maundu *et al*., 1999). It has medicinal properties as well as other ceremonial roles (Rubaihayo *et al*., 2002). It is used as a laxative, root scrapings eases tooth pain (Abass, 2000). Enhanced production of vegetable crop can help farmers to upscale their economic levels (Ndinya, 2005).

The Jute mallow plant belongs to the genus *Corchorus sp*. of the family Tilliaceae. Data on plants species at the world gene bank currently show presence of more than 15 species of *Corchorus* spread across the universe (Roberts, 2009). They are characterized as an annual upright branching, glabrous, slightly woody herb. Leaves can be narrow or broad and can be serrated or entire in margins and varying in measurements averagely 5-13 cm in length. Flowers are small, yellow, with petiole and borne in small clusters in the leaf axils. The cylindrical capsules of 2-5 cm are produced in large numbers, especially during short days. Seeds are dark bluish-green, angular averagely 2 mm long.

Jute mallow morphotypes differ in plant height. They also differ in leaf and fruit shape, leaf and stem colour, pubescence, branching habit and height (Aura, 2013). The most widely cultivated species being *C. olitorius*. Closely related is *C. capsularis* but it differs in fruit shape and other features. *Corchorus sp*. is self pollinating. The choice of species and morphotype for vegetable production is dictated mainly by what is available (Palada and Chang, 2003). African leafy vegetables are stores of genetic diversity and beneficial traits such as drought tolerance, resistance to some pests and diseases and tolerance of poor soil conditions that breeders can use to improve crops (Abass, 2000). These vegetables are easy to grow and resistant to pests and diseases than exotic vegetables (Rubaihayo *et al*., 2002). One of the main constraints facing production of the underutilized Jute mallow vegetable is unavailability of improved cultivars for growers use in crop production (Raymond, 2000).

In recent times very little work of selection has been made to obtain optimum morphotypes. Consequently, Jute mallow vegetables grown by farmers are a mixture of morphotypes. However, clear references have been reported in plant size and architecture, branching capacity, shape and size of leaves and other characteristics which warrants basic breeding efforts (Schippers, 2002). Even though cultivation and utilization has been increasing in recent years, Jute mallow vegetable is still undergoing genetic erosion and loss of indigenous knowledge concerning it. This can be attributed to less than optimum cultivation and utilization (Rubaihayo *et al*., 2002). This means that there is an urgent need for intervention to avoid loss of these very useful identified crops.

One of the interventions that have been used is genetic enhancement. Such will ensure availability of high yielding morphotypes of crop that is well adapted to local ecological conditions hence leading to *in-situ* conservation (conservation of morphotypes in the farmers' fields through cultivation) (The National Academies, 2009). Genetic enhancement can be done through a series of steps. These steps include collection of Germplasm, screening of Germplasm by scientists, identification of desirable morphotypes by farmers, traders and consumers, seed multiplication for a number of morphotypes and selection or purification of desired traits by farmers or traders, development of new morphotypes by combining preferred morphotypes, agronomic practices for seed production (Schippers, 2002, Watson and Eyzaguirre, 2002).

The research concentrated on first two steps that are collection of Germplasm and characterization of Germplasm for morphological differences. The output gotten from research can be used by breeders to come up with morphotypes that have desirable traits such for high seed and leaf yield, longer vegetative phase, adaptation of environmental stress such as drought, high leaf nutrients and palatability. The information generated will be useful for crop improvement and make significant contribution towards availability of high quality seed material for farmers use.

The data output obtained will also help to identify Jute mallow morphotypes to be used in field experiment on spacing, fertilizer and harvesting stages effect on seed quality and leaf yield. The objective of this research was to do morphological characterization of Jute mallow found in five counties in Kenya.

5.3 Materials and Methods

5.3.1 Collection of seed samples of Jute mallow

Seed samples were collected from farmers in the study area using stratified random sampling technique in January/April 2015. This involved collecting seeds from different stratus across transects made across study area with a population of 25,000 and sample size of 250. Seeds were stored in brown paper bags and taken to seed testing laboratory at The University of Eldoret for seed quality analysis. The pure seed portion of Jute mallow was taken to green house ready for planting.

5.3.2 Raising Jute mallow plants in green house and data collection

At the green house, soil was collected at University of Eldoret farm and mixed well with farm yard manure at the rate of 2.5 g/m^3 and used to fill wooden boxes (measuring 50 cm x 30 cm x 30 cm). Soil type was identified as Ferro - orthic acrisol with an average pH of 5.0 (Jaetzold *et al.*, 2006). Jute mallow seed germplasm were planted by making shallow drills in the soil using a stick at a spacing of 15 cm apart. Pure seed samples were then drilled. The boxes were then laid out in green house using randomized complete block design with three blocks and three replications.

Watering of planted Jute mallow germplasm was done appropriately and characterization done as follows: Five random plants from the net plot area were measured for stem height from the base to the tip at harvesting time. Also five plants were sampled from net plot area at harvest and on each, the following was determined; average number of pods per plant, average length of petiole per plant leaves, lamina shape of leaf scored its average length and width per plant leaves lamina determined, direction of serration scored per plant leaves determined, leaf tip shape per plant leaves scored, the leaf colour scored, flower shape, colour, number of sepals and its length and width per plant scored and determined, fruits' shape scored and its average length and width per fruit determined and lastly seed per pod determined, and lastly seed colour scored.

5.3.3 Analysis of morphological traits

Data on measurements of descriptors were analyzed using Analysis of variance (ANOVA) and means were separated using least significant difference (LSD). Statistical analysis software GENSTAT computer package analysis (12.2, 2010) was used and means were separated using SED at $p<0.05$.

5.4 Results

5.4.1 Morphological Characterization of Jute mallow plant materials

During characterization four morphotypes came out based on colour, maturity and height as follows: Early maturing short morphotypes namely; Green Early Maturing Short (GEMS) and Brown Early Maturing Short (BEMS): Late maturing tall morphotypes namely; Green Late Maturing Tall (GLMT) and Brown Late Maturing Tall (BLMT). Such observation was also found out in Nigeria by Epenhuijsen, (1974), though he only found two morphotypes and named them in Nigerian local language as *Amugbadu*, and *Oniyaya* and acknowledges that in reality there exists diversity in Jute mallow grown by farmers. This show that there exists diversity of Jute mallow germplasm from the different sources in Kenya.

5.4.2 Characterization results of Green Early Maturing Short (GEMS) and Brown Early Maturing Short (BEMS) Jute mallow morphotypes

The plant height results (Table 10), show that the Jute mallow collections from North Rift region were averagely short or dwarf (less than 50 cm) and corresponds with what other researchers including results by Buddhadeb, (2012) outlaid. This means that the GEMS (28.3 cm) and BEMS (29.0 cm) morphotypes are same in height and only differentiated by colour during morphological characterization. Shortest Jute mallow morphotypes was from Kapenguria where the GEMS and BEMS were 26 cm in height, while tall morphotypes were from Kapsabet with GEMS (31 cm) and BEMS (33 cm) about the same height.

Table 10: Measurement of plant descriptors of GEMS and BEMS Jute mallow morphotypes at harvesting in North Rift region, Kenya

Source of seed	**Plant height (cm)**		**Pod count (numbers)**		**Leaf Petiole length (cm)**	
	GEMS	BEMS	GEMS	BEMS	GEMS	BEMS
Kapenguria farms	26±0.6	26±1.5	5±0.5	5±1	1.2±0.1	1.2±0.1
Kenya Seed company	27±1.5	0	14±2.1	0	1.2±0.1	0
Iten farms	27±2.5	27±0.6	5±0.6	5±0.5	1.3±0.1	1.2±0.1
Kitale farms	29±1.5	28±1	5±0.5	6±0.5	1.4±0.6	1.3±0.1
Eldoret farms	30±2.5	31±2.9	6±0.5	6±0.5	1.3±0.1	1.2±0.1
Kapsabet farms	31±1	33±3.2	7±1	6±0.5	1.3±0.1	1.3±0.1
North Rift region	28.3	29.0	7	6	1.3	1.2

0 = indicate the morphotype (BEMS) not present in seed collected from source of seed
GEMS = Green early maturing short; BEMS = Brown early maturing short morphotypes

The morphotype with highest pod count per plant was GEMS with 14 pods from Kenya Seed Company selection; while lowest were 5 pods (Kapenguria, Iten and Kitale farms). BEMS pod count per plant highest was 6 pods (Most seed sources), except sources with 5 pods (Kapenguria and Iten farms). On average, North Rift region GEMS had 7 pods in number per plant while BEMS had 6 pods per plant. The petiole length analysis showed the North Rift region had a mean length of 1.3 cm by GEMS and 1.2 cm by BEMS morphotype. The results of GEMS and BEMS leaf lamina shape were lanceolate measuring 6.5 cm length by 2.5 cm width (Table 11) and in alternate positions.

Table 11:Width and length measurements of GEMS and BEMS morphotypes descriptors of Jute mallow in the North Rift, region, Kenya

Morphotype	**Measurement**	**Leaf Lamina**	**flower**	**Fruit**
GEMS	Width (cm)	2.5±0.1	1.2±0.2	1.2±0.1
	Length (cm)	6.5±0.4	1±0.1	3.6±0.5
BEMS	Width (cm)	2.5±0.1	1.2±0.1	1.3±0.2
	Length (cm)	6.5±0.4	1±0.1	3.8±0.6

GEMS = Green early maturing short; BEMS = Brown early maturing short

Leaf Serration was present and facing leaf apex in both GEMS and BEMS morphotypes. Leaftip shape was acute in both GEMS and BEMS. Leaf Colour for the

GEMS was green while BEMS were brown. Flowers for GEMS and BEMS were 1.2 cm length and 1.0 cm width, yellow in colour, solitary in shape, positioned in opposite to leaves and had 5 small narrow sepals.

The fruit width and length results varied (Table 11), where length for GEMS and BEMS were 3.6 cm and 3.8 cm respectively and width were 1.2 cm and 1.3 cm respectively. The fruit was cylindrical, 10 ridged; dehiscing by 5 with traverse septa between seeds averagely 100 seeds per capsule. All GEMS and BEMS seeds were pyramidal in shape, dark grey – blue in colour and measurement of 1 mm in length.

5.4.3 Characterization results of Green Late Maturing Tall (GLMT and Brown Late Maturing Tall (BLMT) Jute mallow morphotypes

The plant height results (Table 12) showed Kapenguria farms had both shortest plants in GLMT (79 cm) and BLMT (77 cm) morphotypes while Kapsabet had the tallest plants (93 cm) in GLMT and 84 cm in BLMT morphotypes. Results show that generally, Green morphotypes were taller than Brown morphotypes of Jute mallow in the North Rift region.

Table 12: Measurements of GLMT and BLMT Jute mallow descriptors of materials from various seed sources in the North Rift region, Kenya

Source of seed	**Plant height (cm)**		**Pods count (numbers)**		**Leaf petiole length (cm)**	
	GLMT	**BLMT**	**GLMT**	**BLMT**	**GLMT**	**BLMT**
Kenya Seed Company	0	0	0	0	0	0
Kapenguria farms	79±3.2	77±3	16±0.6	16±1	1.7±0.1	1.8±0.1
Eldoret farms	82±3.1	84±3.2	17±1	18±1.7	1.8±0.1	1.7±0.2
Iten farms	84±3.5	81±4.2	17±1.2	17±1.5	1.7±0.1	1.7±0.1
Kitale farms	85±4.1	84±5.1	18±1.8	17±1.2	1.8±0.2	1.7±0.1
Kapsabet farms	93±5.2	84±3.2	19±1.5	19±2	1.7±0.1	1.7±0.1
North Rift mean	85	82	17	17	1.7	1.7

0 = indicate morphotypes (GLMT and BLMT) not present in seed collected from source of seed
GLMT = Green late maturing tall; BLMT = Brown early maturing short morphotypes

The highest pod count per plant was from GLMT and BLMT morphotypes at Kapsabet farms (19 pods) and lowest was Kapenguria farms (16 pods). On average the North Rift region GLMT and BLMT morphotypes had same pods per plant at 17 pods and only colours could differentiate them.

Petiole length analysis showed that on average, GLMT and BLMT morphotypes were of 1.7 cm and 1.8 cm in length across the seed sources, and could only be differentiated by their colours. The GLMT and BLMT leaf lamina shape was lanceolate and both had 8.5 cm length by 2.8 cm width respectively (Table 13) and in alternate positions.

Table 13: Width and length measurements of GLMT and BLMT morphotypes descriptors of Jute mallow materials in the North Rift region, Kenya

Morphotype	Measurement	Leaf lamina	Flower	Fruit size
GLMT	Width (cm)	2.8±0.1	1.2±0.1	1.4±0.3
	Length (cm)	8.5±1.1	1.0±0.1	3.9±0.5
BLMT	Width (cm)	2.8±0.1	1.2±0.1	1. 4±0.4
	Length (cm)	8.5±0.2	1.0±0.1	3.9±0.6

GLMT = Green late maturing tall; BLMT = Brown early maturing short morphotypes

Leaf serration in both GLMT and BLMT morphotypes was present and facing leaf apex, while Leaf tip was acute shaped and leaf colour for the GLMT was green while for BLMT it was brown. The flowers for both GLMT and BLMT morphotypes were measuring 1.2 cm in length by 1.0 cm in width, respectively. They were yellow in colour, solitary in shape, positioned in opposite to leaves and had 5 small narrow sepals. The length and width fruit measurements of GLMT and BLMT morphotypes were the same measuring 3.9 cm by 1.4 cm. respectively, were cylindrical, 10 ridged, dehiscing by 5 with traverse septa between the seeds. All seeds of GLMT and BLMT morphotypes were pyramidal in shape, dark grey–blue in colour and measuring 1mm in length.

5.5 Discussion

From the research, four morphotypes were identified based on colour, maturation and height attributes. The four morphotypes were Green Early Maturing Short (GEMS), Brown Early Maturing Short (BEMS), Green Late Maturing Tall (GLMT) and Brown Late Maturing Tall. This is consistent with other research findings which indicate that farmers in the region plant various landraces (Maundu *et al*., 1999). All the morphotypes especially those having common traits like height, colour and maturation period showed resemblance in other characters as well. Take for instance the two early maturing short morphotypes BEMS and GEMS had either colours of brown or green differentiating them apart from the height and maturity period.

Stem and petiole colour are usually used as descriptors even at farmers' level or in crop identification (IBPGR, 1991). These findings agree with those of many researchers in Kenya such as those in KALRO and Kenya Seed Company who have shown exhistence of several lines of *Corchorus olitorious* (KARI, 2014). The colour of the stem and leaves observed were due to the presence of anthocyanins which accumulate in certain plant tissues and are responsible for a range of colours like red, blue and purple. The accumulations of anthocinnins were due to environmental factors such as light, temperatures nutrients and stress as well as genetic factors (Beggs and Wellman, 1994). These pigments belong to the general class of flavonoids, which have many functions that include preinfection mechanisms of disease resistance, increase in osmotic pressure of the cell sap hence enhancing absorption of water by the root hairs from the soil and water movement within the plant, assistance in respiratory and photosynthetic process as well as protection of cholorophyll from being decomposed by strong lights (Kochhar and Krishnamoorthy, 1992). These roles of anthocyanins in Jute mallow morphotypes being researched, gives them the ability to survive in various agroecological zones in North rift, Kenya.

The research findings on Jute mallow show that its morphotypes differ in leaf and fruit size; leaf and stem colour, height and growing duration. These outcomes agree with findings by other researcher including Palada and Chang, (2003); Maundu *et al*., (1999) and K'Opondo *et al*., (2005). Other findings agreeing with this research outcomes include; Kamotho, (2005) as well Scheppers, (2002). Molecular characterization of these morphotypes may be a clearer way of establishing the exact identity of morphotypes and their relationship within and across the morphotypes which was beyond scope of this research or study.

5.6 Conclusion

It is concluded that characterized Jute mallow germplasm exhibit variation in morphological traits with two morphotypes outcome based on stem colour and two morphotypes on plant height and named: Green Early Maturing Short and Brown Early Maturing Short and Green Late Maturing and Brown Late Maturing Tall.

5.7 Recommendations

1. It is recommended that purification be made by seed industry (breeders or seed companies) to come-up with new or improved selections for farmers.
2. It is recommended that in order to avail varietals of Jute mallow to farmers, it is envisaged further work by breeders be embarked on, especially on breeding to produce certified seed of Jute mallow from the local identified available landraces.
3. It is recommended that molecular chericterization be done for clarity of morphotypes and their relatedness among/across the identified morphotypes to beef-up background information for future research on Jute mallow.

CHAPTER SIX

EFFECT OF SPACING AND FERTILIZER ON SEED QUALITY AND LEAF YIELD OF JUTE MALLOW (*Corchorus olitorius*) MORPHOTYPES IN THE NORTH RIFT REGION, KENYA

6.1 Abstract

Production of Jute mallow (*Corchorus olitorius*) in Kenya has been low due to many reasons, some of them being poor production agronomic practices such as poorly spaced plants, incorrect fertilizer rates, incorrect seed harvesting stage and poor quality seeds. The result is that the yield has remained low, 2-4 tons/ha as compared to expected yield of 5-8 tons/ha. Observations from Jute mallow growing areas showed that as much as 7 kg/ha instead of 5 kg/ha of seed is being used, which is required for a density of 250,000 plants/ha. This is 40% extra seed. The objective of the study was to discern effect of agronomic practices on seed quality and leaf yield of Jute mallow morphotypes, in the North Rift region, Kenya. Pure seed samples harvested from experiment on the morphological characterization of Jute mallow in green house (2nd experiment), were planted at two sites of Eldoret and Kitale over one season under three spacing (20 cm x 30 cm, 30 cm x 30 cm and 40 cm x 30 cm) treatments and three fertilizer (0 kg/ha, 60 kg/ha and 120 kg/ha) treatments. Data was collected and analyzed using General Statistics (GENSTAT) computer package version 12. Seed was harvested at three levels of maturity stages of green, tan and black and taken to seed laboratory for seed quality tests of analytical purity, germination and vigour. Data was analyzed according to International Seed Testing Association, (2004). Results showed that Jute mallow morphotypes responded best to higher spacing of 40 cm x 30 cm and high fertilizer rates of 120 kg/ha on Green Late

Maturing Tall and Brown Late Maturing Tall morphotypes with tallest plants being height of 91.67 cm and 93.00 cm at site 1 and 2 respectively. The highest number of branches per plant was 8 and 9 branching per plant at site 1 and 2 respectively. Highest pods per plant were 23 and 24 pods per plant at site 1 and 2 respectively and highest leaf yield per plant were 99.2 g and 96.3 g at site 1 and 2 respectively. Harvesting stage maximizing on seed quality attribute of germination were at tan pod stage with Green Late Maturing Tall germination of 94.5% and Brown Late Maturing Tall (94.25%). It is concluded that spaced plants exhibit varied effect on plant's growth with wider spacing (40 x 30 cm) exhibiting tall plants and highest branching; pod numbers and yield of Jute mallow. The use of increasing nitrogen fertilizer rate increases Jute mallow leaf yield with the high Nitrogen fertilizer rates of 120kg/ha giving the highest plant height, branching, pods per plant and fresh leaf yield. Jute mallow seed harvested at Tan pod stage has highest quality in terms of purity, germination and vigour as opposed to green pod or Black pod stages which had lowest quality. It is recommended that wider spacing (40 cm x 30cm) coupled with higher fertilizer (120 kg/ha) be used for high leaf yield and pods be harvested at tan stage for high quality seed of Jute mallow.

6.2 Introduction

Plants are important for existence and survival of human race (Waithaka *et al*., 2005). They provide direct source of world's stable foodstuffs like leaves, tubers, fruits and seeds (Akubugwo *et al*., 2007). Other plant species provide products or services that people depend on directly for use as medicine, fodder for livestock, fiber, among many uses (Chadha *et al*., 2007). For these reasons over 200 plants have been domesticated and grown for various purposes including Jute mallow (Roberts, 2009).

The origin of many vegetable crops can be traced to various parts of Europe as well as to Asia, Africa and South America (Abbass, 2000). In general terms, the range of latitude within which such vegetable crops are grown varies from 20 degrees north and south of the equator (Yousof *et al*., 2006). Currently African Indigenous Leafy Vegetables, Jute mallow being one of them, are known for their value in having high nutritional contents that is appreciated both in rural and urban areas (Mibei *et al*., 2011). In several communities in Kenya, these vegetables are important as food and economic source (Abukutsa-Onyango, 2002).

Jute mallow has been known to have medicinal and culinary properties (Ayodele, 2005). Reports show that upto 2 billion people in the world lack or suffer from insurfficient intake of vitamins and minerals (Hampson *et al*., 2007), of which Jute mallow can remedy the situation due to its' high nutritive contents needed by body (Ndinya, 2005). Such phenomenon of insurfficiency intakes causes diseases as blindness to anaemia as well as reducing body resistance to other ailments (Chadha and Oluoch, 2003).

The lack of adequate volumes to satisfy demand in both rural and urban market has enhanced the low uptake of this important vegetable (Kimiywe *et al*., 2007). To subdue such impediment there is need to step up production of this crop for both consumption and sale (Musotsi *et al*., 2008). This is possible through increased production by researching best production practices and use of improved agronomic practices like proper spacing, correct fertilizer rates and crop protection (The National Academies, 2009). Research on this will therefore try to ravel information concerning improvement of production of the vegetable (K'Opondo *et al*., 2005). Such information will also help enhance image of Jute mallow among other indigenous vegetables thereby widening scope of its cultivation by farmers (Keller, 2004).

Farmers often desire to produce high Jute mallow yields in order to maximize profit (KARI, 2014). However, scientific data have been scanty especially on the production, management, harvesting and post harvest handling of this crop (Keding, 2007). The Kenya government has been advocating for production and consumption of local vegetables in its strategy for food self sufficiency in the country (MOA, 2013). Despite so, this crops production is limited to the rainy season due to scarcity of water supply during off season (Makokha and Ombwana, 2002). The reason is that it is easily susceptible to moisture stress and can easily dry up as it grows mostly on top soils owing to its shallow rooting depth, though such can be solved by applying irrigation (Fasinmirin, 2001). Studies have shown higher leaf yields can be obtained by application of fertilizer combined with spacing (Schippers, 2000).

The challenge of increased production of most Indigenous leafy vegetables has been poor quality seed (Abukutsa-Onyango, 2007). This is because there are no improved morphotypes or breeding programs available for the crops (Adebooye *et al*., 2005). Research has shown that agricultural production of any crop requires high seed quality (Hampton, 2000), among other factors for its sustainability and profitability (Epkong, 2009). However seed production system of many indigenous vegetables in Africa, Kenya included, is largely informal (Ndinya, 2005). Farmers often produce and store their own seed and distribute seeds among themselves (Onim and Mwaniki, 2008) without knowing seed quality status (Ngoze and Okoko, 2005). This situation has been thought to be due to many factors including inadequate knowledge of seed quality aspects (Bujulu and Matee, 2005) including when is best to harvest crop for seed (Okongo, 2005) necessitating the research to discern effect of agronomic practices on seed quality and leaf yield of Jute mallow morphotypes, in the North Rift region, Kenya..

6.3 Fertilizer use in Jute mallow Production

Jute mallow is among popular indigenous vegetables whose leaves are used widely in Kenya, especially Western, Coast and Rift valley regions (MOA, 2013). This can be attributed to its nutritive value, its relative cheapness in production compared to exotic vegetables (Mibei *et al*., 2011), its ease in cultivation (Rensburg *et al*., 2007), input requirement (van Averbeke *et al*., 2007) and its quick maturity among other factors (Kamotho, 2005). Though so, there is a challenge of inadequate volumes to satisfy demand in both rural and urban market (Kimiywe *et al*., 2007). To subdue such impediment there is need to step up production of crop for both consumption and sale (Musotsi *et al*., 2008) using crop and seed advances (Buddhadeb, 2012).

Among them include use of agricultural inputs like, high quality seed and fertilizer which has great ability to increase on-farm productivity (Okot, 2002). Such also hasten crop storability thereby enhancing food security (Chadha ,*et al*., 2007) since it determines the upper limit on yield (Beck *et al.*, 2003). Improved husbandry practices are capable of increasing Jute mallow production by over 70% (GOK, 2007). Under farmers' conditions, the national average Jute mallow yield is at a range of 2-4 tons/ha/annum (MOA, 2010) as compared to the expected yield of 5-8 tons per ha per annum (KARI, 2009), while potential exists for increasing the yields to over the world's average of 8-12 tons per ha per annum (KARI, 2011). With the use of improved Jute mallow seed, fertilizer and good crop husbandry practices, yields can be improved (Grubben and Denton, 2004). Feistrizer (1975) reported yield increases of up to 112 % in cereals in Central Europe through the use of improved seed and other agricultural inputs. Similar increases are possible with other crops such as Jute mallow (Kipkosgei *et al*., 2003). Fasinmirin, (2001); Taylor and Wepper (1990), for instance reported that adequate watering combined with other production practices gave good crop results.

Research also show several factors like altitude and fertilizer elements and levels combined significantly increased crop and seed yield (Kamwaga *et al*., 2005). The amounts to used are usually varied (Onasanya *et al*., 2009) due to variation of nutrients in soil and its organic matter presence (Diaz *et al*., 2011). For this, the farmer has to establish rates that are most economical for him or her (Ondieki *et al*., 2011). Compound fertilizers or nitrogen fertilizer such as Calcium Ammonium Nitrate or Sulphate of Ammonia can be applied at rate of two and half teaspoonfuls per running meter (Oyewole and Mera, 2010; van Averbeke, 2007). Alternatively foliar feed can be sprayed once every week (Hamayun *et al*., 2011).

There is ample production potential in Kenya of enhancing Jute mallow yield (Mwangi and Mumbi, 2006), not only to meet the growing demand for the domestic use requirement (Irungu *et al*., 2007), but also produce surplus for export (MOA, 2010). The quantity and quality of farm produced Jute mallow by farmers is usually low in yields and of poor seed quality (KARI, 2009). Several reports indicate that the quantity and quality of farm produced Jute mallow is not always optimal (Schippers, 2002; Abukutsa-Onyango, 2005). This has been attributed to poor quality seed (Okongo, 2005) as well the high cost of fertilizers and chemicals (Muli *et al*., 2000) as farmers cannot afford due to their low purchasing power (Gisselquist and Harun, 1998). It is estimated that 90% of seeds produced by farmers have been done without adequate agronomic practices (Ndinya, 2005) and may express poor germination, vigour, and storability (Muliokela, 1999). This leads to reduced seed quality for the progeny (Dornbos Jr. 1995), which could express a more variable emergence (Egli, 1998) leading to low yield (Nekesa and Mesa, 2003). Fertilizer and manure make crops grow vigourously (Oyewole and Mera, 2010) and produce high yield and quality seed (Babatunde *et al*., 2002). A good crop destined for increased yield/seed production needs to be well spaced, fertilized, weeded and harvested at correct stages (Schippers, 2002; Okosun *et al*., 2006) necessitating the research with objective to discern effect of fertilizer on seed quality and leaf yield of Jute mallow morphotypes in the North Rift region, Kenya.

6.4 Spacing of plants and its’ effect on Jute mallow crop production

Indigenous vegetables, Jute mallow included are popular in Kenya (Schippers, 2002). They are mainly grown in kitchen gardens for home consumption (Musotsi *et al*., 2008) and little for the urban market (Abukutsa-Onyango, 2002). However they have been neglected in terms of research on agronomic recommendations (Abbass, 2000); crop and seed production (Okongo, 2005) and improvement (Ndinya, 2005). In most cases, they have been allowed to regenerate with onset of rains without a serious effort to plant new seed (Fondio and Grubben, 2004) or even apply other cultural practices on them (Okongo, 2005). The local demand for the vegetables is still largely unmet (Irungu *et al*., 2007) and farmers have continued to use their own seed (Ndinya, 2005) or purchase the scarce seed of unknown quality from the local market (K’Opondo *et al*., 2005). The advantage of these vegetables is that they are fast growing (Abukutsa-Onyango, 2003) and well adapted to a widerange of agro-ecological zones (Abbass, 2000). They are also less susceptible to diseases and pests (Ashilenje *et al*., 2011) and more nutritious than the exotic vegetables (Mnzava, 1997). These vegetables fetch good prices in market (Irungu *et al*., 2007) though their demand is largely unmet (Shiundu and Oniang'o, 2007).

Jute mallow being a food security crop (Chadha *et al*., 2007), is also a commodity in commerce (Walingo *et al*., 2001) and its production offers job opportunities either directly or indirectly to a vast majority of people right from homes (Musotsi *et al*., 2008), through local markets up to the urban whole sale markets (Okongo, 2005; Weinberger and Msuya, 2004). The expansion of production of these vegetables continues to be hampered by lack of a reliable source of planting materials (Rensburg *et al*., 2007) and technical information like correct spacing of plants for increased yields (Ngoze and Okoko, 2005).

During Jute mallow growing, seeds can be sown by direct drilled on lines prepared beds, preferably at the beginning or end of the wet season, and seedlings thinned to leave plants at a square spacing of 20-30 cm x 20-30 cm, depending on vigour of selection and use of crop as vegetables or for seed production (AVRDC, 2004). Alternatively, seeds may be sown in a seedbed and transplanted in rows between 25-55 cm and 15-45 cm between plants (Kamwaga *et al.*, 2005). Approximately 5 kg/ha of seed is required for a density of 250 000 plants/ha, giving leaf yield varying from 5-8 t/ha per annum (KARI, 2009; MOA, 2009).

In essence Jute mallow species broadly exists by two categories i.e. narrow leaved and broad leaved (Onyango *et al*., 2009). Direct seeding at a spacing of 45 cm between the rows and 15 cm within the plants has been adopted for both cultivars (Abukutsa-Onyango, 2007). Wider spacing's are used for tall cultivars with broad leaves, multiple branches, and harvested several times (Adebooye *et al.*, 2005).

Narrower spacing's are used for short and bushy morphotypes and once-over harvesting (Keding *et al*., 2007). Rows are spaced 10 cm apart with 5–10 cm between plants within row (Sivakumar and Ponnusami, 2011). At transplanting it should be done in the late afternoon or on a cloudy day to minimize water loss and transplant shock (Buddhadeb, 2012). Dig holes 10 cm deep, place the transplant in the hole, cover the roots with soil and lightly firm (Kamwaga *et al*., 2005). Irrigate immediately after transplanting to establish good root-to-soil contact (Berinyinyet *et al.,* 1997). The seedlings are then thinned two weeks later to various spacing of 15-50 cm x 20-30 cm depending on desired production aims, but field be kept weed free throughout the experimental period (Bhattacharjee *et al.*, 2000). The objective of the experiment was to discern effect of spacing on seed quality and leaf yield of Jute mallow morphotypes, in the North Rift region, Kenya.

6.5 Harvesting stage of Jute mallow for quality seed

Agricultural production of any crop requires high quality seed, among other factors for its sustainability and profitability (Ochuodho *et al*., 1999). However seed production system of many indigenous vegetables in Africa, Kenya included, is largely informal (Ndinya, 2005). Farmers often produce and store their own seed and distribute the seeds among themselves without knowing seed quality status in terms of purity, germination or vigour (Ngoze and Okoko, 2005). This situation has been been due to many factors including inadequate knowledge of seed quality aspects including when is best to harvest a crop for seed (Okongo, 2005).

Indigenous Leafy Vegetables, *Corchorus olitorius* included, are an integral part of obtaining income and food security (Habwe *et al*., 2008) as well asbeing a source of important nutrients essential for good health (WHO, 2003). However, Jute mallow production has been low in most parts of Kenya (Abukutsa-Onyango, 2003), North Rift region included. The low level of production is attributed to some extend to the use of low quality farm saved seeds (K'Opondo, 2005).

Research show that in the country, there is ample production potential (Mwangi and Mumbi, 2006) to not only meet the growing demand for domestic use requirement (Irungu *et al*., 2007) but also produce surplus for export (MOA, 2010). Some constraints have been negating this and include use of poor agronomic practices, post harvest handling and storage as well as poor quality seed (Abukutsa-Onyango, 2007). For instance, farmers use as much as 7 kg/ha instead of 5 kg/ha of seed which is required for a density of 250 000 plants/ha (MOA, 2009) thereby using many seeds per hill amounting to 40% extra seed. The problem has been sustained by the no high quality seed of the vegetable from the breeders to farmers (Ndinya, 2005). This has resulted to farmers getting re-cycled planting seed whose quality/ potential is not assured (Adebooye *et al*., 2005).

Jute mallow crop destined for seed production may either be left without cutting or cutback once at 20 cm above ground to stimulate lateral branching (Khatun *et al*., 2002). Plants need to be spaced upto 50 cm x 50 cm and well fertilized to get a good seed yield (Berinyinyet, *et al*., 1997). The stage at which capsules are collected is very important for quality seed (Kamotho, 2005). Fruit capsules left in field become dark brown or black and could get diseased or they could ripen and shatter their seeds (Palada and Chang, 2003). Leaving them for too long also reduces their germination capacity and result in a high percentage of seed dormancy (Hampton, 2000). Ideally, almost mature capsules should be picked by hand and left to dry on a sheet (Fondio and Grubben, 2004). Dried capsules are beaten lightly to release seed (Bhattacharjee *et al*., 2000). The seed is cleaned and stored in sealed containers such as gourds and glass jar or similar containers (Almekinders and Louwaars, 1999; Nagel and Börner, 2010; Groot *et al*., 2012).

Most of the fruits of indigenous vegetables including Jute mallow fruits do not ripen simultaneously (Almekinders and Louwaars, 1999), and fruits left to dry on the mother plant before harvesting face seed losses like deterioration due to weather, lodging and shattering through dehiscence (Schippers, 2002). These loses could be reduced by hand-picking seed pod at mature stage, followed by seed extraction and drying (Kamotho, 2005) necessitating research with objective to discern effect of harvesting stage of Jute mallow seed in respects to analytical purity, germination and seed vigour.

6.6 Materials and Methods

6.6.1Field experimental management of Jute mallow

This is the third and fourth stages of the research wherethe resultant Jute mallow pure seed accession from green house (2ndexperiment) was sampled and planted in field experiments to discern their effect of spacing and fertilizer on seed quality and leaf yield of Jute mallow (3rd experiment). Thereafter seed harvested at three treatment stages (Green, Tan and Black pod (4th experiment) and taken to the laboratory for seed quality tests. The experiment was conducted at two sites of University of Eldoret farm and KALRO - Kitale farm over one season between May - November 2015.

Before the start of experiment, soil sampling was done in both sites at the experimental plots prior to planting Jute mallow seed samples. This was to know the nutrient variation between the soils of the two sites at the time the experiment commenced. The soil samples were then taken to the soil laboratory where it was air dried and passed through a two millimeter sieve. The fraction which passes through the sieve was used to analyze total nitrogen, exchangeable cations, organic carbon, available P and pH using described analytical methods (Tan, 1996; Irungu *et al*, 1997) and available nitrogen analysis determined using fresh soils.

The soils were worked out to fine tilth as recommended for small seeds (MOA, 2013). Jute mallow seeds were then drilled with nitrogenous fertilizer (N) at rates of 0, 60 and 120 kg/ha, (Diaz *et al*., 2011) in the field in well prepared demarcated seed beds at the experimental plots. Weeding was carried out in all plots in the sites simultaneously. The seedlings were then thinned two weeks later to the research spacing treatments of 20 cm x 30 cm, 30 cm x 30 cm and 40 cm x 30 cm (Abukutsa-Onyango 2005). The experimental plots were kept weed free and pests and diseases scouted throughout the experimental period.

To discern the effect of treatments on plant growth, five plants in each plot were systematically random sampled (Gomez and Gomez, 1984), tagged and their heights, branching at main stem, pod count and leaf yield determined. Seed harvesting was done at various stages of maturity, i.e. Green (P.M.), Tan (H.M.) and Black (Overripe) stages and seed taken to laboratory for seed quality tests on analytical purity, germination and seed vigour.

6.6.2 Field Expeimental design

The field experiment was done at two sites; University of Eldoret farm and KALRO Kitale farm over one season. Both sites had land prepared and demarcated into plots and plan laid out in Randomized Complete Block Design (RCBD) on a factorial arrangement with three replicates. The treatments consisted of three levels of Nitrogen fertilizer (0, 60 and 120 kg/ha); three levels of spacings (20 cm x 30 cm; 30 cm x 30 cm and 40 cm x 30 cm); three levels of seed harvesting stages (Green, Tan and Black pod stages) and four levels of Jute mallow morphotypes; Green Early Maturing Short (GEMS), Brown Early Maturing Short (BEMS), Green Late Maturing Tall (GLMT) and Brown Late Maturing Tall (BLMT). The treatments were assigned to the experimental plots in each block using the table of random numbers as described by Gomez and Gomez (1984). Each plot measured 2 m x 3 m with 1 m paths between blocks and 0.5 m path between plots (Shibonje, 2009).

6.6.3 Field data collection of Jute mallow

The data of Jute mallow collected in the field comprised of four parameters (plant height, branching, pods and leaf yield) as follows:

a). Plant height: Plant height was measured in centimeters from ground level up to apex of youngest leaf using a tape measure (Maritim *et al*., 2009) on five sampled plants at harvesting in net plot area.

b). Number of branching per plant: The total number of branches per plant was counted at harvesting on five sampled plants in net plot.

c). Number of pods per plant: The total number of pods per plant was counted at harvesting on five sampled plants in net plot.

d). Fresh leaf yield: Harvesting was done on five sampled fresh leafy plants before on-set of flowering in season (Maritim *et al*., 2009) from net plot area. The harvested leaves were then put in paper bags and fresh weight in grams taken using weighing scale for each plant immediately to avoid lose of moisture (Masinde *et al.*, 2010) and yield analysis done.

6.7 Seed quality test on Jute mallow seed harvested from field.

The Jute mallow seed samples harvested from field treatment replicates on spacing and fertilizer experiments were mixed well and taken for seed quality tests attributes of purity, germination and seed vigour at University of Eldoret seed testing laboratory.

6.7.1 Analytical purity test

The experiment of analytical purity test was conducted at laboratory at University of Eldoret in Department of Seed, Crop and Horticultural Sciences. Jute mallow seeds harvested differently from plots across the two sites were subjected to International Seed Testing Association (ISTA) (2004) sampling analysis procedures. This included mixing well seed by passing through a seed divider several times and subsequently reconstituting them. The sub-samples from each plot were derived by successively halving the sub-sample until working sample of 15 g was gotten. It was then labelled well and taken to seed testing laboratory and placed on a purity work board and separated into three purity portions of; Pure seed, other seeds in sample e.g. grass seeds, other crop seeds and Inert matter (dust, Soil, etc) to determine its purity. Weights of each group were separated and their percentages worked out (as per ISTA, 2004) from their initial weight of each sample (15 g) and results analyzed as per ISTA (2004). Testing of seed samples was done on the day receipt; if not then it was stored in a cool ventilated room to minimize changes occurring in quality of seed.

6.7.2 Germination test

The germination test (ISTA, 2004) was conducted at the laboratory on pure seed portion harvested and sampled from plots across the two sites at the laboratory in the

Department of Seed, Crop and Horticultural Sciences, University of Eldoret. Four replicates of 100 random seeds were obtained from the pure seed sample using a vacuum seed counter (with counting plates counting 100 holes) and placed on moistened filter paper inside a Petri dish, ensuring the seeds are sufficiently spaced. They were then taken to the growth chamber machine set at 30^{o} C temperature. Evaluation of germination was scored daily for 5 days, and evaluation of germinations done and recorded as follows: - normal seedlings, abnormal seedlings and dead seeds as per ISTA (2004) regulations and procedures.

During evaluation, normal seedlings were graded as, those seedlings that showed capacity for continued development into normal plants under favorable conditions, and possessed all essential structures. These essential structures included, well developed root system, intact hypocotyls and epicotyls. The abnormal seedlings included those damaged, deformed, and decayed. Also checked were hard, fresh un-germinated and dead seeds. The data from experiment on germination test was analyzed as per ISTA (2004) and results recorded.

6.7.3 Electrical conductivity test

The Electrical Conductivity test (seed vigour test) (ISTA, 2004) was conducted at University of Eldoret in Department of Seed, Crop and Horticultural Sciences. Distilled water measuring 250 ml was measured and put in 24 well labelled containers (plastic) and covered with aluminum foil to control dust. Two containers of distilled water of 250 ml each were also set as control and covered with aluminum foil. The containers were then put on bench for 24 hrs at room temperature (20-23^{o} C) and 100 Jute seeds added to each of the 24 plastic containers. After 24 hours the contents of the containers were gently swirled for 10-15 seconds and conductivity (μ S $cm^{-1}g^{-1}$) of soak water was then measured and only stable reading on meter taken. In between measurements dip cell was rinsed twice in distilled water and dried using clean dry paper towels. The conductivity per gram of seed weight for each replicate was calculated after accounting for the background conductivity of the original water and the average of the four replicates provided the seed lot result. Thus for each replicate:

$$\frac{\text{Conductivity reading } (\mu\ S\ cm^{-1}g^{-1} - \text{background reading}}{\text{Weight (g) of replicate}} = \text{conductivity } (\mu\ S\ cm^{-1}\ g^{-1})$$

Electrical conductivity readings were taken by Handy lab LF schott conduct meter (Schott Glaswerke Mainz Made in Germany). The data from experiment on Electrical Conductivity test was analyzed as per ISTA (2004) and results recorded.

6.8 Analysis of data from Jute mallow field experiments

The data on seed quality was analyzed as per ISTA (2004) and those from spacing and fertilizer experiments were analyzed using computer package GENSTAT and ANOVA drawn, means obtained and separation done using DMRT at $p \leq 0.05$.

6.9 Results

6.9.1 Plant height

Plant height results (Table 14) of Jute mallow morphotypes under various treatments, show use of higher fertilizer of 120 kg/ha (F2) and wider spacing of 40 cm x 30cm (S3) at both sites 1 and 2 had significant variance ($p<0.05$) in plant height within and across morphotypes (Appendix 3).

Table 14: Means of plant height (cm) of Jute mallow morphotypes from site 1 and 2 in the North Rift region, Kenya, under different fertilizer rates and spacings.

Fertilizer (kg/ha)	**Spacing (cm)**	**Site 1 (Eldoret-UoE)**				**Site 2 (Kitale-KALRO)**			
		Morphotypes				Morphotypes			
		GEMS	BEMS	GLMT	BLMT	GEMS	BEMS	GLMT	BLMT
F0	S1	30.33a	29.00a	78.00a	78.67a	29.67a	30.00a	78.67a	78.67a
	S2	31.00a	30.00a	79.33a	80.33b	31.67b	31.00a	79.67a	81.00b
	S3	31.33a	31.00b	81.00b	80.33b	31.00b	32.00b	81.00b	81.00b
F1	S1	30.00a	31.00b	81.33b	81.33b	30.00a	32.00b	81.67b	81.67b
	S2	31.67a	32.00b	82.33b	83.00c	32.00b	33.00b	83.33c	84.67c
	S3	33.67b	33.00c	86.00c	85.00d	34.00c	34.67c	86.67d	86.00d
F2	S1	35.67b	34.33c	86.00c	85.67d	35.00d	35.67c	87.67d	87.33d
	S2	37.33c	37.00d	88.67d	86.67d	36.33d	38.00d	89.67e	89.67e
	S3	40.00d	38.00d	91.00e	91.67e	38.67e	40.00e	93.00f	92.67f

Figures having same letters ‘a’ or ‘b’ or ‘c’ or ‘d’ or ‘e’ or ‘f’ in columns show no significant difference (p<0.05) in means at site.
Fertilizer; F0=0 kg/ha, F1=60 kg/ha, F2=120 kg/ha. Spacing; S1=20x30 cm, S2=30x30 cm, S3=40x30 cm.
GEMS = Green Early Maturing Short and BEMS = Brown Early Maturing Short morphotypes.
GLMT = Green Late Maturing Tall and BLMT = Brown Late Maturing Tall morphotypes.

Short morphotypes (GEMS and BEMS) had 38-40 cm as the tallest plants and shortest plants at 29-30 cm at site 1 and 2 respectively. This indicates that fertilizer rates and spacing variation have effect on the overall plant growth i.e. plant height, thereby also affecting plant leaf yield in the Jute mallow production. There was significant variance ($p<0.05$) in effect by fertilizer rates and spacing’s treatments on plant height as observed in the tall Jute mallow with morphotypes GLMT and BLMT both having 78 and 79 cm as short plants and 91 cm and 92 cm as tall plants respectively at site 1 (Eldoret-UoE) and site 2 (Kitale-KALRO).

The plant height means separation ($p<0.05$) showed no significant difference (Table 14) within the early maturing morphotypes (BEMS and GEMS) and also within late maturing morphotypes (GLMT and BLMT), but there was significant difference ($p<0.05$) between early maturing morphotypes (BEMS andGEMS) and late maturing (GLMT and BLMT).

6.9.2 Number of branching per plant

Results on number of braches per plant of Jute mallow morphotypes from fertilizer and spacing experiment (Table 15) show that use of higher fertilizer rates of 120 kg/ha (F2) and wider spacing of 40 cm x 30 cm showed an increase in number of braches per plant from both sites 1 and 2 within morphotypes (1-7 and 1-8 branching/plant respectively) and between morphotypes (1-7 and 1-9 branching/plant respectively) (Table 15). Generally there were higher branching of plants in site 2 (9 branching/plant) than those in site 1 (7 branching/plant). The control (F0S1) had lowest branching numbers (1-2) across morphotypes in both sites, while (F2S3) highest being 7-9 branching (Table 15).

Table 15: Means of number of branches per plant from site 1 and 2 in North Rift region, Kenya

Fertilizer (kg/ha)	Spacing (cm)	Site 1 (Eldoret-UoE)				Site 2 (Kitale-KALRO)			
		Morphotypes				Morphotypes			
		GEMS	BEMS	GLMT	BLMT	GEMS	BEMS	GLMT	BLMT
F0	S1	1.00a	1.00a	1.33a	1.33a	1.33a	1.33a	1.67a	1.67a
	S2	1.33a	1.33a	1.67a	2.33b	2.33b	1.67a	2.67b	3.00b
	S3	2.33b	2.33b	2.67b	3.33c	3.00c	2.67b	3.33c	3.33b
F1	S1	3.33c	3.33c	3.33c	3.67c	3.67c	4.00c	4.33d	4.33c
	S2	4.33d	4.33d	5.33d	4.33d	4.67d	5.33d	6.00e	5.33d
	S3	5.33e	5.33e	6.33e	5.33e	6.00e	6.33e	7.33f	6.33e
F2	S1	5.33e	5.33e	6.33e	5.33e	6.33e	6.33e	7.33f	6.33e
	S2	6.33f	6.33f	7.33f	6.33f	7.33f	6.67e	8.33g	7.33f
	S3	7.33g	7.33g	8.33g	7.33g	8.33g	8.33f	9.33h	8.33g

Figures having same letters ‘a’ or ‘b’ or ‘c’ or ‘d’ or ‘e’ or ‘f’ or ‘g’ or ‘h’ in columns show no significant difference (p<0.05) in means at site.
Fertilizer; F0=0 kg/ha, F1=60 kg/ha, F2=120 kg/ha. Spacing; S1=20x30 cm, S2=30x30 cm, S3=40x30 cm.
GEMS = Green Early Maturing Short and BEMS = Brown Early Maturing Short morphotypes.
GLMT = Green Late Maturing Tall and BLMT = Brown Late Maturing Tall morphotypes.

Also it was noted that lower fertilizer rates of 60 kg/ha (F1) combined with wider spacing of 40 cm x 30 cm (S3) had same number of branching as higher fertilizer rates of 120 kg/ha (F2) with closer spacing of 20 cm x 30 cm (S1) i.e. had 6 number of branching per plant showing no significant difference (p<0.05) (Appendix 4). The number of branches means separation showed no significant difference (p<0.05)

(Table 15) within the early maturing morphotypes (BEMS and GEMS) at means of 4.07 and 4.7 for site 1 and 2 respectively, though had significant difference within late maturing morphotypes (GLMT and BLMT). There was significant difference ($p<0.05$) between early maturing morphotypes morphotypes (BEMS and GEMS) and late maturing morphotypes (GLMT and BLMT) from both site 1 (Eldoret - UoE) and 2 (Kitale - KALRO).

6.9.3 Number of pods per plant

The pod per plant results (Table 16) under various treatments, show use of higher fertilizer rates of 120 kg/ha (F2) and wider spacing of 40 x 30 cm (S3) from sites 1 and 2 increases number of plant within and across morphotypes e.g. short morphotypes (GEMS and BEMS) had (control plots) 4-5 pods as the lowest pods per plant and highest pods per plant at 11-13 pods high fertilizer and wider spacing. This indicates that fertilizer rates and spacing variation has effect on the overall pods per plant, thereby also affecting overall seed yield of Jute mallow.

Table 16: Means of the number of Pods per plant of Jute mallow from site 1 and 2 in North Rift region, Kenya

Fertilizer (kg/ha)	Spacing	Site 1 (Eldoret-UoE) Morphotypes				Site 2 (Kitale-KALRO) Morphotypes			
		GEMS	BEMS	GLMT	BLMT	GEMS	BEMS	GLMT	BLMT
F0	S1	4.33a	4.67a	15.00a	14.00a	5.33a	5.33a	16.33a	16.00a
	S2	5.33b	5.33b	16.00b	15.33b	6.33b	6.00b	17.00b	17.00b
	S3	6.67c	6.00c	16.67b	15.33c	7.33c	6.33b	18.67c	18.00c
F1	S1	6.67c	6.67c	18.67c	16.33d	7.33c	7.33c	20.00d	19.33d
	S2	7.67d	8.00d	19.67d	17.33e	8.33d	8.67d	21.33e	20.33e
	S3	8.33e	8.67d	21.33e	18.33f	9.33e	9.33e	22.33f	22.00f
F2	S1	9.33f	9.00e	21.67e	20.00g	9.67e	9.33e	22.33f	22.67f
	S2	10.33g	10.00f	22.67f	21.33h	11.67f	12.00f	23.33g	23.67g
	S3	11.67h	11.33g	23.33g	23.00i	13.00g	13.33g	24.33h	24.67h

Figures having same letters ‘a’ or ‘b’ or ‘c’ or ‘d’ or ‘e’ or ‘f’ or ‘g’ or ‘h’ or 'i' in columns show no significant difference ($p<0.05$) in means at site.
Fertilizer; F0=0 kg/ha, F1=60 kg/ha, F2=120 kg/ha. Spacing; S1=20x30 cm, S2=30x30 cm, S3=40x30 cm.
GEMS = Green Early Maturing Short and BEMS = Brown Early Maturing Short morphotypes.
GLMT = Green Late Maturing Tall and BLMT = Brown Late Maturing Tall morphotypes.

There was no significant variation (p<0.05) (Appendix 5) in number of pods per plant effect by fertilizer and spacing treatments within tall Jute mallow morphotypes (GLMT and BLMT), both had 14-16 pods as least pods per plant and 23-25 pods as highest pods per plant in both site 1 and 2 in North Rift region, Kenya.

The number of pods per plant means separation showed no significant difference (p<0.05) (Table 16) within the early maturing morphotypes (BEMS and GEMS) and also within late maturing morphotypes (GLMT and BLMT). There was significant difference (p<0.05) between the early maturing morphotypes (BEMS and GEMS) and late maturing morphotypes (GLMT and BLMT) from both sites 1 (Eldoret - UoE) and 2 (Kitale - KALRO) in the North Rift region, Kenya.

6.9.4 Fresh leaf yield

Results of fresh leaf yield per plant from treatments (Table 17), show use of higher fertilizer rates of 120 kg/ha (F2) and wider spacing of 40 x 30 cm (S3) had highest yield (99.20 g) for late maturing morphotype GLMT and 66.80 g for early maturing morphotypes (BEMS). This trend of increase in yield weight of fresh leaf yield per plant from both sites within and between morphotypes was observed in other morphotypes across sites as as well. GEMS plants from site 2 (Kitale) had higher weight (66.69 g) than those from site 1 (Eldoret) of 66.31 g. GEMS morphotypes plants with no fertilizer (F0) combined with closer spacing of 20 x 30 cm (S1) had lowest plant weight (27 g) and highest of 66 g being from 120 kg/ha fertilizer (F2) combined with the wider spacing of 40 x 30 cm (S3), an increase in leaf yield by 39 g per plant due to fertilizer and spacing effect.

Table 17: Means of fresh leaf yield (g) per plant from site 1 and 2 in the North Rift region, Kenya

Fertilizer (kg/ha)	**Spacing**	**Site 1 (Eldoret-UoE)** Morphotypes				**Site 2 (Kitale-KALRO)** Morphotypes			
		GEMS	BEMS	GLMT	BLMT	GEMS	BEMS	GLMT	BLMT
F0	S1	27.07a	26.42a	52.66a	46.82a	27.51a	27.56a	52.51a	47.12a
	S2	29.85b	30.24b	53.32a	53.57b	30.36b	30.13b	53.89a	53.46b
	S3	37.72c	38.32c	56.41b	58.16c	38.26c	38.38c	54.66b	57.90c
F1	S1	44.17d	44.49d	72.21c	63.20d	44.39d	44.45d	72.50c	63.24d
	S2	46.24e	46.35e	74.46d	67.38e	47.12e	46.50e	74.56d	67.29e
	S3	47.63e	47.56e	75.57d	70.33f	42.45f	48.30f	75.34d	69.79f
F2	S1	52.82f	52.99f	81.20e	81.05g	52.68g	52.84g	81.88e	80.98g
	S2	64.43g	63.80g	87.76f	85.51h	63.44h	63.67h	87.64f	85.27h
	S3	66.31h	66.77h	99.09g	96.30i	66.69i	66.80i	99.20g	96.15i

Figures having same letters ‘a’ or ‘b’ or ‘c’ or ‘d’ or ‘e’ or ‘f’ or ‘g’ or ‘h’ or ‘i’ in columns show no significant difference (p<0.05) in means at site.
Fertilizer; F0=0 kg/ha, F1=60 kg/ha, F2=120 kg/ha. Spacing; S1=20x30 cm, S2=30x30 cm, S3=40x30 cm.
GEMS = Green Early Maturing Short and BEMS = Brown Early Maturing Short morphotypes.
GLMT = Green Late Maturing Tall and BLMT = Brown Late Maturing Tall morphotypes.

Results across late maturing morphotypes (GLMT, BLMT) show lowest plant leaf weight was 46-52 g for no fertilizer (F0) combined with closest spacing of 20 x 30 cm (S1), while highest plant leaf weight was 96-99 g for higher fertilizer rate of 120 kg/ha (F2) combined with wider spacing of 40 x 30 cm (S3).

The weight of fresh leaf yield means separation (Table 17) showed no significant difference (p<0.05) within early maturing morphotypes (BEMS and GEMS). There was significant difference (p<0.05) within late maturing morphotypes (GLMT and BLMT), but no significant difference (p<0.05) (Appendix 6) between the early maturing morphotypes (BEMS and GEMS) and the late maturing morphotypes (GLMT and BLMT) from both site 1 and 2 in the North Rift region, Kenya.

6.10 Seed quality test

6.10.1 Analytical purity results (%)

Purity of Green pod seeds stage (H1)

Seed purity results of green pod stage (H1) from site 1 and site 2 (Table 18) show that all morphotypes seeds were over 99% purity indicating that seeds were of high quality, thereby meeting ISTA (2004) quality status of above 98% purity. Result also show that use of higher fertilizer rates of 120 kg/ha (F2) and spacing of 40 x 30 cm (S3) had higher % purity seed (99.9%) compared to lower fertilizer of 60 kg/ha (F1S3) having 99.7% and control F0S3 (99.5%).

Table 18: Means of analytical purity results (%) of Green pod seeds stage (H1) in the North Rift region, Kenya

Fertilizer (kg/ha)	Spacing	Site 1 (Eldoret-UoE) Morphotypes				Site 2 (Kitale-KALRO) Morphotypes			
		GEMS	BEMS	GLMT	BLMT	GEMS	BEMS	GLMT	BLMT
F0	S1	99.4a	99.5a	99.4a	99.5a	99.4a	99.4a	99.4a	99.6a
	S2	99.4a	99.6b	99.5b	99.6b	99.6b	99.6c	99.5b	99.7b
	S3	99.5a	99.6b	99.6c	99.6b	99.6b	99.5b	99.7c	99.7b
F1	S1	99.6b	99.6b	99.6c	99.7c	99.7c	99.6c	99.7c	99.7b
	S2	99.7c	99.7c	99.7d	99.7c	99.7c	99.7d	99.7c	99.8c
	S3	99.7c	99.7c	99.7d	99.7c	99.8d	99.8e	99.8d	99.8c
F2	S1	99.8d	99.8d	99.6c	99.8d	99.8d	99.8e	99.8d	99.8c
	S2	99.8d	99.8d	99.7d	99.9e	99.9e	99.8e	99.8d	99.9d
	S3	99.9e	99.9e	99.8e	99.9e	99.8d	99.9f	99.8d	99.9d

Figures having same letters ‘a’ or ‘b’ or ‘c’ or ‘d’ or ‘e’ or ‘f’ in columns show no significant difference (p<0.05) in means at site.
Fertilizer; F0=0 kg/ha, F1=60 kg/ha, F2=120 kg/ha. Spacing; S1=20x30 cm, S2=30x30 cm, S3=40x30 cm.
GEMS = Green Early Maturing Short and BEMS = Brown Early Maturing Short morphotypes.
GLMT = Green Late Maturing Tall and BLMT = Brown Late Maturing Tall morphotypes.

Purity of Tan pod seeds stage (H2)

Seed purity results from Tan pod seed stage (H2) of Jute mallow (Table 19, Appendix 7) show that all morphotypes seeds were over 99% purity indicating that seeds were of high quality; thereby meeting ISTA (2004) seed quality status of above 98% purity. Combination effect of higher fertilizer of 120 kg/ha (F2) and wider spacing levels of

40 x 30 cm on morphotypes results from tan pod harvesting stage of Jute mallow from both sites 1 and site 2 show that there is higher purity of seed when both factors are used across the morphotypes. Findings indicated the highest seed purity (99.9%) was at fertilizer rate of 60 kg/ha combined with wider spacing of 40 cm x 30 cm (F2S3) and lowest seed purity (99.3%) at no fertilizer with spacing of 40 cm x 30 cm (F0S1).

Table 19: Means of analytical purity (%) of Tan pod seed stage (H2) from site 1 and 2 in the North Rift region, Kenya

Fertilizer (kg/ha)	**Spacing**	**Site 1 (Eldoret)**				**Site 2 (Kitale)**			
		Morphotypes				Morphotypes			
		GEMS	BEMS	GLMT	BLMT	GEMS	BEMS	GLMT	BLMT
F0	S1	99.4a	99.5a	99.5a	99.5a	99.4a	99.3a	99.5a	99.5a
	S2	99.5b	99.6b	99.5a	99.7c	99.6b	99.6b	99.6b	99.6b
	S3	99.6c	99.6b	99.7b	99.6b	99.6b	99.6b	99.7c	99.6b
F1	S1	99.7d	99.6b	99.7b	99.7c	99.7c	99.7c	99.6b	99.7c
	S2	99.7d	99.8c	99.7b	99.7c	99.7c	99.7c	99.7c	99.7c
	S3	99.9f	99.8c	99.8c	99.7c	99.8d	99.7c	99.7c	99.8d
F2	S1	99.8e	99.8c	99.7b	99.8d	99.8e	99.7c	99.8d	99.9e
	S2	99.9f	99.9d	99.7c	99.9e	99.9f	99.9d	99.8d	99.9e
	S3	99.9f	99.9d	99.8d	99.9e	99.9f	99.9d	99.9d	99.9e

Figures having same letters 'a' or 'b' or 'c' or 'd' or 'e' or 'f' in columns show no significant difference ($p<0.05$) in means at site.
Fertilizer; F0=0 kg/ha, F1=60 kg/ha, F2=120 kg/ha. Spacing; S1=20x30 cm, S2=30x30 cm, S3=40x30 cm.
GEMS = Green Early Maturing Short and BEMS = Brown Early Maturing Short morphotypes.
GLMT = Green Late Maturing Tall and BLMT = Brown Late Maturing Tall morphotypes.

Purity of Black pod seed stage (H3)

Seed purity results from Black pod seed harvesting stage (Table 20, Appendix 7) show that all Jute mallow morphotypes seeds were over 99% purity indicating that seeds were of high quality, thereby meeting ISTA (2004) quality status (be above 98% purity). The compound comparison of analytical purity of Jute mallow seed harvested at various stages (H1, H2 and H3) (Appendix 7) showed significant variation ($p<0.001$) in purity from black stage within and across morphotypes from site 1 and 2. All the morphotypes seed were of high quality (above 98% purity

Table 20: Means of analytical purity results (%) of Black pod seed stage (H3) from site 1 and 2 in the North Rift region, Kenya

Fertilizer (kg/ha)	**Spacing**	**Site 1 (Eldoret-UoE) Morphotypes**				**Site 2 (Kitale-KALRO) Morphotypes**			
		GEMS	BEMS	GLMT	BLMT	GEMS	BEMS	GLMT	BLMT
F0	S1	99.4a	99.3a	99.4a	99.5a	99.5b	99.3a	99.4a	99.4a
	S2	99.4a	99.5b	99.4a	99.7c	99.4a	99.5b	99.5b	99.6b
	S3	99.5b	99.6c	99.7c	99.5a	99.5b	99.6c	99.6c	99.6b
F1	S1	99.7c	99.6c	99.6b	99.6b	99.6c	99.6c	99.6c	99.6b
	S2	99.7c	99.7d	99.6b	99.7c	99.7d	99.7d	99.7d	99.7c
	S3	99.8d	99.7d	99.7c	99.7c	99.8e	99.7d	99.7d	99.7c
F2	S1	99.8d	99.8e	99.7c	99.7c	99.7d	99.7d	99.7d	99.8d
	S2	99.9e	99.9f	99.7c	99.7c	99.8e	99.8e	99.7d	99.9e
	S3	99.9e	99.9f	99.8d	99.8d	99.9f	99.9f	99.8e	99.9e

Figures having same letters ‘a’ or ‘b’ or ‘c’ or ‘d’ or ‘e’ or ‘f’ in columns show no significant difference (p<0.05) in means at site.
Fertilizer; F0=0 kg/ha, F1=60 kg/ha, F2=120 kg/ha. Spacing; S1=20x30 cm, S2=30x30 cm, S3=40x30 cm.
GEMS = Green Early Maturing Short and BEMS = Brown Early Maturing Short morphotypes.
GLMT = Green Late Maturing Tall and BLMT = Brown Late Maturing Tall morphotypes.

6.10.2 Germination results (%)

Germination (%) of green pod seeds stage (H1)

Germination results from green pod seeds stage (H1) of Jute mallow (Table21, Appendix 8) show that seed germinations were varied ($p<0.001$) across the morphotypes and sites with most seed germinations over 64% indicating that seeds were of high quality, thereby meeting ISTA (2004) quality status of 60% (labelled seed). The highest seed germination was 93.75% (GLMT morphotype) from site 2 (Kitale – KALRO) and lowest was 74.50% (BLMT morphotype) from site 1 (Eldoret – UoE).

Table 21: Means for germination (%) of green pod seeds harvesting stage (H1) from site 1 and 2 in the North Rift region, Kenya

Fertilizer (kg/ha)	**Spacing**	**Site 1 (Eldoret-UoE)** Morphotypes				**Site 2 (Kitale-KALRO)** Morphotypes			
		GEMS	BEMS	GLMT	BLMT	GEMS	BEMS	GLMT	BLMT
F0	S1	75.25a	75.00a	75.00a	74.50a	77.00a	79.00a	76.50a	76.00a
	S2	75.75a	76.50b	75.50a	75.75b	78.00b	79.50a	77.75b	77.25b
	S3	76.25b	76.50b	76.50b	77.00c	79.00c	80.50b	79.00c	79.25c
F1	S1	78.75c	78.75c	78.50c	78.75d	81.50d	80.75b	80.75d	81.00d
	S2	81.25d	82.50d	81.50d	82.25e	84.00e	84.25c	84.00	84.00e
	S3	84.00f	84.50e	84.50e	85.50f	86.25f	87.75d	88.25e	87.75f
F2	S1	83.00e	84.50e	85.75f	86.25g	86.00f	87.50d	88.00e	89.00g
	S2	86.50g	86.75f	87.75g	88.25h	88.75g	90.25e	91.00f	90.25h
	S3	91.00h	91.25g	91.75h	91.00j	93.50h	92.75f	93.75g	93.25i

Figures having same letters ‘a’ or ‘b’ or ‘c’ or ‘d’ or ‘e’ or ‘f’ or ‘g’ or ‘h’ or ‘i’ in columns show no significant difference (p<0.05) in means at site.
Fertilizer; F0=0 kg/ha, F1=60 kg/ha, F2=120 kg/ha. Spacing; S1=20x30 cm, S2=30x30 cm, S3=40x30 cm.
GEMS = Green Early Maturing Short and BEMS = Brown Early Maturing Short morphotypes.
GLMT = Green Late Maturing Tall and BLMT = Brown Late Maturing Tall morphotypes.

Radicle emergence results of green pod seeds stage (H1) (Appendix 10) showed significant variation (p<0.001) across and within morphotypes and their radicle seedlings percentage emergence above 75% with highest as 91% and lowest being 74% (Appendix 10). Though radicle seedling emergence was high, the sizable number of abnormal seedlings reduced germination percentage to lower levels. There were also a sizable percentage of dead seeds across morphotypes with lowest percentage at 9% from BEMS and GLMT morphotypes, while the highest dead seed was 26% from all morphotypes except BEMS morphotype with 25%.

Germination (%) of tan pod seeds stage (H2)

Seed germination results from Tan pod stage (Table 22, Appendix 8) show that seed germinations were varied (p<0.001) within treatments and across morphotypes with seeds germination over 75%, indicating high quality that meets ISTA (2004) quality status of above 60%. The highest seed germination was 94.25% from BEMS morphotype from site 2 (Kitale- KALRO) and the lowest germination was 75.5% from morphotypes GLMT and BLMT from site 1 (Eldoret).

Table 22: Means for germination (%) of tan pod seeds stage from site 1 and 2 in the North Rift region, Kenya

Fertilizer (kg/ha)	Spacing	Site 1 (Eldoret-UoE)				Site 2 (Kitale-KALRO)			
		Morphotypes				Morphotypes			
		GEMS	BEMS	GLMT	BLMT	GEMS	BEMS	GLMT	BLMT
F0	S1	76.50a	78.00a	75.50a	75.50a	78.25a	77.25a	78.75a	76.75a
	S2	78.50b	79.00b	76.25b	76.50b	79.25b	78.50b	79.75b	78.00b
	S3	79.00c	80.25c	77.00c	78.25c	80.50c	80.25c	80.75c	79.00c
F1	S1	81.25d	82.25d	81.00d	81.00d	82.50d	84.50d	82.50d	82.50d
	S2	85.00e	84.75e	83.50e	85.25e	87.75e	88.25e	87.50e	85.75e
	S3	88.00f	88.25f	87.75f	88.25f	90.75f	90.75f	90.50f	89.00f
F2	S1	87.25g	89.00g	89.25g	89.50g	91.25g	91.50g	91.50g	90.50g
	S2	91.25h	91.25h	92.25h	90.75h	93.25h	93.25h	92.50h	92.00h
	S3	93.00i	92.75i	93.75i	92.75i	94.25i	94.00i	94.50i	94.25i

Figures having same letters ‘a’ or ‘b’ or ‘c’ or ‘d’ or ‘e’ or ‘f’ or ‘g’ or ‘h’ or ‘i’ in columns show no significant difference (p<0.05) in means at site.
Fertilizer; F0=0 kg/ha, F1=60 kg/ha, F2=120 kg/ha. Spacing; S1=20x30 cm, S2=30x30 cm, S3=40x30 cm.
GEMS = Green Early Maturing Short and BEMS = Brown Early Maturing Short morphotypes.
GLMT = Green Late Maturing Tall and BLMT = Brown Late Maturing Tall morphotypes.

Seedling radicle emergence results from Tan pod seeds stage (Appendix 10) show that most morphotypes had their radicle percentage emergence above 75% with highest at 93% and lowest being 74% from GLMT morphotype. However, the sizable number of abnormal seedlings reduced the germination percentage to lower levels. There were also a sizable percentage of dead seeds across morphotypes with the lowest percentage at 9% from BEMS and GLMT morphotypes, while the highest dead seed was 26% from all morphotypes except BEMS morphotype with 25%.

Germination (%) of black pod seeds stage (H3)

Seed germination results from Black pod stage of Jute mallow are shown in Table 23 and Appendix 9. Seed germinations were varied ($p<0.001$) across the morphotypes with most seed germinations over 45% indicating that seeds were of poor quality according to ISTA (2004) quality status of labelled seed that have to be above 60%). However, some treatment combinations had shown high seed germination as high as 79.50% (BLMT morphotype) from site 2-Kitale and others as low as 56.25% (BEMS morphotype) from site 1-Eldoret.

Table 23: Means of germination of black pod seeds stage from site 1 and 2 in the North Rift region, Kenya

Fertilizer (kg/ha)	Spacing	Site 1 (Eldoret-UoE) Morphotypes				Site 2 (Kitale-KALRO) Morphotypes			
		GEMS	BEMS	GLMT	BLMT	GEMS	BEMS	GLMT	BLMT
F0	S1	58.50a	56.25a	57.25a	62.75a	61.75a	57.25a	59.25a	58.75a
	S2	60.00b	59.25b	62.00b	59.50b	62.75b	58.75b	60.25b	61.00b
	S3	62.25c	62.50c	62.00b	62.00c	64.50c	62.75c	62.00c	62.75c
F1	S1	61.75d	62.25c	61.75c	62.50c	65.00d	63.75d	63.50d	64.50d
	S2	64.00e	64.75d	64.50d	65.50d	66.75e	66.50e	68.50e	67.75e
	S3	69.50f	68.25e	70.75e	71.50e	70.25f	70.25f	71.00f	72.00f
F2	S1	63.50g	65.50f	65.50f	64.75f	66.50g	68.25g	68.50g	67.00g
	S2	71.75h	72.00g	72.50g	73.00g	72.25h	73.25h	73.25h	74.00h
	S3	77.00i	79.25h	78.00h	79.25h	76.50i	77.50i	78.75i	79.50i

Figures having same letters 'a' or 'b' or 'c' or 'd' or 'e' or 'f' or 'g' or 'h' or 'i' in columns show no significant difference ($p<0.05$) in means at site.
Fertilizer; F0=0 kg/ha, F1=60 kg/ha, F2=120 kg/ha. Spacing; S1=20x30 cm, S2=30x30 cm, S3=40x30 cm.
GEMS = Green Early Maturing Short and BEMS = Brown Early Maturing Short morphotypes.
GLMT = Green Late Maturing Tall and BLMT = Brown Late Maturing Tall morphotypes.

Emergence of radicles from Black pod seed stage (Appendix 10) show that most morphotypes had their radicles emergence above 50% with highest at 79% and lowest being 51% from BEMS morphotype. Though radicle emergence was high, the sizable number of abnormal seedlings varying from 7-12% reduced the germination percentage to lower levels. There was also high percentage of dead seeds observed across morphotypes and sites with the highest and lowest percentage being 49% and 21% respectively from BEMS morphotypes.

6.10.3 Seed vigour 1 (speed of germination) results

Speed of of germination at Green pod seed stage (H1)

At the last germination count, (Appendix 10), the daily seed germination results from green pod harvesting stage of Jute mallow show that over half (50%) of the seeds germinated in 1st day. At the end of germination period (5th day) the highest seed germination was 88% from site 2 (Kitale-KALRO) exhibited by GLMT and BLMT morphotypes, while site 1 (Eldoret-UoE) had highest germination at 83% from all morphotypes except BEMS morphotype which had 82%. On average the lowest daily seed germination was 65% across morphotypes from site 1 while site 2. However some morphotypes exhibited 70% for instance BEMS and BLMT morphotype, though GEMS and GLMT morphotypes had 71% as lowest from both sites 1 (Eldoret - UoE) and 2 (Kitale - KALRO) in the North Rift region, Kenya.

The treatment combination with highest average germination from site 2 was 88% exhibited by GLMT and BLMT morphotypes while the lowest was 65% across morphotypes from site 1. This indicates that seeds from site 2 exhibited higher seed vigour (speed of germination) than seed from site 1. The North Rift regions highest average germination stood at 86% while lowest germination was 68%. However, both site's green pod harvesting stage of Jute mallow seed met ISTA (2004) regulation requiring germination to be above 60% to merit quality status.

Speed of of germination at Tan pod seed stage (H2)

At the last germination count, (Appendix 10), the daily seed germination results from Tan pod harvesting stage of Jute mallow show that over half (70%) of the seeds germinated by end of 1st day. At the end of germination period (5th day) the highest seed germination was 91% from site 2 (Kitale-KALRO) exhibited by BLMT morphotype, while site 1 (Eldoret-UoE) had highest germination at 89% from same morphotype BLMT. On average the lowest daily seed germination was 70% across morphotypes from site 1 except morphotype GLMT at 69%. While so, site 2 morphotypes exhibited lowest average daily germination at 71% across its morphotypes.

The combination effect of fertilizer rates and spacing levels on morphotypes at Tan pod harvesting stage of Jute mallow show that highest germination was 91% from site

2 exhibited by BLMT morphotype, while the lowest was 69% from GLMT morphotype at site 1 . This indicates that generally seeds from site 2 exhibited higher seed quality (vigour) than seed from site 1. However , both site's Tan pod harvesting stage seed of Jute mallow met ISTA (2004) regulation requiring germination percentage to be above 60% to merit quality status.

Speed of of germination at Black pod seeds stage (H3)

At the last germination count, (Appendix 10), the seed germination results from Black pod harvesting stage of Jute mallow (Appendix 10) show that only 45% of the seeds germinated by end of 1^{st}day. At end of germination period (5^{th} day) the highest seed germination was 72% from site 2 (Kitale-KALRO) exhibited by GLMT morphotype, while site 1 (Eldoret-UoE) had highest germination at 68% from BLMT morphotype. On average the lowest daily seed germination was 45% from GLMT morphotype at site 1. While so, site 2 morphotypes exhibited lowest average daily germination at 50% for BEMS, 51% for GLMT and 52% for GEMS and BLMT morphotypes.

Combination effect of fertilizer rates and spacing levels on morphotypes at Black pod harvesting stage of Jute mallow show that the highest average germination from both sites 1and 2 was 72% from site 2 exhibited by GLMT morphotype while the lowest was 69% also from GLMT morphotypes but from site 1. This indicates that generally seeds from site 2 exhibited higher seed quality (vigour) than seed from site 1. However, both sites' Black pod harvesting stage seed of Jute mallow from closer spacingof 20 x 30 cm (S1) and no fertilizer (F0) which ranged between 45% and 59% did not meet ISTA (2004) seed quality standard requiring germination percentage to be above 60%.

Comparison of treatment effects on seed vigour 1(Speed of of germination) at the three seed harvesting stages (Green pod, Tan pod and Black pod)

Results of seed germinations at the three harvesting stages of Green pod, Tan pod and Black pod of Jute mallow (Appendix 11), show that the best overall performing harvesting stage in seedling germinations was Tan pod stage with highest seed vigour at 92% (Kitale site) and 88% (Eldoret site) indicating that seeds were of high quality meeting ISTA (2004) quality status which indicates that the minimum germination should be above 60%.

Fertilizer effect results from the three harvesting stages (Green pod, Tan pod, and Black pod) of Jute mallow (Appendix 11) from both Site 1 (Eldoret-UoE) and Site 2 (Kitale-KALRO) show that the higher the fertilizer rates the higher the normal seedling germinations. This supports findings by MOA (2012) and Taylor *et al*., (1998) that fertilizer significantly increases the quality of seed and thereby enhances crop and seed yield even at various stages of seed harvest.

Spacing effect results from both Site 1 (Eldoret-UoE) and Site 2 (Kitale-KALRO) at three harvesting stages of Jute mallow (Appendix 11) show that as the spacing of the plants is widened there is increase in normal seedling germinations percentage across the morphotypes.

Combination effect of fertilizer rates and spacing on morphotypes from both site 1 and 2 at the three harvesting stages (Green pod, Tan pod, and Black pod) of Jute mallow show that there was higher normal seedling germinations percentage increase with combined increase in fertilizer rates and wider spacing. (Appendix 11). The combination with highest seedling germinations from both sites 1and 2 at the three harvesting stages of Jute mallow were in decreasing; Green pods (88%); Tan pods

(92%) and Black pods (71%). Similarly the lowest were; Green pods at 65%; Tan pods at 70% and Black pods at 41% across the morphotypes. This indicated that the highest normal seedling germinations percentage was from Tan pod harvesting stage (92%) and lowest was from Black pod harvesting stage (41%). This means that late harvested Jute mallow seed was of poor physiological seed quality in terms of seed vigour. Though Green pod stage harvest stage daily germinations (65%) showed high germination than black pod harvest stage (41%), the seeds were at physiological maturity but were not dry enough for harvesting and processing.

6.10.4 Seed Vigour 2 (Electrical Conductivity) (E.C) results of Jute mallow morphotypes from site 1 and 2

E.C of seeds at Green pod stage (H1)

Electrical conductivity test results (Appendix 11), indicates that all morphotypes of *Corchorus olitorius* seed harvested at green stage had low leachate conductivity of below 1.0 $\mu Scm^{-1}g^{-1}$ meaning that the seeds are of high vigour. However, there were variation within treatments but still were of high seed quality. In general it showed that the seed was mature and had passed the seed filling stage and could raise quality crop, supporting observation by Amarjit, (1995) that green stage seed is good for crop production though faces seed processing challenge.

E.C of seeds at Tan pod stage (H2)

From the Electrical conductivity test results (Appendix 11) it's observed that all morphotypes of *Corchorus olitorius* seed harvested at Tan stage had low leachate conductivity of below 1.0 $\mu Scm^{-1}g^{-1}$ meaning that the seeds were of high vigour. However, there was variation within treatments but still seeds were of high quality. In general these show that the seed was good and could produce high yield and quality crop, supporting observation by Amarjit, (1995) as it can be processed without damaging the structure and components of seed.

E.C of seeds at Black pod stage (H3)

Electrical conductivity test results (Appendix 11) show that all morphotypes of *Corchorus olitorius* seed harvested at Black stage had high leachate conductivity meaning that seeds were of low vigour. There was variation in leachate conductivity within treatments results but still seeds were of poor quality.

Comparison of treatment effects on E.C. of seeds at the three pod harvesting stages (Green pod, Tan pod and Black pod) from site 1 and site 2

Fertilizer effect results from the three harvesting stages (Green pod, Tan pod, and Black pod) of Jute mallow (Appendix 11) from both Site 1 and Site 2 show that the higher the fertilizer rates used, the lower the leachate conductivity from the seeds. This indicated that fertilizer use enhances Jute mallow crop and seed quality no matter the stage of seed harvest.

Spacing effect results from both Site 1 and Site 2 at three harvesting stages of Jute mallow show that as the spacing of the plants is widened there is decrease in E.C. This is an indicative of increase in quality of the seed and crop.

Combination effect of fertilizer rates and spacing levels on seed quality (seed vigour) of the morphotypes from both site 1and site 2 at the three harvesting stages (Green pod, Tan pod, and Black pod) of Jute mallow show that there is higher seed quality (vigour) when combined increasing fertilizer rates and wider spacing is used. The combination with highest seed vigour (Appendix 11) from both sites 1 and 2 at the three harvesting stages of Jute mallow were Tan pods stage across morphotypes. The lowest seed vigour was from Black pods stage across the morphotypes. This indicates that late harvested Jute mallow pods are of lower seed quality in terms seed viguor. Though Green pod stage showed better results than black stage, the seeds were at physiological maturity and not dry enough and seed could be damaged at harvesting, processing or storage.

6.11 Discussion

6.11.1 Influence of Spacing on Harvest Index and Yield of Jute mallow

The spacing variation had an effect on plant height of short morphotypes (GEMS and BEMS) as indicated by their plant height of 35 cm and 35.6 cm for the tallest plants and shortest plants at 31.6 cm and 31.4 cm, respectively. This was 0.6 cm increase in height attributed caused by the widening of spacing of plants. The tall Jute mallow morphotypes (GLMT and BLMT), also showed same effect by spacing where both had 81.8 cm and 81.9 cm as short plants and 86.9 cm and 86.6 cm as tall plants respectively. This indicated that spacing variation has effect on the overall plant growth i.e. plant height, thereby also affecting plant leaf yield in the Jute mallow production in the end, concurring with Abukutsa-Onyango, (2007); Keding *et al*., (2007) who also observed the same during their research.

There was spacing effect on number of braches per plant of Jute mallow morphotypes as seen in the spacing of 40 cm x 30 cm where there was an increase in number of braches per plant from both sites 1 and 2 within GEMS and BEMS morphotypes of 1-7 and 1-8 branching/plant respectively and between GLMT and BLMT morphotypes 1-7 and 1-9 branching/plant respectively. Generally there was higher branching of plants in site 2 with 9 branching/plant than those in site 1 with 7 branching/plant.

Such outcome supports what Adebooye *et al*., (2003); AVRDC, (2004) found out in previous research.

There was spacing effect on pod per plant of Jute mallow morphotypes where it was observed that use of wider spacing of 40 x 30 cm at both sites 1 and 2 saw an increase in the number of pods per plant within and across morphotypes. This was observed in Green Early Maturing Short and Brown Early Maturing Short which had highest pods per plant of 11 - 13 pods respectively compared to the control spacing with 4 - 5 pods per plant respectively. This indicates that spacing variation has effect on the overall pods per plant, thereby also affecting overall seed and crop yield of Jute mallow as also observed by AVRDC, (2004); Bujulu and Matee, (2005).

There was effect by spacing on fresh leaf yield per plant of Jute mallow morphotypes with wider spacing of 40 x 30 cm showing highest yield of 99.2 g for late maturing GLMT morphotype and 66.8 g for early maturing BEMS morphotypes. This trend of increase in yield weight of fresh leaf yield per plant from both sites within and between morphotypes was observed in both sites 1 amd 2 concurring also with findings by AVRDC, (2004); Buddhadeb, (2012) in previous research. However, BEMS morphotypes from site 2 (Kitale) had higher weight per plant (66.8 g) than those from site 1 (Eldoret) of 66.31 g. an increase in leaf yield by 33 g per plant due to fertilizer and spacing effect. This supports what was also found out by other researchers including Bhattacharjee *et al*., (2000); Khatun *et al*., (2002); Buddhadeb, (2012). The spacing variation also showed that use of wider spacing of 40 cm x 30 cm gave higher leaf weight per plant by up to 67g per plant more than close spaced crop indicating that spacing enhances crop yield of Jute mallow concurring with what was also observed by Villa *et al*., (2005); Sivakumar and Ponnusami, (2011. This effect was attributed to the fact that wider spacing reduced competition amongst plants enhancing growth of plants and yields.

6.11.2 Influence of Nitrogen fertilizer on Harvest Index and Yield of Jute mallow

Effect of nitrogen (N) fertilizer rates on plant height of Jute mallow

The N fertilizer rates of 120 kg/ha had highest effect on plant height of short morphotypes GEMS (Green Stem) and BEMS (Brown Stem) as indicated by their plant height of 37.67 cm and 37.89 cm as the tallest plants and shortest at 30.78 cm and 30 cm respectively. This showed variation of 0.22 cm and 0.78 cm respectively. The lowest effect was from no fertilizer rate (0 kg/ha) with 30.78 cm and 30 cm for GEMS and BEMS morphotypes respectively from site 1 and 2. The plant height variation between highest N fertilizer (120 kg/ha) and no fertilizer (0 kg/ha) was 7.67 cm. This indicates that fertilizer rates variation has effect on the overall plant growth i.e. plant height, thereby also affecting plant leaf yield in Jute mallow production. Such effect was also shown by higher N fertilizer rate (120 kg/ha) with plant height results of tall Jute mallow morphotypes GLMT and BLMT varied with 90.11 cm and 89.89 cm from Eldoret site as well as 79.44 cm and 79.78 cm from Kitale site respectively. This variation was 0.22 cm and 0.34 cm respectively compared with effect from control (0 kg/ha) having 79.44 cm and 79.78 cm for GLMT and BLMT respectively from site 1 and 2. The plant height variation between highest N fertilizer (120 kg/ha) and 0 kg/ha was 10.67 cm for GLMT Morphotype and 10.11 cm for BLMT Morphotype. Such variation as above findings in plant height by the experiment show there was significant variance ($p<0.05$) in effect by nitrogen fertilizer rates treatments on Jute mallow morphotypes thereby agreeing with findings of other work by Abdelhamid *et al*., (2011) and KARI, (2013).

Effect of nitrogen (N) fertilizer rates on branching of Jute mallow

Nitrogen fertilizer rates had varied effect on number of braches per plant of Jute mallow morphotypes with use of higher N fertilizer rates (120 kg/ha) showing highest increase in number of braches per plant from both tall Jute mallow morphotypes GLMT and BLMT with mean branching/plant at 8.3 and 7.3 and lowest on no fertilizer rate (0 kg/ha) at 1.9 and 2.3 mean branching/plant respectively from both Eldoret site and Kitale site. This gave variation of 6.4 and 5.0 mean branching/plant respectively. Such trend was also seen on fertilizer rate 60 kg/ha where tall morphotypes (GLMT and BLMT) had highest effect with mean branching/plant of 4.9 and 5.8 respectively and lowest from Morphotype GEMS (4.3) at Eldoret site and 4.7 at Kitale site. This gave variation of 0.6 and 1.1 mean branching/plant. This indicates that varied rates of fertilizer used has effect on plant growth as seen by increasing branching of plants supporting observation by Van Averbeke *et al*., (2007) that use of fertilizer rates enhances yield of crop.

Effect of nitrogen (N) fertilizer rates on pods per plant of Jute mallow

There was highest fertilizer effect on number of pods per plant of Jute mallow morphotypes by 120 kg/ha rate where the short morphotypes (GEMS and BEMS) highest mean pods per plant were 11.5 and 11.6 respectively in Eldoret and Kitale sites. The lowest mean pods per plant was observed in no fertilizer rate (0 kg/ha) at 5.4 and 5.3 pods. This gave variation of 6.1 and 6.3 pods/plant for GEMS and BEMS morphotypes respectively from both site 1 and 2 indicating that fertilizer rates has effect of increasing on the overall pods per plant, thereby also affecting the overall yield in the Jute mallow production. Equally, effect was seen in tall Jute mallow morphotypes GLMT and BLMT with highest mean pod count at 22.6 and 21.3 pods by 120 kg/ha N fertilizer rate and lowest mean pod count of 15.9 and 14.8 by no fertilizer (0 kg/ha) rate at Eldoret and Kitale sites respectively. The variation was 7.4 and 6.5 pods/plant for GLMT and BLMT morphotypes respectively from site 1 and 2 indicating that fertilizer use enhances growth of Jute mallow concurring with findings by Shiundu and Oniang'o, (2007). In comparison, the number of pods per plant of Jute mallow morphotypes show that as increasing nitrogen fertilizer rates was used there was consequently increase in number of pods per plant with highest by 120 kg/ha N fertilizer rate exhibited on GLMT (22.6 pods) and BLMT (23.7 pods) from both sites 1 and 2. This was also seen on N fertilizer rate of 60 kg/ha having highest effect from Morphotype GLMT (19.8 pods) site 1 and Morphotype GLMT (21.2 pods) from site 2. Lowest effect was on treatments without fertilizer (0 kg/ha) on Morphotype BEMS (5.3 pods) concurring with Abukutsa (2010) that fertilizer boosts plant growth.

Effect of nitrogen (N) fertilizer rates on fresh leaf yield of Jute mallow

The Jute mallow fresh leaf yield results per plant show that use of higher fertilizer rates gives higher yields. This is shown by higher N fertilizer rates (120 kg/ha) which had the highest leaf yields exhibited by Morphotype GLMT (99.2 g), 60 kg/ha of 74.1 g and 54.1 g from no fertilizer plot (control) respectively. The other tall Morphotype BLMT exhibited the same trend where highest yield per plant was 96.3 g on N fertilizer rate of 120 kg/ha, 66.97 g/ha for 60 kg/ha and 58.9 g per plant for control (0 kg/ha fertilizer rate). Such trends where using of increasing fertilizer rates increases plant leaf yield agree with findings on similar work by Ekwu and Okporie, (2002). This trend of increasing fertilizer use giving increasing leaf yield per plant was also exhibited by all other Morphotypes where short morphotypes GEMS and BEMS highest was 66.7 g and 66.8 g respectively for N fertilizer rate of 120 kg/ha, 46.0 g and 46.4 g respectively for fertilizer rate 60 kg/ha and 31.6 g and 32.0 g respectively for fertilizer rate 0 kg/ha (control). Such variation in increase in leaf yield per plant show there was significant variance ($p<0.05$) in effect by N fertilizer rates on Jute mallow morphotypes supporting observation and findings of similar work obtained by Khandakar, (2003) and Mauyo *et al*., (2008).

6.11.3 Effect of Spacing and Fertilizer on Seed Quality of Jute Mallow

Effect on Seed Purity

There was effect on seed purity of Jute mallow on all (Green, Tan and Black pod seed stage) morphotypes seeds as results show seed purity being high (over 99%) indicating that seeds were of high quality; thereby meeting ISTA (2004) seed quality status of above 98% purity. This show that the seeds were processed well as pointed out by Abukutsa-Onyango, (2007). However, combination effect of higher fertilizer of 120 kg/ha and wider spacing levels of 40 x 30 cm on morphotypes results from tan pod harvesting stage from both sites 1 and site 2 showed highest purity of seed when both factors are used across the morphotypes supporting findings of similar work done by Kamotho, (2005).

Effect on Seed Vigour 1 (Speed of germination or Seed emergence)

There was effect by spacing and fertilize on speed of germinations of the three harvesting stages of Green pod, Tan pod and Black pod of Jute mallow. This is evidenced by varied results with the best overall performing harvesting stage being Tan pod stage with highest seed vigour at 92% (Kitale site) and 88% (Eldoret site) supporting findings of similar work by KARI, (2009) and Ngoze and Okoko, (2005).

Fertilizer effect on the three harvesting stages (Green pod, Tan pod, and Black pod) of Jute mallow from both Site 1 (Eldoret) and Site 2 (Kitale) showed that higher fertilizer rates gave higher seedling germinations in shorter time. This supports findings of similar work by MOA (2012) and Taylor *et al*., (1998) reported that fertilizer significantly increases the quality of seed, especially on emergence and thereby enhances crop yield. Such was also observed by spacing effect results from both Site 1 (Eldoret) and Site 2 (Kitale) at three harvesting stages of Jute mallow which indicated that as the spacing of the plants is widened there is increase in emergence of seedlings across the morphotypes supporting what Schipers, (2002) put forward that well spaced plants for seed perform better than those close spaced.

Effect on Germination

Results of seed germinations of the three harvesting stages of Green pod, Tan pod and Black pod of Jute mallow, show that the best overall performing harvesting stage in seedling germinations was Tan pod stage with highest seed vigour at 92% (Kitale site) and 88% (Eldoret site) indicating that seeds were of high quality meeting ISTA (2004) quality status which indicates that the minimum germination should be above 60%. This means fertilizer had effect on seed quality as shown by varied germination results from the three harvesting stages (Green pod, Tan pod, and Black pod) of Jute mallow from both Site 1 (Eldoret) and Site 2 (Kitale) concurring with KARI, (2014) and MOA, (2013) that applying good production practices improves seed quality, especially the germination aspect. This is supported by best results showed higher fertilizer rates having higher normal seedling germinations. This agree with findings by work by MOA (2012) and Taylor *et al*., (1998) reported that fertilizer significantly increases the quality of seed and thereby affecting crop and seed quality even at various stages of seed harvest.

The varrying of spacing in the experiment had effect on Green pod, Tan pod and Black pod seed as shown by varied results from both Site 1 (Eldoret) and Site 2 (Kitale) at three harvesting stages of Jute mallow. This show that as the spacing of the plants is widened there is increase in normal germinations (KARI, 2014) across the morphotypes concurring also with findings of work by Kimiywe *et al*., (2007) that spaced plant perform well enhancing yields in farming of crops.

In comparison, there was combination effect of fertilizer rates and spacing on morphotypes from both site 1 and 2 at the three harvesting stages (Green pod, Tan pod, and Black pod). This is shown by the varied outcome where higher normal seedling germinations percentage increase when combined increasing fertilizer rates and wider spacing was used supporting findings of work by K'Opondo *et al*., (2005). This is true because the combination of wider/close spacing and higher/No fertilizer showed highest seedling germinations from both sites 1 and 2. The findings from this experiment concurred with what was observed also by Keller, (2004) in the previous research done. Such agreement where visible where; Green pods had 88%; Tan pods at 92% and Black pods at 71%, while the lowest were; Green pods at 65%; Tan pods at 70% and Black pods at 41% across the morphotypes. Such was true since findings from experiment indicated that the highest normal seedling germinations percentage was from Tan pod harvesting stage at 92%. The lowest germination was from Black pod harvesting stage with 41%. Meaning that late harvested Jute mallow was of poor physiological seed quality in terms of seed vigour agreeing with findings and observation by Keding, (2007). The Green pod harvest stage daily germinations (65%) was higher than black pod harvest stage (41%), but seeds were not dry enough and could be damage during processing and storage.

Effect on Seed vigour 2 (Electrical Conductivity) (E.C) of Jute mallow

There was fertilizer effect on seed vigour of three harvested morphotypes seeds (Green pod, Tan pod, and Black pod) of Jute mallow from both Site 1 and Site 2 as evidenced by varied E.C. results where it showed that the higher the fertilizer rates used, the lower the leachate conductivity from the seeds supporting similar findings of work by Musotsi *et al*., (2008). This indicated that fertilizer use enhances Jute mallow seed quality irrespective of stage of seed harvest concurring with findings of similar work by Buddhadeb, (2012).

Spacing effect also emerged as evidenced by varied results from both Site 1 and Site 2 at three harvesting stages seed (Green, Tan and Black pod) of Jute mallow where it showed that as the spacing of the plants is widened there is increase in vigour quality of the seed alluding to findings of similar work by Okot, (2002) as well as Mwangi and Mumbi, (2006). The low leachate E.C. reading indicated high seed vigour concurring with findings of similar work by AVRDC, (2004) that spaced plants enhances quality of seed especially vigour.

In comparison, there was combination effect of fertilizer rates and spacing levels on seed quality (seed viguor) of the morphotypes from both site 1and site 2 at the three harvesting stages (Green pod, Tan pod, and Black pod) of Jute mallow. This was shown by the varied outcome where higher seed quality (vigour) was observed when combined increasing fertilizer rates and wider spacing was used. This findings concurr with what van Averbeke *et al*., (2007) and KARI, (2014) reported in their findings that using combination of factors like inputs and stage of seed harvest during crop production enhances seed vigour. Such is true as the combination with highest seed vigour from the both sites 1and 2 at the three harvesting stages of Jute mallow were Tan pods stage across morphotypes, while the lowest were Black pods across the morphotypes supporting findings by Oyewole and Mera, (2010). This indicated that late harvested Jute mallow seeds lost quality in terms of seed vigour concurring with Ochuodho *et al*., (1999) that for quality seed to be sustained and be of profitable agricultural production stage of harvest be correctly timed. The Green pod stage had higher seed vigour than black pod stage but its' seeds were yet to reach harvest maturity (not dry enough) and seed could be damaged at harvesting, processing or storage. Such findings were in agreement with findings of similar work by Nagel and Börner, (2010); Groot *et al*., (2012) that correct seed stage be observed at harvest.

6.12 Conclusion

It is concluded that:

1. Spaced plants exhibit varied effect on plant's growth with wider spacing (40 cm x 30 cm) exhibiting tall plants and highest branching; pod numbers and yield of Jute mallow.

2. The use of increasing nitrogen fertilizer rate increases Jute mallow leaf yield and that the high Nitrogen fertilizer rates of 120 kg/ha, had highest plant height, branching, pods per plant and fresh leaf yield.

3. Jute mallow seed harvested at Tan pod stage has highest quality in terms of purity, germination and vigour as opposed to green pod or Black pod stages.

6.13 Recommendation

It is recommended that:

1. In order to increase crop yield of Jute mallow, wider spacing of 40 cm x 30 cm is recommended to be used.

2. To enhance plant growth and increase crop yields it is recommended to use increasing nitrogen fertilizer rates at rate of 120 kg/ha in Jute mallow farming.

3. For quality seed of Jute mallow it is recommended that harvesting of pods be done at Tan pod stage.

4. Further studies can be done on effect of location (because Kitale site showed better quality and yield results than Eldoret) especially altitude on seed quality and yield performance of Jute mallow (this research was done at altitudes 1901 m (Kitale- site 2) and 2140 m (Eldoret- site 1) above sea level).

CHAPTER SEVEN

GENERAL CONCLUSION AND RECOMMENDATION

7.1 Summary

From seed survey on the issue of the number of training by farmers, it was evident that few farmers (18%) of farmers interviewed in North Rift region have been trained on vegetable seed production and agronomy. This indicate 82% farmers are doing vegetable seed production and yet have not attended any training in seed production and agronomy. This show that most of them are using their own indigenous knowledge in Jute mallow farming explaining why Jute mallow yield has remained low (2-4tons/ha/annum) as compared to the expected yield of up to 8 tons/ha/annum. It was also observed that over half of the farmers doing seed production are illiterate (54%) have never attended School i.e. cannot read and write, so cannot prepare or use farm records, but rely on their memories to store information. The low level of education could in turn have contributed to low quality of seed production in the region by farmers, leading to decline in quality and productivity of Jute mallow in North Rift region, Kenya.

Seed quality analysis from laboratory test evidently indicate that some North Rift region Jute mallow seed germination sources like Kenya Seed Company (86.25%) and Eldoret farm (66.75%) were high, though seed quality from other sources were far low e.g Kapenguria (45.25%) and Kapsabet (43%), thereby making North Rift regions Jute mallow seeds germination averages dropped to 59.33%, which is below standard by ISTA (2004) minimum germination percentage of 60%. This indicates that North Rift region has its Jute seeds not meeting the required minimum standards and so cannot be recommended for seed. Though the findings from Jute mallow seed collected from the North Rift were of superior quality in terms of purity (over 98%) their seed vigour were generally low. This low seed vigour leads to low quality and yield of Jute mallow crop agreeing with those of many other researchers like Vierra, (1994); Amarjit (1995); Tekrony and Egli, (1997); Walters and Engels, (1998) among many otherswho have shown in their studies positive correlation between reduction of quality and yield and low seed vigour.

During characterization it was found out that collected North Rift region seed germplasm were diversified with four morphoypes coming out based on colour, maturity duration and height as follows: Green Early Maturing Short (GEMS), Brown Early Maturing Short (BEMS), Green Late Maturing Tall (GLMT), and Brown Late Maturing Tall (BLMT). This research finding showed there is variation in characterized Jute mallow accession in North Rift region agreeing with those of other researcher like Alvarez et al., (2006); Aura, (2013) and KARI, (2014) whose reports of their results agree with these findings.

Effect of fertilizer and spacing on seed quality and leaf yield of Jute mallow showed that use of higher fertilizer rates of 120 kg/ha and wider spacing of 40 cm x 30 cm gave higher leaf weight per plant by upto 67 g per plant more than none fertilized and close spaced crop. These findings indicate that fertilizer and spacing enhances crop yield of Jute mallow agreeing with findings of other researchers including Taylor *et al*., (1998) indicatin fertilizer and spacing has effect on yields. The combination effect of high fertilizer rates (120 kg/ha), wider spacing (40 cm x 30 cm) and seeds harvested at tan pod stage showed the highest seed germination of 94.25% campared to no fertilizer by closer spacing (20 cm x 30 cm) treatment and seed harvested at black stage which had germination of 56.25% being lowest. This show that if same seed was planted in field same variation in yield is eminent with fertilizer applied crop performing better than none fertilized agreeing with findings also observed by (Okosun, 2000). This indicated that there was difference in effect of spacing and fertilizer as well as harvesting stage on yield and seed quality of Jute mallow.

Seed quality effect by harvesting stage on Jute mallow showed tan pod stage exhibited best seed quality. Late harvested seeds of Jute mallow (black pod stage) were of poor physiological quality in terms of seed vigour and germination and lighter in weight among the three harvesting stages. Though green pod stage showed better results than black stage, in terms of seed weight, seed germinations, and seed vigour (radicle seedling emergence), seed were not at physiological maturity and could easily be damaged during harvesting, post harvest handling, processing or storage. This means there was difference in seed quality at various harvesting stages of Jute mallow in terms of analytical purity, germination, and seed vigour.

7.2 Conclussion

It is concluded that:

1. The Jute mallow seed grown by farmers in the North Rift region though of high analytical purity are of poor physiological quality and are produced under poor agronomic practices and handling processes.

2. Characterized Jute mallow Germplasm from North Rift region exhibit diversity in morphological traits with four morphotypes coming out based on stem colour, duration time and plant height named: Green Early Maturing Short (GEMS); Brown Early Maturing Short (BEMS); Green Late Maturing Tall (GLMT) and Brown Late Maturing Tall (BLMT).

3. Use of high Nitrogenous (N) fertilizer rates (120 kg/ha) coupled with wider spacing (40 cm x 30 cm) and seed harvested at Tan pod stage during crop production has highest seed quality and leaf yield of Jute mallow.

7.3 Recommendation

1. To enhance Jute mallow production in North Rift region, Kenya, training of farmers on seed production and agronomy can be done by seed production stakeholders including: seed companies, government extension service agents and crop research institutions like KALRO and universities.

2. With the exception of Kenya seed company Jute mallow seed germplasm, it is recommended that all the other seed from the farmers were of poor physiologigal quality and should not be used as planting material.

3. To avail morphotypes of Jute mallow to farmers, it is recommended that breeders embark on breeding programs to produce the certified seed from these identified morphotypes.

4. To increase seed yield and leaf yield, increasing fertilizer of 120 kg/ha and wider spacing of 40 cm x 30cm be used.

5. To enhance seed quality of Jute mallow, harvest it at Tan pod stage.

6. Further studies can be done on seed health component of seed quality to find why there are high dead seeds in germination tests.

7. Further studies can be done on effect of location (because Kitale site showed better quality and yield results than Eldoret) especially altitude on seed quality and yield performance of Jute mallow (this research was done at altitudes 1901 m (Kitale- site 2) and 2140 m (Eldoret- site 1) above sea level).

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APPENDICES

Appendix I: Jute mallow seed collection Questionnaire

a). General Information

Farmers Name ……………………………………………………………………...

Farmers Age ………… Sex ………………..District / Area …………………………

Do you use any fertilizer at any time on Jute mallow crop?

	Tick	When if 'Yes'
No		
Yes		

Where is source of your Jute seed?

	Tick in box	Reason
Own saved		
Neighbors		
Market		
Certified		

Which planting method do you use on jute?

	Tick
Drilling	
Broadcast	

b.) Training attended

Which Jute vegetable training have you attended?

None	One (agronomy)	Two (crop protection)	Three (seed)	Four and above(any other)

c.) Education level

What is your level of education?

Not Schooled	Primary level	Secondary and above

d.) Seed Production.

What are the indicators of maturity of the Jute mallow crop?

Colour of pods	Colour of leaves	Colour of seeds	Others(specify)

How do you harvest your Jute mallow seeds?

Hand plucking	Cutting	Others(specify)

How do you dry your Jute mallow seeds?

In direct sunlight	In shade	Others(specify)

How do you extract/thresh your Jute mallow seeds?

Hand shelling	Beating	Others(specify)

e.) Seed Storage Techniques

How long you store Jute mallow seed?

No. of years	Tick
1	
2	
3	
4	
5and Over	

Where do you store Jute mallow seed?

Pots/Tins	Roof	Fire place	Others(specify)

f.) General remarks (observation during the interview of fieldwork)

………………………………………………………………………………

Name of interviewer…………………………………………………………

Signature ………………………………….

Appendix II: Purity weights of vegetable seeds as recommended by ISTA (2004)

Crop		Maximum weight of seed lot kg	Minimum sample weight	
Common name	Scientific name		Submitted sample (g)	Working sample for purity (g)
Jute mallow	*Corchorus olitorius*	10,000		

Source: ISTA, 2004

<u>Acceptable Purity of (*Corchorus olitorius*) by ISTA (2004)</u>

1. Pure seed (minimum) certified…………….98%

Labelled seeds……………………………......95%

. Inert matter (maximum) certified…………..1%

. Other crop seed (maximum) certified……...0.1%

. Weed seeds (maximum) certified…………0.1%

. Germination (minimum) certified………...60%

Labelled seed……………………………….55%

Testing of <u>*Corchorus olitorius*) by ISTA (2004)</u>

Crop	Substrate	Temp	Light	1st Count	Final Count	Breaking Dormancy
C. olitorius	BP, TP	30^0C	-	3rd day	5th day	-

Appendix III: Plant height (cm) results from the fertilizer and spacing field experiments

(a) Analysis of variance (ANOVA) of plant height from site 1 (Eldoret-UoE)

Variate: Plant_height_Eld

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	4.796	2.398	2.28	
Reps.Morphotype stratum					
Morphotype	3	69317.519	23105.840	21953.94	<.001
Residual	6	6.315	1.052	0.62	
Reps. Morphotype.Fertilizer_rates stratum					
Fertilizer_rates	2	1143.907	571.954	334.80	<.001
Morphotype.Fertilizer_rates	6	36.315	6.052	3.54	0.020
Residual	16	27.333	1.708	1.53	
Reps. Morphotype.Fertilizer_rates.Spacings stratum					
Spacings	2	206.741	103.370	92.65	<.001
Morphotype.Spacings	6	9.704	1.617	1.45	0.216
Fertilizer_rates.Spacings	4	26.037	6.509	5.83	<.001
Morphotype.Fertilizer_rates.Spacings	12	8.630	0.719	0.64	0.793
Residual	48	53.556	1.116		
Total	107	70840.852			

Stratum standard errors and coefficients of variation (plant height-Eldoret-UoE)

Variate: Plant_height_Eld

Stratum	d.f.	s.e.	cv%
Reps	2	0.258	0.4
Reps. Morphotype	6	0.342	0.6
Reps. Morphotype.Fertilizer_rates	16	0.755	1.3
Reps. Morphotype.Fertilizer_rates.Spacing	48	1.056	1.8

(b) Analysis of variance (ANOVA) of plant height from site 2 (Kitale-KALRO)

Variate: Plant_height_Ktl

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	1.556	0.778	0.20	
Reps. Morphotype stratum					
Morphotype	3	70391.954	23463.985	6130.91	<.001
Residual	6	22.963	3.827	1.77	
Reps. Morphotype.Fertilizer_rates stratum					
Fertilizer_rates	2	1254.389	627.194	290.09	<.001
Morphotype.Fertilizer_rates	6	62.796	10.466	4.84	0.005
Residual	16	34.593	2.162	1.52	
Reps. Morphotype.Fertilizer_rates.Spacings stratum					
Spacings	2	231.167	115.583	81.32	<.001
Morphotype.Spacings	6	9.352	1.559	1.10	0.378
Fertilizer_rates.Spacings	4	28.111	7.028	4.94	0.002
Morphotype.Fertilizer_rates.Spacings	12	5.815	0.485	0.34	0.977
Residual	48	68.222	1.421		
Total	107	72110.917			

Stratum standard errors and coefficients of variation of plant height from site 2 (Kitale)

Variate: P_height_Ktl

Stratum	d.f.	s.e.	cv%
Reps	2	0.147	0.2
Reps. Morphotype	6	0.652	1.1
Reps. Morphotype.Fertilizer_rates	16	0.849	1.4
Reps. Morphotype.Fertilizer_rates.Spacing	48	1.192	2.0

Appendix IV: The results for total number of branches per plant (numbers) of Jute mallow from field experiments from site 1 Eldoret (UoE) and site 2 Kitale (KALRO) in North Rift

(a) Analysis of variance (ANOVA) of no. of branches from site 1- Eldoret (UoE)

Variate: Number of_branches_Eld

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	2.5741	1.2870	4.48	
Reps. Morphotype stratum					
Morphotype	3	8.1111	2.7037	9.42	0.011
Residual	6	1.7222	0.2870	0.58	
Reps. Morphotype.Fertilizer_rates stratum					
Fertilizer_rates	2	408.5741	204.2870	412.39	<.001
Morphotype.Fertilizer_rates	6	5.0556	0.8426	1.70	0.185
Residual	16	7.9259	0.4954	2.28	
Reps. Morphotype.Fertilizer_rates.Spacings stratum					
Spacings	2	64.2963	32.1481	147.74	<.001
Morphotype.Spacings	6	0.4444	0.0741	0.34	0.912
Fertilizer_rates.Spacings	4	1.9259	0.4815	2.21	0.082
Morphotype.Fertilizer_rates.Spacings	12	2.2222	0.1852	0.85	0.600
Residual	48	10.4444	0.2176		
Total	107	513.2963			

Stratum standard errors and coefficients of variation of no. of branches from site 1- Eldoret

Variate: Number of_branches_Eld

Stratum	d.f.	s.e.	cv%
Reps	2	0.1891	4.4
Reps. Morphotype	6	0.1786	4.1
Reps. Morphotype.Fertilizer_rates	16	0.4064	9.4
Reps. Morphotype.Fertilizer_rates.Spacing	48	0.4665	10.8

(b) Analysis of variance (ANOVA)of No. of branches from site 2(Kitale-KALRO)

Variate: Number of_branches_Ktl

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	0.7222	0.3611	1.80	
Reps. Morphotype stratum					
Morphotype	3	12.6296	4.2099	20.98	0.001
Residual	6	1.2037	0.2006	0.42	
Reps. Morphotype.Fertilizer_rates stratum					
Fertilizer_rates	2	489.0556	244.5278	512.80	<.001
Morphotype.Fertilizer_rates	6	4.4259	0.7377	1.55	0.226
Residual	16	7.6296	0.4769	1.08	
Reps. Morphotype.Fertilizer_rates.Spacings stratum					
Spacings	2	72.0000	36.0000	81.85	<.001
Morphotype.Spacings	6	1.0370	0.1728	0.39	0.880
Fertilizer_rates.Spacings	4	2.4444	0.6111	1.39	0.252
Morphotype.Fertilizer_rates.Spacings	12	1.4074	0.1173	0.27	0.992
Residual	48	21.1111	0.4398		
Total	107	613.6667			

Stratum standard errors and coefficients of variation of branches from site 2(Kitale-KALRO)

Variate: Number of_branches_Ktl

Stratum	d.f.	s.e.	cv%
Reps	2	0.1002	2.0
Reps. Morphotype	6	0.1493	3.0
Reps. Morphotype.Fertilizer_rates	16	0.3987	7.9
Reps. Morphotype.Fertilizer_rates.Spacing	48	0.6632	13.1

Appendix V: The results of number of pods per plant in numbers from field experiments from site 1 Eldoret (UoE) and site 2 Kitale (KALRO) in North Rift region, Kenya

(a) Analysis of variance (ANOVA) of no. of pods from site1 (Eldoret-UoE)
Variate: Number of_Pods_Eld

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	0.7963	0.3981	0.27	
Reps. Morphotype stratum					
Morphotype	3	3223.1389	1074.3796	729.77	<.001
Residual	6	8.8333	1.4722	1.42	
Reps. Morphotype.Fertilizer_rates stratum					
Fertilizer_rates	2	601.3519	300.6759	289.94	<.001
Morphotype.Fertilizer_rates	6	19.8333	3.3056	3.19	0.030
Residual	16	16.5926	1.0370	4.77	
Reps. Morphotype.Fertilizer_rates.Spacings stratum					
Spacings	2	74.1296	37.0648	170.34	<.001
Morphotype.Spacings	6	0.3889	0.0648	0.30	0.935
Fertilizer_rates.Spacings	4	1.4815	0.3704	1.70	0.165
Morphotype.Fertilizer_rates.Spacings	12	4.2222	0.3519	1.62	0.118
Residual	48	10.4444	0.2176		
Total	107	3961.2130			

Stratum standard errors and coefficients of variation of no. of pods from site 1 (Eld)
Variate: Number of_Pods_Eld

Stratum	d.f.	s.e.	cv%
Reps	2	0.1052	0.8
Reps. Morphotype	6	0.4045	3.1
Reps. Morphotype.Fertilizer_rates	16	0.5879	4.4
Reps. Morphotype.Fertilizer_rates.Spacing	48	0.4665	3.5

(b)Analysis of variance (ANOVA) of no. of pods from site 2 (Kitale-KALRO)
Variate: Number of_Pods_Ktl

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	1.6852	0.8426	0.45	
Reps. Morphotype stratum					
Morphotype	3	3805.4352	1268.4784	679.32	<.001
Residual	6	11.2037	1.8673	2.04	
Reps. Morphotype.Fertilizer_rates stratum					
Fertilizer_rates	2	612.5741	306.2870	334.13	<.001
Morphotype.Fertilizer_rates	6	12.3148	2.0525	2.24	0.093
Residual	16	14.6667	0.9167	2.57	
Reps. Morphotype.Fertilizer_rates.Spacings stratum					
Spacings	2	95.9074	47.9537	134.52	<.001
Morphotype.Spacings	6	0.9815	0.1636	0.46	0.835
Fertilizer_rates.Spacings	4	3.3148	0.8287	2.32	0.070
Morphotype.Fertilizer_rates.Spacings	12	6.6852	0.5571	1.56	0.135
Residual	48	17.1111	0.3565		
Total	107	4581.8796			

Stratum standard errors and coefficients of variation of no. of pods from site 2 (Kitale-KALRO)
Variate: Number of_Pods_Ktl

Stratum	d.f.	s.e.	cv%
Reps	2	0.1530	1.0
Reps. Morphotype	6	0.4555	3.1
Reps. Morphotype.Fertilizer_rates	16	0.5528	3.8
Reps. Morphotype.Fertilizer_rates.Spacing	48	0.5971	4.1

Appendix VI: Results for fresh leaf yield (g) of Jute mallow from the field experiments from site 1 Eldoret (UoE) and site 2 Kitale (KALRO) in North Rift region, Kenya

(a)Analysis of variance (ANOVA) of leaf yield from site 1 (Eldoret-UoE)

Variate: Leaf_yield_Eld

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	3.0094	1.5047	1.47	
Reps. Morphotype stratum					
Morphotype	3	16421.1024	5473.7008	5338.63	<.001
Residual	6	6.1518	1.0253	1.23	
Reps. Morphotype.Fertilizer_rates stratum					
Fertilizer_rates	2	18769.0178	9384.5089	11251.19	<.001
Morphotype.Fertilizer_rates	6	227.0243	37.8374	45.36	<.001
Residual	16	13.3454	0.8341	2.66	
Reps. Morphotype.Fertilizer_rates.Spacings stratum					
Spacings	2	1655.1510	827.5755	2634.41	<.001
Morphotype.Spacings	6	35.1859	5.8643	18.67	<.001
Fertilizer_rates.Spacings	4	371.6196	92.9049	295.74	<.001
Morphotype.Fertilizer_rates.Spacings	12	184.9125	15.4094	49.05	<.001
Residual	48	15.0788	0.3141		
Total	107	37701.5990			

Stratum standard errors and coefficients of variation of leaf yield from site 1 (Eldoret-UoE)

Variate: Lf_yield_Eld

Stratum	d.f.	s.e.	cv%
Reps	2	0.2044	0.3
Reps. Morphotype	6	0.3375	0.6
Reps. Morphotype.Fertilizer_rates	16	0.5273	0.9
Reps. Morphotype.Fertilizer_rates.Spacings	48	0.5605	1.0

(b)Analysis of variance (ANOVA) of leaf yield from site 2 (Kitale-KALRO)

Variate: Leaf_yield_Ktl

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	2.1154	1.0577	1.12	
Reps. Morphotype stratum					
Morphotype	3	15992.3093	5330.7698	5663.39	<.001
Residual	6	5.6476	0.9413	1.21	
Reps. Morphotype.Fertilizer_rates stratum					
Fertilizer_rates	2	18577.3650	9288.6825	11962.50	<.001
Morphotype.Fertilizer_rates	6	285.7474	47.6246	61.33	<.001
Residual	16	12.4237	0.7765	2.44	
Reps. Morphotype.Fertilizer_rates.Spacings stratum					
Spacings	2	1575.3285	787.6642	2471.44	<.001
Morphotype.Spacings	6	34.4283	5.7381	18.00	<.001
Fertilizer_rates.Spacings	4	366.0568	91.5142	287.14	<.001
Morphotype.Fertilizer_rates.Spacings	12	190.0624	15.8385	49.70	<.001
Residual	48	15.2979	0.3187		
Total	107	37056.7824			

Stratum standard errors and coefficients of variation of leaf yield from site 2 (Kitale-KALRO)

Variate: Leaf_yield_Ktl

Stratum	d.f.	s.e.	cv%
Reps	2	0.1714	0.3
Reps. Morphotype	6	0.3234	0.6
Reps. Morphotype.Fertilizer_rates	16	0.5088	0.9
Reps. Morphotype.Fertilizer_rates.Spacings	48	0.5645	1.0

Appendix VII: Results of seed weights (g) of Green pod harvesting stage (H1) of Jute mallow from site 1 Eldoret (UoE) and site 2 Kitale (KALRO) in North Rift region, Kenya

(a)Analysis of variance (ANOVA) for seed weight of green pod from site1 (Eldoret-UoE)

Variate: Green pod seed weight_Eld

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.19252	0.06417	1.02	
Reps. Morphotype stratum					
Morphotype	3	0.21759	0.07253	1.16	0.378
Residual	9	0.56356	0.06262	1.01	
Reps. Morphotype.Fertilizer_rates stratum					
Fertilizer_rates	2	0.33510	0.16755	2.71	0.087
Morphotype.Fertilizer_rates	6	0.38032	0.06339	1.02	0.434
Residual	24	1.48607	0.06192	0.98	
Reps. Morphotype.Fertilizer_rates.Spacings stratum					
Spacings	2	0.14167	0.07083	1.12	0.332
Morphotype.Spacings	6	0.38738	0.06456	1.02	0.418
Fertilizer_rates.Spacings	4	0.24834	0.06209	0.98	0.423
Morphotype.Fertilizer_rates.Spacings	12	0.74246	0.06187	0.98	0.477
Residual	72	4.55022	0.06320		
Total	143	9.24523			

Stratum standard errors and coefficients of variation for seed weight of green pod site1 (Eld)

Variate: Green pod seed weight_Eld

Stratum	d.f.	s.e.	cv%
Reps	3	0.0422	0.3
Reps. Morphotype	9	0.0834	0.6
Reps. Morphotype.Fertilizer_rates	24	0.1437	1.0
Reps. Morphotype.Fertilizer_rate.Spacing	72	0.2514	1.7

(b)Analysis of variance (ANOVA) for seed weight of green pod for site 2 (Kitale-KALRO)

Variate: Green pod seed weight_Ktl

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.0007139	0.0002380	1.05	
Reps. Morphotype stratum					
Morphotype	3	0.0018028	0.0006009	2.66	0.112
Residual	9	0.0020361	0.0002262	0.68	
Reps. Morphotype.Fertilizer_rates stratum					
Fertilizer_rates	2	0.0555264	0.0277632	83.12	<.001
Morphotype.Fertilizer_rates	6	0.0019014	0.0003169	0.95	0.480
Residual	24	0.0080167	0.0003340	1.12	
Reps. Morphotype.Fertilizer_rates.Spacings stratum					
Spacings	2	0.0089847	0.0044924	15.02	<.001
Morphotype.Spacings	6	0.0012764	0.0002127	0.71	0.642
Fertilizer_rates.Spacings	4	0.0006986	0.0001747	0.58	0.675
Morphotype.Fertilizer_rates.Spacings	12	0.0021069	0.0001756	0.59	0.846
Residual	72	0.0215333	0.0002991		
Total	143	0.1045972			

Stratum standard errors and coefficients of variation for seed weight of green pod for site 2 (Kitale-KALRO)

Variate: Green pod seed weight_Ktl

Stratum	d.f.	s.e.	cv%
Reps	3	0.00257	0.0
Reps. Morphotype	9	0.00501	0.0
Reps. Morphotype.Fertilizer_rates	24	0.01055	0.1
Reps. Morphotype.Fertilizer_rate.Spacing	72	0.01729	0.1

Appendix VIII: Seed weight results of Tan pod harvest stage (H2) of Jute mallow from field experiment at site 1 Eldoret (UoE) and site 2 Kitale (KALRO) in North Rift region, Kenya

(a)Analysis of variance (ANOVA) of tan pod seed weight (purity) for site 1(Eld-UoE)

Variate: Tan pod seed weight_Eld

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.09117	0.03039	1.08	
Reps. Morphotype stratum					
Morphotype	3	0.09291	0.03097	1.10	0.398
Residual	9	0.25327	0.02814	1.04	
Reps. Morphotype.Fertilizer_rates stratum					
Fertilizer_rates	2	0.22453	0.11226	4.15	0.028
Morphotype.Fertilizer_rates	6	0.20021	0.03337	1.23	0.325
Residual	24	0.64991	0.02708	0.97	
Reps. Morphotype.Fertilizer_rates.Spacings stratum					
Spacings	2	0.06151	0.03075	1.10	0.338
Morphotype.Spacings	6	0.16583	0.02764	0.99	0.438
Fertilizer_rates.Spacings	4	0.10914	0.02729	0.98	0.425
Morphotype.Fertilizer_rates.Spacings	12	0.33079	0.02757	0.99	0.468
Residual	72	2.00827	0.02789		
Total	143	4.18753			

Stratum standard errors and coefficients of variation of tan pod seed wt (purity) for site 1(Eld)

Variate: Tan pod seed_Eld

Stratum	d.f.	s.e.	cv%
Reps	3	0.0291	0.2
Reps. Morphotype	9	0.0559	0.4
Reps. Morphotype.Fertilizer_rates	24	0.0950	0.6
Reps. Morphotype.Fertilizer_rates.Spacing	72	0.1670	1.1

(b)Analysis of variance (ANOVA) of tan pod seed weight (purity) for site 2 (Kitale-KALRO)

Variate: Tan pod seed weight_Ktl

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.00017431	0.00005810	0.51	
Reps. Morphotype stratum					
Morphotype	3	0.00177431	0.00059144	5.20	0.023
Residual	9	0.00102292	0.00011366	1.03	
Reps. Morphotype.Fertilizer_rates stratum					
Fertilizer_rates	2	0.06101250	0.03050625	276.86	<.001
Morphotype.Fertilizer_rates	6	0.00083194	0.00013866	1.26	0.313
Residual	24	0.00264444	0.00011019	1.16	
Reps. Morphotype.Fertilizer_rates.Spacings stratum					
Spacings	2	0.00882917	0.00441458	46.51	<.001
Morphotype.Spacings	6	0.00044861	0.00007477	0.79	0.582
Fertilizer_rates.Spacings	4	0.00053333	0.00013333	1.40	0.241
Morphotype.Fertilizer_rates.Spacings	12	0.00068889	0.00005741	0.60	0.831
Residual	72	0.00683333	0.00009491		
Total	143	0.08479375			

Stratum standard errors and coefficients of variation of tan pod seed wt (purity) for site 2(Ktl)

Variate: Tan pod seed weight_Ktl

Stratum	d.f.	s.e.	cv%
Reps	3	0.001270	0.0
Reps. Morphotype	9	0.003554	0.0
Reps. Morphotype.Fertilizer_rates	24	0.006060	0.0
Reps. Morphotype.Fertilizer_rate.Spacing	72	0.009742	0.1

Appendix IX: Seed weight result of Black pod harvest stage (H3) of Jute mallow from field experiment at site 1 Eldoret (UoE) and site 2 Kitale (KALRO) in North Rift region, Kenya

(a)Analysis of variance (ANOVA) for black pod seed weight (purity) for site 1 (Eldoret-UoE)

Variate: Black pod_Eld

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.00046319	0.00015440	6.74	
Reps. Morphotype stratum					
Morphotype	3	0.00280764	0.00093588	40.84	<.001
Residual	9	0.00020625	0.00002292	0.22	
Reps. Morphotype.Fertilizer_rates stratum					
Fertilizer_rates	2	0.06748472	0.03374236	321.07	<.001
Morphotype.Fertilizer_rates	6	0.00454861	0.00075810	7.21	<.001
Residual	24	0.00252222	0.00010509	1.71	
Reps. Morphotype.Fertilizer_rates.Spacings stratum					
Spacings	2	0.01140556	0.00570278	92.62	<.001
Morphotype.Spacings	6	0.00146111	0.00024352	3.95	0.002
Fertilizer_rates.Spacings	4	0.00040694	0.00010174	1.65	0.171
Morphotype.Fertilizer_rates.Spacings	12	0.00122639	0.00010220	1.66	0.094
Residual	72	0.00443333	0.00006157		
Total	143	0.09696597			

Stratum standard errors and coefficients of variation for black pod (purity) from site 1 (Eld)

Variate: Black pod seed weight_Eld

Stratum	d.f.	s.e.	cv%
Reps	3	0.002071	0.0
Reps. Morphotype	9	0.001596	0.0
Reps. Morphotype.Fertilizer_rates	24	0.005919	0.0
Reps. Morphotype.Fertilizer_rates.Spacing	72	0.007847	0.1

(b)Analysis of variance (ANOVA) for black pod seed weight for site 2 (Kitale-KALRO)

Variate: Black pod seed weight_Ktl

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.00029097	0.00009699	1.49	
Reps. Morphotype stratum					
Morphotype	3	0.00111875	0.00037292	5.75	0.018
Residual	9	0.00058403	0.00006489	0.79	
Reps. Morphotype.Fertilizer_rates stratum					
Fertilizer_rates	2	0.06537639	0.03268819	398.91	<.001
Morphotype.Fertilizer_rates	6	0.00247917	0.00041319	5.04	0.002
Residual	24	0.00196667	0.00008194	1.91	
Reps. Morphotype.Fertilizer_rates.Spacings stratum					
Spacings	2	0.01205139	0.00602569	140.71	<.001
Morphotype.Spacings	6	0.00028750	0.00004792	1.12	0.360
Fertilizer_rates.Spacings	4	0.00074861	0.00018715	4.37	0.003
Morphotype.Fertilizer_rates.Spacings	12	0.00029583	0.00002465	0.58	0.855
Residual	72	0.00308333	0.00004282		
Total	143	0.08828264			

Stratum standard errors and coefficients of variation black pod (purity) from site1 Eld

Variate: Blackpd_Ktl

Stratum	d.f.	s.e.	cv%
Reps	3	0.001641	0.0
Reps. Morphotype	9	0.002685	0.0
Reps. Morphotype.Fertilizer_rates	24	0.005226	0.0
Reps. Morphotype.Fertilizer_rates.Spacing	72	0.006544	0.0

Appendix X: Germination results of All (Green pod-H1, Tan pod-H2 and Black pod-H3) harvesting stage of Jute mallow from field experiments of Site 1 (Eldoret-UoE)

GERMINATION DATA SHEET														
MORPHOTYPE	FERTILIZER	SPACING	**HARVESTING ……(All pod stages)………SITE…1 (Eldoret-UoE)………**											
			H1				**H2**				**H3**			
			Dead seeds	Abnormal seedlings	Normal seedlings	% Emergence of radicle	Dead seeds	Abnormal seedlings	Normal seedlings	% Emergence of radicle	Dead seeds	Abnormal seedlings	Normal seedlings	% Emergence of radicle
V_1	F_0	S_1	25	9	66	75	24	7	70	77	42	12	47	59
		S_2	24	9	66	76	22	8	72	79	40	10	50	60
		S_3	24	9	67	76	21	6	73	79	38	10	53	62
	F_1	S_1	21	12	67	79	19	7	74	81	38	11	51	62
		S_2	19	11	71	81	15	9	76	85	36	10	55	64
		S_3	16	9	75	84	12	7	81	88	31	10	60	70
	F_2	S_1	17	12	71	83	13	10	77	87	37	8	56	64
		S_2	14	10	71	87	9	8	84	91	28	11	61	72
		S_3	9	9	83	91	7	5	88	93	23	12	66	77
V_2	F_0	S_1	25	10	65	75	22	8	70	78	44	10	41	56
		S_2	24	10	67	77	21	8	72	79	41	9	50	59
		S_3	24	8	69	77	20	7	73	80	38	10	53	63
	F_1	S_1	16	11	68	79	18	7	75	82	38	8	54	62
		S_2	18	11	71	83	15	7	78	85	35	8	57	65
		S_3	16	9	75	85	12	7	81	88	32	8	60	68
	F_2	S_1	16	12	73	85	11	9	80	89	35	8	57	66
		S_2	13	10	77	87	9	8	83	91	28	11	62	72
		S_3	9	8	83	91	7	5	88	93	21	12	67	79
V_3	F_0	S_1	25	10	65	75	25	6	74	76	43	11	47	57
		S_2	25	9	67	76	24	6	71	76	41	9	50	62
		S_3	24	8	68	77	23	6	72	77	38	9	53	62
	F_1	S_1	23	12	67	79	19	8	73	81	38	9	53	62
		S_2	19	11	71	82	17	7	77	84	36	8	57	65
		S_3	16	9	76	85	12	7	81	88	29	9	62	71
	F_2	S_1	14	13	73	86	11	10	79	89	35	8	57	66
		S_2	12	10	78	88	9	7	84	92	28	11	62	73
		S_3	8	9	83	94	6	6	88	94	22	11	67	78
V_4	F_0	S_1	26	9	65	74	25	6	70	76	42	11	47	63
		S_2	24	10	66	76	24	5	71	77	41	10	50	60
		S_3	23	8	69	77	22	6	73	78	38	9	53	62
	F_1	S_1	21	11	68	79	19	6	75	81	38	11	52	63
		S_2	18	10	72	82	15	7	78	85	35	9	56	66
		S_3	15	9	77	86	12	6	82	88	29	10	62	72
	F_2	S_1	14	13	73	86	11	9	81	90	35	8	57	65
		S_2	12	10	79	88	9	7	84	91	27	10	63	73
		S_3	9	8	84	91	7	4	89	93	21	12	68	79

Appendix XI: Germination results of All (Green pod-H1, Tan pod-H2 and Black pod-H3) harvesting stage of Jute mallow from field experiments of Site 2 (Kitale KALRO)

GERMINATION DATA SHEET														
MORPHOTYPE	FERTILIZER	SPACING	HARVESTING ……(All pod stages)………SITE…2 (Kitale KALRO)………											
			Green pod stage (H1)				Tan pod stage (H2)				Black pod stage (H3)			
			Dead seeds	Abnormal seedlings	Normal seedlings	% Emergence of radicle	Dead seeds	Abnormal seedlings	Normal seedlings	% Emergence of radicle	Dead seeds	Abnormal seedlings	Normal seedlings	% Emergence of radicle
V_1	F_0	S_1	22	7	72	77	23	7	71	78	38	10	52	62
		S_2	21	7	72	78	22	6	72	79	37	9	54	63
		S_3	20	7	74	79	21	6	73	81	36	8	57	65
	F_1	S_1	19	8	73	82	18	6	75	83	35	8	57	65
		S_2	16	8	76	84	12	9	79	88	33	7	60	67
		S_3	14	6	80	86	9	7	84	91	30	6	64	70
	F_2	S_1	14	9	77	86	9	9	83	91	34	6	61	67
		S_2	11	7	82	89	7	7	87	93	28	7	66	72
		S_3	7	6	88	94	6	5	89	94	24	7	70	77
V_2	F_0	S_1	23	7	71	79	19	7	72	77	43	7	50	57
		S_2	22	7	72	80	18	7	73	79	42	6	54	59
		S_3	20	7	74	81	20	6	74	80	37	6	57	63
	F_1	S_1	19	8	73	81	16	7	78	85	36	6	58	64
		S_2	16	7	77	84	12	7	81	88	34	6	61	67
		S_3	12	7	81	88	9	6	85	91	30	6	65	70
	F_2	S_1	13	9	79	88	9	7	84	92	32	6	62	68
		S_2	10	8	83	90	7	5	88	93	27	8	66	73
		S_3	7	5	88	93	6	4	91	94	23	7	71	78
V_3	F_0	S_1	21	7	72	77	24	6	71	79	41	8	52	59
		S_2	20	7	73	78	22	5	73	80	40	7	54	60
		S_3	19	7	74	79	21	6	74	81	38	6	56	62
	F_1	S_1	19	7	74	81	18	6	76	83	37	7	57	64
		S_2	16	8	77	84	13	7	80	88	34	6	60	69
		S_3	12	7	81	88	10	7	84	91	29	6	65	71
	F_2	S_1	12	9	79	88	9	7	85	92	32	5	63	69
		S_2	9	7	84	91	8	6	87	93	27	7	67	73
		S_3	6	6	88	94	6	4	91	95	21	7	72	79
V_4	F_0	S_1	24	6	71	76	23	5	72	77	41	8	52	60
		S_2	23	5	72	77	22	5	73	78	39	6	54	61
		S_3	21	6	74	79	21	5	74	79	37	7	57	63
	F_1	S_1	19	7	74	81	18	5	78	83	36	8	57	65
		S_2	16	6	78	84	14	5	81	86	32	8	60	68
		S_3	12	6	82	88	11	4	85	89	28	6	66	72
	F_2	S_1	11	9	80	89	10	4	87	91	33	5	62	67
		S_2	10	7	84	90	8	4	89	92	26	7	67	74
		S_3	7	5	89	94	6	2	92	94	21	8	72	80

Appendix VII: Seed weights results of all harvesting stage (H1, H2, H3) of Jute mallow from field experiments from Site 1 (Eldoret-UoE) and Site 2 (Kitale-KALRO)

MORPHOTYPE	FERTILIZER	SPACING	Site 1 (Eldoret-UoE)			Site 2 (Kitale-KALRO)		
			Green pod stage (H1)	Tan pod stage (H2)	Black pod stage (H3)	Green pod stage (H1)	Tan pod stage (H2	Black pod stage (H3)
			Average weight	Average weight	Average weight	Average weight	Average weight	Average weight
V1 GEMS	F_0	S_1	0.168	0.174	0.168	0.193	0.193	0.197
		S_2	0.195	0.193	0.196	0.210	0.206	0.205
		S_3	0.204	0.205	0.206	0.213	0.214	0.214
	F_1	S_1	0.214	0.215	0.216	0.219	0.219	0.220
		S_2	0.220	0.222	0.222	0.226	0.226	0.228
		S_3	0.230	0.231	0.230	0.234	0.232	0.235
	F_2	S_1	0.238	0.239	0.240	0.234	0.240	0.242
		S_2	0.246	0.244	0.244	0.250	0.250	0.251
		S_3	0.253	0.256	0.258	0.260	0.260	0.260
V2 BEMS	F_0	S_1	0.173	0.171	0.169	0.190	0.194	0.197
		S_2	0.195	0.194	0.195	0.204	0.205	0.204
		S_3	0.205	0.210	0.208	0.212	0.215	0.213
	F_1	S_1	0.213	0.215	0.215	0.219	0.219	0.218
		S_2	0.220	0.222	0.223	0.226	0.227	0.225
		S_3	0.228	0.230	0.229	0.232	0.235	0.233
	F_2	S_1	0.238	0.241	0.240	0.242	0.243	0.243
		S_2	0.247	0.249	0.250	0.254	0.252	0.254
		S_3	0.257	0.258	0.259	0.261	0.263	0.261
V3 GLMT	F_0	S_1	0.169	0.168	0.170	0.194	0.192	0.192
		S_2	0.201	0.206	0.207	0.206	0.206	0.204
		S_3	0.213	0.212	0.213	0.215	0.214	0.215
	F_1	S_1	0.219	0.219	0.220	0.220	0.220	0.221
		S_2	0.226	0.226	0.226	0.226	0.227	0.226
		S_3	0.223	0.232	0.234	0.234	0.234	0.234
	F_2	S_1	0.244	0.242	0.243	0.244	0.244	0.242
		S_2	0.253	0.253	0.252	0.254	0.255	0.253
		S_3	0.262	0.261	0.262	0.264	0.264	0.263
V4 BLMT	F_0	S_1	0.173	0.178	0.173	0.194	0.192	0.196
		S_2	0.195	0.201	0.200	0.206	0.206	0.207
		S_3	0.212	0.211	0.212	0.213	0.214	0.216
	F_1	S_1	0.219	0.219	0.219	0.221	0.220	0.219
		S_2	0.225	0.225	0.224	0.226	0.227	0.226
		S_3	0.233	0.233	0.232	0.235	0.236	0.234
	F_2	S_1	0.243	0.243	0.244	0.242	0.245	0.244
		S_2	0.253	0.254	0.253	0.254	0.253	0.254
		S_3	0.264	0.263	0.263	0.265	0.263	0.263

Appendix XIII: Comparison of effects of the three harvesting stages (Green pod, Tan pod and Black pod) on Electrical Conductivity (E.C) from Site 1 (Eldoret-UoE) and Site 2 (Kitale-KALRO)

MORPHOTYPE	FERTILIZER	SPACING	Site 1 (Eldoret-UoE)			Site 2 (Kitale-KALRO)		
			Green pod stage (H1)	Tan pod stage (H2)	Black pod stage (H3)	Green pod stage (H1)	Tan pod stage (H2)	Black pod stage (H3)
			E.C (µscm^{-1}g^{-1})	E.C (µscm^{-1}g^{-1})	E.C (µscm^{-1}g^{-1})	E.C. (µscm^{-1}g^{-1})	E.C. (µscm^{-1}g^{-1})	E.C. (µscm^{-1}g^{-1})
V1 GEMS	F_0	S_1	0.18	0.06	0.30	0.16	0.05	0.25
		S_2	0.15	0.05	0.26	0.14	0.05	0.24
		S_3	0.10	0.05	0.19	0.09	0.05	0.23
	F_1	S_1	0.14	0.05	0.23	0.09	0.05	0.23
		S_2	0.09	0.05	0.18	0.09	0.04	0.18
		S_3	0.09	0.04	0.17	0.09	0.04	0.17
	F_2	S_1	0.13	0.04	0.17	0.13	0.04	0.17
		S_2	0.12	0.04	0.16	0.12	0.04	0.16
		S_3	0.08	0.04	0.16	0.12	0.04	0.15
V2 BEMS	F_0	S_1	0.17	0.06	0.30	0.16	0.05	0.25
		S_2	0.15	0.05	0.26	0.15	0.05	0.25
		S_3	0.15	0.05	0.23	0.14	0.05	0.23
	F_1	S_1	0.14	0.05	0.23	0.09	0.05	0.23
		S_2	0.09	0.05	0.22	0.13	0.04	0.22
		S_3	0.09	0.04	0.17	0.13	0.05	0.17
	F_2	S_1	0.08	0.04	0.17	0.12	0.04	0.16
		S_2	0.12	0.04	0.16	0.12	0.04	0.16
		S_3	0.08	0.04	0.15	0.11	0.04	0.15
V3 GLMT	F_0	S_1	0.18	0.06	0.35	0.10	0.05	0.31
		S_2	0.15	0.04	0.24	0.10	0.05	0.21
		S_3	0.14	0.05	0.23	0.14	0.05	0.23
	F_1	S_1	0.09	0.05	0.23	0.09	0.05	0.23
		S_2	0.09	0.04	0.22	0.09	0.04	0.22
		S_3	0.09	0.04	0.17	0.09	0.04	0.17
	F_2	S_1	0.08	0.04	0.16	0.08	0.04	0.17
		S_2	0.08	0.04	0.16	0.08	0.04	0.16
		S_3	0.08	0.04	0.15	0.08	0.04	0.15
V4 BLMT	F_0	S_1	0.17	0.06	0.29	0.15	0.05	0.26
		S_2	0.15	0.05	0.25	0.15	0.05	0.24
		S_3	0.09	0.05	0.24	0.14	0.05	0.23
	F_1	S_1	0.14	0.05	0.23	0.14	0.05	0.23
		S_2	0.09	0.04	0.22	0.09	0.04	0.22
		S_3	0.09	0.04	0.17	0.13	0.04	0.17
	F_2	S_1	0.08	0.04	0.16	0.08	0.04	0.16
		S_2	0.08	0.04	0.16	0.08	0.04	0.16
		S_3	0.08	0.04	0.15	0.08	0.04	0.15