CASSAVA PRODUCTION IMPROVEMENT THROUGH STAGGERED PLANTING FOR INDUSTRIAL PROCESSING AND UTILIZATION IN EASTERN AND SOUTHERN ZONES OF TANZANIA

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A DISSERTATION SUBMMITED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER IN CROP SCIENCE OF SOKOINE UNIVERSITY OF AGRICULTURE

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ABSTRACT

Cassava (*Manihot esculenta* Crantz) is mainly cultivated because of its starchy storage roots and it is considered one of the most important staple foods in the tropical countries. High dry matter contents and starch yields are the most important traits for commercialized cassava starch production. The experiment aimed at identifying suitable cassava scheduled planting, harvesting and varietal performance to maximize starch production across the three locations in Eastern and Southern zones of Tanzania during the 2017/18 - 2018/19 cropping seasons. The experiment was laid out in split-split plot under randomized complete block design with variety being main factor, planting schedules as sub plot and scheduled harvesting as sub-sub plot. The total root yield increased significantly from first to third planting and harvesting times respectively. *Kiroba* variety planted in November/December and then harvested at twelve months after planting (MAP) gave higher total root yield of 27 tones per hactre (t/ha) at Southern zone and also at the Eastern zone *Kiroba* variety planted in November/December and March/April yielded higher total root (22t/ha) when harvested at 12MAP. Based on cassava dry matter content; the study concluded that: higher dry matter content was obtained when *Mkuranga* 1 variety planted on November/December and harvested at 12MAP gave 40% followed by *Kiroba* variety planted in November/December and harvested after 12MAP had 39% at Southern zone. Also the study found that; cassava starch content was higher (23%) at Southern zone when *Mkuranga* 1 variety planted during November/December and harvested at 12MAP before the onset of rainfall.

Keywords: Cassava; Scheduled, Staggered, harvesting, planting time; Cassava starch and dry matter contents, yields and yield components.

DECLARATION

I, Festo Frank Masisila do hereby declare to the Senate of the Sokoine University of Agriculture that; this dissertation is my own original work done within the period of my registration and has not been submitted in any other institution.

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The above declaration is confirmed

Prof. C. L. Rweyemamu	**Date**
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DEDICATION

This work is dedicated to God for His mercy and favour upon my life and all who supported me throughout my study.

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LIST OF ABBREVIATION

ACM	African Cassava Mosaic Virus
ANOVA	Analysis of variance
C: AVA	Cassava Added Value for Africa
Ca	Calcium
CBB	Cassava Bacterial Blight
CBSD	Cassava brown streak disease
CGM	Cassava Green Mite
CIAT	Centro Internacional de Agricultura Tropical
cm	centimetres
CMB	Cassava Mealy Bug
CMD	Cassava Mosaic Disease
Cmol	Centimoles
COSTECH	Commission of Science and Technology of Tanzania
CSC	Cassava starch Content
CV	Coefficient of variation
d.f	degree of freedom
DM	Dry matter
DMC	Dry matter content
DMRT	Duncan Multiple range test
EACMV	East African Cassava Mosaic Virus disease
EPZ	Export Processing Zone
EZ	Eastern Zone
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Statistics of the United Nations

Fe	Iron
FW	Fresh Weight
H1	Harvesting one (8 months),
H2	Harvesting two (10 months),
H3	Harvesting three (12 months)
Ha	Hactre
HI	Harvesting Index
HQCF	High Quality Cassava Flour
IITA	International Institute of Tropical Agriculture
Inc	Incidence
K	Potassium
LSD	least significance difference
m.a.s.l	metres above sea level
m.s	mean sum square
MAP	Months after planting
Mg	Magnesium
MgO	Magnesium Oxide
mm	millimetres
Mn	Manganese
MOP	Murate of potash
MSc	Master of Science
N	Nitrogen
OC	Organic carbon
P	Phosphorus
P	Phosphorus
P1	Planting one, (December)

P2	planting two, (January)
P3	Planting three, (March/April)
ppm	parts per million
P-value	Probability value
RCBD	Randomised complete block design
RH	Relative Humidity
S	Sulphur
s.s	sum of square
SD	Standard deviation
SE	Standard error
Sev	Severity
SOV	Source of variation
SUA	Sokoine University of Agriculture
Swt	Shoot weight
SZ	Southern Zone
t	tonne
TARI	Tanzania Agricultural Research Institute
TG	Total green stems
TGB	Total green biomass
TLG	Total lignified biomass
TOSCI	Tanzania Official Seed Certification Institute
TRA	Tanzania Revenue Authority
TRY	Total root yield
UgV	Ugandan variant strain
US	United States
USDA	United States Department of Agriculture

V1	Variety one (*Kiroba*)
V2	Variety two (*Mkuranga* 1)
V3	Variety three (*Chereko*),
Wa	Weight in air
Ww	Weight in water
Zn	Zinc

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Cassava (*Manihot esculenta* Crantz) is a shrub plant from the Euphorbiaceae family the third most important source of calories in the tropics (FAO, 2008) and among the most important root crops worldwide which provides food for over a billion people (Bokanga, 2001). The main food product is the roots, which (depending on variety) can be retrieved from the soil up to three years after maturity (Lebot, 2009), allowing crops to be abandoned during periods of agricultural and social instability. This provides an important form of insurance against social disruption, prolonged droughts, or other periods of stress and unrest. Due to its versatile nature, it is frequently referred to as the drought and famine crop of the developing world (Pearce, 2007). It has the potential to be an important part of the solution to improving food security in a time of climate change (Liu *et al.,* 2008; Gallo and Sayre, 2009).

Cassava has high starch productivity and performs relatively well in low fertility soils and marginal areas (Hershey, 2010). The diverse uses of cassava largely explain its popularity in the tropics (Hershey, 2010). In Africa most cassava produced is used for food consumption, with 50% in processed form, and 38% in the fresh and/ or boil form; 12% is used for animal feed (Abaca *et al.,* 2014). It has been noted that in Africa, fresh root, dried roots, pasty products, granulated products and cassava leaves are five common groups of cassava utilization, (Ugwu and Ay, 1992). Cassava yields vary with cultivars, season, soil type and fertility as well as with the level of infestation and infection with pests and diseases, respectively and crop management (Bock, 2004).

Cassava roots are a major source of carbohydrates in human diets and are processed by various methods into numerous products utilized in diverse ways according to local customs and preferences. Many traditional foods are processed from the roots and leaves of cassava thus constitute the major part of a family's daily food. Cassava is also emerging as an important large-scale agricultural crop for use as a bio-fuel (de Vries, 2010) and a source of industrial starch (Lebot, 2009; Balagopalan, 2002). The global export of cassava starch and flour in 2014 amounted to 8.5 million tons (FAO, 2015). In some cultures, the leaves are also consumed as a favourite green vegetable.

Cassava production in Africa is below 120 million tonnes (Kundy *et al*., 2015). Tanzania is the 6th largest producer of cassava in Africa after Nigeria (the top producer), Democratic Republic of Congo, Ghana, Angola and Mozambique and 12th in the world, with about 800 000 hectares of land under cassava cultivation with estimated annual production of 5 000 000 tons of fresh roots (FAOSTAT, 2018). Tanzania's average cassava fresh root yield is below 8 t/ha whereas the potential yield is 30t/ha (Mkamilo and Jeremiah, 2005), which is below the global cassava average production of 35 t/ha (Lebot, 2009), and the Africa average yield of 9.6 t/ha (FAO, 2009). The yield gap is caused by low genetic yielding potential of local varieties, biotic and abiotic stresses which hinder the high production of roots for the cassava processing industries in the country. Abiotic factors include poor soil fertility and drought. Biotic stresses include diseases such as cassava brown streak disease (CBSD), East African Cassava Mosaic Virus disease (EACMV) and its Ugandan variant strain (UgV); and the African Cassava Mosaic Virus (ACMV). Others are Cassava Bacterial Blight (CBB) and major pests such as Cassava Green Mite (CGM) and Cassava Mealy Bug (CMB) and weeding infestation.

1.2 Problem Statement

Although cassava is regarded as both an important food and industrial crop, most farmers (about 80%) in Tanzania cultivate the crop in small scale (less than one hectare) as a subsistence crop for home consumption (C: AVA, 2013).Therefore; the current low cassava production (about 5 metric tonnes) cannot meet the high demand of estimated potential market of 640 000 metric tonnes (C: AVA, 2013), as raw material to the high quality cassava flour (HQCF) and starch processing industries. Farmers in Tanzania do plant the crop almost at the same time (without staggering); and use varieties of similar growth characteristics that are harvested at almost the same time. Due to these circumstances cassava roots are usually highly available for a short period (June to September of every year) whereas the demand for processing such large quantity (almost 200 000 tonnes) becomes a problem. This situation results into low incentive to farmers as cassava price is usually relatively low due to high supply period at that harvesting time.

1.3 Justification

Despite of the importance of cassava in Eastern and Southern of Tanzania, its productivity is still low as it only averages 8 t/ha (Mkamilo and Jeremiah, 2005) compared to its yield potential of 20-30 t/ha (COSTECH, 2015). The roots are usually readily available in short period starting from June to the end of September per year which leads to short supply for the HQCF roots and starch processing industries as 84% of cassava produce in Tanzania is used for human food (C: AVA, 2012). There has been increasing demand of cassava starch (600 metric tonnes per year) for Tanzanian industries, and in 2011 Tanzania Revenue Authority (TRA) estimated a total 5781 tons per year was required and this was equivalent to 3.2 million US dollar (TRA, 2011).It is well known that good agronomic practices such as timely weeding, use of improved varieties etc. can greatly increase amount cassava productivity (Aina *et al.*, 2007). Therefore immediate agronomic research such as application of phosphate, calcium and potash fertilizers accompanied with staggering planting and harvesting is of paramount need.

The 2025 Tanzania Industrialization mission aims to become a semi-industrialized country (URT, 2016) currently there are some medium-scale cassava processing industries that are active, and investers are expected to construct large processing industries. These include the Dar-Canton Investment Company (DCI) located in Handeni-Tanga, its production capacity will be 200 metric tons of fresh cassava roots (URT, 2017), the Tanzanaia Agricultural Export Processing Zone Ltd and Epoch Agriculture (TAEPZ) from China working at Mtwara, Lindi and Pwani regions will be processing 2 million metric tons of dry cassava chips per year. The other factory which is part of Cassava Starch of Tanzania Corporation (CSTC) has started growing cassava (800 hectares) within Makonde Plateau and processing about 30 000 tons per year. The CSTC will produce more than 6 000 metric tons of high quality cassava flour (HQCF) per year (URT, 2019). In southern zone (SZ), there are also 150 Village Processing Groups (VPG) with average cassava roots processing capacity of 500kg per day per each group (C: AVA, 2012).

Large processing industries and VPG will need to run at their full capacity hence drive the demand of raw materials availability throughout the processing period. This calls for an immediate intervention which can change current production cycles and productivity.

1.4 OBJECTIVES

1.4.1 Overall objective

Increase cassava productivity and production cycles for food and industrial processing in the Eastern and Southern Zones of Tanzania.

1.4.2 Specific objectives

(i) To evaluate cassava varietal performance in growth and development, yield and yield components

(ii) To access the influence of planting schedules and harvesting time on yield and quality of cassava

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Cassava Origin and Distribution

Cassava (*Manihot esculents* Crantz) family euphorbiaceae originated from tropical America (Allem, 2002). It was first introduced into Africa through the Congo basin by the Portuguese around 16^{th} and later spread in East Africa around 18^{th} (Jones, 1959).

2.2 Cassava use and Nutritional Content

Cassava is an among the important root crop in the tropics and the world at large and is utilized by more than a billion people especially in developing countries including Tanzania (Plucknett *et al*., 2000, Ndunguru, 2005). Cassava is among the heavy feeder crops with large nutrients requirements, its growth and yielding in low soil fertility areas is caused by its high adaptability with special physiological traits such as deep rooting systems to absorb water during drought and shadding leaves to minimize water loss (Fageria *et al*., 1997). In terms of its nutritional contents, cassava roots are rich in carbohydrates, vitamins and essential minerals (USDA, 2009). Leaves are consumed as green vegetables in many parts of Africa (Achidi *et al.*, 2005). In Africa, the majority (88%) of cassava produced is for human consumption and the 12% is used as animal feed (on farm and off-farm) and starch based products (starches and alcohol), (Henry *et al*., 1998).

Cassava is utilized in a multiple ways; fresh root but also in processed form like *ugali* in Tanzania (Kayode, 2015). Fermented and non-fermented granulated and flour-based cassava products are increasingly popular in the region (Sudhanshu and Ramesh, 2016). Many countries in sub-Saharan Africa have launched value addition initiatives in the cassava food chain, promoting cassava to support the rural economy and help meet rising dietary needs.

Table 1: Proximate, Vitamin and Mineral Composition of Cassava Roots and Leaves

Proximate composition	Cassava root	Cassava leaves
Food energy (kcal)	110-149	91
Food energy (KJ)	526-611	209-251
Moisture (g)	45.9-85.3	64.8-88.6
Dry weight (g)	29.8-39.3	19-28.3
Protein (g)	0.3-3.5	1.0-10.0
Lipid (g)	0.03-0.5	0.2-2.9
Carbohydrate, total (g)	25.3-35.7	7-18.3
Dietary fibber (g)	0.1-3.7	0.5-10.0
Ashe (g)	0.4-1.7	0.7-4.5
Vitamins		
Thiamin (mg)	0.03-0.28	0.06-0.31
Riboflavin (mg)	0.03-0.06	0.21-0.74
Niacin (mg)	0.6-1.09	1.3-2.8
Ascorbic acid (mg)	14.9-50	60-370
Vitamin A (µg)	1.0-35.0	3800-11800
Minerals		
Calcium (mg)	19-176	34-708
Phosphorus, total (mg)	6-152	27-211
Ca/P	1.6-5.48	2.5
Iron (mg)	0.3-14	0.4-8.3
Potassium (%)	0.25 (0.72)	0.35 (1.23)
Magnesium (%)	0.03 (0.08)	0.12 (0.42)
Copper (ppm)	2.00 (6.00)	3.00 (12.0)
Zinc (ppm)	14.00 (41.00)	71.0 (249.0)
Sodium (ppm)	76.00 (213.00)	51.0 (177.0)
Manganese (ppm)	3.00 (10.00)	72.0 (252.0)

Source: United States Department of Agriculture (USDA, 2009).

However, its nutrient composition differs according to variety and age of the harvested crop, and soil conditions, climate, and other environmental factors including agronomic practices during cultivation (Fageria *et al*., 1997). In Southern and Eastern Zone of Tanzania, the most commonly and available cassava improved varieties are sweet and branching (*Kiroba, Kizimbani, Chereko, Mkumba, Mkuranga*1, and sweet and erect such as *Pwani* and *Kipusa)*. The most local cultivars preferred by farmers which make bigger portion of cultivated cassava in Eastern and Southern Tanzania include; *Namikonga,* *Sheria, Albert, Nachinyaya, Kibanga meno, Mahiza, badi, Nalilekuchumba, Kifuu cha nazi, Mtukane,* and *Kigoma* red.

2.3 Cassava Starch Industrial Value

Cassava starch is normally extracted from the roots of the cassava crop. The large central pith of the cassava root is the starch-reserve flesh and in starch content from as low as 15% to as high as 33%. It is very useful in bakeries and the manufacture of glucose, dextrins and other products.

2.3.1 Cassava Starch in Textile Industries

Modified starch is utilized in sizing and dyeing that make the finished fabrics look brighter, harder and with increased weight (Srinivas, 2007, Tonukari *et al.,* 2015). Modern laundries curently use soluble starch, wrapped with containers for applying starch to clothes during steam ironing (Tonukari *et al.*, 2015).

2.3.2 Cassava Starch in Pharmaceuticals

In pharmaceutical industries, starch is used as a carrier material for chemical active ingredient and bonding agent for producing tablets (Singh and Nath, 2012). Also there is a high demand for glucose syrups, due to its easy availability and high quality starch found in cassava. This starch can be widely used in the making of tablets, capsules, and powder formulations (Atichokudomchai and Varavinit, 2003, Tonukari *et al.*, 2015), as it absorb moisture and swell after swallowing resulting in disintegration of the tablet and dispersal of the active ingredient (Bos *et al.*, 1987).

2.3.3 Cassava Starch in Detergent Industries

In the manufacturing of soap and detergent, starch is used to get better recovery and to improve the shelf life of detergents .Cassava starch is commonly used as fillers in producing soap; it is usually mixed with the particles of soap before milling (Tonukari, 2004).

2.3.4 Cassava Starch in the Production of Confectioneries

Cassava starch can be converted to maltotriose and maltose as well as to other modified sugars and organic acids (Tonukari *et al.*, 2015). Starch is mostly used as an input for producing sugar syrups in a process known as controlled enzymatic hydrolysis, which involves the use of either acid or α-amylase enzyme. Cutting the starch chain using acid will produce a mixture of dextrin maltose and glucose, and cassava starch is particularly suitable for this purpose. Enzymatic isomerization of glucose syrup is use for the preparation of high fructose syrup (Richana *et al.*, 2000). Research has shown that the amylose content of cassava starch is lower than that of arrowroot, but the productivity of cassava roots is much higher than that of arrowroots (Richana *et al.,* 2000).

2.3.5 Cassava Starch in the Production of Bioethanol

The benefits of using cassava as a raw material for ethanol production are due to the fact that it can be planted on marginal land where other agricultural crops such as sugarcane, rice, wheat and maize can not be grown (Zhang *et al.,* 2003). Industrial alcohol made from cassava starch can be used as feedstock to produce a large amount of organic chemicals like organic acids (citric acid and enzymes).

2.4 Crop Morphology

Cassava, which is a shrub reaching 1–4 m height, is commonly known as *muhogo*, tapioca, manioc, mandioca and yuca in different parts of the world. Belonging to the dicotyledon family Euphorbiaceae, the manihot genus is reported to have about 100 species, among which the only commercially cultivated one is *Manihot esculenta* Crantz. There are two distinct plant types: erect, with or without branching at the top, or spreading types.

The morphological characteristics of cassava are highly variable, which indicate a high degree of interspecific hybridization. There are many cassava cultivars in several germplasm banks held at both international and national research institutions. The largest germplasm bank is located at Centro Internacional de Agricultura Tropical (CIAT), Colombia, with approximately 4 700 accessions (Bonierbale *et al.*, 1997, Alves, 2002), followed by EMBRAPA's collection in Cruz das Almas, Bahia, with around 1 700 accessions (Fukuda *et al.,* 1997).

The cassava genotypes are usually characterized on the basis of morphological and agronomic descriptors, about 75 descriptors have defined, 54 being morphological and 21 agronomic (Fukuda *et al*., 1997). Morphological descriptors (for example, lobe shape, root pulp colour, stem external colour) have a higher heritability than agronomic (Alves, 2002). (such as root length, number of roots per plant and root yield), Among morphological descriptors, the following were defined as the minimum or basic descriptors that should be considered for identifying a cultivar: (i) apical leaf colour; (ii) apical leaf pubescence; (iii) central lobe shape; (iv) petiole colour; (v) stem cortex colour; (vi) stem external colour; (vii) phyllotaxis length; (viii) root peduncule presence; (ix) root external colour; (x) root cortex colour; (xi) root pulp colour; (xii) root epidermis texture; and (xiii) flowering (Wheatley and Chuzel, 1993).

The upper leaf surface is covered with a shiny, waxy epidermis. Most stomata are located on the lower (abaxial) surface of the leaves; only a few can be found along the main vein on the upper (adaxial) surface (Cerqueira, 1989; Alves, 2020). The stomata on the upper surface are also functional and bigger than those on the undersurface. Both are morphologically paracytic, with two small guard cells surrounded by two subsidiary cells (Cerqueira, 1989; Alves, 2002).

2.5 Cassava Production in Tanzania

In Tanzania, cassava is produced mostly by small scale farmers on either marginal or sub-marginal soils. The major producing areas in the country includes; the coastal strip along the Indian Ocean (Tanga, Dar es Salaam, Lindi and Mtwara) producing on average 48.8% of the total cassava production, areas along Lake Nyasa (13.7%), Western and Central Zone of Tanzania with estimated production of 7.9% and (5.0%) respectively (Ndunguru, 2005).

Table 2: Cassava Production Trend in Tanzania Since 2006

Year	Area (Ha)	Production (t)
2006	906 387	5 539 160
2007	779 067	5 198 934
2008	837 744	5 392 358
2009	1 081 384	5 916 440
2010	873 000	4 547 940
2011	739 794	4 646 523
2012	954 509	5 462 454
2013	863 678	4 755 160
2014	800 454	4 992 759
2015	1 094 900	5 886 440
2016	1 008 706	5 384 315
2017	896 365	5 014 624

Source: FAOSTAT, 2018

2.6 Production Constraints

A wide range of naturally occurring biotic and abiotic constraints, including poor soils, water scarcity, crop pests and unsuitable temperatures, are well-known to reduce the productivity of food crops, leading to low efficiencies of input use, suppressed crop output, and ultimately reduced food security in Sub Sahan Africa (Strange and Scott 2005;

Gregory *et al*., 2005; Lal, 2009; Waddington *et al*., 2010; Knox *et al*., 2012). Common constrains include pests and diseases, poor agronomic practices, high cyanide levels, lack of clean planting materials, low yielding varieties, and long maturity periods (Thresh *et al*., 1994, Rajabu, 2013).

Pests and diseases are widely considered to be the most important constraints to cassava production in Africa. The most significant pests are mealy bug (*Phenacoccus manihoti* Mat. Ferr) and green spider mite (*Mononychellus tanajoa* (Bondar) (COSCA Tanzania, 1996; Ndunguru, 2005) both of which were introduced inadvertently to Africa from South America in the early 1970s.

Cassava brown streak (CBSD) was first reported in Tanzania in 1936 (Storey, 1936) and shown to be endemic in all coastal cassava growing areas up to 1000 meters above sea level (Nichols, 1950; Hillocks, 2003; Ndunguru, 2005). A virus belonging to the family *Potyviridae*, genus *Ipomovirus* has been identified as the causal agent of CBSD (Monger *et al.,* 2001). Cassava brown streak virus (CBSV) induces root symptoms comprising of dry necrotic rotten patches, as well as brown lesions on the stems and yellowing of leaves (Hillocks *et al.,* 1996). Field experiments to determine the effect of the disease on yield and quality of the roots showed that CBSD can decrease root weight in the most susceptible cassava genotypes by up to 70% in Tanzania (Hillocks *et al.,* 2001). CMD however, constitutes the most formidable threat to cassava production and can be observed wherever cassava is grown in Africa (Legg and Fauquet, 2004). Other production constraints include agronomic problems; soil fertility, water limitation, land degradation, shortage of planting materials, access to markets and limited processing options (COSCA Tanzania, 1996).

There has also been growing concern that farming practices themselves, both in extensive food crop production systems (found widely in Sub-Saharan Africa) and intensifying systems (common in South Asia) are exacerbating biotic and abiotic constraints on food production through negative impacts on the environment (Poppy *et al*., 2014; Dogliotti *et al*., 2014; Reynolds *et al.*, 2015). Common examples include environmental degradation through agriculture-related deforestation, soil erosion, nutrient mining, water depletion, soil/water/air pollution, biodiversity loss, and climate change; all of which threaten the long-term viability of agriculture and agro-ecosystems (Cassman *et al*., 2003; Keating *et al*., 2010; Phalan *et al*., 2011; Pretty *et al*., 2011; Tilman *et al*., 2011; Reynolds *et al.*, 2015).

2.7 Staggered (Scheduled) Planting

In agriculture, staggered planting refers to several planting times that increase crop availability during a growing season by making efficient use of space and timing (Bybee-Finley and Mathew, 2018); it aims at overlapping the harvesting times of several different crops in order to provide the household with a continuous supply of a variety of foods all year round. This staggered cropping is used when the same crop is sown or planted in small amounts, in a succession manner over a period of time, to ensure a continuous supply of that particular crop. This approach is used for foods that are eaten regularly but cannot be easily stored, such as root/tuber crops and leafy vegetables, Mittenthal (2007) as there was no study conducted in cassava staggering in Tanzania, therefore; this research has addressed the issue.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

This study was conducted at the experimental sub- substation in Mkumba Nachingwea, -Lindi, on-stations experimental sites of TARI (Tanzania Agricultural Research Institute) Nalienedele in Mtwara and TARI –Ilonga in Morogoro (Figure 1). The experiments were conducted during growing seasons of 2017/18 and 2018/19. TARI-Naliendele experimental site is located at 10° 33'S and 38°77'E, 125 m. a.s.l. and receives mean annual rainfall of 950mm, the rainy season begins in November/December and ends in April/May. It has unreliable onset dates and a three to four week midseason dry spell period or seasonal interruption, experienced in February (Bennett *et al.*, 1979a; De Pauw, 1984; Matema *et al.*, 2019).The monthly mean temperature of 27°C, average relative humidity of 86% and the soil is characterized by sandy loam soil texture and pH of 5.7 (Daud *et al.*, 2016). Mkumba experimental site is located at 10°38’ S and 40°17’E, 465 m. a.s.l. has a mean annual rainfall of 850 mm, mean monthly temperature of 25°C, characterised with sandy clay soils and annual mean relative humidity of 78%.

TARI- Ilonga is located at 6°79’’ S and 37° 03’’ E and at the altitude of 470 m. a.s.l. It experiences an average rainfall of 800mm –1400mm with black clay and loamy soils. The annual temperature is between 25°C and 30°C (Kahimba *et al*., 2015). The two sites of Southern zone experience a uni-modal type of rainfall distribution while TARI- Ilonga in the Eastern zone experiences bio modal rainfall distribution. At TARI- Ilonga short rains normally start in October to December and long-term rainfall start in mid-February continue to May. Naliendele and Mkumba, long usuall rains start at the end of November to mid-May (Daud *et al*., 2016).

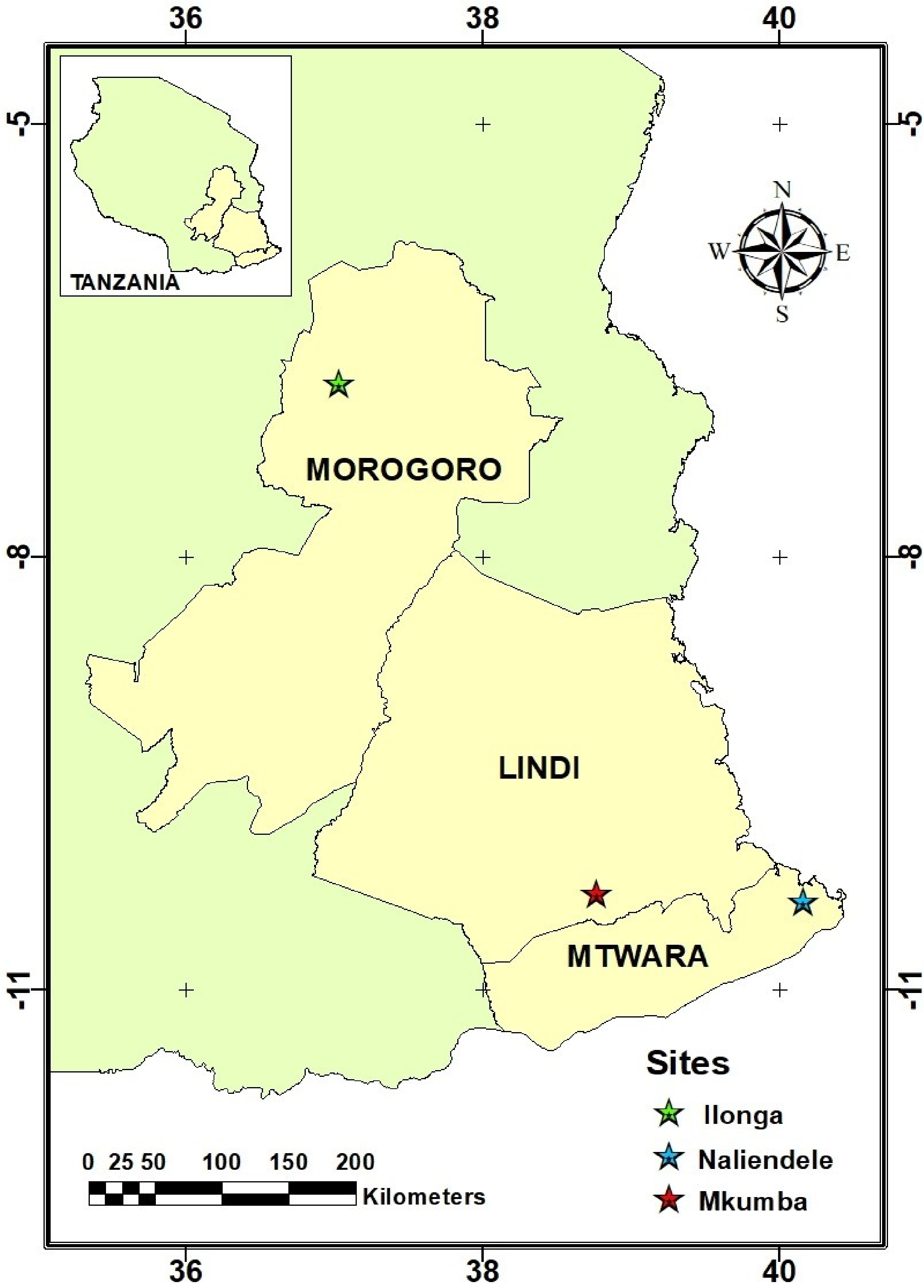

Figure 1: Sites where experiment was conducted

Specific Objective i: To Evaluate Cassava Varietal Performance on Growth, Development, Yield and Yield Components

3.2 Experimental Materials

Three cassava improved varieties sourced from research centres (TARI Naliendele and Ilonga) were used. These varieties were namely; sweet Kiroba, characterized as early maturing (matures at 9 months after planting), branching, tolerant to CBSD and CMD and high yielding variety with a potential production of 30 t/ha. The other cassava variety was Sweet *Mkuranga* 1 is a medium maturing (12 months after planting), branching, tolerant to CBSD and CMD and moderately yielding variety producing on average 20 t/ha and *sweet Chereko* is a late maturing variety up to 13 months after planting, branching, tolerant to CBSD and CMD and moderately yielding variety producing on average 21 t/ha were used (TOSCI, 2015b).

3.3 Experimental Methods

Different mineral fertilizers were used in this study at various application rates. *Minjingu mazao* (N 10%; P2O5 20%; S 5%; CaO 25%; Zn 0.5%, B 0.1%; MgO 1.5%), Barhe and Hailu (2017) with intention of supplying P nutrient was used at the rate of 20 kg P/ha, YARAmilla (N 15%, P 9%, K 20%, MgO 1.8%, SO_3 9.5%, B 0.015%, Mn 0.02% and Zn 0.02%) as a source of N was applied at 75 kg N/ha and Murate of Potash (MOP) as a source of K (60% potash) was applied at 90 kg K /ha as blanket recommendations.

The experiment was conducted as a split- split plot design laid down as randomized complete block design (RCBD) with four replications. The experiment had three factors; which were A, B and C. Factor A was made up of three cassava varieties; *Kiroba, Mkuranga* 1 and *Chereko*. Factor B consisted of harvesting times that were eight as harvest on (H1), ten as harvest two (H2) and twelve months after planting as harvest three

(H3). Factor C included planting schedules that were at the beginning of the cropping season (onset of rainfall usually November/December) as planting one (P1), four weeks after the beginning of the cropping season as planting two (P2) and eight weeks after the beginning of the cropping season as planting three (P3). Cassava was planted at the spacing of 1 m x 1 m equivalent to 10 000 plants per hactre. Cassava cuttings (25 cm) were taken from middle part of stems with eight nodes; four nodes were buried during planting at centre of ridges at an angle of 45° and depth of 15cm. The plot size was 7 m x 7 m where each plot had 7 rows in a sub plot. The net plot was 5 m x 5 m equivalent to 25 m^2, in total there were four replications in each site with 12 main plots, 36 sub plots and 108 sub-sub plots.The distances between plots was 2m and 3m for replications.

3.3.1 Other Agronomic and Crop Protection Measures

Ploughing and harrowing were done using tractor and ridges were constructed (tied ridges 60 cm high and 30 cm wide) by using hand hoe. Planting was done as already explained under (section 3.3) above. Irrigation using the watering canes was done whenever crop indicated water stress signs. Termites attack was controlled by applying *Duduba* at 10mil/15litters of water at planting and every four weeks until the crop was five months of age. No disease control measures were applied. Manual weeds control was applied using hand hoe started two months after planting (2MAP) to harvesting time.

3.3.2 Soil Sampling and Analysis

Before land preparation soil sampling at 0-20 cm and 21-50 cm (Apendix i) was undertaken using soil auger to assess initial soil physical and chemical properties (Mason, 1992). Soil particle distribution analysis was determined by the hydrometer method (Okalebo *et al.*, 2002). Total nitrogen was determined by Kjedahl- digestion- distillation method as described by Anderson *et al.*, (1993); Black, (2013). Available phosphorus was determined by Bray and Kurtz, (1945). Soil organic carbon was determined using oxidation method by Walkley (1935) .The soil pH was determined in water in a ratio of 1:2.5 water suspensions. The Soil cation exchange capacity and exchangeable basic cations were extracted by 1.0 M neutral NH_4AC then N^+ and K^+ were analysed by a flame photometer while Ca^{2+} and Mg^{2+} were determined by atomic absorption spectrophotometer (AAS) as described by Anderson, (1993) and Thomas, (1982). The total exchangeable bases (TEB) were calculated as the sum of the four bases (Ca^{2+}, Mg^{2+}, Na^+ and K^+) as narrated by Black, (2013),

3.4 Weather Data Collection

Weather monthly data were collected from Tanzania Meteorological Authority (TMA) stations at TARI-Naliendele, Mkumba and Ilonga. Relative Humidity (%), Temperature; Minimum and maximum (ºC), Total rainfall (mm), evaporation (mm) were taken once every month from trial establishment till harvest.

3.4.1 Crop Data Collection

3.4.2 Cassava Sprouting (%)

The sprouting count of cassava was collected from $25m^2$ per experimental unit and the sprouting percentage was determined as follows;

Sprouting (%) = Number of plants with buds/ Total number of plants x 100.

This type of data was determined at the 4^{th} week after planting.

3.4.3 Branching and Flowering Time

Number of days to first branching and flowering at 50% were also recorded for each experimental factor.

3.4.4 Diseases and Pest Scoring

Diseases severity scored of foliar symptoms of each of the net plot for cassava brown streak disease (CBSD) and cassava mosaic disease (CMD) starting at three MAP till it was harvested i.e. 8 MAP as early harvest, 10 MAP as middle harvest and 12 MAP as late harvest. Cassava brown streak disease root severity and incidence were evaluated at harvest time i.e. at 8, 10 and 12 (MAP). Plants were assigned disease severity scores based on the standard five point scoring scale for CBSD as described by IITA, (1994), as; 1: No apparent symptoms, 2: Slight foliar feathery chlorosis, no stem lesions, 3: Pronounced foliar feathery chlorosis, mild stem lesions and no die back, 4: Severe foliar feathery chlorosis, severe stem lesions and no die back and 5: Defoliation, severe stem lesions and die back. Root symptoms scoring was done using scale a scale of 1-5 (IITA, 1994), where: 1: No apparent necrosis, 2: Less than 5% of root necrotic, 3: 5-10% of root necrotic, 4: 10-25% of root necrotic, mild root constriction and 5: > 25% of root necrotic with severe root constriction.

The leaf damage assessment against Cassava mealy bug (CMB) and Cassava green mite (CGM) pests was recorded using a scale of 1 to 5 as reported by IITA, 1994, with minor modifications i.e. 1: means no obvious symptom, 2: less than 5% of leaf chlorosis, 3: more than 5% but less than 50% of leaf chlorosis, 4: more than 50%of leaf chlorosis with significant reduction and constriction in leaf area and 5: leaf is dead and perhaps dropped.

3.5 Data Analysis

Descriptive statistics including total, mean and range were calculated and use for soils and weather data. Inferential statistics such as ANOVA at ($P \leq 0.05$) was calculated based on randomized complete block design (RCBD) ANOVA model as indicated below.

$Y_{ij} = \mu + \tau_i + \beta_j + \varepsilon_{ij}$

Where as Yij = response level (e.g cassava sprouting percentage), μ = general mean effect, τi = (variety effect), βj = blocks/ replications effect and εij = are the residuals, the deviations of each observation from their expected values. DMRT at 5% was applied to separate the means.

Specific Objective ii: To Access the Influence of Planting Schedules and Harvesting time on Yields and Quality of cassava

3.6 Data Collection

3.6.1 Determination of Cassava Yield Traits

Harvesting was done by uprooting the plant from the soil. Biological yield was determined by harvesting all plant parts (roots, stems, branches and leaves) from all net experimental units ($25m^2$), counted the number of roots on each plot and fresh weight was determined in (kg). Economic yield was determined by separating the roots from the biological yield (total fresh weight) whereas the roots were thorough cleaned by removing soils and weight was determined in (kg) and converted to t/ha. The cassava roots harvested were used in determination of dry matter content and starch accumulation

3.6.2 Root Diameter

The root diameter (cm) was determined by using a venier calliper, measured at the centre of root. Five roots were randomly selected from each experimental unit.

3.7.3 Root Length

The root length (cm) was determined by using a tape measure, measured from the root attachment from the stem to its tip and the diameter using Vernier calliper as described by Noerwijati and Budiano, (2015).

Based on the weight (kg) of marketable and non-marketable roots; cassava fresh yield was computed in (t/ha) as indicated hereunder.

$$\text{Yield (t / ha)} = \frac{\text{F W (kg)}}{\text{N}} \times 1000 \quad \text{……………… (i)}$$

Where: FW is total fresh weight of tuberized roots per plot in kg, N is number of harvested plants in a plot and 1000 is conversion factor from kg to t ha^{-1}.

Harvesting index (HI) was computed in which all harvested plants per plots were partitioned into roots and biomass (stems and foliage). Separate weights of roots and above-ground biomass were determined, and then HI determined as the ratio of roots to the total biomass (Lahai and Ekanayake, 2009) as indicated below.

$$\text{HI} = \frac{\text{Mass of root}}{\text{Total biomass}} \quad \text{………………..……..(ii)}$$

3.7.4 Determination of Cassava Dry Matter Content (DM)

Estimation of DMC in cassava bases on the principle of a linear relationship between specific gravity with DM (Kawano *et al*., 1987).

DM % = 158.3x – 142; ……………………………………………………….…(iii)

Where; x stands for the specific gravity of the cassava root sample.

The Procedures that were taken to determine DM content for roots were that: Root samples from each plot weighing 3 kg were used.

The samples were weighed in air (wa) and then weighed in water (ww). These weights were then used for computation of specific gravity.

$$\text{Specific gravity}(X) = \frac{\text{Wa}}{\text{Wa} - \text{Ww}} \times 100 \quad \text{……………………..(iv)}$$

DM % = 158.3X - 142 ……………………………………………………….(v)

3.7.5 Determination of Starch Accumulation

According to Kawano *et al*., (1987), determination of starch content was taken with the same principles as those determined % DM. In estimating the starch%, the relationship used was:

Specific gravity(X) $= \frac{Wa}{Wa - Ww} x\ 100$

% Starch Content = 112.1x - 106.4…………………………..………………………(vi)

3.7.6 Data Analysis

Data were subjected to analysis of variance (ANOVA) at ($p < 0.05$) using GenStat Release 18 statistical package under split plot statistical modal as shown below for planting and harvesting time effects;

$Yijk = \mu + ri + \alpha j + (r\alpha)\ ij + \beta k + (r\beta)\ ik + (\alpha\beta)\ jk + (r\alpha\beta)\ ijk + \varrho ijk.$

Whereas;

μ =General mean error, ri: block effects (random), αj: whole-plot factor (planting) as main effects, (rα)ij: planting-plot error (random), βk: sub-plot factor (harvesting schedules) main effects, (rβ)ik: harvesting schedule error, (αβ)jk Interaction between planting and harvesting schedules (rαβ)ijk: interaction of planting and harvesting time error (random ϱijk: harvesting time random error, ϱijk iid∼ N. While the the combine factors and their perspective interaction, split –spit plot statistical modal was applied as indicated below:

$Y_{ijkl} = \mu+\beta_i +A_j +\delta_{ij} B_k +AB_{ik} +\omega_{ijk} +C_m +AC_{im} +BC_{km} +ABC_{jkm} +\varepsilon_{ijk}$

Where, Y_{ijkm} =Response level, μ=General error mean, β_i =block effect, A_j =Varietal effect, δ_{ij} =Varietal (error a), B_k =Harvesting times effect, AB_{ik} =Interaction effect between Varieties and Harvesting times, ω_{ijk} = Harvesting times error (error b), C_m =Planting times effect, BC_{km} = Interaction effect between Varieties and Planting times, ABC_{jkm} =The interaction effect between Varieties and Harvesting times and Planting times and ε_{ijk} = Planting times error effect (error c).

Significant means were separated by using DMRT at 5 % probability (Gomez and Gomez, 1984).

CHAPTER FOUR

4.0 RESULTS

4.1 Soil Physical and Chemical Characteristics at the Experimental Sites

The physical and chemical characteristics of soils sampled at the three experimental sites that is Naliendele (Mtwara), Nachingwea (Lindi) both in the Southern zone and Ilonga (Morogoro) found in the Eastern zone are shown (Table 3). Both physical and chemical characteristics were analysed at IITA soil laboratories in Dar es Salaam to assess fertility status and their suitability for cassava production.

4.1.1 Soil Characteristics

As indicated in (Table 3), the soils at the three sites were found to be sand at Naliendele (91.0% sand, 7.0% clay and 2.0% silts), sandy loam at Nachingwea and sandy clay at Ilonga. The major soil fertility limitations at 0-20cm and 21-50cm soil depth for Naliendele site in Mtwara included low total nitrogen (0.082-0.065 %), available phosphorus (2.4-1.6mg/kg) respectively, and medium organic matter (1.0689%), According to the USDA textural class triangle (Soil staff, 1993). The texture of the soil is predominantly sandy with high sand fraction for both surface and subsurface soils, the soil have weak surface aggregation. Such soil may lack adsorptive capacity for basic plant nutrient and may be susceptible to erosion menace. With the absence of rock fragments (boulders) in the subsurface soils, it may permit available water capacity in direct proportion to their volume (Gbadegesin *et al.*, 2011).

However, at TARI-Ilonga site the texture of soil was classified as sandy clay (Soil staff, 1993) with low total nitrogen (0.13%), sufficient available Phosphorus (11.850meq/kg), high exchangeable, Potasium (0.685cmol$_c$(+)/kg) and sufficient exchangeable Calcium

(4.602). According to Onwueme and Sinha, (1991), cassava can grow on a wide range of soils, but is best adapted to well drained, light-textured, deep soils of intermediate fertility. Under high fertility conditions top growth may be stimulated at the expense of root growth. Optimum soil pH is between 4.5 and 6.5. The crop does not grow well in poorly drained soils, gravelly or saline soils, or in soils with a hardpan. Hence the locations support the cassava production.

Table 3: Physio-Chemical Properties of Soils at the Experimental Sites

		Naliendele (Southern Zone)		**Nachingwea (Southern Zone)**		**Ilonga (Eastern Zone))**		
Soil characteristics	**SI Unit**	**Value**	**Remarks**	**Value**	**Remarks**	**Value**	**Remarks**	**Rated according to;**
Clay	%	7.0		17.6		29		
Silt	%	2.0		3.4		16		
Sand	%	91.0		79		55		
Texture Class	%	Sandy		Loamy sand		Sandy Clay		Soil staff, 1993
pH		5.72	Moderately acid	5.39	Moderately acid	6.44	Slightly acid	Soil staff, 1993
Soil organic matter	%	1.07	Low	3.22	Medium	2.84	Medium	Howeler, 1996
Soil organic carbon	%	0.62	Low	0.97	Medium	1.65	Medium	Landon 2014
Total nitrogen	%	0.07	Low	0.05	Low	0.13	Low	Landon,2014
Cation Exchange Capacity	$cmol_c$/kg	2.62	Very low	4.69	Low	18.96	Medium	Landon,2014
Available phosphorus	meq/kg (+)	2	Low	10.95	Medium	11.85	Medium	Howeler, 1996
Exchaneable Potassium	$cmol_c$/kg (+)	0.23	Medium	0.82	High	0.69	High	Howeler, 1996
Excheable Calcium	$cmol_c$/kg (+)	0.39	Low	2.53	Medium	4.60	Medium	Howeler, 1996
Excheable Sodium	$cmol_c$/kg (+)	0.88		0.75		0.96		
Magnesium	$cmol_c$/kg	0.13	very low	0.59	Medium	0.86	Medium	Howeler, 1996
Copper	meq/kg	0.90	Medium	2.25	High	5.71	High	Howeler, 1996
Zinc	meq/kg	0.85	Low	1.19	Medium	1.39	Medium	Howeler, 1996
Manganese	meq/kg	62.38	Medium	68.75	Medium	83.65	Medium	Howeler, 1996
Iron	meq/kg	27.94	Medium	118.78	High	134.91	High	Howeler, 1996

4.1.2 Soil Reaction (pH)

The soil reactions both surface and subsurface soils were acidic (Table 3) at Naliendele, Nachingwea and Ilonga (pH 5.72, 5.39 and 6.44) respectively. According to Howeler, (1996); physical and chemical properties for cassava growth rated this range as medium hence proper for cassava production. However, Bready and Weil, (2008) suggested that such pH condition of the soils could be attributed to leach out of basic cations from the soil solum and induce phosphate fixation and reduce the ability of microorganisms to fix atmospheric nitrogen.

4.1.3 Total Nitrogen

Total nitrogen contents was very low (range, 0.082 to 0.065%) for Naliendele site and low (0.13, 0.13%) at Ilonga, (Table 3) with surface and subsurface soils respectively. This level of total nitrogen cannot sustain intensive crop production as values were below 0.45% established for cassava productive soil (Gbadegesin *et al*., 2011). This low level of total nitrogen could be attributed to rapid microbial activities (leaching of nitrates).

4.1.4 Available Phosphorus

From the results (Table 3); Phosphorus value was low (range, 3.08 to 2.18 $cmol_c$ /kg) at Naliendele while at Ilonga results showed sufficient P (6.1, 17.6 $cmolc_c$ /kg) in the surface and subsurface soils. Therefore, the soils are poor and good in phosphorus mineral respectively. Exchangeable bases were generally low with the following ranges of values Ca (0.378 to 0.392 $cmol_c$ /kg); Sodium (0.872 to 0.88 $cmol_c$ /kg); Magnesium (0.200 to 0.052meq/kg); Copper (0.352 to 1.454 meq/kg; Zinc (0.980 to 0.715) meq/kg of soil; Manganese (64.953 to 59.813 meq/kg); Iron (27.941 to 27.941 meq/kg). With these levels of exchangeable bases, the soils lack adsorptive capacity for nutrient. These low values reflect the pH, hydrogen and aluminium ions may be the principal contributors to exchangeable acidity in the soils. The Effective Cations Exchange Capacity (ECEC) was generally low. Adequate supplies of the nutrients K, Mg, Zn (Cakmak, 2006; Marschner, 2012) and also of N and Ca (Cakmak, 2006) are also known to help plants combat abiotic stress. Abiotic stress in cassava is known to influence cyanogenic glucoside production (Jørgensen *et al.,* 2005) by mainly increasing it, as observed with water stress (Vandegeer *et al.,* 2013). Copper was additionally sufficient in this site, which considered as good for crop growth range from 0.352 to 1.454 meq/kg. On the other hand Fe and Mn were mainly sufficient. Sufficient levels of Fe and Mn were expected as soils in Mtwara region are predominantly Ferralic cambisols (De Pauw, 1984; Mowo *et al*., 1993, Matema *et al.*, 2019) and are thus dominated by Fe and Mn oxides and hydroxides (IUSS Working Group WRB, 2014) as shown in (Table 3).

4.1.5 Exchangeable Potassium

Exchangeable K in soil at the experimental sites was 0.272, 0.188 and 0.73, 0.64 $cmol_c$ /kg in surface and subsurface soils with Naliendele and Ilonga respectively (Table 3). According to Howeler, (1996), exchangeable K > 0.25 is categorized as high values. This level indicated that soil at the experimental sites does not require K fertilizer for optimum cassava growth and this might be due to the particular parent materials from which these soils were derived since the locations do not have a history of better fertilizer applications. Moreover, application of K fertilizers in future is important as cassava extract high amount of potassium mineral than others (Fageria *et al.*, 1997).

4.2 Weather Data at the Experimental Locations

Weather data were subjected to descriptive statistics. The total rainfall across the sites ranged from 720 to 1200 mm/year; minimum and maximum temperature ranged from 21°C to 32°C and the relative humidity ranged between 79% and 87% (Table 4) shows the monthly mean temperature (minimum and maximum °c), relative humidity (%), total evaporation (mm) and total rainfall (mm) collected during the experimental period at Naliendele, Nachingwea and Ilonga. According to Onwueme and Sinha, (1991), cassava grows best in areas with a mean temperature of 25-29°C, and a soil temperature of about 30°C; below 10°C the plant stops growing. Also it grows well in areas with an annual well-distributed rainfall of 1000-1500 mm, it can tolerates semi-arid conditions with rainfall as low as 500 mm, and may have a competitive advantage over other crops under those conditions (Holower, 1981). The weather data of the sites are within the commended range hence support the crogwth of cassava.

Table 4: Minimum and Maximum Temperature, Relative humidity, Total rainfall, and Evaporation Data for Naliendele, Nachingwea and Ilonga sites during the 2017/18 - 2018/19 cropping seasons.

	Naliendele					Nacxhingwea				Ilonga				
Month	**Temp Min (°c)**	**Temp Max (°c)**	**RH (%)**	**Total Rain (mm)**	**Evapo (mm)**	**Temp Min (°C)**	**Temp Max (°C)**	**Total rain (mm)**	**RH (%)**	**Temp Min (°C)**	**Temp Max (°C)**	**RH (%)**	**Rain (mm)**	**Evapo (mm)**
2017														
November	22.7	31.2	68	40.3	139.8	21.7	33	63.9	67	21.1	32.2	52	76.6	5.8
December	24.1	31.2	73	132.3	6.5	22	31.8	119.2	76	21.7	33.5	47	54.1	6.8
2018														
January	22.7	28.8	76	176.7	114.9	21.4	29.2	208.2	85	20.4	30.1	77	227.6	3.8
February	21.7	28.5	67	69.9	110	21.7	31.7	78.8	82	21.4	33.4	61	25.8	7
March	23.1	31.4	77	169.7	106.7	23	30.6	204.4	85	20.9	31.1	65	226	4.3
April	22.9	30.5	77	303.6	66.7	19.5	29.1	96.2	83	20.7	29.7	62	191.8	3.8
May	22.3	30.9	65	27.2	116.2	20	29.7	20.6	84	19.6	28.8	62	40.7	3.5
June	20.6	30.4	52	3.6	127.6	18	29.1	0	77	16.7	28.2	52	4.3	4
July	19.7	29.8	58	9.8	129.3	17	28.8	0	72	16.9	27.8	50	8.8	3.9
August	19.6	30.4	57	10.3	119.3	17.5	30.6	0	72	17.8	29.5	43	5.7	5.3
September	20.5	29.6	63	47.2	125.2	18.7	30.7	24.8	70	19.9	31.2	43	23.8	6.7
October	21.3	30.8	58	13.7	148.5	21.5	32.9	0	65	21.7	31.5	49	8.9	6.4
November	22.9	32.7	59	4.4	158.9	21.7	34.1	15.9	71	22.8	34.2	44	15	8.4
December	32	332.5	24.1	153.4	6.7	22.4	33.5	91.4	75	22.8	33.7	48	132.7	6.9
2019														
January	24.5	30.7	75	124.1	128.1	112.3	22.8	112.3	31.8	33.2	23	53	77.2	6.1
February	23.8	30.8	85	224.4	74.8	98.6	22.2	98.6	31.2	33.5	22.6	66	150.2	6.8
March	23.9	31.9	72	183.5	144.8	121.6	22.4	121.6	31	33.4	24	68	60.1	6
April	23.8	31.2	76	153.8	96.8	114.4	21.7	114.4	30	31.7	26	71	68.3	4.4

Source: Tanzania Meteorological Authority (TMA), 2019

*Temp min=Temperature minimum, Temp max=Temperature maximum, rain=Ranfall, Evapo= Evaporation, RH= Relative humidity

4.3 Selected Cassava Growth Characteristics at the three Experimental Sites

4.3.1 Effect of Variety on Cassava Sprouting Percentage

Statistically, sprouting percentage was significantly different ($p < 0.05$) at Naliendele and very highly significant ($p < 0.001$) at Nachingwea and Ilonga sites. *Mkuranga* 1 variety had the highest (82.56%) sprouting percentage, followed by *Chereko* (77.67%) and *Kiroba* the least (76.56%) (Table 5). This could be contributed by the use of good planting materials, soaking of planting materials into termiticides (*duduba*) before and after planting, and sufficient soil moisture content during planting.

Plate 1: Soaking Cassava Planting Sticks into ''*duduba*'' termiticides at Naliendele

Table 5: Effects of Varieties on Cassava Sprouting Percentage

	Cassava sprouting (%)		
	Naliendele	**Nachingwea**	**Ilonga**
Kiroba	76.56a	73.33a	72.44a
Mkuranga 1	82.56b	82.33c	79.00c
Chereko	77.67a	76.22b	74.67b
Mean	78.93	77.30	75.37
CV (%)	10.4	11.1	8.4
SD	8.2	8.5	6.3
P value	0.011	<0.001	<0.001

*All means in the same column having the same letters had no significance difference at (p<0.05) when separated by Duncan Multiple Range Test (DMRT).

4.3.2 Effects of Cassava Varieties on Days to 50% first Branching and Flowering at Naliendele, Nachingwea and Ilonga experimental sites

The first branching and flowering days at 50% for Naliendele, Nachingwea and Ilonga sites was observed that varieties had highly significant difference (p < 0.001) except for the days for 50% first flowering at Ilonga site. *Mkuranga* 1 had fewer days both at branching and flowering at 99, 96,102 and 134, 121, 136 respectively. *Kiroba* followed with 118, 116, and 117days for first branching and 152, 137, 150 flowering days. *Chereko* was observed to take many days to first branching and flowering days compared to other two varieties with 132, 132 and 134 days to 50% first branching and 162, 151 and 162 days (Table 6) .

Table 6: Effects of Cassava Varieties on Days to 50% first Branching and Flowering at Naliendele, Nachingwea and Ilonga experimental sites

	Naliendele	Nachingwea	Ilonga

	Days to 50% first branching	Days to 50% flowering	Days to 50% first branching	Days to 50% flowering	Days to 50% first branching	Days to 50% flowering
Kiroba	117.8b	152.3b	116.1b	137.1b	117b	149.6b
Mkuranga 1	99a	134.2a	95.6a	121.3a	101.7a	135.9a
Chereko	132.c	162.4c	132c	150.7c	134.2c	161.8c
Mean	116.4	149.7	114.6	136.4	117.6	149.1
CV (%)	10	8.4	9.6	6.1	11.5	17.1
SD	11.64	12.57	11	8.32	13.52	25.5
P value	<0.001	<0.001	<0.001	<0.001	<0.001	0.0131

*Means in the same column followed by the same letters are not significantly different as determined by Duncan's Multiple Range Test at (P ≤ 0.05).

4.3.3 Effects of Cassava Varieties on Selected Foliar Pests at Naliendele

Results showed that no significant differences existed among the cassava varieties at Naliendele site on cassava pest's incidence (Inc) and severity (Sev). Cassava green mite was higher (4.090%, 1.148 for *Mkuranga 1*) followed by (1.22%, 1.074) for *Chereko*) and lowest (0.46%, 0.968) for *Kiroba* variety for incidence and severirty respectively (Table 7). On the other case, CMB was observed higher in *Mkuaranga* 1 (4.09%, 1.148), followed by *Chereko* (1.22%, 1.074) and *Kiroba* with lowest (0.46%, 0.968). With diseases; CMD was highest in *Kiroba* (1.23%, 1.056) and almost not present on *Mkuaranga 1* and *Chereko* (0.82%, 1.046 and 0.23%, 1.028 respectively), Foliar CBSD was highest in *Mkuaranga 1* (3.29%, 1.157), followed by *Kiroba* (2.97%, 1.171) and *Chereko* (2.21%, 1.204).

Table 7: Effects of Cassava Varieties on Selected Foliar Pests at Naliendele

Factor	CBSDInc	CBSDSev	CMDInc	CMDSev	CGMInc	CGMSev	CMBInc	CMBSev
Kiroba	2.97a	1.171a	1.23a	1.056a	2.407a	2.62	0.46a	0.968a
Mkuranga 1	3.29a	1.157a	0.82a	1.046a	2.657a	2.79	4.09a	1.148ab
Chereko	2.21a	1.204a	0.23a	1.028a	2.519a	2.49	1.22a	1.074b
Mean	2.82	1.0	0.76	1.043	2.528	2.63	1.93	1.063
CV (%)	71.7	34.2	46.7	28.7	30.3	26.2	40.9	32.7
SD	7.76	0.34	3.24	0.3	0.77	19.62	7.78	0.35
P value	0.851	0.919	0.84	0.99	0.314	0.601	0.598	0.399

*Means in the same column followed by the same letters are not significantly different as determined by Duncan's Multiple Range Test at (P ≤ 0.05), CBSDInc means Cassava Brown Streak Disease Incidence, CBSDSev means Cassava Brown Streak Disease Severity,CMDInc means Cassava Mosaic Disease Incidence, CMDSev means Cassava Mosaic Disease Incidence, CGMInc means Cassava Green Mites Incidence, CGMSe means Cassava Green Mites Severity, CMBInc means Cassava Mealy Bug Incidence, CMBSev means Cassava Mealy Bug Severity

4.3.4 Effects Varietal Performance on Selected **Foliar Cassava Pests and Diseases at Nachingwea District in Lindi Region**

Based on the varieties tested, no significance differences existed at (P<0.05) as (Table 8). Chereko variety had the highest CBSDinc (5.2%), while *Mkuranga* 1 had higher CBSDSev (1.73) followed by *Kiroba* (1.73). *Chereko* also showed to have highest CGMInc (86.2% and CMBInc of 13.63%.

Table 8: Effects Varietal Performance on Selected **Foliar Cassava Pests and Diseases at Nachingwea District in Lindi Region**

Factors	CBSDInc	CBSDSev	CMDInc	CMDSev	CGMInc	CGMSev	CMBInc	CMBSev
Kiroba	1.8a	1.227a	1.25a	1.046a	82.2a	2.634a	12.11a	1.727a
Mkuranga 1	4.2a	1.431a	0.12a	1.153a	86.2a	2.676a	11.85a	1.69a
Chereko	5.2a	1.306a	0.15a	1.037a	82.7a	2.667a	13.63a	1.815a
Mean	3.8	1.321	0.51	1.079	83.7	2.659	12.5	1.744
CV (%)	34.1	50.9	491.2	31.3	22.2	11.7	28.1	38.6
SD	12.32	0.67	2.51	0.34	18.58	0.31	13.51	0.67
P value	0.467	0.356	0.064	0.206	0.523	0.444	0.733	0.632

* All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT), CBSDInc means Cassava Brown Streak Disease Incidence, CBSDSev means Cassava Brown Streak Disease Severity,CMDInc means Cassava Mosaic Disease Incidence, CMDSev means Cassava Mosaic Disease Incidence, CGMInc means Cassava Green Mites Incidence, CGMSe means Cassava Green Mites Severity, CMBInc means Cassava Mealy Bug Incidence, CMBSev means Cassava Mealy Bug Severity

4.3.5 Effect of Varieties on Foliar Pests and Diseases of Cassava at Ilonga

The results showed that, statistically; all three varieties tested against the pests and diseases incidences and severity at Ilonga site with (P<0.05) had no significance difference (Table 9). Kiroba variety had the highest CBSDInc and Sev with 4.2% and 1.2 respectively. It was also observed that; CMDSev was higher (1.4).

Table 9: Effect of Varieties on Foliar Pests and Diseases of Cassava at Ilonga

Factors	CBSDInc	CBSDSev	CMDInc	CMDSev	CGMInc	CGMSev	CMBInc	CMBSev
Kiroba	4.24	1.213a	1.07a	1.403a	81.6a	2.875a	1.1a	1.185a

Mkuranga 1	2.66	1.148a	1.09a	1.093a	76.7a	2.843a	1.16a	1.157a
Chereko	0.96	1.083a	1.096a	1.269a	83.7a	2.861a	1.19a	1.139a
Mean	2.6	1.148	2.24	1.255	80.7	2.86	1.15	1.16
CV (%)	42.5	45.6	46.5	56.3	27.1	7.1	32.3	38.4
SD	10.73	0.52	9.78	0.71	21.87	0.2	3.82	0.46
P value	0.059	0.478	0.123	0.127	0.217	0.822	0.996	0.926

All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT), CBSDInc means Cassava Brown Streak Disease Incidence, CBSDSev means Cassava Brown Streak Disease Severity,CMDInc means Cassava Mosaic Disease Incidence, CMDSev means Cassava Mosaic Disease Incidence, CGMInc means Cassava Green Mites Incidence, CGMSe means Cassava Green Mites Severity, CMBInc means Cassava Mealy Bug Incidence, CMBSev means Cassava Mealy Bug Severity

4.3.6 Effect of Varieties on Number of Cassava Roots at Naliendele, Nachingwea and Ilonga

The results on number of cassava roots based on the cassava genotypes used showed that Naliendele and Nachingwea had very high significant differences ($p < 0.001$) with *Kiroba* variety having many (114), followed by *Mkuranga* 1 (105) and *Chereko* (88) with mean root numbers of 102 and 94 respectively per 25m^2 and Ilonga, (84 roots) statistically ($p < 0.05$) the number of roots varied significantly (Table 10).

Table 10: Effect of Varieties on Number of Cassava Roots at Naliendele, Nachingwea and Ilonga

	Cassava root number		
	Naliendele	**Nachingwea**	**Ilonga**
Kiroba	114.1c	107.6c	86.9b
Mkuranga	105.7b	100.1b	88.3b
Chereko	87.4a	88.3a	77.9a
Mean	102.4	94.2	84.3
CV (%)	31.5	32.9	24.4
SD	32.26	31	20.57
P value	≤0.001	≤0.001	0.03

*Values followed by different letters in a column were significantly different as determined by Duncan's Multiple Range Test (P ≤ 0.05).

4.3.7 Influence of Varieties on Cassava Root Size at Naliendele, Nachingwea and Ilonga

The analysis of variance (Table.11) revealed that no significant differences (p < 0.05) existed for diameter and length among the varieties evaluated. Between the varieties; *Kiroba* had a grand mean root size in diameter (cm) and length (cm) of 5.7 and 45, 5.2 and 50cm for *Mkuranga* 1 and *Chereko* with 5.4 and 47cm respectively (Table 11).

Table 11: Influence of Varieties on Cassava Root Size at Naliendele, Nachingwea and Ilonga

	Naliendele		Nachingwea		Ilonga	
	Diameter	**Length**	**Diameter**	**Length**	**Diameter**	**Length**
Kiroba	5.1a	42.2a	5.5a	43.9a	5.2a	44a
Mkuranga 1	5a	44.2a	4.1a	49.7a	4.6b	44a
Chereko	5.2a	42.1a	5.5a	47a	5.2b	47a
Mean	5.1	42.8	5	46	4.9	46
CV (%)	18.8	8.1	15.5	7.6	7.5	23.9
SD	0.96	3.47	0.775	3.5	0.38	11
P value	0.861	0.72	0.72	0.249	0.053	0.115

*All means in the same column having the same letters had no significance difference at (p<0.05) when separated by Duncan Multiple Range Test (DMRT).

4.3.8 Effects of Varieties on Cassava Yield and Yield Components at Naliendele in Mtwara Region

The total roots yield had very high significant differences (p < 0.001) with *Kiroba* showing the highest (25 t/ha) followed by *Chereko* (22.55 t/ha) and *Mkuranga* 1 the least

(20.6 t/ha).The results showed that; cassava dry matter, starch contents, total green biomsss and lignified (which form the total shoot mass) and the harvesting index had no significant difference ($p < 0.05$) between the varieties used in the experiment (Table 12).

Table 12: Effects of Varieties on Cassava Yield and Yield Components at Naliendele in Mtwara Region

	DM%	CSC%	TRY (t/ha)	HI	TGB(t/ha)	TLG(t/ha)
Kiroba	35.28a	19.14a	25c	0.69a	5.0a	9.54a
Mkuranga 1	35.85a	19.54a	20.6b	0.69a	5.4a	9.04a
Chereko	35.19a	19.08a	22.55a	0.70a	5.6a	8.93a
Mean	35.44	19.25	22.72	0.69	8.7	9.17
CV (%)	9.5	12.3	32.1	9.3	9.4	55.3
SD	3.37	2.37	7.29	0.065	0.82	5.07
P value	0. 67	0.52	<0.001	0.37	0.49	0.64

*All means in the same column having the same letters had no significance difference at ($p<0.05$) when separated by Duncan Multiple Range Test (DMRT).

4.3.9 Effects of Varietal Performance on Selected Cassava Properties at Nachingwea District in Lindi Region

Total fresh root weight (t/ha), harvesting index and total green biomass had strong significant different ($P < 0.001$) between the varietal performance with *Kiroba* showing the highest root yield (21.74 t/ha), followed by *Chereko* (20.76 t/ha) and *Mkuranga* 1 (17.73 t/ha). HI was highest (0.601) for Chereko genotypes and Mkuranga 1 the least (0.517). Based on quality characteristics (DM and CSC %), these varieties had no statistical difference ($p < 0.05$). *Mkuranga* 1 had 35.85% and 19.54%, while *Kiroba* had 35.28 and 19.14% and that for *Chereko* was 35.19 and 19.08% respectively (Table 13).

Table 13: Effects of Varietal Performance on Selected Cassava Properties at Nachingwea District in Lindi Region

	DM%	CSC%	TRY (t/ha)	HI	TGB(t/ha)	TLG(t/ha)
Kiroba	34.98a	18.93a	21.74c	0.58b	3.87a	11.64a
Mkuranga 1	35.61a	19.37a	17.73a	0.517a	4.17b	12.36a
Chereko	34.67a	18.71a	20.76b	0.601c	3.91a	9.89a
Mean	35.09	19	20.08	0.688	3.98	11.3
CV (%)	9.8	12.8	18.7	10.3	42.9	41.6
SD	3.44	2.43	3.75	0.07	1.71	4.7

P value	0.17	0.17	<0.001	<0.001	<0.001	0.131

*Values followed by different letters in a column were significantly different as determined by Duncan's Multiple Range Test (P ≤ 0.05).

4.3.10 Effects of Varieties on Selected Cassava Characteristics at Ilonga

The DM, CSC, TRY TGB and HI statistically had strong variation (P < 0.001) with the values of 35.01%, 18.95%, 20.76 t/ha, 3.23 t/ha and 0.57 for *Kiroba*, 36.14%, 19.75%, 17.33 t/ha, 4.2 t/ha and 0.52 for *Mkuranga* 1 while 34.04%, 18.25%, 19.27 t/ha, 3.44 t/ha and 0.53 was for *Chereko* respectively (Table 14).

Table 14: Effects of Varieties on Selected Cassava Characteristics at Ilonga

	DM%	CSC%	TRY (t/ha)	HI	TGB(t/ha)	TLG(t/ha)
Kiroba	35.01ab	18.95ab	20.76c	0.57b	3.23a	12.37a
Mkuranga 1	36.14b	19.75b	17.33a	0.517a	4.02b	11.9a
Chereko	34.04a	18.25a	19.27b	0.5299b	3.44a	13.63a
Mean	35.06	18.98	19.12	0.521	3.62	12.97
CV (%)	6.4	8.4	12.3	41.4	70.9	25.9
SD	2.24	1.6	2.35	0.22	2.57	3.36
P value	<0.001	<0.001	<0.001	0.01	<0.001	0.06

*Values followed by different letters in a column were significantly different as determined by Duncan's Multiple Range Test (P ≤ 0.05).

4.3.11 Effects of Selected Cassava Varietal Responses to CBSD root Necrosis Severity at Naliendele, Nachingwea and Ilonga

Cassava varieties statistically had no significant difference ($p < 0.05$) in their responses to CBSD root necrosis infection. A comparison of patterns of symptom expression in the three encountered varieties (Table 15); generally, they still maintain their tolerance against CBSD root necrosis as the results showed the severity mean (1.25%)

Table 15: Effects of Selected Cassava Varietal Responses to CBSD root Necrosis Severity at Naliendele, Nachingwea and Ilonga

	Naliendele	Nachingwea	Ilonga
Kiroba	1.1a	1.17a	1.08a
Mkuranga 1	1.25a	1.06a	1a
Chereko	1.37a	1.24a	1.06a
Mean	1.25	1.12	1.05
CV (%)	35.5	33.8	20.2
SD	0.44	0.38	0.21
Pvalue	0.16	0.44	0.24

*All means in the same column having the same letters had no significance difference at ($p<0.05$) when separated by Duncan Multiple Range Test (DMRT).

4.4 Effects of Planting and Harvesting Schedules on Cassava Growth, Development, Pests and Yield and Quality of Cassava

4.4.1 Effects of Scheduled Planting on Cassava Sprouting Percentage

Based on scheduled planting, there was highly significant variation ($p < 0.001$) for the crops planed at Ilonga and the trend followed P1< P3< P2 with sprouting percentage of 71.56, 75.33 and 79.22% respectively (Table 16). The plating that was done in April had the highest sprouting (82.3%) at Naliendele site followed by planting in December (79.56%) at Nachingwea site.

Table 16: Effects of Scheduled Planting on Cassava Sprouting Percentage

	Cassava sprouting (%)

	Naliendele	Nachingwea	Ilonga
P1	77.67b	79.56b	71.56a
P2	76.78a	76.53a	79.22c
P3	82.33c	76a	75.33b
Mean	78.93	77.30	75.37
CV (%)	10.4	11.3	8.4
SD	8.2	8.7	6.33
P value	0.019	0.016	<0.001

*P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April),
All means in the same column having the same letters had no significance difference at ($p<0.05$) when separated by Duncan Multiple Range Test (DMRT).

4.4.2 Effect of Planting Schedules on Days to 50% Cassava First Branching and Flowering as Growth and Development Characteristics at Naliendele, Nachingwea and Ilonga

The results showed highly significant differences ($p < 0.001$) existed among planting schedules at Nachingwea experimental site while Naliendele (flowering days) and Ilonga days to 50% first branching did not differ statistically ($p < 0.05$) whereas days to 50% flowering differed significantly ($p < 0.05$). The results showed that, planting 1 (December) took few days (95) for 50% first braching of the crops. Planting 3 took many days (156) at Ilonga for 50% flowering compared to 154 days at Nachingwea and 146 days at Naliendele (Table 17).

Table 17: Effect of Planting Schedules on Days to 50% Cassava First Branching and Flowering as Growth and Development Characteristics at Naliendele, Nachingwea and Ilonga

	Naliendele		Nachingwea		Ilonga	
	50% Branching days	**50% Flowering days**	**50% Branching days**	**50% Flowering days**	**50% Branching days**	**50% Flowering days**
P1	110.4a	154.3b	95a	127.9a	112.1a	137.9a
P2	114.9ab	149.1a	105.4b	127.1a	114.6a	153.7b
P3	123.8b	145.6a	143.2c	154.1b	126.2a	155.7b
Mean	116.4	149.7	114.6	136.4	117.6	149.1
CV (%)	10	12.59	9.6	6.1	11.5	17.1
SD	11.64	18.85	11	8.32	13.52	25.49
P value	0.016	0.035	<0.001	<0.001	0.09	0.0297

*P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April),
All means in the same column having the same letters had no significance difference at ($p<0.05$) when separated by Duncan Multiple Range Test (DMRT).

4.4.3 Effects of Planting Schedules on Cassava Foliar Pests and Diseases at Naliendele (Mtwara) During 2017/18 - 2018/19 Cropping Season

This site showed that strong significant differences existed among the cassava planting times (Table 18) on diseases and pests incidences and severities ($p<0.001$). Planting two (P2) showed (4.3%, 1.185), followed by planting one (P1) with (4.17%, 1.347) and in planting three (P3) was not observed (0.00%, 1.00). CMD Inc and Sev was low in P1 and P2 and was not observed in P3 (1.110%, 1.111; 1.90%, 1.019 and 0.000, 1.000) respectively. CGM on P3 was highest (88.7%, 2.954), followed by P1 (68.6%, 2.44) and P2 (67.5%, 2.185). The CMB also was observed higher in P3 (4.69%, 1.185), lower in P1 (1.09%, 1.088) and was not observed in P2 (0.00%, 0.917).

Table 18: Effects of Planting Schedules on Cassava Foliar Pests and Diseases at Naliendele (Mtwara) During 2017/18 - 2018/19 Cropping Season

Factor	CBSDInc	CBSDSev	CMDInc	CMDSev	CGMInc	CGMSev	CMBInc	CMBSev

P1	4.17b	1.347b	1.1a	1.111a	68.6a	2.44a	1.09a	1.088b
P2	4.3b	1.185b	1.19a	1.019a	67.5a	2.185a	1a	0.917a
P3	1a	1a	1a	1a	88.7b	2.954b	4.69b	1.185b
Mean	2.82	1.0	0.76	1.043	74.9	2.528	1.93	1.063
CV (%)	26.12	31.2	43.7	28.5	21	26.4	37.7	30.6
SD	0.74	0.312	3.22	0.3	15.73	0.67	7.48	0.33
P value	0.023	<0.01	0.228	0.243	<0.001	<0.001	0.025	0.003

*P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT), CBSDInc means Cassava Brown Streak Disease Incidence, CBSDSev means Cassava Brown Streak Disease Severity,CMDInc means Cassava Mosaic Disease Incidence, CMDSev means Cassava Mosaic Disease Incidence, CGMInc means Cassava Green Mites Incidence, CGMSe means Cassava Green Mites Severity, CMBInc means Cassava Mealy Bug Incidence, CMBSev means Cassava Mealy Bug Severity

4.4.4 Effects of Planting, on Selected Foliar Cassava Pests and Diseases at Nachingwea District in Lindi Region

At Nachingwea site, results showed that no significant differences existed among the eight, 10 and 12 harvesting months only for CBSDInc (p<0.05) while CBSDSev, CMDInc, CMDSev, CGMInc, CGMSev, CMBInc and CMBSev varied significantly (Table 19). High significance different was observed on planting times for pests and diseases incidences and severity (P<0.001) except for CMDSev which had no significance variation (P<0.05) among the three planting times.

Table 19: Effects of Planting, on Selected Foliar Cassava Pests and Diseases at Nachingwea District in Lindi Region

Factors	**CBSDInc**	**CBSDSev**	**CMDInc**	**CMDSev**	**CGMInc**	**CGMSev**	**CMBInc**	**CMBSev**
P1	7.98b	1.569b	0.31a	1.088a	94.6b	2.611b	21.8c	2.065b
P2	2.5a	1.301ab	1.1a	1.111a	75.2a	2.472a	12.6b	1.843b
P3	0.8a	1.093a	0.12a	1.037a	81.3a	2.949c	3.18a	1.324a
Mean	3.8	1.321	0.51	1.079	83.7	2.659	12.53	1.744
CV (%)	30.7	48.3	48.7	31.5	19	6	79.6	32.3
SD	11.67	0.64	2.49	0.34	15.9	0.16	9.97	0.56
P value	0.03	0.009	0.216	0.642	<0.001	<0.001	<0.001	<0.001

*P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT), CBSDInc means Cassava Brown Streak Disease Incidence, CBSDSev means Cassava Brown Streak Disease Severity,CMDInc means Cassava Mosaic Disease Incidence, CMDSev means Cassava Mosaic Disease Incidence, CGMInc means Cassava Green Mites Incidence, CGMSe means Cassava Green Mites Severity, CMBInc means Cassava Mealy Bug Incidence, CMBSev means Cassava Mealy Bug Severity

4.4.5 Effect of Planting Schedules on Foliar Cassava Pests and Diseases at Ilonga in Eastern Zone of Tanzania

Based on planting time, CBSDSev and CGM Inc had significant difference at (P< 0.001) with P2 indicating higher incidence (5.8%), followed by P1 (2.06%) incidence and was not observed on P3 (P<0.05%). Other insect pests and diseases varies when tested at (P<0.05) statistically had no differences among the three planting times conducted during the experimentation (Table 20).

Table 20: Effect of Planting Schedules on Foliar Cassava Pests and Diseases at Ilonga in Eastern Zone of Tanzania

Factors	**CBSDInc**	**CBSDSev**	**CMDInc**	**CMDSev**	**CGMInc**	**CGMSev**	**CMBInc**	**CMBSev**
P1	2.06b	1.065a	1a	1a	94.4b	2.787a	0.12a	1.019a
P2	5.8c	1.38b	5.4b	1.519b	73a	2.935ab	2.51b	1.343b
P3	1a	1a	1.32b	1.245a	74.6a	2.856b	0.82ab	1.12a
Mean	2.6	1.148	2.24	1.255	80.7	2.86	1.15	1.16
CV (%)	40.6	42.6	43.9	53.1	23.1	6.7	39	36.1
SD	10.47	0.49	9.5	0.67	18.64	0.19	3.67	0.42
P value	0.058	0.003	0.048	0.006	<0.001	0.006	0.418	0.005

*P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT), CBSDInc means Cassava Brown Streak Disease Incidence, CBSDSev means Cassava Brown Streak Disease Severity,CMDInc means Cassava Mosaic Disease Incidence, CMDSev means Cassava Mosaic Disease Incidence, CGMInc means Cassava Green Mites Incidence, CGMSe means Cassava Green Mites Severity, CMBInc means Cassava Mealy Bug Incidence, CMBSev means Cassava Mealy Bug Severity

4.4.6 Effect of Planting Schedules and Harvesting Times on Number of Cassava Roots at Naliendele, Nachingwea and Ilonga

The results on number of cassava roots based on planting schedules showed that; planting in December, January and April at Naliendele and Ilonga had a very high significant difference ($P < 0.001$), with P1 (112 roots) the highest number, P2 (101 roots) and P 3 (74 roots). Based on harvesting times, there was significant difference ($P < 0.05$) existed between H1, H2 and H3. Harvesting at 8 MAP had 108 roots (Naliendele), followed by H2 (Naliendele) which had 102 roots. Among three harvesting time, few number of roots (79, 86 and 88) were recorded for H1, H2 and H3 respectively at Ilonga compared to harvesting times on other sites (Table 21).

Table 21: Effect of Planting Schedules and Harvesting Times on Number of Cassava Roots at Naliendele, Nachingwea and Ilonga

	Cassava root number		
	Naliendele	**Nachingwea**	**Ilonga**
P1	112.2c	108.8c	83.2a
P2	100.5b	98.8b	86.9b
P3	94.5a	74.9a	82.9a
Mean	102.4	94.2	84.3
CV (%)	31.5	36.2	4.98
SD	32.26	34.1	4.2
P value	≤0.001	<0.001	0.041
H1	107.9b	100.3c	79.4a
H2	101.7ab	88.3a	86.1b
H3	97.7a	93.9b	87.5b
Mean	102.4	94.2	84.3
CV (%)	31.5	36.2	29.14
SD	32.27	34.1	24.57
P value	0.03	0.02	0.023

*P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), H1= Harvesting at 8MAP, H2= harvesting at 10MAP and H3= harvesting at 12MAP, All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range (DMRT)

4.4.7 Influence of Scheduled Planting and Harvesting Time on Cassava Root Size at Naliendele, Nachingwea and Ilonga

Scheduled planting affected the root diameter meaningfully ($p < 0.05$). The highest root diameter was 5.5cm from the crops that were planted in January (P1), followed by 5.3cm planted in April (P3). Based on harvesting time; cassava harvested during 12MAP had the widest diameter (5.6cm) at Naliendele and the least of 4.7 cm for crops harvested 8MAP. The longest length based on planting schedule was 48cm for P3 at Ilonga and the shortest was 42cm from P1. However; based on harvesting time the longest roots were with 54cm harvested at 12MAP from Nachingwea while mean diameter and length for Naliendele, Nachingwea and Ilonga were 5.2 and 38, 5 and 46 and 5.9, 57.4cm respectively (Table 22).

Table 22: Influence of Scheduled Planting and Harvesting Time on Cassava Root Size at Naliendele, Nachingwea and Ilonga

	Naliendele		Nachingwea		Ilonga	
	Diameter	**Length**	**Diameter**	**Length**	**Diameter**	**Length**
P1	4.8a	42.3a	5.1a	43.7a	5.3b	43.a
P2	5.5ab	44.1a	4.9a	46.3a	4.5a	46b
P3	5.3a	45.1a	5.1a	47.6a	5b	48b
Mean	5.1	42.8	5	46	4.9	46
CV (%)	7.3	8.1	15.5	7.6	5.9	23.9
SD	0.37	3.47	0.775	3.5	0.29	10.9
P value	0.036	0.363	0.637	0.133	0.005	0.109
H1	4.7a	41.7a	4.7b	36a	4.7a	41.2a
H2	5.3b	43.4a	4.9a	47.3b	4.9a	47b
H3	5.6a	44.1a	5.4b	54c	5a	49b
Mean	5.1	42.8	5	46	4.9	46
CV (%)	18.8	8.1	15.5	7.6	8.2	23.9
SD	0.96	3.47	0.775	3.5	0.4	10.9
P value	0.01	0.794	<0.001	<0.001	0.036	0.012

* H1= Harvesting at 8MAP, H2= harvesting at 10MAP and H3= harvesting at 12MAP, *P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT).

4.4.8 Effect of Scheduled Planting and Harvesting Times on Cassava Yield and Yield Components at Naliendele in Mtwara Region

Cassava starch content (%CSC) and dry matter content (DMC) for harvesting and planting times (Table 23) varied very significantly (P < 0.001). Total roots yield (TRY t/ha) and harvesting index (HI) had strong significant difference (P < 0.001) among the planting schedules and harvesting times. It was also observed that there was moderate significant difference of cassava green biomass (TG) of harvesting and planting times (P < 0.05). The DM, CSC, TRY and HI had the values of 37.48%, 20.7%, 18.48 t/ha, and 0.68 for first planting, 33.12%, 17.16%, 20.91 t/ha, and 0.68 for second planting while 37.71%, 19.45%, 28.77 t/ha, and 0.73 was for third planting (Table 23). Based on harvesting time, the cassava yield, components and quality characteristcis had the following values; DM, CSC, TRY and HI with 35.23%, 19.11%, 18.48 t/ha, and 0.64 for 8 MAP harvest, 34.26%, 18.42%, 18.73 t/ha, and 0.72 for 10MAP harvest while 36.83%, 20.24%, 22.86 t/ha and 0.73 was for 12MAP harvest respectively (Table 23).

Table 23: Effect of Scheduled Planting and Harvesting Times on Cassava Yield and Yield Components at Naliendele in Mtwara Region

	DM%	CSC%	TRY (t/ha)	HI	TGB(t/ha)	TLG(t/ha)
P1	37.48c	20.7c	18.48a	0.68a	4.4a	5.84a
P2	33.12a	17.61a	20.91b	0.68a	4.1a	8.99b
P3	37.71b	19.45b	28.77c	0.73b	9.6c	12.67c
Mean	35.44	19.25	22.7	0.69	8.7	9.17
CV (%)	7.3	9.5	21.9	8.8	9.5	41.4
SD	2.59	1.83	4.97	0.06	0.83	3.8
P value	<0.001	<0.001	<0.001	<0.001	0.03	˂0.001
H1	35.23a	19.11a	18.48a	0.64a	5.3a	8.94a
H2	34.26a	18.42a	18.73a	0.72b	5.1a	9.11a
H3	36.83b	20.24b	22.86b	0.73b	5.6a	9.46a
Mean	35.44	19.25	22.72	0.69	8.7	9.17
CV (%)	9.5	12.3	32.1	0.69	6.4	55.3
SD	3.67	2.37	7.29	0.014	0.56	5.07
P value	0.002	0.002	<0.001	<0.001	0.382	0.742

* DM%= Percentage dry matter, CSC% = percentage cassava assava starch content, TRY= Total root yield, HI= harvesting index, TGB = Total green biomass, TLG = Total lignified * H1= Harvesting at 8MAP, H2= harvesting at 10MAP and H3= harvesting at 12MAP, *P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT).

4.4.9 Effects of Planting Schedules and Harvesting Time on Selected Cassava Properties at Nachingwea District in Lindi Region

For the DM, CSC and TRY based on planting times (Table 24) statistically had very high significant variation (P < 0.001) while harvesting index and that of TGB and TLG had no variation (p < 0.05). The DM, CSC, TRY and HI had the values of of 35.79%, 19.5%, 23.42 t/ha, and 0.68 for first planting, 33.16%, 17.64%, 18.63 t/ha, and 0.69 for second planting while 36.31%, 19.87%, 18.71 t/ha, and 0.68 was for third planting (Table 24). Based on harvesting time, the cassava yield, components and quality characteristcis had the following values; DM, CSC, TRY and HI with 35.06%, 19.32%, 17.76 t/ha, and 0.64 for 8 MAP harvest, 35.53%, 18.71%, 19.3t/ha, and 0.71 for 10MAP harvest while 34.67%, 18.98%, 23.17 t/ha and 0.68 was for 12MAP hrvest respectively (Table 24).

Table 24: Effects of Planting Schedules and Harvesting Time on Selected Cassava Properties at Nachingwea District in Lindi Region

	DM	CSC	TRY	HI	TGB	TLG
P1	35.79b	19.5b	23.42b	0.6836	4.06b	13.11c
P2	33.16a	17.64a	18.63a	0.6914	3.24a	10.88b
P3	36.31b	19.87b	18.71a	0.6877	4.65c	9.89a
Mean	35.09	19	20.08	0.6876	3.98	11.3
CV (%)	8.6	11.3	12	10.4	39.6	39.5
SD	3.02	1.02	2.41	0.72	1.58	4.46
P value	<0.001	<0.001	<0.001	0.604	0.001	0.01
H1	35.06a	19.32a	17.76a	0.644a	2.63a	10.28b
H2	35.53a	18.71a	19.3b	0.7137b	4.13b	9.27a
H3	34.67a	18.98a	23.17c	0.7047b	5.19c	14.34c
Mean	35.09	19	20.08	0.6876	3.98	11.3
CV (%)	9.8	12.8	18.7	10.3	42.9	41.6
SD	3.44	2.43	3.75	0.07	1.7	4.7
P value	0.229	0.229	<0.001	<0.001	<0.001	˂0.001

* DM%= Percentage dry matter, CSC% = percentage cassava assava starch content, TRY= Total root yield, HI= harvesting index, TGB = Total green biomass, TLG = Total lignified * H1= Harvesting at 8MAP, H2= harvesting at 10MAP and H3= harvesting at 12MAP, *P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT).

4.4.10 Effects of Planting Schedules and Harvesting Time on Selected Cassava Properties at Ilonga

For the DM, CSC and TRY based on planting times (Table 25) statistically had very high significant variation at (P < 0.001) while harvesting index and that of TLG had no variation ($p < 0.05$). The DM, CSC, TRY and HI had the values of 35.71%, 19.44%, 20.16 t/ha, and 0.64 for first planting, 35.09%, 19.01%, 19.76 t/ha, and 0.55 for second planting while 34.37%, 18.5%, 17.44 t/ha, and 0.63 was for third planting (Table 25). Based on harvesting time, the cassava yield, components and quality characteristcis had the following values; DM, CSC, TRY and HI with 35.39%, 19.22%, 16.07 t/ha, and 0.51 for 8 MAP harvest, 33.43%, 17.83%, 19.3 t/ha and 0.53 for 10MAP harvest while 36.35%, 19.9%, 22 t/ha and 0.52 was for 12MAP hrvest respectively (Table 25).

Table 25: Effects of Planting Schedules and Harvesting Time on Selected Cassava Properties at Ilonga

	DM%	CSC%	TRY	HI	TGB	TLG
P1	35.71b	19.44b	20.16b	0.645b	2.69a	13.24a
P2	35.09ab	19.01ab	19.76b	0.2815a	2.94a	12.92a
P3	34.37a	18.5a	17.44a	0.6369b	5.23b	12.74a
Mean	35.06	18.98	19.21	0.5211	3.62	12.97
CV (%)	0.039	8.1	9.8	11.3	60.3	26.2
SD	0.014	1.54	1.88	0.059	2.18	3.4
P value	0.01	0.01	<0.001	<0.0011	<0.0011	0.815
H1	35.39b	19.22b	16.07a	0.5147	2.42a	13.39a
H2	33.43a	17.83	19.3b	0.5294	3.78b	12.38a
H3	36.35b	19.9b	22c	0.5193	4.66c	13.13a
Mean	35.06	18.98	19.12	0.521	3.62	12.97
CV (%)	6.4	8.4	12.3	41.4	70.9	25.9
SD	2.24	1.6	2.35	0.22	2.57	3.36
P value	<0.001	<0.001	<0.001	0.325	<0.001	0.151

* DM%= Percentage dry matter, CSC% = percentage cassava assava starch content, TRY= Total root yield, HI= harvesting index, TGB = Total green biomass, TLG = Total lignified * H1= Harvesting at 8MAP, H2= harvesting at 10MAP and H3= harvesting at 12MAP, *P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT).

4.4.11 Effect of Planting and Harvesting Schedules on CBSD root Necrosis Severity at Naliendele, Nachingwea and Ilonga

Cassava varieties on both planting schedules and harvesting times statistically no significant differences ($P < 0.05$) existed in their responses to CBSD necrosis infection (Table 26). The grand mean of CBSD necrosis severity between the planting and harvesting times was 1.02% Ilonga had the lowest necrosis followed by Nachingwea and Naliendele the highest with values of 1.05, 1.12 and 1.25% respectively.

Table 26: Effect of Planting and Harvesting Schedules on CBSD root Necrosis Severity at Naliendele, Nachingwea and Ilonga

	Naliendele	Nachingwea	Ilonga
P1	1.17a	1.03a	1.03a
P2	1.20a	1.08a	1.06a
P3	1.40a	1.25a	1.06a
Mean	1.25	1.12	1.05
CV (%)	35.5	33.8	20.2
SD	0.44	0.38	0.21
P value	0.07	0.4	0.81
H1	1.28a	1.17a	1.056a
H2	1.28a	1.14a	1.083a
H3	1.2a	1.06a	1a
Mean	1.25	1.12	1.05a
CV (%)	35.5	33.8	20.2
SD	0.44	0.38	0.21
P value	0.68	0.45	0.24

* H1= Harvesting at 8MAP, H2= harvesting at 10MAP and H3= harvesting at 12MAP, *P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT)

4.5 Effect of Varieties, Planting Schedules and Harvesting Times Interactions on Crop Growth, Development, Yields and Yield Components of Cassava Grown at Eastern and Southern Zones of Tanzanuia.

4.5.1 Interaction Effect on Varieties and Scheduled Planting on Cassava Sprouting at Naliendele, Nachingwea and Ilonga

The results showed that the effect of planting schedules on on cassava sprouting was significantly depending on variety ($P < 0.05$). *Mkuranga* 1 variety planted in April had the highest (86%) sprouting percentage at Naliendele experimental site followed by the same variety planted in January (85%) at Nachingwea site in Southern zone and also *Mkuranga* 1 planted in January had 84% cassava sprouting at Ilonga site (Table 27).

Table 27: Interaction Effect on Varieties and Scheduled Planting on Cassava Sprouting at Naliendele, Nachingwea and Ilonga

		Cassava sprouting (%)		
		Naliendele	**Nachingwea**	**Ilonga**
	P1	76.53ab	80.67bcd	69.33ab
Kiroba	**P2**	73.67a	69.67a	74bc
	P3	79.67abc	69.67a	74bc
	P1	82.33bc	79.33bcd	77.67c
Mkuranga 1	**P2**	79.33abc	85.67d	84d
	P3	86c	82c	75.3c
	P1	74.3b	78.67bcd	67.67a
Chereko	**P2**	77.33ab	73.67b	79.67cd
	P3	81.33bc	76.33abc	76.67c
	Site Mean	78.93	77.30	75.37
	CV (%)	11.1	11.3	8.5
	SD	8.76	8.73	6.4
	P value	0.021	0.018	0.015

*P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April),
All means in the same column having the same letters had no significance difference at ($p<0.05$) when separated by Duncan Multiple Range Test (DMRT).

4.5.2 Interaction Effect on Varieties and Scheduled Planting on Days to 50% first Branching and Flowering at Naliendele, Nachingwea and Ilonga

The interaction effect of cassava varieties and scheduled planting at 50% first branching and flowering had significant difference ($p < 0.05$). *Mkuranga* 1 variety planted in December branched earliest (76 days after planting) at Nachingwea site followed by (89 days) of the same variety planted in January at Nachingwea. Earliest 50% flowering (113 days after planting) was observed for *Kiroba* variety planted in December at Nachingwea followed by (117 days) *Kiroba* planted in January at Ilonga site. It was also recorded that *Chereko* variety took many days (160 and 170 days) to 50% branching and flowering respectively at Nachingwea site (Table 28).

Table 28: Interaction Effect on Varieties and Scheduled Planting on Days to 50% first Branching and Flowering at Naliendele, Nachingwea and Ilonga

		Naliendele		Nachingwea		Ilonga	
		Days to 50% first branching	**Days to 50% flowering**	**Days to 50% first branching**	**Days to 50% flowering**	**Days to 50% first branching**	**Days to 50% flowering**
Kiroba	**P1**	112.7bcd	158.7bc	95.7c	128.3ab	115c	147.7b
	P2	114.7bcd	151.7abc	105bcd	125.3b	113c	143.7b
	P3	126cde	146.7abc	147.7e	157.7d	123bc	169.7ab
Mkuranga 1	**P1**	91.7a	139.3ab	76a	114.3a	91.3a	145.3b
	P2	100.3b	131.3a	89.3b	115.3a	102.7b	117a
	P3	105c	132a	121.3d	134.3c	114c	151.3c
Chereko	**P1**	127cde	165c	113.3cd	141bc	130bcd	155.7bc
	P2	129.7de	164.3c	122d	140.7bc	128bcd	147b
	P3	140.3e	158bc	160.7e	170.3e	144d	164.3d
	Mean	116.4	149.7	114.6	136.4	117.6	149.1
	CV (%)	10	8.4	9.6	6.1	11.5	17.1
	SD	11.64	12.57	11	8.32	13.52	25.5
	P value	0.02*	0.014**	0.001**	0.026*	<0.001***	0.012**

*P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April),
All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT)

4.5.3 Effect of Varieties x Planting Schedules and Harvesting times Interactions on number of Cassava Roots at Naliendele, Nachingwea and Ilonga

Furthermore, the interaction effect of three crop varieties tested and the planting times at Naliendele, Nachingwea and Ilonga had significant difference at ($p < 0.05$) (Table 29). It was noted that; significant difference existed among the planting and harvesting times ($p < 0.05$) on number of cassava roots harvested. *Kiroba* variety planted in December gave the highest numbers of roots (132) followed by the same interaction (122) at Nachingwea site and lowest (67) was for *Chereko* planted on April. Crops planted in January and harvested at 12 MAP gave highest (124) root numbers per 5m x5m plot at Naliendele and the lowest (75) was recorded for crop planted in April and harvesting done at eight and 10 MAP.

Table 29: Effect of Varieties x Planting Schedules and Harvesting times Interactions on number of Cassava Roots at Naliendele, Nachingwea and Ilonga

		Cassava root number		
		Naliendele	**Nachingwea**	**Ilonga**
	P1	132.6c	122.1c	89.8c
Kiroba	**P2**	101.6abc	119.7c	81.1b
	P3	108.2abc	84.7ab	78.8a
	P1	120.8b	119.2c	90.1a
Mkuranga 1	**P2**	94.2abc	104bc	91.5a
	P3	83.2abc	73.1ab	79.1a
	P1	102.1abc	81.3ab	80.7a
Chereko	**P2**	105.7abc	76.7b	92.3a
	P3	73.2a	66.8a	75.7a
	Mean	102.4	94.2	84.3
	CV (%)	36.2	36.2	25
	SD	37	34.1	21.08
	P value	0.031	0.047	0.055
H1	**P1**	115bc	106.3cd	76.2a
	P2	123.9d	100.7d	83.1b
	P3	84.7a	89.25c	90.5c
	P1	152e	105.4cd	78.4a
H 2	**P2**	88.9b	104cd	92.2bc
	P3	100.9c	119.5d	90c
	P1	106.4abc	75.3a	83.5b
H3	**P2**	88.6b	75.3a	83.1b
	P3	98abc	80.92b	82.1b
	Mean	102.4	94.2	84.3
	CV (%)	36.2	36.2	25
	SD	37.07	34.1	21.08
	P value	0.002	0.004	0.016

*V1= *Kiroba,* V2= *Mkuranga* 1 and=V3 *Chereko*, H1= Harvesting at 8MAP, H2= harvesting at 10MAP and H3= harvesting at 12MAP, *P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT).

4.5.4 Effect of Varieties x Planting Schedules x Harvesting times Interactions on number of Cassava roots at Naliendele, Nachingwea and Ilonga

Statistically, significance effect at ($p < 0.05$) was observed for the interactions effect of varieties, scheduled planting and harvesting times. *Kiroba* variety planted in December and harvested at eight and 10MAP recorded the highest root numbers 142 and 137 respectively per plot of 5m x5m at Naliendele site, followed by both *Mkuranga* 1 and *Chereko* (133 roots) variety planted in April and January and harvested at 10 and 12 MAP respectively. The lowest root number (61) on this interaction effect was recorded for *Chereko* variety planted in April and harvested during 123 roots MAP (Table 30).

Root Numbers										
		Naliendele			**Nachingwea**			**Ilonga**		
		P1	**P2**	**P3**	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**
Kiroba	**H1**	137g	118f	95bd	119.2e	127.8fg	93. 8d	85.8e	85.5e	76.2c
	H2	141.8h	100.2de	132gh	126.5ef	123.3efg	68.8a	93gh	87.2f	89.8ef
	H3	119f	86.5d	97.8cde	120.5e	106.8cd	81.5c	90.8ef	97.5fgh	76c
Mkuranga 1	**H1**	107.2de	118f	80.2bc	133.8h	118.8a	98d	81d	71.8b	97.2fgh
	H2	133.2gh	80.5bc	90.8cd	99.5d	106.8cd	63.5a	73.2ab	106.5i	89.2ef
	H3	121.8fg	84d	135.2ghf	125.8a	86.5c	78.5b	89f	96.2fgh	90.5ef
Chereko	**H1**	100.7de	135. 8ghf	78.7c	66a	69.8a	76b	61.8a	78c	77c
	H2	70.5b	86d	80bc	76b	82c	68.5a	83de	83de	70.2b
	H3	78.5c	95.2cde	61a	112.3a	67.5a	66a	91.8ef	76.2c	79.8c
	Mean	102.4				94.2				84.3
	CV (%)	31.5				36.2				25

SD	32.26	34.1	21.08
P value	0.037	0.019	0.03

Table 30: Effect of Varieties x Planting Schedules x Harvesting times Interactions on number of Cassava roots at Naliendele, Nachingwea and Ilonga

*V1= *Kiroba*, V2= *Mkuranga* 1 and=V3 *Chereko*, H1= Harvesting at 8MAP, H2= harvesting at 10MAP and H3= harvesting at 12MAP, *P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *$p<0.05$, **$p<0.01$ and ***$p<0.001$ when separated by Duncan Multiple Range Test (DMRT)

4.5.5 Influence of Varieties x Scheduled Planting and Harvesting times Interaction on Cassava root Size at Naliendele, Nachingwea and Ilonga

The results on interaction effect of varieties and planting time statistically, had no significant effects ($p < 0.05$) on diameter at Naliendele and length at Nachingwea where others variables such as length ($p=0.05$) were significantly affected by the traetments apllied ($p < 0.05$). The highest root size (5.6cm diameter and 48cm length) was obtained when *Chereko* variety at Nachingwea was planted on April.Furthermore, planting and harvesting times interaction had no significant differences ($p < 0.05$) on root size for most of the parameters at the sites (Table 31). The highest root size (5.5cm width and 55cm long) was recorded when the cassava planted in January and harvested during 12 MAP.

Table 31: Influence of Varieties x Scheduled Planting and Harvesting times Interactions on Cassava root Size at Naliendele, Nachingwea and Ilonga

		Naliendele		Nachingwea		Ilonga	
		Diameter	**Length**	**Diameter**	**Length**	**Diameter**	**Length**
Kiroba	**P1**	5.8a	41.7a	5.2a	39a	5.7a	43a
	P2	5.4ab	40.8a	5.5ab	46b	5.3a	45a
	P3	5.3ab	44.1a	6.7c	47ab	4.8a	45a
Mkuranga 1	**P1**	4.8a	44.4a	5.2a	46b	4.4a	46a
	P2	5.4ab	42.1a	5.1a	46b	5.6a	39a
	P3	5.3ab	45.9a	5.a	48c	4.8a	46a
Chereko	**P1**	5.4b	40.6a	5.7b	46b	5.7a	55a
	P2	4.7a	40.4a	5.2a	47ab	4.5a	45a
	P3	4.4a	45.3a	5.6ab	48c	5.3a	46a
	Mean	5.1	42.8	5	46	4.9	46
	CV (%)	7.3	28.2	15.5	7.6	19.9	23.9
	SD	0.37	12.07	0.28	3.5	0.98	11
	P value	0.05	0.99	0.03	0.547	0.637	0.28
H1	**P1**	4.7a	49abc	5.7d	39ab	5.6abc	52a
	P2	5.6abc	44ab	5.5cd	37ab	5.9ab	45a
	P3	5.6abc	36.2a	5abc	33a	5.6a	50a
H2	**P1**	5.1ab	41.7b	4.7ab	46abc	5.3abc	50a
	P2	5.3ab	43.4ab	4.7ab	49abc	4.3a	44a
	P3	5.6abc	45.2ab	5.4bcd	47abc	5.3abc	46
H3	**P1**	5.6abc	40.9b	5.8cd	53bc	5.9ab	44a
	P2	5.7abc	44.9ab	5.5cd	55c	4.3a	39a
	P3	5.8abc	44.3ab	4.8abc	55c	5ab	41a
	Mean	5.1	42.8	5	46	4.9	46
	CV (%)	10.3	28.2	15.4	16.7	19.9	23.9
	SD	0.53	12.07	0.77	7.68	0.98	11
	P value	0.059	0.038	0.036	0.069	0.024	0.993

*V1= Kiroba, V2= Mkuranga 1 and=V3 Chereko, H1= Harvesting at 8MAP, H2= harvesting at 10MAP and H3= harvesting at 12MAP, *P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT)

4.5.6 Effect of Varieties x Scheduled Planting x Harvesting times Interactions on Cassava root Size at Naliendele, Nachingwea and Ilonga

The results showed that; interaction of varieties x scheduled planting x harvesting times had significant effect ($p < 0.05$). The longest root length (60cm) was that of *Mkuranga* 1 planted in December and harvested during 12MAP at Ilonga site and the widest diameter (7cm) was for *Kiroba* variety planted in January and harvested during 12MAP at Naliendele site and *Chereko* planted in December with its harvest at 12MAP had 6.1cm diameter (Table 32) with plate 2*b*, *a* and *c* respectively.

Plate 2: *Kiroba* variety planted in December and harvested at 12MAP

Plate 2b: *Mkuranga* 1 variety planted in December and harvested at 12MAP

Plate 2c: ***Chereko*** **variety planted in December and harvested at 12MAP**

Table 32: Effect of Varieties x Scheduled Planting x Harvesting times Interactions on Cassava root Size at Naliendele, Nachingwea and Ilonga

		Naliendele						Nachingwea						Ilonga					
		Diameter			Length			Diameter			Length			Diameter			Length		
		P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
Kiroba	**H1**	4.1a	4.4a	4.7b	35.3a	36.7b	38.6b	5.5cd	5.1c	4.6ab	33.92ab	32.17a	48def	4.2a	4.5bc	4.6bc	41b	43.5b	38a
	H2	4.9ab	4.3a	5.3c	39.7bc	46.6ef	49.2def	5.6cd	5c	4.9abc	37.17bc	51.75ef	51ef	4.9bc	5bc	4.7bc	49.75bcd	49.75bcd	42.5b
	H3	5.5de	6.8	5.8def	46.8ef	38b	48edf	6.2e	5.9cd	5.6	45.83de	54.33	61h	5.2bc	5.5bc	5.1bc	50.75bcd	56.25	50bcd
Mkuranga 1	**H1**	4.1a	5.1c	4.1a	41.3c	44.1c	42.2cd	4.7ab	3.3a	5.1c	35.17c	39.67cd	35c	4.2a	4.3a	4.1b	49.5bcd	45.25bc	42b
	H2	4.7b	3.7a	4.6b	38.7abc	43.2de	43.3de	5.8cd	4.7ab	4.6ab	45de	44.42d	52ef	4.4a	5.2bc	4.5bc	57d	47.25bc	44b
	H3	5.5de	3.9a	5.1c	45.2de	35.2a	46.7ef	5.9cd	4.7ab	5.6cd	57.67efg	55efg	57efg	5.1bc	5.7c	4.7bc	60.25e	50.5bcd	57d
Chereko	**H1**	5.5de	3.7a	4.9ab	41.4c	37.1b	40.8c	5c	4.4b	4b	36.75bc	39.92cd	41cde	3.5a	4.6bc	4.9bc	46bc	41.75b	41b
	H2	5.9ef	4.7b	4.9ab	47.2ef	38.7abc	45.8de	5.1c	4.5ab	4.6ab	47.08def	45.17de	46de	5bc	4.7bc	5.2bc	53.75cd	43.75b	42.3b

H3	6.1f	3.8a	5.8def	44.7de	50.5g	51.3g	5.3c	5.9cd	4.9abc	54.33efg	54.42efg	49ef	5.4bc	5.6c	5.8c	59d	46.25bc	46.5bc
Mean			5.1			42.8			5			46			5			45.6
CV (%)			18.8			28.2			7.7			7.6			19.9			23.9
SD			0.96			12.07			0.39			3.5			0.995			10.9
P value			0.051			0.033			0.022			0.01			0.034			0.03

*V1= Kiroba, V2= Mkuranga 1 and=V3 Chereko, H1= Harvesting at 8MAP, H2= harvesting at 10MAP and H3= harvesting at 12MAP, *P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT)

4.5.7 Effect of Varieties x Harvesting times and Planting Schedules Interactions on Selected Cassava Yields and Yield Components at Naliendele, Nachingwea and Ilonga

Based on interaction effect of varieties, and harvesting times; most of the characteristics selected had very high significant difference ($P < 0.001$) of interactions (Table 33). The total root yield increased significantly from planting one to three and harvesting one to three for almost both sites. The interaction effect of variety and harvesting times recorded the highest (37%) cassava dry matter (DM) for *Mkuranga* 1 variety that was harvested at 12MAP at Naliendele site. Also CSC was highest (21%) at Ilonga site for the *Mkuranga* 1 variety harvested at 12MAP. Highest total root yield (25.6 t/ha) was obtained at Naliendele site with *Kiroba* variety harvested at 12MAP whereas HI was highest (0.76) with *Mkuranga* 1 variety harvested during 12MAP.

The interaction effect of variety and planting times recorded the highest (38%) cassava dry matter (DM) for *Kiroba* variety that was planted in April at Naliendele site. Also CSC was highest (21%) at Naliendele site for the *Kiroba* variety planted in December. Highest total root yield (27t/ha) was obtained at Naliendele site with *Kiroba* variety planted in December whereas highest HI (0.74) with *Mkuranga* 1 variety planted in December was recorded at Ilonga site.

The interaction effect of planting schedules and harvesting times recorded the highest (39%) cassava dry matter (DM) for cassava planted in December and harvested during 12MAP at Naliendele site. Also CSC was highest (22%) at Naliendele site for the cassava planted in December and harvested at 12MAP. Highest total root yield (27t/ha) was obtained at Naliendele site for crops planted in December whereas highest with its harvesting time of 12MAP. Harvesting index (0.76) also was obtained highest with crops planted in December and harvested at 12MAP at Ilonga site (Table 33).

Table 33: Effects of Variety x Harvesting times and Planting Schedules Interactions on Selected Cassava Yields and Yield Components at Naliendele, Nachingwea and Ilonga

		DM (%)			CSC (%)			TRY(t/ha)			HI		
Variety	**Harvesting**	**Naliendele**	**Nachingwea**	**Ilonga**	**Naliendele**	**Nachingwea**	**Ilonga**	**Naliendele**	**Nachingwea**	**Ilonga**	**Naliendele**	**Nachingwea**	**Ilonga**
	H1	35.37abc	35.21ab	36.52de	19.21abc	19.09ab	19.14acd	19.77bc	19.55c	16.78b	0.71cd	0.74de	0.55d
Kiroba	**H2**	34.48ab	34.5a	33.23ab	18.58ab	18.59a	17.69ab	23.61de	19.67c	22cd	0.69bc	0.71d	0.53cd
	H3	35.98abc	35.24ab	35.28bcd	19.64abc	19.11ab	20.02de	25.62f	26.01f	25.28e	0.68b	0.67c	0.55d
	H1	33.98a	35.69ab	34.27abcd	20.03bc	20.09b	18.43abcd	17.26a	16.06a	14.71a	0.71cd	0.64b	0.47a
Mkuranga 1	**H2**	36.54bc	34.52a	35.9cde	18.22a	18.6a	19.58cde	21.78cd	17.64b	17.63b	0.76e	0.71de	0.51bc
	H3	37.02c	36.62b	36.24de	20.37c	19.43ab	21.24e	22.8de	19.49c	19.64c	0.64a	0.59a	0.49ab
	H1	34.31ab	35.48a	33.75abc	18.46ab	18.42a	18.06abc	19.17ab	17.55b	16.7b	0.74de	0.74e	0.52bcd
Chereko	**H2**	33.79a	34.25a	32.78a	18.08a	19.28ab	17.37a	23.2de	20.72d	19.59c	0.73de	0.72de	0.55d
	H3	36.48abc	34.27a	35.53bcd	20.7c	18.41a	19.32bcd	25.28e	24.01e	221.07d	0.62a	0.67c	0.52bcd
	Mean	35.44	35.09	35.06	19.25	19	18.98	22.72	20.08	19.12	0.69	0.69	0.521
	CV (%)	7.3	6.3	5.3	9.5	8.3	6.9	12.6	6.1	7.4	5.4	5.1	8
	SD	2.59	2.21	1.86	1.83	1.58	2.39	2.86	1.27	1.41	0.04	0.04	0.04
	P value	0.105	0.214	0.01	0.105	0.214	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	0.091

*V1= Kiroba, V2= Mkuranga 1 and=V3 Chereko, H1= Harvesting at 8MAP, H2= harvesting at 10MAP and H3= harvesting at 12MAP, *P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT)

		DM (%)			CSC (%)			TRY (t/ha)			HI		
		Naliendele	**Nachingwea**	**Ilonga**	**Naliendele**	**Nachingwea**	**Ilonga**	**Naliendele**	**Nachingwea**	**Ilonga**	**Naliendele**	**Nachingwea**	**Ilonga**
	H1	36.55cd	36.07bc	34.46abc	20.04cd	19.7bc	19.76c	20.28d	21.78e	14.7a	0.72de	0.64b	0.62b
P1	**H2**	36.43cd	34.83bc	36.16c	19.95cd	18.82bc	18.56abc	21.3e	20.92de	15.97b	0.74e	0.70cd	0.65c
	H3	39.47e	36.47c	36.49c	22.11e	19.98c	20	27.73f	26.57f	17.53c	0.58a	0.76e	0.66c
	H1	27.65a	24.74a	23.6a	16.57a	15.4a	17.95ab	21.18c	17.72b	19.32d	0.69c	0.71cd	0.63b
P2	**H2**	26.47a	25.04a	23.01a	17.86ab	18.76bc	18.95bc	21.24c	17.91b	21.14ef	0.7e	0.73d	0.63b
	H3	34.25bc	30ab	36.67c	18.41bc	18.75bc	20.12c	20.32bc	20.27d	17.43c	0.73e	0.69c	0.63b
P3	**H1**	34.58bcd	34.37b	32.23ab	18.64bcd	18.49b	16.98a	9.74a	13.78a	23.64g	0.74e	0.69c	0.63b
	H2	35.81cd	35.39bc	35	19.51cd	19.22bc	18.94bc	18.05b	19.08c	22.16f	0.69cd	0.64b	0.68c
	H3	36.76d	36.17d	35.89bc	20.19d	21.89d	19.57bc	27.65e	21.66e	20.19de	0.62b	0.59a	0.61a
	Mean	35.44	35.09	35.06	19.25	19	18.98	22.72	20.08	19.12	0.69	0.68	0.52
	CV (%)	7.2	6.5	5.1	9.4	8.5	6.7	12.9	6.2	1.156	5.4	4.7	8
	SD	2.55	2.28	1.79	1.81	1.62	1.27	2.93	124	0.22	0.04	0.03	0.04
	P value	0.052	<0.001	0.043	0.046	<0.001	0.43	<0.001	<0.001	<0.001	<0.001	<0.001	0.043

Table 33 Continued…

* H1= Harvesting at 8MAP, H2= harvesting at 10MAP and H3= harvesting at 12MAP, P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT)

4.5.8 Effect of Cassava Genotypes x Planting Schedules x Harvesting times Interactions on Total root Yields

The results showed high significant differences existed ($p < 0.001$) on total cassava root yields among the treatment combinations at Nachingwea site and that at Nachingwea whereas that at Ilonga differed normal ($p < 0.05$). It was also noticed that the interaction between *Kiroba*, *Mkuranga* 1 and *Chereko* varieties, planting the crop during November/December, January/February and March/April, harvesting at eight, ten and 12 MAP at the three experimental sites i.e Naliendele, Nachingwea and Ilonga had the mean of 22.72, 20.08 and 19.12t/ha respectively, Table 34).The interactions of variety x scheduled planting x harvesting times recorded highest total root yield (27 t/ha) for *Kiroba* variety that was planted in December and harvested during 12MAP at Naliendele site in Southern zone and Ilonga site recorded (22t/ha) for *Kiroba* planted in December and April with harvest during 10MAP.

Table 34: Effect of Cassava Genotypes x Planting Schedules x Harvesting times Interactions on Total root Yields

		Total Fresh Root Yields (t/ha)								
		Naliendele			Nachingwea			Ilonga		
		H1	H2	H3	H1	H2	H3	H1	H2	H3
Kiroba	**P1**	19.18fg	20.35i	27.35n	14.31kl	20.86ghi	22.73n	17.8defgh	16.72bcdef	21.6abcd
	P2	16.46efg	19.12fg	21.26ijk	13.46fg	17.47de	18.49ijk	14.81fgh	16.62j	18.69efgh
	P3	12.07ab	15.13cde	24.82jlm	11.24bc	13.32fgh	19.79jk	15.89hi	20.15hi	21.79j
Mkuranga 1	**P1**	14.07cd	15.55cde	17.14efgh	10.72fgh	12.33fgh	20jk	14.88abc	16.59bcdef	18.88fgh
	P2	13.1bc	13.53bc	16.31efg	9.2cde	11.36bcd	18.42ef	12.44b	16.45bcde	1977ij
	P3	8.12a	11.74ab	18.42fg	11.44a	16.21bcd	17.04cde	10.78a	16.4kb	18.65ij
Chereko	**P1**	14.6cd	18.98fg	22.69ijk	12.3ghij	15.56hij	19.98m	13.62ab	14.61ab	19.9bcd
	P2	13.17bc	15.07cde	23.99ijk	13.69cde	16.89fgh	19.91fgh	14.71bcdef	15.04gh	17.15cdefg
	P3	9.02a	19.27fgh	24.72jlm	14.64b	16.7ghi	21.15l	16.98gh	16.93hi	20.02ghi
	Mean		22.72			20.08		19.12		
	CV (%)		12.9			6.2		7		
	SD		2.93			1.24		1.34		
	P value		0.05			<0.01		0.034		

*H1= Harvesting at 8MAP, H2= harvesting at 10MAP and H3= harvesting at 12MAP, *P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT)

4.5.9 Effect of Varieties x Scheduled Planting x Harvesting times on Cassava Starch Content Interactions at Naliendele, Nachingwea and Ilonga

The results obtained from the study indicated that starch content had very high variation ($P < 0.001$). The grand mean was 19.08% whereas the Naliendele, Nachingwea and Ilonga separately had 19.25, 19.003 and 18.983% respectively (Table 35). However, planting and harvesting times of crop at Naliendele, Nachingwea and Ilonga had no significant difference ($P < 0.05$). The interactions of variety x scheduled planting x harvesting times recorded highest CSC (23%) for *Mkuranga* 1 variety that was planted in December and harvested during 12MAP and followed by *Kiroba* (22%) planted during December with its harvest at 12MAP at Naliendele site in Southern zone. Also at Ilonga in Eastern zone, CSC was highest (21%) with *Mkuranga* 1 planted in January and harvested during 12MAP followed by *Kiroba* (20%) planted in January and harvest at 12MAP.

Table 35: Effect of Varieties x Scheduled Planting x Harvesting times on Cassava Starch Content Interactions at Naliendele, Nachingwea and Ilonga

		Cassava Starch Content (%)								
		Naliendele			Nachingwea			Ilonga		
		H1	**H2**	**H3**	**H1**	**H2**	**H3**	**H1**	**H2**	**H3**
Kiroba	**P1**	20.92a	17.05a	21.84a	19.53a	19.75a	19.72a	17.94a	19.4a	17.9a
	P2	16.82a	17.25a	17.18a	19.44a	17.05a	15.32a	19.3a	18.462a	20.41a
	P3	17.99a	20.12a	19.88a	18.3a	17.96a	22.3a	15.83a	20.19a	19.12a
Mkuranga 1	**P1**	19.85a	18.9a	22.63a	20.24a	20.54a	18.41a	18.42a	20.86a	21.2a
	P2	16.81a	15.76a	19.32a	18.67a	19.05a	15.54a	18.62a	17.86a	21.57a
	P3	17.99a	19.43a	19.18a	19.39a	17.68a	21.85a	18.24a	19.02a	20.95a
Chereko	**P1**	19.34a	18.7a	21.86a	18.32a	19.66a	18.34a	19.32a	19.03a	20.9a
	P2	16.08a	16.56a	18.74a	18.16a	19.17a	15.35a	15.93a	17.53a	18.4a
	P3	19.94a	18.99a	21.5a	17.8a	19.02a	21.54a	16.86a	17.62a	18.66a
	Mean		19.25			19			18.98	
	CV (%)		9.4			8.5			6.7	
	SD		1.81			1.62			1.27	
	P value		0.92			0.92			0.12	

*V1= Kiroba, V2= Mkuranga 1 and=V3 Chereko, H1= Harvesting at 8MAP, H2= harvesting at 10MAP and H3= harvesting at 12MAP, *P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT

4.5.10 Effect of Varieties xScheduled Planting x Harvesting times on Cassava Dry Matter Content Interactions at Naliendele, Nachingwea and Ilonga

The dry matter contents from roots of three improved cassava varieties, harvesting at different months of scheduled planting at three sites where the experiment was conducted; statistically showed no significant difference existed (P < 0.05) at each site (Table 36). The mean of DM at the sites were 35.19% with 35.44, 35.09 and 35.06% for Naliendele, Nachingwea and Ilonga respectively. The interactions of variety x scheduled planting x harvesting times recorded highest on DM (40%) for *Mkuranga* 1 variety that was planted in January and harvested during 12MAP and followed by *Kiroba* (39%) planted during December with its harvest at 12MAP at Naliendele site in Southern zone. Also at Ilonga in Eastern zone, DM was highest (39%) with *Mkuranga* 1 planted in January and harvested during 12MAP followed by *Kiroba* (37%) planted in January and harvest at 10MAP.

Table 36: Effect of Varieties xScheduled Planting x Harvesting times on Cassava Dry Matter Content Interactions at Naliendele, Nachingwea and Ilonga

	Cassava Dry matter Content (%)								
	Naliendele			Nachingwea			Ilonga		
Factors	H1	H2	H3	H1	H2	H3	H1	H2	H3
Kiroba 1	37.8	36.85	39.09	35.83	36.15	36.10	33.58	35.65	33.52
	32.00	32.61	32.52	35.70	33.73	29.89	35.51	37.15	37.07
	33.66	36.66	36.32	34.09	33.62	39.74	30.6	36.76	35.25
Mkuranga 1	36.28	37.77	40.21	36.84	37.25	34.25	34.27	37.71	38.19
	31.99	36.16	35.53	34.61	35.15	30.19	34.54	34.88	38.71
	33.65	35.69	35.33	35.63	37.46	39.10	34.01	35.11	37.83
Chereko	35.56	34.66	39.12	35.54	36.01	34.15	35.53	35.12	37.77
	30.96	31.64	34.71	33.89	35.33	29.93	30.75	33	34.23
	36.41	35.06	38.61	33.38	35.11	38.66	32.06	33.13	34.6
		35.44			35.09			35.06	
		1.825			1.565			1.305	
		7.20			6.50			5.10	
		2.55			2.28			1.79	
		0.92			0.07			0.26	

*V1= Kiroba, V2= Mkuranga 1 and=V3 Chereko, H1= Harvesting at 8MAP, H2= harvesting at 10MAP and H3= harvesting at 12MAP,
*P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April)

4.5.11 Effect of Varieties x Scheduled Planting x Harvesting times Interactions on Cassava root Harvesting Index at Naliendele, Nachingwea and Ilonga

The harvesting index of cassava roots interacted with varieties, planting effect and scheduled harvesting months and Nachingwea and Ilonga had high significant difference ($p < 0.001$) and that at Naliendele differed significant at ($p < 0.05$). The mean of harvesting index interacted on three treatment interaction were 0.69, 0.68 and 0.52 at Naliendele, Nachingwea and Ilonga respectively (Table 37). The interactions of variety x scheduled planting x harvesting times recorded highest on HI (0.79) for *Mkuranga* 1 variety that was planted in January and harvested during 12MAP and followed by *Kiroba* (39%) planted during December with its harvest at 12MAP at Nachingwea site in Southern zone. Also at Ilonga in Eastern zone, HI had the highest ratio (0.77) with *Kiroba* planted in January and harvested during 10MAP.

Table 37: Effect of Varieties x Scheduled Planting x Harvesting times Interactions on Cassava root Harvesting Index at Naliendele, Nachingwea and Ilonga

				Harvesting Index						
				Naliendele			**Nachingwea**			**Ilonga**
		H1	H2	H3	H1	H2	H3	H1	H2	H3
Kiroba	**P1**	0.69defg	0.69defg	0.61ab	0.76ijk	0.70fgh	0.79k	0.67ghi	0.63efgh	0.71i
	P2	0.68cdef	0.74fghi	0.797j	0.76ijk	0.69efgh	0.61c	0. 59c	0. 77bc	0. 54b
	P3	0.75fghi	0.64bc	0.62ab	0.65cdef	0.73hij	0.63cd	0.66ghi	0.68hi	0.69hi
Mkuranga 1	**P1**	0.74fghij	0.58a	0.78ij	0.568b	0.72ghij	0.64cde	0.59def	0.67hi	0.63efgh
	P2	0.64bcd	0.77hij	0.73fghi	0.64cde	0.77jk	0.67defg	0. 52a	0. 67hi	0. 75bc
	P3	0.747ghij	0.74fghij	0.62ab	0.71ghi	0.64cde	0.58a	0.57de	0.67hi	0.56b
Chereko	**P1**	0.73fghi	0.73fghi	0.57a	0.72ghij	0.72ijk	0.68defgh	0.6defg	0.65ghi	0.65ghi
	P2	0.75ghij	0.75ghij	0.67bced	0.71ghi	0.73ghij	0.64cde	0.69c	0. 55b	0. 69c
	P3	0.72fghi	0.71efgh	0.62ab	0.79k	0.71ghi	0.69efgh	0.64fghi	0.66ghi	0.57de
	Mean		0.69			0.6876				0.52
	CV (%)		5.4			4.7				8
	SD		0.04			3.23				0.04
	P value		0.004			<0.001				<0.001

*V1= Kiroba, V2= Mkuranga 1 and=V3 Chereko, H1= Harvesting at 8MAP, H2= harvesting at 10MAP and H3= harvesting at 12MAP, *P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT)

4.5.12 Effect of Cassava Varietal Responses x Planting x Harvesting Schedules Interaction on CBSD root necrosis Severity at Naliendele, Nachingwea and Ilonga

The results on interaction effect of varieties x harvesting times, planting schedules x and varieties x planting schedules x harvesting times had no significances (Table 38) effect on CBSD root necrosis severity ($P < 0.05$) with a highest severity (2%) for *Chereko* variety planted on January and harvested during 12MAP at Naliendele site The planting and harvesting schedules interactions had a CBSD severity of 1% (Table 38) and (plate 3) showing the assessment of necrosis during harvesting time.

Plate 3: Assessing cassava root CBSD necrosis at Ilonga site

Table 38: Effect of Cassava Varietal Responses x Planting x Harvesting Schedules Interaction on CBSD root necrosis Severity at Naliendele, Nachingwea and Ilonga

Factors		Naliendele	Nachingwea	Ilonga
	P1	1.17a	1.08a	1.08a
Kiroba	**P2**	1.0a	1a	1.08a
	P3	1.25a	1.41a	1.08a
	P1	1.17a	1a	1a
Mkuranga 1	**P2**	1.25a	1a	1a
	P3	1.34a	1.18a	1a
	P1	1.17a	1a	1a
Chereko	**P2**	1.33a	1.25a	1.08a
	P3	1.62b	1.17a	1.08a
	Mean	1.252	1.12	1.05
	CV (%)	35.5	33.8	20.2
	SD	0.44	0.38	0.21
	P value	0.541	0.236	0.93
H1	**P1**	1.25a	1a	1a
	P2	1.25a	1.08a	1.08a
	P3	1.33a	1.42a	1.08a
	P1	1.09a	1.08a	1.08a
H 2	**P2**	1.17a	1.17a	1.08a
	P3	1.56	1.17a	1.08a
	P1	1.16a	1a	1a
H3	**P2**	1.16a	1a	1a
	P3	1.27a	1.17ab	1a
	Mean	1.25	1.12	1.05
	CV (%)	35.5	33.8	20.2
	SD	0.44	0.38	0.21
	P value	0.46	0.51	0.93
	H1	1.25a	1.17a	1a
Kiroba	**H2**	1.17a	1.25a	1.25a
	H3	1.00a	1.17a	1a
	H1	1.25a	1.17a	1a
Mkuranga 1	**H2**	1.25a	1.17a	1a
	H3	1.25a	1.17a	1a
	H1	1.33a	1.17a	1.17a
Chereko	**H2**	1.42a	1a	1a
	H3	1.36a	1a	1a
	Mean	1.252	1.12	1.046
	CV (%)	35.5	33.8	20.2
	SD	0.44	0.38	0.21
	P value	0.826	0.632	0.5

*H1= Harvesting at 8MAP, H2= harvesting at 10MAP and H3= harvesting at 12MAP, *P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT).

Table 38 cont………………

		Naliendele			Nachingwea			Ilonga		
Factors		**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**
Kiroba	**H1**	1.22a	1.00a	1.50a	1a	1a	1.5a	1a	1a	1a
	H2	1.25a	1.00a	1.25a	1.25a	1a	1.25a	1.25a	1.25a	1.25a
	H3	1.00a	1.00a	1.00a	1a	1a	1.5a	1a	1a	1a
Mkuranga	**H1**	1.25a	1.25a	1.252	1a	1a	1.5a	1a	1a	1a
	H2	1.00a	1.25a	1.50a	1a	1a	1a	1a	1a	1a
	H3	1.25a	1.25a	1.25a	1a	1a	1a	1a	1a	1a
Chereko	**H1**	1.25a	1.50a	1.25a	1a	1.25a	1.25a	1a	1.25a	1.25a
	H2	1.00a	1.25a	2.00b	1a	1.5a	1.25a	1a	1a	1a
	H3	1.252a	1.25a	1.60b	1a	1a	1a	1a	1a	1a
	Mean		1.252				1.12	1.046		
	CV (%)		35.5				33.8	20.2		
	SD		0.44				0.38	0.21		
	P value		0.58				0.85	0.99		

*V1= *Kiroba*, V2= *Mkuranga* 1 and=V3 *Chereko*, H1= Harvesting at 8MAP, H2= harvesting at 10MAP and H3= harvesting at 12MAP, *P1= planting 1(December), P2= Planting 2 (January) and P3= planting 3 (April), All means in the same column having the same letters do not differ significantly at *p<0.05, **p<0.01 and ***p<0.001 when separated by Duncan Multiple Range Test (DMRT)

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effect of Variety on Cassava Sprouting Percentage

The variation in the abilities of *Kiroba, Mkuranga* 1 and *Chereko* varieties on sprouting characteristic at Naliendele, Nachingwea and Ilonga, was probably due to differences in environmental characteristics recorded at the respective sites as indicated in (Table 4) at planting time. Such results have also been recorded by Bah *et al.,* (2004) who worked on cassava using different varieties in Guinea (West Africa). Sprouting happens when the plant had attained its independence on utilization of above and underground soil resources after a period of depending on its internal resources. The auxiliary buds usualy initiate the the gowth phase of the crop which resources the food from stem cuttings (CIAT, 1984).

Differences in sprouting has also be reported by other authors including Lamprecht, (2015) who observed that spouting ability is influenced by very much genetic make up of specific cassava variety be grown, caused by genetic diversity among the varieties and concluded in their studies that the differences were due to efficiency of cassava planting materials rotting. Researchers like Lazano and Booth, (1976) also proved that; despite of genetic diversity existing among the cassava varieties, the quality of stems, edaphic factors and weather conditions are well known as most influencial conditions in cassava general performance beginning from sprouting hence crop growth and development. The quality of stems can negatively or positively affects the establishment of cassava depending on part of the stem (upper, middle or lower), thickness, and number of nodes per stem and health (IITA, 1990). When all these attributes are well kept, sprouting of vigorous plants capable of producing good number of roots will be highly achieved (IITA, 1990; Bah *et al.*, 2004).

5.2 Effects of Cassava Varieties on Days to 50% first Branching and Flowering

The significance differences of first branching and flowering recorded in this study may have been be caused by fluctuating temperature (27-30°c), RH (76-85%), and rainfall (750-1200mm) from (Table 4) which has been reported also by (Irikura *et al*., 1979; Keating *et al*., 1982; Phoncharoen *et al.,* 2019). Peak flowering was observed to occur during conditions of high rainfall, high relative humidity, high available moisture, moderate temperature, and early planting. In crop growth and development; branching is a process which marks the beginning of reproductive phase, the interaction between photoperiodic effect and temperature is the basis for determining phenological development. When the number of nodes produced on the stem is dependent on the assimilate supply. The stem is an important sink and stands in strong competition to tubers for dry matter (Ekanayake, 1998).

The results from this study are contrary with the earlier findings of above scholars in which *Mkuaranga* 1 variety branched earlier than *Kiroba* and *Chereko* but had lower yield compared to other late forking the ’’*Kiroba* and *Chereko*’’ (Table 6) .This indicating a lower leaf photosynthesis efficiency of *Mkuranga* 1 variety and lesser partitioning from the sources to sinks. Therefore, the storage root yield of *Mkuranga* 1 variety could be improved through management practices, such as using wider spacing than that used in this experiment, which would optimize light interception and enhance the suitable proportion between the top and storage root for maximum yield.

In cassava, flowering is one of the vital growth and development process, researches like Corbesier *et al*., (2007); Bull *et al*., (2017).The time for flowering in cassava remains highly associated with varieties and the geographical area where the crop is grown. Observations made by Bull *et al.,* (2017) indicated that; many famers preferred genotypes which are erect to facilitate easy farming management and practices and utilize the maximum stem growth consequent vegetative propagation. This non-branching architecture is also concomitant with poor flowering ability with many genotypes taking more than twelve weeks to start floering in the field (Byrne, 1984; Ceballos *et al.,* 2004; Bull *et al*., 2017).

5.3 Effect of Cassava varieties, Planting Schedules and Harvesting time on root size

The results in this study (Table 31) show that *Mkuranga* 1 variety had the longest root length than *Chereko* and *Kiroba* but had low root yield.This is because the increase in number, length and thickening of the roots contribute to the high average increases in root fresh yield (Oliveira *et al.,* 2017). Further results of this study indicate that the root size is influenced by the varieties, time of planting and harvesting time. Furthemore, Figueiredo *et al*., (2014) found a close positive correlation between root fresh matter and root diameter; whereas the number of roots explained only 60 % the total cassava root yields. This can be attributed to the genetic make up of the cultivar, which, due to its smaller diameter, makes up for lower roots by increasing length. Tewodros *et al.,* (2008 and 2012) reported on the correlation of root length and diameter that had associated positively with root fresh weight of taro and yam.

An increament in total root length and width (diameter) are highly indicating the similarity pattern in increasing cassava root yields (Izumi *et al*., 1999). It also a similar observation was made by Izumi *et al*., (1999) that; low (decrease) in total root size and the total root yield (t/ha) was associated with root bulking. This applied that, the varieties that recorded reduced root length especially the harvesting time that was done at 10MAP planted in December and that in January were iniating root bulking after a period of leaves were shedding off and rejuvenation start up.

Based on root size, the highly significant means that were observed among planting and harvesting times within and across locations, as well as the non-significant genotype by environmental interaction (GxE) indicated insignificant variability in the performance of genotypes within the Southern zone as the varieties were released for this zone (TOSCI, 2015b). Large root size showed to influence the total root yields of cassava as *Chereko* had bigger size followed by *Kiroba* and *Mkuranga* 1 the least.This study still confirming the earlier study done by other scholars like Aina *et al*., (2007) who found that large size cassava roots influence the total fresh root yield.

5.4 Effect of Cassava Genotypes, Planting Schedules and Harvesting times on Total root Yields

The total fresh roots yield on harvesting time, results showed increasing significantly from 8, 10 and 12 MAP respectively (Table 34) .The cassava harvested during this period which was planted in December, January and February received the optimum environmental conditions (Table 4) during the stages of canopy development and storage root bulking may have synthesized higher amount of starch and therefore synthesized starch was accumulated in storage roots. The starch accumulated in these plant parts was further accumulated in storage roots at the later stages of the growth cycle.

It has become evident that the production of cassava roots gradually increased the average yield related to the time, based on which, there is an increased rate in the accumulation of carbohydrates at the end of the first cycle, whereas, the leaves drop in the drier and colder periods. Beginning in the third cycle (12 months), when good precipitations and higher temperatures have been conciliated, the plants grow new leaves and restart more accentuated root development. This was also earlier reported by Fukai *et al*., (1984) and Janket *et al*., (2018) also showed that high solar radiation during the growing period resulted in an increase in the total biomass production and storage root dry weight in cassava

However; crops planted at late rain season observed to have low yields compared with early planting during the onset. In these two zones, late January up to end of February experience drought spell causing stomata closing and hence slows down the growth rate of plant. Lenis *et al*., (2006) suggested that the root dry matter yield decreases under water stress conditions. This is in agreement with Schulthess *et al*., (1991) who observed that the effect of drought caused the breaking of apical dominance, leading to lateral shoot formation which use reserves from roots and stems. Also, Santisopasri *et al*., (2001) had the same observation that; cassava plants which undergo water stress in the first six months after planting produce low yields. Regarding the genotypes on total fresh roots yield, the trend was *Kiroba >Chereko > Mkuranga 1* while Ilonga produced lower compared with Naliendele and Nachingwea.This trend of genotype by- environment effect still confirming the earlier study done by other scientists like Sriroth *et al*., 1999 and Egesi *et al*., (2007) who found that; the high variability observed among cultivars, indicated the presence of sufficient genetic variability for the traits studied.

5.5 Effect of Cassava Varieties, Planting Schedules and Harvesting times on Harvesting Index

The harvesting index also presented variation based on harvest times. It increased significantly linearly to second harvest at 10 MAP and then dropped in 12 MAP (Table 33) indicating a good balance of assimilates directed to the storage roots, until the last harvest. The period with the lowest harvest index was in December/January. This period corresponded to a high vegetative growth period and leaf shading off the plants (Sagrilo *et al.*, 2006). Generally, there were great variations in harvesting index among three genotypes used in this experiment, so that the elevated harvesting index rates are desirable, as they demonstrate the root capacity for attracting and accumulating as starch, the carbohydrates produced by the aerial part (Luiz *et al.*, 2016).

Irrespective of cassava cultivar, *Kiroba* gave higher harvesting index, indicating that it was highly efficient in translocation of assimilates for storage in tuber roots (Polthanee and Wongpichet, 2017). On the locations where experiment was conducted, the trend from highest to lowest HI was Naliendele> Nachingwea > Ilonga respectively. Harvesting index value (0.5-0.6) is optimum level because at higher value of HI, root production potential is affected as a result of photosynthetic area (Iglesias *et al*., 1994). The higher the HI value indicated that the total photosythates amount from the leaves (sources) has been diverted to the storage roots (sinks).

Harvesting index is an important trait making it possible to obtain a proportional ratio between the roots produced as compared to the total biomass of the plants (total fresh roots, total green biomass and total lignified). This parameter can supply a good balance between the total production of carbohydrates by the plants and their distribution to the roots. Currently in crop agronomy programs, a harvest index is included as contributing to agronomic traits selection, due to the enormous existent variation among genotypes (Vorasoot *et al.*, 2003). Kawano, (1990); reported that the increased partitioning of photosynthetic assimilates to storage root is also one of the fundamental traits for promoting the cassava yield whereas Tan and Cock, (1979), suggested that; it is necessary to obtain a balance between the roots and shoot growth in order to increase cassava yield.

5.6 Effect of Cassava Genotypes, Planting Schedules and Harvesting times on Cassava Starch Content

The cassava starch content percentage increased significantly from earlier harvesting of eight to twelve months after planting with drop up at ten months after planting (Table 36). This augmentation of starch was closely related to changes in root related parameters which was accompanied with number of roots; their length and an associated diameter growth (Table 31). In agreement with those reported by (Tewodros, 2012). The same researcher indicated that such results could be due to phenotypic advancement associated with increased plant height that creates the potential to prepare more food through photosynthesis and increased root length with its diameter, which are yield related components.

The cassava starch content (normal range) at harvesting time in 12MAP was 22-31%; young roots were those less than 9 months old were lower in starch (18-27%) and older roots over 24 months were lower and woody (Darkwa *et al.*, 2003). During different harvesting months after planting, cassava starch content was lower in crops planted during mid-rainfall and harvested during the onset of rainfall in November/December where the plants had shed its leaves then use the starch stored has been hydrolysed into free sugars for the growth of new plant tissues. Similar observation was seen by Michael *et al., (*2015) that planting during the late rain season is of a lesser extent because the early growing phases coincide with the dry season.

On the other hand, varietal performance seems to influence starch contents at different levels though generally were similar at statistical level. This also had been observed by Apea-Bah *et al.,* (2011) on effect of genotypic influence on yield and yield components including starch contents. *Mkuaranga* 1 had higher cassava starch contents, followed by

Kiroba and *Chereko* the least. Across the sites, significance differences existed with the trend of Naliendele >Nachingwe*a* >Ilonga. This implies that the genotypes responded differently to the locations and harvesting time. This phenomenon was also the same as reported by Egesi *et al.*, (2007) who observed similar results for cassava fresh root yield. This variation was influenced by genetic as well as various environmental factors which could be linked to variation in temperatures, water deficit, and inefficient distribution of assimilate in favour of the roots and time of harvest (Grant *et al*., 1985; Michael *et al.*, 2015). The productivity of cassava is also limited by soil nutrient status, for cassava cultivated in sandy loam during the dry season; higher root quality in terms of starch content is possible (Santisopasri, 2001).

5.7 Effect of Varieties, Planting Schedules and Harvesting times on Cassava Dry Matter Content

Cassava dry matter content is influenced by several factors such as age, crop season, location and efficiency of canopy to trap sunlight (Lian, 1958). DM% varies from and ranges between 17-47% with majority lying between 20-40% (Barima *et al*., 2000); values above 30% are termed high. From the results; dry matter content increments of harvesting time i.e. 8, 10 and 12 MAP was noticed significantly, a trend also observed by Sagrilo *et al*., (2006). Accumulation of dry matter increased, until physiological rest (9-10MAP) and from that period onwards reserve carbohydrates are mobilized for synthesis of new vegetative growth (Sagrilo *et al*., 2006; Benesi *et al*., 2008).

Scheduled planting affected significantly the dry mater contents in which cassava planted during the onset of rainfall in November/December had higher followed by that planted in late wet season in March/April while planting cassava in January/February during mid-rain dry matter recorded was lower. This may ahve been due to the effect of environmental conditions as indicated in (Tables 3 and 4) during both the initial and late growth when root dry matter content was high (Bakayoko *et al*., 2009). This study confirms the importance of rainfall during cassava growth, especially in the early development stage (Sriroth *et al.,* 1999).The distribution pattern of dry matter among the different organs of cassava plant change markedly during the growth cycle, with shoot having dominance in the first 3-5 months while storage roots become major sink for photoassimilates during the rest of the growth cycle (ElSharkawy, 2004). *Mkuranga* 1 cultivar was superior on cassava dry matter across the three sites where experiments were done followed by *Kiroba* and *Chereko* while *Naliendele* was leading and *Ilonga* the least. This variation on genotypes and locations on cassava yield and yield components like DM% cement the former study done by Egesi *et al*., (2007).

5.8 Effect of Varieties, Planting Schedules and Harvesting times Interaction on Cassava Brown Streak Disease

The varieties used were *Kiroba, Mkuranga* 1 and *Chereko* which exhibited a form of tolerance to CBSD in which some foliar symptoms appeared but the development of root necrosis was delayed allowing the full yield potential to be realized. Results from this study (as the grand mean of root necrosis is 1.15) which is classified as no infection/losses and hence the roots considered marketable (IITA, 1994) have provided insights into the tolerant or resistant varieties against CBSD root necrosis infection and that can help reducing the losses that may be caused by growing susceptible genotypes.

Brown streak virus disease is among the most important biotic constraint to cassava production in Tanzania (Easten and Southern coastal belt inclusive). The disease affects the roots which develop a yellow/brown, dry, corky necrosis within the starch-bearing tissues, sometimes accompanied by pitting and distortion, that is visible externally (Hillocks *et al.,* 2008). The foliar symptoms of the disease often do not greatly affect plant growth, although the most sensitive cultivars may be stunted and defoliated. The main impact of the disease on the crop is by causing root necrosis. This study revealed that Cassava brown streak disease (CBSD) had no effect on decreased root weight and quality characterisrics as no patches of root necrosis that could made roots unmarketable.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The study across the sites showed that, for cassava scheduled planting, harvesting and genotypes based on starch content varied depending on the months the crop planted, harvested and varieties; therefore the study concluded that: *Kiroba* variety planted in November/December and then harvested at 12MAP gave higher total root yield (27t/ha) at Southern zone and also at the Eastern zone *Kiroba* variety planted in November/December and March/April yielded higher total root (22t/ha) when harvested at 12MAP.

Based on cassava dry matter content; the study concluded that: higher dry matter content was obtained when *Mkuranga* 1 variety planted on November/December and harvested at 12MAP gave 40% followed by *Kiroba* variety planted in November/December and harvested after 12MAP had 39% at Southern zone and Ilonga site (Eastern zone) concluded that; dry matter content of *Mkuranga* 1 variety planted in January/February and harvested at 12MAP gave 39% followed by *Kiroba* variety planted in January/February and harvested at 10MAP which had 37%. Also the study found that; cassava starch content was higher (23%) at Southern zone when *Mkuranga* 1 variety planted during November/December and harvested at 12MAP before the onset of rainfall followed by *Kiroba* (22%) planted in November/December and harvested at 12MAP in Southern zone and that at Eastern zone, higher cassava starch content (21% and 20%) was recorded when *Mkuranga* 1 and *Kiroba* varieties planted in January/February and harvested at 12MAP respectively.

The information on cassava yield and yield components at scheduled planting, harvesting months and varietal performance will help starch processing industries investors, farmers and other cassava stakeholders to maximize the dry matter, starch contents, root yields and other related yield components.

6.2 Recommendations

This study recommends that, farmers and other cassava stakeholders should continue practising planting cassava in November/December for home consumption and adopt the late planting in March/April for commercial use in cassava processing industiries in favour of fresh root yields, dry matter and starch contents. However, *Mkuranga* 1 variety is highly recommended to be used for the immerging processing industries in Tanzania for starch while for high fresh root yields it is recommended to use *Kiroba* variety. Generally, Southern zone is highly recommended for starchy processing, followed Eastern Zone. The study also recommends that; breeding programs (crossing) using *Kiroba, Mkuranga* 1 and *Chereko* varieties has to be initiated to get more clones from theses varieties with diverse good qualities. *Kiroba* and *Chereko* has to be planted earlier at least a month then followed by *Mkuranga* 1 which flowers earliest (114 days) at 50% followed by Chereko (140 days) and Kiroba (146 days).

To better understand the physiological basis of cassava growth, further investigations are needed into other crop traits, such as leaf and canopy growth, light transmission, light use efficiency, photosynthesis, e.t.c for the different cassava branching types planted at different planting dates and the relationship of these traits to storage root yields. More research studies are recommended using similar treatments plus other newly release cassava varieties be conducted for at least three consecutive seasons for validating the results obtained from season one.

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APPENDIX

Appendix 1: Physical and Chemical Properties of Soils at Naliendele, Ilonga and Nachingwea during 2017/18-2018/19 Seasons

		NALIENDELE Depth (cm)				**ILONGA** Depth (cm)				**NACHINGWEA**		
Soil characteristics	SI Unit	0-20	21-50	Average	Status	0 – 20	21 – 50	Average	Status	Average	Status	Rated according to;
CLAY	%	7.6	6.6	7.0		30	28	29		17.6		
SILT	%	2.4	1.8	2.0		15	17	16		3.4		
SAND	%	90	92.6	91.0		55	55	55		79		
Texture Class		Sand				Sandy Clay				Loamy sand		Soil staff, 1993
pH		5.73	5.71	5.72	Sufficient	6.40	6.48	6.44	Sufficient	5.39	Sufficient	Howeler, 1996
Soil organic matter	%	1.086	1.0516	1.0689	Low	2.92	2.75	2.837	Medium	3.221	Medium	Howeler, 1996
Soil organic carbon	%	0.63	0.61	0.62	Low	1.70	1.60	1.646	Sufficient	0.965	Sufficient	Landon 2014
Total nitrogen	%	0.082	0.065	0.074	Low	0.13	0.13	0.130	Low	0.05	Low	Landon,2014
Cation Exchangeable Capacity	$cmol_c$/kg	4.122	3.116	2.615	Very low	13.15	24.77	18.959	Sufficient	4.686	Low	Landon,2014
Available phosphorus	meq/kg	2.4	1.6	2	Low	6.1	17.6	11.850	Sufficient	10.95	Sufficient	Howeler, 1996
Exchaneable Potassium	$cmol_c$/kg	0.272	0.188	0.23	Sufficient	0.73	0.64	0.685	High	0.816	High	Howeler, 1996
Excheable Calcium	$cmol_c$/kg	0.378	0.392	0.385	Low	4.53	4.67	4.602	Sufficient	2.533	Sufficient	Howeler, 1996
Excheable Sodium	$cmol_c$/kg	0.872	0.884	0.878		0.92	1.00	0.959		0.751		
Magnesium	$cmol_c$/kg	0.2	0.052	0.126	very low	0.86	0.87	0.863	Sufficient	0.586	Sufficient	Howeler, 1996

Copper	mg/kg (ppm)	0.352	1.454	0.903	Sufficient	5.66	5.75	5.708	High	2.25	High	Howeler, 1996
Zinc	mg/kg (ppm)	0.98	0.715	0.848	Low	1.59	1.19	1.388	Sufficient	1.193	Sufficient	Howeler, 1996
Manganese	mg/kg (ppm)	64.953	59.813	62.383	Sufficient	83.33	83.97	83.654	Sufficient	68.752	Sufficient	Howeler, 1996
Iron	mg/kg (ppm)	27.941	27.941	27.941	Sufficient	124.53	145.28	134.906	High	118.781	High	Howeler, 1996