KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

FACULTY OF RENEWABLE NATURAL RESOURCES

DEPARTMENT OF AGROFORESTRY

EFFECT OF STORAGE AND LENGTH OF CUTTING ON INITIAL GROWTH AND YIELD OF *Jatropha curcas*

KWAME BIILAH DUUT

OCTOBER, 2015

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A THESIS SUBMITTED TO THE BOARD OF GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN AGROFORESTRY

KWAME BIILAH DUUT

BACHELOR OF EDUCATION (SCIENCE)

OCTOBER, 2015

DECLARATION

I do declare that, except references to other people's work which have been duly cited, this work submitted as a thesis to The Department of Agroforestry, Faculty of Renewable Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, for the degree of Master of Science in Agroforestry, is a result of my own investigation, and that it has, neither in whole nor in part, been submitted elsewhere for another degree.

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(SUPERVISOR)

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DR. OLIVIA AGBENYEGA DATE

(HEAD OF DEPARTMENT)

DEDICATION

This piece of work is dedicated to the Souls of my late Brothers- Duut Yakubu and Duut Simon Kimilipaak who departed to their Creator during the Course of my study. May they rest in perfect peace.

ABSTRACT

The *Jatropha curcas* is a multipurpose drought resistant perennial plant with the potential for economic production of biofuel. Vegetative propagation holds better prospects for large scale plantation development. However, storage of stem cuttings and the length of stem cuttings to ensure effective and efficient plantation establishment must be investigated. The main objective of the study was to determine the appropriate cutting length, storage duration and storage method of stem cuttings. Semi- hardwood cuttings were stored vertically and partly buried to a depth of 15 cm under shade (PB) and another stored vertically under shade but not buried (NB). Exactly 30cm length of cuttings were planted in poly bags on the first day (S1), 5 days (S2), 10 days (S3) and 15 days (S4) of storage. Two lengths of stem cuttings 30cm (L1) and 40cm (L2) length cuttings were prepared from stored cuttings for planting on the first day (S1), 5 days

(S2), 10days (S3) and 15 days (S4) of storage. Data was collected at 5 days interval till 40 days on various growth parameters till 42 days in the nursery. After transplanting in the field, data on growth and yield parameters were collected at two weeks interval till 16 weeks. Results of the research showed that 40cm (L2) cuttings performed better in terms of growth and yield parameter such as number of sprouts, number of leaves, number of branches, plant height, number of roots, length of root, root volume, root biomass, shoot biomass, number of flowers and number of fruits than the 30cm (L1) length cuttings. Cuttings that were stored between 0 and 10 days had vigorous growth performed better in terms of growth parameters such as number of sprouts, number of leaves, plant height, number of roots, length of root, root volume, root biomass, shoot biomass than the cuttings stored for 15 days.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND

The increase in human population worldwide has resulted in an increasing demand for petroleum and petroleum products. This subsequently has led to shortages and increases in prices of fossil-fuels on the world market which has significant influence on many countries. Due to increasing price of fossil fuel, special interest has been shown in the cultivation of *Jatropha curcas* for fuel extraction. The Kyoto protocol of 1997 raised environmental and economic concerns that have promoted resurgence in the use of biodiesel throughout the world. This has prompted scientific research into plants such as *Jatropha curcas* (Grimm, 1996; Heller, 1996; Henning, 2002; Pratt *et al*, 2002).

Scientific research recommends plants such as *Pongamia pinnata (*Indian Beech), *Ricinnus communis* (Castor Bean), *Aleurites spp.* (Japan Tree, Tung Nut), *Sapium sebiferum* (Chinese Tallowtree), *Manihot esculenta* (Cassava) and *Jatropha curcas* (Physic Nut) as oil plants, but supports that *Jatropha curcas* has the brightest potential not only for growers but also for processors and end users. *Jatropha curcas* stands out of any of these oil plants because it has many uses such as energy and fuel, medicinal, fodder and for soil improvement. Other potentials of jatropha include its ability to grow on marginal land, resistance and tolerance to many pests and diseases. Results from the Indian Biofuel Awareness Centre (2004) indicated that rain fed Jatropha can yield 1.591 to 1.705litres of oil per plant, while with irrigation; 3-5litres per plant can be obtained every 15 days. Dogbevi (2009) suggests that this production can be doubled through the use of good planting material and proper management of the crop.

Since the oil crises in the 1970s, special interest has been shown in the cultivation of tropical physic nut (*Jatropha curcas*) due to its high quality oil (Heller, 1996; Grimm, 1996; Rockefeller Foundation, 1998).

Jatropha curcas, a cash crop is a plant of Latin American origin which is now widespread throughout the arid and semiarid tropical regions. *Jatropha curcas* belongs to euphorbiaceous family. It is a woody perennial which can live up to 50 years and can be grown on marginal lands (Heller, 1996). It is considered as one of the important multipurpose fast growing large shrub species (Heller, 1996; Grimm, 1996; Rockefeller Foundation, 1998).

Locally, it is grown as a live hedge or boundary fence and can be used to reclaim eroded areas (Heller, 1996; Joker and Jepsen, 2003). Its leaves and stems are toxic to animals, but can be used as food tussle silkworms (Morton, 1981). The seeds or seed cake is also an excellent source of plant manure (Rockefeller Foundation, 1998, Makkar *et al.*, 2001). Traditionally, Jatropha seeds have been harvested by women and used for medical treatment and local soap production (Henning, 2002; Duke, 1983). According to Singh et al. (2007), the bark of the tree produces a dark blue dye to colour fishing nets and lines.

Jatropha can be cultivated using seeds or stem cuttings. Propagation by seed is a natural process resulting in a parent plant forming seeds. Growing Jatropha plants from seeds is cheap and easy but offspring produced from seeds are not genetically identical to each other and to the parents (Heller, 1996). Vegetatively propagated plants on the other hand produce genetically identical offspring which maintain desired characteristics of parents in natural setting.

Propagating *Jatropha curcas* from cuttings is also an easy method for producing new plants within a short time. Under this asexual propagation method, cuttings are usually made from the shoot (stem). It is quicker in terms of growth since there is more food reserve in the cutting for the young plant to depend on. This leads to rapid maturity of plants than those grown from seeds. Desirable characteristics are retained as the offspring are identical to the parent plan.

Jatropha plants have profuse vegetative growth, but the number of seeds produced per plant is very low. Besides, the plants produce seeds after approximately 2–3 years depending on environmental conditions. Seeds have limited viability; they lose almost 50% viability within 15 months (Kobilke, 1989). Propagation through seeds leads to genetic variability and makes the plants vulnerable to diseases whereas propagation through vegetative means offers an advantage in developing genetically homogeneous plant material, disease-free varieties for commercial plantings (Nanda and Kochhar, 1987).

Research on vegetative propagation of Jatropha is limited in terms of the length of cuttings to use as well as on storage of cuttings in terms of method and duration. Thus it is considered useful to undertake a systematic study on the vegetative propagation of Jatropha through stem cuttings. Vegetative propagation through stem cuttings without any hormone application can be a profitable and efficient procedure of multiplication of *Jatropha curcas* since cost of producing plant material is reduced. It also helps to retain the heterotic nature of bred seedlings for long time without fear of segregation because there is no further recombination process.

The study therefore is undertaken to develop the appropriate techniques for mass production of seedlings through stem-cutting in order to maintain genetic purity, uniformity and gainful exploitation of useful variation, and meet the demand for highquality planting material required at commercial scale. A limited research study on storage of cuttings (method of storage and storage duration) has been shown to affect the rooting, sprouting and hence initial growth of jatropha (Syros et al., 2004). This research would study the influence of these factors on the early growth, rooting and yield of *Jatropha curcas*. Finally, the study would consider appropriate length of cutting for faster growth and development.

1.2 PROBLEM STATEMENT

Jatropha curcas is usually propagated by seed. Propagation through seed (sexual propagation) leads to genetic variability in terms of growth, biomass, seed yield and oil content. Low seed viability also limits seed propagation as germination will be affected.

Using cuttings however, more planting materials can be generated from an initial plot in a shorter period with the added advantage of obtaining true-to-type plants. Harvested cuttings may to be transported from one area to the other and may not be planted immediately. Hence the cuttings must be stored in a manner that will help maintain its integrity for successful cultivation and high yield. Length of cuttings is important in vegetative propagation as it affects starch reserve in the cutting. Rooting and growth of cuttings is strongly influenced by genotype, storage duration and length of cutting (Kibbler, *et al.*, 2004).

Inspite of the above, there is dearth of information on the suitable cutting length that best favours vegetative propagation of *Jatropha curcas*. This study therefore aims at

evaluating the effect of storage (storage method and storage duration) and length of cutting on initial growth and yield of *Jatropha curcas.* Successful precultivation treatments of stem cuttings is characterized by the following parameters:

- High sprouting and rooting rates of cuttings
- High survival rates of plants

These parameters will be used to assess the effect of the treatments on the cuttings.

1.3 JUSTIFICATION OF THE PROBLEM

With the interest shown in the cultivation of *Jatropha curcas* in Ghana, planting materials will be required for the establishment of plantations. The planting materials can be obtained from jatropha plants in the wild, fence of gardens, farms or homes. These sources may not be enough or of good quality for plantation purposes. It is therefore necessary to establish and manage plantations where good planting materials (cuttings) can easily be obtained for planting.

For quick establishment of hedges and plantations for erosion control, directly planted cuttings are recommended since they have profuse vegetative growth. However, for long lived plantations for vegetable oil production, plants propagated by seeds are considered better (Heller, 1996), though there is a long wait for seed production before planting materials become available for new areas.

Using cuttings however, more planting materials can be generated from an initial plot in a shorter period with the added advantage of obtaining true-to-type plants. Harvested cuttings may have to be transported from one area to another and may not be planted immediately and has to be stored for some time. The method and period of storage of stem cuttings prior to planting is important in establishing strong jatropha

plantation. Cutting length has effect on vegetative growth of jatropha as it determines amount of carbohydrate reserve in the plant. Amount of Carbohydrate reserve in cuttings influences growth and hence yield of jatropha plant.

There is therefore, the need to investigate the effect of storage of jatropha cuttings on sprouting, rooting, establishment and yield. Additionally, length of cutting may affect sprouting and rooting and yield of *Jatropha curcas.*

1.4 RESEARCH OBJECTIVES

General objective

The general objective of this study is to evaluate the influence of storage (storage method and duration of storage) and length of stem cuttings on sprouting, growth and seed yield of *Jatropha curcas*.

Specific Objectives

1. To evaluate the effects of different storage (methods and duration) and lengths of cuttings on initial growth of *Jatropha curcas.*

2. To study the effect of different storage (methods and duration) and length of cutting on the growth and yield performance of *Jatropha curcas.*

3. To assess survival percentage after transplanting of cuttings.1.5 RESEARCH **HYPOTHESES**

   The hypotheses include the following:

   - *Jatropha curcas* stem cuttings cannot be stored for 15 days without the loss of 50% viability.

- Method of storage and storage duration of *Jatropha curcas* stem cuttings will not influence sprouting, growth and seed yield of the plant.

- Length of stem cuttings will not influence sprouting, growth and yield of *Jatropha curcas.*

The above hypotheses will be tested through field experimentation and laboratory analysis.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 BOTANICAL DESCRIPTION OF *jatropha curcas*

The Genus name Jatropha is derived from the Greek words Jatro's (doctor) and tropheˊ (food), which implies medicinal uses. 'Curcas' is the common name for the physic nut (Correll and Correll, 1982). It is a small tree or large shrub which can reach a height of 5m. Dormancy is induced by fluctuations in rainfall and temperature or light.

It has 5 – 7 shallow lobbed leaves with a length and width of 6–15 cm which are arranged alternatively. The leaves, hypostomatic and stomata are of paracytic (Rubiaceous) type. The trees are deciduous, shedding the leaves in dry season. Normally, five roots are formed from seedlings, one central and four lateral or peripheral. A tap root is not usually formed by vegetatively propagated plants (Kobilke 1989).

Inflorescence is formed terminally on branches and is complex, possessing main and co-inflorescence with paracladi. Botanically, it can be described as a chyme. The plant is monocious and flowers are unisexual; occasionally, hermaphroditic flowers occur. Ten stamens are arranged in two distinct whorls of five each in a single column in the androecium, and in close proximity to each other. In the gynaecium, the three slender styles are connoted to about two-thirds of their length, dilating to massive bifurcate stigmata (Dehgan and Webster, 1979).

Pollination of the physic nut is by insect. Dehgan and Webster (1979) believe that it is pollinated by moths because of "its sweet, heavy perfume at night, greenish white flowers, versatile anthers and protruding sexual organs, copius nector and absence of visible nector guides". When insects are excluded from the greenhouse, seed set does not occur without hand pollination. The rare hermaphroditic flowers can be self-pollinating. During field trials, Heller (1992) observed a number of different insects that visit the flowers and could pollinate. The insects include *Apis florae, Vesp spp. Catopsila Pomona, Chrysommya megacephala.* In Senegal, he observed that staminate flowers open later than the pistillate flowers in the same inflorescence.

To a certain extent, this mechanism promotes cross pollination."It seems that the mechanism is influenced by the environment". After pollination, a trilocular ellipsoidal fruit is formed, the exocarp remains fleshy until they are matured. The *Jatropha curcas* can flower once a year under an active rainy season. In permanently humid regions under irrigated conditions, *Jatropha curcas* flowers almost throughout the year. The seeds are black, 2cm long and 1cm thick. The caruncle is rather small. The physic nut is a diploid species with 2n = 22 chromosomes.

2.2 ORIGIN AND DISTRIBUTION

A number of scientists have attempted to define the origin of the Physic nut, but the sources remain controversial. Martin and Mayeux (1984) identified the Ceara state in Brazil as a centre of origin but without giving any arguments. Dehgan and Webster (1979) cite Wilbur (1954) as follows; "it was without doubt part of the flora of Mexico and probably of northern central America before the arrival of the Cortez, and is most likely to be one which originally was nearly or completely restricted to Mexico". According to other sources, the physic nut seems to be native to Central American as well as Mexico where it occurs naturally in the forest of coastal regions (Henning, 2008; Jepsen *et al*., 2006)). However, Dehgan (1994) did not find true wild physic nut plants when collecting Jatrophas in Mexico. Those found had always "escaped" from cultivated hedges. According to Heller (1996), the Jatropha species were probably distributed by Portuguese Seafarers via Cape Verde Islands and former Portuguese Guinea (now Guinea Bissau) to other countries in African and Asia but maintained that no facts are available in the literature before 1800 as to when the physic nut was introduced into Cape Verde. *Jatropha curcas* grows under a variety of conditions which make its cultivation possible across the world's agroecological regions. Today, the species is cultivated in almost all tropical and subtropical countries as live

fences. Currently, the plant is grown around homesteads as protection hedges since it cannot be browsed by animals.

According to ICRAF (2003), the plant is sensitive to day length. It is hardy and can tolerate high temperature and salinity. Jatropha can also adapt to semiarid conditions which ensured its successful establishment with an annual rainfall range of 300–1000mm.

Jatropha survives at lower altitudes of 0–500m in areas with average annual temperature above 20^{o}C but can grow at higher altitudes and also tolerate slight frost.

2.3 TAXONOMY CLASSIFICATION

The genus Jatropha belongs to the tribe Joannesieae of Crotonoideae in the Euphorbiaceae family and contains approximately 170 known species. Botanical name of *Jatropha curcas*

English Name – Physic nut, purge nut, Jatropha
Akan Name (Ghana) – "Nkrandedua"

Kingdom	-	Plantae
Phylum	-	Embryophyta
Class	-	Spermatopsida
Order	-	Malpighiales

Family - Euphorbiceae

Genus - Jatropha

Species - *Jatropha curcas*

According to Becker *et al.,* (1999), there are three major varieties of Jatropha known so far. These are;

The Cape Verde Variety: This has small seeds of 1,000 seed weight of about 682g. Length of seed is about 16.8mm and is found in almost all countries in the world.

The Nicaragua Variety: This variety is different from the Cape Verde variety. It has large leaves, and 1,000 seed weight of about 878g. Length of seed is about 20.3mm. The yields of the trees seem to be similar to the Cape Verde variety. **The Mexican type:** This variety is good for human consumption after roasting. One thousand (1,000) grains weighs between 524g and 901g. The plant is an uncultivated non–woody wild species which is very poisonous. Other known varieties available are *Jatropha gossypifolia, Jatropha multifida, Jatropha tangorensis and Jatropha poagrica*.

ENVIRONMENTAL REQUIREMENTS FOR JATROPHA GROWTH

2.4.1 Soil Requirement

Jatropha curcas is well adapted to arid and marginal sites with soils of low nutrients. Aerated sands and loams of at least 45cm depth are suited for jatropha growth (Guor, 2006). Heavy clay soils are less suitable and should be avoided, particularly where drainage is impaired, as Jatropha is intolerant to water logged conditions. Ability to grow in alkaline soils has been widely reported, but the soil pH should be within 6.0 – 8.0/8.5 (FACT, 2007). There is evidence from Northwest India that Jatropha is tolerant of saline irrigation, although yield under these conditions is low (Dagar *et al.,* 2006)

Keogh and Pentsil (2001) also reported that jatropha grows well on soils with the following characteristics:

- Good physical characters which allow roots to penetrate, develop and anchor in the soil.
- Rooting zone which is not impeded by a hardpan or concretion that may restrict root development and ramification.
- Good water holding capacity and adequate drainage.
- Good nutrient content, nutrient holding capacity
- Porous enough to permit free circulation of air for the benefit of the roots of growing plant.

Ease of cultivation with conventional tools.

2.4.2 Climatic Requirements

Climatic factors such as precipitation (rainfall) temperature and humidity are essential for plant growth. According to Jiregna Gindaba *et al.* (1997) the ideal rainfall range for Jatropha growth is 1,000–1500mm per year; however, 600– 3000mm per year is acceptable, severe water stress is a major limitation to plant growth. Optimum rainfall for seed production is considered between 1,000mm and 1,500mm (FACT, 2007) which corresponds to subhumid ecologies. Higher precipitation is likely to cause fungal attack and restrict root growth in all but the most free draining soils. Rainfall induces flowering and in areas of unimodal rainfall, flowering is continuous throughout the year.

Optimum temperatures for jatropha growth is between 20–28^{o}C. Very high temperatures can depress yields (Gour, 2006). Jatropha has been found to be intolerant

of frost. The plant is well adapted to conditions of high light intensity and is unsuited to growing in shade (Jongschapp, 2007). The best temperature for growing Jatropha from stem cuttings is the temperature that allows normal photosynthesis and other plant life process to occur. However, the temperature should not be so warm that the plant will lose excessive moisture or respire away food stored in the cuttings at the time cutting was taken from the parent plant.

High humidity around the leaves and stems of softwood and semi-hardwood cuttings keeps cuttings from drying out and allows normal plant functions like photosynthesis and respiration to take place without plant wilting while new roots are forming.

Altitude has an effect on the growth of Jatropha. The plant has spread throughout the tropics and subtropics and can survive at an altitude of between 0–500 mm.

Research carried by Kumar and Gairola (2006) showed that elevations have a significant effect on all yield attributes of *Jatropha curcas* growth. Maximum number of branches/tree, number of fruits/branch were recorded at high elevations (800–1000 m). Marian and Gopalakrishan (1995) also reported that at high altitudes, there was a dominant utilization of photo assimilation for growth as compared to that for the production of oil. According to Tewari (1964) and Diwakar (1993), *Jatropha curcas* is a well suited species and wild growing hardy plant, well adapted to harsh conditions of soil and climate whereas, the oil content variation with respect to soil site condition has not been reported.

2.5 CHEMICAL PROPERTIES OF JATROPHA

Numerous investigations have been carried out to determine the content of the physic nut seeds. Table 2.5.1 shows the moisture, ash, crude protein, crude fat, crude fibre (based on the seed, kernel) and of the crude fat content (based on the seed) of different

samples from Cape Verde (Santiago and Fogo) and Sao Tome and Principi. Part of the analysis was performed only on the seed kernel not on the whole seeds and cannot therefore be compared to other analyses.

Table 2.1: Composition of the Physic nut seeds from Cape Verde (Fogo and Santiago) and Sao Tome and Principi.

	Seed composition (%)		Content (%) Kernel					
Location	**Shell**	**Kernel**	**Moisture**	**Ash**	**Crude Protein**	**Crude Fat**	**Crude Fibre**	
Fogo	35.46	64.54	4.68	4.48	20.25	52.83	0.94	Santiago
44.92	55.08	3.78	3.83	23.48	59.78	1.90		
Sao Tome	47.94	49.94	7.79	6.37	28.44	46.72	4.23	
Mean	42.71	56.53	5.42	4.89	24.06	53.11	2.36	

Source: Ferrao and Ferrao (1984).

Many sources are available on the fatty acid composition of physic nut oil originating from different countries. The following values given refer only to four most important

fatty acids, palmitic acid (16.0%), stearic acid (18.0%), oleic acid (18.1%) and linoleic acid (18.2%). The average saturated fatty acid of the seed samples is low: 15.4% for palmitic (16.4%) and for stearic (18.4%). The average content of the unsaturated fatty acid, oleic (18.1%) and linoleic (18.2%) is considerably higher at 40.2% and 36.4%. Depending on the origin, either oleic or linolec acid group to which the majority of the vegetable oils belong (Rehn and

Epig, 1991).

2.6. Toxicity

The toxicity of the seed is normally due to the following seed components: a toxic protein (curcin) and deterpene esters. Curcin is similar to ricin, the toxic protein of the Castor bean (*ricinus communis*). The pure substances are the most potent toxins in the plant kingdom and will kill when administered in quantities of micrograms. Diterpenes have also been isolated from seeds (Adolf *et al.*, 1984), and roots Naengchomnong *et al.*,1986; Chen *et al.*,1988). These substances promoted skin tumours in a mouse cocarcingenesis experiment. Wink (1993) carried out a study and obtained the following findings

- Seed cake still contains approximately 11% oil in which the thermostable toxic diterpenes are bound.
- Heating up to 100ºC for 30 minutes did not deactivate the lectins in whole seeds and dry seek cake.
- Cooking of ground seeds or cake for 5 minutes deactivated the lectins.
- The oil has no mutagenic properties, when handled with care and there is no danger for workers. Feeding trials were carried out with many different animal species

(Dog–Siegel, 1893; Guinea pigs and hares–Droit, 1932). In most recent trials, the toxicity of ground seeds has been demonstrated on mice, rats, goats, calves and chicks (Adam and Magzoub, 1975; Ahmed and Adam, 1979; Liberalino *et al*., 1988; El–Badwi *et al.,* 1995) and found to have adverse effect on all of them. The results of all these trials cannot be accurately compared because of the different origin of the seeds, the proportion of diet, dosage and other factors.

2.7 PROPAGATION METHODS OF JATROPHA

Jatropha curcas can be propagated using seeds (regenerative propagation or cuttings (vegetative propagation). There are several traditional propagation methods in Cape Verde, and these were; Direct seeding, precultivation of seedlings, transplanting of spontaneous wild plants and direct planting of cuttings. All possibilities for the crop establishment are listed below (Kobilke, 1989).

2.7.1 Generative propagation (seeds)

● Direct seeding

● Transplanting of precultivated plants

- bed (bare roots)

- container

Some factors influencing establishment of the plants propagated by the different methods are:

Generative propagation (seeds)

❖ Direct seeding – seeding depth, quality of seed.

❖ Transplanting – type and length of pre-cultivation of seeds.

Not all factors are of equal importance. Successful pre-cultivation is characterized by high germination rates of seeds, high sprouting rates of cuttings and survival. Comparative research on the influence of different propagation methods on survival

and vegetative development was conducted by Heller (1992) in Senegal in nearly identical trials. The following methods were tested; direct seeding, transplanting of bare root plants (Pre-cultivation in seed bed or in the wild), transplanting of precultivated cuttings and direct planting of cuttings.

The survival rate at Sao Jorge, Cape Verde was significantly higher than that obtained using corresponding methods in Senegal. The ranking of various treatments with respect to survival rate did not change for the different locations. Both vegetative cultivation methods and method of generative pre-cultivation were more successful than direct seedling.

2.7.2 Vegetative propagation

This method involves the use of parts of the plant, but not the seed for planting. Hartmann and Kester (1989) suggested that vegetative propagation is a model for producing disease free genetically uniform superior nursery plants. Vegetative propagation is considered to be key factor in optimizing production. These include situations where

- there is a high proportion of non-additive genetic variance.
- there is useful heterosis
- only the male or only the female plant is required in dioecious species
- there is an unfavourable correlation between vegetative and reproductive growth
- trees are of high value.

According to Sadhu (1999), propagation by cuttings is the simplest method of propagating succulents, hardwood, semi hardwood and softwood plants. Cuttings are taken in spring or in monsoon from strong healthy plants. After cuttings are made,

they are kept in a partly shaded place for a day or two until the wound dries. Cuttings are then placed in a dry sandy soil, in a warm lightly shaded area for rooting.

Types of cuttings

In his investigation, Sadhu (1999) classified cuttings according to the part of the plant used for the vegetative propagation.

These include

Root cuttings in which a section of root is buried just below the soil surface and produces new shoots.

Stem cuttings (herbaceous, softwood, greenwood, semi-hardwood and hardwood) in which a piece stem is part buried in the soil including at least one leaf node. The cutting is able to produce new roots, usually at the node.

Leaf cuttings in which a leaf is placed in moist soil. These leaves have to develop both new stem and new roots. Some leaves will produce one plant at the base of the leaf, others will produce multiple new plants at many places on one leaf, and these can be induced by cutting the leaf.

Leaf bud cuttings are pieces foliated or defoliated stalks with one or more buds.

Scion cuttings are dormant ligneous woody twigs.

Stem cuttings are the most widely used.

According to Hartmann *et al.* (1989), stem cuttings have terminal buds, but new roots develop at the base of the cutting before a new plant will be formed. Stem cuttings are divided into four groups, namely hardwood, semi-hardwood, softwood and herbaceous which are discussed below;

Hardwood cuttings: Hardwood cuttings are usually matured, dormant after leaves have abscised and before new shoot emerge in the spring. The use of hardwood

cuttings is considered as one of the least expensive and easiest method of propagation. The shoots are cut at a length of 15–30cm and propagated outdoor in nursery beds by planting them vertically with just the top bud showing. Hardwood cuttings are easy to prepare, are not perishable and require little or no special equipment during rooting. Generally, hardwood cuttings are ready when leaves are removed without tearing the bark. The cut part should have ample supply of stored foods to nourish the developing roots and shoots until the plant becomes self-sustaining. A porous, sandy loamy soil is best for rooting of hardwood cutting.

Hardwood cuttings desiccate faster during the dry season and therefore, it is important that they do not dry out during handling and storage. The diameter of cuttings usually ranges from 0.6–2.5 or even 5cm (Hartmann *et al.,* 1990)

Semi–Hardwood cuttings: Most broad–leaved evergreen ornamentals, as well as some fruit species, citrus and olive for example, can be propagated by this type of cutting. Cuttings are best taken in the summer, following the splush of spring growth. They are made about 10-15cm long. Four, five leaves should be retained on the upper portion of the cutting and all lower leaves removed. Cuttings are placed in a well-lighted, humid location to minimize water loss from leaves.

The degree of maturity is important for some rather difficult plants. For many shrubs, the exact stage of maturity is not important; except that the more mature they are the longer they will take to root (Hartmann *et al.,* 1989)

Softwood cuttings: They are similar to semi-hardwood cuttings, except that they are prepared from deciduous trees or shrubs. Eg, mork orange, roses, plums. Softwood cuttings are prepared from the soft, succulent, non-lignified new growth of some deciduous or evergreen species. Softwood cuttings are generally easier to propagate and quicker than other types but require more attention and equipment. This type of

cutting is always made with leaves attached. Rooting takes place rapidly and vigorously if the cutting is prepared from such a stem and handled properly. Each cutting is low in carbohydrate and therefore it is essential to retain some of the leaves to manufacture carbohydrate during rooting to reduce water loss.

According to Hartmann and Kester (1990), the required temperature for the growth of softwood cuttings should be maintained at 23ºC to 27ºC during rooting for most species. All leafy cuttings must be rooted under high humidity conditions to reduce water loss.

Storage method for stem cuttings

Hartmann *et al.* (1990) identified three methods of storage. These are

Winter callusing: These occur during the dormant season where cuttings are made into lengths tied together with heavy rubber bands into a convenient sized bundle, placing the tops all one way and stored under cool, moist conditions until spring.

Hartmann *et al. (*1990) again reported that the bundle of cuttings is buried out-doors in sandy soil or sawdust in a well drained location. The basal ends warmer and better aerated than terminal ends which tends to promote root initiation at the base. At planting time in the springs, the bundles of cuttings are dug up and the cutting planted side up.

Direct spring planting: It is often sufficient with easily rooted species to gather the cutting material during the dormant season.

It is then wrapped in heavy paper and stored at 0–4.5ºC until spring. During the storage period, the cuttings are not allowed to dry out or become excessively wet.

According to Hartmann *et al*. (1990), for good bud appearance, storage should be at lower temperatures and the cuttings should be prepared and planted without delay. If

the buds are forcing when the cuttings are planted, leaves will be formed and the cuttings will die due to loss of water from leaves and depletion of stored food reserves prior to rooting.

Bolton heat callusing: This method is successful for difficult–to–root cuttings. Cuttings are collected in either the fall or late winter and the basal ends are treated with IBA at a concentration of 500–700ppm, and then planted upright for about four weeks in dampy packing material over bottom heat at 18–21^{o}C but with the top portion of cutting left exposed to cool temperature.

Advantages of vegetative propagation of Jatropha cuttings over seeds

One of the main problems in Jatropha cultivation is the poor germination of seeds. According to Holms *et al.* (1987), this comes from jatropha seeds having water impermeable testa which exerts physical exogenous dormancy. Jatropha is normally propagated by seeds and very much unreliable in terms of seeds germination. Kobilke (1989) tried to induce germination by removing the testa. Other pretreatment of orthodox seeds did not make an improved impact on the germination and growth rate. He therefore concluded that pre-treatment before planting did not affect germination positively.

Hartmann *et al.* (1990) came out with the following advantages of vegetative propagation which makes stem cuttings of Jatropha better planting material than seeds.

- Cutting are the most efficient method of propagation for most plants that do not produce viable seeds.

- Cuttings ensure that physical and genetic characteristics of individual parents are preserved in the offspring.
- Propagation using cuttings is cheap, fast and easy and does not require the technologies necessary for grafting, layering and budding.
- Many new plants can be started in limited space with a few stock (parent) plants.
- Cuttings which survive and go on to bear fruits do so much earlier than seeds (Short juvenity).
- Fewer losses and more uniform plants can be produced from cuttings. Mini cuttings may be used where parent material is scarce.

They however, added that vegetative propagation has limitations, some of which are:

- Being more expensive than seeds when not planted directly
- New varieties not evolved by means of vegetative propagation.
- Sufficient cuttings of good plants may be difficult and costly to source.
- Plants are comparatively short - lived. They lack a taproot system which results in poor anchorage in the soil.

Improving growth and yield performance of jatropha cuttings

Producing jatropha from cuttings is a fast way to multiply the plant with the same characteristics (clones). In vegetative propagation of *Jatropha curcas*, there may be the need to look at ways by which optimum growth and yield could be obtained. The performance of jatropha stem cuttings may depend on its pre-treatments. These pretreatments include; treatments with growth hormones such as Indol-3-Acetic Acid

(IAA), Indole-3-Butyric Acid (IBA), Naphthalene sprouts. This is because long storage period causes dehydration and exhaustion of starch reserve thereby leading to low sprouting performance and leaf formation. Storage method affects performance of stem cuttings according to Rice *et al.* (1984) who noted that cuttings to be stored are pushed into damp rooting medium (2.5-5cm deep) and placed in plastic bags to prevent Acetic Acid (NAA), storage interval of cuttings, storage method of cuttings and length of cuttings.

According to Chipungu *et al.* (2000), stem cuttings stored for a shorter time produced good moisture loss leading to drying of cuttings. Henning (2003) reported that longer cuttings were amenable to for vegetative propagation than shorter cuttings. Pal (1995) also commented that the sprouting behaviours of cutting depend on factors like physiological age of the cutting, length of the cutting and genotype of the mother plant material.

2.8 USES OF JATROPHA

2.8.1 Food and fodder

According to Morton, (1981), the leaves can be used as food for tussle silkworms and burnt root ashes can be used as a salt substitute. Duke (1985) citing Ochse (1931) says that the young leaves may be eaten when steamed or stewed. It is reported that the physic nut seed is eaten in certain regions of Mexico once it has been boiled and roasted (Panigrahi *et al.*, 1984; Delgado and Parado, 1989).

According to analysis carried out by Wink (1993), the Mexican seeds do not contain phorbol esters. Levingston and Zamora (1983) reported that the seeds are edible, once the embryo has been removed. The seed cake or seeds can be used as animal feed' (*Marker et al.*, 2001). Abdu Aguye et al. (1986) described the poisoning of two

children who accidentally injested the seeds and Joubert et al (1984) reported a similar case in South Africa.

2.8.2 Medicinal

Traditionally, preparations of all parts of the tree (seeds, leaves and bark or fresh as a decoction) are used as medicine and for veterinary purposes. The oil has a strong purgative action and is also widely used for skin diseases and soothing pains such as that caused by rheumatism. A decoction of leaves is used against cough and as an antiseptic after birth. Branches are used to arrest bleeding of wounds. Nath and Dutta (1992) demonstrated the wound healing properties of curcin, a proteolytic enzyme isolated from latex. The latex has antimicrobial properties against S*taphyloccus aureus, Escherichia coli, Klebsiella pneumoniae, Streptococcus pyogenes* and *Candida albican*. Other uses of jatropha in traditional medicine are described in: Irivine (1961) Persinos *et al.* (1964), Lentz (1993) and Manandhar

(1995). Extracts from physic nut fruits showed pregnancy terminating effects in rats (Goonasekera *et al.,* 1988) Extract of the leaves showed potent cardiovascular action in guinea pigs and might be a possible source of beta–blocker agent (Fojas *et al.,* 1986).

2.8.3 Plant protectant and molluscide

In a survey carried by Grainage and Ahmed (1988) on plants with insecticidal properties, extracts from all parts of the physic nuts and the seed oil, and phorbol esters from the oil were used to control various pests, in many cases successful result. The table below shows the various pesticidal properties and the insects (pests) they can control.

Table 2.2: Pesticidal properties of various seed extracts

Insect	Pest of	preparation	Reference
Aphis gossypii	Cotton	aqueous extract from oil Seed oil	Solsoloy *et al.* (1993) Solsoloy *et al*. (1995)
Helicovepa armigera	Cotton	acetone extracts from seeds aqueous extract from oil Seed oil	Solsoloy *et al.* (1987) Solsoloy *et al.*(1995) Solsoloy *et al.* (1995)
Pectinophora gossypiella	Cotton	aqueous extract from seeds Seed oil	Solsoloy *et al.*(1993)
Empoasca biguttula	Cotton	Seed oil	Solsoloy *et al*. (1995)
Phythrorimaea operculleta	Potato	Seed oil	Shelke *et al* (1985)
Callosobrunchus maculatus	Pulse	Seed oil	Jadhav and Jadhav (1984)
Callosobrunchus chinensis	Mungbean	Oil and phorbol esters	Solsoloy *et al*. (1995)
Sesamia calamis	Sorghum	seed oil	Henning (1994)
	Corn		Solsoloy *et al.* (1995)

Aqueous extracts of physic nut leaves were effective in controlling sclerotium species, an Azolla fungal pathogen (Garcia and Lawas, 1990). In a laboratory experiment, ground physic nut showed molluscidal activity against the host of liver fluke, a disease which is

widely distributed in the Philippines (Agaceta *et al.*, 1981), and also against host of Fasciola gigantean and schistosomia in Senegal. Phorbo esters were probably the active agent in the various extracts used.

2.8.4 Fuel

Jatropha seed cake has a high energy content of 25MJKG-^{1}. Experiments have shown that some 60% more biogas was produced from Jatropha seed cake in anaerobic digesters than from cattle dung, and that it had a higher calorific value (Abreu, 2008). In 1911, the inventor of the diesel engine, Rudolf Diesel had this to say in a letter "It is generally forgotten that that vegetable and animal oils can be used directly in diesel engines.
A small diesel engine ran with peanut oil during the world exhibition of paris in 1900, and which worked so exceptionally well, and that the change of fuel was realized by only a few visistors" (Kiefer, 1986). The use of physic nut seed oil in car engines is reported in the literature (Takeda 1982) and in unpublished research reports. In addition, economic analyses have also shown that these fuels can be used partly to substitute costly oil imports for landlocked countries.

The recent development is the "Schur Diesel" where vegetable oil (80%), petrol (14%), alcohol (6%) and a certain amount of an unknown component are mixed. This fuel can be used in all diesel engines (Lutz 1992; Anon 1993). However, owing to the unavailability of petrol and alcohol in rural areas of developing countries, this process is yet to be applicable in such areas.

It is generally accepted by engine manufacturers that blends of up to 5% biodiesel should cause no engine compatibility problems. Jatropha biodiesel has proven to conform to required

European and USA quality standards. The table below shows the extent to which Jatropha biodiesel conforms to European standards.

Table 2.3: Characteristics of Jatropha biodiesel compared to European specification

Characteristics	Jatropha Biodiesel	European standard	Remarks[a]
Density (gcm^{-3} at 20°C)	0.87	0.86 – 0.90	+
Flash point (°C)	191	>101	+
Centane No. (Iso 5165)	57 – 62	>51	+ + +
Viscosity ($mm^2/_S$ at 40°C)	4.20	3.5 – 5.0	+
Net Cal. Val. (MJ/L)	34.4	-	-
Iodine No.	95 – 106	<120	+
Sulphated ash	0.014	<0.02	+
Carbon residue	0.025	<0.30	+ +

a+ indicates that Jatropha performs better than the European standard

Source: *Francis et al* (2005).

2.8.5 Soil improvement, protection/green manure

Jatropha seed cake makes an excellent organic fertilizer with high nitrogen content similar to or better than chicken manure, its macro-and micronutrients make valuable contribution to soil nutrients requirement (Patolia *et al.*, 2007). The press cake is valuable as organic manure since it has nitrogen content similar to that of the seed cake of castobean and chicken manure. The nitrogen content ranges from

3.8% to 5% depending on the source (Moreira, 1970). Applications of physic nut seed cake at different rates to crops showed phytoxicity, expressed as reduced germination, when high rates of up to 5t/ha were applied.

A GTZ project in Mali carried out a fertilizer trial with pearl millet where the effect of manure (5t/ha), physic nut press cake (5t/ha) and mineral fertilizer (100kg ammonium sulphate and 50kg urea/ha) on pearl millet was investigated. Pearl millet yields per ha were 630kg for the control, 815kg for manure, 1366kg for press cake and 1135kg for mineral fertilizer. As the cost for mineral fertilizer was higher than those for press cake, the retention was 30,000 FCFA (US$60) higher for the latter (Henning *et al*. 1996).

2.8.6 Technical uses

The indigenous production of soap is a laborious process, which uses a basis of ground seeds, is described by Freitas (1906). Research carried out by the Tata oil mills co ltd., Bombay has shown that with a mixture of 75% hydrogenated physic nut, 15% refined and bleached physic nut oil and 10% coconut oil, soap can be produced with lathering values equivalent to their regular production line toilet soap. Hardened physic nut oil could be satisfactory substitute for tallow or hardened rice bran oil (Holla *et al*. 1993) Chemical extraction cannot be achieved on small scale basis so several types of mechanical equipment are available: screw press (hand– or engine–powered), spindle presses which are distributed widely throughout developing countries for the extraction of seed oils for nutrition purposes. Hydraulic presses are widely used for sheanut processing in West Africa

2.8.7 Limitation Of Jatropha Cultivation

There are certain factors that limit Jatropha production, and must be kept in mind when dealing with the species. These limiting factors are;

- The golden flea butterfly is particularly harmful to young Jatropha plants.
- In unadapted provenances, low yield is recorded .
- The ideal climatic conditions for Jatropha can be summarized as annual rainfall not exceeding 600mm under moderate climatic conditions, 1200mm under hot climatic zones and soil pH less than 9. These conditions may not be stable and this affects Jatropha growth and yield (Heller, 1996).

2.8.8 Prospect of *Jatropha curcas* as multipurpose tree in agroforestry *Jatropha curcas* has numerous positive claims, but only a few can be scientifically sustained (Ouwens *et al.* 2007). As a multipurpose tree or shrub in Agroforestry, it has the following potentials.

Reclamation of marginal land (soil): Miller and Jones (1992); Makkar *et al* (1997) and

Openshaw (2002) reported that *Jatropha curcas* as a multipurpose shrub can grow in semi-arid and arid conditions in tropical areas. Under semi-arid condtions, *Jatropha curcas* has the possibility for reclaiming marginal soils through exploration of soil with its root system. This results in recycling nutrient from deeper soil layers, providing shade to the soil and thereby reducing risks of erosion and desertification. It can grow under low rainfall, where it grows without competing with annual food crops, thus filling ecological niche.

As an energy crop: The use of Jatropha oil as substitute for diesel and for soap production in rural areas would improve the living conditions of the people and would offer additional income. Jatropha oil is an important product for meeting lighting

needs of the rural population, boiler fuel for industrial purposes. The substitution of firewood by the plant oil for household cooking in rural areas will help alleviate the problems of deforestation. Jatropha oil performs very satisfactorily when burnt using a conventional (paraffin) wick after some simple design changes in the physical configuration of the lamp. Jatropha oil can be used directly in diesel engines or added to diesel fuel as a an extender to a bio-diesel fuel.

Numerous uses of the crop: The species has numerous uses in which lie the potential of this crop.

Resistance and tolerance to pests and diseases: Although, the plant is tolerant to pests and diseases, Heller (1996) conducted a study in Senegal and observed that *Jatropha curcas* suffer from certain diseases and pests. In other countries, pests and diseases do not cause severe problems although millipede can cause total loss of young seedlings.

2.4: Pests and disease observed on Jatropha plants by different authors.

Name of pest	Damage and Symptoms	Source
Phytophthora spp; Pythium spp.		
Fusarium spp., etc.	Damping off, root rot	Heller (1992)
Helminthosporium tetramera	Leaf spots	Singh (1983)
Pestalotiopsis paraguarensis	Leaf spots	Singh (1983)
Pestalotiopsis vericolor	Leaf spots	Philips (1975)
Cerospora jatrophae – curcas	Leaf spots	Kar & Das (1987
*Julus spp. (*Millipede)	Total loss of seedlings	Heller (1992)
Lepidoterae larvae	Galleries in leaves	Heller (1992)
Spodoptera litura	Larval feeding on leaves	Meshrand and Joshi (1994)

)

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 STUDY SITE

The study was conducted at the Kwame Nkrumah University of Science and Technology (KNUST) Agricultural Research station (ARS), Anwomaso. The total size of the area is 561 hectares (1,386 acres). Anwomaso is located in the EjisuJuaben Municipality of Ashanti Region. The area is classified under the semideciduous forest zone and experiences a bimodal rainfall pattern with the major rainfall starting in March and ends in early August. The minor rainfall season starts in September and ends in December. The annual rainfall range is between 1500 mm and 2000 mm with the mean temperature range between 25^{o}C and 27^{o}C. The soils of the study area are Ferric Acrisol according to FAO/UNESCO or OxicHaplustult (USDA – Soil Taxonomy) Classification.

3.2 METHODOLOGY

3.2.1 Source of Planting Materials

Jatropha curcas cuttings were obtained from the KNUST Agricultural Research station (ARS) at Anwomaso.

3.2.2 Method and duration of storage

The first experiment was factorial with two (2) methods of storage (M) and four (4) storage durations (S) laid in a Randomized Complete Block Design (RCBD) with four (4) replications (Fig 3.1). The two methods of storage were; partly buried to a depth of 15 cm under shade (PB) and not buried (NB), while the four storage durations were S_1 for 0 day, S_2 for 5 days, S_3 for 10 days and S_4 for 15 days of storage.

Growth data collected in the nursery were number of sprouts, number of leaves, number of branches, stem diameter shoot biomass, rooting characteristics such as number of roots, length of roots, root volume, root biomass from 22nd June, 2011 to 3rd August, 2011. In the field, data on growth and seed yield were collected. Growth data collected were number of sprouts, number of leaves, number of branches, stem diameter, plant height. Yield data collected were number of flowers and number of fruits, and percentage survival from 10th August, 2011 to 30th November, 2011. The plot layouts were the same for both the nursery and field studies. Materials used in the experiment were a cutlass, rule, venier calipers, thermometer, light meter, electronic balance.

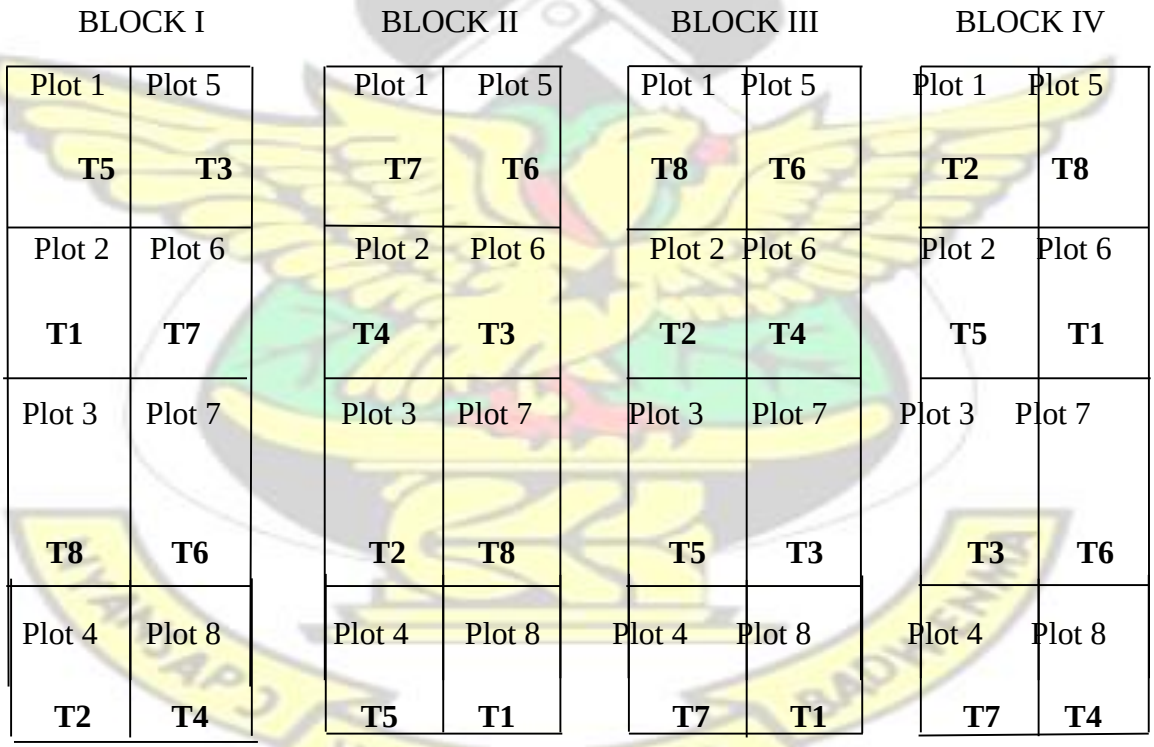

Figure 3.1: Randomized Complete Block Design (RCBD) and layout for assessing influence of storage method and duration of *Jatropha curcas* cuttings on growth and yield

Treatment combination

T1 (PBS1): cuttings stored vertically and partly buried for 0 day

T2 (NBS_1): cuttings stored vertically and not buried for 0 day

T3 (PBS_2): cuttings stored vertically and partly buried for 5 days

T4 (NBS_2): cuttings stored vertically and not buried for 5 days

T5 (PBS_3): cuttings stored vertically and partly buried for 10 days

T6 (NBS_3): cuttings stored vertically and not buried for 10 days

T7 (PBS_4): cuttings stored vertically and partly buried for 15 days

T8 (NBS_4): cuttings stored vertically and not buried for 15 days

3.3.2 Length of cutting and duration of storage

The second experiment was factorial with two (2) Lengths of cutting L) and four (4) storage durations (S) laid in a Randomized Complete Block Design (RCBD) with four (4) replications (Fig 3.2). The two lengths of cuttings were; 30cm (L_1) and 40cm (L_2), while the four storage durations were S_1 for 0 day, S_2 for 5 days, S_3 for 10 days and S_4 for 14 days of storage.

Specific data on growth collected in the nursery were number of sprouts, number of leaves, number of branches, stem diameter and shoot biomass. Data on rooting characteristics collected were number of roots, length of roots, root volume and root biomass. And in the field, data on growth and yield that were collected included number of sprouts, number of leaves, number of branches, stem diameter, plant height, number of flowers, number of fruits and percentage survival. The plot layouts were the same for both the Nursery and Field studies. Materials used in the experiment were a cutlass, rule, calipers, thermometer, light meter, electronic balance.

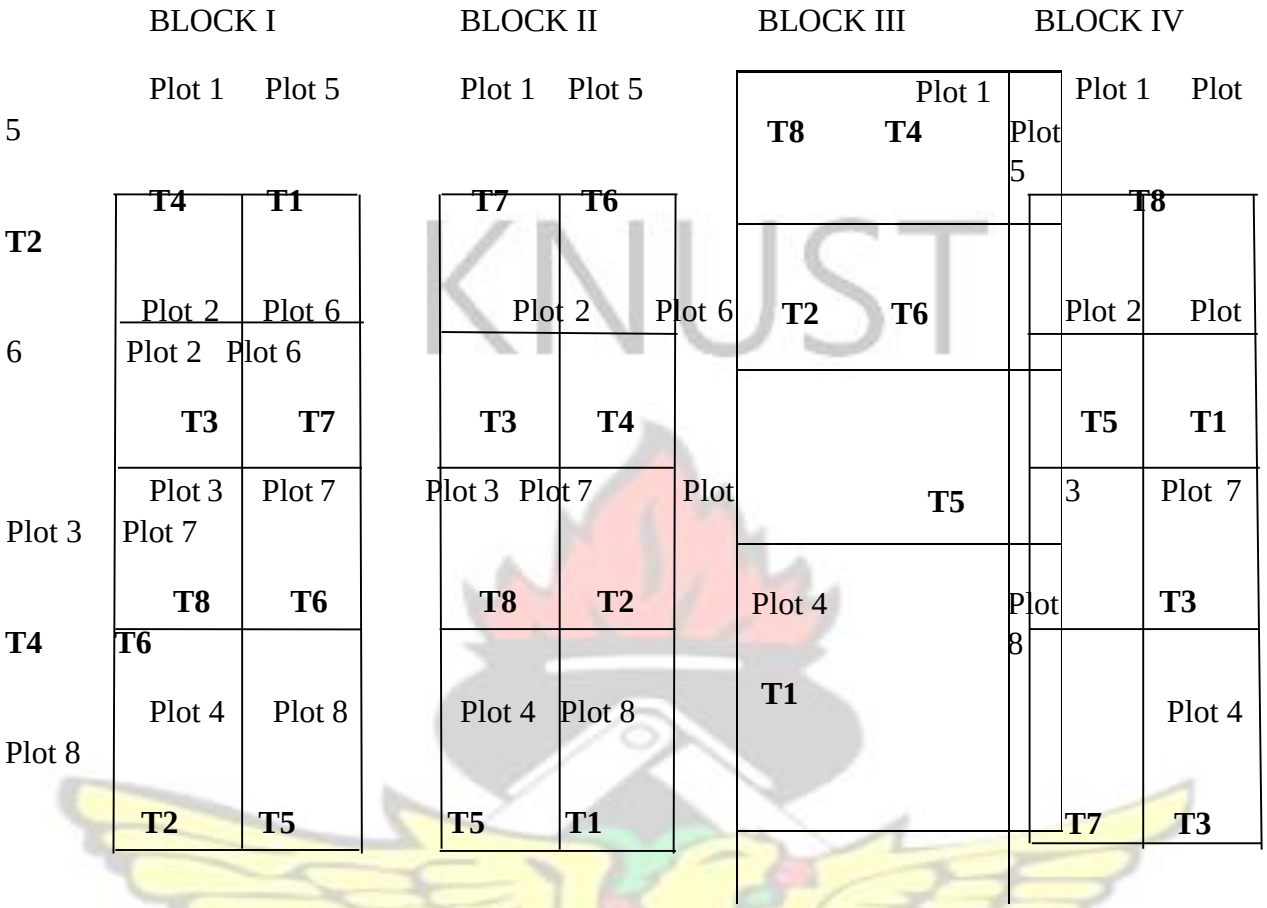

Figure 3.2: Randomized Complete Block Design (RCBD) and layout for assessing influence of length of cutting and duration of storage of *Jatropha curcas* cuttings on growth and yield

Treatment combination

T1 **(**L_1S_1): 30cm length cuttings stored for a period of 0 day

T2 (L_2S_1): 40cm length cuttings stored for a period of 0 day

T3 (L_1S_2): 30cm length cuttings stored for a period of 5 days

T4 (L_2S_2): 40cm length cuttings stored for a period of 5 days

T5 (L_1S_3): 30cm length cuttings stored for a period of 10 days

T6 (L_2S_3): 40cm length cuttings stored for a period of 10 days

T7 (L_1S_4): 30cm length cuttings stored for a period of 15 days T8 (L_2S_4): 40cm length cuttings stored for a period of 15 days

3.4. STEM CUTTINGS

3.4.1 Nursery studies

Semi-hardwood cuttings of *Jatropha curcas* of diameter 2.5–3cm were harvested from the Faculty of Agriculture farm on 22nd June, 2011 and divided into two lots. From the first lot, 30cm length of cuttings were prepared and planted on the day of harvest (22nd June, 2011). The remaining lot was divided into two sets. Each of the two sets of cuttings was tied together and one set stored vertically under shade. The other set was stored vertically under shade but buried in soil to a depth of 15cm and watered once in every two days. From the two sets of stored cuttings, 30cm length cuttings were prepared for planting at five days interval until 7th July, 2011 in a 20×35cm polybags filled with top soil (propagation substrate) collected from the Faculty of Agriculture farm. The polybags were perforated at the base to allow for drainage of excess water.

The cuttings were inserted (planted) to a depth of 10cm in the polybags at five days intervals. Observations were recorded every five days up to 40 days on initial growth parameters such as number of sprouts, number of leaves, number of branches and stem diameter. Additionally, three cuttings from each treatment were inspected every 10 days for root initiation. On the day of transplanting, plants were sampled from the various treatments and number of roots counted, length of roots measured using a rule. Root volume was subsequently determined by removing all lateral roots from the plant and immersion in a given volume of water. The Volume of water displaced was

recorded as root volume. Root biomass was also determined by drying the root in an oven to constant weight and weighing them using electronic balance. (plate 3.5.1) . Measurement of shoot biomass followed the same trend as the root biomass. The plants were then transferred into the field. Mean light intensity during storage under the shade was 3.45 lux and the mean temperature was 23^{o}C. In the nursery, the mean light intensity was 3.65 lux and the mean temperature was
24^{o}C.

3.4.2 Field studies

The plants were transplanted from the Nursery into the field with five (5) plants per plot with dimension of 1× 1m. In the field the plants were also inspected on biweekly interval up to 16 weeks on survival rate, number of sprouts, number of leaves, number of branches, stem diameter, plant height, number flowers and number of fruits. Mean light intensity was 5.25 lux while mean temperature was 30^{o}C in the field. Photometer and thermometer were used to measure the light intensity and temperature respectively.

3.4.3 Nursery studies

For the second experiment, semi-hardwood cuttings of *Jatropha curcas* of diameter 2.5–3cm was harvested from the Faculty of Agriculture farm on 22nd June, 2011 and divided into two lots. From one of the lots, 30cm and 40cm lengths were prepared and planted on the day of harvest (22nd June, 2011). The remaining lot was tied together and stored vertically under shade, partly buried to a depth 15cm and watered regularly. From the stored cuttings, 30cm and 40cm cuttings were prepared for planting at five days interval in a 20×35cm polybags filled with top soil as propagation substrate

collected from the Faculty of Agriculture farm. The polybags were perforated at the base to allow for drainage of excess water.

The cuttings were inserted (planted) to a depth of 10cm in the polybags at five day intervals. Cuttings were inspected regularly at five day interval for survival rate, number of sprouts, number of leaves, number of branches and stem diameter up to forty days. Additionally, three cuttings from each treatment were inspected every 10 days for root initiation. Mean light intensity during storage under the shade was 3.45 lux and the mean temperature was 23^{o}C. In the nursery, the mean light intensity was 3.65 lux and the mean temperature was 24^{o}C.

On the day of transplanting, plants were sampled from the various treatments and number of roots counted, length of roots measured using a rule. Root volume was subsequently determined by removing all lateral roots from the plant and immersion in a given volume of water. The Volume of water displaced was recorded as root volume. Root biomass was also determined by drying the root in an oven to constant weight and weighing them using electronic balance (Plate 3.1). Measurement of shoot biomass followed the same trend as the root biomass. The plants were then transferred into the field with five (5) plants per plot with dimension of 1× 1m.

3.4.4 Field studies

In the field, the plants were also observed on biweekly interval up to 16 weeks for survival rate, number of sprouts, number of leaves, number of branches, plant height, stem diameter number of flowers and number fruits. Mean light intensity was 5.25 lux while mean temperature was 30^{o}C in the field. Photometer and thermometer were used to measure the light intensity and temperature respectively.

Plate 3.1: Root examination on day 42 of Nursery.

3.7 DATA ANALYSIS

For statistical analysis, all data obtained from the study were analyzed using SAS Statistical package version 9.01 (2008). Where the ANOVA indicated significant differences, means were compared using the Least Significant Difference (LSD) at 5% level of probability.

CHAPTER FOUR

4.0 RESULTS

4.1. EFFECT OF STORAGE METHOD AND STORAGE DURATION OF

CUTTINGS ON GROWTH AND YIELD OF *Jatropha curcas*

4.1.1 Number of Sprouts

The interaction between storage method and duration of storage significantly influenced the number of sprouts produced by the cuttings (Tables 4.1 and 4.2). Cuttings stored for 15 days produced significantly higher number of sprouts than those stored for 0, 5 and 10 days on the 15th and 20th day in nursery (DIN). On the 25th and 30th DIN, however, cuttings stored for 0, 5 and 10 days produced significantly higher number of sprouts than those stored for 15 days. Thereafter, there was no significant difference among the treatments (Table 4.2). There was no significant difference in the number of sprouts produced by the two storage methods. Cuttings that were partly buried (PB) and those that were not buried (NB) over the various storage durations had similar number of sprouts.

After transplanting, significant interaction was observed between storage method and storage duration on 2nd, 4th and 16th weeks (Table 4.4). Cuttings stored for 0, 5 and 10 days produced significantly more sprouts than those stored for 15 days. However, there was no significant effect of the two storage methods, PB and NB on the number of sprouts during the storage duration (Tables 4.3 and 4.4).

Table 4.1: Summary of Analysis Of Variance for number of sprouts influenced by storage method and storage duration of *Jatropha curcas* cuttings within 40 days in the nursery.

	Days in nursery					
	15	20	25	30	35	40
SM	0.95^{ns}	0.50^{ns}	2.00^{ns}	2.00^{ns}	0.13^{ns}	0.13^{ns}
SD	0.40^{ns}	2.00^{ns}	0.67^{ns}	1.00^{ns}	0.46^{ns}	0.71^{ns}
SM × SD	2.70*	3.17*	0.67*	0.33*	0.80*	1.04*
Residual	0.01	1.11	1.11	1.11	1.11	0.05

SM- Storage Method SD-Storage Duration ns- not significantly different at 5% level of probability *- significantly different at 5% level of probability using the LSD test.

Table 4.2: Influence of storage method and duration of storage of *Jatropha curcas* cuttings on number of sprouts in a nursery.

	Days in nursery											
	15		**20**		**25**		**30**		**35**		**40**	
Storage duration	**Storage method**											
(days)	PB	NB	PB	NB	PB	NB	PB	NB	PB	NB	PB	NB
0	4.0	4.0	6.0	6.0	6.8	7.0	5.0	5.0	2.9	2.9	3.0	3.0
5	4.0	3.9	6.0	6.1	7.0	6.9	5.0	5.1	3.0	3.0	2.9	3.0
10	4.0	4.0	6.0	6.0	7.0	7.0	4.9	5.0	3.0	3.0	2.9	3.0
15	5.2	5.0	6.9	6.5	5.0	5.0	3.0	3.0	3.0	2.9	2.3	1.6
P	0.0051		0.0011		0.0001		0.0081		0.0022		0.0001	
LSD (5%)	0.24		0.44		0.56		0.24		0.32		0.34	

PB-Partially Buried

NB-Not Buried

Table 4.3: Summary of Analysis of Variance for number of sprouts influenced by storage method and storage duration of *Jatropha curcas* cuttings after transplanting.

	Weeks after transplanting							
	2	**4**	**6**	**8**	**10**	**12**	**14**	**16**
SM	1.13^{ns}	1.13^{ns}	0.50^{ns}	2.00^{ns}	0.50^{ns}	0.03^{ns}	1.21^{ns}	0.50^{ns}
SD	3.79^{ns}	2.13^{ns}	3.67^{ns}	2.75^{ns}	1.89^{ns}	1.71^{ns}	1.21^{ns}	0.50^{ns}
SD × SD	1.13*	1.13*	0.17^{ns}	0.42^{ns}	0.58^{ns}	0.03^{ns}	0.08^{ns}	1.83*
Residual	1.11	1.11	0.17	0.33	0.23	0.47	0.14	1.11

SM- Storage Method SD-Storage Duration ns- not significantly different at 5% level of Probability, *- significantly different at 5% level of probability using the LSD test.

Table 4.4: Effect of storage method and duration of storage of *Jatropha curcas* cuttings on number of sprouts after transplanting

	Weeks after transplanting					
	2		**4**		**16**	
Storage duration			**Storage method**			
(days)	PB	NB	PB	NB	PB	NB
0	3.0	3.0	4.0	3.9	2.0	1.9
5	2.8	3.0	4.1	3.9	1.8	2.0
10	3.0	3.0	4.0	4.0	1.8	2.0
15	1.0	1.4	2.0	1.8	1.0	1.0

P	0.0001	0.0001	0.000
LSD (5%)	0.48	0.60	0.44

PB-Partially Buried

NB-NotBuried

4.1.2 Number of leaves

Number of leaves was influenced by the interaction between method of storage and duration of storage (Table 4.5). In the nursery, leaves started forming on the 10th day for cuttings stored for 15 days and on the 15th day for cuttings stored for 0, 5 and 10 days. Thereafter, there was incremental progress in the number of leaves in all treatments up to 40 days in nursery (DIN). On the 10th and 15th days, cuttings stored 15 days produced more leaves than those stored for 0, 5 and 10 days. On the 20th and 25th DIN, cuttings stored for 15 days produced significantly higher number of leaves than the cuttings stored for 0, 5 and 10 days. However, on the 30th, 35th and 40th days of DIN, cuttings stored for 0, 5 and 10 days produced significantly higher number leaves than those stored for 15 days (Table 4.6).

After transplanting in the field, Tables 4.7and 4.8, there were increases in the number of leaves in all treatments up to 12 weeks after transplanting (WAT) before declining. The interaction between method of storage and duration of storage significantly influenced the number of leaves. Cuttings stored for 0, 5 and 10 days continued to produce significantly higher number of leaves than those stored for 15 days for both storage methods. This was observed on the 2nd, 4th, 6th, 10th, 12th,

14th and 16th WAT. Also, for cuttings that were stored for 15 days, the partly buried (PB) cuttings produced higher number of leaves than the cuttings that were not buried (NB) (Table 4.8).

Table 4.5: Summary of Analysis of Variance for number of leaves influenced by storage method and storage duration of *Jatropha curcas* cuttings within 40 days in the nursery.

	Days in nursery					
	15	**20**	**25**	**30**	**35**	**40**
SM	0.01^{ns}	1.39^{ns}	0.28^{ns}	18.00^{ns}	4.50^{ns}	0.50^{ns}
SD	0.17^{ns}	2.28^{ns}	14.67^{ns}	35.17^{ns}	34.83^{ns}	1.72^{ns}
SM × SD	0.59*	0.33*	0.61*	3.33*	3.17*	0.17*
Residual	0.36	0.21	0.20	1.11	1.11	1.11

SM- Storage Method SD-Storage Duration ns- Not significantly different at 5% level of probability *- significantly different at 5% level of probability using the LSD test.

Table 4.6: Influence of storage method and duration of storage of *Jatropha curcas* cuttings on number of leaves in a nursery.

	Days in nursery											
	15		20		25		30		35		40	
Storage duration	**storage method**											
(Days)	PB	NB	PB	NB	PB	NB	PB	NB	PB	NB	PB	NB
0	0.0	0.0	5.0	5.0	7.0	7.0	10.8	11.0	12.5	13.0	14.0	13.0
5	0.0	0.0	5.0	5.5	7.0	7.0	11.0	11.0	12.0	12.6	13.0	13.0
10	2.0	2.5	5.0	5.0	7.2	7.1	10.8	11.0	12.0	12.6	14.0	14.0
15	5.0	4.5	6.5	6.5	8.0	7.8	1.0	10.0	11.0	11.0	12.5	11.2
P	0.0359		0.0219		0.0485		0.0001		0.0001		0.0001	
LSD (5%)	ns		0.62		0.64		0.68		0.98		1.06	

PB- Partially Buried NB- Not Buried

Table 4.7: Summary of Analysis of Variance for number of leaves influenced by storage method and storage duration of *Jatropha curcas* cuttings after transplanting.

	Weeks after transplanting							
	2	**4**	**6**	**8**	**10**	**12**	**14**	**16**
SM	15.13^{ns}	0.13^{ns}	0.78^{ns}	2.53^{ns}	7.03^{ns}	3.13^{ns}	11.28^{ns}	2.00^{ns}
SD	22.46^{ns}	15.46^{ns}	19.53^{ns}	47.95^{ns}	63.03^{ns}	52.46^{ns}	44.70^{ns}	27.33^{ns}
SM × SD	9.13*	4.38*	1.45*	0.53*	1.03*	7.13*	5.95*	3.33*
Residual	1.11	1.11	0.39	0.35	0.28	0.13	0.38	1.11

SM- Storage Method SD-Storage Duration ns- not significantly different at 5% level of probability *- significantly different at 5% level of probability using the LSD test.

Table 4.8: Influence of storage method and duration of storage of *Jatropha curcas* cuttings on number of leaves after transplanting.

	Weeks after transplanting													
	2		4		6		10		12		14		16	
Storage duration	storage method													
(days)	PB	NB	PB	NB	PB	NB	PB	NB	PB	NB	PB	NB	PB	NB
0	15.0	14.0	17.0	18.0	18.0	19.0	20.0	20.0	19.0	20.0	14.0	13.6	9.0	9.0
5	14.0	13.0	18.0	18.0	19.0	18.0	21.0	20.0	20.0	19.0	13.6	13.5	8.9	8.7
10	15.0	15.0	17.0	18.0	19.0	19.0	21.0	21.0	21.0	21.0	14.0	13.6	9.0	9.0
15	13.1	12.0	15.4	14.0	16.2	15.0	16.8	15.0	16.8	15.0	12.0	11.0	4.0	5.0
P	0.0001		0.00		0.0271		0.0287		0.0001		0.0001		0.0001	
LSD (5%)	1.08		1.10		1.12		1.20		1.14		0.54		0.36	

4.1.3 Plant Height

There interaction between method of storage and duration of storage significantly influenced plant height after transplanting in the field (Table 4.9). During the 2nd and 4th WAT in the field, cuttings stored for 0, 5 and 10 days produced significantly higher plant height than those stored for 15 days for both storage methods. Also, Method of storage had influence on the plant height for cuttings that were stored 15 days. The partly buried (PB) cuttings produced taller plants than the cuttings that were not buried (NB) (Table 10a). Period of storage also had significant influence on plant height (Table 4.9). Cuttings stored for 0, 5 and 10 days were observed to have significantly greater plant height than those stored for 15 days. This was observed in the 6th, 8th, 10th, 12th, 14th and 16th WAT in the field (Table 4.10b).

Table 4.9: Summary of Analysis of Variance for plant height influenced by Storage Method and storage duration of *Jatropha curcas* cuttings After transplanting.

	Weeks after transplanting							
	2	**4**	**6**	**8**	**10**	**12**	**14**	**16**
SM	1.13^{ns}	1.13^{ns}	1.13^{ns}	7.03^{ns}	6.16^{ns}	0.50^{ns}	0.28^{ns}	0.13^{ns}
SD	12.13*	18.58*	22.25*	29.28*	30.25*	30.79*	27.12*	25.38*
SM × SD	7.13*	1.88*	1.21^{ns}	0.87^{ns}	2.08^{ns}	5.83^{ns}	0.03^{ns}	1.88^{ns}
Residual	0.49	0.27	1.14	1.57	0.77	2.80	1.92	1.2

SM- Storage Method SD-Storage Duration ns- not significantly different at 5% level of probability

*- significantly different at 5% level of probability using the LSD test.

Table 4.10a: Influence of storage method and duration of storage of *Jatropha curcas* cuttings on plant height (cm) after transplanting.

	Weeks after transplanting			
	2		4	
Storage duration	**storage method**			
(days)	PB	NB	PB	NB
0	41.0	40.5	47.0	47.0
5	40.5	41.0	47.0	47.0
10	40.6	41.0	46.7	47.8
15	38.9	37.0	42.4	41.0
P	0.0001		0.0021	
LSD (5%)	1.00		1.14	

PB- Partly Buried NB- Not Buried

Table 4.10b: Influence of duration of storage of *Jatropha curcas* cuttings on plant height (cm) produced after transplanting.

	Weeks after transplanting					
	6	8	10	12	14	16
Storage duration (days)						
0	51.0	56.5	61.6	66.5	68.0	69.4
5	52.5	57.5	62.3	66.8	68.6	69.3
10	51.6	57.5	61.8	66.5	68.1	70.6
15	42.4	48.9	53.0	55.5	59.1	60.8

P	0.0243	0.0443	0.0115	0.0400	0.0180	0.0408
LSD (5%)	1.08	1.26	0.88	1.68	1.48	1.14

ROOTING PARAMETERS

4.1.4 Number of roots

The interaction between method of storage and duration of storage of cuttings significantly influenced the number of roots (Table 4.11). Observation of roots of the plant on the day of transplanting showed that cuttings that were stored for 0, and 5 days produced significantly higher number of roots than those stored for 10 and 15 days ($p = 0.0163$). Generally, cuttings that were stored vertically and partly buried had more roots than those that were vertically stored but not buried. Whereas the difference in root number between 0 and 5 days duration of storage were not significant with both not buried (NB) and partly buried (PB) cuttings, the difference in root number produced by the NB and PB cuttings stored between 0 and 5 days were significantly higher than the NB and PB cuttings stored between 10 and 15 (days Fig 4.1)..

Table 4.11: Summary of Analysis of Variance for different rooting attributes and shoot biomass influenced by storage method and storage duration of *Jatropha curcas* cuttings on the day of transplanting.

	Number of roots	Length of root	Root volume	Root biomass	Shoot biomass
SM	0.0007^{ns}	0.1250^{ns}	0.1800^{ns}	0.0003^{ns}	0.0025^{ns}
SD	53.7920*	10.7413*	12.1380^{ns}	0.0040*	0.0369^{ns}
SM × SD	2.6670*	0.4317*	0.3930^{ns}	0.0004*	0.0025^{ns}
Residual	0.5660	0.1009	0.6440	0.0002	0.0016

SM- Storage Method SD-Storage Duration

ns- not significantly different at 5% level of probability

*- significantly different at 5% level of probability using the LSD test.

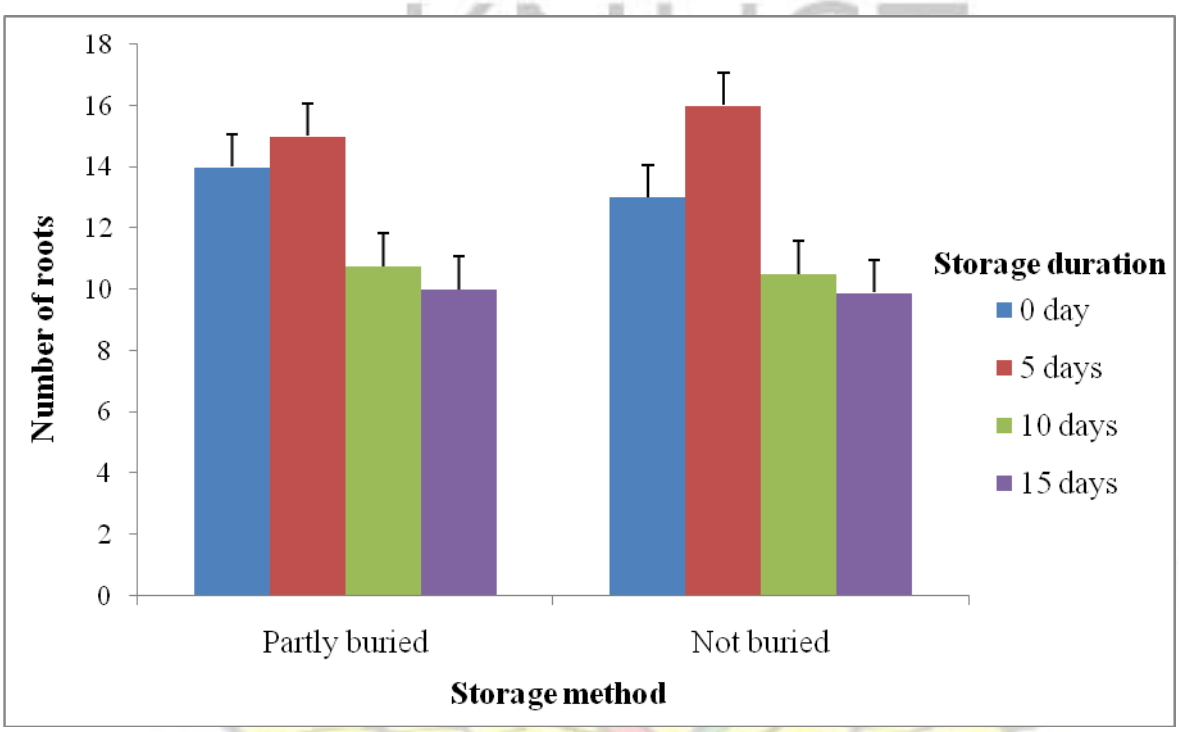

Figure 4.1: Influence of storage method and duration of storage of *Jatropha curcas* cuttings on number of roots on the day of transplanting. Error bars= LSD, p=0.0163

4.1.5 Length of root

Interaction between method of storage and duration of storage of *Jatropha curcas* cuttings significantly influenced the length of root produced (Table 4.11). On the day of transplanting, it was observed that cuttings that were stored for 0 and 5 days produced significantly longer roots than those stored for 10 and 15 days for both partly buried and not buried storage methods. There was however, no significant effect of storage method of *Jatropha curcas* cuttings on number of roots produced (Fig 4.2).

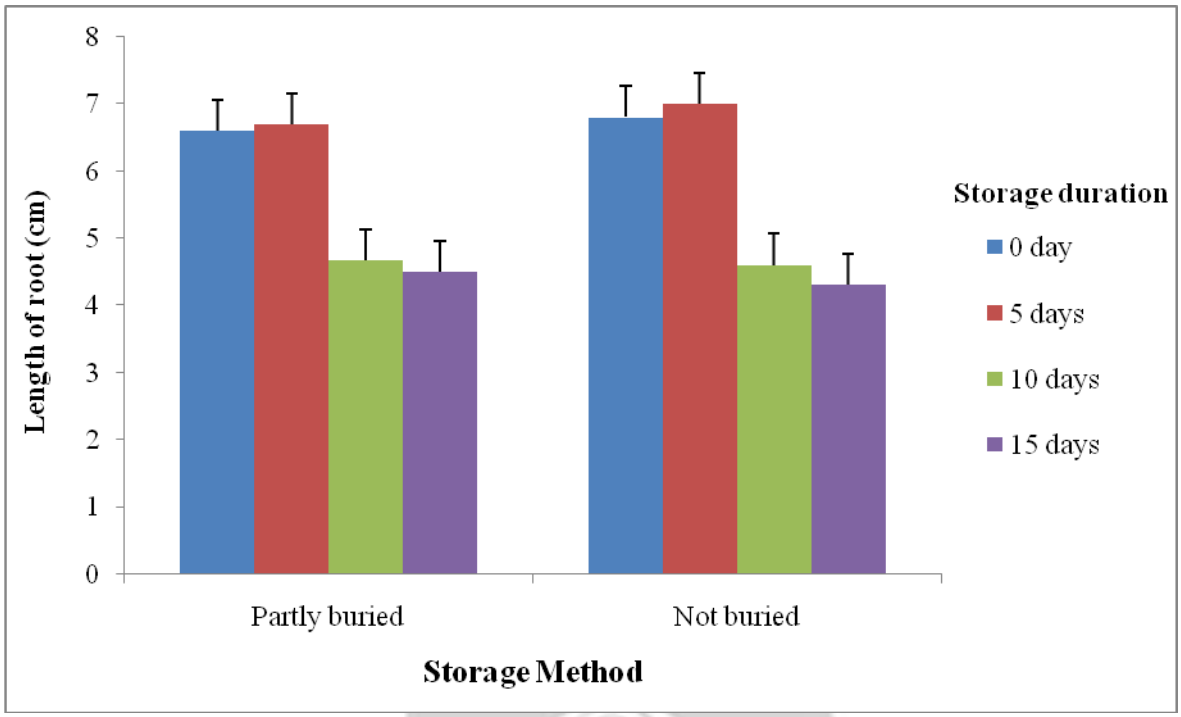

Figure 4.2: Influence of storage method and duration of storage of *Jatropha curcas* cuttings on length of roots (cm) on the day of transplanting. Error bars= LSD, p= 0.0255

4.1.6 Root Volume

The interaction between method of storage and duration of storage did not significantly influenced root volume produced by the *Jatropha curcas* plant on the day of transplanting. Period of storage, however, had significant influence on the root volume of the plant (Fig 4.3). It was observed that cuttings that were stored for 0 and 5 days produced significantly higher root volume than those stored for 10 and 15 days. Root volume reduced by more than 50% at 15 days storage duration compared with the cuttings stored between 0 and 10 days period.

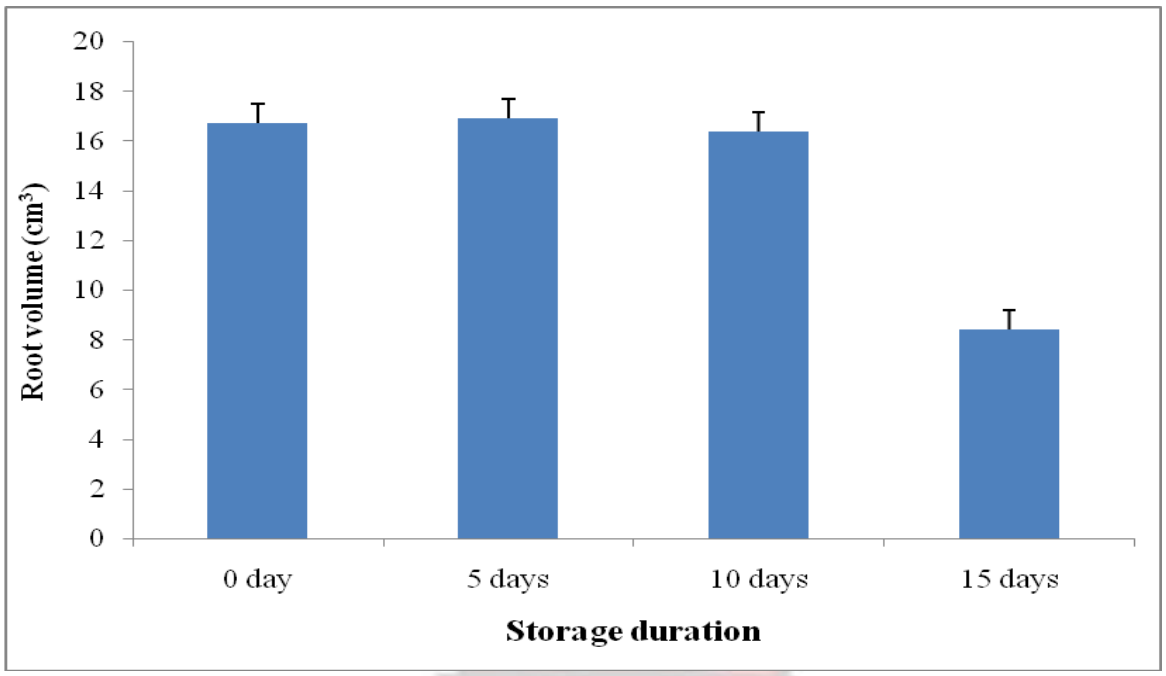

Figure 4.3: Influence of duration of storage of *Jatropha curcas* cuttings on root volume on the day of transplanting. Error bars= LSD, p= 0.0001

4.1.7 Root Biomass

There interaction between method of storage and duration of storage of cuttings significantly influenced root biomass produced by the Jatropha plant (Table 4.11). On the day of transplanting, it was observed that cuttings that were stored for 0, 5 and 10 days had significantly higher root biomass than those stored for 15 days. Root biomass was not significantly influenced by the storage methods, partly buried (PB) and not buried (NB) cuttings. Generally, the longer the storage duration, the less root biomass produced (Fig 4.4).

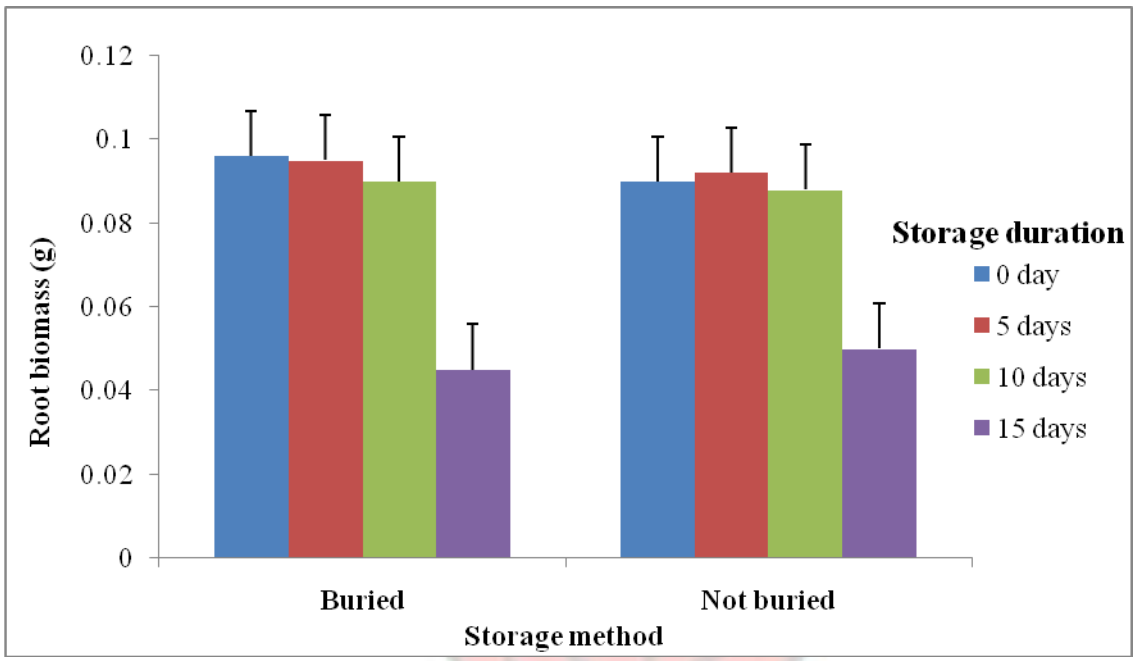

Figure 4.4: Influence storage method and duration of storage of *Jatropha curcas* cuttings on root biomass on the day of transplanting. Error bars= LSD, p=0.0073

4.1.8 Shoot Biomass

The duration of storage significantly influenced shoot biomass produced by the plant (p= 0.0205) (Table 4.11). It was observed on the day of transplanting that cuttings stored for 0, 5 and 10 days were similar but had significantly higher shoot biomass than those stored for 15 days (Fig 4.5).

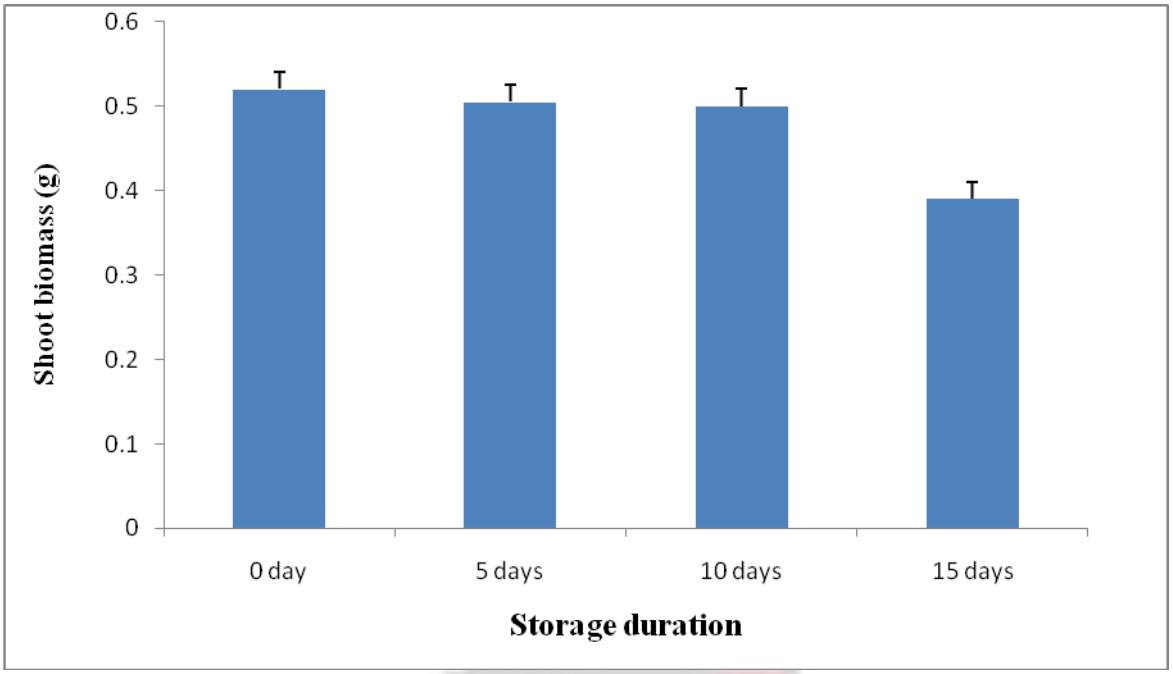

Figure 4.5: Influence of storage duration of *Jatropha curcas* cuttings on shoot biomass on the day of transplanting. Error bars= LSD, p= 0.0205

4.2 INFLUENCE OF CUTTING LENGTH AND STORAGE DURATION ON

GROWTH AND YIELD OF *jatropha curcas*.

4.2.1 Number of Sprouts.

The interaction between length of cutting and duration of storage of *Jatropha curcas* cuttings resulted in significant difference in number of sprouts (Table 4.12). Sprout initiation started on the day of transfer into the nursery for cuttings that were stored for 15 days. For cuttings that were stored for 5 and 10 days, sprouting started on the 5th day in nursery (DIN) while for cuttings stored for 0 day, sprouts initiated on the 15th DIN. It was observed that, the 40cm cuttings stored for 0, 5 and 10 days had higher number of sprouts than the 30cm cuttings stored for the same period, and this occurred on the 10th and 15th DIN (Table 4.13a). Also, all the cuttings stored for 0, 5 and 10 days produced higher number of sprouts than those stored for 15 days. On the 20th, 25th, 30th, 35th and 40th DIN, there was no significant interaction between length of cutting and duration of storage, cutting length, however, significantly influenced sprouting. The 40cm cuttings produced significantly higher number of sprouts than the 30cm cuttings (Table 4.13b).

After transplanting in the field, there was interaction between length of cutting and duration of storage of *Jatropha curcas* (Table 4.14). The 40cm cuttings for the various storage durations continued to produce significantly more sprouts than the 30cm cuttings stored for the same durations (Table 4.15). Generally, there was significant decline in the number of sprouts on the 8th, 12th and 16th WAT in the field.

Table 4.12: Summary of Analysis of Variance for number of sprouts influenced by length of cutting and storage duration of *Jatropha curcas* cuttings within 40 days in the nursery.

	Days in nursery							
	5	**10**	**15**	**20**	**25**	**30**	**35**	**40**
CL	0.00^{ns}	1.00^{ns}	1.13^{ns}	5.28^{ns}	11.52^{ns}	12.00^{ns}	16.53^{ns}	1.13^{ns}
SD	0.00^{ns}	2.00*	1.28*	7.87*	0.28*	0.38*	0.53*	0.08*
CL × SD	2.20^{ns}	1.50*	0.13*	2.28*	0.03^{ns}	0.21^{ns}	0.03^{ns}	1.21^{ns}
Residual	3.00	2.00	0.45	0.35	0.34	0.30	0.22	0.47

CL- Cutting Length SD-Storage Duration ns- not significantly different at 5% level of probability *- significantly different at 5% level of probability using the LSD test.

Table 4.13a: Influence of length of cutting and duration of storage of *Jatropha curcas* cuttings on number of sprouts in a nursery.

	Days in nursery					
	5		10		15	
Storage duration (days)	Length of cutting (cm)					
	30	**40**	**30**	**40**	**30**	40
0	0.0	0.0	3.8	4.5	5.6	6.8
5	0.0	2.0	4.0	5.0	5.2	7.1
10	4.2	3.5	4.0	4.8	5.2	5.6
15	5.0	4.0	4.0	4.8	3.3	4.0
P			0.0344		0.0122	
LSD (5%)	ns		0.60		0.56	

Table 4.13b: Influence of length of cutting of *Jatropha curcas* on number of sprouts after transplanting.

	Days in nursery				
	20	**25**	**30**	**35**	**40**
Length of cutting (cm)					
30	3.3	4.1	3.3	3.0	3.3
40	5.1	5.6	4.9	4.5	4.4
P	0.0009	0.0001	0.0001	0.0001	0.0049
LSD (5%)	0.42	0.40	0.40	0.34	0.30

Table 4.14: Summary of Analysis of Variance for number of sprouts influenced by length of cutting and storage duration of *Jatropha curcas* cuttings after transplanting.

	Weeks after transplanting							
	2	**4**	**6**	**8**	**10**	**12**	**14**	**16**
CL	2.00^{ns}	0.50^{ns}	0.50^{ns}	1.13^{ns}	8.00^{ns}	4.50^{ns}	0.50^{ns}	0.50^{ns}
SD	0.17*	1.00 *	0.21*	0.08^{ns}	0.83^{ns}	1.50*	0.50^{ns}	0.17*
CL × SD	1.67*	0.83*	0.25*	0.21*	0.33	0.83*	0.50^{ns}	1.50*
Residual	0.44	0.18	0.21	0.17	0.17	0.19	0.19	0.26

CL- Cutting Length SD-Storage Duration ns- not significantly different at 5% level of probability
*- significantly different at 5% level of probability using the LSD test.

Table 4.15: Influence of length of cutting and duration of storage of *Jatropha curcas* cuttings on number of sprouts after transplanting.

Weeks after transplanting	2		4		6		8		12		16	
Storage duration	**Length of cutting (cm)**											
(days)	**30**	**40**	**30**	**40**	**30**	**40**	**30**	**40**	**30**	**40**	**30**	**40**
0	2.5	4.7	2.5	4.2	3.0	4.4	2.5	3.3	2.0	2.3	1.2	2.2
5	2.5	5.0	3.5	4.2	3.2	4.5	2.6	4.5	2.0	2.2	1.1	2.1
10	2.5	5.0	2.5	4.5	3.1	4.4	2.5	4.2	2.1	2.3	1.1	2.1
15	3.0	4.0	3.0	3.8	3.0	4.4	3.0	4.3	2.1	2.5	1.1	2.1
P	0.0258		0.0119		0.0334		0.0316		0.0153		0.0050	
LSD (5%)	0.94		0.60		0.70		0.96		0.61		0.20	

4.2.2 Number of leaves

There were increases in the number of leaves in all treatments up to day 40 of nursery but was highest in 40cm cuttings. Interaction between length of cuttings and duration of storage resulted in significant difference in number of leaves (Table 4.16). On days 15, 20, 25 and 40 in nursery, the 40cm cuttings stored for 0, 5, 10 and 15 days produced significantly higher number of leaves than the 30cm cuttings stored for the same period (Table 4.17a). Similarly, both cuttings stored for 0, 5 and 10 days produced higher number of leaves than those stored for 15 days. On the 30th 35th DIN, cutting length had significant influence on number of leaves, as the 40cm cuttings produced more leaves than the 30cm cuttings (Table 4.17b). However, leaves started forming earlier on cuttings that were stored for 15 days than those stored between 0 and 10 days (Table 4.8b). After transplanting in the field, there were increases in the number of leaves in all treatments up to week 10 before declining, but was highest with 40cm cuttings. The interaction between cutting length and duration of storage significantly influenced the number of leaves (Table 4.18). The 40 cm cutting stored 0, 5, 10 and 15 days continued to produce significantly higher number of leaves than the 30 cm stored for the same period (Table 4.19).

Table 4.16: Summary of Analysis of Variance for number of leaves influenced by length of cutting and storage duration of *Jatropha curcas* cuttings within 40 days in the nursery.

	Days in nursery						
	10	**15**	**20**	**25**	**30**	**35**	**40**
CL	0.00^{sn}	0.28*	2.67*	14.50*	18.78*	27.53*	30.78*
SD	0.00^{ns}	4.03*	0.13*	4.50*	17.28^{ns}	31.70^{ns}	36.37*
CL × SD	1.00^{ns}	0.20*	0.42*	1.00*	0.87^{ns}	0.95^{ns}	5.53*
Residual	0.00	1.02	0.35	0.26	0.66	1.03	1.13

CL- Cutting Length SD-Storage Duration

ns- not significantly different at 5% level of probability

*- significantly different at 5% level of probability using the LSD test.

Table 4.17a: Influence of length of cutting and duration of storage on number of leaves of *Jatropha curcas* cutting in a nursery.

	Days in Nursery									
	10		**15**		**20**		**25**		**40**	
Storage duration (days)	**Length of cutting**									
	30	**40**	**30**	**40**	**30**	**40**	**30**	**40**	**30**	**40**
0	0.0	0.0	2.0	2.2	4.0	5.0	4.3	6.5	12.8	19.0
5	0.0	0.0	1.8	2.0	4.0	5.0	4.5	6.3	12.3	10.0
10	2.2	2.3	2.6	4.1	4.1	5.0	4.3	6.5	12.3	18.5
15	2.0	2.3	2.5	4.0	4.0	5.6	4.5	6.3	8.8	12.0
P			0.0099		0.0010		0.0250		0.0097	
LSD (5%)	ns		0.48		0.74		0.72		1.90	

Table 4.17b: Influence of length of cutting on number of leaves produced by the *Jatropha curcas* in a nursery.

	Days after nursery	
	30	**35**
Length of cutting (cm)		
30	6.9	9.8
40	10.6	15.4
P	0.0299	0.0448
LSD (5%)	0.58	0.72

Table 4.18: Summary of Analysis of Variance for number of leaves influenced by length of cutting and storage duration of *Jatropha curcas* cuttings after transplanting. Weeks after transplanting

	2	**4**	**6**	**8**	**10**	**12**	**14**	**16**
SM	76.13*	82.50*	88.00*	92.00*	98.00*	88.00*	62.00*	50.00*
SD	44.79^{ns}	37.83^{ns}	44.00*	51.33*	88.50*	64.67*	44.00*	36.00*
SM × SD	2.14*	0.50*	1.33*	0.67*	1.83*	8.67*	3.33*	3.33*
Residual	2.63	1.31	1.11	1.11	1.11	1.11	1.11	1.11

CL- Cutting Length SD-Storage Duration ns- not significantly different at 5% level of probability *- significantly different at 5% level of probability using the LSD test.

Table 4.19: Influence of length of cutting and duration of storage of *Jatropha curcas* cuttings on number of leaves after transplanting.

Weeks after transplanting	**2**		**4**		**6**		**8**		**10**		**12**		**14**		**16**	
Storage duration	**Length of cutting (cm)**															
(days)	**30**	**40**	**30**	**40**	**30**	**40**	**30**	**40**	**30**	**40**	**30**	**40**	**30**	**40**	**30**	**40**
0	14.0	19.0	15.0	20.8	16.0	22.0	18.0	24.0	18.0	25.0	13.0	19.5	8.0	14.0	4.0	8.0
5	13.0	19.0	14.1	20.0	15.0	22.0	17.0	23.0	18.0	26.0	12.6	19.3	8.0	14.0	5.0	9.0
10	13.0	20.0	14.1	20.0	16.0	21.0	18.0	23.0	19.0	25.0	13.0	20.0	8.0	13.0	5.0	8.0
15	9.0	14.0	10.0	16.0	11.0	17.0	13.0	18.0	12.0	19.0	8.0	12.0	8.0	14.0	5.0	9.0
P	0.0095		0.0029		0.0023		0.0022		0.0021		0.0099		0.0123		0.0433	
LSD (5%)	1.10	1.00	1.04	1.04	1.10	0.82	1.04	1.22								

4.2.3 Number of branches

Number of branches was significantly influenced by the interaction between cutting length and storage duration (Table 4.20). The longer cuttings (40 cm) stored for 0, 5, 10 and 15 days produced significantly more branches than the shorter cuttings (30 cm) stored for the same period. This occurred on 20th and 30th DIN (Tables 4.21a)). On the 25th, 35th and 40th DIN, cutting length significantly influenced the number of leaves. The 40cm length cuttings produced higher number of cuttings than the 30cm length cuttings (Table 4.21b) However, cuttings stored for 15 days formed branches much earlier than the other treatments.

After transplanting in the field, cutting length was observed to have significant influence on number of branches per plant (Table 4.22). The 40 cm cuttings produced more branches than the 30 cm cuttings (Table 4.23).

Table 4.20: Summary of Analysis of Variance for number of branches influenced by Length of cutting and storage duration of *Jatropha curcas* cuttings within 40 days in a nursery.

Days in nursery

	15	20	25	30	35	40
CL	0.0000^{ns}	0.0001*	0.0078*	0.0080*	0.1250*	8.0000*
SD	0.0000^{ns}	0.3333^{ns}	1.1328^{ns}	0.2000^{ns}	0.1250^{ns}	0.0833^{ns}
CL × SD	1.0000^{ns}	1.0000*	0.3412^{ns}	0.3333*	0.1250^{ns}	0.0833^{ns}
Residual	0.0000	0.2738	0.0465	0.0923	0.0113	0.2730

CL- Cutting Length SD-Storage Duration ns- not significantly different at 5% level of probability

*- significantly different at 5% level of probability using the LSD test.

Table 4.21a: Influence of length of cutting and duration of storage of *Jatropha curcas* cuttings on number of branches in a nursery. Days in nursery

	15		20		30	
Storage duration	**Length of cutting (cm)**					
(days)	**30**	**40**	**30**	**40**	**30**	**40**
0	0.0	0.0	1.4	2.1	1.5	2.0
5	0.0	0.0	1.4	2.0	1.5	2.0
10	1.2	2.0	1.5	2.0	1.5	2.0
15	1.2	2.0	1.4	2.0	1.8	2.2

P		0.001	0.0001
LSD (5%)	ns	0.18	0.04

Table 4.21b: Influence of length of cutting on number of branches produced by the *Jatropha curcas* plant in a nursery.

	Days in nursery		
	25	**35**	**40**
Length of cutting (cm)			
30	1.4	2.8	2.8
40	2.0	3.6	3.8
P	0.0356	0.0090	0.0009
LSD (5%)	0.18	0.30	0.32

Table 4.22: Summary of Analysis of Variance for number of branches influenced by length of cutting and storage duration of *Jatropha curcas* cuttings after transplanting.

	Weeks after transplanting							
	2	**4**	**6**	**8**	**10**	**12**	**14**	**16**
CL	7.03*	7.03*	4.50*	8.00*	12.50*	15.13*	24.50*	24.50*
SD	0.12^{ns}	0.20^{ns}	0.33^{ns}	0.21^{ns}	0.25^{ns}	0.46^{ns}	0.50^{ns}	0.50^{ns}
CL × SD	0.12^{ns}	0.37^{ns}	0.33^{ns}	0.25^{ns}	0.08^{ns}	0.13^{ns}	0.83^{ns}	0.83^{ns}
Residual	0.34	0.31	0.25	0.26	0.27	0.35	0.32	0.32

CL- Cutting Length SD-Storage Duration ns- not significantly different at 5% level of probability *- significantly different at 5% level of probability using the LSD test.

Table 4.23: Influence of length of cutting on number of branches produced by the *Jatropha curcas* plant after transplanting.

	Weeks after transplanting							
	2	**4**	**6**	**8**	**10**	**12**	**14**	**16**
Length of cutting (cm)								
30	2.8	2.8	3.0	3.2	3.3	3.5	3.5	3.5
40	3.7	3.8	3.8	4.2	4.5	4.9	5.3	5.3
P	0.0032	0.0018	0.0009	0.0008	0.0008	0.0010	0.0011	0.0011
LSD (5%)	0.42	0.40	0.36	0.36	0.38	0.42	0.40	0.40

4.2.4 Plant height

Plant height was significantly influenced by the interaction between cutting length and storage duration (Table 4.24). The 40cm cuttings stored for 0, 5, 10 and 15 days produced significantly greater plant height than the 30 cm cuttings stored for the same period, and this was observed on the 2nd, 4th, 6th, 10th, and 16th WAT (Table 4.25a). Also, cutting length had significant influence on plant height. The 30cm length cuttings produced taller plants than the 30cm length cuttings. This was observed on the 8th, 12th, and 14th WAT (Table 4.25b).

Table 4.24: Summary of Analysis of Variance for plant height influenced by length of cutting and storage duration of *Jatropha curcas* cuttings after transplanting.

	Weeks after transplanting							
	2	**4**	**6**	**8**	**10**	**12**	**14**	**16**
CL	228.13*	235.78*	239.53*	242.53*	246.13*	255.13*	266.13*	267.03*
SD	113.08^{ns}	107.20^{ns}	103.87^{ns}	97.70^{ns}	89.08^{ns}	88.00^{ns}	83.38^{ns}	83.37^{ns}
CL × SD	11.71*	9.95*	4.37*	0.62^{ns}	2.54*	6.46^{ns}	4.04^{ns}	4.95*
Residual	0.14	1.26	1.88	1.17	0.51	2.50	1.73	1.29

CL- Cutting Length SD-Storage Duration ns- not significantly different at 5% level of probability
*- significantly different at 5% level of probability using the LSD test.

Table 4.25a: Influence of method of storage and period of storage of *Jatropha curcas* cuttings on plant height after transplanting.

Weeks after transplanting	2		4		6		10		16	
Storage duration (days)	**Length of cutting (cm)**									
	30	**40**	**30**	**40**	**30**	**40**	**30**	**40**	**30**	**40**
0	46.0	55.3	47.0	56.0	51.5	57.7	61.0	69.5	69.5	80.0
5	45.5	54.8	46.0	55.8	52.8	57.8	61.5	68.8	69.5	79.8
10	45.3	54.8	46.0	55.5	52.3	57.8	62.0	69.0	70.5	79.8
15	40.5	45.0	41.3	46.3	43.5	51.8	55.8	61.5	64.8	72.0
P	0.0006		0.0010		0.0040		0.0367		0.0093	
LSD (5%)	1.64		1.58		1.94		1.02		1.62	

Table 4.25b: Influence of length of cutting on plant height produced by the *Jatropha curcas* plant after transplanting.

	Weeks after transplanting		
	8	**12**	**14**
Length of cutting (cm)			
30	56.1	65.1	67.4
40	63.5	73.7	76.4
P	0.0001	0.0001	0.0001
LSD (5%)	0.76	1.12	0.94

4.2.5 Number of roots

The interaction between cutting length and duration of storage of *Jatropha curcas* cuttings significantly influenced the number of roots of the plant (Table 4.26). Observation of roots of the plant on the day of transplanting showed that both 30 and 40cm length cuttings that were stored for 0, and 5 days produced significantly more roots than those stored for 10 and 15 days. Also, the 40cm cuttings stored for 0 and 5 days produced more roots than the 30cm cuttings stored for the same period.

There was, however, no significant difference in the more roots produced by the 40cm cuttings stored for 10 and 15 days and the 30cm cuttings stored for the same period (Fig 4.6).

Table 4.26: Summary of Analysis of Variance for different rooting attributes and shoot biomass influenced by length of cutting and storage duration of Jatropha *curcas* cuttings on the day of transplanting.

	Number of roots	Length of root	Root volume	Root biomass	Shoot biomass
LC	38.2813*	14.9870*	13.9129*	0.0034*	0.1405*
SD	24.1146*	7.4728*	77.5587*	0.0037*	0.0843*
LC × SD	2.5313*	0.1853*	0.8387^{ns}	0.0002^{ns}	0.0054*
Residual	0.3289	0.0307	0.9332	0.0001	0.0004

CL- Cutting Length SD-Storage Duration ns- not significantly different at 5% level of probability

*- significantly different at 5% level of probability using the LSD test.

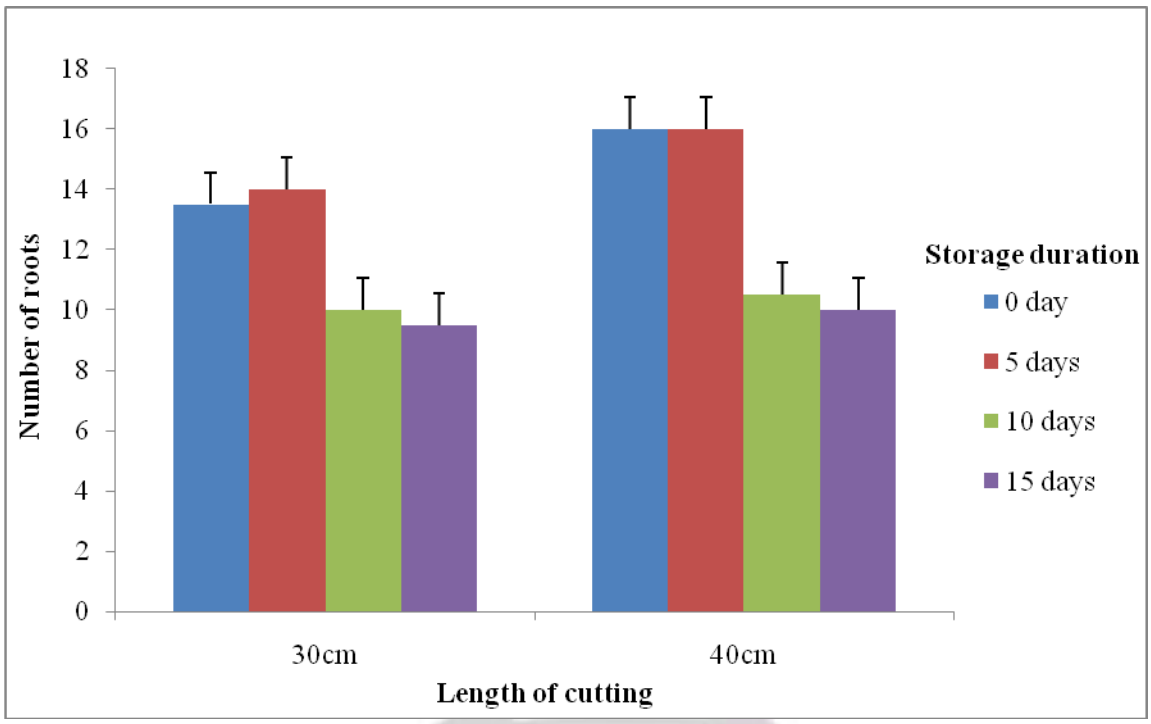

Figure 4.6: Influence of length of cutting and duration of storage on number of roots of *Jatropha curcas* cuttings on the day of transplanting.

Error bars= LSD, p=0.0012

4.2.6 Length of root

The interaction between cutting length and duration of storage of *Jatropha curcas* cuttings significantly influenced the length of root of the plant (Table 4.26). Observation of roots of the plant on the day of transplanting showed that both 30 and 40cm length cuttings that were stored for 0, and 5 days produced significantly longer roots than those stored for 10 and 15 days. Also, the 40cm cuttings stored for 0 and 5 days produced longer roots than the 30cm cuttings stored for the same period. There was, however, no significant difference in the length of root produced by the 40cm cuttings stored for 10 and 15 days and the 30cm cuttings stored for the same period (Fig 4.7).

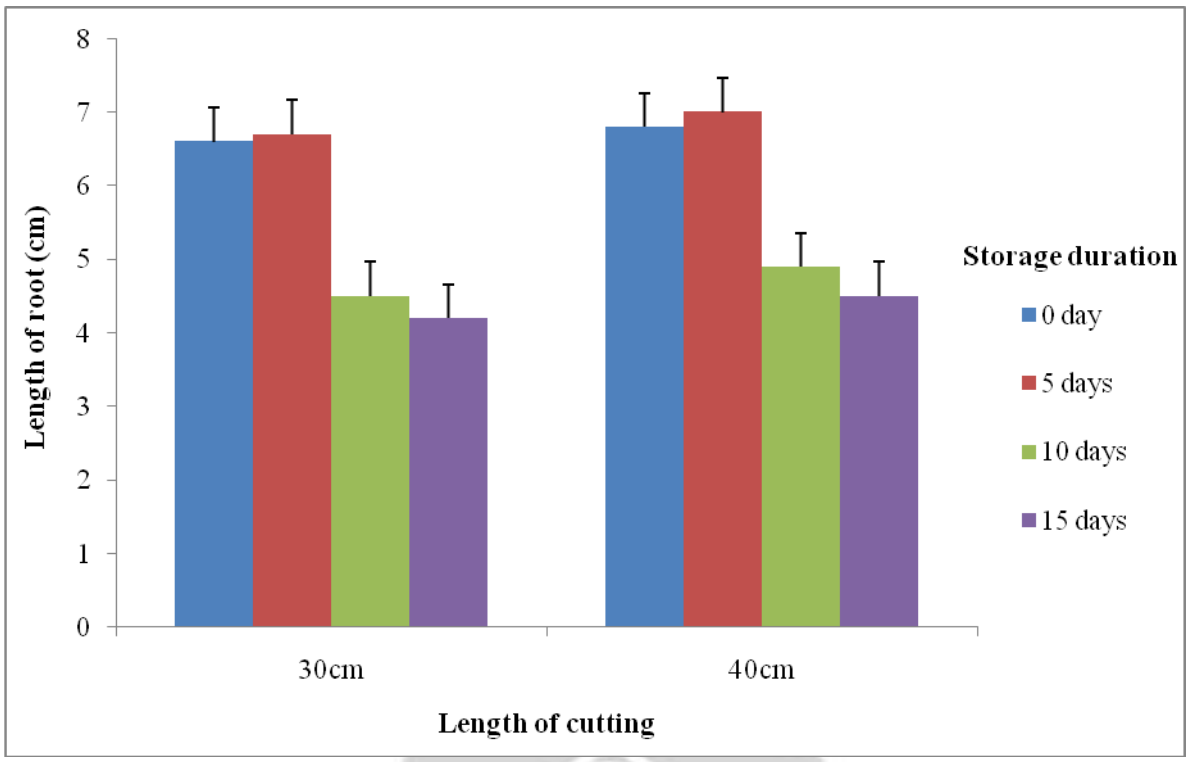

Figure 4.7: Influence of length of cutting and duration of storage on length of root of *Jatropha curcas* cuttings on the day of transplanting. Error bars= LSD, p=0.0039

4.2.7 Root Volume

Length of cutting had significant influence on root volume produced by the *Jatropha curcas* plant on the day of transplanting (Table 4.26). The 40cm cuttings produced significantly higher root volume than the 30cm cuttings (Fig 4.8a). Also duration of storage of cuttings had significant influence on root volume (Table 4.26). Cuttings stored for 0 and 5 days produced greater root volume than those stored 10 and 15 days. There was no difference in root volume for cuttings stored between 0 and 5 days and also between 10 and 15 days (Fig 4.8b).

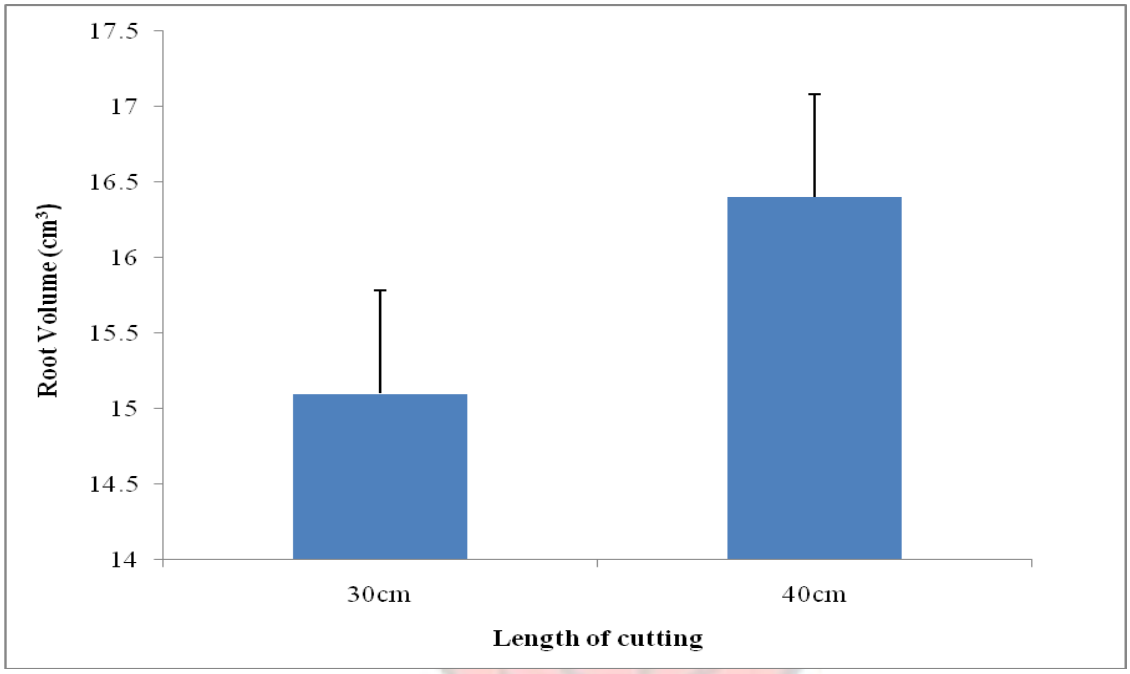

Figure 4.8a: Influence of length of cutting on root volume of *Jatropha curcas* cuttings on the day of transplanting. Error bars= LSD, p= 0.0009

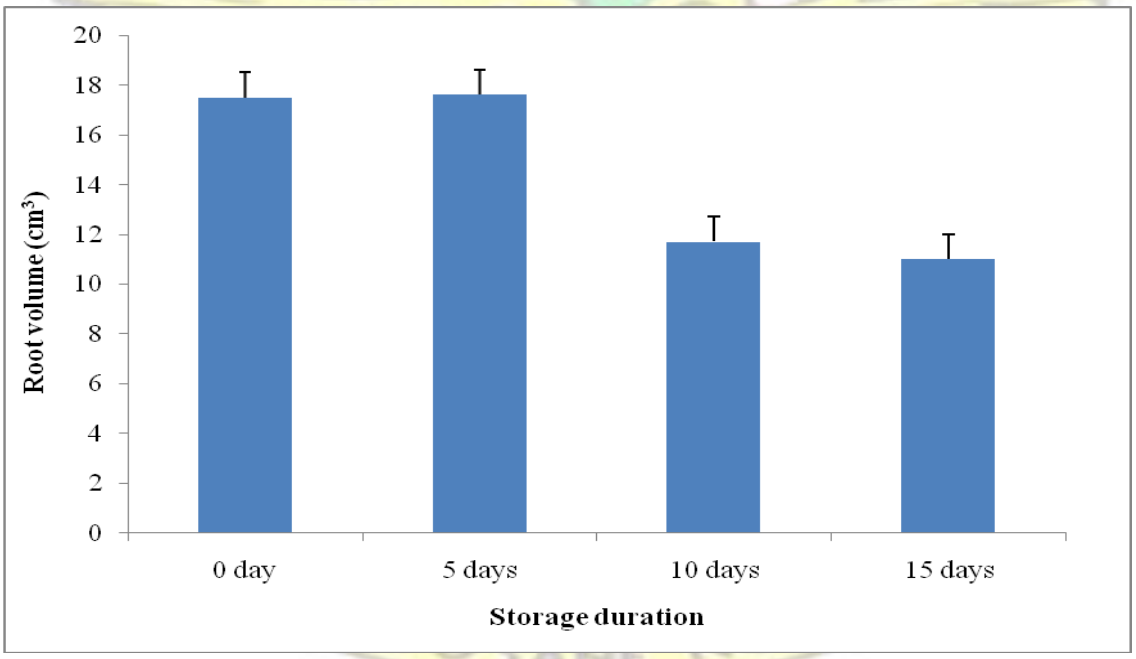

Figure 4.8b: Influence of storage duration of *Jatropha curcas* cutting on root volume on the day of transplanting. Error bars= LSD, p=0.0001

4.2.8 Root Biomass

Length of cutting significantly influenced root biomass (Table 4.26). The 40cm cuttings had higher accumulation of dry matter in their roots than the 30cm cuttings (Fig 4.9a).

Also, duration of storage of cuttings had significant influence on root biomass. Cuttings stored for 0 and 5 days had significantly higher root biomass than those stored for 10 or 15 days. There was no difference in root biomass for cuttings stored between 0 and 5 days and also between 10 and 15 days (Fig 4.9b).

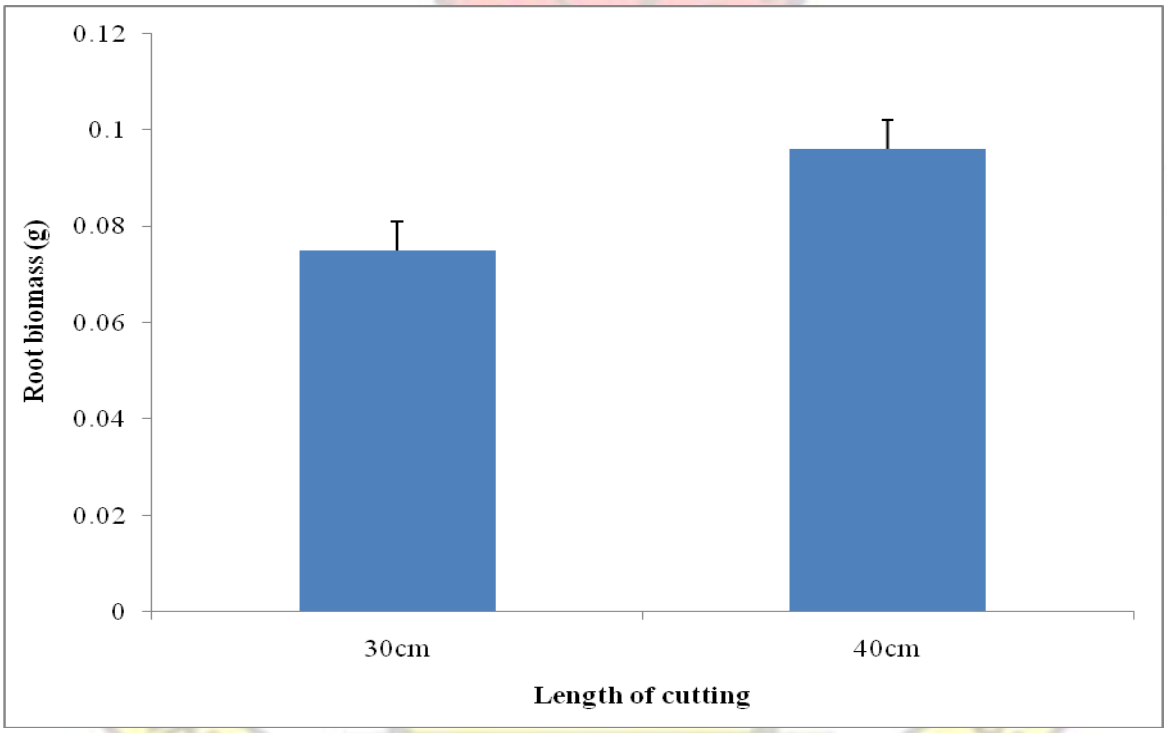

Table 4.9a: Influence of length of cutting of *Jatropha curcas* cuttings on root biomass (g) on the day of transplanting. Error bars= LSD, p= 0.0001

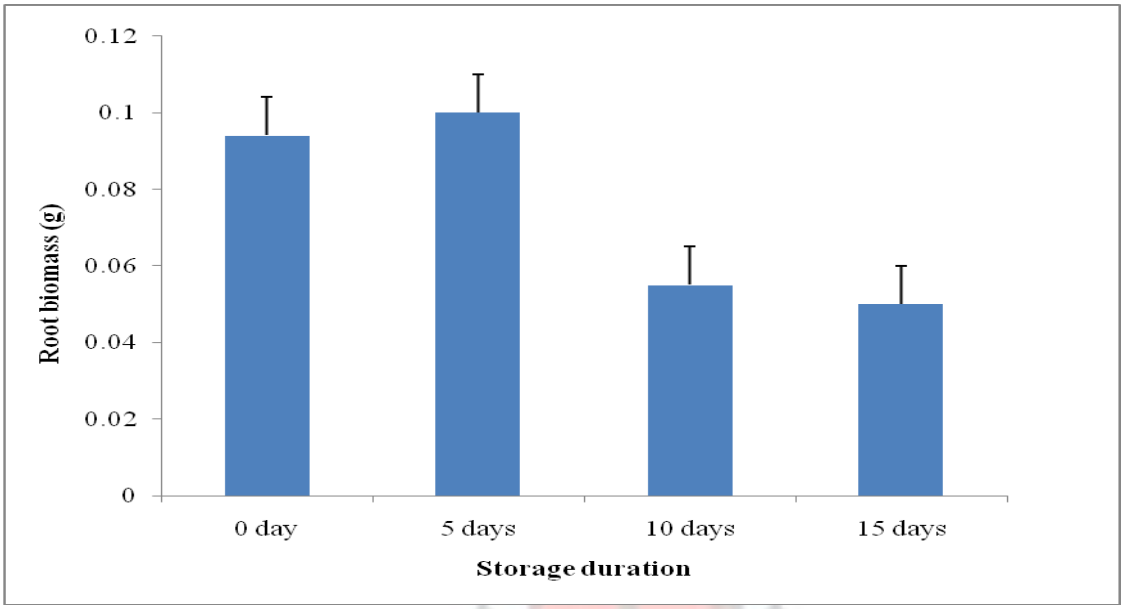

Figure 4.9b: Influence of duration of storage on root biomass of *Jatropha curcas* cuttings on the day of transplanting. Error bars= LSD, p= 0.0001

4.2.9 Shoot biomass

The interaction between cutting length and duration of storage of *Jatropha curcas* cuttings significantly influenced the shoot biomass (Table 4.26). Observation of the plant on the day of transplanting showed that the 40cm cuttings stored for 0 or 5 days produced significantly higher shoot biomass than the 30cm cuttings stored for the same period. Cuttings stored 0 and 5 days produced higher root biomass than those stored for 10 and 15 days for both lengths of cuttings. However, difference in shoot biomass yield between cuttings stored for 1 and 5 days for both lengths of cuttings was not significant. Similarly, observation made for cuttings stored for 10 and 15 days for both lengths did not show significant difference in shoot biomass.

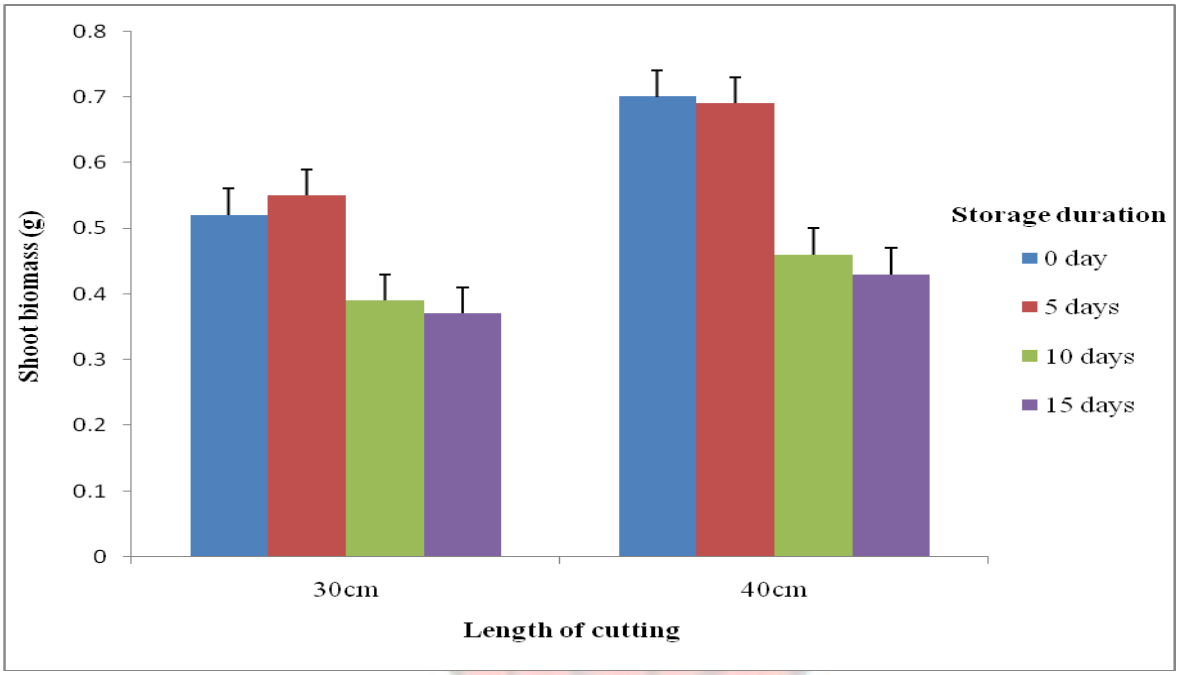

Figure 4.10: Influence of length of cutting and duration of storage on shoot biomass of *Jatropha curcas* cuttings on the day of transplanting.

Error bars= LSD, p=0.0001

4.2.10 Flower yield

The interaction between cutting length and duration of storage of *Jatropha curcas* cuttings significantly influenced flower yield of the plant (Table 4.27). Observation of flowers of the plant in the field showed that both 30 and 40cm length cuttings that were stored for 0, and 5 days produced significantly higher number of flowers than those stored for 10 and 15 days. Also, the 40cm cuttings stored for 0 and 5 days produced more flowers than the 30cm cuttings stored for the same period. Similarly, the 40cm cuttings stored for 10 and 15 days produced more flowers than the 30cm cuttings stored for the same period (Fig 4.11).

Table 4.27: Summary of Analysis of Variance for yield influenced by length of cutting and storage duration of *Jatropha curcas* cuttings after transplanting.

	Number of flowers	Number of fruits
CL	19.53*	28.12*
SD	50.13^{ns}	58.53^{ns}
CL × SD	2.13*	4.28*
Residual	0.69	1.42

CL- Cutting Length SD-Storage Duration

ns- not significantly different at 5% level of probability

*- significantly different at 5% level of probability using the LSD test.

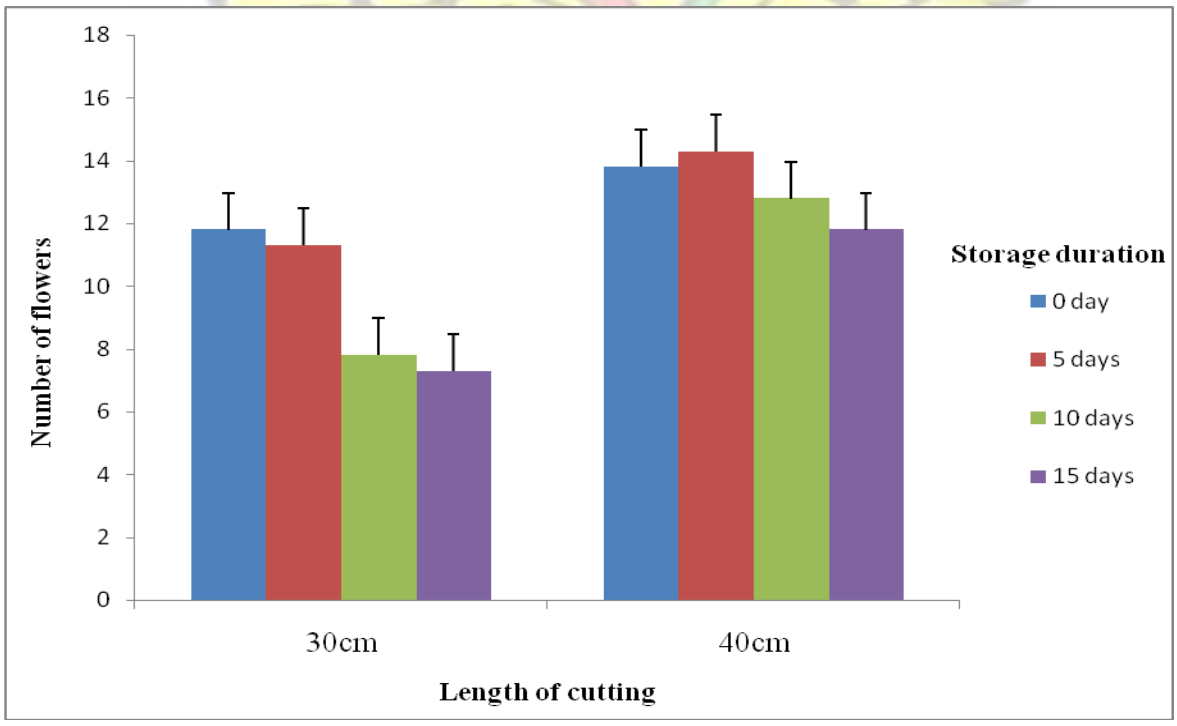

Figure 4.11: Influence of length of cutting and duration of storage of

***Jatropha curcas* cuttings on number of flowers after transplanting.**

Error bars= LSD, p= 0.0485

4.2.11 Fruit yield

The interaction between cutting length and duration of storage of *Jatropha curcas* cuttings significantly influenced the number fruits of the plant (Table 4.27). It was observed that both the 30 and 40cm length cuttings that were stored for 0, and 5 days produced significantly more fruits than those stored for 10 and 15 days. Also, the 40cm cuttings stored for 0 and 5 days produced higher number of fruits than the 30cm cuttings stored for the same period. There was, however, no significant difference in the number fruits produced by the 40cm cuttings stored for 10 and 15 days and the 30cm cuttings stored for the same period(Fig 4.12).

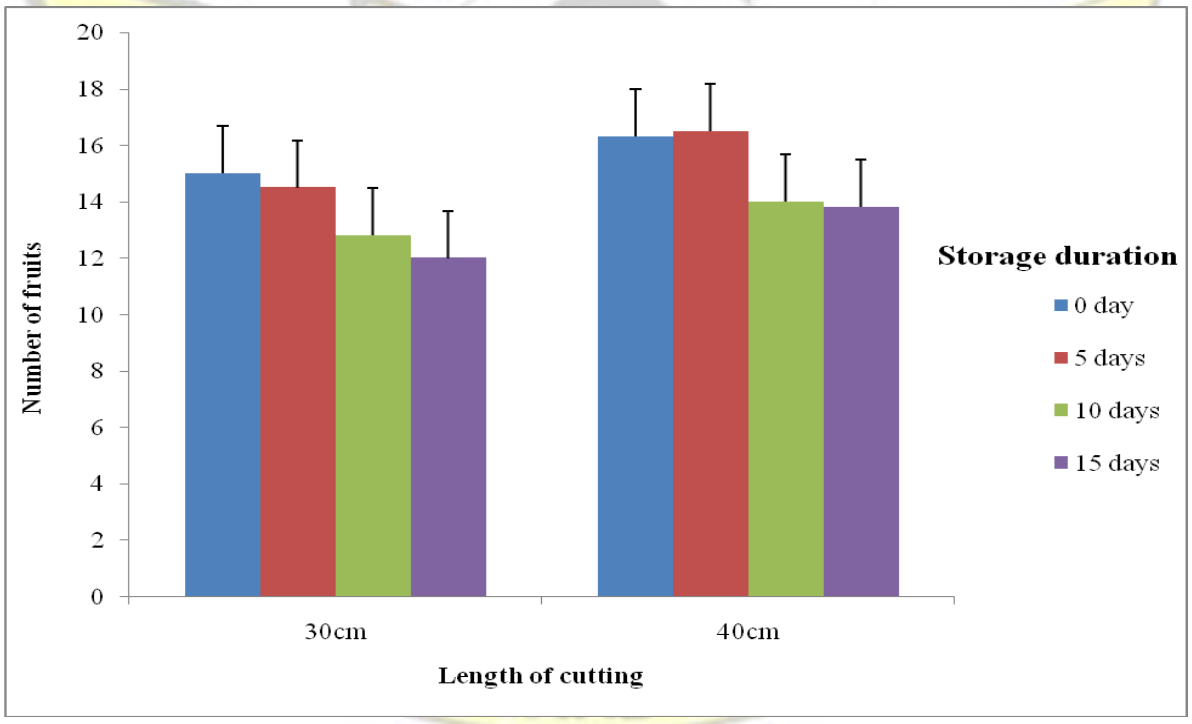

Figure 4.12: Influence of length of cutting and duration of storage of *Jatropha curcas* cuttings on number of fruits after transplanting.

Error bars= LSD, p= 0.0433

CHAPTER FIVE

5.0 DISCUSSION

5.1 EFFECT OF PERIOD OF STORAGE AND METHOD OF STORAGE OF STEM CUTTINGS ON GROWTH OF *jatropha curcas* PLANT.

The significantly higher number of sprouts and leaves observed with 0 to 10 day storage cuttings could be attributed to the fact that long duration in storage causes dehydration and exhaustion of starch reserve. This could result in low sprouting performance, exposing cuttings to pests and diseases (Chipungu *et al.,* 2000). Hartmann *et al*., (1990) also observed that, storage duration reduces starch content which affects carbohydrates accumulation in stored cuttings. Thus, starch reserve decreases with time as some of it is used for metabolic activities. Dehydration due to long storage duration and storage method may have severely affected the cuttings that were stored for fifteen days compared to the rest. This is supported by Rice *et al.,* (1984), when they noted that cuttings to be stored are pushed into damp rooting medium (2.5 – 5cm deep) and placed in plastic bags to prevent moisture loss. This accounted for stronger growth performance in cuttings that were partly buried than those that were not buried during storage.

Storage of cuttings for zero and ten days before planting may have caused changes in auxin content of the cutting which induced sprouting. Krishnankatty (2005) observed differential rooting and sprouting behaviour of two Jatropha species and associated physiological and chemical changes that, the concentration of auxin had to reach a certain threshold in order to signal the processes of root and leaf initiation.

The lower plant height growth observed with the 15 days storage cuttings could be due to reduction in starch reserve in the stored cuttings.

The more vigorous rooting with less than 10 days storage duration cuttings could be attributed to the loss of water and decline in reserved food by the cuttings that were stored 10 and 15 days. This is in conformity with Hartmann *et al*. (1990), observing that, longer storage duration reduces starch which affects carbohydrates accumulation in stored cuttings. Thus, starch reserve change with time as some of it is used for metabolic activities. This could be the reason why the cuttings that were stored between 0 and 10 days rooted better than those stored for 15 days. Other factors such as nitrogenous compounds also promote rooting (Krishnankatty, 2005).

The improved rooting of the partly buried cuttings during storage rooted could be attributed to decline in reserved food by the cuttings that were not buried during storage. Similar observation was made by Rice *et al.,* (1984). Since presence of buds and leaves influence rooting of cuttings (Karikari *et al.* 1990), it goes to explain that reduction in the number of leaves for cuttings stored between 10 and 15 days and cutting that were not buried during storage led to poor root formation.

5.2 EFFECT OF METHOD OF STORAGE AND DURATION OF STORAGE OF CUTTINGS ON YIELD OF *Jatropha curcas* PLANT.

The lower number of flowers produced by cuttings stored for fifteen days compared to cuttings stored between 0 and 10 days was attributed to low amount of carbohydrate in stored cutting, leading to poor bud and leaf formation which eventually affected flowering. Stem cuttings, that were stored for 15 days produced fewer fruits compared to those that were stored between 0 to 10 days. This was attributed to the low amount

of carbohydrate in the stored cuttings which affected flowering, leading to poor fruit formation. Flowering depends on the ability of the plant to differentiate its vegetative buds to flower buds. According to Karikari *et al*. (1990), the differentiation of vegetative buds to flower buds is influenced by reserved food which is more in large sized cuttings. Carbohydrate utitilization, abundant supply of water and nutrients are necessary for development of flower buds, fruits and seeds.

Since presence of buds and leaves influence rooting of cuttings (Karikari *et al.,* 1990), the reduction in the number of leaves for cuttings stored between 10 and 15 days might have led to poor root formation.

5.3 EFFECT OF LENGTH OF CUTTINGS AND DURATION OF STORAGE ON GROWTH OF *jatropha curcas* PLANT.

The higher sprouts and leaves observed in the 40cm cuttings could be attributed to the fact that longer cuttings have more nodes than shorter cuttings, hence will have more sprouts. Most likely, longer cuttings could contain more carbohydrate reserve and thus promote higher vegetative growth. What accounted for the higher number of leaves produced by the 40cm cuttings is the fact that longer stem cuttings contain more sprouts and hence more likely to form more leaves. Also, the fact that larger cuttings contain more carbohydrate food reserve. The high sprouting and leave formation in 40cm cuttings accounted for the higher shoot biomass.

The difference in the plant height may be due to larger carbohydrate reserve in the 40cm stem cuttings compared to the 30cm stem cutting. The carbohydrate reserve in the longer cuttings is further enhanced by photosynthetic ability as a result of aerial dominance Hartmann *et al*. (1990). The more vigorous roots by 40cm cuttings could

be attributed to higher amount of accumulated carbohydrate in the 40cm cuttings which may have promoted the vigour in rooting while the availability of an optimum amount of nitrogen may have increased the number of roots. The longer cuttings had more sprouts and leaves and this could have influenced rooting. This agrees with Mathew *et al,* (1990) observation that presence of buds and leaves influence rooting of cuttings.

Longer cuttings (40cm) were found to perform better in terms of all the rooting parameters examined in this study. This could be attributed to the fact that longer cuttings probably have higher food reserves and are more successful in vegetative propagation (Aminul-Islam *et al.*, 2010; Kathiravan *et al.*, 2009; Henning, 2003).

5.4 EFFECT OF LENGTH OF CUTTINGS AND DURATION OF STORAGE ON YIELD OF *jatropha curcas* PLANT.

Yield performance was higher in the 40cm cuttings than in the 30cm cuttings. According to Karikari *et al.* (1990), Flowering and fruiting are influenced by reserved food present in the plant. They added that, carbohydrate utitilization, abundant supply of water and nutrients are necessary for development of flower buds, fruits and seeds. This may be the reason for higher yield in longer cuttings compared to shorter cuttings.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDAITON

6.1 CONCLUSION

The main objective of this study was to determine the more appropriate storage period, storage method and length of cutting that will enhance growth and yield of *Jatropha curcas*.

From the results obtained the following conclusions.

- Storing stem cuttings of *Jatropha curcas* between 0 and 10 days produced plant with more vigorous forage, root characteristics and higher yield. Therefore, for suitable storage duration of Jatropha stem cuttings for commercial cultivation, it is suggested not to store stem cuttings for more than 10 days before planting.

- Cultivation of 40cm stem cuttings resulted in more vigorous establishment and higher yield than 30cm cuttings. Attributed to higher carbohydrate and water content in longer cuttings such as the 40cm cuttings. Carbohydrate concentrations in the base of stored cuttings contribute to shoot and root formation. Thus, 40cm length of stem cutting of *Jatropha curcas* is more appropriate for commercial vegetation propagation.

- Storing cuttings vertically and partly buried under shade and watered is necessary to conserve water in the cuttings. This led to better sprouting and leaf formation and resultant strong rooting. Hence this should be considered as more appropriate storage method of stem cutting of *Jatropha curcas* for commercial vegetation propagation.

6.2 RECOMMENDATIONS

In the course of the study, the following issues were noted for recommendation.

 To further investigate the best storage method of stem cuttings for improved growth and yield of *Jatropha curcas*, horizontal storage of cuttings under shade should therefore be looked at.

 The research was carried out without the use of rooting hormones. It is therefore recommended that rooting hormones on the cuttings should be investigated.

 Cuttings of different sizes were used in this study. It is necessary to consider cuttings of the same size for the study to further ascertain extent to which storage method and interval can affect growth and yield of *Jatropha curcas* plant.

 The study took place within one year due to time constraints. Therefore, it is important to consider such a study to cover a period of 2 to 3 years and at different ecological zones. This will help ascertain consistency in the yield performance of the *Jatropha curcas* plant.

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