CHAPTER ONE
INTRODUCTION

Jatropha curcas L. is a tropical species from the family *Euphobiaceae*. Special interest has been shown in cultivation of Jatropha species for oil extraction, especially based on it is drought resistance adaptation to marginal land, and not competing with food production (Heller, 1996; Grimm, 1996; RF, 1998). Today, *Jatropha curcas* has gained much attention (Grimm, 1996; Heller, 1996; Henning, 2000a ;) for both non oil producing and oil producing countries around the world. African countries are no exception. The species has high oil content and can be used as fuel for diesel engines as well as for medical and insecticidal purposes (Anon. 2006). Jatropha grows on well-drained soils with good aeration and as well as being adapted to marginal soils with low nutrient content (Anon. 2006). In many African countries, it is grown as a live fence, property demarcation and can be used to reclaim eroded areas (Heller, 1996; and Anon. 2006). Jatropha can grow 6 meters high or more (Heller, 1996; Makkar *et al*., 2001). Traditionally the seeds are used for medical treatments and soap production (Henning, 2002). Jatropha is fast growing and produce seeds after approximately two years; depending on many factors such as rainfall conditions and either the plant is propagated from cuttings or from seeds. Research on cultivation and propagation of *Jatropha curcas* is very limited, especially in the sahelian region of Africa. But quick establishment of live fences is usually achieved by directly planted cuttings. Unfortunately researches have shown that plants propagated by cuttings show a lower longevity and possess less drought and disease resistance than plants propagated by seeds (Heller, 1996) besides, the more suitable cutting length has not been established. But traditionally, cuttings of fifty to sixty centimeters long, or slightly more, are generally used by farmers and citizens to establish their live fences.

The scenario of ever increasing and pressing in the wake of rising prices of petrol and food in international market and in the domestic one, will justifying the research for alternative source of energy from non-edible origin food stuffs. In addition, to the growing demand for energy, and concerns about global warming, declining fossil fuel resources (Blažková *et al*., 1997) are the key factors driving the increasing interest in renewable energy source and in biofuels in particular (Brittaine *et al.*, 2010). Sudan is importing all its needs from fossil petrol and gas which increased drastically through the increase in the agricultural sector areas, transforming fabrication and development needs. The secession of South Sudan created a huge energy gap that aggravated the growing energy demand. This matter enforced the government of Sudan to search for substitutes. Significant efforts has been made to boost bio-fuels with the expectation of positive contribution to renewable fuel that not compete with wildlife, food crops with limited agricultural inputs and can be used in areas of land that are not suitable for the currently commercial crop.

One of the main problems in Jatropha cultivation is the poor germination of their seeds. This comes from the hard impermeable testa, which exerts a physical exogenous dormancy European Geosciences Union (2013) the present Jatropha plantations in Sudan are highly mixed. Sexual propagation of such highly out grossing plant will end with wide genetic variations. Asexual propagation will insure true to type plants from selected high yielding and high quality trees. Jatropha proved to be an opportunistic crop in tropical areas with unfavorable environments.

Objectives of the study:

1- Maximizing germination of cuttings and enhancing root formation for the production of elite seedlings under Central Sudan environment conditions.

2- Identifying proper cutting length, hormone concentration and rooting media for mass asexual propagation for *Jatropha curcas L;*

3- Examine pre-sowing seed treatments and rooting media for production of elite seedlings of Jatropha.

CHAPTER TWO
LITERATURE REVIEW

Uses: - Folk Medicine:

All parts of the plant including seeds, leaves and bark, are used in traditional medicine, veterinary purposes and as pesticides. The oil has a strong purgative action and is also widely used for skin diseases and to sooth pains such as rheumatism. A decoction of leaves is used against cough and as an antiseptic after birth. Branches are used as a chewing stick in Nigeria (Isawumi, 1978) the sap flowing from the stem is used to arrest bleeding of wounds. (Nath and Dutta, 1992) demonstrated the wound-healing properties of curcain, a proteolytic enzyme isolated from latex. Latex has antimicrobial properties against *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumoniae*, *Streptococcus pyogenes* and *Candida albicans* (Thomas 1989; Kone-Bamba *et al.*, 1987) found the coagulating effects on blood plasma. Other uses of traditional medicine are described by (Persinos *et al.*, (1964); Levingston and Zamora (1983); Gupta (1985); Oliver-Bever (1986); Elisabetsky and Gely (1987); Lentz (1993) and Manandhar (1995). Extracts from physic nut fruits showed pregnancy-terminating effects in rats Goonasekera *et al.*, (1995). Muanza *et al.*, (1995) found that a methanol extract of physic nut leaves afforded moderate protection for cultured human lymphoblastoid cells against the cytopathic effects of human immunodeficiency virus. 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).

Diesel fuel:

As early as 1911, Rudolf Diesel* who invented the diesel engine, made the following statement in a letter: “It is generally forgotten, 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, that the change of fuel was realized by only a few visitors” (Kiefer, 1986). In experiments carried out up to 1950, vegetable oils were used without problem in common engines with pre-chamber injection

Other uses:

Its leaves and stems are toxic to animals (Anon. 2006), but after treatment, the seeds or seed cake can be used as an animal feed (Makkar *et al.*, 2001) its nitrogen - rich seed cake is a good soil fertilizer (RF, 1998; Makkar *et al.*, 2001 and Anon. 2006).

Effects of Auxins on Adventitious Root Initiation:

Auxins, cytokinins, gibberellins, abscisic acid and ethylene are the five classical groups of plant hormones (Kende and Zeevaart, 1997) auxin play a major role in controlling growth and development of plants, early stages of embryogenesis, organization of apical meristem (phyllotaxy) and branching of the plant aerial parts (apical dominance), formation of main root, lateral and adventitious root initiation (Went and Thimann, 1937) auxin is synthesized mainly in young leaves and is actively transported to other tissues to coordinate growth and facilitate responses to environmental variations. Practical application of auxin for rooting became possible when it was discovered that it also acts when added on the cut surface of cuttings (Hitchcock and Zimmerman, 1936) after the discovery of IAA (Indole-3- acetic acid), IBA (indole-3-butyric acid) and NAA (α-naphthalene acetic acid) were synthesized chemically, their capability to induce roots was discovered by (Zimmerman and Wilcoxon, 1935), and talc powder was introduced as a carrier for auxin (Grace, 1937).

IBA is commercially used for rooting followed by IAA and NAA in addition chemical analogues synthesized and examined for auxin-like activity. Auxin enters cuttings mostly via the cut surface (Kenney *et al.*, 1969). Even in micro cuttings that are known to have poorly functioning epidermis (Guan and De Klerk, 2000) as well as being rapidly taken up in cells by pH trapping (Rubery and Sheldrake, 1973) and by influx carriers (Delbarre *et al.*, 1996) although roots may be induced by auxin, wounding is usually required to achieve rooting and it was suggested that WRCs (wounding-related compounds) play a main role in the dedifferentiation phase (de Klerk *et al.*, 1999) the widely used sources of growth hormones for cuttings rooting are the IBA, NAA, IAA and commercial root promoters (root-growing powders) the successful formation of adventitious roots is an obligatory phase of vegetative propagation in many woody plants in presence of auxin. (Kim *et al.*, 1998; McClelland, *et al.* 1990). IAA was the first used to stimulate rooting of cuttings (Cooper, 1935). And soon after, another auxin which also promoted rooting IBA was discovered and was considered even more effective. (Zimmerman and Wilcoxon, 1935). Nowadays IBA is used commercially to root micro cuttings and is more efficient than IAA (Epstein and Ludwig-Müller, 1993) Auxin is one of the major endogenous hormones known to be intimately involved in the process of adventitious rooting (Wiesman *et al.*, 1988) and the physiological stages of rooting are correlated with changes in endogenous auxin concentrations (Heloir *et al.*, 1996) high endogenous auxin concentration is normally associated with a high rooting rate at the beginning of the rooting process (Blažková *et al.*, 1997; Caboni *et al.*, 1997) auxins have been shown to be effective inducers of adventitious roots in many woody species (de Klerk *et al.*, 1999; Diaz-Sala *et al.*, 1996; Goldfarb *et al.*, 1998 and Selby *et al.*, 1992) and are usually synthesized in the stem tip and tender leaves of aerial parts of plants and then transported to the action sites (Ljung *et al.*, 2001). When applying exogenous auxin on cuttings, the endogenous auxin concentration reaches a peak after wounding (Gaspar *et al.*, 1996; Gatineau *et al.*, 1997). Coinciding with the initiation of the rooting proces, the pattern of auxin action, despite its crucial role in adventitious root development, is still poorly understood. The process of adventitious root formation is very complex and plays a key role in the vegetative propagation of difficult-to-root genotypes. Although the importance of auxin in root development is well known, this plant hormone is not always efficient and the molecular mechanisms involved in the formation of adventitious roots are still partly unknown.

Effect of rooting media:

Planting medium is considered to be an important and necessary for the growth and development of plants. It provides the basic necessities required by the plant throughout its life. In general, seedling and cuttings are grown in various types of soils however; the root environment is significantly affected by the physical and chemical properties of the media used. According to Larson, 1980 the best planting media must have a pH conducive to plant growth, a structure that will permit gaseous exchange to provide aeration for the root and permit water infiltration and movement.

Worldwide distribution and production:

Jatropha occurs mainly at lower altitudes (0-500 m) in areas with average annual temperatures well above 20℃ but can grow at higher altitudes and tolerates slight frost. It is not sensitive to day length (Caboni *et al.*, 1997) Official statistics on areas planted and production are still lacking. In recent years, most of these are still in the pilot stage of development. In 2008, jatropha was planted on an estimated 900 000 ha globally – 760 000 ha (85%) in Asia, followed by Africa with 120 000 ha and Latin America with 20 000 ha. By 2015, forecasts suggest that jatropha will be planted on 12.8 million ha. The largest producing country in Asia will be Indonesia. In Africa Ghana and Madagascar and in Latin America Brazil. Locally, *J. curcas L*; known in Sudan for folk medicine - (the seed as well as the fruit) – are used as contraceptive. (Delbarre *et al*., 1996) in West States in (Abbasiya) and (Kutom) as well as in many areas in Central States private possessions (mostly hedges or fences), and can be used to reclaim eroded areas(Achten *et al.*, 2008; Diaz-Sala *et al*., 1996). Some other Jatropha curcas varieties found in Sudan:

J. aceroides Hutch. In Northern Sudan (Khor Ashat, Khor Gwob) and in dry savanna zone of Red Sea Hills.

J. curcas L; was introduced as a hedge plant, in Kordofan, White Nile and Blue Nile States.

J. gallabatensis Schweinf. Was found in Central Sudan.

J. glauca Vahl. In Northern and Central Sudan.

J. villosa Muel. Arg. In Eastern Sudan between Suakin and Kassala (Jebel Iskeneib). (Personal communication, Saif ElAmin).

Conceptual Framework:

Different planting materials, medium and mixtures are being used for growing different crops in the nursery. For proper growth to take place there should be an understanding of soils and the propagation medium. The type of planting materials - whether seeds or cuttings as well as the soil media, pure sand, silt-loam and compost - has expected to influence growth performance of jatropha, in terms of germination, sprouting and other agronomic characters like plant shoot length, stem diameter, root length, root number, number of leaves/plant.

Economic importance: Interest centered on poverty alleviation, job creation, and the provision of alternative energy sources. The current focus on biofuel as major marketable production from Jatropha depends on its strength to compete with fossil diesel, and thus relies on the development of the crude oil prices, in addition to utilizing of barren government land and farmers fallow land. It also generates an additional employment for the rural masses which will results in augmenting farmer's income through sale of seeds, soap, and seed cake, carbon credit and availability of bio fertilizers etc. At present public and private sectors are promoting Jatropha production, processing and marketing, beside using biodiesel for running direct Generator Sets in remote rural areas for power generation.

A case study in Ethiopia showed that planting jatropha could be an effective prevention and mitigation measure against soil erosion (Bach, 2012) the build-up of biomass and collection of seeds to secure local energy needs also allows for green house gas (GHG) savings. Thus, jatropha has the potential to alleviate soil degradation, increase carbon stocks and contribute to energy security.

Environmental importance: According to a 2013 study published by the European Geosciences Union, the jatropha tree may have applications in the absorption of carbon dioxide, whose sequestration is regarded by some as important in combating climate change. (Fojas *et al*., 1986) This small tree is very drought-resistant to aridity, perennial and living up to 50 yrs and grows in marginal soils. The plant does not need much water to grow, so coastal areas where desalinated sea-water can be made available are ideal. In addition, it could Increase green cover for overall environmental improvement through reducing toxic emission, besides reducing of (GHG) emissions through substitution of fossil fuel with plant oils based fuels, and simultaneously to develop wasteland.

Political importance: Producing of biodiesel in commercial quantities aims to achieve energy security goals, in spite of depending on odd source of energy and generates rural employment through increasing their income that leads finally to their settlement and elevating poverty.

J. curcas has the potential to become one of the world's key energy crops. However, inexpensive biodiesel can be produced to offer a clean substitute for expensive fossil fuel imports, enabling the country to meet the objectives of economic growth, fuel security and clean environment.

Jatropha's chief weaknesses related to the fact that it is an essentially wild plant that has undergone little crop improvement. Genetic variation among known Jatropha *curcas* accessions may be less than previously thought, and breeding inter-specific hybrids may offer a promising route to crop improvement. Jatropha displays considerable genetic–environment interaction, meaning that different clones may appear and perform very differently under different environmental conditions. Short-term goals should aim at producing superior clonal plants using cuttings and/or cell culture techniques, with longer term goals aimed at developing improved varieties with reliable trait expression and with a seed production system that ensures farmer access to productive and reliable planting materials

Sexual propagation: Sexual reproduction results in a mixture of genetic characteristics in the offspring, so each plant will appear slightly different from its parents and each other. Because maintenance of genetic diversity is so important in ecosystem management and restoration projects, seed propagation is encouraged whenever possible. It is easier to capture and preserve biodiversity with seeds than with vegetative propagation.

Asexual propagation methods: Vegetative propagation, on the other hand, produces exact duplicates of the parent. The major methods of asexual propagation are cuttings, layering, division, budding and grafting. Many types of plants, both woody and herbaceous, are frequently propagated by cuttings. A cutting is a vegetative plant part which is severed from the parent plant in order to regenerate itself, thereby forming a whole new plant.

Availability of propagation material, time constraints and economics must be considered. Many native plants do not produce good seed crops each year, so it may be impossible to obtain enough seeds. This is especially true for emergency projects, such as forest restoration, where crops must be grown in a very short time. Economically, seed propagation is always less expensive than vegetative propagation, which involves more hand labor and often requires special equipment and structures.

While jatropha has known to grow on a wide range of soils, certainly, there are certain types of soil to which it is best suited. According to the International Union of Forests and Research Organizations (1980) as cited by Costales and Martinez, (2006) the type of potting media has an influence on the fitness of seedlings for field planting because it affects seedling dimension (height and growth), root development and other morphological attributes. The appropriate type of planting materials and growth media combinations, along with a host of other factors like climate and the environment, play an important role in enhancing optimum growth, survival and productivity under local conditions.

Today the species was projected to be planted at a large scale in Sudan for biofuel production purposes. This will require a very large amount of cuttings and seeds. The adequate length of cuttings needs then to be found in order to get more cuttings by reducing the usual length traditionally adopted. But Henning (2000c) has noticed that pre-cultivation of Jatropha seedlings in polyethylene bags is more appropriate and helps to accelerate the installation of a plantation by at least 3 months compared to directly planted cutting.

Research on *Jatropha curcas* for oil production has started recently; unfortunately, this research has characterized more by sporadic action than by continuous work. This explains the current lack of in-depth and long-term information (*J. curcas*). Current plantation practices are based on data from experimental plots and small-scale experience. Therefore, all growers make decisions according to the local conditions where they want to establish their plantations.

Charlie (2010), stated that a seed of (*J. curcas*) taken from black colored fruits during the dry season and dark yellow for the rainy season were recommend for the better germination and growth, while Til, *et al* (2007) in seed treatment experiment using different substrates, they reported that seeds from old dried up fruits had a far lower germination rate, compared to the seeds from fruits that were just ripe and air dried which amounted 41 – 92%, while the seeds from fresh fruits showed a germination rate of up to only 7 %. The storage time had an even stronger impact, air-drying of seeds to break primary dormancy is indispensable. Additionally, it can be assumed that some kind of degradation occurred to the seeds while hanging on the shrub after being ripe. Similarly Samba, *et al* (2007) reported that seeds of *J. curcas* which were collected and oven dried to (5 – 7%) moisture content and stored in air-tight container in a cold room at 4°C during 90 days prior to sowing in a poly-ethylene bags after soaking to 12hrs in drinking water, germination percentage amounted 86% 15 days after sowing, while using coatless seeds allowed 20% of germination. They added that seedling growth was faster on clayey soils than in sandy soils. Sprout number produced by seedlings followed the same trend.

Bassiaka, *et al*. (2007) tested two accessions of *J.curcas* fruits collected from different areas, air-dried to constant moisture content and stored for 10 months prior to sowing. Immersed seed in tap water for 12h, compared to dry seed both sown in sandy soil in green house. They reported that, seed germination started 3 days after sowing from water soaked seeds with water regime of 50% field capacity, and continued up to 14 days increasing the final germination percentage from 26.9 to 36.8% and ensured that there was an interaction between water regime and pre-sowing treatments. Whereas, lower germination rate has found in dry seed with water regime 50% field capacity. Effect of pre-sowing seed treatments on germination behavior and the possibilities of increasing germination rate of *J. curcas*, was studied by Islam *et al.* (2009) Seeds were subjected to three pre-sowing treatments: dry seeds directly sown in the poly-bags and watered up to saturation, seeds placed on filter paper in Petridis and moistened once with water, and seeds kept under stone sand and moistened once with water. They revealed that pre-sowing treatments significantly enhanced seed germination parameters of Jatropha. Seed germination started 5 days after sowing and continued up to 12 days. Seeds germinated under stone sand have the highest germination percentage, germination index, seedling vigor index, and speed and energy of germination while the lower parameters was observed in seeds on filter paper in Petri-dish. Seeds germinated under stones with water moistening were found more effective.

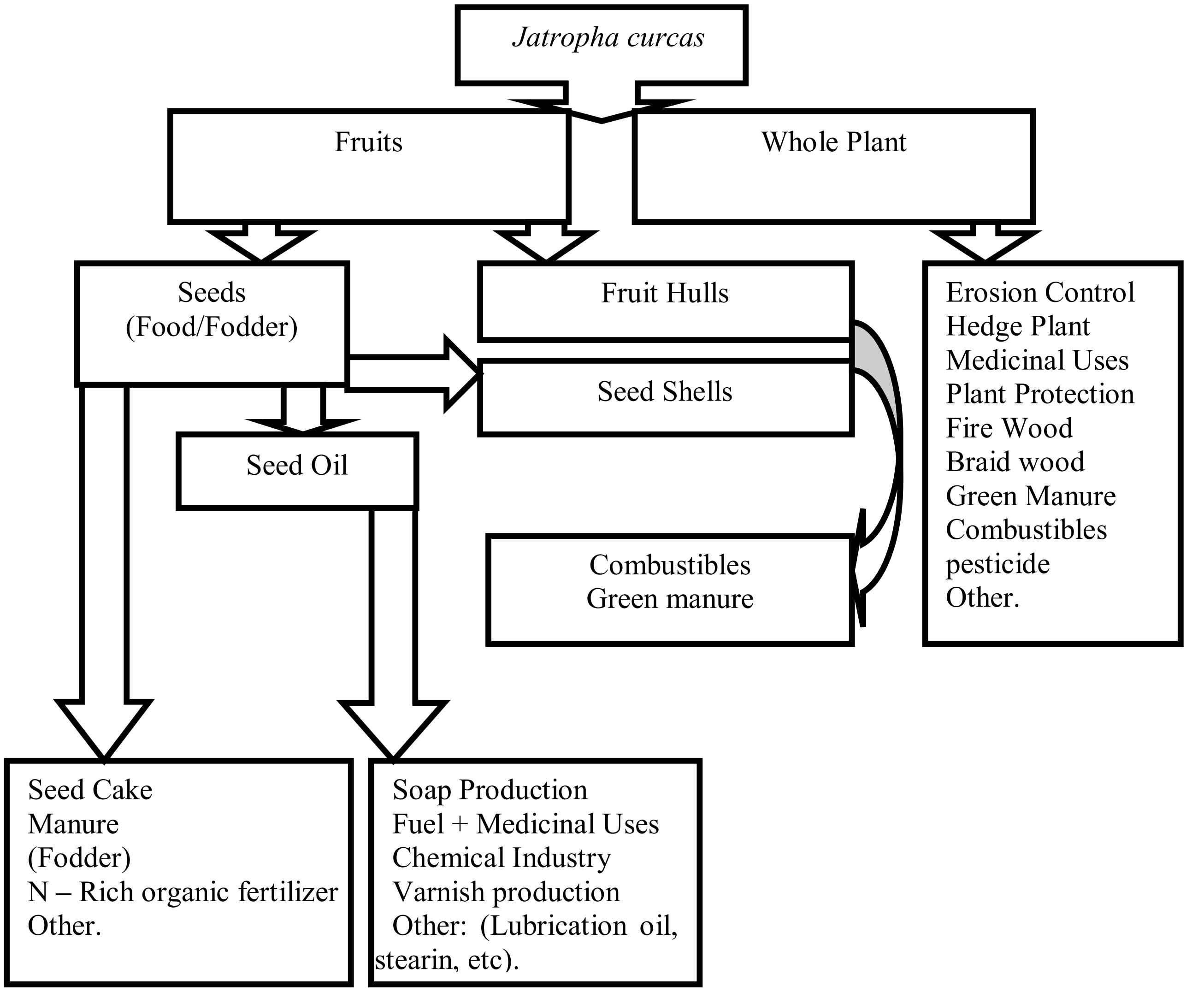


Fig 1: Different usage patterns of *J. curcas* plant and products.

Source: Adapted from (Münch and Kiefer 1986).

Maya, *et al*.(2010), reported that , in one year old branch (hard and semi-hard) *J. curcas* wood cutting of (diameter 1 - > 1.5 cm) and (10 - 15cm) long was treated with IBA (0,50. 100, 200, 300, 400, 500 mg/L) for 4hrs to assess its effect on shooting and rooting response on variety DARL-2, they found that hormonal treatment significantly increased sprouting and rooting percentage in all types of cuttings tried, and the sprouting percentage was best in cuttings from basal portion followed by middle and top position, using 50 and 200 mg/L IBA. Days to sprouting were the least in 50 mg/L IBA whereas for rooting it was the least, in 50 mg/L and 200 mg/L IBA. Also rooting percentage was the highest in basal > middle > top, for both 50mg/L and 200mg/L IBA. These results reveal that cutting treated with IBA induced rooting. Some basal callusing had been observed in all the cuttings prior to root development. Noor.*et al*. (2009) has also reported this phenomenon. Noor. *et al*. (2009) added that, *Jatropha curcas* cuttings treated with (2000 mg/L IBA) rooted faster than the control (0 mg/L).

Although the root primordial seems to be emerged from the callus, closer examination from histological analysis showed that the root was emerged from an area near the vascular bundle and not from the callus itself (Noor *et al*.2009) they also found that, hardwood cutting gave the highest mean value for root length. Highly significant effect was obtained between IBA concentrations, (0.00, 10.000, 15.000, 20.000 and 25.000 mg/L). For root number, 20.000 mg/L was best.

Til, *et al*. (2007).Reported that vegetative and generative propagation of *J. curcas* cuttings were grown in containers in two different kinds of substrates: local topsoil + mixture of topsoil and sand+ compost + rice hull. Half of the cuttings were treated with a plant growth hormone. Cuttings were taken from apical, medial and distal parts of physic nut stems to test variations in their performance. Four different types of pre-treatment seeds were tested: soaking in water, soaking in hormone solution, an interval of soaking-drying-soaking and the control. (Seven weeks for cuttings and eleven weeks for the seed) the choice of the stem part had the strongest influence with distal cuttings producing most biomass. The variation in substrate didn't show any effect, same as the treatment of cuttings with a hormone solution. Several factor combinations showed significant effects. However no clear trends could be observed. They added that biomass production by cuttings seems to depend strongly on the starting mass of the cuttings. When looking at root dry matter the differences between cuttings from apical, medial and distal stem parts are much minor. It stands to reason that it wasn't necessary for the thicker cuttings to produce many roots, as they could still "feed on" their resources for producing aerial plant parts. In comparison the thinner cuttings had to build up more roots and show a smaller leaf-root-ratio. Plants from seeds that had been soaked in water over night showed the highest survival rate.

Samba, *et al*. (2007) Reported that, in *J. curcas* Percentages of dead cuttings seemed to decrease with increasing cutting length in greenhouse conditions, added Liv, *et al.* (2011) that, the growth and development of Jatropha Plants has influenced by length and basal area of stem cuttings. Short cuttings favor early sprouting, but long and thick cuttings promote more shoot and root growth. Plants originated from stem cuttings obtained from the base of the branch grew more shoot structures (buds, stems, and leaves) than stem cutting from middle and apex of the branch. The most vigorous root system has observed in plants originated from direct seeding, Propagation using bag and root plug interfere with the formation of a taproot. Propagation through stem cuttings resulted in a very different root system structure, with predominance of superficial and thin roots. When the cap of a taproot is lost, the plant was able to regenerate a new root.

Kathiravan *et al*. (2009) grew cuttings of 20, 30 and 40 cm long of *J. Curcas* in high nursery beds without hormonal treatment. They revealed that cuttings of (40cm) long and 2.5-3.5cm in thickness were very suitable for quicker regeneration with seedling of quality characteristics, whilst plants that propagated through seeds, recorded better performance related to yield and quality compared to cuttings.

CHAPTER THREE
MATERIALS AND METHODS

Study area:

The experiment was conducted under shade house in the nursery of the Collage of Agriculture Studies, Sudan University of Science and Technology at Shambat. The area enjoys semi-arid type of climate with mean annual rainfall (200 - 600ml/yr), and means minimum and maximum temperature, February (21℃) and May (45℃). It focused only on nursery production of jatropha cuttings for three months from the planting date. The study was conducted in 18m² flat and open area for the seed experiment in the nursery site.

Sources of materials and preparation:

a) **Area Preparation and experiment Layout:** The nursery or study area measured 6 meters x 3 meters. (Seed experiment) (4blocks) each block consisted of 12 treatments 5 bags with 5 seeds in each one, in area of (1*2.5meters) the area used as a nursery has cleaned and flattened to facilitate placement of bags. A spade has used as mixture in all soil media preparations. Lay outing was done using plastic twine, steel tape, thread, iron stick. And bamboo stakes.

Under the shed net of the College Nursery, two tunnels made of a combination of bamboo as posts, plastic water pipes of (1.5"daimiter) as rafters, and a white plastic sheet as roofing material was constructed. Three bamboo posts measuring 8 meters long have placed one at each side while the third on the top at equal distances along the length of the tunnel, fixed on water pipes, bended and fixed on the iron stick fixed I meter apart in the ground. The structure stood at 1.5 meters height, just enough for the researcher to work in and out of the tunnel during the study period. The tunnel measured 10 meters long and 2.5 meters wide. Outside alleys measured 1 meter on each side. The long and short inside alleys measured 0.5. After drawing tunnels markers for each treatment and replication has written on the black poly-bags using white marker, numbering from (1- 12runs for the sexual propagation) and (1 – 27runs for the asexual one) in a capital letters (E, F, G, and H), (A, B, C, and D) respectively for the blocks, to distinguish each experimental treatment from the other.

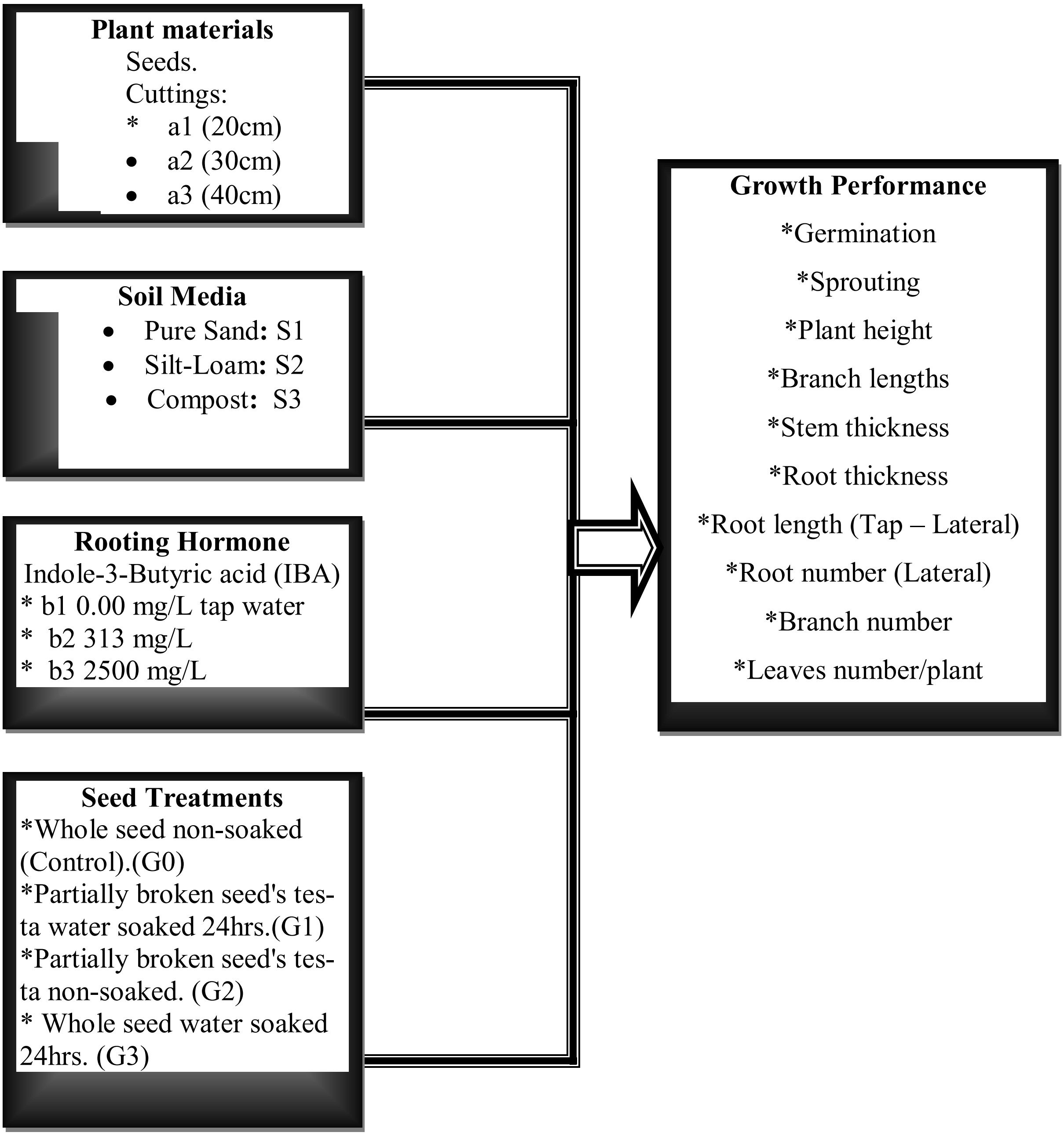


Fig 2: The conceptual framework of the study

First step before bending the pipes on the iron sticks, all the poly-bags were filled with the suitable growing media (Sand, Silt-loam and compost), using a hand shovel. Second step was arranging the poly-bags each in their named blocks. (Two blocks/tunnel). Third step was the spraying the clean water on the poly-bags till saturation, two days before cuttings planting.

b): Preparation of the rooting hormone (IBA):

IBA hormone from tissue culture lab, (College of Agricultural Studies – Shambat) – weight of 78.3 mg b2 and 625.00 mg b3 was used as rooting hormone. The hormone was dissolved in a little amount of Ethanol alcohol then completed with a tap water to 250 ml that will be equivalent to (313 mg/L) b2 and (2500 mg/L) b3 for both concentrations respectively besides 00.0 mg/L b1 as control. The concentrations were prepared and stored at 4°C.

c): preparation of the cuttings and seed:

Cuttings were collected from three yrs old Jatropha plants from Shambat Agricultural Research Station 300 m from nursery site, for the 1st season, and the 2nd season cuttings were from Soba Energy Research Center 20 km south of Khartoum. Mature stem cuttings from basal and intermediate branches with diameter of (2.5-3.5cm) were divided in to three groups (20 cm a1, 30 cm a2 and 40 cm a3), (180pieces) each.

The bases of the cutting were made straight and their tips slanted, then kept for 5hrs for the fluid to dry up before dipped in the rooting hormone solution with their basal ends for 1hr, then immediately insert one third from their lengths in the holes made in the rooting media and firmly closed with adjacent media and sprayed with a few drops of water just to raise the humidity percentage inside the tunnel atmosphere. Tunnels were kept firmly closed and only opened in early mornings for 10 minutes, besides some holes were poked in it so that air can circulate. Watering was done periodically or when needed till sprouting ended. That was repeated during the 2nd season. No disinfectant was used.

The study was multifactor experiment in a (RCBD with factorial) replicated four times. The soil media combinations were limited to: silt-loam (S1) from the river bank, (Pure sand (S2) from

East Khartoum barren area and Compost (Shomookh el-tabya) (S3), from the local market for planting material, seeds and cuttings. A black polyethylene bags (Poly bags) of (35×20×10cm) size has used for the propagation in both (Seed) and (Cutting) experiments. The experimental design used in both experiments was (RCBD with factorial) 3x4x4 .Each treatment consists of 5 bags in every bag 5 seeds sown, (That was 300 seeds in each replication). These bags has arranged under direct sun light.

Table: 1 Overview of number of treatments

cuttings	**seeds**
3 substrate (media) 3 hormone concentration 3 stem lengths 4 replications	3 substrate (media) 4 seed treatments 4 replications
27 x 5 cuttings = 135 × 4 (r) =540 cuttings	12x5x5 seeds = 300×4 (r) =1200 seeds

Seed source:

Two experiments had laid out in each season. In the first experiment (Seed) or (Sexual propagation), seeds were collected from the first production of three years old *Jatropha curcas* farm which was located at (Souba) area South Khartoum Centre. (Lat 15 5667 N, Long 32: 51667 E and Alt 385m) The mother plants of this farm had originated from (Abbasiya) area (North Kurdufan district) (Lat 12° 1' 0N, Long 27° 58' 0 E Altitude (Elevation) 1591 ft – 484m, and about (391.5) km from Khartoum.

The whole amount of the seeds divided as follows:

1 - 300 Whole seeds without water soaking (Control).

2 - 300 partially broken seed’s testa without water soaking.

3 - 300 partially broken seed's testa water soaked for 24hr.

4 - 300 Whole seeds water soaked for (24hrs).

Preparing holes and seed drilling:

The media has saturated with clean water two days prior to sawing date. Then with suitable pointed rounded stick marked 3cm 5 holes of 3cm deep were made (method after Henning 2000b) And one seed in every hole was placed and covered with adjacent media then only the surface was wetted with water and repeated in every day or as needed till sprouting completed.

Table: 2 Treatment combinations of seed experiment

Block (G)		Block (E)		Block (H)		Block (F)	
9	G2S3	10	G3S1	3	G0S3	8	G2S2
5	G1S2	7	G2S1	10	G3S1	10	G3S1
12	G3S3	4	G1S1	12	G3S3	5	G1S2
10	G3S1	12	G3S3	8	G2S2	1	G0S1
4	G1S1	6	G1S3	5	G1S2	11	G3S2
1	G0S1	1	G0S1	6	G1S3	3	G0S3
2	G0S2	9	G2S3	9	G2S3	6	G1S3
8	G2S2	8	G2S2	7	G2S1	4	G1S1
7	G2S1	2	G0S2	4	G1S1	2	G0S2
11	G3S2	11	G3S2	1	G0S1	12	G3S3
6	G1S3	3	G0S3	2	G0S2	7	G2S1
3	G0S3	5	G1S2	11	G3S2	9	G2S3

Key:

S1, S2 and S3 propagating media: sand, silt-loam and compost.

G0, G1, G2 and G3 seed treatments: Dry whole seed, partially broken seed's testa without water soaking, Partially broken seed's testa with water soaked 24hr and whole seed water soaked 24hr respectively. (1 -12) Polyethylene bag's number.

Table: 3 Treatment combinations of cutting experiment

Tunnel (1)				Tunnel (2)			
Block (A)		Block (B)		Block (C)		Block (D)	
10	S1a1b1	1	S2a1b1	19	S3a1b1	1	S2a1b1
11	Ss1a1b2	2	S2a1b2	20	S3a1b2	2	S2a1b2
12	S1a1b3	3	S2a1b3	21	S3a1b3	3	S2a1b3
13	S1a2b1	4	S2a2b1	22	S3a2b1	4	S2a2b1
14	S1a2b2	5	S2a2b2	23	S3a2b2	5	S2a2b2
15	S1a2b3	6	S2a2b3	24	S3a2b3	6	S2a2b3
16	S1a3b1	7	S2a3b1	25	S3a3b1	7	S2a3b1
17	S1a3b2	8	S2a3b2	26	S3a3b2	8	S2a3b2
18	S1a3b3	9	S2a3b3	27	S3a3b3	9	S2a3b3
1	S2a1b1	19	S3a1b1	10	S1a1b1	19	S3a1b1
2	S2a1b2	20	S3a1b2	11	Ss1a1b2	20	S3a1b2
3	S2a1b3	21	S3a1b3	12	S1a1b3	21	S3a1b3
4	S2a2b1	22	S3a2b1	13	S1a2b1	22	S3a2b1
5	S2a2b2	23	S3a2b2	14	S1a2b2	23	S3a2b2
6	S2a2b3	24	S3a2b3	15	S1a2b3	24	S3a2b3
7	S2a3b1	25	S3a3b1	16	S1a3b1	25	S3a3b1
8	S2a3b2	26	S3a3b2	17	S1a3b2	26	S3a3b2
9	S2a3b3	27	S3a3b3	18	S1a3b3	27	S3a3b3
19	S3a1b1	10	S1a1b1	1	S2a1b1	10	S1a1b1
20	S3a1b2	11	Ss1a1b2	2	S2a1b2	11	Ss1a1b2
21	S3a1b3	12	S1a1b3	3	S2a1b3	12	S1a1b3
22	S3a2b1	13	S1a2b1	4	S2a2b1	13	S1a2b1
23	S3a2b2	14	S1a2b2	5	S2a2b2	14	S1a2b2
24	S3a2b3	15	S1a2b3	6	S2a2b3	15	S1a2b3
25	S3a3b1	16	S1a3b1	7	S2a3b1	16	S1a3b1
26	S3a3b2	17	S1a3b2	8	S2a3b2	17	S1a3b2
27	S3a3b3	18	S1a3b3	9	S2a3b3	18	S1a3b3

Key:

S1, S2 and S3 rooting media: sand, silt-loam and compost respectively

a1, a2 and a3 cutting lengths: 20, 30 and 40cm respectively.

b1, b2 and b3 IBA concentrations: 00.0, 313 and 2500 mg/L respectively.

Data Collection:

Primary data such as germination, sprouting, plant height, stem thickness, root thickness, root number, root length and seedlings or cutting survival were taken from observations and measurements throughout the three months study period in the nursery. Temperature and prevailing weather condition during the period has taken from the (Sudan Geo-Physical and Astronomical Corporation).and no soil analysis of disinfectants was done.

Plant height/branches length and root lengths were measured with a ruler and/or plastic tape, while stem diameter was measured with a digital caliper. All data or measurement has recorded in a field notebook.

Data on plant height/shoot length and stem diameter were taken weekly from the total survived plants (240 seedlings) for the seed experiment, and (540cuttings) for the cutting experiment, and average of four weeks recorded during the (third) last month of the study in the nursery.

Data on plant height or shoot length and stem diameter has determined by adding all measurements per plant per treatment and recording the average. Data on root Lengths have been taken from total of the, maximum and the minimums of the roots in the treatments in four weeks and record the average. Moreover, that has repeated in each replication. Means were separated using DMRT as reported by Montgomery (2001).

CHAPTER FOUR
RESULTS AND DISCUSSION

Experiment One (Seed):-

Some characteristics of (*Jatropha curcas* L.) seeds:

An average of (100) seed's weight about (65.50) g, (18, 12) mm length and 12.00 mm in width, with dark to dark brown color. Kaushik, *et al.* (2007) found for 24 accessions, that the hundred-seed weight ranged from 49.2 g up to 69.2 g, however, the authors state that in general the phenotypic coefficient of variation was higher than the genotypic coefficient of variation indicating the predominant role of the environment.

a): Tap and Lateral root lengths:

All seed types gave significantly high values under silt-loam and compost rooting media. Sand media has significantly lower values for all other treatments. Only dry whole seed gave similar results under sand media. (Table: 4). In Season two significantly high values were reported from whole dry seed and broken water soaked seed under sand and silt-loam media, broken dry seed under all rooting media, whole seed soaked only under silt-loam media (Table:5).

From the observations during washing process of the media around roots for measurements, , the compost media unlike sand and silt-loam adhered firmly on the lateral and taproots of the seedlings resulting in many difficulties to carry out the process without losing some centimeters from their tips. In addition the wrinkled growth habit of both lateral and taproots of the seedlings through the soil media in the poly bags resulted in difficulties in stretching the roots for maximum possible lengths (Fig 3 and 4).

In general, for the lateral roots, significantly high values were observed from dry seeds under silt-loam and compost media. Sand media has week influence for lateral root development. Whole seed water soaked for 24hr recorded significantly high values with the all media used. (Table: 4) In season two significantly high results were obtained for the whole seeds under sand and silt-loam media while compost media gave only short lateral roots. Partially broken seed's testa recorded high similar results under all media used. (Table: 5).

b): Taproot thickness: Significantly high results were obtained for the four treatment combinations with the compost rooting media. Sand and silt-loam media has small effect on all treatments (Table 4). In season two all seed treatment except for whole soaked seeds gave markedly high readings for taproot thickness under all media used (Table 5). Supporting reports come from Islam *et al*. (2009) and Samba *et al*. (2007). Results obtained showed that compost rooting media has strong positive effect on all shoot and root parameters of the seedlings due to the relatively high nutrient contents facilitate nutrient absorption and the high water holding capacity which prevents the media from drying out.

c): Number of branches: Data from (Table 4) showed that significantly high values was obtained for the partially broken seed's testa without water soaking using compost rooting media and whole seed water soaked for 24hr with compost rooting media. The other two seed treatments resulted in significantly lower values with all rooting media used. In the 2nd season significantly high values were recorded for whole dry seed using both silt-loam and compost rooting media, whereas, with sand media no response was observed. Similar results were recorded for the partially broken seed's testa without water soaking with silt-loam and compost rooting media. Sand media gave only small number of branches. Partially broken seed's testa and water soaked for 24hr with silt-loam rooting media gave significantly high values whereas, sand and compost rooting media has negative influence. Whole seed with water soaking for 24hr was not effected by all media used. (Table: 5). From the data obtained and observations, whole dry or partially broken seed's testa using silt-loam or compost rooting media were the best choice to obtain high number of branches per plant, as reported by Bassiaca et al. (2009) and Samba et al.(2007).

d): Shoot length: All treatment combinations used obtained significantly high similar results with the compost rooting media. Sand and silt-loam rooting media has less response for all treatments in the 1st season. (Table: 4). In the 2nd season significantly high values were recorded for the whole dry seeds, broken dry seeds and partially broken seed's testa with water soaking while the whole seed

Table (4): Effect of Different media and Seed treatments on some Parameters of J.curcas Seedlings season (2012)

2012	Tap. R.oot length cm	Lateral. Root length cm	Taproot thickness mm	No of branches	Shoot length cm	Stem thickness mm	No of leaves	Seed treatments	Media
1	19.72 abcd	11.52 bc	1.65 fg	0.33 e	3.93 d	3.18 de	5.33 b	G0*	S1*
2	24.40 ab	19.27 ab	3.53 bcde	1.53 ed	14.95 bc	4.63 abc	8.58 b		S2*
3	22.28 ab	18.88 ab	4.15 abcd	2.28 bc	20.88 a	5.65 ab	15.45 a		S3*
4	13.73 cd	7.03 c	1.33 fg	0.35 e	8.58 d	2.48 e	4.98 b	G1*	S1
5	26.85 ab	17.90 ab	3.13 bcdef	1.43 ed	11.85 cd	4.53 abc	9.23 b		S2
6	23.08 abc	14.82 abc	4.60 ab	3.53 a	20.55 a	5.60 ab	16.83 a		S3
7	11.65 d	7.10 c	0.95 g	0.13 e	11.43 cd	2.68 e	4.65 b	G2*	S1
8	22.65 abc	14.15 abc	2.50 defg	1.35 d	11.43 cd	4.08 cd	7.93 b		S2
9	22.65 abc	21.15 a	4.95 ab	3.03 d	18.05 ab	5.53 ab	16.48 a		S3
10	18.90 bcd	13.57 abc	1.80 efg	0.65 de	8.73 cd	2.95 de	6.80 b	G3*	S1
11	24.52 ab	18.48 ab	2.98 cdef	1.45 cd	12.45 cd	4.28 bcd	8.68 b		S2
12	29.67 a	17.15 ab	5.63 a	3.63 a	18.60 ab	5.80 a	17.20 a		S3
C.V%	28.25%	37.32%	37.11%	34.50%	22.08%	20.08%	30.20%		
P-Value	0.1746*	0.1723*	0.1709*	0.1791*	0..3201*	0.2781*	0.3524*		
Lsd0.05	8.8	8.099	1.654	0.8125	4.375	1.237	4.42		
SE±	3.059	2.815	0.5749	0.2824	1.521	0.4298	1.536		

Table (5): Effect of Different media and Seed treatments on some Parameters of *J.curcas* Seedlings season (2013)

2013	Tap. R.oot length- cm	Lateral. Root length. cm	Taproot thickness mm	No of branches	Shoot length cm	Stem thickness mm	No of leaves	Seed treatments	Media
1	29.05 ab	27.77ab	5.75 abc	1.00 bcdef	14.64 ab	8.15 ab	6.84 bcd	G0*	S1*
2	28.65 ab	28.45 ab	7.48 a	1.69 abc	16.02ab	9.50 a	9.85 abc		S2*
3	24.33 b	23.22 b	6.45 ab	1.94 ab	18.37 a	9.25 a	12.52 ab		S3*
4	31.95 ab	30.72 a	6.88 ab	1.13 bcde	14.04 ab	8.43 ab	8.44 abcd	G1*	S1
5	27.15 ab	29.52 ab	6.75 ab	1.93 ab	16.14 ab	9.28 ab	11.01 ab		S2
6	26.72 ab	24.47 ab	7.73 a	2.45 a	19.64 a	9.85 a	14.11 a		S3
7	27.70 ab	26.27 ab	6.68 ab	0.79 cdef	13.62 ab	8.55 ab	8.04 abcd	G2*	S1
8	28.40 ab	29.13 ab	6.75 ab	1.62 abc	14.88 ab	8.83 ab	9.61 abcd		S2
9	23.27 bc	23.90ab	7.05 ab	1.41 bcd	16.99 a	8.33 ab	10.56 abc		S3
10	22.75 bc	25.70 ab	4.13 c	0.04 f	6.46 cd	4.43 bc	3.54 d	G3*	S1
11	26.08 ab	25.45 ab	4.65 bc	0.55 def	10.13 bc	5.78 abc	6.30 bcd		S2
12	17.08 c	23.25 b	4.80 bc	0.36ef	3.00d	3.00 c	4.63 cd		S3
C.V%	16.40%	16.40%	24.60%	49.98%	29.78%	35.95%	43.03%		
P-Value	0.0749*	0.1768*	0.0289*	0.0195*	0.1628*	0.0283*	0.1825*		
Lsd0.05	6.155	6.249	2.216.	0.8926	5.854	4.045	5.439		
SE±	2.139	2.172	0.7701	0.3102	2.035	1.406	1.89		

Key: S1* = Sand, S2* = Silt-loam, S3* = Compost, G0* = Whole seeds (control), G1* = Partially Broken seed's testa without water soaking, G2* = Partially Broken seed's testa water soaked for 24hrs, G3* = Whole seeds water soaked for 24hrs.

Table 6: Germination percentage of seed treatments using different rooting media in seasons (2012 and 2013)

Seed treatments	Germination%							
	Sand		Silt-loam		Compost		Average	
	2012	2013	2012	2013	2012	2013	2012	2013
Dry whole seed (Control)	45	76	60	71	68	72	57.6	69.7
Partially broken seed's testa without soaking	20	70	51	59	59	74	43.3	67.7
Partially broken seed's testa water soake for24hr	24	54	46	66	31	55	33.7	58.3
Whole seed water soaked for24hr	16	4	39	7	16	1	23.7	4.0
Mean	26.3	51	49	50.8	43.5	50.5	39.8	49.9

with water soaking 24hr under all types of rooting media and gave only short plants (Table 5).Similar results were observed by Islam *et al*. (2009), Til *et al*. (2007) and Willan (1985).

e): Stem thickness: In season one, dry seeds were recorded significantly high values with compost and silt-loam rooting media. In addition, water soaked seeds behaved similarly only under compost (Table: 4). In the 2nd season both broken seed types and the dry whole seed gave high values for stem thickness under all rooting media while soaked whole seed gave comparable high results only under silt-loam rooting media (Table: 5). Overall results showed that media with proper nutrient content more or less is the best choice for nursery production technique for seed propagation of *J. curcas*. Supporting results were reported by Samba *et al.* (2007), Til *et al.* (2007) and Bassiaca *et al.* (2009).

f): Number of leaves: All seed treatment combinations recorded highly significant values with the compost rooting media. Sand and silt-loam media has less influence on number of leaves (Table: 4). In the 2nd season the dry and broken soaked seeds gave significantly high values with all rooting media except for whole dry seed under sand media and whole soaked seed under all types of media. (Table: 5) In general compost media has an influence on plant shoot growth resulted in increase in overall shoot performance. As observed by Til *et al*. (2007) Samba *et al.* (2007) and Fatima and Muna (2013).

Fig 3: Growth habit of *J. curcas* roots using different rooting media, F4 /sand, F5 / silt-loam and (F6/ compost. With wrinkled habit).

Fig 4: Growth habit of *J. curcas* roots using different rooting media, H1/ sand, H2 /silt-loam and (H3/ compost firmly adhered beneath the soil media).

Experiment two (Cuttings):

a): Number of roots: There were significant differences between length of cuttings (20, 30 and 40cm), IBA concentration (00.0, 313 and 2500 mg/L) and rooting media (Silt-loam, Sand and Compost) on all parameters measured at ($P\leq_{0.05}$). (Number of roots, root length, number of branches, length of branches and number of the leaves) (Table 7 and 8) and (Figure 5, 6 and 7). data from Table (2) showed that highest number of roots per stem cut resulted from high IBA concentration using silt-loam media for 20 and 30 cm long cuttings. 40 cm cuttings resulted in high number of roots on low and high IBA under silt-loam media. While sand media gave results comparable to the above under high and low IBA concentration and 30, 40 cm cuttings. Similar results were recorded under compost media only with high IBA concentration for 30 and 40 cm long cuttings. In the second season, data from Table (7) showed that high number of root per stem cut resulted from low IBA concentration using silt-loam media for 30 cm long cuttings. 40 cm cutting resulted in highest number of roots on low and high IBA under silt-loam media. While sand media gave results comparable to the above only under low IBA concentration for 30 cm long cuttings. Similar results were recorded under compost media with all IBA concentrations including control only for 40 cm long cuttings.

Number of roots per cutting increased with increase of cutting length for silt-loam and compost media and overall best results are obtained from 40 cm long cuttings. The overall results from IBA concentration indicated that low concentration (313 mg/L) is economically best for rooting of *Jatropha curcas* stem cuttings. This was supported with the results recorded by Krishnankutty (2005), Noor *et al*., (2009) Kathiravan *et al*., (2009) Maya *et al*., (2010) and Liv *et al*., (2011).

b): Root length: Significantly long roots were recorded for both low and high IBA for 20 and 30 cm long cuttings under silt-loam while the 40 cm cuttings gave similar results even without IBA. Under sand media similar results came from 30 cm cuttings without IBA and high IBA concentration while 40 cm cuttings resulted in comparable long roots even without rooting hormone.

Under compost similar results were recorded for only 40 cm long cuttings treated with low and high IBA

(Table: 7). Season two data showed significantly long roots under only low IBA concentration for 30 cm long cuttings under silt-loam media, while the 40 cm cutting gave similar results even without IBA under silt-loam media. Under sand media similar results came from 30 cm and 40 cm long cuttings even without rooting hormone. Under compost high comparable results were recorded for only 40 cm long cuttings, even without rooting hormone. (Table: 8). Again results obtained from season two supports the findings of season one that the stored nutrients in longer 30 and 40 cm cuttings may be the main decisive factor for root length. Hormonal treatments in low or high concentrations for long stem cuttings encouraged the initiation and root elongation in all of root media used, thus, when length of roots was main goal it is economical to use silt-loam for *J. curcas* propagation. Supporting our results was reported by Kathiravan *et al.*, (2009) and Noor *et al*., (2009).

c): Number of branches: Highest numbers of branches were obtained from only 30 and 40 cm with low and high IBA under silt-loam media. Sand media resulted in high number of branches with 30 cm and high IBA and both low and high IBA with 40 cm long cuttings. For compost media, comparable results came only from 40 cm long cuttings with low and high IBA (Table 7). Season two showed that, the highest number of branches was obtained from only 40 cm long cuttings even without rooting hormone under silt-loam media. Sand media resulted in high number of branches only with 40 cm long cutting and zero and low IBA concentration, compost media gave highest values under zero and low IBA. (Table: 8). Number of branches is highly influenced by cutting length rather than by IBA concentrations or rooting media for propagation of *J. curcas*. Similar results were reported by Kathiravan *et al*., (2009) Table (7): Effect: of cutting length (cm) and IBA concentrations (00.0, 313 and 2500 mg/L water) on different shoot and root parameters of *J. curcas* using different rooting media season (2012)

2012	No of roots	Root length cm	No of branches	Branches length cm	No of leaves	Cutting length cm	IBA mg/L	Media
1	13.48 ^{fg}	36.75 ^{cde}	4.38 ^{ghi}	15.13 ^{abc}	24.35 ^{hij}		0.00	
2	13.38 ^{fg}	40.63 ^{abcde}	4.78 ^{fghi}	17.00 ^{ab}	30.75 ^{defghij}	20	313	
3	20.73 ^{abcd}	39.06 ^{abcde}	4.00 ^{ghi}	17.38 ^{ab}	27.80 ^{efghij}		2500	
4	14.56 ^{efg}	35.69 ^{de}	5.05 ^{efghi}	17.25 ^{ab}	27.30 ^{fghij}		0.00	
5	16.38 ^{cdefg}	44.44 ^{abc}	6.68 ^{abcde}	17.13 ^{ab}	39.42 ^{abcd}	30	313	Silt-loam
6	20.88 ^{abcd}	41.00 ^{abcde}	6.60 ^{abcde}	17.75 ^{ab}	42.45 ^{ab}		2500	
7	17.75 ^{bcdefg}	44.31 ^{abc}	6.35 ^{bcdef}	17.00 ^{ab}	39.65 ^{abcd}		0.00	
8	21.94 ^{abc}	44.69 ^{abc}	7.53 ^{ab}	17.25 ^{ab}	41.70 ^{abc}	40	313	
9	21.75 ^{abc}	41.25 ^{abcd}	8.25 ^{a}	17.75 ^{ab}	49.33 ^{a}		2500	
10	15.88 ^{defg}	33.75 ^{defg}	3.85 ^{hi}	7.75 ^{de}	20.73 ^{j}		0.00	
11	14.81 ^{efg}	34.94 ^{def}	3.73 ^{i}	11.38 ^{bcde}	23.58 ^{ij}	20	313	
12	14.52 ^{efg}	33.50 ^{defg}	4.30 ^{ghi}	7.63 ^{e}	25.42 ^{fghij}		2500	
13	17.00 ^{cdefg}	40.31 ^{abcde}	4.98 ^{efghi}	9.00 ^{cde}	27.27 ^{fghij}		0.00	
14	20.19 ^{abcde}	37.00 ^{bcde}	5.60 ^{cdefgh}	12.88 ^{bcde}	29,70 ^{defghij}	30	313	Sand
15	20.19 ^{abcde}	41.25 abcd	6.65 ^{abcde}	14.63 ^{abcde}	38.17 ^{bcde}		2500	
16	15.08 ^{defg}	46.26 ^{a}	5.53 ^{defgh}	14.75 ^{abcd}	26.42 ^{fghij}		0.00	
17	17.35 ^{cdefg}	45.06 ^{ab}	7.73 ^{ab}	13.88 ^{abcde}	38.80 ^{bcd}	40	313	
18	19.96 ^{abcde}	40.94 ^{abcde}	6.58 ^{abcde}	11.38 ^{bcde}	34.70 ^{bcdefgh}		2500	
19	13.25 ^{g}	26.69 ^{g}	4.68 ^{fghi}	16.75 ^{ab}	25.02 ^{ghij}		0.00	
20	15.18 ^{defg}	26.69 ^{g}	4.60 ^{fghi}	18.00 ^{ab}	27.73 ^{efghij}	20	313	
21	15.23 ^{defg}	26.38 ^{g}	4.35 ^{ghi}	17.88 ^{ab}	25.27 ^{fghij}		2500	
22	15.69 ^{defg}	32.81 ^{efg}	5.38 ^{defghi}	20.38 ^{a}	26.9 0 ^{fghij}		0.00	
23	19.44 ^{bcde}	35.19 ^{def}	5.53 ^{defgh}	14.63 ^{abcde}	32.60 ^{bcdefghi}	30	313	Compost
24	23.19 ^{ab}	27.81 ^{fg}	5.68 ^{cdefg}	17.25 ^{ab}	31.02 ^{cdefghij}		2500	
25	19.19 ^{bcdef}	35.81 ^{de}	7.05 ^{abcd}	18.50 ^{ab}	36.13 ^{bcdef}		0.00	
26	17.19 ^{cdefg}	40.06 ^{abcde}	7.33 ^{abc}	16.25 ^{ab}	35.80 ^{bcdefg}	40	313	
27	25.44 ^{a}	38.75 ^{abcde}	5.63 ^{cdefgh}	16.63 ^{ab}	26.55 ^{fghij}		2500	
C.V%	19.12%	12.98%	18.40%	27.92%	19.98%			
P-value	0.0163*	0.025*	0.0259	0.0435*	0.0419			
$Lsd_{0.05}$	4.781	6.841	0.8462	6.014	8.978			
SE±	1.698	2.43	0.3006	2/136	3.189			

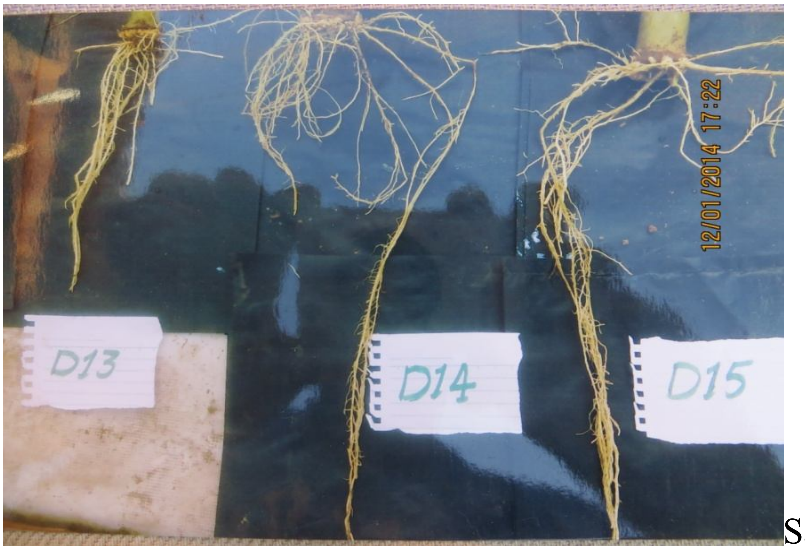
Table (8): Effect: of cutting length (cm) and IBA concentrations (00.0, 313 and 2500 mg/L water) on different shoot and root parameters of *J. curcas* using different rooting media season (2013)

2013	No of roots	Root length cm	No of branches	Branche length cm	No of leaves	Cutting length cm	IBA mg/L	Media
1	10.89 ^{ghi}	26.74 ^{efgh}	7.35 ^{gh}	13.69 ^{bcdefgh}	32.44 ^{efghij}		0.00	
2	11.69 ^{efghi}	27.75 ^{defgh}	6.36 ^{hi}	14.15 ^{bcdefgh}	33.44 ^{defghi}	20	313	
3	15.35 ^{bcd}	23.20 ^{hi}	5.75 ^{hij}	11.21 ^{efgh}	30.48 ^{efghij}		2500	
4	14.00 ^{bdefgh}	30.00 ^{bcdefg}	10.15 ^{cdefg}	17.75 ^{bcdef}	51.53 ^{bcde}		0.00	
5	16.31 ^{abc}	31.00 ^{abcdef}	11.38 ^{bcde}	19.38 ^{bcd}	57.44 ^{abc}	30	313	Silt-loam
6	13.06 ^{cdefgh}	30.31 ^{bcdefg}	9.81 ^{cdefg}	18.44 ^{bcd}	53.43 ^{bcd}		2500	
7	15.38 ^{bcd}	33.31 ^{abcde}	13.66 ^{ab}	26.63 ^{a}	70.51 ^{ab}		0.00	
8	17.19 ^{ab}	33.44 ^{abcd}	14.63 ^{a}	21.19 ^{ab}	74.01 ^{a}	40	313	
9	17.31 ^{ab}	32.06 ^{abcdef}	12.54 ^{abcd}	16.19 ^{bcdefg}	55.57 ^{a}		2500	
10	9.31 ^{i}	30.38 ^{bcdefg}	5.84 ^{hij}	7.63 ^{h}	25.77 ^{ghij}		0.00	
11	10.63 ^{hi}	28,69 ^{cdefgh}	5.90 hij	8.94 ^{gh}	24.73 ^{ghij}	20	313	
12	13.46 ^{cdefgh}	25.58 ^{fghi}	3.88 ij	7.04 ^{h}	17.18 ^{ij}		2500	
13	12.81 ^{defgh}	31.06 ^{abcdef}	9.60 ^{defg}	13.00 ^{cdefgh}	44.38 ^{cdefg}		0.00	
14	16.06 ^{abcd}	32.38 ^{abcde}	10.57 ^{cdef}	13.31 ^{bcdefgh}	44.79 ^{cdefg}	30	313	Sand
15	12.81 ^{defgh}	32.02 ^{abcdef}	8.33 ^{efgh}	11.13 ^{efgh}	38.10 ^{cdefgh}		2500	
16	14.08 ^{bcdefg}	31,44 ^{abcdef}	11.87 ^{abcd}	9.54 ^{gh}	44.60 ^{cdefg}		0.00	
17	14.48 ^{bcdef}	32.35 ^{abcde}	12.86 abc	11.75 ^{defgh}	50.60 ^{cdef}	40	313	
18	15.71 ^{bcd}	31.67 ^{abcdef}	9.57 ^{defg}	9.21 ^{gh}	33.24 ^{defghi}		2500	
19	11.21 ^{fghi}	26.81 ^{efgh}	4.05 ^{ij}	9.54 ^{gh}	18.21 ^{hij}		0.00	
20	11.93 ^{efghi}	24.56 ^{ghi}	3.06 ^{j}	11.13 ^{efgh}	14.47 ^{ij}	20	313	
21	11.48 ^{efghi}	20.71 ^{i}	2.71 ^{j}	10.31 ^{fgh}	11.96 ^{j}		2500	
22	13.00 ^{cdefgh}	28,63 ^{defgh}	5.73 ^{ijh}	15.63 ^{bcdefg}	28.05 ^{ghij}		0.00	
23	14.69 ^{bcde}	27.81 ^{defgh}	5.79 ^{hij}	15.81 ^{bcdefg}	28.41 ^{ghij}	30	313	Compost
24	15.81 ^{bcd}	31.25 ^{abcdef}	5.82 ^{hij}	16.56 ^{bcdefg}	31.22 ^{efghij}		2500	
25	16.38 ^{abc}	36.50 ^{ab}	7.51 ^{fgh}	19.94 ^{abc}	38.30 ^{cdefgh}		0.00	
26	17.25 ^{ab}	35.19 ^{abc}	7.58 ^{fgh}	18.88 ^{bcde}	40.74 ^{cdefg}	40	313	
27	19.13 ^{a}	37.25 ^{a}	8.54 ^{efgh}	18,06 ^{bcdef}	44.54 ^{cdefg}		2500	
C.V%	14.19%	15.95%	22.37%	32.74%	23.65%			
P-value	0,0842*	0.0582*	0.0639*	0.1536*	0.3945*			
$Lsd_{0.05}$	2.822	6.671	14.19	6.589	2.714			
SE±	1.002	2.369	5.039	2.34	0.964			

d): Length of branches: Significantly long branches were recorded for long stem cuttings lengths and all IBA concentrations under silt-loam and compost media. For the sand media 30 cm long with high IBA and 40 cm long cuttings with zero and high IBA gave similar results for rooting media. Season two showed that significant long branches were recorded for 40 cm long cuttings with zero and low IBA under silt-loam media. Compost media gave similar results only with zero IBA for 40 cm long cuttings. No significantly high results were recorded under sand rooting media. (Table: 8).This ensure that long stem cuttings were most preferable when planted under suitable rooting media (silt-loam or compost) as reported by Plaster (1997) while the silt-loam and sand rooting media were economically cheaper, even when no rooting hormone is used.

e): Number of leaves: Markedly high number of leaves was reported from silt-loam media using 30 cm cuttings with low and high IBA or 40 cm cuttings with or without IBA. The other two media were not comparable and resulted in small number of leaves. (Table: 7). Similarly season two showed that significant number of leaves was reported only from silt-loam media with 30 cm cuttings under low IBA concentration, or by 40 cm with or without IBA. The other two media were not comparable and resulted in small number of leaves similar to 1st season (Table: 8). The number of leaves was linked with long mature stem cuttings and under silt-loam media. Findings of Noor *et al*. (2009), Maya *et al.* (2010), Liv *et al*. (2011) supported our results.

Biomass production by cuttings seems to depend strongly on the "starting mass" of the cuttings. It can be assumed that the reason for this is the difference in assimilates that are stored in the cuttings. Similar to that results were recorded by Maya *et al*. (2010), Noor *et al*. (2009), Liv *et al.* (2011), and Kathiravan *et al.* (2009).



Sand

Silt-loam

Compost

Fig 5,6 and 7: from (Top to bottom) Effect: of IBA concentration, 00.0, 313 and 2500 mg/L water from (left to right) on number and length of roots of *J. curcas* using three types of rooting media.

Conclusion: On the basis of results obtained from this study, it is concluded that propagation of *J. curcas* through hard wood cuttings could be with or without the use of rooting hormones, however, the results showed good response to silt-loam media in root length, plant height and other aerial parameters.

From the results obtained and observation through the two seasons it is more suitable to propagate dry *J. curcas* seeds under silt-loam or sand rooting media for best tap and lateral root establishment. It can be concluded that, cuttings performed better than seedlings in terms of all parameters except the absence of taproot. Silt-loam and compost showed more and taller branches with more and healthy leaves.

Recommendations:

1- Mature stem cutting of 30 to 40 cm long are best for propagation of *J. curcas.*

2- Silt-loam rooting media should be used based on it is results and being economical.

3- Low concentration of rooting hormone IBA (313 mg/L) is more efficient and economical.

4- Combination of 30 to 40 cm long stem cuttings on silt-loam media using 313mg/L IBA is recommended for mass propagation of *J. curcas* under nursery conditions of Sudan.

5- Dry whole seeds should be used for successful seed germination and vigorous seedlings.

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Appendices

Appendix 1: Some Analysis of rooting media used:

	Sand	Silt-loam	Compost
C:N			16 – 20
Organic matter	0.5 – 1.0	5.5 – 7.5	35 – 60
Humidity	0.5 – 0.8	7.5 – 8.0	30 – 35
pH	7.4 – 8.1	6.8 – 7.8	7.5 – 8.0
EC	1.0 – 1.5	1.2 – 1.5	1.5 – 2.0 ds/m
Particle size	.25 - .50 mm	.002 - .02 mm	0.5 – 2.0 mm
N	0.022%	NA	1.3 – 1.5 %
P	13.04ppm	NA	1.9 – 2.2 %
K	0.029me/100g	NA	4 – 7 %
Ca	NA	NA	3 – 5 %
Mg	NA	NA	1.0 – 1.5 %
Mn	NA	NA	2.5 – 3.5 %

Appendix 2:

Cultivation limits of *Jatropha curcas* (*Source:* Brittaine and Lutaladio 2010)