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Maximizing Ecosystem Services in *Jatropha curcas*; The Appropriate Planting Method

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Abstract The study, which was a pot experiment, was carried out to evaluate the effect of depth of planting on growth and flowering of physic nut (*Jatropha curcas*). It was conducted at the Sinna Garden, Department of Crop Science, University of Ghana. Seeds were planted at different depths of 2 cm, 4 cm and 6 cm using completely randomized design. Data were collected on leaf number per plant, number of flowers produced per plant, plant height, girth of the stem, canopy size, number of branches per plant, total leaf area, and total plant fresh and dry weight. Growth analysis was performed and correlation among characters also analyzed. Results obtained in the studies revealed that percent emergence deceased with increased depth of planting and significant differences were observed in percent emergence among the different depths of planting. The 2 cm planting depth proved to be the most effective depth to achieve high emergence rate while the 6 cm was the least. Planting depths of 2 cm and 6 cm were the best in terms of growth parameters and flowering production. In all the analyses conducted, it was observed that planting *Jatropha curcas* seeds at 2 cm and 6 cm depths yielded the highest number of flowers, growth rate, and biomass production. Therefore, the study recommended that in order to ensure faster growth to maximize the benefits from *Jatropha curcas* in terms of ecosystem services delivery; it is highly recommended that you plant at 2cm and 6 cm.

Keywords: *Jatropha curcas, planting depth, ecosystem benefits, Carbon sequestration*

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1. Introduction

Jatropha curcus is a plant domesticated in the tropics, has been known in many areas of Africa and Asia for several hundreds of years. It belongs to the family Euphorbiaceae and believed to be a native of Mexico and Central America [1]. It is a multipurpose deciduous shrub, reported performing well in all parts of Ghana. Jatropha has a wide range of uses. Seeds, leaves, and bark are used in traditional medicine and for veterinary purposes. In Ghana, most villagers use the leaves and wood-ashes to clean their teeth [2]. *Jatropha curcas* has been found to be a highly promising species which can yield oil-seed as a source of energy in the form of biodiesel. The plant is tolerant of drought and produces high-quality oil [3]. The aqueous extract from oil has potential as an insecticide [4]. The seed cake after oil extraction has the potential for use as fertilizer [2]. The oil can also be used in soap and candle industries. Glycerin, a by-product from Jatropha seed is used in the pharmaceutical industry [5]. Apart from its saponification and medicinal value, Jatropha has the potential to restore the ecosystem and biodiversity of the environment. It improves rainfall pattern and prevents soil erosion. On the basis of these benefits, Jatropha plantations have been established in some districts Ghana under commercial production to reap its economic, social, environmental and agricultural benefits. In view of this, it has become necessary to establish a scientifically appropriate planting technique to ensure it faster growth to serve its purpose. it is against this backdrop that this study was carried out to examine the effect of depth of planting depth on growth and development, including flowering of *Jatropha curcas*.

1.1. Growth and Development of *Jatropha curcas*

1.1.1. Root, Stem and Branching Pattern

Environmental factors in combination with genetic and physiological factors also play important role in branching of *Jatropha curcas* [3]. These characters appear to be under strong genetic control. Branching normally occurs at the fourth to a fifth week after planting if given enough water and nutrients [1]. *Jatropha curcas* has five roots formed from seeds, one central (tap root) and four peripherals. Cuttings, when planted, do not form a taproot [6].

1.1.2. Flowers and Flowering Pattern

The flowers are unisexual, male and female flowers are produced on the same inflorescence. The inflorescence is formed in the leaf axil and normally, produces a central female flower surrounded by a group of male flowers [7]. Numerically, 1 – 5 female flowers and 25 – 93 male flowers are produced per inflorescence and the average male to female flower ratio is 29: 1. The female flowers are usually slightly larger. The flowering pattern is such that the male flower appears first. Each plant, once it begins flowering, flowers daily, and the flowering period lasts for 11 days [8]. The plant has two flowering peaks, which occur during the wet season [9]. Occasionally hermaphroditic flowers also occur. The rare hermaphroditic flowers can be self-pollinating. Ten stamens arranged in two distinct whorls of five each in a single column in the androecium and in close proximity to each other. In the gynoecium, the three slender styles are connate to about two or three of their length, dilating to a massive bifurcate stigma [10]. Jatropha is pollinated by insect and each inflorescence yields a bunch of ovoid fruits [1]. The exocarp remains fleshy until the seeds are mature. Jatropha is a diploid species with 2n = 22 chromosomes. Fruit development needs 90 days from flowering until seeds mature [11].

1.1.3. Fruiting

After pollination, the trilocular ellipsoid fruit is formed. These fruits take about three months to mature after flowering [12]. The ellipsoid capsules are 2.5 - 3 cm long, 2 - 3 cm in diameter and green in color. Seed production starts within 12 months from planting but reaches its maximum productivity level after 4 to 5 years [13]. In permanently humid equatorial regions, flowering occurs throughout the year. In India, flowering occurs between September-December and March –April, whereas in Thailand, there are two flowering peaks, in November and May. In the tropical African climate, the tree has three main fruit bearing periods in a year. Each fruit-bearing cycle is about four months. During these periods, the tree produces flowers every two weeks that develop into matured fruits in 30 days. Early growth is fast and with good rainfall conditions nursery plants may bear fruits after the first rainy season and direct sown plants after the second rainy season. The flowers are pollinated by honey bees [14]. The onset of maturity comes with changes in colour of the fruit or capsule from green to yellow [15].

2. Methods of Propagation

Jatropha plant can be propagated by seeds, cuttings, and tissue culture technique.

2.1. Seed Propagation

Seeds are the most common planting materials used by farmers. Most often, seeds intended for sowing are soaked in water for twelve hours before being sown [16]. This treatment is usually done to soften the seed coat to facilitate germination. In some cases, seeds are cracked in order to ensure the early emergence of the embryo. Germination occurs six days after sowing [17]. Soaked seeds are generally sown in poly bags filled with soil, sand and farmyard manure in the ratio of 1:2:1, respectively [18]. For a one-hectare plantation about 5 – 7.5 kg seeds are required.

2.2. Vegetative Propagation Using Cuttings

Cuttings used for propagating *Jatropha curcas* should be obtained from eight months old and above plants [19] Hardwood cuttings are found to be the best source of vegetative planting material. Plants from hardwood cuttings flower and produce seeds earlier than from seeds [20]. Research shows that *Jatropha curcas* propagated by cuttings show lower longevity and possess a lower drought and disease resistance than plants propagated by seeds [18]. Likewise, pre-cultivation of *Jatropha* seedlings in poly-ethylene bags has been shown to accelerate the establishment of a plantation by at least three months [1]. It is reported that for quick establishment of hedges and plantations for erosion control, directly planted cuttings are recommended and for long-lived plantations for oil production, plants propagated by seeds are better than cuttings [18].

Comparative research on the influence of different propagation methods on survival and vegetative development was conducted by [21] in Florida and by [22] in Senegal in nearly identical trials. The studies comparing direct seeding, transplanting of seedlings and direct planting of cuttings of different diameters have shown significant differences in seed yields [22]. The first seed yield of cuttings with a diameter greater than 30 mm was significantly higher than that of pre-cultivated plants [6].

2.3. Tissue culture technique

Jatropha curcas can also be propagated by tissue culture technique. This method is a laboratory technique, which utilizes artificial and sterilized propagated medium. [23] have reported a method for the differentiation of adventitious shoots through callus derived from hypocotyl, petiole, and leaf explants of *Jatropha curcas*. On another hand, [2] have also reported the induction of adventitious buds and regenerated shoots from epicotyl explants through callus.

2.4. Factors Affecting Growth and Development of *Jatropha curcas*

2.4.1. Climatic Factors

Climatically, *Jatropha curcas* prefers the warmer regions of tropics and subtropics and at a relative humidity of 74 – 80 %. It does well even in slightly cool conditions and can withstand a high frost. It tolerates an annual temperature range of 18 – 28°C. Extremely higher temperatures at the time of flowering do not favour fruiting, but for the emergence of seeds, hot and humid climate is preferred [21]. It grows well in low rainfall conditions of about 300mm, but can also tolerate high rainfall up to 1200 mm. According to Henning [17], rainfall above 1200 mm will result in excessive leaf production without flowers. The leaves are shed during certain months to form mulch around the base of the plant. The organic matter from the shed leaves enhances earth-worm activity in the soil around the root zone of the plants, which improves the fertility of the soil.

2.4.2. Edaphic factor

Jatropha curcas grows almost everywhere- even on sandy, acidic and alkaline soils with pH ranging from 5.5 – 8.5. Any pH value below this affects its growth and development [24]. Generally, most soil types, such as sandy or loamy are suitable for raising *Jatropha curcas* plantation. On heavy soils, root formation is reduced and eventually affects the growth and survival of the plant [21]. It is very tolerant and thrives well under a wide range of edaphic conditions [24]. It is very drought tolerant and can withstand slight frost soils but not extremely heavy frost soils because of its affinity to the tropical environment [25].

2.4.3. Depth of Planting

Planting depth tends to play a vital role in the growth and survival of plants as far as emergence and harvesting of the fruits are concerned [15]. Depth allocated for Jatropha curcas seedling planting ranges from 45 cm x 45 cm x 45 cm to 30 cm x 30 cm x 30 cm. However, in the case of seeds, it can range from 2 cm to 3 cm depending on the soil condition [26]. Deeper plantings tend to affect the rate of emergence [24]. At the bottom of these holes, neem oil cake is applied to protect either the seeds or the plant from attack by pest or immediately provide the nitrogen requirements of the plant [27]. In temperate zones, for instance, planting depth is very essential since it serves as a form of protection and also reduces mechanical damage in flower beds during winter. The depth of planting is a determinant of germination because it has great influence on moisture, temperature, oxygen, and light that can reach the seed [20]. Some seeds need to be planted deeper than others for best emergence and subsequent desirable growth because they do not need light for germination [7]. It has been shown that the depth of planting of the Russian wild rye (Elymus junsceus) influenced the seedling growth during the seedling year in the field planting over four years at two locations [28] Similarly, [23] reported that Chenopodium album showed superior seedling performance for seeds planted close to the soil surface. [29] observed that height difference between the range grasses planted at different depths apparently resulted from some form of seedling selection at greater depths. Growth habit and number of tillers produced are influenced by the planting depth in several kinds of grass and cereal grains [30], with those planted at depths of 2.5 cm - 3.8 cm growing significantly taller than those at 1.3 cm depth [31]. Therefore, to ensure efficient and effective harvesting of Jatropha curcas fruits, planting depth should be considered when planting.

2.5. Ecosystem Benefit of *Jatropha curcas*

2.5.1. Social Benefits

Jatropha curcas has social, agricultural, environmental, industrial, and pharmaceutical and energy production potentials. Jatropha seed cake, compost from debris and slurry from biogas plant are good sources of soil nutrition. Protein from seed cake can be utilized as animal feed. As a plant, Jatropha can assimilate Co_2 from climate and it can also be used as bio adsorbent of heavy metal from effluents. Protein, lignin and other products of Jatropha can substitute the hazard synthetic chemicals of polymers production. Seed oil has been using in soap, dying and cosmetic industry from long before. Extract from Jatropha leaf, bark possesses biological active compounds that have medicinal potentials. Jatropha is more familiar as an energy crop. It provides energy in the form of firewood, seed oil as a lamp, cooking and engine fuel directly. Biodiesel the chemical conversion of seed oil can be used directly or blend with fossil diesel with modified or conventional engine. However, the presence of toxic substances (pherbol ester) renders its utilization as therapeutic agents and animal feed. The high viscosity of seed oil and biodiesel is the hurdle to use [32].

2.5.2. Environmental and Agricultural Benefit

Climate change mitigation is one of the key arguments for promoting biofuels. Cultivation of *Jatropha curcas* contributes to the reduction of carbon stock. Research has shown that bioenergy from *Jatropha curcas* can generate GHG savings of more than 40% compared with fossil fuels [33]. *Jatropha Curcas* is known to store a substantial quantity of Carbon in the above soil portion of the plant [18]. According to research, planting *Jatropha curcas* in coastal deserts could facilitate carbon capture, reduce harsh desert temperatures, boost rainfall, revitalize soils and produce cheap biofuels. Large-scale plantations of *Jatropha curcas* could help sequester carbon dioxide through a process known as 'carbon farming', according to a study based on data gathered in Mexico and Oman. According to Klaus Becker, a hectare of *Jatropha curcas* tree could soak up 17-25 tonnes of carbon dioxide a year, and at a cost of US$56-84 per tonne of gas. This makes the technique competitive with high-tech carbon capture and storage. A study by Klaus Becker shows that because of Jatropha plantations, average desert temperatures went down by 1.1 degree Celsius and induced rainfall in the desert area. Local people intercrop beans within Jatropha plantation and harvest them, providing a vital source of protein and creating a symbiotic exchange of nitrogen fixed from the air by beans and enjoy the shade provided by the Jatropha trees.

2.5.3. Agricultural and Social Benefit

The average oil content of a Jatropha seed is about 35%, and depending on the extraction technology, about 75% of this oil can be collected. For each kilogram of straight Jatropha oil that is collected, about 2.8 kilograms of press cake are therefore produced. The press cake contains several toxic compounds and therefore cannot be used as animal feed without first undergoing detoxification. It does, however, have high nutrient levels and can be used directly as a fertilizer to close the nutrient cycle (substituting fertilizer). This provides an opportunity for farmers to reduce production cost (Mapaco, *et al*., 1998). The press cake fraction also contains more energy than the oil fraction and therefore great potential exists for using the press cake as a biogas feedstock (substituting natural gas) or for direct combustion as briquettes or pellets (substituting charcoal or firewood).

3. Materials and Methods

3.1. Experimental Sites

The study was conducted in the Sinna Garden, Department of Crop Science University of Ghana, under a temperature between 30°C – 35°C and the average relative humidity of 75 - 80 %. Weather data obtained from the metrological Department, Legon indicated that the average rainfall at the time of the study was about 700 mm - 1000 mm with a temperature of 30°C – 35°C and relative humidity of 75- 80 %.

Seeds were collected from the Department of Crop Science, cracked and soaked in water for 12 hours. The seeds were then sown in plastic pots, 24 cm high with a top interior diameter of 22 cm and the bottom interior diameter of 19 cm. Four seeds were sown per hole. The germinated seedlings were thinned to one per pot a week after emergence. Each pot contained 1500g of topsoil. The treatments for the study comprised seeds planted at depths of 2 cm, 4 cm, and 6 cm. A completely randomized design was used with four replications. Pots were randomly placed in rows 2 m apart and 2 m within the rows. A total of forty-eight plants were used in the study (four plants per plot, per treatment, per replication (4x3x4)). Four randomly selected plants from each treatment were used as record plants. Harvested plants were dried in a thermos scientific precision mechanical convention oven at 85°C for 72 hours and the dry weight being determined.

3.1.1. Cultural Practices

Seedlings were sprayed with an insecticide (Pawa 2.5EC) at a concentration of 0.01 liter/ 2 liters of water to control leaf miners after two weeks of emergence. Pyrenex was also sprayed at a concentration of 2 ml per liter of water at the fourth week of emergence to control termites which were attacking the seedlings.

Watering was done once a day from the time of emergence until plants was about four weeks old when they were watered three times a week till flowering. Weeds were controlled daily by hand picking to control their population and to avoid competition in the pot. Cow dung manure was applied at a quantity of 0.7kg per seedling two weeks after emergence and 0.14kg at two months after emergence till flowering.

3.2. Data Collection

Plant height (cm) was measured with a meter rule from the soil surface to the apical leaf at two weeks' interval and started two weeks after seedling emergence. The horizontal spread of the canopy of each of the four record plants per treatment was measured at two weeks' interval and started two weeks after emergence. Stem girth (cm) was measured at two weeks using the vernier calipers. It was taken from the circumference of the stem at 5 cm above the soil level and started two weeks after emergence. Leaf area per plant was estimated using a leaf area meter. The whole plant was harvested and then separated into leaves, stem, and root to facilitate the process. This was done at four weeks' interval starting two weeks after emergence. The number of leaves per plant were counted for individual treatments and then recorded. This was taken two weeks after emergence from four individual plants per treatment and at two weeks' interval**.** Leaf area index was estimated by dividing the total leaf area per plant by land area occupied by each plant. This was done two weeks after emergence and continued four weeks' interval after the first estimate. The number of branches was determined by counting the branches on individual plant four weeks after emergence. Flower counting started on the 14th week after emergence and then continued daily until flower production stopped. Two plants from each of the three treatments per replicate were harvested and leave detached from the main stem every four weeks for fresh and dry leaf weight (g) determination after two weeks of emergence. Roots of two harvested plants from each of the three treatments per replicate were separated from the stem, washed and weighed (g) at four weeks' interval after two weeks of emergence.

Two plants from each of the three treatments per replicate were harvested and average fresh and dry weights (g) of stem taken at four weeks' interval after two weeks of emergence.

4. Results and Discussions

4.1. Effect of Planting Depth on the Performance of *Jatropha curcas*

4.1.1. Days to Emergence and Percentage of Emerged Seedlings

Seeds planted at depths of 2, 4, and 6 cm emerged at 3, 5 and 7 days after planting, respectively. Percent emergence decreased with increased depth of planting. There were significant differences in percent emergence between 2 and 6 cm planting depths but no significant differences were observed between 4 and 6 cm planting depths (Table 1).

Table 1. Effect of planting depth on emergence of seedlings

Depth of Planting (cm)	Days to emergence	Emergence (%)
2	3	72.9
4	5	60.4
6	7	54.2
LSD (5%)		13.6

4.1.2. Vegetative Growth Characteristics

4.1.2.1. Plant size Features

There were no significant differences among the treatments in terms of canopy size (Table 2). Generally, canopy size was highest for plants from the deepest depth and lowest for plants at shallowest depth. The trend in plant height was as in canopy size, with plants from shallow planting depth having the shortest plant height. Plants from 6 cm planting depth plants were significantly taller than those of the 2 cm but not significantly different from those of the 4 cm planting depth. However, plant height of 2 and 4 cm planting depth was not significantly different from each other (Table 2). Based on stem girth obtained at all the growth stages specified in this experiment, no significant differences were recorded among the three treatments. Even though there were no significant differences among them, the 6 cm planting depth recorded the highest mean girth size while the 2 cm planting depth recorded the least (Table 2). The number of branches did not differ significantly among plants from different depths of planting (Table 2). With regard to the number of leaves produced per plant, the 6 cm planting depth had the highest mean number of leaves followed by the 4 cm planting depth while the 2 cm planting depth recorded the least number of leaves (Table 2). However, the above differences in the number of leaves for the three treatments were not significant. From Table 3, different planting depths also did not produce any significant effect on the leaf area of the plants. Though no significant differences were observed among the different planting depths, the 4 cm planting depth recorded the highest mean total leaf area while those planted at 6 cm depth recorded the least total leaf area. There was no significant difference in the leaf area index (LAI) between plants planted at the depths of 2 cm and 4 cm. But those planted at the depth of 4 cm were significantly higher than those planted at 2 and 6 cm, respectively (Table 3).

4.1.3. Dry Matter Accumulation and Distribution

There was no significant difference between the plant leaf dry weight of 2 cm and 4 cm planting depths. The leaf dry weight of the 6 cm planting depth was significantly higher than those planted at 2 cm but not significantly different from those planted at 4 cm (Table 4). The stem dry weight obtained from the three planting depths: 2 cm, 4 cm and 6 cm were 25.5, 34.8 and 45.1 g, respectively (Table 4). Even though, there were no significant differences among the treatments, the 6 cm treatment recorded the highest weight while the 2 cm treatment recorded the least weight.

There were no significant differences among the treatments for root dry weight (Table 4).

4.1.3.1. Percentage dry weight

In the case of percent dry weight of leaf, stem and root, different planting depths did not produce any significant differences in leaf and stem dry weights. However, significant differences were observed among the percent root dry weight. Two and 4 cm planting depths produced significant differences between their root dry weights but no significant differences were observed between the root dry weight of the 4 and 6 cm plants. In all, 2, 4 and 6 cm planting depths did not show any significant differences in the total dry matter of the plants (Table 5).

Table 2. Effect of planting depth on vegetative growth characteristics of *Jatropha curcas*

Planting Depth (cm)	Canopy spread (cm)	Plant height (cm)	Stem girth (cm)	Number of leaves/plant	Number of branches/plant
2	43.8	49.8	2.44	43	2
4	49.3	50.4	2.72	48	2
6	52.4	61.6	2.87	53	2
LSD (5%)	NS	11.6	NS	NS	NS

NS= not significant.

Table 3. Effect of planting depth on number of flowers produced, leaf area and leaf area index (LAI) per plant of *Jatropha curcas*

Planting depth (cm)	Number of flowers (cm^2)	Leaf area	Leaf area index (LAI)
2	115	116.3	2.4
4	121	172.5	3.3
6	107	102.1	2.3
LSD (5%)	NS	NS	1.0

NS: not significant.

Table 4. Effect of planting depth on weight of vegetative parts of *Jatropha curcas*

Planting Depth (cm)	Fresh leaf weight (g)	Fresh stem weight (g)	Fresh root weight (g)	Leaf dry weight (g)	Stem dry weight (g)	Root dry weight (g)	Total dry weight (g)
2	60.0	115.0	55.0	15.0	25.5	14.7	55.2
4	84.0	159.0	81.0	20.9	34.8	17.1	73.2
6	166.0	210.0	79.3	38.5	45.1	17.5	101.1
LSD(5%)	75.2	NS	NS	17.7	NS	NS	NS

NS= not significant.

Table 5. Percentage dry matter accumulation and distribution of *Jatropha curcas* seeds planted at different depths of 2, 4 and 6 cm

Planting Depth (cm)	Leaf dry weight (g)	Stem dry weight (g)	Root dry weight (g)	Total dry weight (g)
2	25.0	22.2	26.7	73.9
4	24.9	21.9	21.1	67.9
6	23.2	21.5	22.1	66.8
LSD(5%)	NS	NS	5.5	NS

NS: not significant.

4.1.4. Number of Flowers Produced Per Plant

The 4 cm planting depth recorded the first flower appearance on plants 105 days after planting followed by 2 cm which took 114 days to flower and finally, 6 cm with 119 days to flowering. In terms of the number of flowers produced per plant, however, there were no significant differences among the three depths of planting, the 4cm depth recorded higher mean number of flowers per plant (121) than the 2 (115) and 6cm (107) (Table 3).

4.1.5. Growth Trend after Planting

4.1.5.1. Canopy spread from the 2nd to the 20th week after planting

The first two weeks after planting, the 6 cm planting depth recorded an increase in canopy size while the 2 and 4 cm planting depths remained similar in terms of canopy size. The 6 cm treatment maintained a sturdy increase in canopy spread until the sixth week after planting when all the three treatments observed similar canopy size. However, it was observed that from the sixth to the tenth week, 4 cm planting depth canopy spread was relatively larger than the 2 cm and 6 cm. As it can be observed above, 2 cm planting depth recorded larger canopy spread from the tenth week to the twentieth week after planning as compared to 4 and 6 cm. 2cm and 6cm treatments recorded canopy size of about 1m as at twentieth week while 4 cm treatment recorded as low as 0.8 m (Figure 1).

4.1.5.2. Plant height (cm) from the 2nd to the 20th week after planting

All the treatments obtained similar plant heights at two weeks after planting. However, the 2 cm planting depth obtained relatively higher height as compared to the other treatments from the fourth to the eight weeks. On the other hand, 4 cm and the 6 cm planting depths recorded similar height at the fourth week and although some differences were observed at the sixth week, they were similar as at the tenth week. The 2 cm depth treatment maintained its height advantage over the other treatments up to the eighteenth week after planting. Meanwhile, between the 6 cm and 4 cm treatments, differences in height began to show with the 6 cm treatment gaining significant height increases from the twelfth week but the two treatments were again similar in height by the fourteenth week. There was a rapid increase in height of plants of the 6 cm treatments from the fourteenth week which persisted to the twentieth week, consequently, plant from the 6 cm planting depth obtained the tallest height among the three treatment by the twentieth week. As at the end of the twentieth week, plants of the 6 and 2 cm treatments had attained heights greater than a meter but those of the 4 cm treatment was about 80 cm tall. Also notable in this study was the similar height obtained for all the treatments at the tenth week especially, those of the 4 cm and the 6 cm treatments (Figure 2).

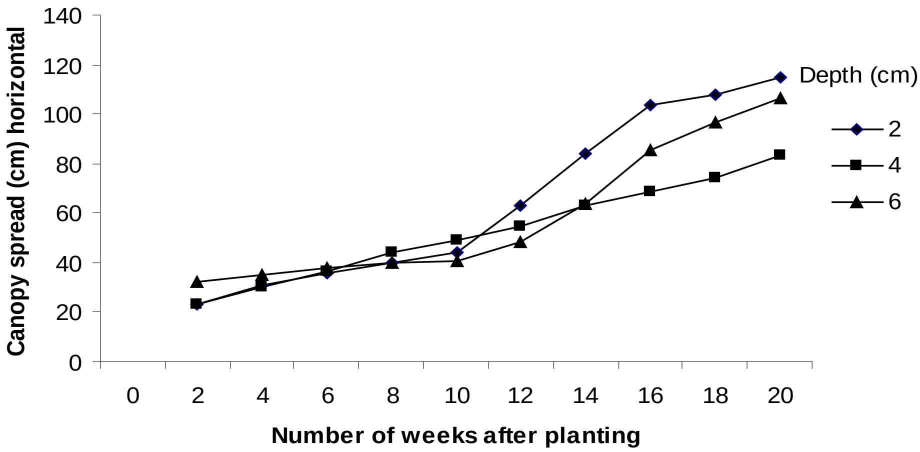

Figure 1. Canopy spread of *Jatropha curcas* planted at different depths (Bars represent LSD values at 5 %

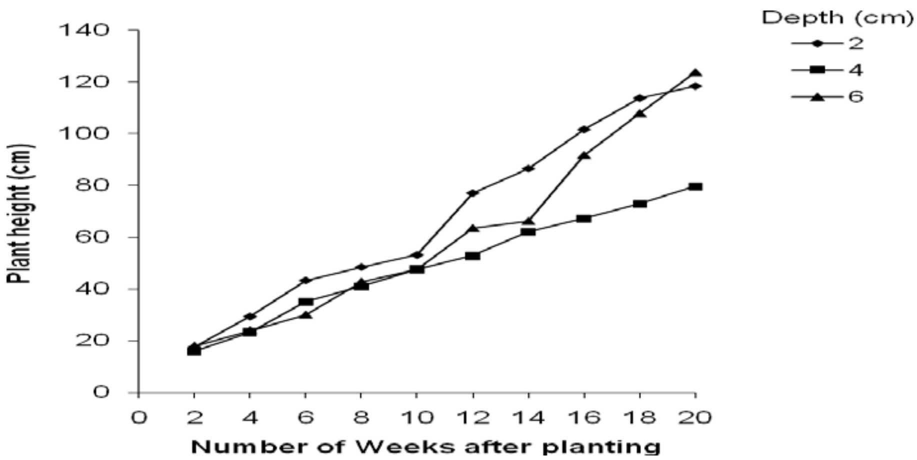

Figure 2. Plant height of *Jatropha* plant planted at different depths (Bars represent LSD values at 5 %)

4.1.5.3. Number of flowers produced per plant from 14thweek to 20thweek after planting

Flower production started on the fourteenth week after planting. Six centimeters planting depth at the fourteenth week produced a higher number of flowers as compared to the 2 and 4 cm treatments. Even though 2 cm treatment recorded the least number of flowers at the fourteenth week, it showed significant and sturdy increased in the number of flowers after the fourteenth week to the twentieth week while the 4 and 6 cm treatments produced a similar number of flowers. The highest difference in the number of flowers among the treatments occurred at the sixteenth week. At this period, the 2 cm treatment recorded more than 120 flowers on the average while the 4 cm and 6 cm treatments obtained less than a hundred flowers each. The significant difference between the 2 cm planting depth on one hand and the 4 and 6 cm planting depths on the other, persisted throughout the growth period up to the eighteenth week but after which this gap was slightly closed by the twentieth week. At a sixteenth week, the 6 cm treatment maintained a slight lead over the 4 cm planting depth in terms of a number of flowers produced but this trend was reversed with the 4 cm planting depth recording higher number of flowers at the eighteenth week. However, by the twentieth week, the 6 cm planting depth recorded a higher number of flowers than the 4 cm planting depth (Figure 3).

4.1.5.4. Total leaf area per plant (cm^2) from the 2nd to the 18th week after planting

As it can be seen from Figure 4, significantly higher total leaf area of more than 1000 cm^2 was recorded by 6 cm planting depth at the second week after planting while 2 and 4 cm recorded similar total leaf area of less than 1000 cm^2. The 6 cm planting depth maintained consistent increased in total leaf area from the sixth week to the eighteenth week after planting but was not significantly different from the 2 and 4 cm planting depths at the sixth week.

At the tenth week after planting, 2 and 4 cm planting depths did not show any significant differences between them but remained significantly different at the fourteenth and the eighteenth week after planting. From Figure 4, it was also observed that total leaf area of the 6 cm planting depth recorded almost 8000 cm^2 while 2 and 4 cm had 6500 cm^2 and 4500 $cm^{2,}$ respectively.

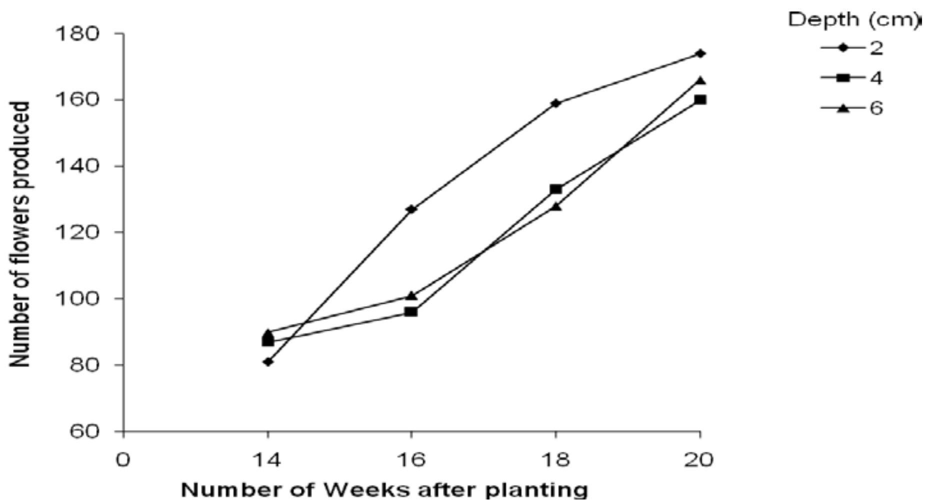

Figure 3. Flower production per plant of *Jatropha curcas* planted at different depths (Bars represent LSD values at 5 %)

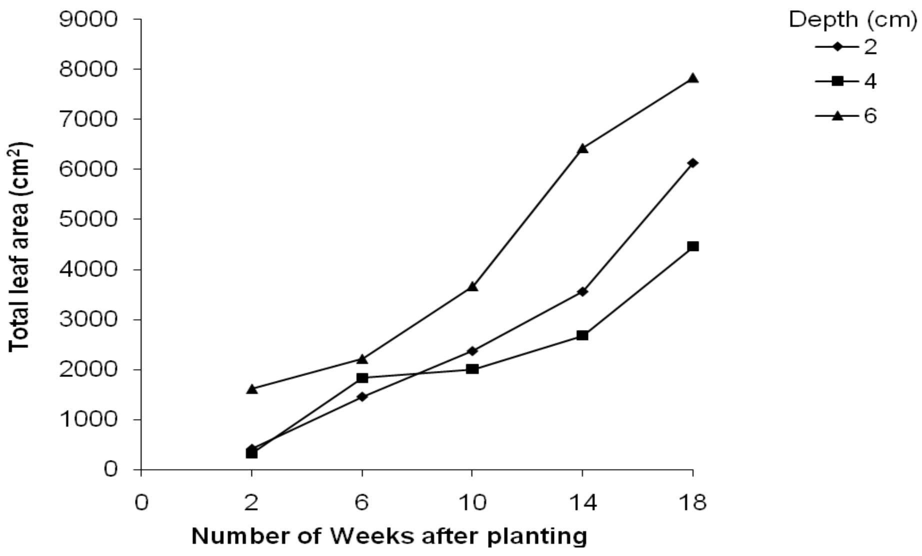

Figure 4. Total Leaf Area per plant of *Jatropha curcas* after planting (Bars represent LSD values at 5 %)

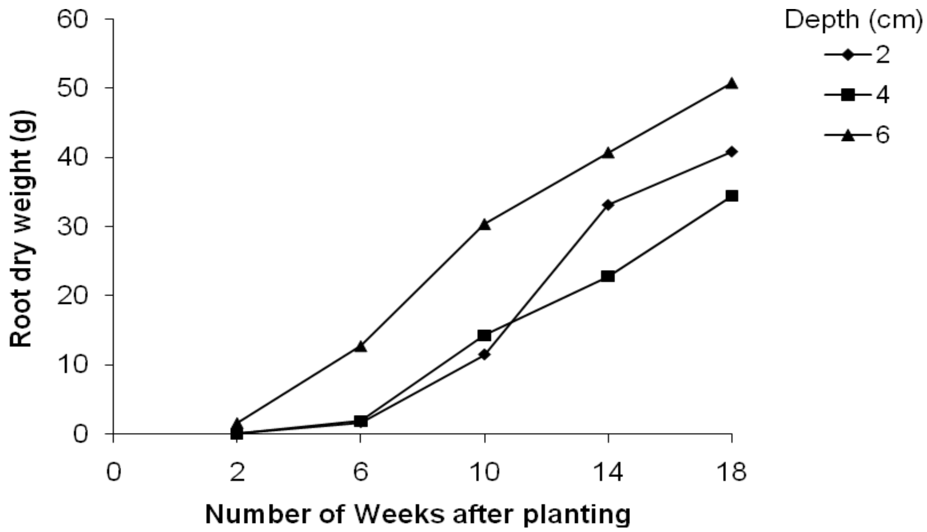

Figure 5. Root dry weight of *Jatropha curcas* planted at different Depths (Bars represent LSD values at 5 %)

Specimen A: treatments at 18th weeks after planting

4.1.5.5. Root dry weight (g) from the 2nd to the 18th week after planting

With regards to root dry weight, all the treatments recorded almost the same results in the second week after planting (Figure 5). From the second week onwards, the 6cm treatment showed a consistent increase in weight over the 2 and 4 cm planting depths. The maximum difference in root dry weight between the 6 cm planting depth and those of 2 and 4cm was obtained at the tenth week. The 4 cm and 2 cm planting depths were similar in root dry weight with only slight differences observed until the tenth week after which the 2 cm planting depth recorded a consistent increase in root dry weight over the 4 cm planting depth up to the eighteenth week. In sum, the 6 cm planting depth obtained the highest root dry weight followed by the 2 cm planting depth with the 4 cm planting depth obtaining the least root dry weight.

4.1.5.6. Stem dry weight (g) as measured from 2nd week to 18th after planting

With the exception of the second week where all the treatments were relatively similar in stem dry weight, the 6 cm depth showed a consistent noticeable gain in stem dry weight over the both the 4 and 2cm planting depths. The 4 cm and 2 cm plants, on the other hand, recorded a similar stem dry weight up to the sixth week after which slight differences began to show. However, it was after the tenth week that a clear and consistent difference in stem dry weight between the 4 and 2 cm planting depths was recorded with the 2 cm planting depth obtaining a higher weight than the 4 cm treatment (Figure 6).

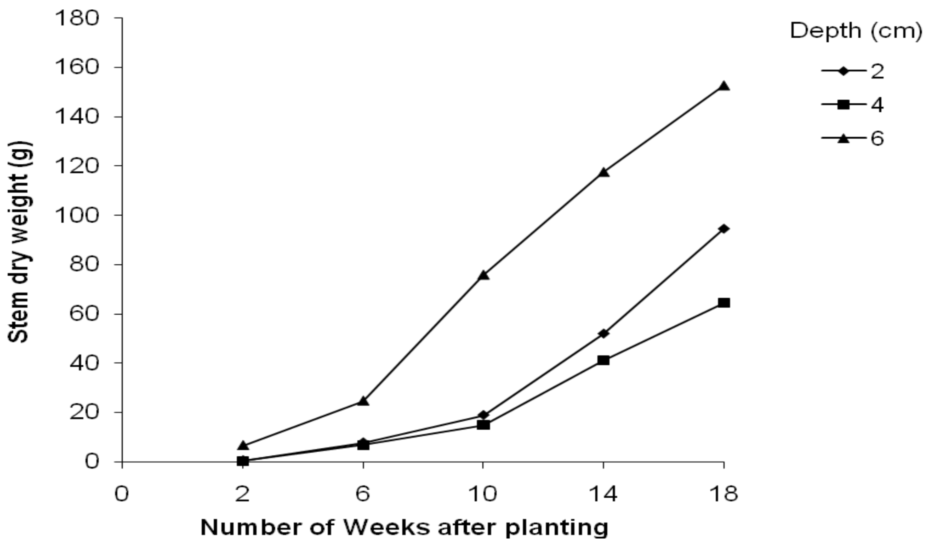

Figure 6. Stem dry weight of *Jatropha curacas* planted at different depths (Bars represent LSD values at 5 %)

Specimen B: treatments root growth at 18th Weeks

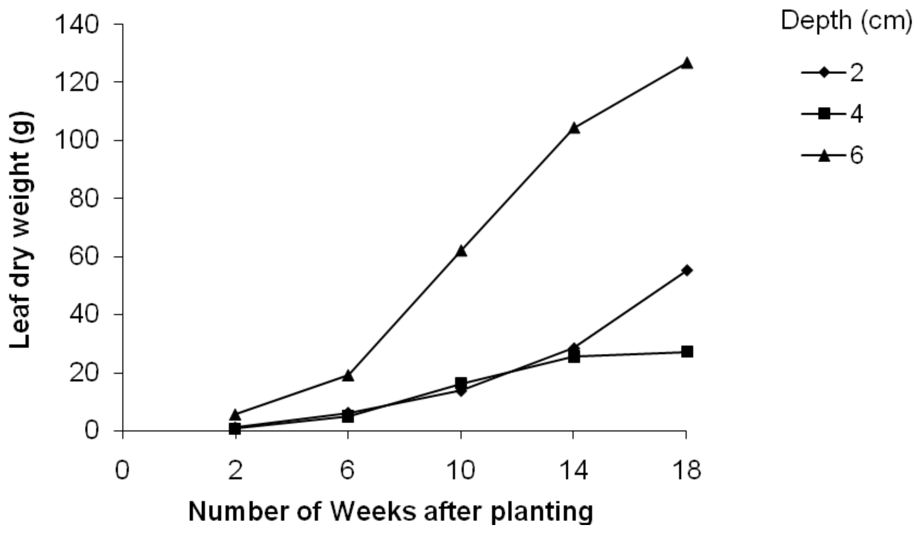

Figure 7. Leaf dry weight of *Jatropha curcas* after planting at different depths (Bars represent LSD values at 5 %)

4.1.5.7. Leaf Dry weight (g) from 2nd week to 18th weeks after planting

As indicated in Figure 7, 6 cm treatment recorded the highest leaf dry weight by the second week after planting as compared to the 2 and 4 cm. The difference between the 6 cm treatment and the other treatments became more pronounced after the sixth week and by the eighteenth week, it had gained about 60 g more leaf dry weight than the 2 cm treatment which recorded the second highest dry leaf weight in this study. The 4 and 2 cm treatments were similar in leaf dry weight from the second to the fourteenth week after planting. However, noticeable differences emerged after the fourteenth week and by the eighteenth week, the 2 cm treatment had recorded over 20g more weight than the 4 cm treatment.

4.1.6. Correlation among growth parameters

4.1.6.1. Correlation among growth parameters observed on 6 cm planting depth

Table 6 shows the correlation among growth traits observed on 6 cm planting depth. Plant heights significantly and positively correlated with leaf area, root dry weight, leaf dry weight and stem dry weight but negatively correlated with a number of leaves and number of flowers produced per plant. Leaf area had a significant positive correlation with the number of leaves, number of flowers produced, and leaf dry weight and stem dry weight. It however correlated positively with root dry weight but was not significant. The number of leaves showed a positive correlation with the number of flowers, leaf dry weight, root dry weight, and stem dry weight. It however correlated significantly with root and stem dry weight. On the other hand, the number of flowers also had a significant positive correlation with stem dry weight. Although the number of flowers had a positive correlation with leaf dry weight and root dry weight, these correlations were not significant. Leaf dry weight, on the other hand, correlated significantly and positively with root dry weight and stem dry weight. Whereas root dry weight correlated significantly and positively with stem dry weight.

Table 6. Correlation among growth parameter of *Jatropha curcas* seeds planted at 6 cm

Parameters	2	3	4	5	6	7
1) Plant height	0.96*	-0.99**	-0.99**	0.87	0.99**	0.95*
2) Leaf area		0.96*	0.98*	0.98*	0.86	0.98*
3) Number of leaves			0.84	0.91	0.99**	0.98*
4) Number of flowers				0.83	0.85	0.96*
5) Leaf dry weight					0.99**	0.96*
6) Root dry weight						0.97*
7) Stem dry weight						

*, * *, significant at 5% and 1% levels, respectively.

Table 7. Correlation among growth parameter of *Jatropha curcas* seeds planted at 4 cm

Parameters	2	3	4	5	6	7
1) Plant height	0.98*	-0.99**	0.87	0.99**	-0.98*	0.97*
2) Leaf area		-0.99**	0.90	-0.99**	0.91	0.85
3) Number of leaves			- 0.96*	0.97*	0.96*	-0.96*
4) Number of flowers				0.96 *	0.86	0.95*
5) Leaf dry weight					0.91	0.99**
6) Root dry weight						-0.94
7) Stem dry weight						

*, * *, significant at 5% and 1% levels, respectively.

Table 8. Correlation among growth traits of *Jatropha curcas* seeds planted at 2 cm depth

Parameters	2	3	4	5	6	7
1) Plant height	0.98*	0.98*	-0.99**	-0.99**	-0.98*	0.96*
2) Leaf area		0.99**	-0.99**	-0.99**	0.71	0.80
3) Number of leaves			- 0.96*	0.97*	0.99**	-0.96*
4) Number of flowers				0.96 *	0.79	0.73
5) Leaf dry weight					0.96*	0.96*
6) Root dry weight						0.96*
7) Stem dry weight						

*, * *, significant at 5% and 1% levels, respectively.

4.1.6.2. Correlation observed among growth traits of 4 cm planting depth

From Table 7, plant height correlated significantly and positively with leaf area, the number of flowers produced, leaf dry weight and stem dry weight but significantly and negatively correlated with a number of leaves per plant and root dry weight. Leaf area on another hand, correlated significantly and positively with the number of flowers produced, root dry weight and stems dry weight but showed a significant negative correlation with the number of leaves and leaf dry weight. The number of leaves produced per plant had a significant positive correlation with leaf dry weight and root dry weight but showed a significantly negative correlation with the number of flowers produced per plant and stem dry weight. It was observed that the number of flowers produced per plant was significantly and positively correlated with leaf dry weight and stem dry weight. Although the number of flowers had a positive correlation with root dry weight, it was not significant. Leaf dry weight had a positive correlation with stem and root dry weight but only the correlation with stem dry weight was observed to be significant. Finally, Root dry weight correlated negatively with stem dry weight.

4.1.6.3. Correlation among growth parameter of *Jatropha curcas* seeds planted at 2 cm

Table 8 shows that plant height correlated significantly and positively with leaf area stems dry weight and number of leaves produced per plant but significantly and negatively correlated with the number of flowers, leaf dry weight, and root dry weight. Leaf area correlated positively with root dry weight, stem dry weight, and showed positive and significant correlation with the number of leaves produced per plant but had a significant negative correlation with the number of flowers and leaf dry weight. Apart from the positive correlation between leaf area and the number of leaves per plant, the correlation was also significant. The number of leaves produced per plant had a significant negative correlation with the number of flowers produced and stem dry weight but a significant positive correlated with leaf dry weight and root dry weight. On another hand, the number of flowers produced per plant correlated significantly and positively with leaf dry weight but positively with root and stem dry weight. Stem dry weight had a significant positive correlation with plant height and root dry weight but significantly and negatively correlated with leaf dry as well as the number of leaves produced per plant. Leaf dry weight was significantly and positively correlated with root and stem dry weight. While root dry weight also correlated significantly and positively with stem dry weight.

5. Discussion

5.1. Effect of Planting Depth on Early Growth and Development

The rate of emergence of seedlings varied with the depth of planting, with seeds at shallowest depth being the first to emerge and also having the highest emergence rate. These results are similar to those of [15] on the emergence of tomato seeds. [29] have also observed reduced survival of upland rice emerging from deep depths This can be attributed to the fact that shallow planted depth had easy access to enough aeration and water compared to seeds planted at a deeper depth. Also, restriction from topsoil was low hence, very easy for seedling emergence. Canopy size increased with increasing planting depth. Planting depth has been reported to play a tremendous role in determining the size of the plant. This result agrees with work done by [34] on turmeric (*Curcuma longa*). They examined the canopy size of tumeric when setts were pre-sprouted and planted at different depths. They found out that the canopy size of turmeric increased when setts were pre-sprouted and planted at different depths of 5, 6 and 7 cm. The present observation made may be due to the fact that 6 cm planting depth seedlings were able to exploit more nutrients from the 6 cm depth and beyond as compared to 2 and 4 cm. Unlike canopy size, the number of branches showed no definite relationship with planting depth. Research by [3] showed that environmental factors in combination with genetic and physiological factors play important role in branching of *Jatropha curcas*. The current result agrees with the findings of [3]. The trend for the number of leaves was similar to that of canopy size. This suggests that as leaf number increases and expands, canopy size also increases since canopy has a direct relationship with leaf number and it can be described in terms of the number and size of leaves as well as the number of branches on the plant. Different trends were observed for plant height at different growth stages until the 20th week where 6 cm recorded the highest. The 2 cm planting depth showed an initial higher plant height than that of other planting depths which were similar until the 14th week after planting. The variations in plant height due to planting depths can be attributed to soil temperature and moisture. [35] working on planting depth of rice indicated that those planted at 5 cm depth recorded the tallest plant measurement as compared to deepest planting of 8 cm. He attributed his findings to conditions such as soil temperature, moisture, and soil nutrients. High or low soil temperature affects root growth and development. Temperature decreases with soil depth [36]. Plant root and its length respond to soil temperature hence, in high soil temperature, root injuries and root elongation occurs and soil microbial activities, water, and nutrients uptake are enhanced. Similar observations were made by [37] that deep planting of apple seeds has been recognized as a means of reducing or eliminating problems such as heat injury to roots during summer and poor anchorage of grafted rootstocks. This suggests that there were variations in soil temperature at a certain growth stage within the soil and perhaps caused injuries to plant roots or affected its growth and consequently retarding their growth. In the case of 6 cm soil depth, since soil temperature decreases with depth, the roots of the 6 cm planting depths perhaps were able to utilize the suitable soil temperature at that depth to absorb more water and nutrients for growth. It has been reported by [38] that deeper planting of palms seeds provides better physical support and uniform height among palms of differing heights, indicating that shallow planting depths may bring about variations in plant height and poor anchorage among the shallow planting depths. *Jatropha curcas* seeds planted at a depth of 2 cm produced improved total leaf area, leaf area index (LAI), flowered earlier and had higher flower production than plants of 4 and 6 cm planting depths. Environmental factors and genetic factors play a vital role in plant growth and flowering. Environmental factors such as temperature, moistures, biotic factors, the supply of mineral nutrients, soil aeration and soil structure account for growth and development as well as the flowering of the plant. Variations in temperature within soil depths affect water and nutrient uptake by roots, the rate of absorption of which increases with an increase in temperature [20]. However, [20] in his studies on heat transfer in soil noted that there was a good relationship between soil temperature and root growth and absorption rate. This suggests that the higher total leaf area, leaf area index (LAI) and a number of flowers recorded by 2 and 4 cm as compared to 6 cm might be due to variations in temperature. As reported by [39] that suitable planting depth (4-5 cm) of cotton seeds seems to hasten to flower. All these factors perhaps caused more absorption of water and nutrients to enhance the leaf area and flower production. In all, the highest total leaf area, leaf area index and a number of flowers recorded by 4 cm planting depth suggest that variations in soil temperature and amount of nutrients might have contributed to the enhanced leaf area and number of flowers by 4 cm depth as compared to 2 and 6 cm.

In the case of leaf dry matter accumulation, 6 and 2 cm planting depth showed higher dry matter weight than the 2 cm planting depth. Dry matter accumulation is known to be a predictor for optimal yield and this was confirmed by the results of this study as the 4 and 6 cm planting depths recorded a higher number of flowers than the 2 cm planting depth. Hence, 2 and 6 cm planting depths have high chances of producing a higher yield at least during initial fruiting period. In a study of planting depth effects on potatoes grown from true potato seed, the planting depth had a significant effect on the dry weight of shoots, the total length of the stolons, and the number of tubers of plants [40]. Though the dry matter accumulation of 4 cm planting depth was slightly lower than the 6 cm planting depth, the LAI was higher than the other planting depths. Report by Moyo [41], indicated that deeper planting of above 5 cm reduces plant survival and root growth, increased water stress symptoms, and iron or manganese deficiency symptoms in the canopy of ornamentals. These results from *Jatropha curcas* were similar to those of [41] that deeper planting depth hinders the performance of plants.

6. Conclusions and Recommendations

6.1. Conclusion

Two sets of experiments were conducted to determine the effect of planting depth and age of transplant on growth and flowering of *Jatropha curcas*. Upon successful collection and analysis of data from both experiments, the following conclusions were drawn:

- Two centimeters (2 cm) planting depth proved to be the most effective depth to achieve high emergence rate while the 6 cm was the least.
- Two (2) and 6 cm planting depths were the best in terms of growth parameters and biomass production.
- In all, planting *Jatropha curcas* at 2 cm and 6 cm depths averagely yielded higher biomass in the experiments.

6.2. Recommendations

To achieve good growth and number of flowers, it is recommended that *Jatropha curcas* should be planted at 2 cm and 6 cm depths. It is highly recommended further study should be carried out to assess the effect of planting depth and age of transplant on yield.

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