Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), vol 12(2), 2024
http://dx.doi.org/10.7770/safer-V12N2-art789

Growth and yield of *Jatropha curcas* l. as influenced by different regimes of apical bud removal.

Crecimiento y rendimiento *de Jatropha curcas* l. influenciados por diferentes regimenes de eliminacion de la yema apical

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ABSTRACT

An experiment was conducted on the influence of time of apical bud removal on the growth and yield of *Jatropha curcas* which has low performance due to poor production practices. Removal of apical dominance by apical bud removal has potential to improve yield of plants. However, the capacity at which apical bud removal can improve growth and yield of *Jatropha curcas* has not been adequately explored. The effects of apical bud removal was assessed on growth in pots in a research garden, University of Ibadan and growth and seed yield were examined on the field, at 6, 10, 14 and 18 weeks after sowing in the Institute of Agricultural Research and training, Ibadan. A control (without apical bud removal) was used as check. The experiments were arranged in pot and field studies using CRD and RCBD, respectively replicated four times. Number of leaves, number of branches, leaf area(cm^2), dry weigh(g), days to flowering, days to fruiting, and days to fruit maturity and seed yield (g) were determined. Data were analysed using descriptive statistics and ANOVA at $\alpha_{0.05.}$ The results from the pot experiment showed that plants decapitated at 6weeks had significantly (p>0.05) higher number of branches (6.3), Leaf area (1647.6cm2) and Dry weight (245.0g) than control (1.8; 898.7cm2 and 188.5g, respectively) and other treatments. On the field, days to flowering and days to fruit maturity showed that control plants (220.5 and 310.3)flowed and produced matured fruits earlier thanplants decapitated at 6weeks (223.8; 314.3).This was followed by apical bud removal at10 weeks(230.0; 321.0) and apical bud removal at 14weeks (238.0; 321.0).Plants decapitated at18weeks were the last to fruits and matured (240.8; 323.5). Highest Seed yield was at D6 (75.8) and least in control (29.0). The results showed that apical bud removal at six weeks after sowing increased growth and seed yield *of Jatropha curcas.*

Keywords: Bio diesel, Crop improvement, apical bud removal, Environmental sustainability, *Jatrophas curcas.*

RESUMEN

Se realizó un experimento sobre la influencia del momento de remoción de las yemas apicales en el crecimiento y rendimiento de *Jatropha curcas* la cual presenta bajo rendimiento debido a malas prácticas de producción. La eliminación de la dominancia apical mediante la eliminación de las yemas apicales tiene potencial para mejorar el rendimiento de las plantas. Sin embargo, no se ha explorado adecuadamente la capacidad con la que la eliminación de las yemas apicales puede mejorar el crecimiento y el rendimiento de *Jatropha curcas*. Se evaluaron los efectos de la eliminación de las yemas apicales sobre el crecimiento en macetas en un jardín de investigación de la Universidad de Ibadan y se examinaron el crecimiento y el rendimiento de las semillas en el campo, a las 6, 10, 14 y 18 semanas después de la siembra en el Instituto de Investigación y Capacitación Agrícola, Ibadán. Como testigo se utilizó un control (sin eliminación de yema apical). Los experimentos se organizaron en estudios de campo y en maceta utilizando CRD y RCBD, respectivamente, replicados cuatro veces. Se determinó número de hojas, número de ramas, área foliar (cm2), peso seco (g), días a floración, días a fructificación y días a madurez de fruto y rendimiento de semilla (g). Los datos se analizaron mediante estadística descriptiva y ANOVA a α0,05. Los resultados del experimento en maceta mostraron que las plantas decapitadas a las 6 semanas tenían significativamente (p>0,05) mayor número de ramas (6,3), área foliar (1647,6 cm2) y peso seco (245,0 g) que el control (1,8; 898,7 cm2 y 188,5 g). , respectivamente) y otros tratamientos. En el campo, los días hasta la floración y los días hasta la madurez del fruto mostraron que las plantas de control (220,5 y 310,3) fluyeron y produjeron frutos maduros antes que las plantas decapitadas a las 6 semanas (223,8; 314,3). Esto fue seguido por la eliminación de las yemas apicales a las 10 semanas (230,0; 321,0).) y remoción de yemas apicales a las 14 semanas (238.0; 321.0). Las plantas decapitadas a las 18 semanas fueron las últimas en dar frutos y madurar (240.8; 323.5). El mayor rendimiento de semillas fue en el D6 (75,8) y el menor en el control (29,0). Los resultados mostraron que la eliminación de las yemas apicales a las seis semanas después de la siembra incrementó el crecimiento y el rendimiento de semillas de Jatropha curcas.

Palabras clave: Biodiesel, Mejoramiento de cultivos, remoción de yemas apicales, Sostenibilidad ambiental, *Jatrophas curcas*.

INTRODUCTION

The main sources of energy in Nigeria are fossil fuels such as petroleum and coal. However, various damaging environmental effects which include; air pollution, emission of greenhouse gases, and global warming have been attributed to the use of these energy sources. Therefore there is need to investigate alternative energy sources (Sharma and Ganguly, 2011; Zhang *et al.,* 2011).*Jatropha curcas* is a multipurpose, energy plant. It is a deciduous large shrub which can reach a height of 3-5 m. It has smooth gray bark, which exudes watery and sticky latex, when cut (Aker, 1997).In considering oil producing plants, *Jatropha curcas* has been recognized as the most suitable oil bearing plant species, because it has the ability to produce high amount of oil. In addition, *Jatropha* can control soil erosion and serve as habitat for wildlife, it is hardy early maturing and it's not a food crop unlike most sources of bio-fuel (Heller, 1996;Openshaw, 2002; Yammama, 2009).

Jatropha oil is an important product from the plant apart from other industrial and medicinal products. The oil produced by this crop can be easily converted to liquid bio-fuel. Biodiesel is a major substitute for mitigating greenhouse effects caused by prolongs use of fossils fuel. The fact that Nigeria has fossil energy reserves is not a good argument for its uncontrolled exploitation and fuel demand is projected to increase over the next decades (Demirbas, 2005; Harinder*et al*., 2009). The prices of fossil oil prices today are fluctuating unpredictably and may likely stay higher. To compensate for the demand, renewable energy resources should cover an appreciable part.

The first step towards bio-diesel production is the cultivation of *Jatropha curcas* trees to produce oil-bearing fruits (Achten *et al.,* 2008).Production of *Jatropha curcas* can be improved, if more researches are carried out on apical bud removal practices for optimum production.Apical bud removal is the removal of apical dominance in plant to enhance outgrow of lateral buds. Physiologically, apical bud removal induces new growth and enhances yield stabilisation in plants (Makueti *et al*., 2013). Apical bud removal and canopy management is a crucial crop architectural intervention which enhances branches production and induction of ample and healthy inflorescence, which leads to good fruit setting and seed yield (Yordanov*et al.,* 2008). It reduces plant height to facilitate harvesting of capsules in *Jatropha curcas* production. *Jatropha* cultivation is at its infant stage in Nigeria because of inadequate awareness on its inherent benefits, scanty information on the production and management requirements (Hussein *et al*., 2012)

Knowing the appropriate time to decapitate *Jatropha curcas* will improve the yield and other yield attributes and will be critical to canvas for the use of *Jatropha curcas* as a commercial crop.This research work was aimed to examine the effect o fapical bud removal on fruit yield of *Jatropha curcas* and to investigate the appropriate plant age for apical bud removal for optimum *Jatropha curcas* production.

MATERIALS AND METHODS

Pot experiment was carried out at the Crop Garden of the Department of Crop Protection and Environmental Biology (CPEB) University of Ibadan on longitude 7˚27`02.72``N,and latitude 3˚53`49.71``E, Elevation: 231m above sea level The field study was carried out at experimental site of Institute of Agricultural Research and Training, Moor Plantation Ibadan (IAR&T) on longitude 7˚22`38.13``N and latitude 3˚50`24.38``E, Elevation: 186m above sea level. Both sites are located in South-West region of Nigeria. Four different apical bud removal regimes were adopted: D6, D10, D14 and D18 (6, 10, 14 and 18 weeks after sowing) while control plants were not decapitated. The experiment was a completely randomized design replicated 4 times. Pots were filled with 5kg soil. Seeds of *Jatropha curcas* were sown at 2 seeds per hole at depth of 3cm. After two weeks thinning was done to have 1 seedling per pot. Weeding was done at 2 weeks interval, watering was carried out to maintain the soil at field capacity and white flies were controlled with Cypermethrin at the rate of 2L/ha according to manufacturer recommendation to prevent damage to the plant when infestation was noticed. Plants were decapitated (surgical blade was used to make a clean slant cut on the plant) from the topmost first 4 nodes of the plant the cut were made from the right hand side at angle 45˚. At 6 weeks after sowing growth parameters were assessed; Plant height (cm) measured with meter rule from the base of the plant just above the soil to the tip of the plant, stem girth (mm); measured with digital caliper placed at the base of the plant just above the soil. Number of leaves was recorded by counting the number of individual leaves on the plant and number of branches by counting the branches on the plant. Leaf Area (cm^2) was measured using Tayo and Togun (1984) method. At28 WAS, plant dry matter was obtained by setting in the oven set at 80˚Cto dry to constant weight.

The second phase of the experiment consists of field trial. The experiment was a Randomized Complete Block Design, replicated four times. A land area of 42×33m was ploughed, harrowed and mapped in to plot of size 6 × 6 m each. Plant spacing was 2×2 m and 3m within and between each plot; this gave a total of 16 plants per plot. *Jatropha curcas* seeds were sown and thinned to one seedling per stand. Weeding was carried as required and pest was also controlled. Apical bud removal was carried out as in the pot experiment at 6, 10, 14 and 18 WAS. Control plants were not decapitated. Plants were also decapitated as in the pot experiment. Four plants were selected randomly and tagged from each plot and growth parameters were assessed. At 28WAS, when a bud was noticed, the following phenology parameters were assessed: days to first flower formation, days to first fruit formation, days to first mature fruit formation. At fruit maturity when the fruit coat turned yellow, the following yield parameters were assessed: total number of matured fruits formed per plant, weight of fruit (g), number of seed per plant, weight of seed (g), seed husk weight (g), 100 seed weight (g), fruit length (cm), fruit breadth (cm), seed length (cm) and seed breath (cm). After harvesting plants were partitioned into leaves, stem and root and oven dried at 80˚C to constant weight to determine the dry weight. The collected data were analysed with analysis of variance (ANOVA) and significant mean were separated with Duncan Multiple Range Test at $\alpha_{0.05.}$

Plant with apical bud removal

RESULTS

No significant difference was observed in the plant heights before plants were decapitated at 6WAS, but significant differences were observed when the plants were measured at the completion of the experiment (28WAS) in pot. Plants from control treatment had the highest height of 133.25cm followed by 60.00cm from plants decapitated at 18WAS, there were no significant differences between apical bud removal at 18WAS and apical bud removal at 14WAS and 10WAS with values of 44.75cm and 41.25cm respectively, apical bud removal at 6WAS has the least height of 22.25cm (Table 1). The number of leaves showed no significant increase at the first 8WAS, starting from 10WAS, plant that were decapitated at 6WAS have the highest numbers of leaves (80.25) which was significantly higher from other treatment, similar trend was observed at 12WAS and 14WAS. At 16WAS apical bud removal at 6WAS still gave the highest numbers of leaves (83.00) but it was not significantly higher than apical bud removal at 10WAS (67.00), others were not significantly different from control. Similar trend was observed till 26WAS, where plant that were decapitated at 6WAS produced highest leaves of 136.50, this was not significantly different from apical bud removal at 10WAS (92.75) 14WAS (91.50) and 18WAS (86.00). Similar trend was observed at 28WAS. There was no significant difference in the stem girth throughout the period of observation. The number of branches was not significantly different from each other in all the treatments before apical bud removal (Tale 2). At 8WAS, plants that were decapitated at 6 WAS were significantly higher than all other treatment. At 10WAS decapitated plant at 6WAS had the highest number of branches (5.75) followed by those that were decapitated at 10WAS (3.50). Others were not significantly different from each other and control. Similar trend was observed at 14WAS. At 16WAS, plants that were decapitated at 6WAS still have significantly higher number of branches compared to control and other treatments (6.25). Followed by apical bud removal at 10WAS and 14WAS (3.75). Control plants had the least branches with no significant difference from plant that were decapitated at 16WAS (Table 2). Similar trend was observed at 18WAS. At 20WAS apical bud removal at 6WAS gave the highest branches (6.25) followed by apical bud removal at 10WAS (4.25) with no significant difference in their means. Control gave the least branches (1.75). Similar trend observed at 20 WAS was observed till 28WAS.In terms of leaf area (Figure 1), plants that were decapitated at 6WAP had the highest leaf area (1647.60) which was significantly higher than other treatment including control. The dry matter accumulation pattern showed significant higher difference in plants that were decapitated at 6WAP in the leaves dry weight, stem dry weight and root dry weight. Controls had the least leaves, stem and root dry weight which was significantly lower than other treatment (Table3).

On the field, the vegetative parameters followed a similar trend as it was observed in the pot experiment. Significant difference were not observed in the number of days to first flower formation, first fruit formation and first mature fruit formation across all the levels of treatment, although apical bud removal delay flower and fruit setting slightly(Table 4). The highest number of fruits was recorded on D6 (24.50) followed byD10 (21.75) and D14 (19.50) respectively, with no significance differences in their means. D18 recorded (16.75) which were significantly lower than all other treatment except control. Whereas control plants produced the least number of fruits (9.50) with significantly lower value than all other treatments (Table 5). The fruit weight was at same level with the number of fruit. Where D6, D10 and D14 had the highest weight with no significant difference between their means: 191.48, 186.66 and 175.20g respectively. D18 gave 160.66g while control gave

73.85g. The number of seed showed that D6 produced the highest number of seed (68.00), followed by D10 (62.00) with no significant difference in their means. Apical bud removal at 14WAS produced 54.00 which were not significantly higher than D10 and neither is it significantly higher than D18 that gave 48.25. Control recorded the least seed (25.75) which was significantly lower than all other treatment. In term of see weight; D6 has the highest seed weight of (76.83g) followed by D10 (70.06g), D14 has 60.28g which was not significantly higher than D10 also not significantly higher than D18 (54.27g). Control has the least weight (29.05g) which was significantly lower than all other treatments. The 100 seed weight showed no significant differences in the means among all the treatments. The husk weight showed that control has the least husk (44.77g) which was significantly lower than all other treatment that are statistically at same level with each other. The parameters; fruit length, fruit breath, seed length and seed breath recorded means with no significant difference among all the treatments used (Table 6).

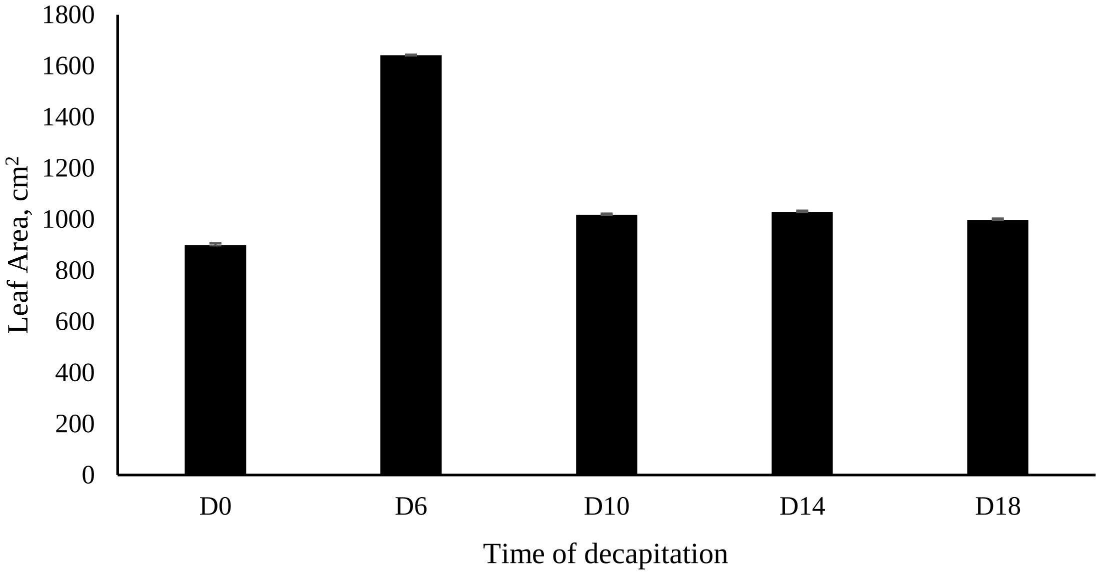

Figure 1: Effect of decapitation on leaf area in pot experiment

Table 1: Effect of apical bud removal regime on plant height (cm) of *Jatropha curcas* (pot experiment)

Treatment	Before apical bud removal	After apical bud removal
D0	24.47a	133.25a
D6	22.18a	22.25c
D10	26.23a	41.25bc
D14	25.38a	44.75bc
D18	25.85a	60.00b

Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), vol 12(2), 2024
http://dx.doi.org/10.7770/safer-V12N2-art789

Table 2: Effect of apical bud removal regime on growth parameters of *Jatropha curcas* (pot experiment)

Treatment	6WAS	8WAS	10WAS	12WAS	14WAS	16WAS	18WAS	20WAS	22WAS	24WAS	26WAP	28WAP
LeaveD0	18.00a	28.50a	39.25b	43.75b	44.75b	44.75b	51.50b	61.50b	63.50b	64.00b	62.50b	62.75b
D6	18.25a	42.50a	80.25a	84.00a	86.75a	83.00a	91.25a	122.50a	127.75a	133.75a	136.50a	138.5a
D10	26.00a	33.00a	44.25b	57.00b	62.50b	67.00ab	65.50b	70.75b	78.50b	89.75b	92.75ab	96.25ab
D14	20.25a	24.75a	39.50b	42.25b	44.25b	49.25b	71.75ab	71.75b	77.25b	83.00b	91.50ab	90.75ab
D18	26.5a	32.00a	40.50b	47.50b	47.00b	47.00b	67.50b	67.50b	67.50b	77.50b	86.00ab	86.5ab
D0	15.41a	18.49a	24.69a	26.30a	30.42a	32.28a	37.95a	37.95a	38.72a	40.30a	41.09a	42.02a
D6	16.56a	21.21a	25.96a	27.40a	30.63a	32.16a	38.69a	38.69a	38.76a	44.66a	45.72a	47.73a
GirthD10	16.83a	21.13a	27.22a	28.54a	32.28a	33.60a	39.63a	39.63a	40.34a	44.03a	44.85a	46.57a
D14	15.69a	19.62a	25.68a	27.10a	30.37a	32.54a	38.17a	38.17a	39.36a	42.52a	43.48a	44.83a
D18	15.67a	20.47a	26.78a	28.07a	31.31a	33.79a	33.79a	39.48a	40.16a	42.27a	44.52a	45.97a
D0	0.75a	0.75b	0.75b	0.75c	1.00c	1.25c	1.75c	1.75c	1.75c	1.75c	1.75c	1.75c
D6	0.50a	3.25a	5.50a	5.75a	6.25a	6.25a	6.25a	6.25a	6.25a	6.25a	6.25a	6.25a
BranchesD10	0.75a	1.25b	1.25b	3.50b	3.50b	3.75b	3.75b	4.23ab	4.25ab	4.25ab	4.25ab	4.25ab
D14	0.25a	0.25b	0.25b	0.50c	0.50c	3.75b	3.75b	3.75b	3.75b	3.75b	3.75bc	3.75b
D18	0.50a	0.50b	0.50b	0.50c	0.50c	1.25c	2.00c	3.75b	3.75b	4.7ab	4.75ab	4.75ab

Table 3: Effect of apical bud removal regime on dry weight (g) of *Jatropha curcas*(pot experiment)

Treatment	Leaf	Stem	Root
D0	41.65b	88.50b	58.46b
D6	104.56a	141.24a	86.01a
D10	66.81ab	128.95ab	78.39ab
D14	68.72ab	105.88ab	70.06ab
D18	59.91ab	107.47ab	73.71ab

Table 4: Effect of apical bud removal on phenological parameters of *Jatropha curcas* (Field experiment)

Treatment	Days to 1st flower formation	Days to 1st fruit formation	Day of 1st matured fruits formation
Do	213.00a	220.50a	310.25a
D6	210.75a	223.75a	314.00a
D10	224.00a	230.00a	321.00a
D14	228.25a	238.00a	321.00a
D18	233.75a	240.75a	323.50a

Table 5: Effect of apical bud removal on yield of *Jatropha curcas* (Field experiment)

Treatment	N0of fruit/plant	Weightof fruit(g)	N0of seed/plant	Weightof seed(g)	Seedhusk Weight(g)	100Seed Weight(g)
Do	9.50c	73.85c	25.75d	29.05d	44.77b	103.14a
D6	24.50a	191.48a	68.00a	76.83a	114.63a	114.25a
D10	21.75ab	186.66a	62.00ab	70.06ab	116.72a	97.03a
D14	19.50ab	175.20a	54.00bc	60.28bc	114.92a	110.94a
D18	16.75b	160.66b	48.25c	54.27c	106.38a	99.82a

Table 6: Effect of apical bud removal on yield attributes of *Jatrophacurcas*(Field experiment)

Treatment	Fruit length(cm)	Fruit breath(cm)	Seed length(cm)	Seed breath(cm)
Do	2.76a	2.13a	1.80a	1.12a
D6	2.67a	2.14a	1.77a	1.07a
D10	2.60a	2.16a	1.81a	1.10a
D14	2.66a	2.16a	1.81a	1.10a
D18	2.68a	2.13a	1.80a	1.10a

Mean having different letters among treatments are different significantly at $\alpha_{0.05}$ with DMRT

Where; D0 = No Apical bud removal; Dn = Apical bud removal at 6, 10, 14 and 18 weeks after sowing

Discussion

Source manipulation through apical bud removal plays an important role in diversification of food materials from source to sink leading to greater seed yield. Apical bud removal is a dwarfing process as there were no significant differences in all the *Jatropha curcas* heights before apical bud removal including control plants. In the cause of the experiment, it was observed that apical bud removal regimes adopted had significant effects on the plant height as plant height from base to the decapitated point were significantly short throughout the period of observation especially those that were decapitated at 6 weeks after sowing. The reduction in plant height observed on all the decapitated plants in the experiment confirms that apical bud removal is a dwarfing process. Wilson (2000) reported that apical bud removal reduces the total size of a tree and enhance early shoot branching. The reduction in height facilitate ease of harvesting and other silvicultural practices on the plants as, fruits of *Jatropha curcas* did not mature at the same time, requiring frequent picking.

This was also observed by Makueti *et al.* (2013), who reported that early branching of shoot reduced the total height of the tree and thus make harvesting of fruits and other silvicultural management easier.

Apical bud removal greatly influenced branching, as number of branches increased rapidly after apical bud removal in each case. This may be because the auxin in the apical meristem inhibiting the rapid growth and development of branches may have been removed. Branching in trees is a function of apical dominance and the correlative inhibition of axillary buds by the apical shoots and apical control suppresses growth of younger shoots (Leakey & Longman, 1986; Behera *et al.,* 2010). From the experiment, early apical bud removal enhanced *Jatropha curcas* performance better than latter regimes. This was in line with observation of Noggle and Fritz (1993), it was reported that an earlier removal of apical dominance in plant may explain the higher number of branch recorded when compared with apical bud removal at later date, also early apical bud removal induced auxiliary bud outgrowth in a vital mechanism whereby shoots are able to recover and continue normal growth and development. From the experiment, stem girth and leaf area follow the same trend as the branches. This affirms the findings made by Makueti *et al.* (2013) on African plum (*Dacryodes edulis).*They claimed that before apical bud removal, seedling height did not show significant variation. However, the number of branches, number of leaves and leaf area showed significant variation ($\alpha_{0.05}$). They concluded that *D. edulis* showed a synchronal shoot growth after apical bud removal.

Some phonological parameters like days to first flower formation, days to first fruit formation, and days to first mature fruit formation were not affected by apical bud removal significantly. However plants that were not decapitated at all attain reproductive stage earlier than decapitated ones. This may be attributed to time used in recovering from the wound of apical bud removal. Stefanov *et al.* (2011) reported that damaged shoot structure after apical bud removal is compensated by more flexible adjustment to the altered environmental conditions. The experiment revealed that apical bud removal has the strong effect on the individual plant productivity based on time of apical bud removal. Fruit yield and subsequent seed yield increased as number of branches and other vegetative parameter increases. This may be because the altered sink-source relationships in decapitated plants affect photosynthesis, thus producing the compensating effect which leads to increased plant fitness by redirecting the source to other part. This was in line with Tayo (1980, 1982) who stated that favourable seed yield responses have been observed when apical bud removal has been employed for a number of grain legume species.

The experiment further revealed that apical bud removal does not have effect on some parameters like: fruit length, fruit breath, seed length seed breath and 100 seed weight as decapitated plants were not significantly better than control plants.T his is corroborated by Decoteau (1990), who stated that characteristic feature of apical bud removal in plant development is that more shoot meristems are initiated and fully developed, bringing out fruit, this may increase harvest indices, but fruits may not have greater absolute weight compared to plant not decapitated. Apical bud removal enhanced the dry weight of *J. curca* especially when it was carried out early. This may be attributed to increase vegetative growth observed on the decapitated plants compared to control.

Conclusion

In conclusion, apical bud removal of *Jatropha curcas* in the experiment facilitated ease of harvesting seeds and other silvilcutural practices. It induced branching of the plant generally while early apical bud removal induced early branching. Apical bud removal improved number of leaf, leaf area, stem girth and plant dry matter accumulation. Some parameters like days to first flower formation, days to first fruit formation, days to first mature fruit formation, fruit length, fruit breath, seed length seed breath and 100 seed weight were not affected by apical bud removal regime significantly. Fruit and seed yield were all significantly positively influenced by apical bud removal at six weeks after sowing.

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Received: 02th November 2023; Accepted: 06th January 2024; Distribution: 10th February 2024.