

# Determination of the Upper Limit Age of *Jatropha Curcas* Plantation for Optimum Yield Production

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## ABSTRACT

*Jatropha curcas* (L.) provenances were grown to determine the upper limit age for maximum seed yield production. The study had been conducted at Shewa robit district in the lowland areas of the North Shewa zone. In this study, fourteen *Jatropha curcas* provenances had been collected from different parts of Ethiopia. Sixteen plants per plot had been planted in a randomized complete block design with three replications. The survival rate, number of branches, seed yields and growth parameter data had been collected from those plants. Survival rate ranged from 85-100%; root collar diameter was ranged between 11.80 cm and 13.51 cm at the age of six years. The maximum and minimum plant heights were 281.96 cm and 233.88 cm, respectively, at the age of five years after planting. Those different traits of *Jatropha curcas* indicated that statistically insignificant difference ( $p > 0.05$ ) except the seed yield of Cheffa provenance was significantly highest at the age of four years. The maximum seed yield (cheffa) was 38.837 ton/ha/year, and the minimum was 9.016 ton/ha/year (Jewuha) within the same year. All *Jatropha curcas* provenances seed yield was maximum at the age of four years and declined after six years of age.

**Key words:** Growth parameter, *Jatropha curcas*, provenances, survival, yield

## INTRODUCTION

The increasing global demand for energy and recognition of limitations in the availability of the crude oil supply has resulted increase in crude oil prices, and will continue to do so. Due to severe energy crises and rising petroleum prices, developing alternate energy sources, especially biodiesel are gained attention (Ragauskas *et al.* 2006; Tilman *et al.* 2006; Kumar and Sharma, 2011) Population growth, urbanization and industrialization dramatically increase the need for energy. At the same time, the society is aware of the environmental concerns of fossil oil and depletion of fossil oil. Due to these issues, an alternative energy source such as biodiesel from nonedible oil sources which has less effect on the environment has gained momentum (Agarwal *et al.*, 2013; Atabani *et al.*, 2013).

Biodiesel can be produced from nonedible oils such as *Jatropha curcas*. *Jatropha curcas* is a perennial and drought-resistant large shrub plant that belongs to *Euphorbiaceae* family native to tropical American. But it also grows in tropical areas in different climatic zones as a hedge, or commercial plant (Jongschaap *et al.*, 2007; Kumar and

Sharma, 2008). *Jatropha* oil is nonedible plant oil that has great potential for alternative diesel fuel. Its property is like methyl ester and resembles diesel fuel and can minimize carbon dioxide emission to the atmosphere (Wardana 2010).

*Jatropha curcas* starts producing seed in twelve months after planting. Low production report on young *J. curcas* plantations (1 -2 years age) comes recently. Based on *Jatropha* crop management, soil nutrition and availability of water presently, production shows that seed yield ranges from 0.6 to 4.1 tone ha<sup>-1</sup> /year can be harvested. Projections show mature *Jatropha* crops could give up to 7.8 tone seed ha<sup>-1</sup> if site conditions are good and without diseases incidence (Jongschaap *et al.* 2007). In most cases, *Jatropha curcas* reaches maximum productivity level after 4 to 5 years (Shyam, 2008). Similar findings reported by Jongschaap *et al.* (2007) indicated that *J. curcas* might fully mature and reach full production about 3-4 years of age after planting. Experts and literature show, in optimal environmental situation, the current genotypes can give up to 5 tones dry seed yield/ha/yr for mature *Jatropha* plants (Achten *et al.*, 2008).



Some research findings show that dry seed yield /ha/year increases up to seven and a half years. After seven and a half years, *Jatropha* gives nearly similar yields (Kim and Dale; 200). Some reports also showed there is a decrease in productivity for old *Jatropha curcas* stands (Jongschaap, Corré, *et al.* 2007). The low production may be related to diseases attach especially fungus. Nevertheless, in Ethiopia, up to now, there is no single documented and scientific proof available as to what age is the yield of *Jatropha curcas* increases at maximum. Knowing the age of *Jatropha curcas* to give optimum yield is necessary in to manage the tree properly and enhance investors to invest in *Jatropha curcas*. The objective of this study was to determine the upper limit age of *Jatropha Curcas* for maximum yield production.

**MATERIALS AND METHODS**

**Description of the study site**

The research has been done at Shewarobit, Kewot district. Shewarobit is located at 10° 5' 32" N latitude and 39° 54' 51" E longitude. The altitude of the study area is 1260 m.a s.l. The minimum annual rainfall of the site is 868mm, and the maximum annual rainfall reaches up to 1386mm. Temperature ranges from 14.2 to 30.1 (Gessesse *et al.*, 2015). There has been a bimodal type of rain with short rain between March and April and rain between June and September (Atlaw, 2018). Sorghum, teff, mung bean and maize are the dominant crops grown in the area. In addition, also, horticultural crops and vegetables are grown widely (Tsegahun *et al.*, 2015). The soil texture of the study area is clay with a strong coarse sub angular blocky structure. This soil has a consistency that is hard when dry, friable when moist and sticky and plastic when wet. The soil depth is more than 150 cm. The surface soil has a pH value of 7.9, which is moderately alkaline. The organic carbon and total nitrogen contents of the surface horizon is 1.796% (low) and 0.199% (medium), respectively. The available phosphorous content of the surface horizon is 23.4 ppm (very high), and ranges from 1.74 to 6.44 ppm in subsurface horizons (very low) (Esayas *et al.*, 2006).

**Experimental Design and Data Collection**

Seeds had been collected from *Jatropha curcas* populations growing areas in Ethiopia. Fourteen *Jatropha curcas* provenance seeds were collected and sown at Shewarobit nursery site. The grown seedlings from these provenances were planted in 6 m x 6 m plot of land during July 2009 using randomized complete block design (RCBD) with three replications at Shewarobit site. The spacing between trees was 2 m, the spacing between blocks and plots were 2 m and 3 m, respectively. The Survival rate, seed yield, number of branches, and plant growth parameters such as height, root collar diameter had been collected from inner (non-border) individuals.

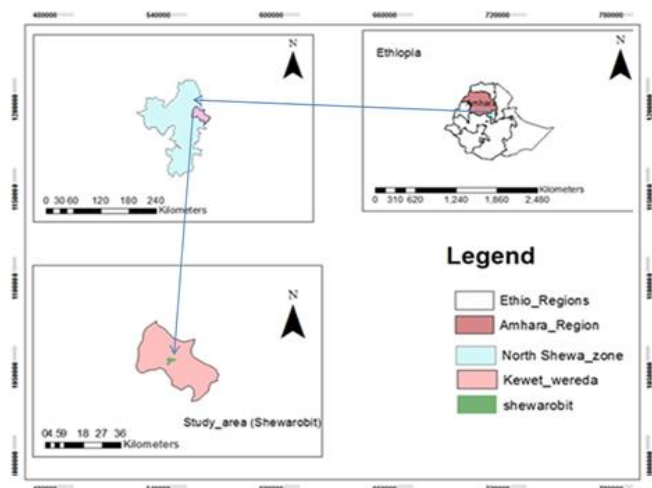


Figure 1. Map of the study area

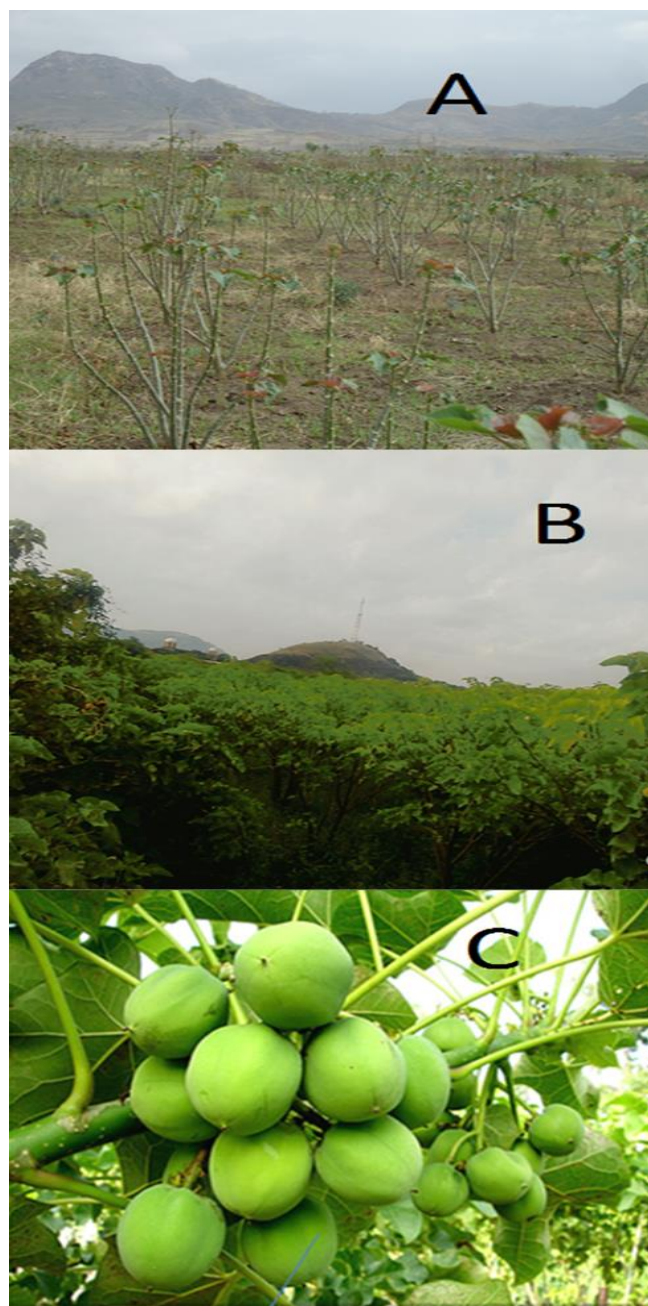


Figure 2: Experimental *Jatropha* plantation during the dry season (A), during the rainy season (B) and at fruit setting period (C)

**Data Analysis**

A one-way analysis of variance (ANOVA) was performed through SPSS version 20 and SAS version 9 to assess variations among provenances in different ages ( $\alpha \geq 5\%$ ). Pearson correlation analysis was also had been used to relate seed yield with different parameters.

**RESULTS AND DISCUSSIONS**

**Survival Rate**

Except for the three provenances (Jewha, Yellen, and Togo), survival rate was higher (above 86%) for all provenances. Except Cheffa and R2-004 provenances, there was mortality observed in other *Jatropha* provenances. In this study the survival rate ranged from 85% to 100%, other studies also showed that *Jatropha* could be survived successfully in tropical African's semi-arid regions where the climate is harsh, and soils are relatively poor in physical and chemical quality (Ngethe R., 2008). This means that these species can be easily had been cultivated in marginal land, which is not suitable for food crop production.

**Plant height and root collar diameter**

The growth rate had been varied greatly by source; for example, at the age of 1 year, tree height was 93.51cm with root collar diameter 4.41cm for source Togo provenance. On the other hand, only 137.39 cm height with root collar diameter 5.71 cm was recorded at one year of age for source Cheffa provenance (Table2& Table 3). At the age of four years, the growth of *Jatropha* provenances average tree height, and root collar diameter were 191.32 – 249.39 cm and 9.31 -11.5 cm, respectively. At the age of six years, the root collar diameter and plant height of 14 provenances ranged from 10.18 to 13.51 cm and 164.50 to 281.67 cm, respectively, and an average size of 12.59 cm in root collar diameter and 244.91 cm in height (Table 2 & Table 3).

Table 1: Root collar diameter (cm) of *Jatropha Curcas* provenances at different years after planting at Shewa robit

Provenances	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Assossa	4.99	7.69	9.53	10.35	10.17	12.53
Meiso	5.23	7.48	9.21	10.55	11.4	13.51
Jewiha	4.89	7.07	8.78	10.05	10.46	13.06
Cheffa	5.71	7.97	9.73	11.54	12.06	13.51
Mersa	5.05	7.53	9.57	10.84	11.22	12.87
R2-004	5.04	7.27	9.06	10.49	10.49	12.92
Mali	5.01	7.56	9.44	10.9	11.68	13.19
R3-002	4.79	6.96	9.16	10.71	10.73	13.18
R3-004	5.19	7.58	9.47	10.76	10.56	11.94
R2-003	4.64	7.2	9.04	10.34	11.2	11.8
R1-012	4.73	7.1	9.02	10.44	10.64	12.95
R1-009	5.11	7.58	9.43	10.78	11.45	12.08
Togo	4.41	6.26	7.98	9.39	10.06	12.63
Yelen	4.31	7.19	9.33	11.55	12.39	10.18
Level of sig. (0.05)	Ns	Ns	ns	ns	ns	ns

Table 2: Plant height (cm) of *Jatropha curcas* provenances at different years after planting at Shewa robit

Provenances	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Assossa	116.49	182.11	215.75	230.25	242	164.5
Meiso	115.86	170.31	205.41	226.49	236.83	247.08
Jewiha	118.43	170.69	197.99	222.99	242.35	265.56
Cheffa	137.39	187.85	220.65	249.39	281.96	281.67
Mersa	115.52	166.42	198.54	221.82	246.5	255.83
R2-004	126.35	174.66	201.83	219.98	233.88	271.42
Mali	116.61	174.13	210.44	238.18	247.11	237.67
R3-002	117.72	166.72	192.65	224.04	238.46	273.19
R3-004	135.96	186.81	210.85	225.07	240.71	245.42
R2-003	114.09	168.65	201.97	219.39	236.81	228.33
R1-012	119.06	167.19	194.39	213.2	244.25	246.25
R1-009	132.79	182.9	213.27	234.15	258.17	228.06
Togo	93.51	143.21	173.1	191.32	214.42	231.25
Yellen	94.99	154.16	195.21	227.86	261.75	252.5
Level of sig.(0.05)	Ns	Ns	ns	ns	ns	ns

There were not significant differences between *Jatropha* provenance height in over the ages, which are nearly constant after five years of planting and never measured after six years old age of those provenances.

**Seed yield Production**

*Jatropha curcas* had been started seed set at has three years ago after planting at Shewarobit lowland area Ethiopia. Cheffa provenance has the highest seed yield at four years old of the *Jatropha* plant. Seed yield production showed significant variation between *Jatropha* ages. This seed yield was significantly highest than other provenances. There were not any other significant differences between provenances over the ages (Table 3).

Table 3: *Jatropha curcas* provenances seed yield (ton/ha./year) at different ages after planting at Shewa robit

Provenances	age 3	age 4	age 5	age 6	age 7	age 8	age 9
Assossa	0.203	27.52b	0.901	4.207	0.958	1.449	3.846
Meiso	0.002	12.00c	4.758	2.526	1.61	3.994	8.733
Jewiha	0.052	9.016c	2.641	2.664	1.762	1.292	4.263
Cheffa	0.068	38.83a	4.184	8.033	2.304	3.323	4.908
Mersa	0.029	19.45bc	3.916	4.927	2.758	3.471	4.454
R2-004	0	17.60bc	3.189	4.089	1.589	3.635	4.142
Mali	0.007	15.65bc	2.678	2.211	1.203	1.769	2.646
R3-002	0.123	11.88c	4.077	3.404	2.182	0.916	4.908
R3-004	0.026	19.05bc	5.554	2.649	1.127	1.927	2.75
R2-003	0.001	11.19c	3.038	1.873	0.803	1.942	2.146
R1-012	0.03	15.01bc	4.003	4.781	2.091	3.527	2.967
R1-009	0.011	10.39c	4.522	4.379	2.475	0.762	3.333
Togo	0.029	11.24c	2.544	2.597	1.178	1.539	2.679
Yelen	0.049	20.55bc	3.476	5.784	1.991	3.096	4.275
Level of sig.(0.05)	ns	**	ns	ns	ns	ns	ns

The seed yield of *Jatropha* depends on many different factors, like the genetic material used for propagating the *Jatropha* plants, the agro-ecological conditions, the number of nutrients, and water (Rijssenbeek, 2010). Franken (2010) stated that *Jatropha* provenance seed yields could differ between 0.25 and 6 tons per hectare per year, depending on water supply, and soil fertility. The

most normal seed yield is assumed to be between 0.5 and 3.5 ton/ha/year. In this study, the mean *Jatropha* seed yield ranged between 19.28 ton/ ha. /year and 2.49 ton/ha/year at the age of 4 and 8 years of *Jatropha*, respectively. After four years of *Jatropha*, the seed decreases for all provenances. A research done in India on the effect of Nitrogen(N) and Phosphorus(P) fertilizations on the *Jatropha* yields shows that the *Jatropha* seed yield is significantly influenced by N and P<sub>2</sub>O<sub>5</sub> fertilization and that fertilization of *Jatropha* promotes growth and yields (Patolia et al. 2007). Contrary to this study (Ouwens et al. 2007) confirmed that *Jatropha* yields increase with age after four years.

Different scholars showed that from the time of plantation, *Jatropha* could produce seed yield in 2 years, and full yield is obtained after five years up to 50 years and a single tree provides 5 kg seeds. According to (Achten et al., 2008), *Jatropha curcas* can produce 4-5 tons of dry seeds per hectare per year as a reasonable yield estimate for a well-managed plantation with good environmental conditions. Even under adequate rainfall, irrigation may be required for the first three years to help plant establishment (Reinhardt et al., 2008). If well managed, *Jatropha* starts producing 4-5 kg of seeds per tree from the 5th year onwards, and the plant has a durability of 40-50 years (Banapurmath et al., 2008; Singh et al., 2008). It can be produced seed yields on average about 3.5 t/ha/year, and when grown under rain fed conditions in wastelands, yields of 1-1.25 t/ ha/year are common (Kumar et al., 2003)

**Jatropha branches and pods**

Cheffa provenance has relatively highest branches per plant (8.89) than other provenances, while Togo provenance is the least branched (5.27). Similarly, Cheffa provenance sets a relatively highest number of seeds per individual pod (2.70) than other provenances, whereas Yellen provenance sets the least number of seeds per pod (2.33) (Table 4).

Table 4: *Jatropha curcas* provenances number of branch /plant and number of seeds/pods of the study population at Shewa robit

Name of provenances	No. branch/plant	No. seeds/pod
Cheffa	8.89	2.70
R1-009	6.02	2.53
R3-004	6.98	2.50
Mersa	6.93	2.56
R2-004	6.22	2.50
Meiso	6.45	2.50
R3-002	6.72	2.53
Jewiha	6.86	2.65
Assossa	6.19	2.55
R1-012	6.24	2.43
Mali	5.96	2.46
R2-003	5.80	2.46
Yelen	5.70	2.33
Togo	5.27	2.60
Level of sig.(0.05)	Ns	ns

Franken (2010) indicated that *Jatropha*, in 4-5 years old, should have about 200- 250 lateral branches after good pruning and good growth. In this study, all *Jatropha* provenances were not pruned and had about 8.89 to 5.27 main branches that emerged on the main steam at eight years old.

**Relationship of height, RCD and seed yield with selected *Jatropha curcas* morphological properties**

Simple correlation analysis had been carried out for selected physic nut morphological properties with plant height, seed yield, number of branches per plant, and number of seeds per pod (Table 5). *Jatropha* tree height is significantly correlated with RCD (R=0.55, p<0.001), seed yield (r=0.589, p<0.01), meaning that seed yields increase with tree sizes. However, number of seeds per pod is not significantly correlated with the tree height, seed yield and RCD. This means that the biggest *Jatropha* trees could be given higher seed yield without sinking the number of seed per pod (Table 5).

Table 5: The relationship between some selected *Jatropha curcas* morphological parameters with plant height, seed yield and number of branches per plant at Shewarobit district, Ethiopia

	Height	RCD	Seed yield	No. of branch /plant	No. of Seed/ pod
Height	1				
RCD	0.855***	1			
Seed yield	0.589***	0.545***	1		
No. of branch /plant	0.649***	0.687***	0.478***	1	
No. of seed /pod	0.131*	-0.012	0.308*	0.125	1

**Relationship of *Jatropha* yield and annual rainfall**

*Jatropha* yield was poorly related to annual rainfall.

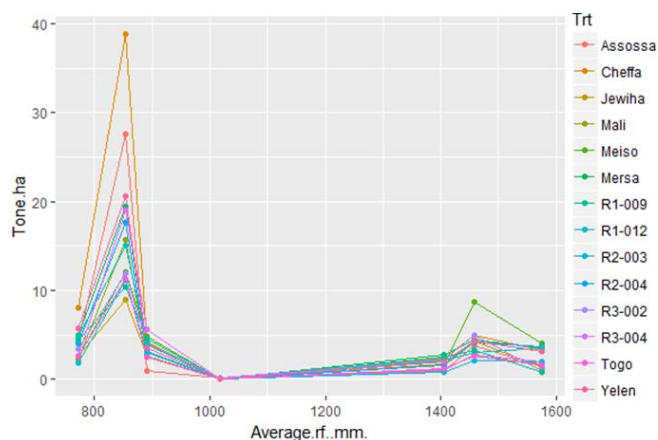


Figure 3: Relationship between *Jatropha* provenances and annual rainfall at Shewa robit district

Yield is a function of water, nutrients, heat, and the age of *Jatropha* plant, and many different methods of establishment, farming, and harvesting are possible. *Jatropha curcas* has mainly evolved for xerophytic

adaptation and is naturalized in the seasonally dry tropics, particularly in the southern hemisphere, where there is no severe and prolonged frost (Xu *et al.*, 2012). It grows well with 600 mm of rainfall per year or more. Deficit irrigation and salinity stress significantly reduced the growth and leaf development of greenhouse-grown *Jatropha* plants (Niu *et al.*, 2012). Land use impact is one of those that is rarely affected *Jatropha* yield production; However, flows of land area, water, vegetation, and biodiversity are certainly as important for the viability and sustainability of production systems occupying substantial portions of land (Mattsson *et al.* 2000; Lindeijer *et al.*, 2002; Wagendorp *et al.*, 2006; Garcia-Quijano *et al.*, 2007). In this study, the annual rainfall was sufficient for *Jatropha* yield production in all years. Therefore, the yield did not depend on that rainfall extent in Shewawrobit site Kewot district.

## CONCLUSION AND RECOMMENDATION

We can be concluded that *Jatropha curcas* is fast growing and high seed yielder tree. Among fourteen *Jatropha* provenances tree height, root collar diameter, number of branches per tree, number of seed per pod, and seed yields does not vary between provenances in all ages of *Jatropha* except seed yield at age four, which is significantly varies both between years and among provenances. Even if there were no significant differences among provenances, Cheffa, Meiso, Mersa, and Yelen sources were recommended for further plantation since these provenances can produce high seed yield than others. Further study is needed to determine the effect of *Jatropha curcas* on understory crops and soil characteristics.

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