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Provenance Evaluation of Jatropha curcas L. in Lai Birr Farm (Jabe Tahinan District) Western Amhara Region

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Abstract
The experiment was conducted in Jabe Tahinan District 5 year old, from year 2008 to 2012 West Gojam Zone, Lai Birr Alamudin Farm, is located in northwestern part of Ethiopia. This study was carried out with the objective of evaluating the adaptability and characterization of provenances from oil content point of view and selecting appropriate provenances for the trial site agro ecological condition.Six provenances of *Jatropha curcas* from different agro-climatic locations of Ethiopia(Mersa, Metema and Shewarobit) and three introduced from abroad(Mexico, India and Tanzania) were grown in randomized block design; that differed in morphological characteristics, were studied**.** There is no significant differences, (P>0.05) occurred among the provenances for growth performances (height and diameter increment). At present the effect of spacing, canopy management and crown form and surface on the yield is not known, but there were no significant differences among parameters crown diameter, primary and secondary branches as well as inflorescence numbers and yield.Seed yield of the provenances ranged from 215.0 to 1164.0g/plant with an average of 556.0gm/plant, indicating varietal difference among means.In general the study revealed that considerable variations existed among provenances for except collar & crown diameter, and 100 seed weight means. There were significant differences (P<0.05) in seed oil yield among provenances (accessions). The top ranking oil yielder: Mexico (A1) closely followed by Shewarobit & Metema differed significantly with all the remaining provenances. The LSD test also revealed that maximum collar & crown diameter, fruit and seed yield/per plant were important oil yield parameters. Selection of these characters may help in indirect selection of high oil content yielding provenances.Maximum 100 seed weight was recorded in seeds collected from Tanzania (C1) and the least weight was recorded in India (B1) and Metema. The maximum oil yield obtained from Mexico (A1) provenance was 45.67% with high fruit and seed yield/plant, collar and crown diameter attributing parameters. Therefore, from test results, it can be used A1, Shewarobit and Metema for establishment of seed orchard and delivered to end users for successful use of biodiesel production, respectively. In addition, the results may trigger interested farmers and other stakeholders for cultivation of *J.curcas*. But much more research is required on propagation, quality of planting material (potted or bar root or direct planting), amount and frequency of irrigation, type and amount of fertilizers, spacing, pruning, diseases and insect pests identification, control measure for powdery mildew and termites attack should be devised soonest to realize full potential yield of *J.curcas* and training needed for oil processing.
Keywords: Jatropha curcas, %, growth parameter, morphological character, provenances

Introduction

World dependent on diesel fuel (None-renewable) mineral resources and the price of mineral fuel particularly diesel is a huge burden and has reached beyond a point where most Ethiopians cannot afford (Wolde-Ghiorgis, 2002). Hence, the government of Ethiopia is involving foreign and local companies for the production of particularly castor and physic nut to some extent other oil crops. Some companies have shown interest to be involved in palm production (Energy Conference, 2002). Not only large companies but also small farmers can be involves almost half the population (41%) was living in very severely degraded land which forms 10% of the overall area of the country (FAO, 2005). In Ethiopia, around 90% of the population lives in degraded areas where agricultural productivity is reduced (S. Bach, 2012).

Ethiopia imports one billion liters of diesel fuel per year. It is assumed that this amount of diesel fuel can be produced by involving 1 250 000 farmers in the production of physic nut. However, the government assumes that this amount can be increased for export by involving farmers and large commercial farms. The by-product remaining from bio fuels can be used as fertilizers as well as glycerol. In Ethiopia one liter of physic nut oil can be produced at cost of 0.45-0.76 Dollar. If one liter of physic nut oils are sent to Germany it costs 0.575 to 0.885 Dollar for transportation. The costs of one liter of physic nut oil are indicating that these crops can be used for local mineral diesel substitution as well as export.

The government of Ethiopia has developed bio fuel development strategy which is coordinated by Ministry of Energy and Mines.. Bio fuels include fuel wood, biogas, bioethanol and biodiesel. The strategy stresses that Castor, physic nut, palm, and gomenzer are the priority crops. The seed yield of physic nut varies from 10 q/ha on marginal fields to 20 q/ha on intensive management with about 30% oil in the seed. Therefore, 3 to 5 q/ha of oil can be harvested from physic nut. Ethiopia has huge genetic resources of physics nut almost any desired

genotype can be selected out of the germplasm. Small scale farmers or large farmers with intensive management can grow physic nut as hedges.

Jatropha curcas Linn (Physic nut or Ratanjot) is a tree-borne oil seed crop comprising 160-175 species (Dehgan and Webster, 1979). It is native to Tropical America and belongs to family Euphorbiaceae. *J. curcas,* is a small tree or large shrub which can reaches a height of 3-5m and has an annual seed yield of up to 5 t per hectare (Raina and Gaikwad, 1987; Heller, 1996).

Jatropha grows in the so called "Jatropha Belt" which has an extent from 30° North to 35° South (Jongschaap et al. 2007). Jatropha (Physic nut) is also found in moisture stressed growing areas of Ethiopia. Recent assessment (2006) showed J.curcas found in different growing areas of amhara national regional state. In eastern amhara such as Kobo, Habru, Kalu, Bati, Dawa Chefa, Artuma Farsi, Antsokia, Efrata Ena Gidi, Kewt, Merha Bete, and kemissie. Especially, in the region of the town Bati, a lot of farmers are using this plant for several years now, first as hedges and more and more as soil and water conservation technologies (S. Bach, 2012). In other regions such as Goffa, Arba Minch, Tibila, North Shoa,Pawe, Arba Minch and other sites. It adapts well to semi arid marginal site, waste land and dry environment and animals do not browse its leaves.

Jatropha has evoked many researchers in comparison to other oilseed crop because of its better adaptation to a wide range of environment especially to semi-arid marginal sites, its oil can be processed for use as a diesel fuel substitute and for erosion control, low cost of seeds, high oil content, small gestation period and smaller plant size that makes the seed collection easier.

The seed weighs about 0.75g, contains 30-32% protein and66% lipid (Liberalino *et al., 1988)* indicating good nutritional value.

Until now this crop has not been fully domesticated. Success of commercial cultivation of Jatropha is much dependent on use of high yielding provenances instead of low-yielding local and exotic provenances; therefore selection of improved ones of this crop is quite indispensable to develop high-yielding provenances. Selection of high yielding provenances depends on the environmental conditions they grow.

Therefore, the major objective of the bio fuel strategy and study are to select better oil yield provenances for import substitution as well as export. It stresses to substitute mineral oils that are being imported with locally produced biodiesel.

Objective

To evaluate the adaptability and characterization of different provenances from oil content point of view
To select appropriate *Jatropha* provenances for the trial site agro ecological condition

Materials and methods

Description of study area

The experiment was conducted in Lai Birr farm development (Birshleko) 5 year old, from august 2008 to January 2012 started on 1st week of August 2008 (West Gojam Zone, Lai Birr Alamudin Farm, is located in northwestern part of Ethiopia with coordinates 10 º41'53"N, 37º10´35"E. It is found at a distance of 13 km from nearby city Mankusa, 24 km from Finoteselam, east of, Bahir Dar the capital of amhara national regional state (ANRS).

According to meteorological data of Lai Birr, the monthly mean maximum and minimum temperature of lai birr recorded between 2003 and 2004 indicated an average range of 19.5 ^{o}C – 24.8 ^{o}C. The highest mean monthly maximum temperature occurs in April (about 23.6 ^{o}C), whereas the lowest mean maximum is in October and December about 19.5 ^{o}C (Lai Birr metrological data, 2003). The area is experiencing the highest temperature, around the months (April 35.8 ^{o}C) and the minimum 8 ^{o}C in the coldest month (January) of the year. The mean annual precipitation recorded at Lai Birr Station is 1020mm. High rainfall months of the season are between June and September. There is a significant seasonal variation of rainfall. Almost 60.3percent of the annual rainfall occurs in July and August with a maximum mean value of 192.9mm (Lai Birr planning and programming division office, 2004).

The altitude of Lai Birr farm ranges from 1,600 to 2, 040m above sea level (asl). The farm is characterized by little slope difference so that the farm is suitable for cultivation and the soil is characterized by red brown soils (silt and clay) in farm areas.

According to Lai Birr farm manager, the population of birr farm (upper and lower) is estimated to be over 10,000 (lai birr office. 2004). Total 3040 employers live in lai birr farm, among these 1711 male and 1329 female households engaged in different jobs.

Total land area of lai birr farm is 8851 hectare (ha). Lai birr is a place where different farm development activities have been carried out and therefore different land use types were existed. The dominant land use type is crop land (7673ha productive lands), 292ha Unproductive lands covered by plantation and forestry and 496ha gully areas. In addition, 390ha residential, offices, stores, schools and roads are also categorized as infrastructural areas (Lai

Birr Office, 2004).

Methods

Source of Provenances

Among the six jatropha provenances: three different provenances had been collected from Ethiopia and three, which are introduced from different countries included in the treatment. Among the six provenances three exotics come from Mexico (A1), India (B1) and Tanzania (C1) and three locally collected provenances was conducted from *Jatropha curcas* growing areas of Ethiopia, namely: Metema, Shewarobit, Mersa (hereafter referred to by their origin local names) were found in jatropha growing area of Amhara region collected by the Institute of Amhara Agricultural Research (ARARI) with the collaboration of BoARD.

Experimental Design

The predetermined targeted sample was conducted in a randomized block design with three replications and planted at 2m distance between the plants in a plot, 2.5 m distance between the plots in a block and 3 m distance between the blocks with a plot size of 10mx10m. 25 plants are found per plot (0.01ha), and the experiment has been replicated three times (75seedlings per species and total 450per site) and with a density of about 2,500 plants per hectare.

For planting 1 hectare, around 5 to 6 Kg. of seed is enough. The distance between the two rows should also be 2meters. This spacing will accommodate 2500 plants/ha. The trial site covers about 0.18hectare (60.5m x 30m).

Plant growth experiment

With estimated ranges 3-5months old healthy seedlings of *J. curcas* were transported and transplanted to the experimental plots. The plants were weeded in every 3-6 months range depending on rain fail that enhance weeds, and for avoiding free grazing damages particularly boundary plants excluded in the sample.

The survival rate and growth of plants (height, root collar diameter and pest problems) in each plot was recorded after a growth period of 6 months.

Parameter Measurement Techniques

The height of the ten sampled tree was recorded with the help of measuring wooden meter, employed for this purpose. Collar diameter was recorded with the help of measuring caliper. Crown spread was also measured in tape meter and recorded. Jatropha fruits harvested only by hand, no machines used. From each 5sampled trees in each plot were counted and the matured ones harvested for weight measurement as well as oil analysis during September 2012.

The seeds were separated from the fruit which is moist, cleaned by hand and stored in plastic bags at laboratory conditions. Thus seeds collected from 6 provenances were submitted to Essential oil research centre in Addis Ababa in 2011 (figure 4). The primary branches which were bearing at least one functional secondary branch were counted separately in five sampled plants and the average value was recorded as number of primary branches per plant. It was recorded in the month of August 2012.

Analysis of growth performance, morphology and oil content

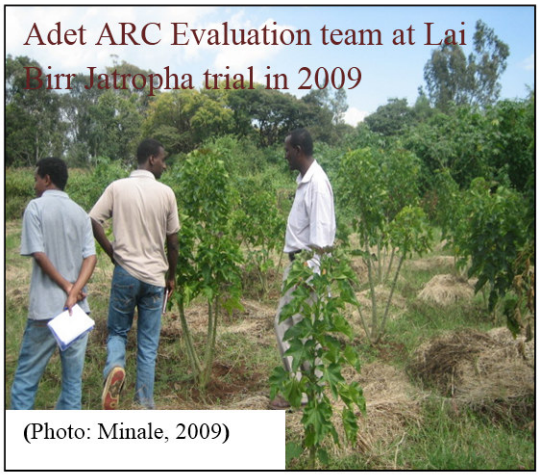
The data of growth and dry matter yield of plants under different treatments was analyzed by using MS Excel for statistical analysis.

The seedling growth parameters mainly height abbreviated in (HT), diameter considered as root collar diameter (RCD).

Total fruit plant was obtained by counting the number of fruit on each sampled jatropha tree and averaging the sampled per plot.

Figure 1: The appearances and description of fruit color maturity for measurement of *J. curcas*

Appearance of color maturity	Description of the appearances of the fruit color maturity
	photo1 Immature, small dark green fruit
	Photo 2 More yellow than green



(Photo: Minale, 2009)

Percentage oil yield in laboratory

The extraction of Jatropha seed oil had been done Soxhlet extraction apparatus chemically with Hexane solvent. For each samples 90-100 gm of powdered seed samples were taken and the extraction process was continued for four hours. Solvent extraction (with hexane) generally yields the maximum seed oil by percentage of the total available oil. These species can possible by used to improve *Jatropha curcas* for its oil contents.

The difference in weight of the seed sample just before and after the extraction of oil is taken as the weight of oil expelled. Percentage oil yield is then calculated thus:

$$Y_{OIL} = \frac{w_{OE}}{} \times 100$$

Where Y_{OIL}, the percentage oil yield expressed in %; w_{oe} the weight of the oil expelled in g and, W_{IS} the weight of the initial sample in g.

Results and Discussion

Seedlings Survival

The results of the RCBD experiment conducted over 5 years to study the establishment of the plant and their seedling survival in that last five years as shown in the fig. 1.

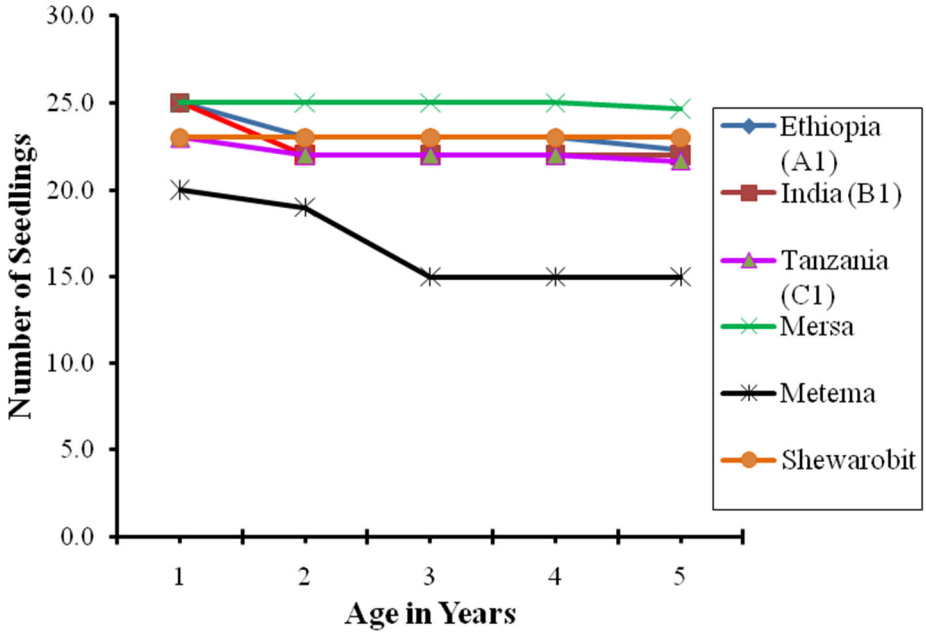


Fig.2. Survival of provenances (*J.curcas* L.) in five years

Seedling survival was might be affected by agro ecological niches and is related to their natural growth

habitats, soil fertility and rainfall, especially the latter (K. Openshaw, 2000).

For all species seedling survival ranged between 75% (Metema) and Mersa and Shewarobit (100% (fig. 1). Survival decreased over time, and most species had highest survival (> 60% the national average). Highest survival was shown by Mersa and Shewarobit (100%) followed by Tanzania (96%) and Ethiopia (92%), and the lowest by Metema (75%) and India (88%), respectively.

Table 1: Mean performance of 6 *Jatropha curcas* (provenances)

Provenances	plant height (cm)	Collar diameter (cm)	Crown diameter (cm)	Primary branches/plant	Secondary branches/plant	inflorescences/plant	Fruits/plant	100seed wt(gm)	Seed yield /plant (gm)	Oil content (%)
Mexico (A1)	189.4[a b]	5.6[a]	162.2[a]	2.7[ab]	6.7[ab]	3.9b	138.0[ab]	11.3[a]	414.0[ab]	45.7[a]
India (B1)	195.5[a b]	4.8[a]	126.8[a]	2.3[ab]	4.7[ab]	4.2ab	71.7b	9.3 [a]	215.0 b	34.0[cd]
Tanzania (C1)	184.0[a b]	5.3 [a]	174.3[a]	3.0[ab]	6.3[ab]	5.2 [a]	178.7[ab]	12.7[a]	536.0[ab]	36.2[bcd]
Mersa	158.7[a b]	5.7 [a]	165.0[a]	5.0[a]	12.0[a]	4.1ab	152.3[ab]	11.7[a]	457.0[ab]	32.1[d]
Metema	153.5[b]	5.8 [a]	155.5 [a]	1.3[b]	3.0[b]	5.0 [a]	388.0[a]	9.3[a]	1164.0 a	41.4[abc]
Shewarobit	236.8[a]	5.6 [a]	169.0 [a]	2.7[ab]	5.7[ab]	4.8ab	184.7[ab]	9.3[a]	554.0[ab]	43.3[ab]
Grand Mean	**186.3**	**5.5**	**158.8**	**2.8**	**6.4**	**4.5**	**185.6**	**10.6**	**556.7**	**38.8**
Cv(%)	**12.4**	**10.1**	**9.7**	**52.8**	**58.8**	**6.4**	**45.1**	**8.6**	**45.1**	**10.8**
LSD (5%)	**81.5**	**2.0**	**56.2**	**3.2**	**8.6**	**1.1**	**271.8**	**0.5**	**815.5**	**3.3**

Note: 'a' and 'b' are showed us not significantly different, "ab" significantly different
Between columns (i.e., between parameters of Jatropha *curcas*)
Between rows (between provenances of *Jatropha curcas*)

The blocking effect is significant; only for the interaction between provenances and blocks in terms of number of primary and secondary branches is significant at the 90% and 95% level.

The horizontal column contains information collected to determine which provenances at experiment site were likely to record in its respective character. The provenances A1, B1, C1, Mersa, Metema and Shewarobit have average records in height, collar diameter, primary and secondary branches, number of inflorescences, fruits and seed yields per plant, and oil yields.

The table shows different parameters which means are significant and non-significant different.

Height and diameter growth performance

There is no significant differences, (P>0.05) occurred among the provenances for growth performances (height and diameter increment).

At present the effect of spacing, canopy management and crown form and surface on the yield is not known, but there is no significant differences among parameters crown diameter, primary and secondary branches as well as inflorescence numbers and yield.

Parameter of Yield and Other Characters

Seed yield of the provenances ranged from 215.0 to 1164.0g/plant with an average of 556.0gm/plant, indicating varietal difference among means.

Highest yields variations partly due to the fact, collection in full production don't exist up to now, because unknown flowering and fruiting time, and the Jatropha bushes need about 4 to 5 years until full production. Study in India showed that, with average annual rainfall was about 1700 mm and it is expected that the crop would be in full production from year six.These can be 7.5 t of fruit will produce 3.45 t of seed, 1.80 t of shells and 2.25 t of coat (K. Openshaw, 2000).

Metema, Tanzania, A1, and Shewarobit had above average (>556.7g) seed yield per plant. Metema the higher yielder had fewer primary and secondary branches as well as low increment in height and but its high yield is mainly due to very high inflorescence (5.2) and fruit number per plant (388.0). India showed low performance for 100 seed weight and oil yield and high performance in collar and crown diameter, fruit and seed yield per plant and moderate values for other characters. The provenances india and mersa very low yield performance of less than 556.7g/plant.

Metema recorded high value (1086.013kg/10.86ql/ 0.11tone) in respect of yield after they reached a height of about 118.68 cm and with 4.68cm thickness. About 0.11 tones of Jatropha seed per ha and year, a value; which is very high and is not yet confirmed by other Jatropha trials in Ethiopia.

Seed production ranges from about 0.4 to over 12 t/ha/y, after five years of growth, this is equivalent and in between the range 0.11t/ha/y. This range in production must be from low to high precipitation. In Mali, where jatropha is planted in hedges, the reported productivity is from 0.8 to 1.0 kg of seed per meter of live fence ((K. Openshaw, 2000). Similarly studies in Zimbabwe, the seed cake is being promoted as a commercial fertilizer, for it is rich in NPK which contains about 6% N, 3% P and 1% K as well as traces of Ca and Mg. One tone of seedcake

applied to the soil is equivalent to applying 0.15 t of NPK [40:20:10] mineral fertilizer. The fruit is normally toxic, unless treated, but there are varieties that produce non-toxic fruit. A varnish can be made from the oil and the leaves are a feedstock for silk worms.

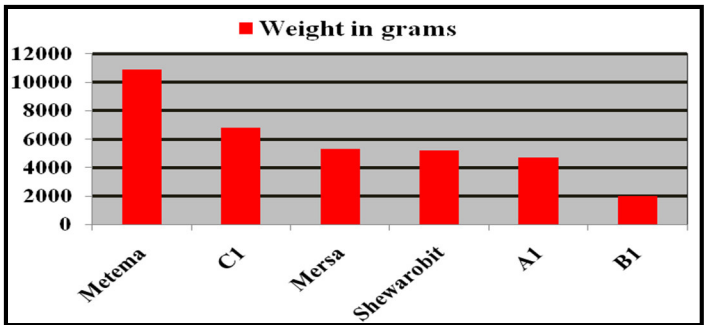


Figure 3: Average yield of seeds (in grams) of 6 *Jatropha* provenances during five years in Lai Birr (Ethiopia)

This shows clearly, that it is very important to look for high yielding plants right from the beginning to wards left. The species come from different locations have same genetic information as the mother jatropha plants. Metema recorded high seed yield per plant in respect of all the provenances studied and the rest were showed lower yields (see graphic above). Yield depends on site characteristics (rainfall, soil type and soil fertility) (Aker 1997; Openshaw 2000; Francis *et al.* 2005), genetics (Ginwal *et al.* 2004), plant age (Heller 1996; Sharma *et al.* 1997) and management: propagation method, spacing, pruning, fertilizing, irrigation, etc. (Heller 1996; Singh *et al.* 2006; Gour 2006). Seed yield was not significant and positively correlated with seed oil content (0.2).

Seed weight and Oil content

The six provenances showed non-significant variability for 100 seed weight. But there is significant variability recorded among the different provenances for oil content.

Oil content variability was varied from 45.6% in A1 to 32.1% in Mersa with an average of 38.8%. For oil content (45.6%) the top ranking provenances was A1 (Mexico) closely followed by Shewarobit and Metema. A1 come from Mexico the higher yielder had fewer inflorescence numbers, moderate height, primary/secondary branches and 100 seed weight but high collar and crown diameter, high fruit and seed yield. The top ranking provenances differed significantly with all the remaining provenances. Minimum oil content (32.1) was recorded in mersa.

Significant differences ($P<0.05$) occurred among the provenances for oil content with correlation ($R_{O} = 0.71$) estimates. All the 6 parameters showed positive correlation with provenances among themselves but the magnitude of association varied.

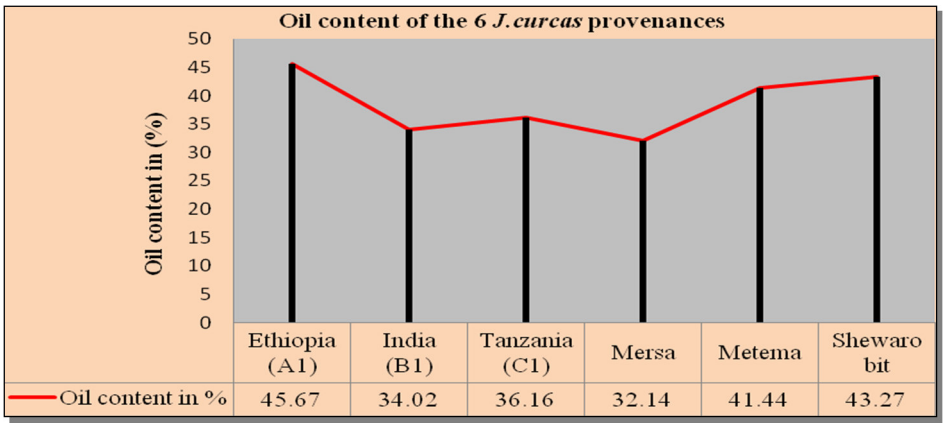


Figure 4: Results of seed oil content of the six provenances (*J.curcas L.*)

Partial information is available about the silvi-culture and management of jatropha. It is known that can be established from seed, seed- lings and cuttings. Plants from seeds develop a Taproot and four lateral roots, whereas cuttings do not develop a tap- root.

The best time for planting is in the warm season before or at the onset of the rains. In the former case, watering of the plants is required.

The recommended spacing for hedgerows or soil conservation is 15-25 cm apart (within and between rows) in one or two rows and 2-3 m by 1.5-3 m for plantations. Thus there will be between 4000-6700 plants per kilometer for a single hedgerow and double that when two rows are planted. The number of trees per hectare at planting may range from 1100 to 3300. Wider spacing is reported to give larger yields of fruit, at least in early

years. Further information is required on to the planting practices, management and the spacing employed. Growth of the plants is dependent on soil fertility and, especially rainfall. Flower and seed production respond to rainfall and nutrients. With one rainy season per year, there will be only one annual fruiting; for irrigated crops, up to three fruiting can occur each year (K. Openshaw, 2000).

Photo: Abraham, 2012

Figure 5: General view of the experimental site

Such variations in relation to habitat have also been reported in a number of tree species.

Conclusion

Jatropha curcas is a tropical multipurpose plant with many attributes that can be grown in low to high rainfall areas and can be used to reclaim land, as a hedge and/or as a commercial crop.

Six provenances (*Jatropha curcas*) three from Ethiopia and three from abroad was investigated in the last five years in Lai Birr(Jabe Tahinan district) in western Amhara region.

Aiming to evaluate provenances of *jatropha curcas* for better oil content for fuel to make it as a seed source and for wide spread distribution of the provenances in the region.

Thus, growing it could provide employment, improve the degraded environment, erosion control, enhance soil fertility, for better microclimate and greenhouse gas (GHG) mitigation and enhance the quality of rural life.

Among the six (3 indigenous and 3 exotic) provenances studied. Indigenous provenance sourced from Metema has the highest survival and seed yield produced up to 10860.13gm with 41.44% oil put as the third rank. Mexico (A1) which has 45.67% oils with a lower seed yield of 4690.62gm. When we compared field survival, second to the last among the six provenances but seed weight were much lower than the oil in all cases. In general

the study revealed that considerable variations existed among the six provenances for most of the parameters. The f statics revealed that collar and crown diameter, fruit per plant and seed yield per plant all are important oil yield attributing parameters. Because selection of these characters May help in indirect selection of high yield in oil content.

Therefore, the best provenances selected will improve the degraded sites and wastelands for energy plantations and agro forestry systems.

Recommendation

The maximum oil yield obtained from A1 (Mexico) provenance was 45.67% having high fruit & seed yield per plant, collar & crown diameter attributing parameters. Therefore, from the oil test results, it can be used A1 for establishment of seed orchard and delivered to end users for successful use of biodiesel production.

In addition, the results could also trigger off the interest of Ethiopian farmers and other stakeholders to be actively involved in the cultivation of *Jatropha curcas* plants for biodiesel production. The full potential of the plant is to be realized, much more research is required into the growing diseases and pest's problem of Jatropha curcas and more information is needed on the management, oil processing, and potential markets for all its products.

References

Anonymous. 1998. A concept paper the potential of *Jatropha curcas* in Rural Development and Environment Protection-An Exploratory. Rockefeller Foundation and Scientific & Industrial Research & Development,. Harare, Zimbabwe.

Buchanan, R.A and et al., 1978. Hydrocarbon and Rubber producing Crops. Evaluation of U.S. Plant Species.Econ.Bot

Dehgan, B. and G.L. Webster.1979. Morphology and Infrageneric Relashinships of the Genus Jatropha. (Euphorbiaceae). Vol.74. University of California.USA

Heller, J.,1996. Physic nut ***Jatropha Curcas*** L. Promoting the conservation and use of underutilized and neglected crops. Institute of Plant Genetics and Crop Plant Research, Gartersleben, International Plant Genetic Resources Institute, Rome.

H. P. S. Makkar, A. 0. Aderibigbe" and K. Becker, 1997. Comparative evaluation of non-toxic and toxic varieties of *Jatropha curcas* for chemical composition, digestibility, protein degradability and toxic factors. *institute for Animal Production in the Tropics and Subtropics (480), Department of Animal Nutrition and Aquaculture, University of Hohenheim, D-70593 Stuttgart, Germany*

Raina, A. K. and Gaikwad, B. R. (1987) Chemobotany of Jatropha species in India and further characterization of 'curcas oil'. ***Journal of Oil Technology, India.***

Liberalino, A. A. A., Bambirra, E. A., Moraes-Santos, T. and Viera, E. C. (1988) ***Jatropha curcas*** L. seeds: Chemical analysis and toxicity. ***Arquivos de biologia e technologia.***

Buchanan, R.A and et al., 1978. Hydrocarbon and Rubber producing Crops. Evaluation of U.S. Plant Species.Econ.Bot

Dehgan, B. and G.L. Webster.1979. Morphology and Infrageneric Relashinships of the Genus Jatropha. (Euphorbiaceae). Vol.74. University of California.USA

Heller J. 1996. Physic nut, Jatropha curcas L. Promoting the conservation and use of underutilized and neglected crops.1. International Plant Genetic Resource Institute (IPGRI), Rome,Italy.

James A. Duke. 1983. Hand Book of Energy Crops. Un-published, www.Biodieseltoday.com

S. Bach, 2012.Potentials and limitations of Jatropha curcas as a multipurpose crop for sustainable energy supply and soil and water conservation: a case study in Bati, Ethiopia, using the WOCAT approach. Master thesis of the Natural Science Faculty of the University of Bern