Effects of differences in stem diameters on oil yields from the wildly growing *E. tirucalli* trees in different agro-ecological zones in Tanzania

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Abstract: *Stems, leaves and plant roots have been known from ancient times for their potential to produce oils used in energy sources, medicine and food. This study examined effects of stem diameters on oil yields from the wildly growing milk bush trees, Euphorbia tirucalli L., through differences in oil yields from stems with the following diameters 20cm, 30cm, 40cm, 50cm, 60cm, 70cm and 80cm. Soxhlet extraction method using different solvents was used to extract the oil which can be used as an alternative sources of liquid biofuel. The oil content was determined by measuring the weight in grams of the oil in the total weight of sample extracts used. ANOVA performed using SPSS version 16 showed that E. tirucalli older stems having larger diameters produced significantly higher amounts of oil than small stem diameters. On dry weight basis, oil yields varied from 43.50g/kg for samples from trees with small stem diameters (20cm) to 170g/kg for samples from trees with larger stem diameters (80cm). There was no difference in oil yields among stem diameters that had 10cm difference in all agro-ecological zones. Overall, trees growing in Dodoma produced more oil extracts than Mbeya and Dar es Salaam agro-ecological zones due to favourable semi-arid climatic conditions especially temperatures and soil physicochemical properties which influenced oil productivity of E. tirucalli.*

Key Words: *E. tirucalli, liquid biofuel, milk bush tree, stem diameters, agro-ecological zones*

1. INTRODUCTION

The current worldwide decrease in oil supplies with constraints exacerbated by global climate change has inspired the scientific world to search for alternative bio-energy plant species and use their biomass as alternative energy sources. The milk bush tree, *Euphorbia tirucalli L.,* being a facultative Crassulacean Acid metabolizing (CAM) plant in its leaves and stems, and which can grow on marginal, arid and semi-arid lands can be a good alternative source of energy. The plant belongs to genus *Euphorbia* within the family Euphorbiaceae (Priya and Rao, 2011) which is composed of five subfamilies, 49 tribes, 317 genera and about 8,000 species. Due its high diversity this family becomes one of the largest plant families with the higher possibility of having more species that are energy producing in comparison to other families. According to Van Damme (1989), Schmelzer and Gurib-Fakim (2008) the plant originated from tropical East Africa and it is endemic in many African countries including Angola, Eritrea, Ethiopia, Kenya, Malawi, Mauritius, Rwanda, Senegal, Sudan, Tanzania, Uganda and Zanzibar. It is a shrub or small tree which is probably the best known and the most widespread of all the members of the genus Euphorbia (Gildenhuys, 2006). Its growth ranges from tropical semi-arid through subtropical semi-arid to semi-humid, moderate to warm climates, moist forest life zones as well as more mesic zones (Duke 1983).

According to Van Damme (1985, 1990, and 2001), the morphology of *E. tirucalli* reveals that it is a shrub or small tree that can grow from 4 to 12 m high and about 15 to 20 cm in trunk diameter. However, observations from study areas used in the present study *viz.,* Dar es Salaam, Dodoma and Mbeya showed that some of the wildly grown *E. tirucalli* trees grew up to a diameter of about 80cm and more at old ages. At this stage (age) their stems become rough, brown and lose their photosynthetic ability. *Euphorbia tirucalli* has been noted for its high latex content which can be freely exuded from the twigs, branchlets (phylloclades) and stems at the slightest injury (Van Damme, 2009). Its latex contains high amounts of sterols and triterpenes, and has been investigated for oil (Calvin, 1978). In 1978 *Euphorbia tirucalli* was documented to produce the equivalent to 10–50 barrels oil L ha^{-1}. This oil could be used as sources of energy for engines and domestic uses (Calvin, 1978). Findings from Nielsen *et al*., (1977) showed that the composition of *E. tirucalli* extracts (including oil) vary within its stems, stem callus, stem bark and leaves. But, information on effects of differences in stem diameters on oil yields have not been stipulated by extant literatures in different parts of the world, including Tanzania, where these plants grow abundantly in the wild. Thus, the present study intended to evaluate effects of stem diameters on oil yields from the wildly grown *Euphorbia tirucalli* trees in different agro-ecological zones of Tanzania such as Dar es Salaam, Dodoma and Mbeya. This was carried out in order to elucidate the best *E. tirucalli* stem harvests that would produce higher oil yields in the event the species is commercialized.

2. LITERATURE REVIEW:

Description of *Euphorbia tirucalli*

Euphorbia tirucalli L., belongs to the genus *Euphorbia*, Kingdom: Plantae, Division: Magnoliophyta, Class: Magnoliopsida, Order: Malpighiales and Family: Euphorbiaceae. The family Euphorbiaceae is composed of five subfamilies, 49 tribes, 317 genera and about 8,000 species (Priya and Rao, 2011). This composition makes it one among the highest in species richness in many habitats. This means that, there is a higher probability of having more oil producing species in that one family as compared to other families. According to Van Damme (2001), *E. tirucalli* is an unarmed shrub or small tree that can grow up to 4 - 12 m high and up to a diameter of about 75cm. Its branches are evergreen, longitudinal, succulent; about 7 mm thick and usually produced in whorls, rarely single, giving it a broom-like structure (Van Damme, 1990 and 2001). Its young stem is green, and photosynthetic with grooves which in fact are small canal-like structures containing stomata protected from extreme conditions. The stem stomatal frequency is estimated at 12 per mm^2 in grooves on older stem parts, while it may reach 40 per mm^2 on a smooth younger part of the stem. Older stems become rough, brown and lose their photosynthetic ability with age. The plant's stem bark is rough, cracked, greenish brown and exudes a milky sap when wounded (Van Damme, 1989; 1990) (Plate 1).

Plate 1: The stem (trunk) (A) and stem bark (B) of an old *E. tirucalli* tree (Photo by Author, 2013).

Geographical distribution and suitable climate for the growth and survival of *Euphorbia tirucalli* in different areas.

E. tirucalli is probably the best known and the most widespread of all members of the genus Euphorbia (Gildenhuys, 2006). Its distribution ranges from tropical semi-arid to moist, through subtropical semi-arid to semi-humid, moderate to warm climates, moist forest life zones as well as more mesic zones (Duke 1983). *E. tirucalli* is tree is very well adapted to semi-arid conditions and occurs in both dry and moist forests, hot savannah conditions and shrub land. It withstands salt stress associated with coastal conditions, but not frost. According to Van Damme (1989), Schmelzer and Gurib-Fakim (2008) *E. tirucalli* originated from tropical East Africa and it is endemic in countries such as Eritrea, Ethiopia, Kenya, Mauritius, Rwanda, Tanzania, Uganda and Zanzibar. The same authors including Orwa *et al.,* (2009) indicated that the tree was widely distributed in southern Europe, Asia and the Americas (Figure 1), having been steadily introduced due to its ornamental and medicinal features. Like some other Euphorbias, *E. tirucalli* combines the C_3 and the Crassulacean Acid Metabolism (CAM) photosynthetic pathways which could probably be the reason for its survival in harder conditions. The CAM pathway entails a higher carboxylic acid accumulation than the C_3 pathway at night, lowering the osmotic potential of the plant which increases its salt tolerance (Duke, 1983). Also, like other succulent plants, *E. tirucalli* stores extra water in the parenchyma and vacuoles which can be used to dilute salt ions entering the plant and as a reserve for survival in dry conditions.

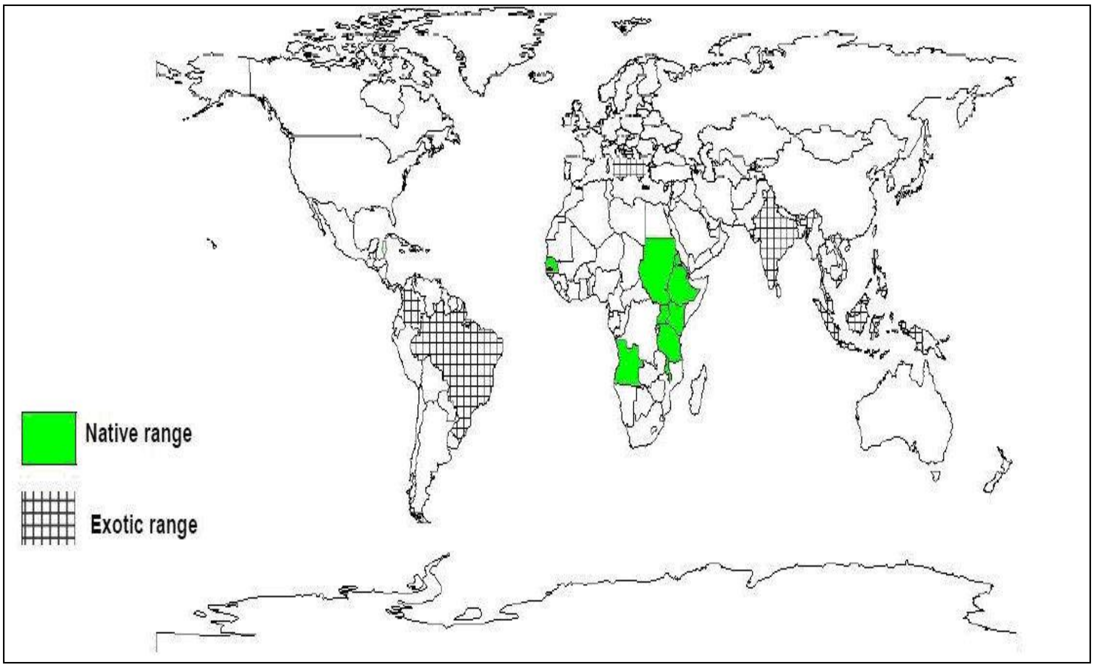

Figure 1 Geographical distribution of *Euphorbia tirucalli* in the world. Adopted from Orwa *et al*., (2009).

The plant is very drought resistant and can survive in dry conditions during the whole summer, and tolerates annual precipitation of 250 to 500 mm, and annual average temperature of 21 to 28 °C (Calvin, 1980; Duke, 1983). *Euphorbia tirucalli* plants cannot tolerate freezing temperatures (Christman, 2000) and generally temperatures that fall below 7 °C (Corman, 2001).

The use of *E. tirucalli* extracts from various parts of its shoot including stem as potential sources of oil for liquid biofuel

A study by Calvin (1978) on members of Euphorbioaceae in the United States revealed that some species, *viz. Euphorbia lathyris* and *Euphorbia tirucalli* produced about 8 – 12% of their dry weight as oil per hectare per year (equivalent to not less than 20 barrels or 3180 litres). In the same study, isoprenoid hydrocarbons were isolated form *E. tiruculli* extracts. Calvin (1978) reported that a rate of 3975 – 7950 litres of oil per hectare per year was achieved through studies carried out in Okinawa Japan on *Euphorbia lathyris* and *Euphorbia tirucalli*. *Euphorbia tirucalli* contains large quantities of the white milky latex in all parts of its shoot which is freely exuded by the twigs, branchlets (phylloclades) and stems at the slightest injury (Plate 2.6). Like many other *Euphorbia* species, the *Euphorbia tirucalli* latex contains many chemical substances including those described above, that are suitable for conversion to petroleum motor fuels. According to Kapaczewski (1947), the latex from *E. tirucalli* contains about 28% solid matter whose composition is 21 - 27 % water soluble substances such as alkaloids, sterols, organic acids and fats, 59 - 63 % resin-soluble substances such as terpene compounds and their derivatives and 12 - 14 % rubber-like substances. Again, a study conducted by Uchida *et al*., (2004; 2010) revealed that the most latex produced in *Euphorbia tirucalli* was found in the shoot system of the plant when compared with the roots which produced the least. This was probably because squalene epoxidase enzyme which catalyzes the first oxygenation step in the biosynthesis of phytosterols and triterpenoid saponin is found in abundance in the parenchyma cells adjacent to primary latex producing cells, laticifers located in the cortex and pith of the stem as well as the spongy mesophyll cells of the deciduous leaves. This is interesting because these phytosterols and triterpenoids have biofuel properties. The latex hydrocarbons are largely C_{30} triterpenoids which, after cracking, yield high octane gasoline. Furthermore, the chemical composition of the different parts of *E. tirucalli* plant has been extensively studied and a variety of chemical compounds have been isolated from them. Apart from the potential value of *E. tirucalli* extracts in oil production, the plant has also been reported to be one of the highly valued species for live fences in Tanzania with qualities such as growing under adverse conditions with little or no maintenance; growing well in close spacing; being propagated by cuttings; withstanding lopping and trimming; possessing poisonous branches and leaves that animals do not like to eat; being resistant to pests and diseases, and having a long life (FAO, 2009). However, information on effects of differences in stem diameters on oil yields have not been much exposed in the literatures in different parts of the world, Tanzania in particular where *E. tirucalli* plants are found richly in the wild. This is why, the present study evaluated effects of stem diameters on oil yields from the wildly grown *Euphorbia tirucalli* trees in different agro-ecological zones of Tanzania such as Dar es Salaam, Dodoma and Mbeya in order to establish excellent oil yielding stem diameters that could be harvested in the event the species is commercialized.

3. MATERIALS

Description of study areas

The study was conducted in three agro ecological zones of Tanzania i.e. Ibihwa village in Bahi District, Dodoma for Semi-arid -Zone, Kinzudi village in Goba-Mbezi, Dar es Salaam for coastal Zone and Iyela in Mbeya Urban for the Southern Highlands Zone. The Choice of Agro-ecological Zones was based on differences in terms of altitude, growth, precipitation and temperature patterns, as well as differences in edaphic and other physiographic features (URT, 2007b).

Dodoma agro-ecological zone lies between latitudes 4°S and 7°S and longitudes 35°E – 37°E at an altitude of 1000-1500 metres above the sea level. This zone is semi – arid in nature with undulating plains with rocky hills, low scarps and well drained soils with low fertility. Apart from having the average maximum and minimum annual temperatures of about 31°C and 17°C respectively, the Region receives an annual average unreliable unimodal rainfall distribution of around 500-800mm (URT, 2007a and b; URT, 2011; WHF, 2011). The growing season in Dodoma semi-arid sub-zone is during December and March.

The Dar es Salaam agro-ecological zone is tropical or warm and humid throughout the year. It lies between latitudes 6.45°S and 7.25°S, and longitudes 39°E and 39.55°E at an altitude of under 300 metres. Dar es Salaam is gently rolling uplands with moderately low fertility sand soils and occupies soils mixed with alluvial deposits in some parts. Apart from having the mean annual temperature of about 26°C which can rise to 32°C during the hottest, the Region receives average annual bimodal rainfall of 750-1200mm (URT, 1997; 2003; 2004; 2007b). The growing season in Dar es Salaam sub-zone is during October to December and March to June.

Mbeya Region experiences a tropical climate. It lies between latitudes 7°S and 9°S and between Longitudes 32°E and 35°E and has a mean annual unimodal and reliable rainfall of between 800-1400mm while the mean annual temperature is 21°C (URT, 1997; Janssen *et al.,* 2005; URT, 2007). Mbeya lies at an altitude of 1200-1500m while its topography is covered by undulating plains to dissected hills and mountains. The area has moderately fertile clay and volcanic soils. The growing season in Mbeya zone is during November to April (URT, 1997; URT, 2007a and b).

Preparation of Materials

Sample Collection

From each of the three study areas four bark strip samples each measuring 20cm wide by 20cm long were collected from *E. tirucalli* trees, at varying diameters of 20cm, 30cm, 40cm, 50cm, 60cm, 70cm and 80cm diameters at breast height (DBH). The samples were kept separately in properly labeled plastic bags and transferred to the Chemical and Mining laboratory of the College of Engineering and Technology, University of Dar es Salaam where they were weighed to determine their fresh weight before being oven-dried to a constant weight at a temperature of 70°C. Using an electric milling machine the oven-dried samples were then pulverized into small-sized particles that could pass through a 2 mm-diameter mesh sieve and again weighed to determine their dry weight prior to extraction of the oil. Safety measures like proper cleaning of samples, were taken to avoid sample contamination in order to maximize the efficiency of extraction process.

4. METHOD

Extraction and Separation of Oil Fractions from Stem Bark Samples of *E. tirucalli*

The extraction-partitioning scheme (Figure 2) was followed in the extraction of oil from the samples. During extraction, quadruplicate 20-g sub-samples from each of the finely ground stem bark collected from the three different study areas were extracted using 150mls of analytical grade acetone for eight hours in a Soxhlet apparatus according to the method described by Kalita and Saekia (2004).

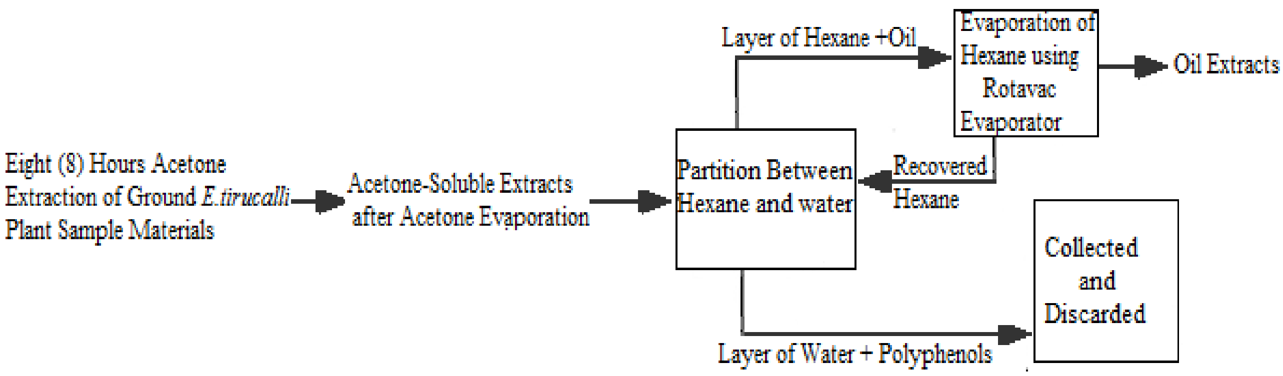

Figure 2. The extraction-Partitioning Scheme for Extraction of Oil adapted from Buchanan *et al*., (1978); Photi, (2005) and then Modified by the Researcher.

Subsequently for each extract, acetone was evaporated out using a rotary evaporator at a temperature of 38°C to obtain a mixture of acetone-soluble extracts which were collected in a round bottomed flask. The obtained acetone-soluble extracts were each separately partitioned in a separating funnel using a mixture of analytical grade hexane and water. In that partitioning the oil fractions dissolved in hexane while the polar components (mainly polyphenols) dissolved in water. The oil fractions were then freed from hexane by evaporation in a rotary evaporator at a temperature of 68°C and the oil extracts that remained in the rotary evaporator were collected in previously weighed flasks and left to cool down for about 5 minutes before weighing the flasks again. Then, the weight of the oil extracts was determined by subtracting the weight of the empty flask from the weight of the flask with oil and the obtained oil yield was stored in refrigerator at 4°C until further used. Then, the mean oil yields (quantities) in grammes per kilograms (g/kg) were calculated and recorded.

5. STATISTICAL ANALYSIS:

The obtained data were subjected to statistical analysis using Statistical Package for Social Sciences (SPSS v.15) whereby the analysis of variance (Two-way ANOVA) at $P \leq 0.05$ was applied to test for statistical differences in the mean oil yields of the plant bark at different plant diameters from the three study areas. Post-hoc tests (Tukey Honestly Significant Difference Tests (HSD) were computed to determine whether individual means differed significantly.

6. FINDINGS :

The study found that effects of different stem diameters on oil yields from the wildly growing *E. tirucalli* trees in different agro-ecological zones of Tanzania can be demonstrated as follows; oil yields increased significantly from small diameter stems (20cm) towards larger diameters (80cm) regardless of the agro-ecological zone from which the samples were collected. But the differences were not significant when the differences between the stem diameters were less than 10cm. Yet, findings showed that there were within-zone variations in quantities of oil extracted from the study plants under different agro-ecological zones. The findings further demonstrated that *E. tirucalli* trees wildly growing in Dodoma agro-ecological zone produced significantly higher quantities of oil than those growing in the Mbeya, and Dar es Salaam agro-ecological zones. Ultimately, findings revealed that higher oil yields were obtained from *E. tirucalli* trees with large diameter stems.

7. RESULTS:

Oil yields from the stem bark of *E. tirucalli* stripped from different stem diameters and agro-ecological zones showed increasing trends in which stems with larger diameters (80cm) produced higher amounts of oil than stems with smaller stem diameters (20cm) (Figure 3). Further analyses showed that, there were significant differences in the quantity of oil extracted from the stem bark samples of *E. tirucalli* with different stem diameters between agro-ecological zones, nevertheless there were within-zone variations in quantities of oil extracted from the plants (Figure 3). The results also showed that *E. tirucalli* trees wildly growing in Dodoma agro-ecological zone produced significantly higher quantities of oil than those growing in the Mbeya, and Dar es Salaam agro-ecological zones i.e., oil yields in Dodoma varied from 43.50g/kg for 20cm diameter trees to 170g/kg for 80cm diameter trees. In Dar es Salaam oil yield ranged from 45g/kg for 20cm diameter trees to 155g/kg for 80cm diameter trees. In Mbeya, oil yields varied from 45g/kg to 165g/kg for trees measuring 20cm and 80cm in diameters respectively (Figure 3).

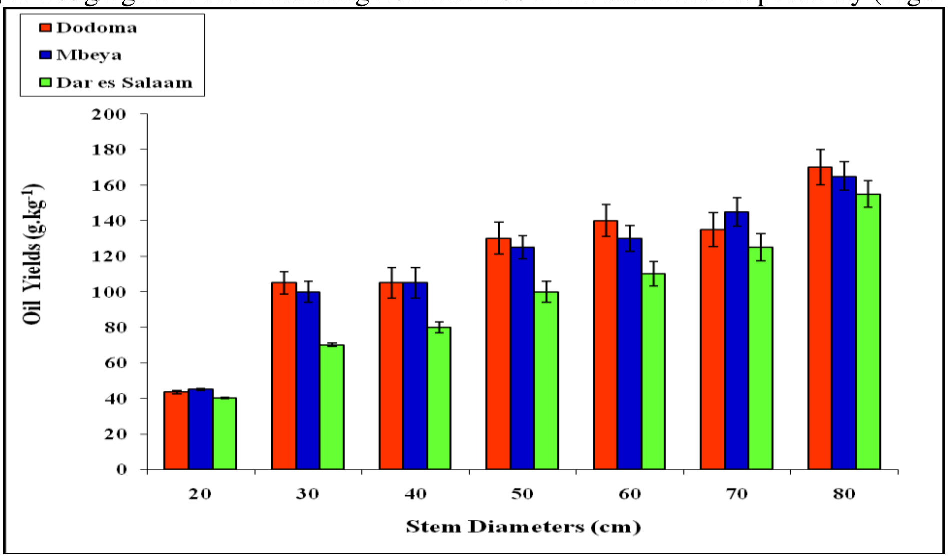

Figure 3. Variations in the quantity of oil extracted from *E. tirucalli* trees with different stem diameters in different agro-ecological zones.

The Two-Way ANOVA results (Table 1) showed that, there were statistically significant difference in quantities of oil extracted from the stem bark with different stem diameters between ecological zones at $P = 0.003$. The magnitude of the difference was large (Partial Eta Square (0.168 > 0.14) Cohen's (1988). There were also statistically significant differences in quantities of oils extracted from the stem bark of *E. tirucalli* between stem diameters (Diameters) at the $P = 0.000$. In this case, the magnitude of the difference was very large as indicated by the Partial Eta Squared (0.77 > 0.14) Cohen's (1988).

Table 1. ANOVA Results for the Difference in the Quantity of Oil from the Stem Bark between *E. tirucalli* Stem Diameters and Ecological Zones.

Tests of Between-Subjects Effects						
Dependent Variable:Quantity of Oil from the Stem Bark (gm)						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	46.667[a]	20	2.333	11.819	0.000	0.790
Intercept	409.646	1	409.646	2074.99	0.000	0.971
Ecology	2.506	2	1.253	6.347	0.003	0.168
Girth	43.125	6	7.188	36.407	0.000	0.776
Ecology * Girth	1.036	12	0.086	0.437	0.942	0.77
Error	12.437	63	0.197			
Total	468.75	84				
Corrected Total	59.104	83				
a. R Squared = 0.790 (Adjusted R Squared = 0.723						

Furthermore, data presented in Table 2 revealed significant increasing trends of differences ($p < 0.005$) in larger diameter stems to produce higher quantities of oil than small diameter stems regardless of the agro-ecological zone from which the samples were collected. However, this occurred only if the differences between the stem diameters were higher than 10cm, but the differences were not significant when the differences between the stem diameters were less than 10cm.

Multiple Comparisons

Dependent Variable: Quantity of Oil from the Stem Bark (gm)
Tukey HSD

(I) The stem's Diameters	(J) The stem's Diameters	Mean Difference (I-J)	Std. Error	Sig.
20	30	-.833*	.1814	.000
	40	-1.083*	.1814	.000
	50	-1.500*	.1814	.000
	60	-1.708*	.1814	.000
	70	-1.833*	.1814	.000
	80	-2.375*	.1814	.000
30	20	.833*	.1814	.000
	40	-.250	.1814	.811
	50	-.667*	.1814	.008
	60	-.875*	.1814	.000
	70	-1.000*	.1814	.000
	80	-1.542*	.1814	.000
40	20	1.083*	.1814	.000
	30	.250	.1814	.811
	50	-.417	.1814	.262
	60	-.625*	.1814	.017
	70	-.750*	.1814	.002
	80	-1.292*	.1814	.000
50	20	1.500*	.1814	.000
	30	.667*	.1814	.008
	40	.417	.1814	.262
	60	-.208	.1814	.910
	70	-.333	.1814	.528
	80	-.875*	.1814	.000
60	20	1.708*	.1814	.000
	30	.875*	.1814	.000
	40	.625*	.1814	.017
	50	.208	.1814	.910
	70	-.125	.1814	.993
	80	-.667*	.1814	.008
70	20	1.833*	.1814	.000
	30	1.000*	.1814	.000
	40	.750*	.1814	.002
	50	.333	.1814	.528
	60	.125	.1814	.993
	80	-.542	.1814	.058
80	20	2.375*	.1814	.000
	30	1.542*	.1814	.000
	40	1.292*	.1814	.000
	50	.875*	.1814	.000
	60	.667*	.1814	.008
	70	.542	.1814	.058

Based on observed means.
*. The mean difference is significant at the .05 level.

Table 2. Multiple Comparisons for the Differences in the Quantity of Oil from the Stem bark of *E. tirucalli* with Stem Diameters and Ecological zones

8. DISCUSSION:

Oil yield results showed increasing trends where by larger diameter (80cm) stems produced higher amounts of oil than smaller stem diameters (20cm). Regarding the obtained differences in the quantity of oil extracted from the stem bark samples of *E. tirucalli* with different stem diameters between agro-ecological zones and within-zone variations in quantities of extracted oil, the study demonstrated that, these results were probably accounted for by the difference in stem diameters whereby trees with smaller diameter yielded less oil than larger diameter trees. This can be possibly because *E. tirucalli* trees like many other petroplants have lactiferous canals in their stems that form and accumulate the photo-synthetic products including oils as they increase in stem diameters during growth (Maugh, 1976; Calvin, 1980). Apart from the observed results presented in Table 2 which revealed significantly increasing trends for differences in larger diameter stems to produce higher quantities of oil than small diameter stems regardless of the agro-ecological zone from which the samples were collected, these results indicated that extracted oil from trees measuring 60cm diameters produced oil quantity not significantly different from that of trees with diameters of 70cm but was significantly lower than the quantity of oil extracted from the stem bark samples from trees measuring 80cm diameters. Also, the quantities of oil extracted from the stem bark samples collected from trees measuring 70cm and 80cm diameters were not significantly different from each other. Considering the quantity of oil extracted from trees measuring 30cm diameters which was not significantly lower than that from trees with diameters of 40cm, it was significantly lower than trees measuring 50cm, 60cm, 70cm and 80cm diameters (Table 2). Also, Findings showed that *E. tirucalli* stems that had diameter differences of less than 10cm yielded quantities of oil that were not significantly different from each other irrespective of the ecological zones from which the samples were collected. This is possibly due to the fact that *E. tirucalli* trees that grew to the diameter difference of 10cm in different ecological zones accumulated almost equal quantities of oil.

Generally, the results obtained in the present research regarding significant difference in quantities of oil extracted from the stem bark of *E. tirucally* with different stem diameters, are in line with those earlier reported by Geng *et al,* (2011) who narrated differences in the pattern of oil yields between 5 - 12 years oil stem bark of *Cinnamomum cassia* and suggested the choice of stem bark according to trees' growth stages. They also reported that there was significantly positively correlation between extracted plant oil from Lemon balm (*Mellisa officinalis* L.) with stem dry weight among other factors. Furthermore, accumulation of oil in *E. tirucalli* stems as diameter increases is probably due to an increase in the amount of photo-synthetic products (milky latex containing extractable oils) in lactiferous canals of their stems. These products increased with increasing stem diameters during the vegetative periods. This was observed in all investigated agro-ecological zones. Again, the production of higher quantities of oils in older stems than younger ones could be due to the fact that, after its establishment, *E. tirucalli* trees grow vigorously (Maugh, 1976; Calvin, 1980) this causes an increase in biomass leading to rapid accumulation of their oils. Thus, the increase in plant's biomass as the plants grow is related with the increase in oil yields. These results have also been supported by different researchers from Guangzhou, people in republic of China who reported variations in essential oil yields (i.e., 0.41-2.61w/w) from the stem bark of *Cinnamomum cassia* due to differences in age Geng *et al,* (2011).

9. RECOMMENDATIONS:

The study recommend that, for mass production of oil for liquid biofuel purposes from *E.tirucalli*, Dodoma offers better opportunities in terms the quantities of oil extracted when compared with the Mbeya and Dar es Salaam agro-ecological zones, because the growth and productivity of the study plant was most favoured in Dodoma than in the other two agro-ecological zones. Also Fresh latex should also be tapped from *E. tirucalli* trees and investigated for the quantity of oil other than its stem. Finally, in order to obtain oil from *E. tirucalli* in large quantities, it is recommended to use older trees with larger diameters.

10. CONCLUSION:

The present research work was carried out to evaluate the effects of stem diameters on oil yields from the wildly grown *E. tirucalli* trees, through differences in yields for oils from stems with different diameters such as 20cm, 30cm, 40cm, 50cm, 60cm, 70cm and 80cm as a potential source of liquid biofuel in three different agro-ecological zones, i.e. Dodoma, Dar es Salaam and Mbeya.

The yields of oil have been observed to vary widely within different agro-ecological zones considered in this study. Results of the present study also showed that more oil can be obtained by harvesting older parts of *E. tirucalli* (wildly grown stem bark) stems. The results of this study also concluded that *E. tirucalli* trees with diameter differences of 10cm produced almost equal quantities of oil irrespective of the agro-ecological zones. Furthermore, the findings reported that oil yields from the stem bark samples in Dodoma agro-ecological zone were significantly higher than those extracted from the stem bark samples of the same species collected from Mbeya and Dar es Salaam agro-ecological zones. This was possibly because, semi-arid condition favoured *E. tirucalli* grown in Dodoma agro-ecological zone to have more physiological activities which increased the amount of oil produced than other ecological zones. Also the overall differences in oil yields plus higher yields in Dodoma were accounted by differences in terms of altitude, growth, precipitation and temperature patterns, as well as differences in edaphic and other physiographic features than other agro-ecological zones as narrated by the National Adaptation Programme of Action (NAPA) and the URT, (2007b). Furthermore, *E. tirucalli* is a succulent plant with a survival strategy for inhabiting arid and semi-arid areas. Succulence behavior has been positively correlated to both colonization of increasingly arid habitats and CAM activity to total carbon gain. Hence, Dodoma offers better opportunities in terms of optimization in oil production when compared with the Mbeya and Dar es Salaam agro-ecological zones.

REFERENCES:

1. Buchanan, R.A., cull, I.M. Otey, F. H., and Russell, C.R. (1978). *Econ. Bot.* 32, 13 and 146.
2. Calvin, M. (1978). *Chem. and Eng*. News 30, March 20.
3. Calvin, M. (1980). *Die Naturwissenschaften* 67, 525.
4. Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.) Hillsdale, NJ: Lawrence Earlbaum Associates.
5. Christman, S. (2000). *Euphorbia tirucalli.* [Internet] Updated 12/29/07. Floridata. Floridata.com LC Tallahassee, Florida USA. http://www.floridata.com/ref/e/euph_tir.cfm. Accessed 21 March 2011.
6. Duke J. (1983). *Euphorbia tirucalli* L, handbook of energy crops. Purdue University centre for new crops and plant products. www.hort.purdue.educ. Acessed on 15 March, 2012.
7. FAO (2012). *Corporate Document Repository, Indigenous Multipurpose Trees of Tanzania:* uses and economic benefits for people.retrieved from http://www.fao.org/docrep/X5327e/x5327e12.htm on 4th/July/2012
8. Geng, S., Cui, Z., Huang, X., Chen, Y., Xu, D., and Xiong, P. (2011). Variations in essential oil yield and composition during *Cinnamomum cassia* bark growth. *Industrial Crops and Products, 33*, 248-252.
9. Gildenhuys, S. (2006), *The three most abundant tree Euphorbia species of the Transvaal* (South Africa), *Euphorbia* World, Vol. 2 n. 1 - April 2006, Hatfield, South Africa.
10. Janssen. R, Woods, J. and Brown, G. (2005). *Liquid Biofuels for Transportation in Tanzania. Potential and Implications for Sustainable Agriculture and Energy in the 21st Century*; A Study commissioned by the German Technical Cooperation (GTZ) through BMELV and FNR. Retrieved from http://www.tatedo.org/files/publications/Research%20And%20Studies/biofueltransport.pdf on 6th September, 2011.
11. Kalita D. and Saekia C.N. (2004). *Chemical constituents and energy content of some latex bearing plants*. Bioresource Technology; 92: 219-22.
12. Kapaczewski W. (1947). *Latex composition of some Euphorbias.* Journal of Science, Chemistry and Biology. 20:924-928.
13. Maugh, T.H., II. (1976). *Perhaps we can grow gasoline*. Science 194:46.
14. Nielsen, P.E., H. Nishmura, J. W.Otavos, and M. Calvin. (1977). *Plant crops as a source of fuel and hydrocarbon-like materials*. Science; 198: 942-944.
15. Photi, K. (2005). *Determination of Oil and Hydrocarbon from Latex Plants for Liquid Fuel,* A PhD Thesis (Published) Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science, Mahidol University retrieved from http://opac.tistr.or.th/Multimedia/Web/0050/wb0050444.pdf on 25th April, 2010.
16. Priya, C. L. and Rao, K. V. (2011). *Pharmacologyonline: N*ewsletter on a Review of Phytochemical and Pharmacological Profile of *Euphorbia TirucallI,* **2:** 384-390. Retrieved from http://www.unisa.it/uploads/4979/035.rao.pdf on Thursday, 19, 2012.
17. Schmelzer G.H., Gurib-Fakim A. (2008). *Medicinal plants*. Plant Resources of Tropical Africa. pp. 412–415.
18. The Wide Heart Founder (WHF) (2011). The Wide Heart Tanzania, Dodoma Streetchildren Security Project Proposal June 1st 2011 ± June 30 th 2013. Retrieved from http://www.scribd.com/doc/53000365/THE-WIDE-HEART-TANZANIA on 7th September, 2011.
19. Uchida, H., Nakayachi, O., Otani, M., and Kijikawa, M. (2004). *Plant regeneration from inter node explants of Euphorbia tirucalli*. Plant Biotechnology, 21: 397-399.
20. Uchida, H., Ohyama, K., and Suzuki, M. (2010). *Triterpenoid levels are reduced during Euphorbia tirucalli L. callus formation*. Plant Biotechnology 27, 105–109.
21. United Republic of Tanzania (URT) (1997). Mbeya District Socio-Economic Profile. *The Planning Commission Dar es Salaam and Mbeya District Council Mbeya*, retrieved from http://www.tzonline.org/pdf/Mbeyadis.pdf on 21st March, 2012.

22. United Republic of Tanzania (URT) (2003). *'Dodoma Region: Socio-economic profile'* 2nd edition joint publication by National Bureau of Statistics and Dodoma Regional commissioner's office. Coordinated by The President's Office Planning and Privatization, Dar es Salaam, Tanzania.
23. United Republic of Tanzania (URT) (2004). City Profile for Dar es Salaam, retrieved from http://jp1.estis.net on 2nd August, 2011.
24. United Republic of Tanzania (URT) (2007a). Prime Minister's Office Regional administration and Local Government. Dar es Salaam Regional Profile. Regional Commissioner's office, Dar e s Salaam.
25. United Republic of Tanzania (URT) (2007b). National Adaptation Programme of Action (NAPA), Vice President's Office, Division of Environment. Retrieved from unfccc.int/resource/docs/napa/tza01.pdf
26. United Republic of Tanzania (URT) (2011). Dodoma Region Socio-Economic Profile, retrieved from http://www.tanzania.go.tz/Regions/dodoma/profile.htm on 22nd October, 2012.
27. Van Damme P. (1985). *Destructive and non-destructive methods for determining stem and leaf areas on Euphorbia tirucalli L.* Mededelingen van de Faculteit Landbouwwetenschappen Rijksuniversiteit Gent 37:1369-1382.
28. Van Damme P. (1989). *Het traditioneel gebruik van Euphorbia tirucalli*. (The traditional uses of *Euphorbia tirucalli*). Afrika Focus 5:176-193.
29. Van Damme P. (1990). Gebruik van *Euphorbia tirucall*i als rubberleverancier en energiegewas (The use of *Euphorbia tirucalli* as rubber and energy crop). Afrika Focus 6:19-44.
30. Van Damme PLJ (2001). *Euphorbia tirucalli for high biomass production*, in: A. Schlisseland D. Pasternak (Eds.), Combating desertification with plants, Kluwer Academic Pub. pp. 169-187.
31. Van Damme, P. (2009), *Bio-energy from plants*; Alternatives to fossil fuels, an eye on *Jatropha curcas, Euphorbia tirucalli* and banana waste, Retrieved from http//www.cdo.ugent.he on Friday, 12th December, 2009.