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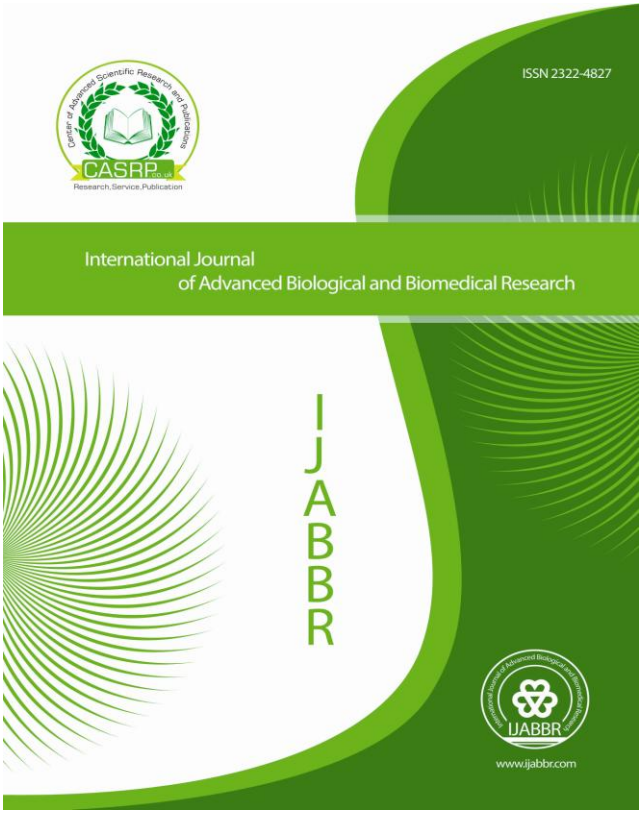

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Oil content, fruit and seed characteristics Ethiopian Jatropha (*Jatropha curacas* L.) provenances

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Abstract

For determining the oil content, seed and fruit characteristics of Ethiopian Jatropha provenances, the study was conducted in five regions of Ethiopia namely Southern Nation Nationalities Peoples Regional state, Amhara region, Tigria region, Oromia region and Benishangul Gumuz Regions, where Jatropha is found abundantly. A total of 23 Zones, 36 Weredas and 40 sampling sites were considered from five regions of the country for the study. Data on seed to shell ratio, thousand seed weight, seed coat weight, endosperm weight, endosperm to seed ratio and oil content were collected and summarized. The values of seed to shell ration was ranged from 2.7 to 2.85. The 1000 seed weight was varied from 546.47 g to 714.4 g. The seeds were found to have a relatively similar endosperm to seed shell ration ranging between 1.83 and 1.87. Endosperm weight of the seeds ranges from 5.58 g to 6.27 g. Averaged over the study regions, the oil content of Ethiopian Jatropha populations ranged from 29.88% to 34.34%. Seeds with higher endosperm weight were positively and strongly associated with oil content. Hence, considering endosperm weight during selection and improvement program plays a significant role in maximizing oil content of. Jatropha provenances having oil content ranging between 30-35% are considered good for oil

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production. The values obtained from Ethiopian Jatropha populations growing in different regions are within the ranges of the different reports. This indicates the possibility of using the existing Jatropha populations for the production of Jatropha oil.

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Keywords: Ethiopia, Jatropha, Oil content, Seed, Thousand seed weight.

1. Introduction

Jatropha (*Jatropha curcas* L.) is a perennial treethat belongs to the family Euphorbiaceaenative to Africa, North America and Caribbean regions (Nzikou et al., 2009). It assumed that originating from Caribbean and spread as a valuable hedge plant to Africa and Asia by Portuguese traders (Waghmare and Naik, 2015; Heller, 1996). Now it thrives in many parts of the tropics and sub-tropics in Africa/Asia (Gubitz et al., 1999; Openshaw, 2000; Martinez-Herrera et al., 2006). It can grow almost on any type of soil whether gravelly, sandy or saline and thrives even on the poorest stony soils and crevices. It is a perennial plant which does not require much care and produces well for over 40 years after establishment (Musa et al., 2011). Jatrophahas capability to grow on marginal and it has ability to reclaim problematic lands and restore eroded areas. It is known to aid the plants grown under condition where phosphate is limiting, as has mycorrhizal association (Jones and Miller, 1992).

Jatropha grows in various parts of Ethiopia, as a hedge around homesteads and farmlands, such as in Wolayita, Metekel, Southern Wollo, Northern and Eastern Shoa, Tigrai, Gamo Gofa zones and Gambella region (Getinet et al., 2009). This suggests that Jatropha can be cultivated either as large-scale plantations on marginal areas, as small-scale hedges, or intercropped to assist rural livelihoods. Although Jatropha already exists in many places of Ethiopia; its economic importance is far from being realized due to absence of proper evaluation and promotion of the existing local Jatropha provenances for their oil content, oil yield and oil quality for biodiesel utilization.

There are different reports indicating the existence of performance variation in oil content and quality due to growing environment and genotype variation was reported for Jatropha (Kaushik et al., 2007), Heller, 1996; Ginwal et al., 2004; Thongbai et al., 2006; Benge, 2006). Adaptability testing for varietal development, silvicultural and propagation techniques is being under way in Ethiopian Institute of Agricultural Research at Melkassa and Wondo Genet Agricultural Research Centers. Likewise, variability evaluation using13 Jatropha provenances are also initiated by Debrebrhan Agricultural Research Center. Omarsherif (2010) has also reported the existence of variation in oil content and quality for provenances of Jatropha growing in Bati wereda. However, the study does not compare the content and quality of the oil with other provenances for biodiesel utilization. This clearly indicates that the existing Jatropha providences were not properly evaluated for their oil content and quality for biodiesel utilization under their growing ecologies. As a result, field experience and documented information with regard to variation in oil contents, seed and fruit characteristics about the local population of Jatropha providences growing under different ecologies of Ethiopia is very limited. Therefore, the aim of this study is conducted for providing basic information on oil content, seed and fruit characteristics of Ethiopian Jatropha populations.

2. Materials and methods

2.1. Brief description Ethiopia

Ethiopia is geographically located in the eastern Africa within the tropics between 3 degrees and 15 degrees of north latitude and between 33 degrees and 48 degrees of east longitude. It has common borders with Kenya, Sudan, South Sudan Republic, Somalia, Eritrea and Djibouti. There is great variation in altitude ranging from about 116 meters below sea level to 4620 meters above sea level (IBC, 2007; EPA, 1998). The country has an undulating topography providing ample opportunity to satisfy bio-based development interests. The mean annual temperature of the country is 22.2^{o}C. The lowest temperature ranges from 4^{o}C to 15^{o}C in the highlands, and the highest mean temperature is 31^{o}C in the lowlands at the Denakil Depression (Awulachew et al., 2007). The country receives mean annual rainfall of 812.4 mm, with a minimum of 91 mm and a maximum of 2,122 mm. Relief

variability and the resulting climatic characteristics make the country home to a wide range of plant, animal and microbial diversity. Consequently, the country is regarded as a centre of endemism (IBC, 2007; Vivero et al., 2010).

2.2. Study areas and sampling sites

The study was conducted in five regions namely Southern Nation Nationalities Peoples Regional State (SNNPRS), Amhara region, Tigria region, Oromia region and Benishangul Gumuz Regions, where Jatropha is found abundantly (Table 1). For each region, representative sampling sites were selected following thorough discussion with head of Mines and Energy at zonal level. During representative sample site selection, one knowledgeable and responsible expert was assigned from the zonal mines and energy office for making the site selection more perfect and easier and thereby to collect representative data from each region. Following this arrestment, a total of 23 Zones, 36 Weredas and 40 sampling sites were considered from five regions of the country for the study.

A total of 40 study and sample collection sites were identified from the five regions of the country for collecting sufficient Jatropha composite seed samples for this particular study. The detailed descriptions of representative sampling and study sites selected from each region were summarized in table 2. As Jatropha is found as a hedge, semi-cultivated or domesticated, sampling and analysis will be done based on the assumption that any given hedge from a single household will have high degree of similarity. Likewise, Jatropha trees in a given live fences or hedge will be considered as they are from a clone of the same ancestors by taking assumption that Jatropha is propagated vegetatively without any special technique.

About 30-40 kg fruits were collected randomly from representative plants (healthy, not too young or too old) from each study sites in order to have sufficient seeds for determining oil content, seed and fruit characteristics. Data on seed to shell ratio, thousand seed weight, seed coat weight, endosperm weight and endosperm to seed ratio were measured and summarized before oil content determination.

2.3. Oil content determination

The oil content (%) was determined through solvent extraction method from composite seed samples taken from each study sites. Soxhlet extraction apparatus (Model EAM 9204, MTOPS) was employed according to PORIM Test Method (1995). The seeds were separated For extraction of straight vegetable oil, 10-15 kg of seeds taken from individual sample plots (composite seed samples of individual trees considered in the sample plots) was used. The seeds were crushed in presser mortar. Then the crushed seeds were weighted in tumble and put in Soxhlet apparatus. The Soxhlet apparatus was placed over a heating mantle and the oil was extracted for 4-6 hours with the help of hexane solvent (Horowitz, 1984). The oil was concentrated by removing the hexane by using distillation method in a Clevenger type apparatus according to Guenther (1972). Then, the oil content was calculated as follows.

$$\text{Oil content } (\%\ {}^{w}/_{w}) = \frac{Woil}{Wseedsample} \times 100 \quad \text{.....(eq. 1)}$$

2.4. Field data analysis

As all the samples were collected on individual testing sites, all the data presentations were made on mean basis. To statistically analyze the association among different seed characteristics and oil content were done following person correlation coefficients using SAS PROC GLM (2002).

Table 1
Representative Jatropha study sites of the country selected for the study.

	Study sites selected from potential Jatropha growing areas of the country for the study			
No	**Regions**	**Zones**	**Weredas**	**Study sites**
1	SNNPRS	4	9	12
2	Oromia	9	11	11
3	Tigray	8	8	8
4	Amhara	1	5	6
5	Benishangul Gumuze	1	3	5
Total	5	23	36	40

Table 2

Description of study sites considered for Jatropha provenance assessment study.

Regions	Zones	Weredas	Kebele	Code	Altitude	Longitude	Latitude
SNNPRS	Segene	Derashe Leyu Wereda	Gato	S-S-DLW-G	1281	05'32.933	037'24.970
	Wolayita	Kindo Koisha	Multicho	S-W-KK-M	1189	06'54.570	037'30.765
		Damot Woyde	Torasedebo	S-W-DW-T	1491	06'51.53	037'57.726
		Humbo	Abela Faricho	S-W-H-AF	1387	06'38.938	037'49.627
	Gamo Gofa	Kucha	Dana	S-W-K-D	1283	06'34.18	037'33.108
		Arbaminch Zuria	Sile	S-GG-AZ-S	1123	05'54.542	037'30.236
		Arbaminch Zuria	Chalo mile	S-GG-AZ-CM	1220	06'06.927	037'35.781
		Gofa	Zenga Zelgo	S-GG-G-ZZ	1163	06'22.661	037'00.093
	South Omo	Hammer	Dimeka	S-SO-H-D	1119	05'10.683	036'32.807
		Salamago	Hanna	S-SO-S-H	591	06'13.483	036'07.807
		Bena Tsemai	Asheker	S-SO-BT-A	1134	05'51.744	036'43.486
		Bena Tsemai	Chali	S-SO-BT-C	1343	05'40.797	036'43.383
Amhara	South Wollo	Jile Tumuga	Ireti	A-SW-JT-I	1514		
		Artuma Fursi	Jimate/chireti	A-SW-AF-J/C	1300		
		Dawa Chefe	Gerbi	A-SW-DC-G	1410		
		Bati ketema zuria	Salmene	A-SW-BKZ-S	1502		
		Bati Geter zuria	Ella	A-SW-BGZ-E	1502		
		Bati Geter zuria	Qurqura	A-SW-BGZ-Q	1502		
Benishangul	Metekel	Pawe	K2M4	BG-M-P-K2M4	1038	$11^0$15'09.95"	$036^0$22.29"
		Pawe	K1M49	BG-M-P-K1M49	1038	$11^0$14'01.46"	$036^0$18.04"
		Dangur	Manbuk	BG-M-D-M	1171	$11^0$17.24'	$036^0$14.83"
		Dangur	Dilsanbi	BG-M-D-D	1000	$11^0$12.989'	$036^0$07.75'
		Guba	Mankush	BG-M-G-M	875	$11^0$16'11.78"	$035^0$17'12"
Tigrai	South Tigray	Alemata	-	T-ST-A-	1497	12^0 20.125``	039^0 35.37``
	Mahakalawi	Kola Tibe	Kebala	T-M-KT-K	1801	13^0 38.164``	038^0 56.64``
	Berga abargilu	Shaha takilu		T-BA-ST-	1596	13^0 32.720``	039^0 02.33``
	Aksum	Zuyifirom	Masbir	T-A-Z-M	2033	14^0 18.264``	039^0 03.35``
	Centeral Tigray	Warihalaha	Hindafalas	T-CT-W-H	2038	14^0 13.352``	039^0 11.29``
	Mahikalawi	Merab		T-M-M-	1730	13^0 20.390``	039^0 04.29``
	Dabub misiraq	sahart samire	cali	T-DM-SS-C	1742	03^0 19.84``	039^0 03.14``
	West Zone	Adiramats	Mogu	T-WZ-A-M	878	14^0 0.172``	037^0 29.31``
Oromia	East Wallaga	Sasiga	Ambalta	O-EW-S-A	1577	9^0 16.158``	036^0 31.07``
	Kelam Welaga	Dale	Egu kufale	O-KW-D-EK	1427	08^0 48.672``	035^0 03.56``
		Lalo kile	Kursa jawi	O-KW-LK-KJ	1452	08^0 50.966``	035^0 24.83``
	Jimma	Goma	Cocelami	O-J-G-C	1745	07^0 50.882``	036^0 39.45``
	East Hararge	Babile	Tula	O-EH-B-T	1824	12^0 00.874``	037^0 43.06``
	West Hararge	Meiso	Arkola	O-WH-M-A	1540	09^0 09.483``	040^0 42.80``
	East shewa	Adama	Huluka	O-ES-A-H	1437	08^0 24.185``	039^0 22.48``
	Bale	Delomana	Burkitu	O-B-D-B	1181	06^0 25.261``	039^0 51.28``
		Meda walabu	Walkite	O-B-MW-W		06^0 19.131``	039^0 50.08``
	Ilu abba bora	Boracha	Dara sidan, Marqafo	O-IAB-B-DSM			
	Borana	Abaya	Samaroa Gambella	O-B-A-SG	1504	06^0 24.653	038^0 15.27``

3. Results and discussion

3.1. Seed and fruit characteristics of Jatropha in Ethiopia

3.1.1. Study areas

The study covers different Jatropha producing areas of the country. The study included five regions, 25 zones, 36 Weredas and 40 Kebeles of Jatropha growing areas of the country (figure 1).

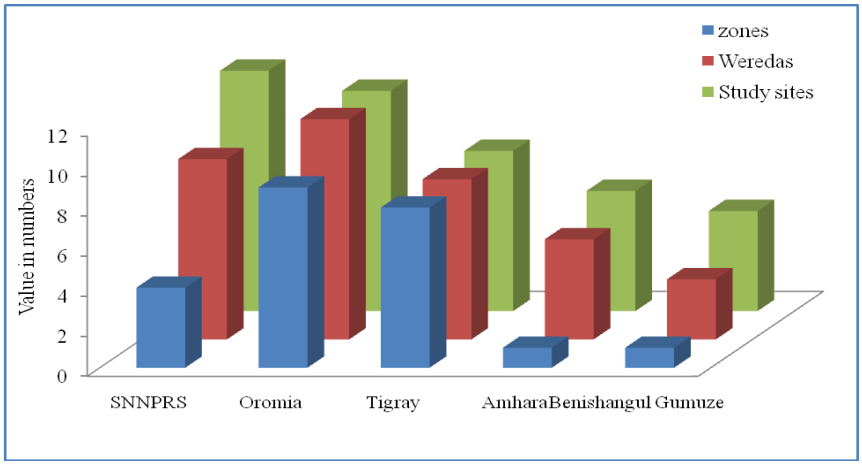

Fig. 1. Summary of testing areas selected for the study.

The study area covers from an altitude of 591 masl at Hanna kebele of South Omo Zone, Salamago Wereda in SNNRPS to 2038 masl at Hindafalas Kebele of Centeral Tigrai Zone, Warihalaha Wereda of Tigrai Region (Table 2). Altitudes ranging from 0-1500 masl are suitable, 1500-2150 masl are moderately suitable and below 0 masl and above 2150 masl are considered as unsuitable areas for Jathropha (Gour, 2006; ICRAF, 2009; Achten et al., 2008; Wiesenhütter, 2003). On the basis of altitude, the cultivation of Jatropha is practiced more or less in its suitable growing ecologies of Ethiopia. However, it was observed that Jatropha was observed being planted outside of its recommended altitudinal ranges. Hence it is advisable to cultivate Jatropha in suitable areas for getting optimum benefits from the crop.

3.1.2. Seed and fruit characteristics of Jatropha in Ethiopia

Different seed and fruit characteristics of Jatropha including seed to shell ratio, thousand seed weight, seed coat weight, endosperm weight, endosperm to seed ratio were collected and summarized in table 3.

3.1.2.1. Seed to shell ration

The overall seed to shell ratio of Jatropha was 2.79. The values of seed to shell ration was ranged from 2.7 to 2.85. The highest being obtained for seed collected from Benishangul gumuz region and the lowest was brained from Amhara regions. From this it is possible to estimate how much seed will be obtained from unshelled Jatropha fruits. As an instance, from a kilo of unshelled Jatropha it is possible to get 0.74 kg of seed and 0.26 kg of shell on an average basis. Compared with the current study, a relatively lower proportion of seed to shell ration (1.67) was reported by Abreu (2008) as shown in figure 2. This indicates that, there is a higher possibility of getting heavier seeds from the fruits of Ethiopian Jatropha populations following proper selection and improvement programs.

3.1.2.2. Thousand seed weight and seed characteristics

The overall average value of thousand seed weight of Ethiopian Jatropha populations was 603.11 g. It ranged from 546.47 g for seeds collected from Oromia region to 714.4 g for seeds collected from Benishangul Gumuz regions. The thousand seed weights of Ethiopian Jatropha populations were found within the ranges of values ranging from 550 to 800 g (FACT Foundation, 2010). Relatively high values of 100 seed weight values ranging from 84.1-86.3 g was reported for experiments conducted under different management conditions in Thailand (Srinophakun et al., 2011). Generally it was observed that there existed a variation on 1000 seed weight among

Ethiopian Jatropha populations, indicating that the existing variation would allow selection for larger seed size for getting higher oil content as 1000 seed weight is strongly and positively associated (r=0.26*) with oil content (Table 6). Kaushik et al. (2007) showed that there was significant variability for 100-seed weight and oil content among 24 accessions of Jatrophafrom Haryana areas in India. Similarly, Ginwal et al. (2004) found that seed sources of Jatropha varied significantly with respect to seed weight and oil content in whole seeds and in the kernel. Heller (1996) reported that the weight of seeds per shrub and 1000-seed weight were significant in Senegal. Knowing thousand seed weight is important for estimating the number of seeds to be obtained from a certain weight of seeds. This value is very important in planning phase of seedling development for the cultivation of Jatropha.

3.1.2.3. Seed coat to endosperm ratio

These seeds were found to have a relatively similar endosperm to seed shell ration ranging between 1.83 and 1.87. The consistent value of seed coat and endosperm expressed in terms of their ration is due to a significant and strong positive association (r=0.60**) of seed coat and endosperm of Jatropha seed (Table 6). The higher value was recorded for populations collected from Oromia region and the lowest was from Amhara. Endosperm weight of the seeds ranges from 5.58 g to 6.27 g. As per the person correlation coefficient analyses, seeds with higher endosperm weight was positively and strongly associated (r=0.22*) with essential oil content (Table 6). Hence, considering endosperm weight during selection and improvement program plays a significant role in maximizing oil content of Jatropha. In other words, heavier seeds have higher oil yield than the lighter ones.

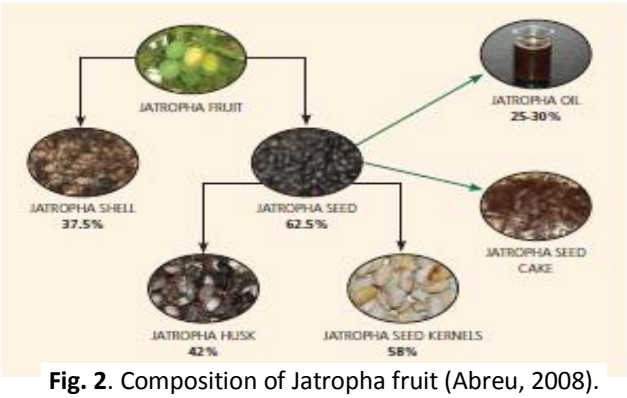

Fig. 2. Composition of Jatropha fruit (Abreu, 2008).

3.2. Oil content Ethiopian Jatropha populations

Samples collected from 40 study sites form 5 regions, 23 Zones and 36 Weredas were subjected for oil content analysis following soxhlet apparatus as shown in. The overall average oil content of 31.89±3.48% was recorded for Jatropha populations collected from different potential Jatropha growing regions of the country. Averaged over the study regions, the oil content of Ethiopian jathropha populations ranged from 29.88% to 34.34% and the highest oil content was obtained from SNNPRS and the lowest form Oromia region (Table 4). The mean oil content, 32.19±3.48%, obtained in this study was comparable to reported results elsewhere, *e.g*. Kaushik et al. (2007) 33%, Ginwal et al. (2004) 36%, and Sunil et al. (2007) 35-40%. The oil content of 13 provenances varied from 25% by weight of the seed in the Cape Verde islands (Wiesenhutter, 2003), to 42% in Toubacouta (Heller, 1996). In India, Kaushik et al. (2007), in their attempt to investigate genetic variability in seed traits and oil content among accessions collected from different regions of India, found the oil content to range between 28–38%. Variation with seed source in the growth performance and oil yield of Jatropha in India was studied by Ginwal et al. (2004) and seeds obtained from different sources, tested at one location, varied between 33.5-39.1% in oil content. Different reports indicated that the oil content of Jatropha seed can range from 18.4-42.3% (Heller, 1996) but generally lies in the range of 30-35% (Fairless, 2007). The values obtained from Ethiopian Jatropha populations growing in different regions of Ethiopian are within the ranges of the different reports. This indicates the possibility of using the existing Jatropha populations for the production of Jatropha oil. The result observed in the present study indicated that Ethiopian Jatropha populations demonstrated a comparable oil contents with other oil bearing plants including groundnut kernel (42 percent), rape seed (37 percent), soybean seed (14 percent) and sunflower seed (32 percent) (FAO, 2010).

Table 3
Summary of fruit and seed characteristics of Jatropha populations of Ethiopia.

Regions	Codes	Seed to shell ratio	1000 seed weight	Seed coat wt	Endosperm Wt	Endosperm to seed coat ratio
	S-S-DLW-G	2.74	587.00	3.10	5.60	1.81
	S-W-KK-M	2.35	552.30	3.00	5.50	1.83
	S-W-DW-T	3.05	591.50	3.30	6.10	1.85
	S-W-H-AF	2.82	660.10	4.10	7.50	1.83
	S-W-K-D	2.75	630.70	3.00	5.70	1.90
	S-GG-AZ-S	2.74	579.90	3.30	7.10	2.15
SNNPRS	S-GG-AZ-CM	2.73	608.40	3.20	6.60	2.06
	S-GG-G-ZZ	3.13	518.20	3.00	5.20	1.73
	S-SO-H-D	2.75	651.00	3.90	6.70	1.72
	S-SO-S-H	3.13	501.80	3.30	5.50	1.67
	S-SO-BT-A	2.65	528.90	3.00	5.90	1.97
	S-SO-BT-C	3.07	591.50	3.50	5.80	1.66
	Average	**2.83**	**583.44**	**3.31**	**6.10**	**1.85**
	A-SW-JT-I	2.6	603.10	3.20	6.20	1.94
	A-SW-AF-J/C	2.5	674.80	3.30	6.30	1.91
	A-SW-DC-G	2.89	562.40	3.10	5.90	1.90
Amhara	A-SW-BKZ-S	2.78	669.10	3.90	6.60	1.69
	A-SW-BGZ-E	2.94	598.20	3.60	6.30	1.75
	A-SW-BGZ-Q	2.51	577.20	3.50	6.30	1.80
	Average	**2.70**	**614.13**	**3.43**	**6.27**	**1.83**
	BG-M-P-K2M4	3.04	730.60	3.20	5.50	1.72
	BG-M-P-K1M49	2.98	713.70	3.00	6.00	2.00
Benishangul	BG-M-D-M	2.42	626.80	3.50	5.50	1.72
Gumuz	BG-M-D-D	2.66	733.40	3.00	5.30	1.77
	BG-M-G-M	3.14	767.50	2.80	5.60	2.00
	Average	**2.85**	**714.40**	**3.10**	**5.58**	**1.84**
	T-ST-A-		550.00	3.80	6.10	1.61
	T-M-KT-K		649.00	3.10	5.90	1.90
	T-BA-ST-		542.00	3.40	6.55	1.93
	T-A-Z-M		541.00	3.10	5.82	1.88
Tigrai	T-CT-W-H		659.00	3.50	5.48	1.57
	T-M-M-		594.00	3.30	5.68	1.72
	T-DM-SS-C		678.00	3.10	6.01	1.94
	T-WZ-A-M		735.00	3.20	6.90	2.16
	Average		**618.50**	**3.31**	**6.05**	**1.84**
	O-EW-S-A		606.00	2.40	3.60	1.50
	O-KW-D-EK		337.10	3.09	3.78	1.23
	O-J-G-C		467.20	2.89	5.86	2.03
	O-EH-B-T		606.00	3.08	6.10	1.98
Oromiya	O-WH-M-A		586.00	3.12	5.81	1.86
	O-ES-A-H		573.00	3.28	6.80	2.07
	O-B-D-B		554.00	3.30	6.70	2.03
	O-IAB-B-DSM		576.00	2.90	5.90	2.03
	O-B-A-SG		613.00	3.16	5.96	1.89
	Average		**546.47**	**3.07**	**5.74**	**1.87**
Overall average±SD		2.799±0.23	603.11±80.1	3.24±0.32	5.94±0.73	1.84±0.18

Table 4
Average oil content (%) values for Jatropha populations of Ethiopia over study regions.

No	Region	Oil content (%) Range	Average oil content (%)
1	SNNPRS	31.18-35.91	34.34
2	Oromia	21.23-33.26	29.88
3	Tigray	30.18-33.16	31.89
4	Amhara	21.89-34.99	30.25
5	Benishangul Gumuze	31.03-35.27	33.09
Overall average		21.23-35.91	32.19±3.48

The oil content values for different study sites of the country are summarized in table 5. It was observed that more oil content was observed from samples collected from SNNPRS and lowest from Oromia region. The existing Ethiopian Jatropha provenances demonstrated an overall oil content of 32.19±3.48. Jatropha provenances having oil content ranging between 30-35% are considered good for oil production. Considering the existing Ethiopian Jatropha provenances growing in different testing sites, 15.79% of the provenances demonstrated oil content value of > 35%, 71.05% between 30 and 35% and the remaining 13.16% demonstrated oil content value of < 30%. This indicates that Ethiopian Jatropha provenances can be exploited for the production of oil for different purposes from their existing growing conditions. Likewise, the observed variation confirms the potential of the local population of *Jatropha* to produce a high-yielding genetic material through selection.

Table 5
Oil content values of Jatropha populations samples collected from different parts of the country.

No	Sample code	Altitude	1000 Seed weight	% Oil content
1	S-S-DLW-G	1281	587.00	33.01
2	S-W-KK-M	1189	552.30	34.78
3	S-W-DW-T	1491	591.50	31.18
4	S-W-H-AF	1387	660.10	33.00
5	S-W-K-D	1283	630.70	35.91
6	S-GG-AZ-S	1123	579.90	31.74
7	S-GG-AZ-CM	1220	608.40	34.59
8	S-GG-G-ZZ	1163	518.20	35.61
9	S-SO-H-D	1119	651.00	35.90
10	S-SO-S-H	591	501.80	34.94
11	S-SO-BT-A	1134	528.90	35.89
12	S-SO-BT-C	1343	591.50	35.57
13	A-SW-JT-I	1514	603.10	23.57
14	A-SW-AF-J/C	1300	674.80	32.35
15	A-SW-DC-G	1410	562.40	34.56
16	A-SW-BKZ-S	1502	669.10	34.99
17	A-SW-BGZ-E	1502	598.20	21.89
18	A-SW-BGZ-Q	1502	577.20	34.13
19	BG-M-P-K2M4	1038	730.60	31.03
20	BG-M-P-K1M49	1038	713.70	33.33
21	BG-M-D-M	1171	626.80	33.53
22	BG-M-D-D	1000	733.40	32.27
23	BG-M-G-M	875	767.50	35.27
24	T-ST-A-	1497	550.00	33.13
25	T-M-KT-K	1801	649.00	33.16
26	T-BA-ST-	1596	542.00	31.16
27	T-A-Z-M	2033	541.00	31.98
28	T-CT-W-H	2038	659.00	32.54

29	T-M-M-	1730	594.00	31.01
30	T-DM-SS-C	1742	678.00	30.18
31	T-WZ-A-M	878	735.00	32.00
32	O-EW-S-A	1577	606.00	-
33	O-KW-D-EK	1427	337.10	21.23
34	O-J-G-C	1745	467.20	33.10
35	O-EH-B-T	1824	606.00	33.26
36	O-WH-M-A	1540	586.00	29.58
37	O-ES-A-H	1437	573.00	32.55
38	O-B-D-B	1181	554.00	-
39	O-IAB-B-DSM	-	576.00	29.27
40	O-B-A-SG	1504	613.00	30.19
Overall Average±SD			603.11±80.10	32.19±3.48

The association of altitude, 1000 seed weight and other seed characteristics are summarized in table 6. The higher oil contents were obtained from areas of lower altitudes. This was supported with the significant and negative association (r=-0.27*) of altitude and oil content (table 6). Higher altitudes are negatively and significantly associated (r=-0.21*) with 1000 seed weight and (r=-0.06) with seed endosperm weight. However, 1000 seed weight (r=0.26*) and seed endosperm weight (r=0.22*) were associated positively and significantly with oil content. Therefore, with increasing altitudes from a recommended range from 0-1500 masl (Gour, 2006; ICRAF, 2009; Achten et al., 2008; Wiesenhütter, 2003); it will negatively affect the oil yield there by affecting the yield of the plant and reducing the weight of individual seeds by reducing the production of endosperm by individual seeds. In addition, variation in seed oil content in *Jatropha curcas*from different altitudinal ranges and site conditions in India showed that a maximum oil content of 45.00% was obtained from the lower altitudinal range 400-600 masl, whereas the minimum, 22.68%, was obtained from the higher altitudinal range 800-1000 masl. Hence, it is good to cultivate Jatropha in lower altitudes than going for higher altitudes. This is observed in some parts of Tigrai and Oromia regions.

Table 6
Association among oil content and different seed characters of Ethiopian Jatropha provenances.

	Altitude	**Seed coat weight**	**Endosperm weight**	**1000 Seed weight**	**Oil content(%)**
Altitude	**1**	0.04	-0.06	-0.21*	-0.27**
Seed coat weight	0.04	**1**	0.6**	0.08	0.03
Endosperm weight	-0.06	0.6**	**1**	0.29**	0.22*
1000 seed weight	-0.21*	0.08	0.29**	**1**	0.26*
Oil content (%)	-0.27**	0.03	0.22*	0.26*	**1**

4. Conclusion

Different seed and fruit characteristics of Jatropha including seed to shell ratio, thousand seed weight, seed coat weight, endosperm weight, endosperm to seed ratio and oil content were collected and summerized. The overall seed to shell ratio of Jatropha was 2.79. The values of seed to shell ration was ranged from 2.7 to 2.85. The overall average value of thousand seed weight of Ethiopian Jatropha populations was 603.11 g. It ranged from 546.47 g for seeds collected from Oromia region to 714.4 g for seeds collected from Benishangul Gumuz regions. Knowing thousand seed weight is important for estimating the number of seeds to be obtained from a certain weight of seeds. This value is very important in planning phase of seedling development for the cultivation of Jatropha. These seeds were found to have a relatively similar endosperm to seed shell ration ranging between 1.83 and 1.87. Endosperm weight of the seeds ranges from 5.58 g to 6.27 g. As per the person correlation coefficient analyses, seeds with higher endosperm weight was positively and strongly associated with essential oil content. Hence, considering endosperm weight during selection and improvement program plays a significant role in maximizing oil content of Jatropha i.e heavier seeds have higher oil yield than the lighter ones.

Averaged over the study regions, the oil content of Ethiopian Jatropha populations ranged from 29.88% to 34.34% and the highest oil content was obtained from SNNPRS and the lowest form Oromia region. Jatropha provenances having oil content ranging between 30-35% are considered good for oil production. The values obtained from Ethiopian Jatropha populations growing in different regions of Ethiopian are within the ranges of the different reports. This indicates the possibility of using the existing Jatropha populations for the production of Jatropha oil. The result observed in the present study indicated that Ethiopian Jatropha populations demonstrated a comparable oil contents with other oil bearing plants including groundnut kernel (42%), rape seed (37%), soybean seed (14%) and sunflower seed (32%).

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