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Phenotypic Variability in Ethiopian Castor (*Ricinus communis* L.) Accessions

Getinet Alemaw^{1*}, Beemnet Mengesha Kassahun², Girma Taye³, Chalachew Endalamaw¹

¹Ethiopian Institute of Agricultural Research (EIAR), Melkassa Agriculture Research Center P. O. Box 436 Adama, Ethiopia

²Ethiopian Institute of Agricultural Research (EIAR), Wondo Genet Agricultural Research Center, P.O. Box 198, Shashemene, Ethiopia

³Ethiopian Institute of Agricultural Research (EIAR), Biometrics GIS, Agro Meteorology and Biometrics Directorate, P.O. Box 2003, Addis Abeba, Ethiopia

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ABSTRACT

Objective: Castor (*Ricinus communis* L.) is an industrial oilseed that belongs to the family Euphorbiaceae. Castor is believed to be originated in East Africa probably Ethiopia. Although Ethiopia is known as a primary diversity for castor the knowledge on nature and extent of variation of the indigenous germplasm is limited. The present test was conducted to study the nature and extent of variability among Ethiopian castor accessions. **Methods:** The test was conducted at Melkassa and Arsi Negelle, in the Central Rift Valley of Ethiopia during the main season of 2013/14. A total of 105 accessions were arranged in a randomized complete block design with three replications. Data of 12 characters were collected and analyzed statistically. Combined analysis of variance over locations revealed the existence of significant variation among accession in all the traits considered in this study. The interaction between accessions and environment was significant for eight of the 12 traits studied. **Results:** The accessions showed a wide range of variation on days to first flowering (52-148), days to second flowering (65-161), days to first maturity (118-217), days to second maturity (142-237), inflorescence length (13-74 cm), node length (2-32 cm), number of nodes/plant (5-26), number of inflorescence/plant (1-26), plant height (89-356), number of branches/plant (1-9), number of capsules/plant (10-350), hundred seed weight (21-99 g), number of seeds/plant (30-990). Overall highest value of heritability, genetic coefficient of variability and genetic advance as percent of the mean was recorded for number of nodes/plant, number of capsules/plant and 100 seed weight.

1. INTRODUCTION

Castor (*Ricinus communis* L.) an annual/perennial shrub and non edible oil seed crop that belongs to a member of Euphorbiaceae family (Weiss, 2000). The plant is believed to be native of East Africa and probably originated in Ethiopia where it shows tremendous variability (Anjani, 2012). In Ethiopia, Castor grows as

annual in the low lands to small tree perennial in the high lands. India, china, Brazil and USA are the major castor producers globally.

Castor oil is non edible and has been used almost entirely for pharmaceutical and industrial applications (Serverino et al., 2012). Castor oil is unique among vegetable oil because it is the only commercial source of a hydroxylated fatty acid or ricinoleic acid (Liv et al., 2012). This unique fatty acid comprises about 90% of the

*Corresponding Author: Getinet Alemaw, Ethiopian Institute of Agricultural Research (EIAR), Melkassa Agriculture Research Center P. O. Box 436 Adama, Ethiopia (mengeshabeemnet@gmail.com)

castor oil (Serverinoet al., 2012). No other commercial vegetable oil produces such a high level of ricinoleic acid. It appears that the level of ricinoleic acid is not significantly influenced by environment. Serverinoet al (2012) also reported that the high content of ricinoleic acid in castor allows the production of high purity derivatives. The hydroxyl group in ricinoleic acid is important point of chemical reaction that allows several chemical reactions (ICOA, 1992; Ogunniyi, 2006). Castor oil is highly soluble in alcohol at room temperature that facilitates several chemical reactions (da Silva et al., 2006). Castor oil has also high viscosity over a wide range of temperatures which makes it a valuable ingredient of lubricants (Serverinoet al., 2012). Mutlu and Meier (2010) stated that castor oil is one of the most promising renewable raw materials for the chemical and polymer industries due to its manifold uses and to a series of well established industrial procedures that yield a variety of different renewable platform chemicals. Although Ethiopia is considered as one of the centers of diversity, little effort was made to evaluate the nature and extent of castor variation that exists in Ethiopian germplasm. This lack of information is a prerequisite to exploit the wealth of castor diversity through plant breeding in the country. Therefore, the available germplasms should be properly evaluated and their attributes have to be known to the breeders. Therefore, the present study was designed with the objective of evaluating the available germplasm for morphological and agronomic traits.

2. MATERIALS AND METHODS

The experiment was conducted on two locations in the central rift valley of Ethiopia at Melkassa and ArsiNegelle. Melkassa Agricultural Research Center is found at 8 ° 24'N and longitude of 39 ° 21'E an altitude of 1650 meters above sea level. The site receives average annual rain fall of 853 mm. The average annual temperature of Melkassa testing site ranges from 13.45 to 28.8°C. The soil textural class is clay loam with a pH of 6.7. Geographically ArsiNegelle is located at latitude 7° 20'N, longitude 38° 9'E and 1960 meter above sea level. The site receives average annual rain fall of 888 mm. The average annual temperature of ArsiNegelle testing site ranges from 9.1 to 26°C.

The experiment included 105 germplasm of castor arranged in randomized complete block design with three replications. Seeds were sown on a two rows and five meters long and plant spacing of 80 and 60 cm. Two seeds were planted in a single hole by hand and thinned out to one at four leaf stage. All plots were cultivated once and weeded twice and no fertilizer or pesticide was applied. Data on days to first flowering, days to second flowering, days to first maturity, days to second maturity, inflorescence length, node length, number of nodes/plant, number of inflorescence/plant, plant height,

number of branches/plant, number of capsules/plant, hundred seed weight, number of seeds/plant.

Variability among Ethiopian castor germplasm were estimated using range, mean, least significant difference, phenotypic and genotypic variance and coefficient of variability according to Burton and Devane (1953). Statistical analysis of experimental data was performed by analysis of variance (ANOVA) using SAS PROC GLM (2002) at $P < 0.05$. Differences between means were assessed using the least significance difference (LSD) test at $P < 0.05$. Broad sense heritability, genetic advance and genetic advance as percent of the mean were analyzed according to Johnson *et al.* (1955).

3. RESULTS AND DISCUSSION

Estimates of mean squares, range, mean and standard errors from combined analysis of variance for 12 traits of 105 Ethiopian castor accessions over two locations is shown on Table 1. Mean squares from the combined ANOVA revealed a highly significant variation ($P < 0.01$) among the accessions for all the traits considered in this study. The variation among the germplasm is expected for the reason of Ethiopia is the center of diversity for castor (Anjani, 2012).

Location had a significant influence ($P < 0.01$) on days to first flowering, days to second flowering, days to first maturity, days to second maturity, inflorescence length (cm), node length, number of nodes/plant, number of inflorescence/plant, plant height (cm), number of branches/plant, number of capsules/plant, 100 seed weight (g) and number of seeds/plant. This indicates these traits were influenced by a change in the environment. The significance of location effect was expected because Melkassa and Arsi Negelle vary in their rainfall, temperature and other environmental factors. The influence of location on morpho agronomic characteristics of oil bearing plants were also reported for *Coriandrum sativum* L. (Beemnet and Getinet, 2010), *Oreganum vulgare* L. (Beemnet *et al.*, 2014), *Aloysiatriphylla* L. (Beemnet *et al.*, 2013), *Cymbopogon citratus* L. (Beemnet *et al.*, 2011), *Artemisia annua* L. (Belay, 2007; Zewdineshet *et al.*, 2011), *Stevia rebaudiana* Bertoni (Beemnet *et al.*, 2012) and Aflatuni (2005) for *Mentha arvensis* L. and *M. piperita* L.

Interaction effects of accessions and location exerted a significant influence on days to second flowering, days to first maturity, days to second maturity, node length, number of inflorescence/plant, plant height (cm), number of branches/plant, number of capsules/plant and number of seeds/plant, thus, indicating performance inconsistency of accessions to varied environments; hence, wider agro-ecological test trial is inquired to evaluate these traits. In agreement to the present study, Fehr (1991) reported that every factor that is a part of the environment of a plant has the potential to cause differential performance. Likewise, Frankel *et al.* (1994) and IRRI (1996) reported that fluctuating features of the location such as rainfall, relative humidity,

temperature, etc. are some of the environmental factors that cause performance variation in plants.

Table 1.

Analysis of variance of combined data of 12 agronomic traits for 105 castor accessions grown at ArsiNegelle and Melkassa during 2013/14.

| Trait | Location (L) | Accession (A) | L x A | CV |
|-----------------------------------|--------------|---------------|-------|------|
| Days to first flowering | * | * | ns | 27.0 |
| Days to second flowering | * | * | * | 10.8 |
| Days to first maturity | * | * | * | 5.6 |
| Days to second maturity | * | * | * | 4.4 |
| Inflorescence length in cm | * | * | ns | 23.6 |
| Node length in cm | * | * | * | 21.6 |
| Number of nodes per plant | * | * | ns | 17.5 |
| Number of inflorescence per plant | * | * | * | 37.0 |
| Plant height in cm | * | * | * | 15.1 |
| Number of capsules per plant | * | * | * | 44.4 |
| Seed weight g/100 | * | * | ns | 20.3 |
| Number of seeds per plant | * | * | * | 44.3 |

*=Significant at $P < 0.01$ and ns=Non significant at $P < 0.05$

A very wide range of values in agronomic traits was observed at both locations (Table 2). The accessions demonstrated a wide range of variation on days to first flowering (52-148), days to second flowering (65-161), days to first maturity (118-217), days to second maturity (142-237), inflorescence length (13-74 cm), node length (2-32 cm), number of nodes/plant (5-26), number of inflorescence/plant (1-26), plant height (89-356), number of branches/plant (1-9), number of capsules/plant (10-350), 100 seed weight (21-99 g), number of seeds/plant (30-990). The values of range and mean observed shows that accessions had more capsules, branches, seeds/plant and heavier seeds but took longer time to flower and mature at Arsi Negelle than Melkassa. This is because Arsi Negelle is located at higher altitude and receives more rainfall with lower temperature than Melkassa. However, plant height was taller at Melkassa

probably due to higher temperature. The values reported in this study are much higher than that reported by Bolajiet *al.* (2013), Goodarziet *al.* (2012), Wang *et al.* (2013), Anjaniet *al.* (2014) and Lu *et al.* (2010). Wang *et al.* (2011) reported that the range of 100 seed weight in the entire USDA castor collection was 10.1 to 73.3 as compared to 21 to 91 g observed at Melkassa and 22 to 99 g at ArsiNegelle observed in this study. The wide range of days to flower and maturity observed in this study is indicative of the possibility of developing early genotypes through selection. In addition, the values observed in plant height and branches per plant shows that selection of genotypes containing few or single inflorescence with short plant height can be realized. From this it is possible to conclude that there is sufficient genetic variability among the tested accessions to initiate castor breeding program in Ethiopia.

Table 2.

Range, mean and standard deviation of castor accessions for agronomic and morphological traits

| Trait | Locations | | | | | |
|-----------------------------------|-----------|------|------|-------------|------|-------|
| | Melkassa | | | ArsiNegelle | | |
| | Range | Mean | SD± | Range | Mean | SD± |
| Days to first flowering | 52-111 | 72 | 26.5 | 76-148 | 111 | 13.2 |
| Days to second flowering | 65-138 | 93 | 32.0 | 93-161 | 134 | 14.2 |
| Days to first maturity | 118-182 | 146 | 27.0 | 163-217 | 192 | 13.1 |
| Days to second maturity | 142-196 | 164 | 26.5 | 182-237 | 218 | 11.9 |
| Inflorescence length | 13-67 | 36 | 0.5 | 15-74 | 39 | 11.0 |
| Node length | 8-32 | 20 | 7.8 | 2-27 | 13 | 4.8 |
| Number of nodes per plant | 7-26 | 12 | 2.8 | 5-22 | 13 | 3.2 |
| Number of inflorescence per plant | 1-26 | 3 | 2.0 | 1-12 | 4 | 1.9 |
| Plant height in cm | 139-356 | 239 | 21.0 | 89-353 | 208 | 47.9 |
| Number of branches per plant | 1-7 | 3 | 1.2 | 1-9 | 3 | 1.57 |
| Number of capsules per plant | 10-180 | 48 | 0.5 | 13-350 | 98 | 52.3 |
| Seed weight per g 100 seeds | 21-91 | 50 | 10.0 | 21-99 | 47 | 15.5 |
| Number of seeds per plant | 30-540 | 143 | 1.5 | 39-990 | 294 | 156.9 |

Table 3.

Estimation of variance components (phenotypic coefficient of variability, genotypic coefficient of variability and environmental coefficient of variability), heritability in a broad sense, genetic advance and Genetic Advance as Percent of mean for 105 castor germplasm tested at ArsiNegele and Melkassa during 2013/2014.

| Traits | DF1 | DF2 | DM1 | DM2 | IL | NN | NIP | PHT | NBP | NCP | HSW | NSP |
|--|-------|-------|-------|-------|-------|-------|-------|--------|-------|--------|--------|---------|
| Phenotypic Variance | 51.80 | 77.10 | 91.20 | 79.00 | 26.70 | 2.60 | 0.70 | 527.20 | 0.40 | 555.00 | 134.90 | 4891.50 |
| Genotypic Variance | 28.90 | 51.90 | 53.60 | 42.7 | 12.50 | 1.70 | 0.30 | 100.30 | 0.20 | 276.50 | 116.70 | 2394.90 |
| Environmental variance | 22.91 | 25.23 | 37.67 | 36.26 | 14.23 | 0.94 | 0.39 | 426.99 | 0.22 | 278.47 | 18.18 | 2496.63 |
| Phenotypic Coefficient of Variation | 7.85 | 7.70 | 5.65 | 4.65 | 13.75 | 12.95 | 23.43 | 10.27 | 20.12 | 31.84 | 23.80 | 31.31 |
| Genotypic Coefficient of Variation | 5.86 | 6.32 | 4.33 | 3.42 | 9.40 | 10.38 | 15.21 | 4.48 | 13.17 | 22.47 | 22.14 | 21.91 |
| Environmental coefficient of Variation | 5.22 | 4.41 | 3.63 | 3.15 | 10.03 | 7.75 | 17.82 | 9.24 | 15.21 | 22.55 | 8.74 | 22.37 |
| Heritability (%) | 56.00 | 67.00 | 59.00 | 54.00 | 47.00 | 64.00 | 42.00 | 19.00 | 43.00 | 50.00 | 87.00 | 49.00 |
| Genetic Advance | 6.17 | 9.99 | 8.85 | 7.28 | 3.41 | 1.72 | 0.46 | 3.92 | 0.36 | 17.07 | 19.25 | 49.36 |
| Genetic Advance as (% of mean) | 6.73 | 8.76 | 5.23 | 3.81 | 9.06 | 13.73 | 13.20 | 1.75 | 11.63 | 23.07 | 39.46 | 22.09 |

DF1= Days to first flowering, DF2= Days to second flowering, DM1= Days to first maturity, DM2= Days to second maturity, IL= Inflorescence length NN= Number of nodes per plant, NIP= Number of inflorescence per plant, PHT= Plant height in cm, NBP= Number of branches per plant, NCP= Number of capsules per plant, HSW= 100 seed weight in g, NSP= number of seeds per plant.

Estimates of genetic variance ranged from 0.2 for number of branches/plant to 2394.9 for number of seeds/plant. The range of phenotypic variance was 0.4 for number of branches/plant AND 4891.5 for number seeds/plant (Table 3). Compared with environmental variance, genetic variance was larger for days to first flowering, days to second flowering, days to first maturity, days to second maturity, number of nodes/plant, plant height and 100 seed weight. Therefore, the higher proportion of phenotypic variance observed on these traits was due to the larger proportion of genotypic variance. According to Miller *et al.* (1957), these traits can be utilized in breeding programme to evaluate castor accessions for seed yield by using few replicates, location and years.

The higher value of genotypic coefficient of variability (>10%) was obtained for number of nodes/plant, number of inflorescence/plant, number of branches/plant, number of capsules/plant, 100 seed weight and number of seeds/plant (Table 3) indicating that these traits were least affected by the environment. Genetic coefficient of variation indicates the genetic variability present in various quantitative characters without the level of heritability. Genetic coefficient of variation together with heritability estimates would give the best indication of the amount of gain due to selection (Johnson *et al.*, 1955).

Broad sense heritability of more than 50% was obtained for 7 of the 12 characters (Table 3). The heritability estimates were ranged from 19% for plant height to 87% for 100 seed weight. When heritability of a character is very high (>80%), selection for such character may be fairly easy owing to close correspondence between the genotypes and the phenotypes arising from a relatively smaller contribution of the environment to the phenotype (Singh, 1990). For a character with low heritability (<40%), selection may be considerably difficult or virtually impractical due to the masking effect of environment on the genotypic effects (Singh, 1990). Thus, in the present study, selection of accessions based on seed number/plant would be more satisfactory to increase seed yield of castor.

The genetic advance and genetic advance as percent of mean was larger for number of capsules/plant, 100 seed weight and number of seeds/plant; moderate for days to start first flowering, days to second flowering and days to first maturity; and lowest for remaining characters (Table 3). Johnson *et al.* (1955) indicated that the estimate of heritability and genetic advance should always be considered simultaneously as high heritability is not always associated with high genetic gain. The utility of heritability estimates increased when they are used in conjunction with genetic advance expressed as a percentage of mean (Johnson *et al.*, 1955; Allard, 1960). In addition, Panes (1957) reported that association of high heritability with high genetic gain is due to additive gene effect. In the present study, the overall highest value of heritability and genetic advance as percent of means

was found higher for number of nodes/plant, number of capsules/plant and 100 seed weight (Table 3). Therefore, selection based on these traits could predict the performance of the progenies.

CONCLUSION

The data presented in the preceding paragraphs had shown the presence of substantial variability in Ethiopian castor germplasm. Hence, the possibility for further improvement using these variations is wide. Therefore, some of the major economical traits of castor such as seed yield and fatty oil contents which are important for oleochemical industry, pharmaceutical industry, processing industry and trade can possibly be improved for their quality and quantity through selection.

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