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Diversity of Castor (*Ricinus communis* L.) in Ethiopia

Getinet Alemaw
Ethiopian Agricultural Research Council Secretariat, Addis Abeba, Ethiopia, E-mail: getalebir@gmail.com

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ጉሎ ዘርፈ ብዙ የኢንዱስትሪ ጥቅም ያለው ዘይት የሚሰጥ የቅባት እህል ሲሆን መገኛውም ኢትዮጵያ ውስጥ እንደሆነ ይታመናል። በዚህም የተነሳ በአገራችን በዘ ያለ ብዝሀ-ዘር እንደሚገኝና የዚህን ተለያይነት ማጥናት በሰብሉ ላይ ለሚደረገው የዝርያ ማሻሻል ቅድመ-ሁኔታ እንደሆነ ይታመናል። ይህ ጥናት ጠ102 ብዝሀ-ዘሮች፣ ሁለት የተለቀቁ ዝርያዎችና አንድ የተሻሻለ ዝርያ ተለያይነትን በመልካሳና አርሲ ነገሌ ለአንድ ዓመት የተደረገ ውጤትን ያትታል። በውጤቱም መሰረት ብዙዘሮች ለተጠኑት 12 ቱም ባህርያት ሰፊ ተለያይነት አሳይተዋል። ይህም በሌሎች አገሮች ከተደረገው የተለያይነት ጥናት የሰፋ ሲሆን ሁሉንም ብዙዘሮች ለአምስት ዋና ዋና ምድቦች መከፈል ተችሏል።

Abstract

An experiment was carried out to assess the diversity of castor germplasm in Ethiopia. A total of 102 accessions, one elite genotype and two standard varieties were characterized at Melkassa and Arsi Negelle, in the Central Rift Valley of Ethiopia using 12 traits for one during 2013 main season. Analysis of variance, principal component and cluster analysis was performed for the combined data. The result showed that there is tremendous phenotypic variability for agronomic and morphological traits of castor among the tested accessions. For some traits such as 100 seed weight, wider variation was observed compared to the entire USDA germplasm collection. In this study the accessions were clustered in two five classes with cluster V having only one accession. Principal component analysis indicated that PC1 contributed 79% of the variation and capsules per plant and seeds per plant constituting the most to variation among accessions. In this study, number of capsules and seeds per plant were the two most important yield component traits to be considered in the future breeding program.

Introduction

Castor (*Ricinus communis* L.) is non edible oilseed crop adapted to dry lands of tropics and semi-arid tropics. The plant is believed to be native of East Africa and probably originated in Ethiopia where it shows tremendous variability. 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 bears seeds that containing highly valuable industrial oil. Castor oil is unique among vegetable oil because it is the only commercial source of a hydroxylated fatty acid or ricinoleic acid (Severino *et al.* 2012). This unique fatty acid comprises about 90% of the castor oil and 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. The high content of ricinoliec 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. Castor oil is highly soluble in alcohol at room temperature that facilitates several chemical reactions. Castor oil has also high

viscosity over a wide range of temperatures which makes it a valuable ingredient of lubricants.

In Ethiopia, castor does well under dry land or moisture stress areas in the rift valley, Eastern and North West Ethiopia. In these areas, sorghum, tef and haricot bean are the major crops and castor can be a good alternative for rotation. In addition, the production cost of castor namely seed, fertilizer and cultivation is lower than cereals and pulses. Castor crop covers that soil rapidly and does not require frequent weeding and tolerates moisture stress than other crops.

Castor germplasm collected within Ethiopia is deposited in Institute of Biodiversity Conservation in Addis Abeba. Castor breeding and variety development is entirely dependent on this germplasm, although some foreign germplasm is necessary for hetrosis breeding. During the last ten years we have been characterizing the available germplasm at Melkassa Agriculture Research Center for further multi-location testing. The variability observed during the course of this study is shown on Table 1. The present study was conducted to evaluate the available germplasm for morphological and agronomic traits and classify in to various hetrotic groups.

Materials and Methods

The test includes 102 accessions originally obtained from Institute of Biodiversity Conservation and available at Melkassa Agriculture Research Center, two registered varieties and one elite genotype. The test was conducted at Melkassa and its sub Center Arsi Negelle. Melkassa Agricultural Research Center is found at 8^{o} 24'N and longitude of 39^{o} 21'E an altitude of 1650 meters above sea level with long term average of 853 mm rain fall, minimum temperature 13^{o} C, maximum temperature of 29 ^{o}C and 52 % humidity per year. Arsi Negelle is found at latitude 7^{o} 20'N, longitude 38^{o} 9'E and 1960 meter above sea level with long term average of 886 mm rain fall per year. The soil at both locations was clay loam.

The test plots were plowed and harrowed by tractor once and ridges were made at 80 com interval between rows. Two seeds were planted by hand at an interval of 60 cm and reduced to one at four leaf stage. All plots were cultivated once and weeded twice and no fertilizer or pesticide was applied. Days to first flowering was recorded as the number of days from emergence to anthesis of the main raceme. Days to second flowering was recorded as the number of days from emergence to anthesis of the racemes on the secondary branch. Days to first maturity was recorded as the number of days from emergence to maturity of the main raceme.

Days to second maturity was recorded as the number of days from emergence to maturity of the secondary raceme. Plant Height was recorded as the length from the ground to the tip of the main raceme. Number of inflorescence was counted as the total number of racemes on one plant while the length was measured in cm. The total number of nodes was counted on a plant and was recorded as an average of five plants. Number of branches per plant was recorded as the total number of primary and secondary branches.

Number of capsules per plant was recorded by counting all capsules on a plant. Seed weight per 100 seeds was measured by counting 100 seeds and recording the weight in g. The number capsules per plant was multiplied by three to give the number of seeds per plant. This is because one capsule contains three seeds and in essence this was recorded as an average of five plants.

Statistical Analysis

The analysis of variance (ANOVA) was conducted separately for each site and following homogeneity of variance test using Leven's method. This was followed by a combined analysis across sites for all traits measured during trail period using SAS (SAS Institute, Inc. 2001). Broad sense heritability (H), genetic advance, genetic advance as percent of mean was analyzed according to Johnson et al. (955). In the combined analysis of variance, accessions, test environments, replications, accession by environment interaction were all considered as random effects for estimation of BLUPs and Heritability (H). Cluster analysis was used for each site separately and for combined data to group accessions based on all measured traits to study diversity.

Results and Discussion

Range and mean of agronomic traits

A very wide range of values in agronomic traits was observed at both locations (Table 1). The range of values in days to flowering, days to maturity, plant height, seeds per plant and seed weight per 100 seeds were very high. The range of days to flower and maturity, plant height, number of branches, capsules, and seeds per plant was wide.

Table 1. Range, mean and standard deviation of castor accessions for agronomic and morphological traits.

Trait	Location					
	Melkassa			Arsi Negelle		
	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(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

The values of range and mean observed shows that accessions had more capsules, branches, seeds per 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 than Melkassa. However, plant height was taller at Melkassa

probably due to higher temperature. The mean and range values reported in this study are much higher than that reported by Goodarzi et al (2012), Wang et al (2013), Anjani et 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 at Melkassa and 22 to 99 g at Arsi Negelle 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 obtained in plant height and branches per plant shows that selection of genotypes containing few or single inflorescence with short plant height can be realized. Although, only one third of Ethiopian castor collection was included in this study, the values observed can be indicative of the available germplasm variation in the country. In Ethiopia, castor grows from as low as 500 meters of elevation up to 3000 meters as perennial small tree with life span of five to six years. The analysis of variance also indicates that there is sufficient genetic variability among accessions to initiate breeding program in castor. Ethiopia is considered as a center of origin of castor oil plant and there is a great phenotypic variability in the wild.

Analysis of variance

Analysis of variance for 12 agronomic traits grown at Arsi Negelle and Melkassa shows significant difference for all the traits except for days to first flowering at Melkassa. The coefficient of variability for number of inflorescence, number of capsules and number of seeds per plant was high. Similarly, the mean of squares of combined data for locations and accessions were all significant for all traits (Table 2). The mean square for days to first flowering, inflorescence length, number of nodes per plant, and 100 seed weight was non-significant for location x accession interaction.

Table 2. Analysis of variance of combined data of 12 agronomic traits for 105 castor accessions grown at Arsi Negelle and Melkassa during 2013/14.

Trait	Location	Accession	Location x Accession	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 (cm)	*	*	ns	23.6
Node length (cm)	*	*	*	21.6
Number of nodes per plant	*	*	ns	17.5
Number of inflorescence per plant	*	*	*	27.0
Plant height (cm)	*	*	*	15.1
Number of capsules per plant	*	*	*	34.4
Seed weight g/100	*	*	ns	20.3
Number of seeds per plant	*	*	*	24.3

Phenotypic, genotypic variances

Phenotypic genotypic and environmental variances are shown on Table 3. In all cases the Phenotypic variance was higher than both genotypic and environmental components. Environmental variance was lower than genotypic components for days to first flowering,

days to maturity, number of nodes, and hundred seed weight and higher for plant height, internode length, number of inflorescence per plant and number of branches per plant. The phenotypic, genotypic and environmental coefficients of variation followed similar trends.

Heritability and genetic advance

The heritability of traits except inflorescence length, number of inflorescence, and plant height was more than 0.5. The highest heritability value is observed for hundred seed weight. Genetic advance was higher for number of capsules per plant (17.07), hundred seed weight (19.25) and number of seeds per plant (49.36). However the genetic advance as percent of means (5%) was very high for number of nodes (13.73), number of inflorescence per plant (13.20), number of capsules per plant (23.07), hundred seed weight (39.46), and number of seeds per plant (49.36).

The heritability of 12 traits included in this study showed that the values for days to flowering and maturity, number of nodes per plant, seed weight and seeds per plant was higher. This indicates that selection for traits such as 100 seed weight with high heritability may be relatively easy. A review on the research works of castor by Directorate of Oilseeds (India) DOS (2003) in India reported that, all agronomic traits except plant height have high heritability. However in all other oil seeds the low heritability of oil content is a general phenomenon. Destaw (2014) studied phenotypic variability of 48 accessions under irrigation for one season at Melkassa. He reported that the heritability value for days to flowering, days to maturity, capsules per plant and hundred seed weight was significantly, higher than other traits. This is in agreement with the present study but the lower values for seeds per plant, branches per plant, number of inflorescence and inflorescence length was not observed in this study. This could be probably due to differences in number of accessions and locations as well as seasons. The result observed in this study indicates that most traits in Ethiopian castor germplasm can be improved through plant breeding. The higher values of genetic advance as percent of mean for capsules per plant, days to flowering and hundred seed weight reported by Desatw (2014) were also observed in this study.

Table 3. Estimation of phenotypic, genotypic and environmental variance components, heritability in a broad sense, genetic advance and genetic advance as percent of mean for the combined data

Variance components	Traits											
	DF1	DF2	DM1	DM2	IL	NN	NIP	PHT	NBP	NCP	HSW	NSP
Phenotypic variance	51.8	77.1	91.2	79.0	26.7	2.6	0.7	527.2	0.4	555.0	134.9	4891.5
Genotypic variance	28.9	51.9	53.6	42.7	12.5	1.7	0.3	100.3	0.2	276.5	116.7	2394.9
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	0.56	0.67	0.59	0.54	0.47	0.64	0.42	0.19	0.43	0.50	0.87	0.49
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(% 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.

Phenotypic and genetic correlations

Phenotypic and genetic correlation values are shown on Table 4. In all cases genetic correlations were higher in value than phenotypic correlations. Days to flowering and maturity were positively correlated both at phenotypic and genotypic levels. Days to flowering and maturity were positively correlated with number of nodes per plant both at phenotypic and genotypic levels but negatively with number of inflorescence length, inflorescence per plant, number of branches per plant and number of capsules per plant. However days to first and second maturity were positively correlated with plant height and hundred seed weight at both genotypic and phenotypic levels. Number of seeds per plant was negatively correlated with days to flowering, days to maturity, number of nodes and hundred seed weight and positively with inflorescence length, number of inflorescence per plant, number of branches per plant and number of capsules per plant.

The phenotypic and genotypic coefficient of correlations followed similar trend except the lower values of the former. The strong negative phenotypic and genotypic correlations of seeds per plant with flowering and maturity dates indicates that earlier genotypes do not bear much seed. In addition, the strong positive correlation between number of seeds per plant with capsules per plant and negative between number of seeds and hundred seed weight shows that, as accessions bear more capsules and seeds, seed size decreases probably due to competition. The positive correlation of days to maturity with plant height and hundred seed weight shows that late genotypes tends to be taller and bear larger seeds. The positive correlation between plant height and number of nodes indicates that taller plants have more nodes. However, the plant height of castor can be decreased through introgression of dwarfing genes (DOS 2003).

Table 4. Estimation of Phenotypic (below Diagonal) and genotypic (above diagonal) correlation coefficients in 105 castor accessions grown at Melkassa and Arsi Negelle.

Trait	DF1	DF2	DM1	DM2	IL	NN	NIP	PHT	NBP	NCP	HSW	NSP
Days to first flowering		0.99	0.99	0.99	-0.56	0.89	-0.99	0.30	-0.86	-0.99	0.38	-0.99
Days to second flowering	0.91		0.90	0.90	-0.50	0.80	-0.99	-0.10	-0.70	-0.99	0.30	-0.99
Days to first maturity	0.88	0.81		0.99	-0.64	0.99	-0.97	0.72	-0.56	-0.99	0.62	-0.99
Days to second maturity	0.86	0.78	0.97		-0.61	0.99	-0.98	0.94	0.53	-0.99	0.70	-0.99
Internode length	-0.30	-0.29	-0.37	-0.33		-0.29	0.49	0.07	0.36	0.85	-0.34	0.80
Number of nodes per plant	0.60	0.54	0.69	0.72	0.00		-0.99	0.70	-0.58	-0.69	0.65	-0.71
Number of Inflorescence per plant	-0.73	-0.68	-0.60	-0.58	0.38	-0.44		-0.33	0.88	0.99	-0.35	0.99
Plant height	0.08	-0.03	0.25	0.30	0.29	0.51	0.12		0.36	0.08	0.38	0.01
Number of branches per plant	-0.46	-0.40	-0.33	-0.29	0.28	-0.23	0.77	0.18		0.84	-0.14	0.84
Number of capsules per plant	-0.73	-0.70	-0.68	-0.67	0.52	-0.38	0.79	0.22	0.61		-0.49	0.99
Hundred seed weight in gm	0.30	0.27	0.49	0.52	-0.21	0.51	-0.22	0.42	-0.12	-0.31		-0.49
Number of seeds per plant	-0.74	-0.70	-0.69	-0.67	0.49	-0.39	0.78	0.20	0.60	0.99	-0.31	

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

Cluster analysis

The 105 castor accessions were grouped in to five clusters based on 12 traits (Table 5). Cluster 1 has 32 accessions that are early to flower and mature having high number of seeds per plant and intermediate 100 seed weight. Cluster II has 28 accessions and is very late to mature, has longest inter node length, more number of nodes per plant, tall in plant height and with heaviest seed weight. Cluster III has 27 accessions is late to flower and mature, has few branches per plant, lowest number of capsules per plant, short plant height and inflorescence, lowest number of capsules and seeds per plant. Cluster IV has only six accessions that have more number of branches per plant, highest number of capsules per plant and highest number of seeds per plant as well as the lightest 100 seed weight. Cluster IV accessions are bushy type. Cluster V has only one accession that has few numbers of branches and inflorescence per plant. Cluster V is late to flower but took shortest time to days to grain filling as compared to all other clusters. .

Cluster analysis also confirms the diversity of the castor germplasm included in the present study. Cluster analysis is used to group similar genotypes in to classes. Goodarzi et al. (2012) in his study of 12 castor genotypes clustered in to three groups. Lu et al. (2010) studied 81 Chinese castor germplasm using molecular techniques and grouped the genotypes in to four classes at the dissimilarity coefficient threshold of 0.43. Anjani (2010) assessed the genetic diversity of 20 wilt resistant germplasm using multivariate analysis of nine agronomic and morphological traits. The result classified the 21 germplasm in to three clusters. Similarly (Beemneet et al. (2011) grouped 49 coriander (*Coriandrumsativum* L.) accessions based on morphological traits, fatty and essential oil contents. Adam et al (2007) classified 28 Ethiopian black cumin (*Nigellasativa* L.) accessions and two introductions in to seven clusters based on oil content and morphological traits. Abraham et al. (2011) also classified 27 indigenous and nine introduced accessions of ginger (*Zingiberofficinale*Rose) in to five clusters based on morphological traits, oleoresin and gengerol contents.

Table 5. Average value of 12 agronomic traits for 105 castor accessions in five clusters

Trait	Cluster				
	I	II	III	IV	V
Number of Accessions	32	27	28	6	1
Days to first flowering	87	94	96	80	121
Days to Second flowering	109	116	119	99	197
Days to first maturity	162	173	174	157	174
Days to Second maturity	185	195	195	180	195
Inflorescence length in cm	40	38	34	42	36
Node Length in cm	16	18	17	15	15
Number of nodes per plant	12	14	12	11	14
Number of Inflorescence per plant	4	3	3	5	3
Plant height (cm)	223	239	201	235	219
Number of branches per plant	3	3	2	4	2
Number of capsules per plant	93	66	48	126	57
Seed weight g/100	44	52	48	42	50
Number of seeds per plant	184	166	138	238	134

Principal component analysis

Principal component of the agronomic traits based on combined data of the two locations is shown on Table 6. The first PC accounted for 79% that explained almost all the total variation. The first PC has accounted for nearly 80% and is sufficient to explain variation in the data. That means all the traits measured do not exhibit sufficient variation in the accessions. Hence, the dimension of the data can be reduced to just one or two variables which would a combination of the original traits used. The coefficients of the new variable are shown on Table 6. Principal

component analysis revealed that number of capsules per plant and number of seeds per plant have large coefficients, indicating that these variables are highly influential in discriminating accessions. Anjani (2010) studied 20 wilt resistant germplasm using principal component analysis. His result indicated that the first and second PCs accounted for 82% of the variation and the first PC alone constituted for 72% of the variation.

Table 6. Results of Principal components and coefficients of the first principal component.

Axis	% accountable	Trait	PC1 coefficient
PC 1	79.0	Number of capsules per plant	0.31
PC 2	11.0	Number of inter nodes per plant	0.01
PC 3	7.0	Node length	-0.01
PC 4	1.7	Number of inflorescence per plant	0.01
PC 5	0.7	Number of nodes per plant	-0.01
		Number of seeds per plant	0.94
		Plant height	0.01
		SW/100 seeds	-0.01
		Days to first flowering	0.03
		Days to second flowering	0.04
		Days to first maturity	0.06
		Days to second maturity	0.07
		Internode length	0.01
		Number of branches per plant	0.01

References

Adam Abebe, Gentinet Alemaw and Kebede WoldeTsadik 2007. Agronomic Characteristics and oil contents in Black Cumin (Nigella sativa L.) Ethiopian J. Agric. Sci.19 (1/2)1-16.

Abraham Shumblo, Getinet Alemaw, Hussien Mohammed and Daniel Bisrat 2011. Rhizome yield and Oleoresin and Total gingerol content of Ginger (*Zingiber officinale* Rosc.) Accessions from Southern Ethiopia, Ethiop. J. Crop Sci.2 (1)1-14.

Anjani K. 2010. Pattern of genetic diversity among *Fusarium* wilt resistant castor germplasm accessions (*Ricinus communis* L.) Electronic Journal of Plant Breeding 1(2)182-187.

BeemnetMengesha, Getinet Alemaw and Bizuayehu Tesfaye 2011. Genetic Divergence in Ethiopian Coriander accessions and its implications breeding of desired plant types, African Crop Science Journal 19(1)39-47.

DestawMulualem 2014.Phenotypic variability and association of traits among yield and yield related traits in Castor (*Ricinus communis* L.), M. Sc. Thesis Haromaya University, Ethiopia.

Directorate of Oilseeds Research 2003. Castor in India, Indian Council of Agricultural Research, Rajendranagar, Hyderabad-500 030, A. P. India.

Goodarzi F., Darvishzadeh R., Hassani A., and Hassanzaeh A. 2112. Study on genetic variation in Iranian castor bean (*Ricinus communis*L.) accessions using multivariate statistical techniques, Journal of medicinal Plants Research Vol.6 (7)1160-1167.

Johnson, H. W., Robinson, H. F. and Comstock R. E. 1955. Estimation of genetic and environmental variability in soybeans, Agronomy Journal 47:314-318.

Lu Zheng, Ql Jian Ming, Fang Ping-Ping, Su Jian-Guang, Xu Jian-Tang and Tao, Ai-Fan. 2010. Genetic diversity and phytogenetic relationship of castor germplasm as revealed by SRAP analysis. Journal of Wuhan Botanical Research 28(1)1-6 (Chinese with English Summery).

SAS Institute 2001. SAS/STAT User's Manual, North Carolina, USA.

Severino LS., L S., Dick L. Auld, Marco Baldanzi, Magno J D. Candido, Grace Chen, William Crosby, Tan D Xiaohua He, P. Lakshmamma, C Lavanya, Olga LT Machado, Thomas Mielke, Maira Milani, Travis D. Miller, J. b. Morris, Stephen A. Morse, Alejanndro A.Navas, Dartanha J Soars, Valdinei Sofiatti, Ming L Wang, Mauricio D Zanotto and helge Zielder 2012. A Review on the Challenges for Increased Production of Castor. Agronomy Journal 104(4) 853-880.

Wang, M. L., Morris J. B., Pinnow,D. L. J. Davis, .Raymer P., and Pederson 2011. A survey of the castor oil content, seed weight and seed coat color on the United States Department of Agriculture germplasm collection. J. Agric and Food Chem

Weiss , E. A. 2000. Oilseed crops, Blackwell Ltd. London