GERMPLASM COLLECTION, SEED PHYSICAL CHARACTERISTICS AND FIELD SEEDLING ESTABLISHMENT OF CASTOR (*RICINUS COMMUNIS* L.) IN NIGERIA

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ABSTRACT

Castor oil plant (Ricinus communis L.) is one of the most versatile oil crops with high socio-economic values around the world. The crop has been demonstrating its economic potentials by earning notable foreign exchange credits to many countries. However, following the incorporation of castor into national research mandate in Nigeria, lack of adequate germplasm and active castor breeding programs that can generate improved varieties have been identified as some of the limitations to commercialization of castor in the country. Based on this background, local and exotic castor germplasm were collected, characterized based on seed physical properties and evaluated for field seedling establishment at three locations. The collections revealed high divergence in seed colour, seed shape, seed mottle, seed caruncle and seed sizes. Variability observed in 100 seed-weights among the accessions ranged from 8.51g to 65g with average of 26.48g. High significant variability in seedling establishment was observed among the accessions. The highest establishments (87 – 89 %) were recorded in Acc.002 and Acc.062 across the locations and the least (10 – 17 %) was recorded in Acc.104. Significant genotypic effect and no significant effect of genotype X location were recorded. High broad sense heritability of 88 and 22.51 per cent genetic gain show good expected gain from selection programs. The germplasm reported here represents some available genetic resources for castor research. This is to enhance the uses of castor genetic resources for integrated research among scientists.

Keyword: Castor, Germplasm, Nigeria, Establishment, Characteristics

INTRODUCTION

Castor (*Ricinus communis* L., 2n = 20) is an oil crop with high economic values (Anjani, 2012). Castor production contributes millions of dollars to India, China and Brazil economy (Salihu *et al.*, 2014). Castor oil is critical to many industrial applications because of its unique ability to withstand high and low temperatures, and to form many valuable derivatives (Mutlu and Meier, 2010; Ogunniyi, 2006). The rapid increase in demand of castor seed/oil in local and international markets (Mutlu and Meier, 2010; Ogunniyi, 2006) has aroused the interest of Nigerian farmers to cultivate the crop. Unfortunately, castor is presently receiving little or no active research attention in Nigeria, resulting to lack of improved production technologies for farmers. This has necessitated integrated castor research efforts among Nigerian scientists. Some of the factors that limit castor research in Nigeria include lack of adequate genetic resources and free information on the gene banks (Salihu *et*

al., 2014). Therefore, the aim of this research is to depict some of available castor genetic resources in Nigeria and provide some basic information to enhance castor genetic improvement programs in Nigeria.

METHODOLOGY

Germplasm Collection

Local collection: Castor germplasm collection was carried in some states of Nigeria between 2012 and 2014. The exploration covered Kogi, Osun, Oyo and Kwara States, and also collections from some institutions within the country. Contact and arrangement were made to the ADP headquarter in the selected states and the tour was scheduled in coincides with the harvesting period of castor in the states. During the exploration, a total of 27 castor producing villages across the states were visited and a total of 54 accessions were collected from 34 different respondents. Collection questionnaires were administered, covering passport data, farming system, production and market constraints. The exploration also included identification of other castor stakeholders ranging from local castor seed marketers, industrialists, processors, machine fabricators to policy makers (Not reported here).

Exotic Collection: For the exotic collection, a letters of request was sent to Plant Genetic Resources Conservation Unit, Agricultural Research Services (ARS), United State Department of Agriculture (USDA) and a total of 50 collections were received.

Seed Physical Characteristics

In 2014, the seeds of all the collections were multiplied and 100 seeds weights were taken from three replicate samples per accession. The seeds were characterized based on the seed shape, seed colour, mottle, caruncle, seed size and seed weight using INDIA Castor Descriptors (2004). The seed colour was determined using Graf Colour Chart (2012).

Seedling Establishment

Ninety-nine (99) castor accessions including 51 local and 48 exotic collections were evaluated on experimental field at three different locations; NCRI Mokwa (Lat. 9° 12'N, Long. 5° 20'E), NCRI, Badeggi (Lat. 9°45'N, long. 6°07'E) and Mina (Lat. 9°36'50"N, Long. 6° 33'25"E). The treatments were laid out on Alpha Lattice Design with 3 replications. Each plot size was 3m X 1.5m in dimension with inter-row and intra-row of 75cm. Thirty (30) intact seeds, pre-treated for seed-borne diseases, were planted at two seeds per hole in each of the replicate plots, resulting to 90 seeds planted per location and total of 270 seeds across the locations. The planting was done in Mid-June 2015, when rainfall has completely stabilized at the locations. Insecticide (Cypermethrin) was applied at 5, 15, 25 and 35 days after planting to prevent seedling lost due to insects' attack. Seedlings' establishment was taken (at 40 days after planting) as the number of plant stands expressed in percentage. Descriptive statistics was used to summarize the date. Combined Analysis of Variance was performed across the locations. Genotypic effect and GXE effect were tested using -2 log-likelihood ratio test procedure of PBtools 1.3. Broad Sense Heritability was estimated according to Eckechi *et al.* (1977), Genetic advance (at 10% selection differential) as described by Johanson *et al.* (1955) and Genetic gain (%) as genetic advance (GA) expressed in percentage of the population mean.

RESULTS AND DISCUSSION

Germplasm Collections and Seed Physical Properties of Castor Accessions at NCRI, Badeggi

Table 1 & 2 present collections and seed physical characteristics of exotic and local castor accessions. The exotic collection represents diverse castor accessions, cutting across four continents including Africa, Asia, America and Europe. The local represents collections from eight states in Nigeria; Benue, Kaduna, Kogi, Kwara, Oyo, Osun, Niger and Yobe States. The exploration reveals very high castor production activities in Kogi and Oyo among all the states. The accessions revealed high divergence in seed colour, seed shape, seed mottle, seed caruncle and seed sizes (Table 1 & 2).Exotic collections comprise of 17 large seeded (diameter > 15mm), 23 medium (diameter, 9mm – 15mm) and 13 small seeded (diameter < 9mm) castor types. The locals include 17 large seeded, 8 medium and 23 small seeded types. The castor germplasm reported here represents some available genetic resources for research in castor. The use of genetic resources could only be effective if there is free access to information on the gene banks (Anjani, 2011). This would enhance research on castor genetic improvement among scientists.Against 104 accessions reported here, Severino *et al.* (2012) reporteda total of 11, 300 castor accessions contained in major castor repositories located in 10 countries.

Variability (CV – 46.62%) observed in 100 seed-weight among the accessions ranged from 8.51g to 65g with average 26.48 (Table 3). The result obtained is in conformity with result of 1033 accessions reported by Wang *et al.* (2010). Seed weight is one of most important yield components which show strong 0positivecorrelation with seed and seed-oil yield in castor (Wang *et al.*, 2010). Seed weight and Seed health serve as important factors, coordinately controlled by the growth of maternal and zygotic tissues, influenced by several signaling pathways. Understanding the mechanism of these pathways can be of great breakthrough in improvement of castor. Basic research and proper practical applications are very important in this respect. The divergence in seed weight exist in the germplasm provide good source of variability upon which selection can be made for improved genotypes.

Field Seedling Establishment

High significant variability in seedling establishment was observed among the accessions (Table 5). The highest establishments (87 – 89 %) were recorded in Acc. 002 and Acc.062 across the locations and the least (10 – 17 %) was recorded in Acc.104 (Table 6). The pattern of the observations, displayed.with boxplot (Figure 1), revealed two outliers at smallest end. The spread between the smallest and largest non-outliers fell between 20 and 100 per cents. The middle half of the data fell between 60 and 90 establishments. The data were skewed left, revealing the concentration of the data towards high values and thus large number of the accessions had relatively good field seedling establishments.

Analysis of variance revealed no effects of blocks and location, and genotype variation has the highest value among the sources of variation (Table 4). Significant genotypic effect and no significant effect of genotype X location were recorded (Table 5). High broad sense heritability of 88 and 22.51 per cent genetic gain show good expected gain from various kinds of selection programs.

Inherent problem of castor field seedling establishment caused by poor seed germination is an issue that deserves attention from scientists. Machado *et al.*

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Inherent problem of castor field seedling establishment caused by poor seed germination is an issue that deserves attention from scientists. Machado *et al.*

(2010) reported seed internal morphology and apparent level of reserved food as two important factors for fast germination and seedling establishment. Seed dormancy of 9.3% at just after harvest and 5.5% 12 months after-ripening were reported (Machado *et al*., 2010). Moshkin (1986) reported low soil temperatures as one of factors for poor germination and seedling establishment in castor.

CONCLUSION

Collection of adequate castor germplasm is an integral part of any effective breeding program. The genetic resource reported here are some available castor germplasm which can be of benefit to geneticists, breeders and other scientist who are interested in castor research. The diversity in seed weight and seedling establishment observed in the germplasm provides good sources of variability upon which selection can be made to generate improved genotypes. Although the results reported here may justify the aim of the research, however there is need for proactive research in seed technology and genetic improvement to enhance the seedling establishment of the present castor cultivars among Nigerian farmers.

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Table 1: Exotic Collections of castor at NCRI Badeggi, Nigeria

	Source/Place Of Collection	Seed Shape	Seed Colour	Seed Mottle	Caruncle	Seed Size
NCRICAS/ACC.001	Brazil/IAR	Square	Maroon	Less conspicuous	Conspicuous	Large
NCRICAS/ACC.002	Brazil/IAR	Oval	Dark Chocolate	Conspicuous	Conspicuous	Small
NCRICAS/ACC.003	Brazil/IAR	Oval	Dark Chocolate	Conspicuous	Less conspicuous	Small
NCRICAS/ACC.052	Turkey	Oval	Brown	Less conspicuous	Less conspicuous	Medium
NCRICAS/ACC.053	Turkey	Oval	Dark Chocolate	Less conspicuous	Less conspicuous	Medium
NCRICAS/ACC.054	Turkey	Elongated	B. Red	Less conspicuous	Less conspicuous	Large
NCRICAS/ACC.055	Turkey	Oval	B. Red	Less conspicuous	Less conspicuous	Medium
NCRICAS/ACC.056	Turkey	Oval	B. Red	Conspicuous	Less conspicuous	Medium
NCRICAS/ACC.057	India	Oval	B. Red	Conspicuous	Less conspicuous	Medium
NCRICAS/ACC.058	Turkey	Oval	Brown	Less conspicuous	Less conspicuous	Small
NCRICAS/ACC.059	Turkey	Elongated	Dark Chocolate	Conspicuous	Conspicuous	Large
NCRICAS/ACC.060	India	Oval	B. Red	Conspicuous	Less conspicuous	Large
NCRICAS/ACC.061	Brazil	Elongated	B. Red	Conspicuous	Conspicuous	Small
NCRICAS/ACC.062	India	Elongated	B. Red	Conspicuous	Conspicuous	Medium
NCRICAS/ACC.063	India	Elongated	B. Red	Less conspicuous	Less conspicuous	Medium
NCRICAS/ACC.064	India	Elongated	Dark Chocolate	Conspicuous	Conspicuous	Large
NCRICAS/ACC.065	India	Oval	B. Red	Less conspicuous	Less conspicuous	Small
NCRICAS/ACC.066	India	Oval	Dark Chocolate	Conspicuous	Conspicuous	Medium
NCRICAS/ACC.067	Algeria	Elongated	B. Red	Conspicuous	Conspicuous	Large
NCRICAS/ACC.068	Cuba	Oval	Dark Chocolate	Conspicuous	Less conspicuous	Medium
NCRICAS/ACC.069	Cuba	Oval	Dark Chocolate	Less conspicuous	Less conspicuous	Small
NCRICAS/ACC.070	Puerto	Oval	Dark Chocolate	Less conspicuous	Less conspicuous	Small
NCRICAS/ACC.071	U.S	Elongated	Dark Chocolate	Conspicuous	Less conspicuous	Small
NCRICAS/ACC.072	Panama	Oval	Brown	Less conspicuous	Conspicuous	Small
NCRICAS/ACC.073	Cuba	Oval	Dark Chocolate	Conspicuous	Less conspicuous	Medium
NCRICAS/ACC.074	Afghanistan	Oval	Dark Chocolate	Less conspicuous	Conspicuous	Medium
NCRICAS/ACC.075	Argentina	Elongated	Dark Chocolate	Conspicuous	Conspicuous	Medium
NCRICAS/ACC.076	Iran	Elongated	Dark Chocolate	Less conspicuous	Less conspicuous	Small
NCRICAS/ACC.077	Iran	Oval	Dark Chocolate	Less conspicuous	Less conspicuous	Small
NCRICAS/ACC.078	Uruguay	Oval	Dark Chocolate	Conspicuous	Conspicuous	Small
NCRICAS/ACC.079	Uruguay	Oval	Dark Chocolate	Conspicuous	Less conspicuous	Small
NCRICAS/ACC.080	Brazil	Oval	Dark Chocolate	Conspicuous	Less conspicuous	Medium
NCRICAS/ACC.081	India	Oval	Dark Chocolate	Conspicuous	Less conspicuous	Medium
NCRICAS/ACC.082	India	Oval	Dark Chocolate	Conspicuous	Conspicuous	Medium
NCRICAS/ACC.083	India	Elongated	B. Red	Conspicuous	Less conspicuous	Large
NCRICAS/ACC.084	India	Oval	B. Red	Less conspicuous	Less conspicuous	Large
NCRICAS/ACC.085	Iran	Oval	Dark Chocolate	Conspicuous	Conspicuous	Medium
NCRICAS/ACC.086	Morocco	Oval	Dark Chocolate	Conspicuous	Conspicuous	Large
NCRICAS/ACC.087	India	Elongated	B. Red	Less conspicuous	Less conspicuous	Large
NCRICAS/ACC.088	S. Africa	Oval	Dark Chocolate	Less conspicuous	Less conspicuous	Medium
NCRICAS/ACC.089	S. Africa	Oval	Dark Chocolate	Conspicuous	Conspicuous	Large
NCRICAS/ACC.090	S. Africa	Elongated	B. Red	Less conspicuous	Less conspicuous	Large
NCRICAS/ACC.091	S. Africa	Oval	Dark Chocolate	Conspicuous	Less conspicuous	Large
NCRICAS/ACC.092	S. Africa	Oval	B. Red	Conspicuous	Conspicuous	Large
NCRICAS/ACC.093	S. Africa	Oval	B. Red	Conspicuous	Conspicuous	Large
NCRICAS/ACC.094	Russia	Oval	Brown	Less conspicuous	Less conspicuous	Large
NCRICAS/ACC.095	U.S	Oval	Brown	Less conspicuous	Less conspicuous	Medium
NCRICAS/ACC.096	U.S	Oval	B. Red	Conspicuous	Less conspicuous	Large
NCRICAS/ACC.097	Colombia	Elongated	Dark Chocolate	Less conspicuous	Less conspicuous	Medium
NCRICAS/ACC.098	Ecuador	Oval	Dark Chocolate	Conspicuous	Less conspicuous	Medium
NCRICAS/ACC.099	U.S.	Oval	Dark Chocolate	Less conspicuous	Less conspicuous	Medium
NCRICAS/ACC.100	U.S.	Oval	Dark Chocolate	Conspicuous	Less conspicuous	Medium
NCRICAS/ACC.101	U. S.			Less conspicuous	Less conspicuous	Medium

Table 2: Local collections of castor at NCRI Badeggi, Nigeria

	Place of Collection	Seed Shape	Seed Colour	Seed Mottle	Caruncle	Seed Size
NCRICAS/ACC.004	Benue	Oval	Brown	Less conspicuous	Less conspicuous	Small
NCRICAS/ACC.005	Yobe	Oval	Brown	Less conspicuous	Less conspicuous	Small
NCRICAS/ACC.006	UAM/Benue	Oval	Brown	Less conspicuous	Less conspicuous	Small
NCRICAS/ACC.007	IAR/Kaduna	Elongated	Brown	Less conspicuous	Conspicuous	Medium
NCRICAS/ACC.008	IAR/Kaduna	Elongated	Maroon	Conspicuous	Conspicuous	Medium
NCRICAS/ACC.009	IAR/Kaduna	Square	White	Conspicuous	Conspicuous	Large
NCRICAS/ACC.010	Kat./Benue	Oval	Dark Chocolate	Less conspicuous	Conspicuous	Small
NCRICAS/ACC.011	Kat./Benue	Oval	Dark Chocolate	Less conspicuous	Conspicuous	Small
NCRICAS/ACC.012	Ankpa/Kogi	Oval	Brown	Less conspicuous	Conspicuous	Small
NCRICAS/ACC.014	Ankpa/Kogi	Square	White	Less conspicuous	Conspicuous	Large
NCRICAS/ACC.015	Ankpa/Kogi	Square	Dark Chocolate	Conspicuous	Conspicuous	Large
NCRICAS/ACC.016	Dekina/Kogi	Square	White	Conspicuous	Conspicuous	Large
NCRICAS/ACC.017	Dekina/Kogi	Square	White	Conspicuous	Conspicuous	Small
NCRICAS/ACC.018	Dekina/Kogi	Elongated	Brown	Less conspicuous	Conspicuous	Medium
NCRICAS/ACC.019	Dekina/Kogi	Elongated	Brown	Less conspicuous	Conspicuous	Small
NCRICAS/ACC.020	Kabba/Kogi	Square	White	Less conspicuous	Conspicuous	Large
NCRICAS/ACC.021	Kabba/Kogi	Oval	Maroon	Conspicuous	Conspicuous	Small
NCRICAS/ACC.022	Ofu/Kogi	Oval	Dark Chocolate	Less conspicuous	Conspicuous	Small
NCRICAS/ACC.023	Ofu/Kogi	Elongated	Brown	Less conspicuous	Conspicuous	Small
NCRICAS/ACC.024	Lokoja/Kogi	Ovall	Maroon	Conspicuous	Conspicuous	Large
NCRICAS/ACC.026	Ilorin/Kwara	Ovall	Brown	Less conspicuous	Conspicuous	Small
NCRICAS/ACC.027	Ilorin/Kwara	Ovall	Maroon	Less conspicuous	Conspicuous	Medium
NCRICAS/ACC.028	Asa/Kwara	Elongated	Brown	Less conspicuous	Conspicuous	Medium
NCRICAS/ACC.029	Ilorin/Kwara	Elongated	Brown	Conspicuous	Conspicuous	Small
NCRICAS/ACC.030	Songo/Kwara	Square	White	Less conspicuous	Less conspicuous	Large
NCRICAS/ACC.031	Asa/Kwara	Square	Brown	Less conspicuous	Less conspicuous	Small
NCRICAS/ACC.032	Bida/Niger	Oval	Dark Chocolate	Conspicuous	Conspicuous	Large
NCRICAS/ACC.033	Badeggi/Niger	Elongated	Brown	Conspicuous	Conspicuous	Medium
NCRICAS/ACC.034	Badeggi/Niger	Ovall	Brown	Less conspicuous	Less conspicuous	Small
NCRICAS/ACC.035	Bida/Niger	Ovall	B. Red	Conspicuous	Less conspicuous	Medium
NCRICAS/ACC.036	Badeggi/Niger	Ovall	Dark-chocolate	Less conspicuous	Conspicuous	Medium
NCRICAS/ACC.037	Bida/Niger	Ovall	Brown	Less conspicuous	Conspicuous	Small
NCRICAS/ACC.038	Ikoyi/Oyo	Square	White	Less conspicuous	Conspicuous	Large
NCRICAS/ACC.039	Ikoyi/Oyo	Oval	Brown	Less conspicuous	Less conspicuous	Small
NCRICAS/ACC.040	Ogbomosho	Square	White	Less conspicuous	Conspicuous	Large
NCRICAS/ACC.041	Alaja/Oyo	Square	White	Less conspicuous	Conspicuous	Large
NCRICAS/ACC.042	Alaja/Oyo	Oval	B. Red	Conspicuous	Less conspicuous	Small
NCRICAS/ACC.043	Alaja/Oyo	Oval	Black	Less conspicuous	Conspicuous	Large
NCRICAS/ACC.044	Ogbomosho	Square	White	Less conspicuous	Conspicuous	Large
NCRICAS/ACC.045	Ogbomosho	Square	White	Less conspicuous	Less conspicuous	Large
NCRICAS/ACC.046	Ifelodun/Kwara	Oval	Brown	Conspicuous	Conspicuous	Small
NCRICAS/ACC.047	Ede/Osun	Square	Black	Less conspicuous	Conspicuous	Large
NCRICAS/ACC.048	Osogbo/Osun	Square	White	Less conspicuous	Conspicuous	Large
NCRICAS/ACC.049	Mansifa/Oyo	Square	White	Less conspicuous	Conspicuous	Large
NCRICAS/ACC.050	Joro/Kwara	Square	White	Less conspicuous	Conspicuous	Large
NCRICAS/ACC.051	Asa/Kwara	Oval	Brown	Less conspicuous	Less conspicuous	Small
NCRICAS/ACC.102	Ilorin/Kwara	Oval	Brown	Less conspicuous	Less conspicuous	Small
NCRICAS/ACC.103	Bida	Oval	Brown	Less conspicuous	Less conspicuous	Small
NCRICAS/ACC.104	Bida	Oval	Brown	Less conspicuous	Less conspicuous	Small

Table 3: Descriptive statistics of 100 seed weight (g) among castor accessions

Accession	Min	Max	Mean	S.E. Mean
Acc.012	11.70	12.21	11.93	0.15
Acc.022	12.00	12.35	12.22	0.11
Acc.023	8.00	12.48	10.88	1.44
Acc.024	35.82	36.53	36.12	0.21
Acc.026	10.89	11.89	11.26	0.32
Acc.027	22.00	22.74	22.42	0.22
Acc.028	26.00	26.25	26.12	0.07
Acc.029	11.00	11.57	11.37	0.19
Acc.030	34.85	35.56	35.14	0.22
Acc.031	14.00	14.56	14.27	0.16
Acc.032	33.98	34.50	34.22	0.15
Acc.014	8.96	9.00	8.99	0.01
Acc.033	28.00	28.72	28.28	0.22
Acc.034	14.00	14.53	14.35	0.17
Acc.035	23.97	25.21	24.39	0.41
Acc.036	15.45	15.67	15.56	0.06

Treatment	Min	Max	Mean	S.E. Mean
36M4	20.00	21.25	20.63	0.36
Acc.037	8.00	9.29	8.80	0.40
Acc.038	48.98	50.91	49.96	0.56
Acc.039	10.50	11.13	10.91	0.21
Acc.040	58.10	59.15	58.75	0.33
Acc.041	54.57	55.00	54.74	0.13
Acc.042	38.67	39.82	39.24	0.33
Acc.015	57.10	58.28	57.79	0.36
Acc.043	49.12	50.00	49.44	0.28
Acc.044	40.00	41.12	40.74	0.37
Acc.045	48.83	49.00	48.92	0.05
Acc.046	14.00	14.55	14.30	0.16
Acc.047	12.00	12.86	12.46	0.25
Acc.048	10.00	26.91	15.97	5.48
Acc.049	45.80	46.10	45.91	0.10
Acc.050	12.53	13.14	12.82	0.18
Acc.104	9.10	9.92	9.38	0.27
Acc.104	12.20	12.51	12.36	0.09
Acc.103	52.16	53.00	52.49	0.26
Acc.051	9.00	10.29	9.61	0.37
Acc.052	21.92	22.82	22.28	0.27
Acc.053	29.00	29.34	29.19	0.10
Acc.054	35.93	36.13	36.03	0.06
Acc.055	22.76	23.31	23.01	0.16
Acc.056	24.85	26.53	25.57	0.50
Acc.057	22.56	22.76	22.66	0.06
Acc.058	16.86	17.15	16.96	0.10
Acc.059	43.69	44.89	44.39	0.36
Acc.017	10.81	10.94	10.88	0.06
Acc.060	30.61	31.24	30.84	0.20
Acc.061	17.12	17.31	17.23	0.06
Acc.062	26.00	26.51	26.25	0.15
Acc.063	21.59	26.90	23.54	1.69
Acc.064	30.91	31.35	31.19	0.14
Acc.065	20.83	21.00	20.89	0.06
Acc.066	26.02	26.98	26.62	0.30
Acc.067	32.95	32.98	32.96	0.01
Acc.068	23.93	24.84	24.32	0.27
Acc.069	15.64	16.25	15.84	0.20
Acc.018	25.98	26.47	26.15	0.16
Acc.070	18.53	18.59	18.57	0.02
Acc.071	17.55	17.92	17.73	0.11
Acc.072	19.12	19.81	19.55	0.22
Acc.073	23.17	24.04	23.49	0.27
Acc.074	18.89	29.10	25.68	3.40
Acc.075	27.96	28.86	28.54	0.29
Acc.076	18.98	19.54	19.25	0.16
Acc.077	19.40	20.11	19.68	0.22
Acc.078	20.21	20.39	20.27	0.06
Acc.079	18.67	18.86	18.76	0.05
Acc.019	12.01	12.31	12.14	0.09
Acc.080	26.42	26.57	26.47	0.05
Acc.081	24.58	24.98	24.72	0.13
Acc.082	29.45	29.67	29.56	0.06
Acc.083	33.08	33.38	33.26	0.09
Acc.084	30.12	30.73	30.34	0.20
Acc.085	21.69	21.96	21.86	0.08
Acc.086	30.96	32.12	31.62	0.35
Acc.087	38.92	39.42	39.21	0.15
Acc.088	29.79	29.79	29.79	0.00
Acc.089	30.56	31.13	30.75	0.19
Acc.020	64.10	65.00	64.67	0.29
Acc.090	18.82	32.89	27.94	4.56
Acc.091	33.27	38.19	35.09	1.56
Acc.092	30.18	30.40	30.33	0.07
Acc.093	30.17	32.10	30.94	0.59
Acc.094	35.10	35.69	35.34	0.18
Acc.095	26.86	26.99	26.94	0.04
Acc.096	31.16	32.48	31.67	0.41
Acc.097	19.40	27.84	24.99	2.79
Acc.098	31.07	32.10	31.42	0.34
Acc.099	28.55	29.37	29.08	0.27
Acc.021	17.00	17.18	17.09	0.09
Acc.100	27.95	28.21	28.04	0.08
Acc.101	29.39	29.93	29.57	0.18
Acc.010	8.20	8.51	8.36	0.09
Acc.009	48.99	49.61	49.40	0.21
Acc.008	32.10	33.00	32.43	0.28
Acc.007	31.68	31.81	31.73	0.04
Acc.006	12.41	12.51	12.47	0.03
Acc.005	9.93	10.20	10.04	0.08
Acc.004	9.59	9.73	9.64	0.05
Acc.003	13.97	14.44	14.24	0.14
Acc.002	32.00	33.20	32.47	0.37
Acc.001	52.86	52.99	52.94	0.04

Overall Mean 26.48
SE. Mean 0.73
CV (%) 46.62

Table 4: Combined analysis of variances for seedling establishment of castor at three locations

Sources of Variation	Variances	Std. Deviations
Genotype X Location	11.686	3.419
Genotype	158.165	12.576
Rep X Block X Location	4.013e-13	6.335e-07
Rep X Location	24.857	4.986
Location	0.000	0.000
Residual	42.099	2.052

Table 5: Genotypic and genotype x location effects on seedling establishment of castor at three locations

Genotypic Effect

Df	Sum Sq	Mean Sq	F value	Pr (>F)
97	158835.5	1637.479	3.9002	0.0000

Genotype X Location Effect

	AIC	BIC	logLik	ChisqDf	Pr(>Chisq)
Model2	6940.53	7422.24	-3368.26		
Model1	6942.42	7428.85	-3368.21	0.113	1 0.7363

Table 6: Means range values of seedling establishment of 98 castor accessionsat Badeggi, Mokwa and Minna

Treatment	Badeggi	Mokwa	Minna1
1. Acc.001	77.513	77.898	77.7202
2. Acc.002	88.779	88.623	89.265
3 Acc.003	83.270	82.843	83.328
4 Acc.004	86.512	87.167	86.322
5 Acc.005	72.653	72.091	71.922
6 Acc.006	69.710	69.959	70.331
7 Acc.007	74.921	74.494	73.919
8 Acc.008	73.854	73.292	72.853
9 Acc.009	77.053	75.949	76.998
10 Acc.010	74.109	74.629	74.595
11 Acc.012	65.971	67.302	66.727
12 Acc.015	62.383	62.226	62.057
13 Acc.016	85.310	85.560	85.797
14 Acc.017	38.456	38.224	38.130
15 Acc.018	84.650	84.764	83.919
16 Acc.019	80.911	81.431	80.991
17 Acc.020	25.500	30.598	29.888
18 Acc.021	17.147	21.589	15.930
19 Acc.022	57.323	55.544	57.133
20 Acc.023	20.910	31.411	32.744
21 Acc.024	81.707	82.632	82.328
22 Acc.026	83.449	82.887	83.665
23 Acc.027	80.251	79.959	79.790
24 Acc.028	81.046	81.025	81.261
25 Acc.029	85.716	85.695	85.255
26 Acc.030	28.288	35.658	26.035
27 Acc.031	30.892	38.991	32.987
28 Acc.032	82.524	82.250	82.333
29 Acc.033	26.217	26.467	25.972
30 Acc.034	69.033	70.500	70.467
31 Acc.035	53.839	54.900	54.595
S/N Treatment	**Badeggy**	**Mokwa**	**Minna**
32 Acc.036	81.587	81.296	80.450
33 Acc.037	65.987	65.154	65.526
34 Acc.038	62.112	62.632	61.922
35 Acc.039	74.587	74.863	74.532
36 Acc.040	67.307	67.827	68.199
37 Acc.041	37.702	38.221	36.952
38 Acc.042	39.439	40.094	40.466
39 Acc.043	39.455	38.487	38.724
40 Acc.044	69.726	68.622	68.318
41 Acc.045	48.525	47.692	47.117
42 Acc.046	59.757	59.600	59.521
43 Acc.047	72.367	72.649	72.447
44 Acc.048	80.596	81.228	80.947
45 Acc.050	57.984	58.368	56.982
46 Acc.052	66.647	66.355	66.998
47 Acc.053	80.074	78.627	79.671
48 Acc.054	77.578	77.962	77.793
49 Acc.055	72.637	73.292	74.070
50 Acc.056	81.317	80.619	81.397
51 Acc.057	80.438	80.590	81.368
52 Acc.058	67.537	66.975	69.117
53 Acc.059	75.042	73.790	74.838
54 Acc.060	78.508	78.622	79.536
55 Acc.061	83.838	84.764	84.731
56 Acc.062	87.307	88.233	87.793
57 Acc.063	71.272	71.579	70.522
58 Acc.064	87.307	87.692	88.334
59 Acc.065	69.811	70.296	69.365
60 Acc.066	57.674	58.194	58.190
61 Acc.067	71.850	72.535	71.554
62 Acc.068	83.178	83.021	83.800
63 Acc.069	66.376	67.032	66.592
64 Acc.070	82.959	83.298	83.904
65 Acc.071	73.584	73.292	73.123
66 Acc.072	75.581	75.695	75.391
67 Acc.073	75.095	75.377	75.520
68 Acc.074	73.766	73.959	73.469
69 Acc.075	81.842	82.362	82.463
70 Acc.076	81.745	82.265	81.931
71 Acc.077	61.816	61.774	62.572
72 Acc.078	75.581	75.965	75.120
73 Acc.079	84.515	84.088	84.731
74 Acc.080	77.188	76.896	75.916
75 Acc.081	80.521	79.959	79.520
76 Acc.082	45.446	45.019	46.202
77 Acc.083	83.043	83.292	83.665
78 Acc.084	73.904	73.952	73.783
79 Acc.085	66.782	66.896	66.322
80 Acc.086	76.782	76.761	76.457
81 Acc.087	84.130	83.297	83.857
82 Acc.088	79.980	80.635	79.384
83 Acc.089	85.581	85.560	85.526
84 Acc.090	54.524	54.705	55.423
85 Acc.091	76.512	77.167	76.322
86 Acc.092	77.385	77.926	77.487
87 Acc.093	71.587	71.431	70.315
88 Acc.094	73.746	72.305	73.400
89 Acc.095	81.920	82.180	82.812
90 Acc.096	81.046	81.025	81.262
91 Acc.097	86.190	85.976	86.406
92 Acc.098	59.726	59.164	57.777
93 Acc.099	82.248	81.956	82.463
94 Acc.100	62.924	61.821	61.922
95 Acc.101	62.175	61.883	61.958
96 Acc.102	55.581	56.236	54.850
97 Acc.103	65.851	65.289	65.526
98 Acc.104	15.087	17.028	10.910
OVERALL MEAN:		**71.071**	
S.E. OF DIFFERENCE		**10.489**	
HERITABILITY (%):		**88.000**	
GENETIC ADVANCE:			**16.270**
GENETIC GAIN (%):			**22.513**

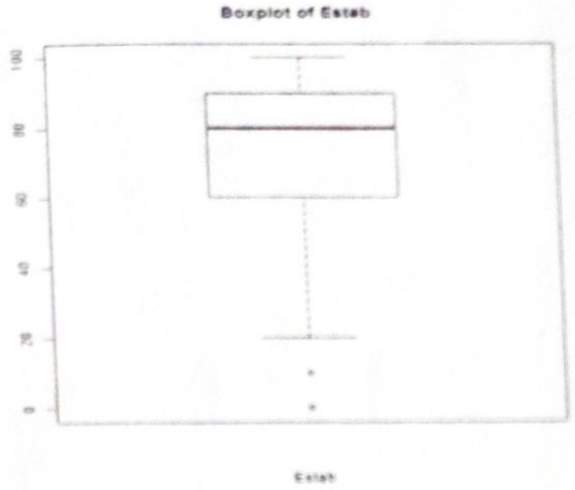

Figure 1: Boxplot of Seedling Establishment among Castor Accessions at three locations