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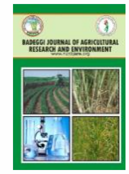

Research Article

Morpho-genetic Diversity and Traits Relationship in Castor Germplasm

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Abstract
Adequate knowledge of the extent of dissimilarity among germplasm accessions and traits' relationships are of great importance in active breeding programme. In the present study, genetic diversity and traits' relationship were assessed among 74 castor germplasm accessions collected at the National Cereals Research Institute Badeggi, Nigeria. The accessions were evaluated on replicated plots of 7.5m^2 size, arranged in a randomized complete block design. The data were taken on 20 individual plants, using standard castor descriptors. The results revealed significant variations for all the traits studied among the entries. Phenotypic and genotypic coefficients of variation estimated showed low environmental effects on the observed variations. High (≥ 70%) broad sense heritability coupled with high (≥ 20%) genetic advance as percentage of mean were observed in all the traits except days to days to first raceme maturity, number of leaf lobes and seed yield. Six cluster groups, with 4 to 38 members, were identified among the accessions. Significant positive correlations were observed between the seed yield and leaf length (0.269*), and spike length (0.972**). The partitioning of the correlations into direct and indirect yield contributors showed positive direct effects for number of internodes to first raceme, spike length and height to first raceme. The findings showed that selection for long spike early accessions could result in constituting a high yielding breeding population. The identified superior accessions could serve as good germplasm sources for castor breeding programme in Nigeria.

Keywords: *Castor accessions, correlation, diversity, genetic variability, path coefficient*

Introduction
Castor plant (*Ricinus communis* L.) is an oil-crop considered very critical for many industrial applications because of its ability to form many important derivatives (Ogunniyi, 2006). The oil, which extracted from the seed, is used in more than 700 applications, including the applications in pharmaceutical industries, rubber/plastic industries, and lubricants/biodiesel industries (Mutlu and Meier, 2010). In the southern part of Nigeria, a food condiment (Ogiri) among the Igbo tribe is produced from castor seeds (Salihu *et al*., 2014). The residual meal of castor seed, after detoxified by boiling, could be used as supplement feed in preparation of broiler finishing diets without any harmful effects (Ani and Okorie, 2009). Also, the meal (autoclaved) could be used in place of the soybean meal in sheep rations (Pompeu, 2009). Organic fertilizer produced from castor meal was reported to have advantage of high nitrogen content, fast mineralization and anti-nematode effects (Lima *et al*., 2011). The leaves, seeds and capsules of castor are used for traditional medicines (Gana, 2015). Concoctions

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prepared from the leaves and roots are used in the treatment of after birth weakness in baby.

Despite the huge economic benefits of castor, its genetic improvement in Nigeria has not been receiving much attention. Consequently, the seed yield among Nigerian castor farmers is low in comparison with the average yields in other countries (Salihu *et al*., 2019). Therefore, there is the need for active castor research in the Nigeria if the country is to exploit the potential of the crop for economic growth. With the availability of castor germplasm in some research centres like National Cereals Research Institute Badeggi, there are opportunities to increase the yield level of castor in Nigeria. However, for any successful genetic improvement programme, constitution of appropriate breeding population is very crucial (Shivanna, 2008). Information on genetic diversity and the traits' association of the available germplasm is of high priority. Savy-Filho (2005) observed wide-range of variability for vegetative traits in castor. Prominent variations were also reported from the reproductive characters such as seed size, number of flowers per raceme, peduncle length and fruit dehiscence (Popova and Moshkin, 1986; Servugaperumal *et al*., 2000). In a study on sixty castor genotypes, Servugaperumal *et al*. (2000) reported high genotypic coefficients for seed yield per plant and racemes per plant. High genetic variation with high heritability and expected genetic progress for traits in castor have been reported from previous studies (Solanki and Joshi, 2000; Lakshmamma *et al*., 2005; Rao *et al*., 2006; Golakia *et al*. (2015); Alhaji *et al*., 2019; Salihu *et al*., 2021). In a traits' association study, Ramesh and Venkate (2001) observed positive relationship and direct impact of plant tallness and raceme length on the seed yield in castor. Spike characters were identified by Alhaji *et al*. (2019) as most effective traits for indirect selection for improved seed yield in castor.

Establishing appropriate breeding populations is of importance at the present status of castor breeding in Nigeria if the country is to bridge the deficit gaps of its local castor oil production. Under this idea, the present research assessed the morpho-genetic diversity and traits relationship in the available promising castor germplasm to constitute improved breeding populations.

Materials and Methods

Seventy-four castor germplasm, sourced from the Castor Breeding Unit of the National Cereals Research Institute (NCRI) Badeggi Nigeria, were evaluated at the Castor Experimental Field at Badeggi (9. 45°N, 6.07°E) during 2020 raining season.

The germplasm accessions were evaluated on a replicated progeny row plots arranged in a randomized complete block design. Three replicated plot sizes of 1m x 7.5m were used and plant spacing of 75cm and 1m for intra-row and inter-row respectively were adopted, making up 22 plant samples per replicate. Two seeds per hole were planted and later thinned to one seedling per hole at three to four weeks after planting. Fertilizer at 60:30:30 kg/ha of N:P:K was applied. Weeding was done three times before the harvest.
Data were taken on Days to First Raceme Maturity (DFRM), Number of Internodes to First Raceme (NIFR), Number of Leaf Lobes (NLL), Leaf Length - LL (cm), Leaf Petiole Length - PL (cm), Spike Length - SL (cm), Height to First Raceme - HFR (cm) and Seed Yield - SY (g/plant). The data were taken on 20 individual plants, using standard castor descriptors (Salihu *et al*., 2021). A significant difference for the traits studied among the entries was assessed by analysis of variance. Phenotypic and genotypic variations as well as broad heritability were estimated according to Allard (1964). The genetic diversity among the accessions was assessed through cluster analysis procedure of Statistical Package for Agricultural Research (STAR 4.0.1, 2013). Traits-relationship, through correlations and path coefficients, was examined according to the procedure described by Akintunde (2012).

Results and Discussion

Table 1 presents the means of the morphological parameters recorded among the castor accessions evaluated. The results revealed variations for all the studied traits among the entries. Days to First Raceme Maturity varied from 80 days to 118 days with an average mean of 103.95 days. The number of internodes to First Raceme ranged between 11 and 21. The length of the spike was between 15.40cm and 49.20cm among the accessions.

Height of 44.20cm to 135.4cm was recorded among the accessions for Height to First Raceme. The seed yield per plant recorded among the accessions was between 80 and 480 g/plant. The results of variance components are shown in the Table 2. The mean square obtained was significant for all the studied traits among the entries (Table 2). Coefficients of variation estimated showed low environmental effects on the observed variations (Table 2). Broad sense heritability otherwise known as repeatability is high in the traits considered. Moderate (10 – 20 %) phenotypic and genotypic coefficients of variation were observed for number of internodes to first raceme, leaf length, petiole length and height to first raceme (Table 2). Low (< 10%) phenotypic and genotypic coefficients were registered for days to first raceme maturity, number of leaf lobes and seed yield. Spike length recorded high (≥ 20%) phenotypic and genotypic variation. However, high (≥ 20%) genetic advance as percentage of mean were observed in all the traits except days to days to first raceme maturity, number of leaf lobes and seed yield. advance observed in most of the traits is an indication of adequate variation and optimum expect genetic gain upon selection for improvement of the traits among the entries. Similar investigations of morpho-genetic characterizations for identification of promising genotypes have been earlier reported by Muhammad *et al*. (1971), Varier *et al*. (1999), Rajendraprasad *et al* (2003) and Salihu *et al.* (2018). Adequate variabilities in castor have also been reported on stem colour, types of inter nodes on stem, plant branching pattern, petiole colour, lamina leaf colour, bloom, type of inflorescence, colour of stigma, capsule type, spike shape, spike compactness, seed colour (Srinivasa *et al*., 2014). Golakia *et al*. (2015), Salihu *et al.* (2017), Silva *et al.* 2017, Alhaji *et al.* (2019) and Oliveira-Neto *et al*. (2021) also documented adequate variability for most of characters in castor, including seed yield per plant. Similar moderate coefficient of variation for days to maturity and the range of broad sense heritability as well as genetic advance reported in the present study were also observed by Salihu *et al*. (2018), Alhaji *et al.* (2019) and Oliveira-Neto *et al*. (2021). However, Salihu *et al*. (2018) and Alhaji *et al.* (2019) reported moderate coefficients of variation for petiole length and seed yield. This is contrary to the magnitudes of variation for the two traits in the present study. The nature of germplasm and their pedigree might be the cause of the dissimilarities.

The agglomerative cluster dendrogram constructed from morphological data among the accessions is presented in Figure 1. The summary statistics for the agronomic performances of the cluster groups are shown in the Table 3. Six cluster groups, with 4 to 38 members, were identified (Figure 1 and Table 3). The cophenetic coefficient was 0.681, signifying optimum genetic distance among the accessions. Cluster VI was the largest groups with 38 cluster members. Cluster III comprises of seven early maturing accessions (Line2, Line29, Line36, Line37, Line38, Line47, Line5) with a range between 80 to 93 days; moreover, early maturing accessions of 87 days to maturity could also be sourced from the cluster IV (Table 3). Short height to first raceme could be found among the members of the Cluster II and III. Parent with long spike could be sourced within the members of the cluster I. Populations with high seed yields could be constituted from the cluster group I and IV. From the cluster groups, an improved population from the accessions could be constituted. The knowledge of the extent of dissimilarity among germplasm accessions is of great importance in breeding programme. Diversity studies, through several methodologies, have been also reported by many authors (Allan *et al*., 2008; Rao *et al*., 2006 and Zheng *et al*., 2010). The genetic dissimilarity observed among the studied castor germplasm accessions was similarly observed by Oliveira-Neto *et al*. (2021) who reported three distinct cluster groups from 40 Brazilian castor germplasm accessions. High morpho-genetic diversity in castor has been reported from several earlier studies (Gana, 2015 and Salihu *et al*., 2019). Diversity in castor germplasm has also been observed by Salihu *et al.* (2013) in as fewer as 11 germplasm accessions. Anjani and Reddy (2003) reported high divergence among twenty-one castor genotypes in India. Costa and Pereira (2006) distinguished two particular clusters among nine castor accessions and attributed the divergence to the diversity in days to flowering, raceme length, plant height and seed oil content. Distinct four clusters and no geographic clustering pattern were reported among forty-six castor germplasm (Zhang-Xishun and Yang-Jian, 2006).

Table 4 shows correlation coefficients for the 8 studied traits. Significant positive correlations were observed between the seed yield and leaf length (0.269*), and spike length (0.972**). Days to first raceme maturity recorded strong and significant negative correlations with the seed yield. The number of leaf lobes showed significant positive correlation (0.478**) with plant height to first maturity (HFR). Significant positive correlations were recorded between the petiole length and and leaf length (0.619**). The partitioning of the correlations into direct and indirect yield contributors showed positive direct effects for number of internodes to first raceme, spike length and height to first raceme (Table 5). Negative direct effects were recorded for days to first raceme maturity, leaf length, petiole length and number of leaf lobes. Highest positive and negative effects were observed in spike length (0.530) and days to first raceme maturity (-0.471) respectively. Leaf length recorded positive indirect contributory effect through days to first raceme maturity (0.133) and spike length (0.146). An indirect positive yield contribution from spike length through days to first raceme maturity was observed. Petiole length recorded indirect contributions through four out of the seven causal traits. The strong and significant correlation and high direct effects observed in some of the traits revealed optimum relationship for effective indirect selection for yield through the traits. The observed high direct yield contribution of the spike length and indirect effect of days maturity through the spike length showed that selection for long spike early genotypes would result in constituting a high yielding breeding population. The significant positive correlation observed between the seed yield and leaf length is because is a factor of larger surface area for absorbing more light for photosynthesis (Ross *et al*. 2000; Zhu *et al*. 2010), while the correlation between seed yields with spike length can be attributed to the fact that the longer the spike, the more the available spaces for flowers to produce seeds. According to Liu *et al.* (2022), Spike length is one of the important selection indicators used in high-yield breeding. Long petioles ensure good orientation of the leaves for more harvest of energy from the sunlight, resulting in more photosynthesis; more accumulation wet and dry weight, and eventually increase in seed yield (Mann 1999; Csaba *et al*. 2019). This indicates that increase in these growth parameters increases yield. Maturity negatively contributes to the yield: negatively correlated means lesser days to maturity and lesser days to flowering. Castor is an indeterminate crop with continuous production of spikes and yield. For such plant, the earlier the better yield when all factors are kept. increasing these growth parameters increases yield. Similar reports of traits' relationships in castor were presented by Salihu *et al.* (2018); Alhaji *et al*. (2019) and Oliveira-Neto *et al*. (2021). The weak and non-significant correlation between seed yield and plant height observed in the present study was also documented by Salihu *et al.* (2018) and Alhaji *et al*. (2019). Similar to the high direct yield contributory effect of spike length presented in this study was the findings of Alhaji *et al*. (2019) who reported 0.562 direct effect for the trait. However, contrary to the present findings were the reports of Ramesh and Venkate (2001) and Aswani *et al*. (2003) who documented strong correlation between seed yield and plant height to primary spike.

Conclusion

The present study revealed the presence of high morpho-genetic diversity among 74 castor germplasm accessions in Nigeria. The 74 accessions were delineated into six distinct cluster groups with characteristic futures. The genetic variances obtained in the study showed optimum variability in 8 the traits assessed. The spike length, leaf length and days to maturity established strong relationships with the seed yield among the germplasm accessions assessed. The identified superior accessions could serve as good genetic variability source for castor breeding programme in Nigeria.

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Table 1: Means of 8 morphological traits studied among 74 castor genotypes at Badeggi, Nigeria

Entries	Days to First Raceme Maturity	Number of Internodes to First Raceme	Leaf Length (cm)	Petiole Length (cm)	Spike Length (cm)	Height to First Raceme (cm)	Number of Leaf Lobes	Seed Yield (g/plant)
Line1	117.00	16.00	16.20	12.60	23.40	49.60	8.60	150.00
Line10	104.00	14.40	17.00	15.80	26.00	63.60	9.60	230.00
Line11	115.00	14.80	19.40	19.60	19.20	63.40	9.00	130.00
Line12	102.00	13.60	18.80	12.80	28.00	97.60	9.20	280.00
Line13	107.00	14.20	19.20	12.00	25.20	55.40	9.00	210.00
Line14	117.00	17.60	19.00	17.80	23.60	92.80	9.80	140.00
Line15	94.00	13.80	23.60	15.00	32.80	64.60	7.80	360.00
Line16	110.00	14.60	22.20	18.00	19.60	98.00	9.00	180.00
Line17	103.00	14.40	25.20	20.00	26.50	48.20	9.00	230.00
Line18	112.00	14.80	19.60	15.20	19.80	69.60	8.40	170.00
Line19	104.00	18.40	21.80	18.40	25.60	88.60	8.80	230.00
Line2	83.00	11.40	21.20	17.80	41.60	96.60	8.60	470.00
Line20	102.00	14.80	18.60	17.40	28.60	75.20	8.20	280.00
Line21	100.00	16.80	18.40	17.60	29.20	108.20	9.60	290.00
Line22	97.00	14.40	28.60	18.80	30.40	69.20	8.20	330.00
Line23	102.00	15.00	21.60	15.80	28.00	86.80	9.40	280.00
Line24	112.00	14.20	21.80	18.20	17.20	71.20	8.80	90.00
Line25	112.00	17.20	20.80	19.40	17.40	80.80	9.00	90.00
Line26	109.00	15.40	24.00	19.40	25.00	71.00	9.60	200.00
Line27	112.00	16.60	20.00	18.80	21.80	73.20	9.40	160.00
Line28	96.00	14.20	20.00	14.60	30.60	104.40	9.00	330.00
Line29	93.00	16.00	25.40	19.40	34.40	57.40	9.20	360.00
Line3	112.00	14.60	19.40	15.00	20.80	44.20	9.00	170.00
Line30	97.00	19.80	21.80	16.80	30.20	95.60	9.00	320.00
Line31	98.00	21.00	26.60	21.60	30.20	98.20	10.00	320.00
Line32	102.00	15.40	22.40	20.60	27.80	71.60	9.20	270.00
Line33	94.00	15.80	21.00	15.40	33.80	92.60	10.00	360.00
Line34	109.00	19.20	19.00	15.20	24.80	91.40	9.40	200.00
Line35	110.00	17.20	17.60	16.40	19.60	98.40	9.00	180.00
Line36	88.00	15.40	20.20	16.20	37.00	65.60	9.00	380.00
Line37	84.00	16.60	24.00	20.20	39.00	56.20	9.00	440.00
Line38	84.00	11.80	19.60	16.60	39.60	62.40	8.60	450.00
Line39	99.00	16.00	24.40	17.20	29.20	92.80	9.20	300.00
Line4	96.00	13.60	21.00	15.20	32.00	86.80	8.60	350.00
Line40	102.00	13.60	19.20	19.20	27.40	87.20	9.40	270.00
Line41	112.00	17.00	19.00	14.40	15.40	84.40	8.80	80.00
Line42	99.00	12.60	22.60	22.60	29.60	96.80	9.40	310.00
Line43	114.00	14.20	19.80	18.00	18.40	81.40	8.80	100.00
Line44	110.00	16.80	21.80	17.60	19.60	73.40	8.80	180.00
Line45	102.00	12.40	23.60	20.00	27.00	135.40	10.00	250.00
Line46	96.00	14.80	19.40	15.00	32.00	68.60	8.00	330.00
Line47	87.00	17.00	22.60	20.80	37.40	91.80	9.20	400.00
Line48	111.00	14.40	25.00	17.60	19.60	66.60	9.20	170.00
Line49	112.00	16.50	27.20	21.20	21.00	89.60	9.20	160.00
Line5	80.00	15.40	28.60	19.00	49.20	66.00	8.80	480.00
Line50	92.00	17.60	23.20	17.20	35.40	72.20	9.80	380.00
Line51	87.00	16.40	25.00	17.80	37.40	61.80	8.00	400.00

Line52	110.00	15.60	21.60	23.00	24.60	80.80	8.80	190.00
Line53	97.00	15.60	24.00	17.40	30.20	78.20	9.00	330.00
Line54	96.00	18.20	20.80	17.40	30.80	105.40	9.60	330.00
Line55	112.00	17.60	25.40	19.40	22.00	84.80	9.40	150.00
Line56	117.00	19.00	21.20	16.80	24.40	78.60	9.60	140.00
Line57	113.00	16.40	23.40	18.00	17.40	90.40	9.00	90.00
Line58	106.00	12.60	20.80	17.20	25.20	65.40	8.60	220.00
Line59	101.00	18.00	21.00	17.60	28.60	71.60	9.80	290.00
Line6	107.00	13.40	16.40	12.40	25.00	48.60	8.80	210.00
Line60	112.00	17.80	24.20	20.40	21.40	90.20	9.40	160.00
Line61	114.00	18.40	22.40	17.80	18.60	65.60	9.00	110.00
Line62	118.00	19.20	22.00	19.40	22.60	69.80	8.00	150.00
Line63	102.00	16.40	25.40	21.00	27.20	93.60	9.40	260.00
Line64	103.00	15.60	16.20	12.60	26.60	86.20	9.80	240.00
Line65	114.00	14.60	23.40	19.20	19.20	106.40	9.60	120.00
Line66	114.00	15.80	18.60	18.00	17.60	61.80	9.20	100.00
Line67	111.00	19.00	21.40	18.40	19.80	114.80	9.60	170.00
Line68	117.00	18.60	21.00	17.20	19.40	130.60	10.00	130.00
Line69	114.00	17.60	22.00	18.60	18.80	111.00	10.00	110.00
Line7	92.00	13.80	20.40	16.40	35.00	78.80	8.40	370.00
Line70	112.00	15.80	20.60	18.80	17.00	93.00	9.00	80.00
Line71	99.00	14.40	22.00	20.40	30.00	75.20	8.40	320.00
Line72	107.00	15.00	19.80	16.60	25.20	87.60	9.80	210.00
Line73	102.00	13.40	20.00	12.60	26.80	64.80	8.20	250.00
Line74	114.00	17.80	21.40	17.33	19.00	64.00	9.00	120.00
Line8	96.00	19.60	25.40	21.40	32.80	84.80	9.80	360.00
Line9	112.00	15.80	19.40	18.60	20.00	114.60	8.60	170.00
Minimum	80.00	11.00	16.20	12.00	15.40	44.20	7.80	80.00
Maximum	118.00	21.00	28.60	23.00	49.20	135.40	10.00	480.00
Mean	104.00	16.00	21.58	17.64	26.39	81.26	9.09	240.00
$LSD_{0.05}$	12.43	2.27	3.11	2.01	5.67	15.82	1.01	33.50

Table 2: Genetic variances and broad sense heritability for 8 morphological traits studied among 74 castor genotypes at Badeggi, Nigeria

Parameters	Mean Square	Genotype variance	Phenotypic variance	Environmental variance	Broad sense Heritability (h^2)	Genotypic Coefficient of Variability	Phenotypc coefficient of variation	GAM
Days to 1st Raceme Maturity	228.70**	72.00	84.70	12.70	0.85	8.16	8.85	15.50
Internodes to First Raceme	11.23**	3.60	4.03	0.42	0.90	11.86	12.54	23.12
Leaf Length (cm)	20.01**	6.40	7.20	0.80	0.89	11.73	12.43	22.78
Petiole Length (cm)	15.70**	5.14	5.42	0.29	0.95	12.85	13.20	25.76
Spike Length (cm)	162.77*	50.02	62.73	12.70	0.80	26.80	30.01	49.30
Height to First Raceme (cm)	277.63**	88.28	101.06	12.78	0.87	11.56	12.37	22.26
Number of Leaf Lobes	0.87**	0.27	0.32	0.05	0.85	5.75	6.23	10.93
Seed Yield (g/plant)	312.20**	100.70	110.81	10.11	0.91	4.18	4.39	8.21

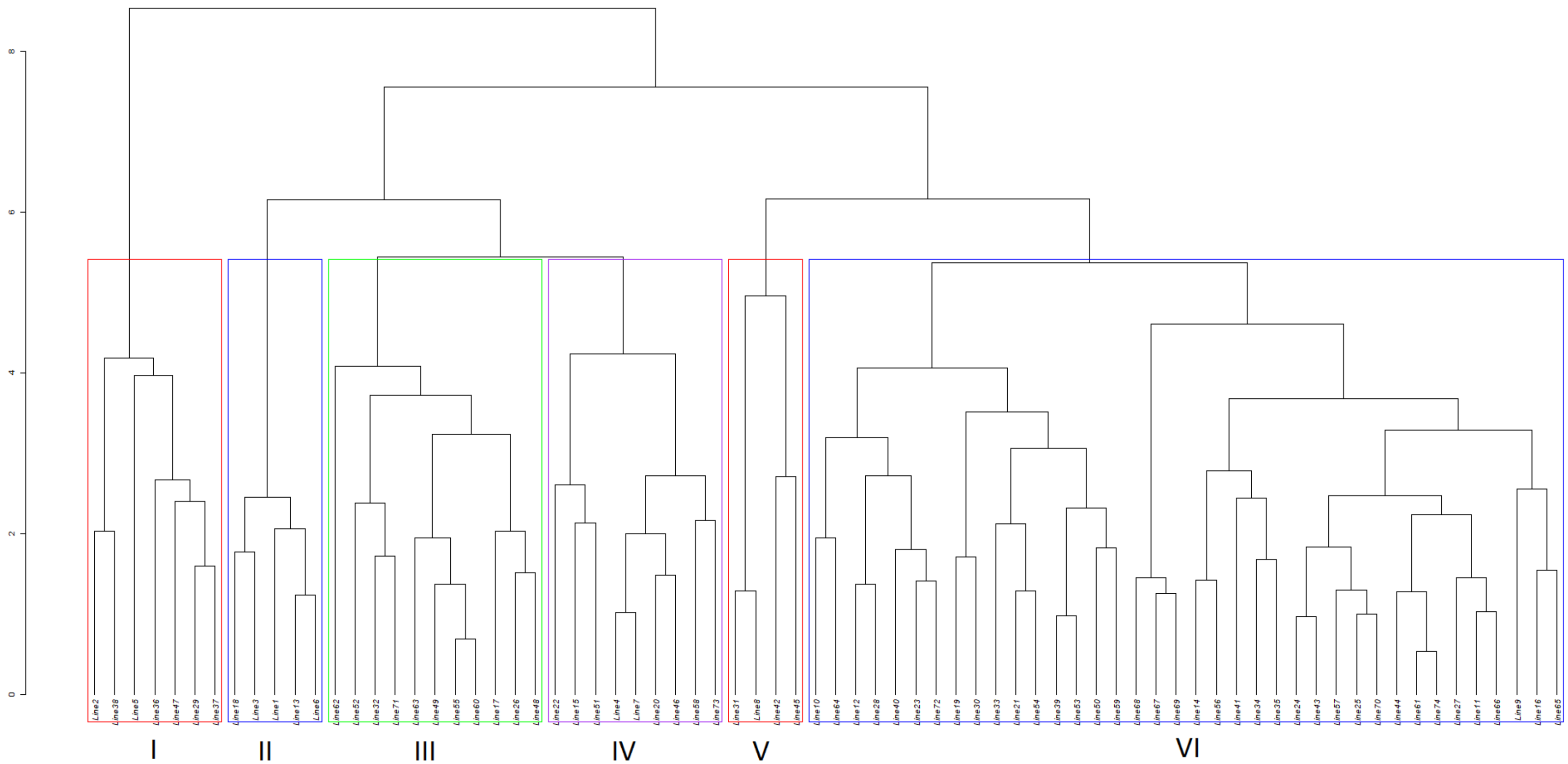

Figure 1: Dendrogram Constructed from 8 Morphological Traits of 74 castor genotypes at Badeggi, Nigeria

Table 3: Summary statistics for agronomic performances of the cluster groups generated among 74 castor genotypes

Variable	**Cluster I**		**Cluster II**		**Cluster III**		**Cluster IV**		**Cluster V**		**Cluster VI**	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Days to 1st Raceme Maturity	80.00	93.00	107.00	117.00	99.00	118.00	87.00	106.00	96.00	102.00	92.00	117.00
Internodes to First Raceme	11.40	17.00	13.40	16.00	14.40	19.20	12.60	16.40	12.40	21.00	13.60	19.80
Leaf Length (cm)	19.60	28.60	16.20	19.60	21.60	27.20	18.60	28.60	22.60	26.60	16.20	24.40
Petiole Length (cm)	16.20	20.80	12.00	15.20	17.60	23.00	12.60	18.80	20.00	22.60	12.60	19.60
Spike Length (cm)	34.40	49.20	19.80	25.20	19.60	30.00	25.20	37.40	27.00	32.80	15.40	35.40
Height to First Raceme (cm)	56.20	96.60	44.20	69.60	48.20	93.60	61.80	86.80	84.80	135.40	61.80	130.60
Number of Leaf Lobes	8.60	9.20	8.40	9.00	8.00	9.60	7.80	8.60	9.40	10.00	8.60	10.00
Seed Yield (g/plant)	360.00	480.00	150.00	210.00	150.00	320.00	220.00	400.00	250.12	360.01	80.10	380.00
Number of Members	**7**		**5**		**11**		**9**		**4**		**38**	
Members	Line2 Line29 Line36 Line37 Line38 Line47 Line5		Line1 Line13 Line18 Line3 Line6		Line17 Line26 Line32 Line48 Line49 Line52 Line55 Line60 Line62 Line63 Line71		Line15 Line20 Line22 Line4 Line46 Line51 Line58 Line7 Line73		Line31 Line42 Line45 Line8		Line10 Line11 Line12 Line14 Line16 Line19 Line21 Line23 Line24 Line25 Line27 Line28 Line30 Line33 Line34 Line35 Line39 Line40 Line41 Line43 Line44 Line50 Line53 Line54 Line56 Line57 Line59 Line61 Line64 Line65 Line66 Line67 Line68 Line69 Line70 Line72 Line74 Line9	

COPHENETIC CORRELATION COEFFICIENT = 0.681

Table 4: Pearson's correlation coefficients for 8 morphological traits studied among 74 castor genotypes

		DFRM	NIFR	LL (cm)	PL (cm)	SL (cm)	HFR (cm)	NLL	SY (g/plant).
DFRM	Coefficient	1	0.2621	-0.2823	-0.0195	-0.9478	0.0970	0.1654	-0.9708
	p-value		0.0241	0.0148	0.8689	0.0000	0.4111	0.1591	0.0000
	n	74	74	74	74	74	74	74	74
NIFR	Coefficient	0.2621	1	0.1780	0.2323	-0.2031	0.2155	0.3693	-0.2293
	p-value	0.0241		0.1291	0.0464	0.0826	0.0652	0.0012	0.0494
	n	74	74	74	74	74	74	74	74
LL (cm)	Coefficient	-0.2823	0.1780	1	0.6195	0.2750	0.0380	0.0396	0.2686
	p-value	0.0148	0.1291		0.0000	0.0177	0.7477	0.7376	0.0207
	n	74	74	74	74	74	74	74	74
PL (cm)	Coefficient	-0.0195	0.2323	0.6195	1	0.0167	0.2258	0.2082	0.0101
	p-value	0.8689	0.0464	0.0000		0.8876	0.0531	0.0751	0.9320
	n	74	74	74	74	74	74	74	74
SL (cm)	Coefficient	-0.9478	-0.2031	0.2750	0.0167	1	-0.1370	-0.1338	0.9717
	p-value	0.0000	0.0826	0.0177	0.8876		0.2444	0.2557	0.0000
	N	74	74	74	74	74	74	74	74
HFR (cm)	Coefficient	0.0970	0.2155	0.0380	0.2258	-0.1370	1	0.4784	-0.0868
	p-value	0.4111	0.0652	0.7477	0.0531	0.2444		0.0000	0.4623
	n	74	74	74	74	74	74	74	74
NLL	Coefficient	0.1654	0.3693	0.0396	0.2082	-0.1338	0.4784	1	-0.1492
	p-value	0.1591	0.0012	0.7376	0.0751	0.2557	0.0000		0.2045
	N	74	74	74	74	74	74	74	74
SY (g/plant)	Coefficient	-0.9708	-0.2293	0.2686	0.0101	0.9717	-0.0868	-0.1492	1
	p-value	0.0000	0.0494	0.0207	0.9320	0.0000	0.4623	0.2045	
	N	74	74	74	74	74	74	74	74

Note: DFRM = Days to First Raceme Maturity; NIFR = Number of Internodes to First Raceme; LL = Leaf Length (cm); PL = Petiole Length (cm); SL = Spike Length (cm); HFR = Height to First Raceme (cm); NLL = Number of Leaf Lobes; SY = Seed Yield (g/plant)

Table 5: Direct (Bold diagonal) and indirect path coefficients for 8 morphological traits studied among 74 castor genotypes

	DFRM	NIFR	LL (cm)	PL (cm)	SL (cm)	HFR (cm)	NLL
DFRM	**-0.4718**	-0.1237	0.1332	0.0092	0.4472	-0.0457	-0.0780
NIFR	0.0009	**0.0035**	0.0006	0.0008	-0.0007	0.0008	0.0013
LL (cm)	0.0013	-0.0008	**-0.0048**	-0.0029	-0.0013	-0.0002	-0.0002
PL (cm)	0.0002	-0.0027	-0.0071	**-0.0115**	-0.0002	-0.0026	-0.0024
SL (cm)	-0.5024	-0.1077	0.1458	0.0089	**0.5301**	-0.0726	-0.0709
HFR (cm)	0.0042	0.0093	0.0016	0.0097	-0.0059	**0.0430**	0.0206
NLL	-0.0032	-0.0072	-0.0008	-0.0041	0.0026	-0.0094	**-0.0195**

Note: DFRM = Days to First Raceme Maturity; NIFR = Number of Internodes to First Raceme; LL = Leaf Length (cm); PL = Petiole Length (cm); SL = Spike Length (cm); HFR = Height to First Raceme (cm); NLL = Number of Leaf Lobes; SY = Seed Yield (g/plant). Residual effect = 0.033 (*i.e 96.7% of total observed variation was accounted for by the traits*)