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Evaluation of Seed Morphometrics, Germination and Oil Content of Collected Castor Landraces

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Abstract
Castor (*Ricinus communis* L.) is a valuable non-edible oilseed crop with industrial and medical applications, known for its high seed oil content (35–65%) and ricinoleic acid (85–90%). This study evaluated seed morphometrics, germination, and oil content of 15 castor landraces collected from six sites in Ilorin, Kwara State, Nigeria. Morphological traits such as stem color, leaf petiole texture, seed color, and size were analyzed, revealing significant variability. Light green stems (73.3%), dark chocolate seeds (66.7%) were predominant, while white, and light brown seeds were rare. Seed size varied, with small seeds (60%) being most common. Germination parameters showed high variability: germination percentage ranged from 32.67% to 78.00%, with a mean of 55.82%, while mean germination time varied from 3.78 to 8.75 days. Seed oil content ranged from 23.89% to 41.77%, with Samples 15 (41.77%) and 14 (39.72%) exhibiting the highest yields. Morphometric analysis using ImageJ software revealed significant differences in seed traits such as area, perimeter, and circularity, indicating diverse seed shapes and sizes. Correlation analysis showed weak relationships between seed morphometrics and oil content, suggesting that seed size and shape are poor predictors of oil yield. The findings highlight the genetic diversity among castor landraces in Ilorin, with implications for breeding programs aimed at improving oil yield and germination performance. The study underscores the need for integrated approaches combining morphological, biochemical, and genomic data to optimize castor cultivation for industrial applications.

Keywords: Oilseed, Morphometrics, Genetic traits, Seed colour, Germination performance
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Introduction

Castor (*Ricinus communis* L.) is a profitable, non-edible oilseed crop with broad applications in the industrial and medical sectors (Deepika *et al.*, 2025). It thrives in drylands and semi-arid tropical regions, showing strong adaptability to various environmental conditions (Alemaw, 2016). Castor is an indeterminate plant that continuously produces spikes, leading to prolonged seed yield (Oke *et al*., 2024). The seeds of castor contain highly valuable industrial oil but different from other oilseed crops among vegetable oils. The interest toward this plant has increased exponentially in recent years due to its high seed oil content (around 35–65%) and a high percentage of ricinoleic acid (85–90%) which distinguishes castor oil from other vegetable oils (Severino *et al*., 2012).

Given its economic value and ecological adaptability, castor has drawn increased research interest. However, despite the presence of diverse landraces in Nigeria, detailed morphological and agronomic characterization remains limited (Odeje and Alonge, 2023). Morphometric analysis—assessing seed shape, size, and other traits—

is vital for plant classification, genetic diversity studies, and conservation efforts (Lestari et al., 2024). Variability in seed size, oil content, and vegetative traits among castor populations suggests significant untapped genetic resources (Weiss, 2000). Diversity was assessed mostly by using morphometric traits and to some extent by molecular techniques in castor (Anjani, 2012).

Landraces are traditional, locally adapted plant varieties that have evolved over time through natural and farmer-driven selection processes (Casañas, 2017). They represent a rich reservoir of genetic diversity, which is vital for the sustainability and resilience of agricultural systems. Unlike modern cultivars that are often genetically uniform, landraces harbor a wide range of genetic traits, including tolerance to abiotic stresses (drought, salinity, and temperature extremes), resistance to pests and diseases, and adaptability to specific agro-ecological zones (Villalobos-López *et al*., 2022).

The genetic variability found in landraces is crucial for crop improvement programs, as it offers plant breeders a broad genetic base for developing new cultivars with improved traits such as higher yield, better quality, and enhanced resilience to climate change (Begna and Teressa, 2024). Furthermore, landraces often possess traits that are no longer present in modern varieties due to genetic erosion, making them essential for conservation and reintroduction of lost or rare alleles.

In the case of castor (*Ricinus communis* L.), landraces may exhibit significant variability in seed size, oil content, and germination behavior—traits that are key to both industrial utility and agronomic performance (Patel et al., 2024). Utilizing landraces in breeding efforts not only ensures the preservation of genetic heritage but also supports the development of locally adapted and sustainable castor varieties, especially in regions where modern hybrids may not perform optimally (Laziridi *et al*., 2024).

In Nigeria, the lack of proper documentation has made identification and classification of castor landraces challenging (Odeje and Alonge, 2023). Morphological characterization serves as a foundation for cultivar development, and combined with data on germination and oil content, can guide the selection of superior varieties. Therefore, this study aimed to evaluate the seed morphometrics, germination performance, and oil content of collected castor landraces in Ilorin, Kwara State, Nigeria.

Materials and Methods

Collection of castor landraces were carried out at six (6) sites in Ilorin Kwara State. The sites were chosen based on quantity of castor population present at each sites. The farmers across the sites claimed the ownership of the castor plants, leaving the vegetation for commercial and medicinal uses. Multiple collections at each site were made based on distinctive features like stem colour, seed colour and size, and leaf petiole surface character (rough & smooth), dried capsule samples were collected and on-site seed assessment for colour and size was carried out using the method of Goodarzil *et al*. (2011); Salihu *et al*. (2013a) and Odeje and Alonge (2023). The collected samples were well labelled and the site coordinates were taken.

The collected capsules were manually threshed. The seed germination and quantification of seed oil content were done at the Department of Plant and Environmental Biology, Kwara State University, Malete, Nigeria. The germination test was carried as described by Lago *et al*. (1979). Germination percentage (G%), germination rate (GR) and mean germination time (MGT) were recorded. The seed oil contents of the samples was determined using Soxhlet extractor (2000mL - Borosilicate Glass - SKU CH0888G) with a reflux condenser and a distillation flask according to AOAC (2012).

Four castor seed plants, each consisting of 25–30 seeds, were selected from each collection and used for the morphometric analysis. The samples were spatially arranged to avoid image merging during the analysis. The seed image was taken vertically with flashing digital camera. The seed morphometric analysis was carried out with

ImageJ software (ImageJ 1.54g – http://imagej.org). Twenty-two seed morphometric readings were considered for the seed image analysis. Seed shape analysis was done according to the method described by Isaza *et al.* (2018), Morphometric analysis of seeds by Quintanilla Carvajal *et al*. (2015) and Seed geometry and size by Ali and, Akbar (2012). Fifteen (15) sample collections from four-plant replicate were used for the analysis.

Data were subjected to analysis of variance (ANOVA) and means were compared with Turkish Honest Significant Difference (HSD). Correlation between germination, seed oil content and morphometric parameters was assessed for any associated morphological markers. The statistical package “Statistical Tools for Agricultural Research” was used to analysis the data.

Results

Morphological and Geographical Traits

The Figure 1 and Table 1 shows the collected castor samples from different locations and the features for collections, which are based on the morphological and geographical traits. The colour of the stem varies from Light green (the most common stem colour) appearing in 11 out of 15 samples (73.3%), Dark green and Wine-coloured stems which were observed in only 2 samples each with 13.3%. The Wine-coloured stems appear in only two locations (Odo Sanda and Gaa Odota), and both samples have dark chocolate seeds with small sizes. Dark green stems are relatively rare but are seen associated with rough petiole surfaces and dark chocolate seeds. Smooth Petiole texture were observed in 8 samples (53.3%) but their associated seed sizes vary widely while Rough petiole is found in 7 samples with 46.7% but are mostly linked with small-seeded plants (except one large-seeded sample). The seed varied from Dark chocolate, the predominant seed colour that appeared in 10 out of 15 samples (66.7%). The White seeds was observed in only 2 samples (13.3%) with locations at Egbejila Road and Odo-Okun respectively. Light brown seeds appear in 2 samples (13.3%) also from Egbejila Road. Dark chocolate seeds are found across all seed sizes, making it the most genetically diverse trait, while White seeds are found only in large-seeded plants and Light brown seeds appear in medium-sized plants, with no small or large-sized variants in the dataset. The most common seed size is Small seeds, occupying 60% of the total seed samples, followed by Medium-sized seeds appear in 3 samples (20%) while the Large seeds are found in only 2 samples (13.3%), both at Egbejila Road and Odo-Okun.

Seed Germination Parameters and Morphometrics

The analysis of variance (ANOVA) presented in Table 2 evaluates the significance of differences among 15 castor landraces for various seed germination parameters and morphometric traits. Germination Percentage F-value of 278.92 ($p < 0.001$) indicates highly significant differences among the landraces. Similarly, for Germination Rate, the F-value of 278.92 ($p < 0.001$) underscores significant variability in the speed of germination across landraces. Mean Germination Time F-value of 12.84 ($p < 0.001$) reflects significant differences in the time required for germination. Percentage Seed Oil Content high F-value of 231.49 ($p < 0.001$) highlights substantial variability in oil content among landraces.

Traits such as Area (F = 706.64), Perimeter (F = 2363.97), Width (F = 203.17), and Height (F = 288.12) exhibit highly significant differences ($p < 0.001$), this indicate diversity in seed sizes and shapes among the landraces. Circularity (F = 259.72), Aspect Ratio (AR; F = 68.60), and Roundness (F = 89.41) show significant differences ($p < 0.001$) Feret diameter (F = 513.24), Min Feret (F = 890.50), and Feret Angle (F = 37.37) also exhibit significant variability.

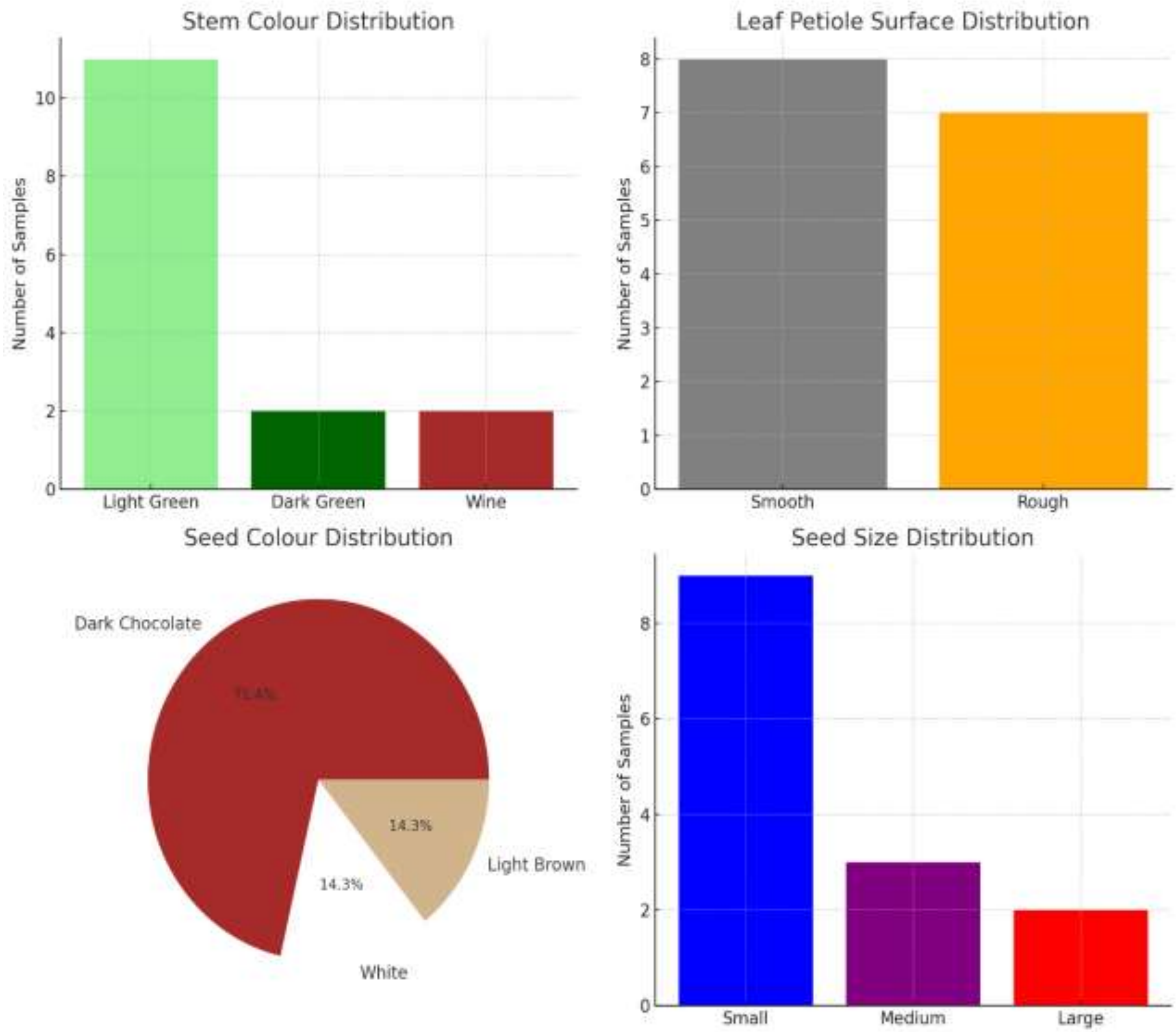

Figure 1: Castor samples Attributes

Table 1: Collected castor samples, locations and features for collections

S/N	Collection site	GPS	Samples	Stem Colour	Leaf Petiole Surface	Seed colour	Seed Size
1	Odo Sanda Akalambi, Sobi Road	N8º30'24.00" E4º33'8.40"	Sample1	Wine	smooth	Dark chocolate	small
		"do"	Sample2	Light green	rough	Dark chocolate	small
		"do"	Sample3	Light green	smooth	Dark chocolate	small
2	Sokoto Aloba, Egbejila road, Ilorin	N8º25'51.60" E4º31'31.96"	Sample4	Dark green	rough	Dark chocolate	small
		"do"	Sample5	Light green	smooth	Dark chocolate	small
3	Egbejila Road, Asadam, Ilorin	N8º28'37.05" E4º33'15.40"	Sample6	Light green	rough	Dark chocolate	small
		"do"	Sample7	Light green	rough	White	large
		"do"	Sample8	Light green	rough	Light brown	medium
		"do"	Sample9	Light green	smooth	Light brown	medium
4	Odo-Okun, Irewolede, Ilorin	N8º26'33.62" E4º31'34.39"	Sample10	Light green	Smooth	White	large
		"do"	Sample11	Dark green	rough	Dark chocolate	small
5	Yidi Prayer Ground	N8º28'5.90" E4º33'10.75"	Sample12	Light green	smooth	Dark chocolate	small
6	Gaa Odota, Airport Road, Ilorin	N8º27'18.07" E4º30'45.37"	Sample13	Wine	rough	Dark chocolate	small
		"do"	Sample14	Light green	smooth	Dark chocolate	small
		"do"	Sample15	Light green	smooth	Dark chocolate	medium

Table 2: Analysis of variance for seed germination parameters and morphometrics of 15 collected castor landraces

Parameters	SS	MS	F-value	Pr (>F)
Germination Percentage	5206.58	371.90	278.92	0.00
Germination Rate	52.07	3.72	278.92	0.00
Mean Germination Time	73.18	5.23	12.84	0.00
Percentage seed oil content	1329.66	94.98	231.49	0.00
Area	17.09	1.14	706.64	0.00
X	5.77	0.38	2.06	0.03
Y	7.19	0.48	7.84	0.00
XM	7.22	0.48	2.34	0.01
YM	11.56	0.77	15.41	0.00

Perimeter	350.02	23.33	2363.97	0.00
BX	6.67	0.44	2.08	0.03
BY	12.56	0.84	9.88	0.00
Width	6.02	0.40	203.17	0.00
Height	7.52	0.50	288.12	0.00
Major	7.61	0.51	356.64	0.00
Minor	4.90	0.33	584.45	0.00
Angle	15019.65	1001.31	40.04	0.00
Circular	2.02	0.13	259.72	0.00
Feret	8.01	0.53	513.24	0.00
Int-Den	1110977.92	74065.19	714.71	0.00
Raw-Int-Den	1165127354901660.00	77675156993444.30	5040.34	0.00
Feret-X	4682992.28	312199.49	178.05	0.00
Feret-Y	7476642.74	498442.85	529.93	0.00
Feret Angle	16899.69	1126.65	37.37	0.00
Min Feret	5.17	0.34	890.50	0.00
AR	1.45	0.10	68.60	0.00
Round	0.30	0.02	89.41	0.00
Solidity	0.05	0.00	18.95	0.00

Y: Width of Seed, X: Length of Seed, XM: maximum length of the seed, YM: maximum, BX: length of the seed at its broadest point, BY: length of the seed at its broadest point

Germination Parameters and Oil Content

Table 3 show the germination parameters and oil content of the samples of the Castor seed. The germination percentage varies significantly among samples, ranging from 32.67% (Sample 2) to 78.00% (Sample 9). The mean germination percentage across all samples is 55.82%. The high Honestly Significant Difference (HSD) of 13.47. The highest germination percentages were observed in Samples 9 (78%) and 8 (70%), indicating superior viability, whereas Samples 2 (32.67%) and 13 (42%) exhibited poor germination. A low Coefficient Variation (CV) % (2.52%) indicates a relatively consistent germination percentage across samples. The germination rate (GR) ranges from 2.270 in Sample 2 to 6.800 in Sample 9. The overall mean germination rate is 4.580, showing moderate speed across landraces. Samples 9 and 8 showed the highest germination rates with values 6.800 and 6.000 respectively, which also correspond to those with high germination percentages. Conversely, Sample 2 (2.270) had the slowest germination, aligning with its low germination percentage. The mean germination time (MGT) ranged from 3.780 (Sample 2) to 8.750 (Sample 9). The average MGT is 5.990, meaning that most samples germinate within approximately 6 days. Samples 2, 13 and 4 with values 3.780, 4.230, and 4.640 respectively had the shortest germination times, suggesting faster seed emergence. Seed oil content varies significantly among the landraces with values ranging from 23.89% to 41.77% in samples 3 and 15 respectively with the mean oil content of 31.72%. The highest oil-yielding landraces include Samples 15 (41.77%) and 14 (39.72%), making them valuable for oil production. The lowest oil contents were recorded in Sample 3 (23.89%) and Sample 4 (24.70%), which may be less desirable for commercial oil extraction. The seed oil content (SOC%) exhibited a broad range, from 23.89% (Sample 3) to 41.77% (Sample 15), with a mean of 31.72%. The high oil-yielding landraces, particularly Sample 15 (41.77%) and Sample 14 (39.72%), are promising candidates for oil extraction and biofuel production. This variability in oil content (HSD = 3.149, CV% = 1.559) suggests strong genetic influence, reinforcing the need for targeted selection of high-oil genotypes.

Morphometric Parameters of Seeds

Table 4 presents detailed morphometric parameters of seeds from 15 castor landraces. The seed area varies widely among samples, ranging from 0.310 (Sample12) to 1.950 (Sample7), with a mean of 0.730. Similarly, the perimeter ranges from 2.200 (Sample12) to 11.450 (Sample2), with a mean of 3.790. The mean width (0.990) and height (0.980) are nearly identical, suggesting a symmetrical seed shape in most landraces. However, Sample7 exhibits the highest values (1.520 and 1.800, respectively), the major axis (mean: 1.140) and minor axis (mean: 0.730) show variability, with Sample7 again displaying the highest values (1.970 and 1.250). The angle parameter, likely representing seed orientation or curvature, varies significantly (74.38° to 124.41°), with a mean of 96.92° and a CV of 5.16%. Circularity values range from 0.130 (Sample2) to 0.860 (Sample13), with a mean of 0.750. These coordinates (likely representing seed center or bounding box) show variability, with high CVs for BX (8.14%) and XM (7.44%).

This continuation of Table 4 provides additional morphometric parameters that further elucidate the structural and densitometric variability among the 15 castor landraces. Feret (Max Caliper Diameter) ranges from 0.86 (Sample12) to 2.03 (Sample7), with a mean of 1.20. The low CV (2.69%) indicates minimal variability, suggesting uniform maximum seed length across landraces. Min-Feret (Min Caliper Diameter) **v**aries from 0.49 (Sample11) to 1.35 (Sample10), with a mean of 0.76. The low CV (2.58%) further supports uniformity in seed width. Feret-Angle shows moderate variability (CV: 5.55%), with values ranging from 74.49° (Sample14) to 133.40° (Sample4). The mean AR (1.59) suggests an elongated seed shape, with Sample6 exhibiting the highest AR (1.82). Int-Den (Integrated Density) ranges from 80.03 (Sample12) to 496.90 (Sample7), with a mean of 186.34. Raw-Int-Den displays extreme variability (CV: 6.93%), with Sample8 (16,130,476.19) and Sample2 (9,015,789.51) standing out. Roundness varies from 0.51 (Sample11) to 0.78 (Sample10), with a mean of 0.63. Solidity shows high consistency (mean: 0.94; CV: 1.37%).

Table 3: Germination parameters and seed oil content of collected castor landraces

Parameters	Germination Percentage (G%)	Germination Rate (GR)	Mean Germination Time (MGT)	Seed Oil Content (SOC %)
Sample1	50.67	4.070	6.720	27.690
Sample10	58.00	4.800	7.080	31.680
Sample11	54.00	4.400	5.560	26.680
Sample12	50.67	4.070	4.950	32.000
Sample13	42.00	3.200	4.230	30.970
Sample14	62.00	5.200	5.830	39.720
Sample15	58.67	4.870	6.520	41.770
Sample2	32.67	2.270	3.780	33.580
Sample3	46.00	3.600	5.730	23.890
Sample4	52.00	4.200	4.640	24.700
Sample5	63.33	5.330	6.260	27.860
Sample6	62.00	5.200	6.150	35.140
Sample7	57.33	4.730	5.720	35.380
Sample8	70.00	6.000	7.850	26.010
Sample9	78.00	6.800	8.750	38.730
Mean	55.82	4.580	5.990	31.720
HSD	13.47	0.347	1.920	3.149
CV (%)	2.520	2.520	6.660	1.559

Table 4: Seed morphometric parameters of 15 collected castor landraces

Parameters	Area	Perimeter	Width	Height	Major	Minor	Angle	Circ.	XM	YM	BX	BY
Sample1	0.450	3.470	1.070	0.910	1.000	0.570	110.090	0.780	6.080	6.680	5.560	7.180
Sample10	1.700	5.460	1.450	1.590	1.660	1.300	93.200	0.750	6.190	6.450	5.480	7.490
Sample11	0.350	2.230	0.810	0.630	0.780	0.470	114.460	0.760	5.410	5.240	6.140	6.540
Sample12	0.310	2.200	0.710	0.660	0.840	0.480	114.020	0.810	5.720	5.730	5.370	6.060
Sample13	0.490	2.680	0.800	0.840	0.960	0.650	85.980	0.860	6.680	6.450	6.280	6.870
Sample14	0.430	2.550	0.800	0.760	0.940	0.580	74.380	0.830	6.060	6.680	5.660	7.050
Sample15	0.440	2.580	0.780	0.790	0.940	0.590	100.180	0.820	6.520	6.370	6.120	6.730
Sample2	1.140	11.450	1.460	1.360	1.540	0.940	96.470	0.130	6.220	6.800	5.450	7.430
Sample3	0.370	2.400	0.770	0.710	0.910	0.520	83.950	0.810	5.960	6.220	5.580	6.570
Sample4	0.460	2.630	0.850	0.740	0.950	0.610	124.410	0.830	6.690	6.910	6.270	7.540
Sample5	0.360	2.320	0.670	0.770	0.860	0.530	88.100	0.840	5.820	5.900	5.500	6.260
Sample6	0.430	2.610	0.670	0.930	0.990	0.550	88.260	0.790	5.820	5.880	5.480	6.340
Sample7	1.950	5.520	1.520	1.800	1.970	1.250	90.850	0.800	6.380	6.340	5.620	7.250
Sample8	1.430	6.140	1.440	1.360	1.540	1.180	78.090	0.500	5.890	6.030	5.170	6.720
Sample9	0.940	3.760	1.210	1.070	1.350	0.880	123.580	0.830	6.150	6.500	5.560	7.050
Mean	0.730	3.790	0.990	0.980	1.140	0.730	96.920	0.750	6.100	6.270	5.680	6.850
HSD	0.103	0.254	0.114	0.107	0.096	0.060	12.775	0.058	1.159	0.571	1.181	0.744
CV (%)	5.490	2.620	4.500	4.250	3.320	3.230	5.160	3.050	7.440	3.570	8.140	4.250

Circ.: Circularity, XM: maximum length of the seed, YM: maximum width of the seed, BX: length of the seed at its broadest point, BY: length of the seed at its broadest point

Table 4 *Contd*: Seed morphometric parameters of 15 collected castor land races

Parameters	Feret	Feret X	Feret Y	Min-Feret	Feret-Angle	AR	Int-Den	Raw-Int-Den	Round	Solidity
Sample1	1.290	258.940	326.750	0.650	112.740	1.750	115.460	244299.070	0.590	0.920
Sample10	1.710	191.060	233.500	1.350	88.700	1.290	433.520	472550.000	0.780	0.940
Sample11	0.930	260.050	263.570	0.490	112.420	1.400	88.810	157003.820	0.510	0.950
Sample12	0.860	216.890	240.260	0.500	119.290	1.750	80.030	128388.280	0.570	0.940
Sample13	1.000	268.440	283.860	0.660	86.200	1.480	125.380	222311.110	0.680	0.960
Sample14	0.970	252.330	298.450	0.600	74.490	1.610	109.430	212281.820	0.620	0.950
Sample15	0.970	272.950	297.260	0.610	99.350	1.610	111.460	216785.710	0.620	0.950
Sample2	1.680	980.130	1250.140	1.060	94.790	1.670	290.470	9015789.510	0.620	0.850
Sample3	0.930	235.860	266.030	0.540	85.340	1.740	94.710	167071.580	0.580	0.950
Sample4	0.980	248.420	231.600	0.630	133.400	1.550	116.180	177753.260	0.650	0.950
Sample5	0.890	213.040	243.070	0.550	89.810	1.630	91.910	134186.300	0.610	0.950
Sample6	1.020	208.420	232.270	0.570	90.300	1.820	109.170	150437.220	0.550	0.940
Sample7	2.030	218.510	227.310	1.290	100.120	1.580	496.900	682257.890	0.640	0.970
Sample8	1.580	1115.700	1335.060	1.170	86.640	1.310	364.590	16130476.190	0.760	0.970
Sample9	1.400	220.480	284.070	0.900	124.390	1.530	240.430	366659.260	0.650	0.960
Mean	1.200	337.560	392.170	0.760	98.870	1.590	186.340	1792349.800	0.630	0.940
HSD	0.082	106.970	78.345	0.050	14.027	0.096	26.005	317122.502	0.038	0.033
CV (%)	2.690	12.400	7.820	2.580	5.550	2.370	5.460	6.930	2.390	1.370

AR: Aspect ratio of seed, Int-Den: Integrated density, Raw-Int-Den: Raw integrated density

Table 5 presents the correlation coefficients between various seed morphometric traits and seed oil content in collected castor landraces. Germination percentage and germination rate showed a weak positive correlation with seed oil content (r = 0.285 for both). Mean germination time exhibited an even weaker correlation with oil content (r = 0.182). Most seed size and shape parameters (e.g., Area, Width, Height, Major, Minor) showed weak to negligible correlations with oil content (r values ranging from 0.050 to 0.322). The highest correlation among these was for the Minor axis (r = 0.322), but it remains modest. Negative correlations were observed for some traits, such as Perimeter (r = -0.315) and BX (r = -0.405), though their practical significance is limited due to the low magnitude. Solidity, a measure of seed compactness, showed a moderate positive correlation with germination percentage and rate (r = 0.657 for both) but virtually no correlation with oil content (r = -0.002). Circularity had a modest correlation with germination percentage and rate (r = 0.383 and 0.382, respectively), but its relationship with oil content was weak (r = 0.065). Traits like Angle, FeretAngle, and RawIntDen showed minimal or no correlation with oil content suggesting these parameters are unlikely to be useful predictors of oil content in castor seeds.

Table 5: Correlations coefficients between seed morphometrics and seed oil contents among collected castor landraces

	Germination Percentage	Germination Rate	Mean Germination Time	Seed oil content (%)
Germination Percentage		0.980	0.868	0.285
Germination Rate	0.980		0.868	0.285
Mean Germination Time	0.868	0.868		0.182
Seed oil content (%)	0.285	0.285	0.182	
Area	0.163	0.163	0.271	0.129
XM	-0.225	-0.226	-0.229	0.238
YM	-0.203	-0.203	-0.101	0.216
Perimeter	-0.315	-0.315	-0.138	0.077
BX	-0.272	-0.272	-0.405	0.002
BY	-0.176	-0.176	-0.047	0.082
Width	0.050	0.050	0.257	0.068
Height	0.101	0.100	0.228	0.174
Major	0.126	0.126	0.241	0.191
Minor	0.199	0.199	0.322	0.118
Angle	0.021	0.022	0.029	-0.073
Circ.	0.383	0.382	0.228	0.065
Feret	0.061	0.060	0.229	0.147
IntDen	0.163	0.163	0.271	0.129
RawIntDen	0.037	0.038	0.131	-0.198
FeretX	-0.132	-0.132	-0.024	-0.161
FeretY	-0.137	-0.136	-0.010	-0.131
FeretAngle	0.065	0.066	0.026	-0.138
MinFeret	0.136	0.135	0.284	0.124
AR	-0.274	-0.274	-0.295	0.140
Round	0.255	0.255	0.356	0.011
Solidity	0.657	0.657	0.462	-0.002

Discussion

The morphological characteristics observed in the collected samples showed variations in stem colour, leaf petiole texture, seed colour and seed size (Udoh *et al*., 2016; Mensah and Ochran, 2005). Dark green and Wine-coloured stems that were observed were unlike Yamanura *et al.* (2024), who reported a mahogany stem dominance, this study found light green to be more prevalent, possibly due to environmental adaptation in Ilorin. From Tab. 1, the distribution suggests that light green stems may be the most adaptable or naturally occurring in the region. Light green stems dominate across all locations and are associated with the most diverse seed sizes and colours, suggesting it may be the most adaptable variation (Weiss, 2020). Light green stems may be the most genetically stable or widely adapted phenotype, while wine-coloured and dark green stems could represent unique genetic strains with specific advantages or disadvantages. The geographical pattern observed can be an influence on Castor Plant Traits. The Castor plant at Odo-Okun has large white-seeded plants, suggesting that the location may have favorable conditions for castor plant growth (Omotehinse, 2021) worth exploring for high-yield cultivation. Dark chocolate seeds are dominant in almost all locations this signifies that this might be the most adapted or prevalent genetic strain in Ilorin. The geographic Influence on morphological Traits of these Castor plants shows that samples collected at Egbejila Road has the highest diversity in seed colour (dark chocolate, white, and light brown) and size (small, medium, and large). This suggests a possible genetic hotspot where crossbreeding or environmental adaptation is occurring (Oke *et al*., 2024 and Munclinger *et al*., 2022). Yidi Prayer Ground and Gaa Odota have only small-seeded, dark chocolate plants, suggesting they may have less genetic diversity.

The significant differences in germination percentage, suggests that genetic or environmental factors significantly influence germination success, which aligns with findings by Bewley *et al*. (2013) on seed germination variability in plant species, and mean germination time may be related to seed dormancy mechanisms (Finch-Savage and Leubner-Metzger, 2006). High F-value of the seed oil content is a trait critical for castor bean's economic value, as oil content is a key determinant of biodiesel and industrial uses (Severino *et al*., 2012). Traits such as Area, Perimeter, Width, and Height are variability often linked to adaptation to different environments (Gomez-Campo, 2006). Circularity, Aspect Ratio, and Roundness suggest variations in seed morphology that may affect dispersal and germination (Hernandez-Davila *et al*., 2020; Wang *et al*., 2019; and De Jager *et al*., 2018). Feret diameter, Min Feret, and Feret Angle also exhibit significant variability, which could influence seed packaging and mechanical properties (Dobrzański and Stępniewski, 2013).

The mean germination percentage across all samples is similar to the study of Tchuenteu *et al*. (2013) and Odeje and Alonge (2023) who reported mean germination % 54.8% and 52% in castor bean accessions investigated respectively. The high HSD suggesting notable differences in germination performance among the landraces. This is in line with Hu *et al*. (2013) study, which revealed that the germination indices of major seeds from *Plantago asiatica* L. are significantly influenced by environmental factors, such as precipitation, temperature, altitude, and longitude. These results align with previous studies on castor seed germination (Šerá and Hnilička, 2023). The mean germination time in this study is contrary to the study of Tchuenteu *et al*., (2019) who reported that five accessions of castor beans seed emergence observed at 14 days after sowing (DAS). High CV% indicates more variation in germination timing among samples. The findings support the report of Martins *et al*. (2009) that *Ricinus* seeds germinate in a wide range of conditions and that germination was enhanced by some factors, and seeds were able to germinate under various circumstances. Hence, these landraces shows a generalist germination behaviour, which may explain the differences in *Ricinus* germination responses found in the present study and in other investigations, as well as inter-population variability (Probert 1993, Escudero *et al*. 2002) and influence of parental environment during seed maturation (Fenner, 1985). The oil content range is similar to the report of Karuna Sri *et al*. (2024) that oil content fluctuation ranged from 39.78% to 44.57% among the 18 castor genotypes cultivated. The Highest SD suggests significant differences in oil content between samples while the very low CV% implies that oil content is relatively stable across the landraces. The size of the seed does not fully determine oil content although, larger seeds generally contain more oil, also, the geographical differences may influence oil content (Weiss, 2000), but other factors such as genetics and environmental conditions also play a role.

The morphometric seeds parameters are critical for understanding the phenotypic diversity and agronomic potential of castor landraces, which can inform breeding programs and conservation efforts. The high CV for perimeter and area indicates moderate variability, which may reflect adaptations to different environmental conditions or genetic diversity (Yin *et al*., 2019) and, the mean width and height indicating potential outliers or unique morphological traits (Milani and Nobrega, 2013). The minor axis' lower compared to the major axis suggests less variability in seed thickness. The angle parameter could indicate differences in seed shape or attachment mechanisms (Zhu *et al*., 2022). Lower circularity in some samples suggests elongation or irregular shapes, which may affect seed dispersal or germination (Lehtilä and Ehrlén, 2005). The coordinates BX and XM indicate significant spatial heterogeneity among seeds. This could be linked to genetic or environmental factors influencing seed development (Cao *et al*., 2020). The Feret-Angle may reflect differences in seed orientation or curvature, which could influence seed dispersal mechanisms (Lehtilä and Ehrlén, 2005) while the low CV (2.37%) of AR indicates consistent elongation across samples, a trait linked to efficient packing and dispersal (Li *et al*., 2024). The higher values of integrated Density (Int-Den) suggest denser seed structures, possibly due to thicker seed coats or higher lipid content (Devkota *et al*., 2022) while the Raw-Int-Den outliers may indicate unique biochemical compositions, such as high oil or protein content, which are valuable for industrial applications (Rahim *et al*., 2023). The lower roundness values suggest irregular shapes, which may affect mechanical processing (Omobuwajo *et al*., 2000) while solidity indicate robust seed structures with minimal internal voids. This trait is crucial for seed durability and storage (Lehtilä and Ehrlén, 2005).

The correlation coefficients between various seed morphometric traits and seed oil content in collected castor landraces reveal that germination percentage and germination rate showed a weak positive correlation with seed oil content. This suggests that seeds with higher germination potential may slightly favour higher oil accumulation (Izquierdo *et al*., 2017), though the relationship is not strong. Mean germination time also exhibited an even weaker correlation with oil content suggesting that the speed of germination is less influential on oil content (Gardarin *et al*., 2011 and Savy Son *et al*., 2007).

Conclusion

The morphological diversity observed among the collected castor samples highlights the genetic variability within the species in the study areas. Although some traits appear widespread, others are more location-specific, suggesting an interaction between genetic and environmental factors. The significant differences in oil content and seed morphology emphasize the potential for selecting superior genotypes for breeding purposes. The variability observed in germination parameters and seed oil content among the castor landraces are importance for genotype selection in castor breeding. Although many landraces demonstrate exceptional germination performance, others are distinguished by high oil yield, requiring a judicious selection of cultivars for certain agronomic and industrial purposes. The intricate association between seed morphology and oil content in castor landraces emphasizes the necessity for comprehensive strategies in castor breeding, blending morphometric, biochemical, and genomic data to attain enhancements in seed quality and oil output.

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