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Research Article

Phenotypic Variation in Fruit Morphology among Provenances of *Sclerocarya birrea* (A. Rich.) Hochst.

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Sclerocarya birrea (A. Rich.) Hochst. is a multipurpose fruit tree which is very useful in providing food security and meeting nutritional and economic needs. This study was conducted to assess eighteen provenances of *Sclerocarya birrea* planted in Mangochi, Malawi. The trial was assessed for fruit traits at fifteen years of age. There were significant ($P < 0.001$) variations among the provenances in number of fruits, fruit weight, pulp weight, seed weight, fruit length, and diameter. Magunde provenance from Mozambique had the highest mean number of fruits, 2196 ± 200. Mangochi and Moamba provenances from Malawi and Mozambique were the most outstanding in the other parameters measured attaining the mean fruit weight of 20.89 ± 0.25 g and 25.67 ± 0.67 g, pulp weight of 25.70 ± 0.08 g and 21.55 ± 0.83 g, seed weight of 4.81 ± 0.35 g and 4.12 ± 0.18 g, fruit length of 2.61 ± 0.14 cm and 2.33 ± 0.07 cm, and fruit diameter of 2.33 ± 0.15 cm and 1.97 ± 0.08 cm, respectively. There was no significant ($P > 0.05$) correlation between number of fruits and the other fruit traits. However, there were significant ($P < 0.05$) and strong positive relationships between fruit weight and pulp weight ($r = 0.987$) and fruit length and diameter ($r = 0.775$). This suggests that fruit weight can be used indirectly for selection of pulp. Further studies should investigate fruit taste quality of products from the fruits.

1. Introduction

Sclerocarya birrea (A. Rich.) Hochst. is a member of the Anacardiaceae [1, 2]. The genus name *Sclerocarya* is derived from the Greek word skleros, meaning hard, and karyon, meaning a nut which refers to the hard stone of the fruit. It is a multipurpose fruit tree occurring in the semiarid, deciduous savannas in sub-Saharan Africa [3]. *Sclerocarya birrea* under normal conditions can grow up to 15 m, although under favourable conditions it can go up to 20 m with a mean diameter of 80–100 cm at maturity [4]. It occurs in areas receiving 200–1600 mm rainfall per annum having sandy to loamy soils. In Malawi, the species thrives mainly in hot dry areas at 500–1000 m altitude above sea level with mean annual rainfall of 900–1000 mm and mean annual temperature of 22-23°C. Furthermore, the species thrives in hydromorphic soils with limited drainage which are seasonally waterlogged [5]. Most *S. birrea* trees are dioecious, and the monoecious ones are predominantly male. The fruit is abscised when ripening commences so that final ripening takes place on the ground. Male and female flowers are borne on separate trees; the flowers of male plants produce pollen and the female flowers produce the fruit. The fruits are green on the tree and turn yellow after falling. The compound leaves tend to be mostly crowded at the end of the branches. A big and mature tree of *S. birrea* is capable of producing 21,000 to 91,000 fruits. In southern Africa, flowering occurs towards the end of dry season (September to November) and fruiting occurs in wet season (January to May). Like many riverine species, it is dispersed by water streams and shows adaptation to water dispersal by having air spaces in the fruits [6, 7].

Sclerocarya birrea is widely used for its fruits, timber, bark, and medicine. *Sclerocarya birrea* has multiple uses, including the fruits that are eaten fresh or fermented to make beer, the kernels are eaten, the oil is also extracted, and the leaves are browsed by livestock and have medicinal uses, as does the bark. The wood is carved into utilitarian items such as spoons and plates as well as decorative animal figures. Because of these multiple uses, and its significance in the landscape, several African cultures have specific beliefs and ceremonies associated with this species [8].

At present *Sclerocarya birrea* is revered for providing food security and meeting nutritional and economic needs for the rural poor communities [9]. Thus, the species is currently gaining more economic value [10]. Unfortunately, the extensive clearing of woodlands for settlement and agriculture threatens ecosystem services and the genetic diversity [11]. This presents the challenge in sustaining the provision of diverse needs from the species benefit of human society. In addition wide genetic diversity is fundamental in the era of climatic change. World Agroforestry Centre (WAC) developed a research strategy to drive the domestication of priority indigenous fruit tree species in Southern Africa. Some of the priority fruit species selected for domestication included *Sclerocarya birrea, Uapaca kirkiana, Strychnos cocculoides, Vangueria infausta, Parinari curatellifolia, Ziziphus mauritiana, Adansonia digitata,* and *Syzygium cordatum* (Gaertner), and *Vitex species*. *S. birrea* was in the top two priority species together with *Uapaca kirkiana*. A range wide seed collection for both species was done to evaluate the natural variation [12].

Domestication is the process of adapting wild plants or animals for human use [13]. This requires selection of any plant species that can be conserved and managed by human being. The species to be domesticated should be able to meet many diverse needs of man. However, the process of domestication requires identification of important product characteristics, which should be improved through selection [14]. The selection depends largely on phenotypic variations that occur among the populations. Variation is defined as the occurrences of differences among individuals of the same species attributable to difference in their genetic composition or the environment in which they are raised [15]. It is important to understand phenotypic variations in fruit morphology when initiating domestication of *Sclerocarya birrea*. Thus, understanding of species variation at provenance level is important before starting domestication and tree breeding activities [16]. Domestication efforts have been tried for this species in South Africa and Israel to establish orchards that will supply both fresh fruit and fruit for the canning and beverage industry [17]. In Malawi, the program on domestication led to the establishment of provenance trials of *Sclerocarya birrea* in Mangochi in 1999 from selected natural populations within the SADC region. These provenances were collected from different ecological regions in order to find out the natural variability in wild population by evaluating growth, fruit production, and fruit quality (palatability and size) as well as developing silvicultural management techniques growth and fruiting parameters [11]. Although *Sclerocarya birrea* has been traditionally useful to people, the products from the tree have recently gained far higher economic value due to the commercial demand for Marula beer and nut oil. There is an increasing demand for *S. birrea* fruits in many parts of southern Africa [18]. In Malawi, studies on *S. birrea* have concentrated on phenotypic variations on vegetative, flowering, and fruit productivity [11]. However, there is still lack of information on phenotypic variations on fruit traits such as fruit weight, seed weight, pulp weight, fruit length and diameter, and relationship between the fruit traits. The present study was conducted with an aim to determine the phenotypic variations of fruits traits and the relationships between the fruit traits of the *Sclerocarya birrea* at the age of fifteen years.

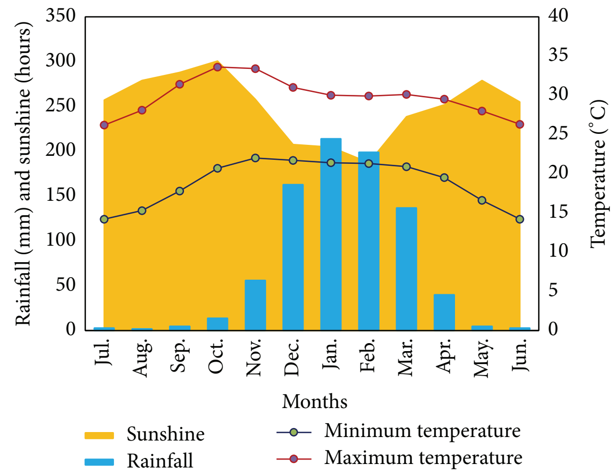

Figure 1: Weather from July 2013 to June 2014 for the study area.

2. Materials and Methods

2.1. Study Site. The trial was established in Malawi at Palm Forest Reserve in Mangochi (14°28′S, 35°14′E). The area is at an altitude of 200 m above sea level with mean annual rainfall of 800–1200 mm and a mean annual temperature of 23.9°C. Temperature and rainfall during the study period are given in Figure 1. The site has a high water table and occasionally is prone to seasonal flooding. The terrain is flat consisting of sandy soils that become loamy sand at over 50 cm depth. The soil pH ranges from acid to alkaline (4 to 7.1) in the subsoil. The dominating vegetation constitutes palms (*Hyphaene* species) and *Acacias* species [11]. It is situated about 290 km southeast of the capital Lilongwe.

2.2. Experimental Material and Data Collection. The establishment of the trial was facilitated by World Agroforestry Centre (ICRAF) in February 1999. Seeds used to establish the trial were collected from thirty provenances in eight countries as follows: Malawi (4), Mali (1), Mozambique (3), Namibia (3), Swaziland (1), Tanzania (10), Zambia (2), and Zimbabwe (6). Most Tanzanian provenances did not germinate well with Makadaga-Mbarali (T1), Nyamahanga-Iringa (T2), and Kigwa-Tabora (T10) not providing enough seedlings to be included in the field experiment. Those provenances with relatively few seedlings were bulked including Mkata-Morogoro (T3), Ubena-Bagamoyo (T4), Chalinze-Bagamoyo (T5), Kigwe-Dodoma (T7), Mialo-Kondoa (T8), and Mandimu-Singida (T9). Only the provenance from Magamba-Turiani (T6) had enough seedlings and was therefore evaluated as an individual treatment. Thus there were

Table 1: Site characteristics of the original place of the fruiting provenances.

Country-provenance	Code	Species	Number of families	Latitude	Longitude	Elevation (m)
Malawi						
Chikwawa	ML1	*S. birrea* ssp. *caffra*	10	16°46′S	35°17′E	100–300
Mangochi	ML2	*S. birrea* ssp. *caffra*	20	14°02′S	34°53′E	200–600
Mozambique						
Marracuene	MZ1	*S. birrea* ssp. *caffra*	17	25°58′S	32°95′E	0–200
Magunde	MZ2	*S. birrea* ssp. *caffra*	20	24°95′S	32°92′E	0–200
Moamba	MZ3	*S. birrea* ssp. *caffra*	20	25°55′S	32°55′E	0–200
Namibia						
Oshikondilingo	N1	*S. birrea* ssp. *caffra*	16	17°40′S	15°40′E	1030
Ohangwena	N2	*S. birrea* ssp. *caffra*	15	17°35′S	16°49′E	1144
Kalimbeza	N3	*S. birrea* ssp. *caffra*	20	17°34′S	24°31′E	967
Zimbabwe						
Ngundu	Z1	*S. birrea* ssp. *caffra*	13	20°50′S	32°05′E	457
Mudzi	Z2	*S. birrea* ssp. *caffra*	15	16°17′S	32°45′E	400
Biriwiri	Z3	*S. birrea* ssp. *caffra*	15	19°50′S	32°40′E	1500
Muzarabani	Z4	*S. birrea* ssp. *caffra*	15	16°35′S	32°27′E	600
Matabeleland N	Z5	*S. birrea* ssp. *caffra*	14	18°00′S	28°00′E	996
Matabeleland S	Z6	*S. birrea* ssp. *caffra*	15	21°00′S	32°01′E	388
Swaziland						
Kalanga	S1	*S. birrea* ssp. *caffra*	20	26°45′S	31°45′E	239
Tanzania						
Mkata-Kilosa	T3	*S. birrea* ssp. *caffra*	P	7°22′S	37°50′E	430
Ubena-Bagamoyo	T4	*S. birrea* ssp. *caffra*	P	6°11′S	38°10′E	305
Chalinze-Bagamoyo	T5	*S. birrea* ssp. *caffra*	P	6°55′S	38°20′E	550
Magamba-Turiani	T6	*S. birrea* ssp. *caffra*	9	5°40′S	38°12′E	530
Mali						
Missira	M1	*S. birrea* ssp. *birrea*	19	13°43′N	8°27′W	352

P = Pooled provenance due to low seedling numbers during trial establishment.

21 provenances and one bulked seed lot as treatments. The trial was laid out as a randomized complete block design in four replications. Each treatment had a line plot with 20 trees that also represented the total possible number of families collected for each provenance. One tree plot of provenances was allocated randomly, whereas families were allocated arbitrarily to maximize their representation in the trial. Where the provenance had less than 20 families, other families were repeated to have a full number of trees in a line plot. The seedlings were planted at the spacing of 4 m between families and 5 m between provenances.

At the age of fifteen years between February and May 2014, data for the following traits were collected: number of fruiting trees, number of fruits, fruit weight, seed weight, pulp weight, fruit length, and diameter. Fruits were physically counted using a tally counter from each fruiting tree. Health fruits (free from disturbance) from each tree were once collected from the ground, separately bagged, and labelled and were immediately taken to the processing site to avoid loss of weight. Fruits that were collected were those that ripen at the same time. This was done for accurate assessment and to avoid bias. Fruits were collected from the ground because the purpose of the study was to collect mature and ripen fruit. According to Danida Forest Seed Centre [7], *S. birrea* fruits abscise before they are mature. At the time of fruitfall the fruits are still green and firm and final ripening takes places on the ground. A sample size of 25 fruits per tree was used to assess fruit length, fruit diameter, seed weight, pulp weight, and fruit weight. The fruits were washed to remove soil particles and other inert materials. The mass of the fruits and seed weight were measured by using an electronic weigh balance, recorded, and averaged. Seeds were separated from the fruits using the procedure outline in the seed leaflet of the Danida Forest Seed Centre [7]. Length and width of the fruits were determined by using the micro caliper. Pulp weight was obtained by subtracting the seed weight from the fruit weight. In this study pulp weight has peel weight in it, because it was difficult to separate the peels from the pulp. The results were then recorded and subjected to Excel package to determine the average. The amount of variation (%) was obtained by dividing the highest and the lowest number and multiplying it by hundred. Details of the fruiting provenances are given in Table 1.

2.3. Statistical Analysis. Number of fruits and fruit characteristics data obtained were tested for normality and homogeneity with Kolmogorov-Smirnov D and normal probability plot tests using Statistical Analysis of Systems software version

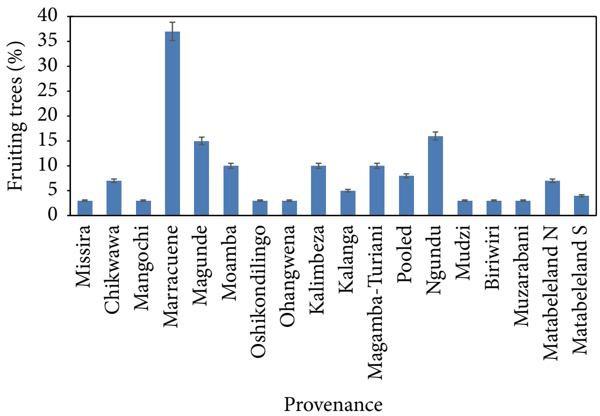

Figure 2: Percentage of fruiting trees within provenances of *Sclerocarya birrea* in Malawi.

9.2 [19]. After the two criteria were met, the data were subjected to analysis of variance (ANOVA) using PROC GLM procedure of the same Statistical Analysis of Systems software and means were separated with Fischer's least significant difference (LSD) at the 0.05 significance level. Pearson's correlation coefficient was calculated to determine the relationship among the fruits traits.

3. Results

3.1. Fruiting Trees. The results (Figure 2) showed that there were differences in number of fruiting trees among the provenances. The fruiting percentage within provenances ranged from 3 to 37%. The provenance with largest number of fruiting trees (37%) was Marracuene, whilst Missira, Chikwawa, Mudzi, Oshikondilingo, Ohangwena, Biriwiri, and Muzarabani had low (3%) fruiting trees.

3.2. Variation in Fruiting among Provenances. There were significant ($P < 0.001$) differences in mean number of fruits among provenances. The number of fruits among provenances ranged from 140 to 2196 (Table 2). The provenances with the most outstanding fruiting potential were Magunde (2196 ± 200), Marracuene (2124 ± 198), and Moamba (2134 ± 290) from Mozambique. The results also indicated that Matabeleland (South) had also high fruiting potential (1435 ± 604). The least fruiting provenances were Magamba (194 ± 47) and Missira (140 ± 20) from Tanzania and Mali, respectively. The results showed a coefficient of variation of 63.9%.

3.3. Variation in Fruit Weight, Seed Weight, Pulp Weight, Fruit Length, and Diameter among Provenances. There were significant ($P < 0.001$) differences among provenances in all fruit traits. The results indicated that fruit weight ranged from 11.37 to 25.70 g. The coefficient of variation in fruit weight was 16.4%. The seed weight ranged from 2.65 to 4.81 g. The coefficient of variation in seed weight was 17%. Pulp weight ranged from 8.72 to 32.17 g and the coefficient of variation was 20.8%. Fruit length ranged from 1.75 to 2.6 cm with a coefficient of variation of 10.6% and fruit diameter (cm) ranged from 1.4 to 2.33 cm with a coefficient of variation of 12.8% (Table 3). The results indicated that Mangochi (25.7 ± 0.08 g), Moamba (25.67 ± 0.67 g), Ngundu (24.40 ± 1.54 g), and Matabeleland (North) (24.01 ± 2.25 g) had the largest fruits. Mudzi (4.34 ± 0.54 g), Ngundu (4.49 ± 0.23 g), Moamba (4.12 ± 0.18 g), and Mangochi (4.81 ± 0.35 g) provenances had largest seed weight. The results also showed that Mangochi (20.89 ± 0.25 g), Moamba (21.55 ± 0.83 g), Ohangwena (17.17 ± 0.80 g), Ngundu (19.91 ± 1.68 g), Muzarabani (17.00 ± 1.38 g), and Matabeleland (North) and fruits had large pulp content. Ngundu, Mangochi, and Oshikondilingo had large fruit size in both length (2.60–2.75 cm) and diameter (2.10–2.33 cm). Missira provenance was the poorest in fruit characteristics (Table 3). The amount of variations that existed between the provenances in all fruit traits was fruit weight (226%), fruit pulp (247%), seed weight (182%), fruit length (157%), and fruit diameter (163%).

Table 2: Mean number of fruits per tree for fruiting trees per provenance.

Country-provenance	Code	Mean number of fruits
Mali		
Missira	M1	140 ± 20^{b}
Malawi		
Chikwawa	ML1	542 ± 143^{b}
Mangochi	ML2	352 ± 120^{b}
Mozambique		
Marracuene	MZ1	2124 ± 198^{a}
Magunde	MZ2	2196 ± 200^{a}
Moamba	MZ3	2134 ± 290^{a}
Namibia		
Oshikondilingo	N1	249 ± 52^{b}
Ohangwena	N2	664 ± 24^{b}
Kalimbeza	N3	353 ± 117^{b}
Swaziland		
Kalanga	S1	214 ± 72^{b}
Tanzania		
Magamba	T6	194 ± 47^{b}
Bulked Provenances	T3, T4, T5	607 ± 210^{b}
Zimbabwe		
Ngundu	Z1	778 ± 127^{b}
Mudzi	Z2	904 ± 529^{b}
Biriwiri	Z3	545 ± 135^{b}
Muzarabani	Z4	489 ± 206^{b}
Matabeleland N	Z5	438 ± 83^{b}
Matabeleland S	Z6	1435 ± 604^{ab}
Grand mean		1163 ± 203
CV (%)		63.9

Note: mean values are followed by standard errors; ^{a,b}means with different superscript within a column significantly differ ($P < 0.001$).

Table 3: Variation in fruit traits characteristics among fruiting provenances in Malawi.

Provenance	Fruit weight (g)	Seed weight (g)	Pulp (g)	Fruit length (cm)	Fruit diameter (cm)
Mali					
Missira	11.37 ± 0.34^{c}	2.65 ± 0.43^{c}	8.72 ± 0.63^{c}	1.75 ± 0.17^{c}	1.4 ± 0.17^{c}
Malawi					
Chikwawa	18.22 ± 1.78^{bc}	3.61 ± 0.25^{bc}	14.61 ± 1.7^{b}	2.34 ± 0.10^{b}	2.01 ± 0.10^{ab}
Mangochi	25.70 ± 0.08^{a}	4.81 ± 0.35^{a}	20.89 ± 0.25^{a}	2.61 ± 0.14^{ab}	2.33 ± 0.15^{a}
Mozambique					
Marracuene	18.31 ± 0.32^{bc}	3.64 ± 0.12^{bc}	14.67 ± 0.31^{b}	2.22 ± 0.05^{bc}	1.83 ± 0.05^{bc}
Moamba	25.67 ± 0.67^{a}	4.12 ± 0.18^{ab}	21.55 ± 0.83^{a}	2.33 ± 0.07^{b}	1.97 ± 0.08^{b}
Magunde	15.66 ± 0.58^{c}	2.96 ± 0.20^{c}	12.70 ± 0.60^{bc}	2.24 ± 0.08^{b}	1.89 ± 0.08^{bc}
Namibia					
Oshikondilingo	18.00 ± 0.75^{bc}	3.25 ± 0.43^{bc}	14.76 ± 0.89^{b}	2.60 ± 0.17^{ab}	2.10 ± 0.17^{ab}
Kalimbeza	16.91 ± 0.25^{bc}	3.16 ± 0.43^{bc}	13.75 ± 0.31^{bc}	2.32 ± 0.17^{b}	1.91 ± 0.17^{bc}
Ohangwena	19.84 ± 0.84^{bc}	2.67 ± 0.20^{c}	17.17 ± 0.80^{ab}	2.26 ± 0.08^{b}	1.88 ± 0.08^{bc}
Swaziland					
Kalanga	17.15 ± 1.14^{bc}	3.89 ± 0.27^{b}	13.26 ± 1.28^{bc}	2.15 ± 0.13^{bc}	1.7 ± 0.11^{bc}
Tanzania					
Pooled	12.66 ± 0.96^{c}	2.76 ± 0.23^{c}	9.90 ± 0.93^{c}	1.91 ± 0.09^{c}	1.53 ± 0.09^{c}
Magamba	15.35 ± 1.21^{c}	3.54 ± 0.27^{bc}	11.81 ± 1.24^{bc}	2.15 ± 0.11^{bc}	1.89 ± 0.08^{bc}
Zimbabwe					
Ngundu	24.40 ± 1.54^{ab}	4.49 ± 0.23^{ab}	19.91 ± 1.68^{a}	2.75 ± 0.07^{a}	2.28 ± 0.07^{ab}
Mudzi	13.08 ± 1.89^{c}	4.34 ± 0.54^{ab}	8.75 ± 2.43^{c}	2.45 ± 0.17^{ab}	1.95 ± 0.17^{b}
Biriwiri	18.04 ± 0.34^{bc}	3.42 ± 0.60^{bc}	14.62 ± 0.94^{b}	2.30 ± 0.17^{abc}	1.60 ± 0.17^{c}
Muzarabani	20.17 ± 1.23^{b}	3.16 ± 0.18^{bc}	17.00 ± 1.38^{ab}	2.27 ± 0.14^{abc}	1.93 ± 0.14^{b}
Matabeleland (N)	24.01 ± 2.25^{ab}	3.84 ± 0.25^{b}	20.16 ± 2.15^{a}	2.45 ± 0.10^{ab}	1.91 ± 0.10^{c}
Matabeleland (S)	20.72 ± 0.44^{b}	3.22 ± 0.10^{bc}	17.5 ± 1.39^{ab}	2.56 ± 0.12^{ab}	2.17 ± 0.12^{ab}
Grand mean	19.34 ± 0.28	3.60 ± 0.16	15.75 ± 0.21	2.31 ± 0.16	1.91 ± 0.07
CV (%)	16.40	17.00	20.80	10.60	12.80

Note: mean values are followed by standard errors; ^{a,b,c}means with different superscript within a column significantly differ ($P < 0.001$).

3.4. Pearson's Correlation Coefficient of Fruit Characteristics. There were no significant ($P > 0.05$) correlations between number of fruits and fruit characteristics. However, there was a significant ($P < 0.01$) correlation between fruit weight and other fruit traits (seed weight, pulp weight, fruit length, and diameter). There was also a significant ($P < 0.05$) correlation between seed weight and pulp content. Strong relationship ($r = 0.987$) was observed between fruit weight and pulp weight and weak relationship ($r = 0.196$) was observed between seed weight and pulp weight (Table 4).

4. Discussion

4.1. Variations in Number of Fruiting Trees among Provenances. The results have indicated that at 15 years of age less than 20% of the trees have started fruiting within the 18 provenances (Figure 2). This may indicate that some trees are of early fruiting genotypes while others are not. It is also speculated that the majority of trees are male. The current study did not determine the sex ratio which should be studied later. The large variation as shown by the coefficient of variation of 63.9% probably is an indication of the huge variation that exists in the wild [20]. The revealed variation is showing potential for high genetic gain following selection. Furthermore, it was observed that large variation between individual families and tree exists. Thus selection could also be achieved through selection of superior individual trees and cloning them without following conventional classical tree breeding. Likewise, farmers may quickly benefit from the germplasm in the trials through selection of a combination of provenance, family, and individual tree selection and practicing vegetative propagation.

Similar studies conducted by [11] also revealed that not all provenances had started fruiting in this provenance trial. Within the provenances, many trees were also still in nonfruiting state since their establishment. Raven et al. [21] stated that it is important to know whether the trees did not bloom at all, bloomed but did not set fruits, or bloomed and set but all fruits fell down before maturity in order to know the causes of nonfruiting trees. In their study, there was an observation that fruit shed could account for about 80% before maturity. The cause of high fruit abortion remains unknown. Thus, future studies should investigate the phenomenon before domestication is promoted.

4.2. Variations in Number of Fruits. The study has indicated that large variations (176%) in number of fruits do exist

Table 4: Relationship between fruit traits in *Sclerocarya birrea* in Malawi.

	Fruit weight (g)	Seed weight (g)	Pulp (g)	Fruit Length (cm)	Fruit diameter (cm)
Number of fruits	0.106	0.029	0.106	0.021	0.031
Fruit weight		0.350^{**}	0.987^{*}	0.364^{**}	0.336^{**}
Seed weight (g)			0.196^{*}	0.318^{**}	0.268^{**}
Pulp (g)				0.327^{**}	0.307^{**}
Fruit Length (cm)					0.775^{*}

**Significant at $P < 0.01$; *significant at $P < 0.05$ with R values.

among the provenances. The variation could be largely attributed to genetic differences since the genotypes were tested at the same site. The 63.9% coefficient of variation may be an indication of massive untapped variation that could be used in selecting superior genotypes in breeding programmes. The results are supported by [22] that stated that a given provenance can sometimes contain quite large differences related to differing sites of their origin. The large variation should be used and conserved for the benefit of poor people.

The study has further indicated that provenances from Mozambique (Table 2), namely, Magunde, Marracuene, and Moamba, are most outstanding performers followed by Matabeleland (S) of Zimbabwe. Mozambican provenances have maintained their superiority, while Missira from Mali has consistently underperformed in all traits throughout the life of the trial. However, poor performance of the Mali populations could be due to poor sampling in provenance collection. Thus, future trials could consider fresh collections of new populations assuming Mali has wide genetic diversity.

The contribution of indigenous fruits to the livelihoods of rural households as sources of income, food, and medicine can easily be achieved from high productive provenances upon understanding these variations. The fruit-producing tree species are important for food security, especially in the dry season [23]. Therefore, the generated information on variations in fruit production between provenances implies that superior provenances can be selected in domestication, tree improvement, and commercialization of *S. birrea*. Hence, provenances with the highest number of fruits can be selected because it means that more products such as wine and nut oil can be obtained in large quantities. These can also be used as clones in tree improvement. The trait of production can further be used to recommend for trees that produce more number of fruits for industrial purposes even though this may take long. The variation between provenances also helps to understand the superior provenances which can be used for vegetative propagation.

4.3. Variation in Fruit Characteristics among Provenances. The variations in fruit characteristics among the provenances have shown a clear pattern of differing in genotype despite being grown in the same geoclimatic conditions. The information in fruit weight implies that it can be used during selection when fruit weight becomes an objective for domestication. The results have shown that fruit weight can be emphasized in the course of trade where people prefer bigger fruits. However, further research needs to be conducted in order to determine whether the bigger fruits are also sweet because consumers preferences may be based not only on fruit size but also on taste [24, 25]. The variation is of significance if the fruit weight is to be improved; then provenances that can be used in vegetative propagation can be easily chosen. The results revealed that Mozambique provenances had both high fruit load and bigger fruit size. This could be attributed to the genetic superiority of the species [6].

The results also indicated the variations in pulp weight. This illustrates that *S. birrea* produces pulp of different weights depending on the provenance. The variability among the provenances can form part of further domestication because, apart from brewing, it is also consumed by people and wild animals like elephants. This can be achieved by selecting the best pulp weight provenance for further distribution or grafting. This is a very important fruit trait of *S. birrea* where production of Marula beer and wine is much dependent on it [26, 27].

The results revealed presence of large variations among provenances in fruit length of 44% and diameter of 50%. These show that genotype with long and large fruits may be considered to be more productive. The variation could be attributed to genetic influence [16, 25] as attested by the low coefficient of variation (10.60 and 12.8% for fruit length and diameter, resp.) (Table 4). The superior genotype could be ideal for domestication [16].

Kadu et al. [28] reported that bigger seeds are the best for selection for early seedling growth and development. In the present study seed weight ranged from 2.65 to 4.81 g. Further study should investigate whether larger seed will produce high quality transplants compared to lighter seed in *S. birrea.* Furthermore, it should be studied whether larger seed produces more quality oil than lighter seed.

4.4. Correlation among Fruit Characteristics. The significant correlation and strong relationship (Table 4) between fruit weight and pulp weight were observed in the present study. Similar results were also obtained on fruit weight and pulp of *S. birrea* fruits by [22]. Moyo et al. [22] stated that correlations can be used in indirect selection. Selection can be used on fruit weight to select for pulp which is difficult to assess. Strong relationship between fruit length and diameter is also important in selection as they determine fruit size. Weak or no relationships that existed in some traits mean that indirect selection may not be feasible.

The current study was based on a single growing season and hence possesses uncertainty in variations among provenances due to growth with seasonal fluctuation. Therefore, continuing research for several consecutive years is needed to fully establish the genetic and phenotypic characteristics of *S. birrea*. This would help in understanding the variations which occurred due to seasonal variations in each growing season period. Further studies should include data at flowering period, as this would help identify male trees based on the type of flowers. Fruit self-thinning study should also be conducted. This is an essential trait to be considered for genetic improvement. Research should also be carried out on fruit quality of products (juice, wine, and oil) prior to promoting the species for Agroforestry programmes.

5. Conclusion

The present study has revealed substantial variation occurring among the 18 provenances of the first generation of *Sclerocarya birrea* samples from Southern Africa. The provenance from Mozambique outperformed all the other genotypes in all traits. Mangochi provenance from Malawi was also outstanding in fruit weight, peel-pulp weight, seed weight, fruit length, and fruit diameter. Missira province from Mali was the most inferior genotype. Mali provenance was the only genotype that was tested from outside Southern Africa. Poor performance could be due to poor site matching. Large numbers of trees are not yet fruiting at 15 years. It is not yet known whether nonfruiting trees are all males. High fruit abortions were also observed. Assessment should continue to investigate the sex ratio in the trial and also to investigate the cause of high fruit shedding. High positive linear correlation of fruit traits will facilitate indirect selection in breeding programmes. The results cannot be conclusive on which genotype is superior and recommended for domestication. Investigation should be carried out on fruit quality of products such as juice, wine, and oil prior to promoting the species for Agroforestry programmes.

Conflict of Interests

The authors declare that there is no conflict of interests in any form regarding the publication of this paper.

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