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Variability and heritability of nutritional composition among *L. siceraria* landraces from Northern KwaZulu-Natal, South Africa

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Abstract

Lagenaria siceraria (Molina) Standley of the Cucurbitaceae family has nutritious tender shoots, fruits, and seeds that are of culinary use in rural communities as vegetables. However, no studies on variation, correlation, heritability and genetic advance of its nutritional traits were conducted in northern KwaZulu-Natal, South Africa. This study aimed to characterise nutritional variability and heritability among *L. siceraria* genotypes from different origins. Nutritional traits were compared among different landraces using ANOVA, correlation, principal component analysis, cluster analysis and heritability estimates. Landraces varied significantly in their nutritional traits. Significant positive correlations were recorded among nutritional traits. The first three informative principal components had a total variability of 80.270%. Landraces in a biplot and dendrogram clustered closely to the nutritional components they strongly relate with, either positively or negatively. In five distinct clusters, landraces NRC, KSP and NRB were singletons in Clusters I, II and V, respectively. Cluster (III) consisted of NqSC, KSC, KRI, NSRC and DSI; whereas Cluster IV grouped landraces NSRC, RRP, MSC, NSRP, NqRC and RSP. High heritability estimates and genetic advance were recorded among nutritional traits. Therefore, this study serves as a reference for potential *L. siceraria* germplasm with ideal nutritional composition for future breeding programmes.

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Introduction

Lagenaria siceraria, a member of the Cucurbitaceae family is well known for having the highest choline content of any other vegetable known—containing essential nutritional traits and mineral elements for human consumption, for good health and synthesis of neurotransmitters that aid in the treatment of mental disorders (Rahman, 2003; Koffi *et al.,* 2009; Ntuli *et al.,* 2017). The area of origin, and abiotic factors such as soil type and fertility, have significant effects on the mineral content of different cucurbits (Abbey *et al.,* 2017). *L. siceraria* is one of the oldest cultigens to be collected, consumed and preserved by mankind, with compelling archaeological evidence dating back an estimated 12 000 years (Yetisir *et al.,* 2008). It is regarded as the poor man's crop due to its ability to tolerate and flourish under stressful conditions (Koffi *et al.,* 2009; Mlandenovic *et al.,* 2012). This vegetable is among the main sources of essential nutrients and mineral elements for rural communities in South Africa (Sithole *et al.,* 2015). Yet has been neglected in the face of modern agronomic practices (Sithole *et al.,* 2015). The plant has great potential as most of its parts can be of culinary use (Koffi *et al.,* 2009). Juvenile and mature fruits, seeds, flowers, leaves, and shoot tips can be consumed as a vegetable relish (Sithole *et al.,* 2016).

The fruits of *L. siceraria* possess essential nutrient traits such as moisture content (90.25%), ash (1.03%), protein (1.25%), fats (0.12%) and carbohydrates (2.65%) (Aliu *et al.,* 2012). It has neutral detergent fibre (NDF) of 21.16 g/100g, acid detergent fibre (ADF) of 15.67 g/100g, and vitamin C of 10.1mg/100g (Upaganlawar and Balaraman, 2009). Its fruits also contain essential mineral elements (in units ofmg/100g) such as iron (5.129), copper (0.057), silver (0.682), manganese (0.318), zinc (1.629), cobalt (0.137) and lead (0.5) (Ahmed *et al.,* 2016). They also contain phosphorus (187.33), potassium (3356.67), magnesium (146.33), calcium (52.78) and sodium (36.68) (Upaganlawar and Balaraman, 2009). Although the morphological variation of *L. siceraria* landraces has received some attention from researchers in South Africa, including material from KwaZulu-Natal (KZN), the nutritional and mineral content, the correlation among the nutritional traits as well as their heritability among landraces from northern KZN, has not been documented. Hence, a study on these properties across various genotypes will be beneficial in selecting and recommending parental material for future breeding programmes. In the study reported here we investigated the variability in nutritional and mineral contents, the correlation as well as the heritability of different nutritional and mineral element traits among 14 *L. siceraria* landraces, the most comprehensive account of its kind to date.

Materials and methods

Collection and study area

Germplasm for the study represented of 14 *L. siceraria* landraces that were collected from Dundee (28.1650° S, 30.2343° E), Khangelani (29.0106° S, 31.2211° E), Mbazwana (27.4937° S, 32.5882° E), Ndumo (26.9342° S, 32.2824° E), Nquthu (28.2195° S, 30.6746° E) and Rorke's Drift (28.3492° S, 30.5351° E) in northern KZN. Landrace names were coined according to their origin as well as fruit and seed morphology (Table 1). The field experiment was conducted at the University of Zululand, KwaDlangezwa Campus (28.8530° S, 31.8500° E), which has a sub–tropical climate (Ntuli and Zobolo 2008). The KwaDlangezwa area has a daily mean temperature of 28.4°C in summer and 14.5°C in winter (Nelson *et al.,* 2014). This study was conducted over two summer seasons (September 2016–February 2017) and (September 2017–February 2018), in a complete randomized block design.

Design and sampling procedures

Eighty (80) seeds from each of the 14 landraces were sown onto the plug trays and irrigated to plug tray capacity two to three times per week. At 31 days after sowing (31 DAS) all 14 landraces were at first to second true leaf stage and were transplanted onto a 1050m² plot of land with three replicate plots randomly assayed for each of the 14 landraces, corresponding to 42 plots within the 1050 m² in total. Each plot was 9m² in area with 2m inter-plot spacing and 1m intra-row spacing, housing 16 plants per plot and 672 plants in total. At transplanting, fertilizer NPK 2:3:4 (30) at a rate of 40g/m² was applied below the seedlings in 10–15-cm-deep pits and the field was irrigated to capacity. At 31 days after transplant (DAT), nitrogen fertilizer (limestone ammonium nitrate (LAN 28)) at the same rate was band placed around each plant. Plants were irrigated adequately depending on the amount of rainfall and temperature. Weeding and insecticides applications were performed when necessary.

Mature fruits of *Lagenaria siceraria* were harvested 125 DAT. Forty-two fruit samples were collected representing all 14 landraces with three replicate fruits per landrace. Fruits were rinsed with tap water and dissected using a clean, stainless–steel knife. Fruit pulp was removed from the rind, separated from the seeds, sun-dried for 24 hours and then oven–dried at 60°C for 24 hours. The samples were ground into powder using a Hammer Mill grinder and pass–through at 0.84mm sieve.

Table 1. Description of landraces according to their origin as well as their fruit and seed morphology.

LR	Area	Fruit colour	Fruit texture	Fruit shape	Seed type	Seed colour	Seed texture	Seed size	Seed line	Seed shape
KSP	Khangelani	Pale green	Smooth	Pear	Asiatica	Brown	Leathery	Large	Present	Slightly oblong to rectangular
KSC	Khangelani	Pale green	Smooth	Curvilinear	Asiatica	Brown	Leathery	Large	Present	Slightly oblong to rectangular
KRI	Khangelani	Green	Rough	Isodiametric	Siceraria	Dark brown	Leathery	Large	Present	Slightly oblong to rectangular
NRB	Ndumo	Dark green	Rough	Cylindrical	Siceraria	Dark brown	Smooth	Small	Absent	Oblong
NRC	Ndumo	Dark green	Rough	Cylindrical	Siceraria	Creamy brown	Smooth	Small	Absent	Oblong
MSC	Mbazwana	Pale green	Smooth	Curvilinear	Asiatica	Brown	Leathery	Large	Present	Slightly oblong to rectangular
RSP	Rorke's Drift	Pale green	Smooth	Pear	Asiatica	Light brown	Leathery	Large	Present	Rectangular
RRP	Rorke's Drift	Pale green	Rough	Pear	Asiatica	Light brown	Leathery	Large	Present	Rectangular
NqRC	Nquthu	Pale green	Rough	Curvilinear	Intermediate	Light brown	Leathery	Medium	Present	Slightly oblong
NSRP	Nquthu	Pale green	Semi-rough	Pear	Intermediate	Brown	Leathery	Medium	Present	Slightly oblong
NqSC	Nquthu	Pale green	Smooth	Semi-Curvilinear	Asiatica	Light brown	Leathery	Medium	Present	Slightly oblong
NSC	Nquthu	Pale green	Smooth	Curvilinear	Asiatica	Light brown	Leathery	Medium	Present	Slightly oblong
NSRC	Nquthu	Green	Semi-rough	Curvilinear	Intermediate	Brown	Leathery	Medium	Present	Slightly oblong
DSI	Dundee	Dark green	Smooth	Isodiametric	Siceraria	Dark brown	Smooth	Large	Present	Oblong

LR-Landraces – from Khangelani area with smooth, pear-shaped (KSP); smooth, curvilinear shape (KSC); and (KRI) rough isodiametric shape fruits (KRI); from Ndumo area with rough fruits with brown seeds (NRB) and rough fruits with creamy seeds (NRC); from Mbazwana area with smooth cylindrical-shape (MSC); from Rorke's Drift area with smooth pear-shaped (RSP) and rough pear-shaped (RRP); from Nquthu area with rough curvilinear shape (NqRC), with semi-rough pear-shaped (NSRP), with smooth curvilinear shaped (NqSC) and (NSC) and semi-rough curvilinear shaped (NSRC) and from Dundee area with smooth isodiametric shape (DSI).

Nutritional content analysis

Proximate analysis

Milled fruit pulp of the study samples was assayed for ash, fat, crude protein and fibre according to AOAC (1999) methods. The ash content was obtained by burning the dried, milled samples in the furnace at 450°C for 24 h. The fat content was determined using the Soxhlet apparatus and petroleum ether as a reagent (AOAC, 1999). Acid detergent fibre (ADF), was determined by using Dosi–fiber extractor and neutral detergent fibre (NDF) was obtained with enzyme addition as suggested by Van Soest, (1963). The nitrogen content was determined using the Kjeldahl method and the protein content was estimated by multiplying the nitrogen content by a conversion factor of 6.25. All the samples were in triplicate.

Mineral element analysis

The samples were also analysed for both macronutrients; N, P, Ca, K, andmg, and micronutrients; Na, Zn, Cu, Mn, Fe, Al and B at the Soil Fertility and Analytical Services Section Laboratory—Department of Agriculture and Rural Development in Cedara, Hilton, midlands KZN (Manson and Roberts, 2000). Sub-samples of fruit pulp material were dried and ashed at 450°C overnight. The ash was dissolved in 1 M HCl. The supernatant was analysed for Al, Ca, Cu, K,mg, Mn, Na, and Zn by atomic absorption spectroscopy (AAS). Phosphorus concentrations were determined colorimetrically on a 2 mL aliquot of filtrate using a modification of the Murphy and Riley (1962) molybdenum blue procedure (Hunter, 1974). Potassium was determined from the supernatant directly on a flame photometer. Samples for boron (B) analysis were ashed separately, and boron was determined photometrically by the azomethine H method (Gaines and Mitchell, 1979).

Genetic parameters

Variability is an essential factor in crop enhancement and characterisation of variability of desired traits is a prerequisite for obtaining access to significant alleles for genetic enhancement in nutritional traits (Nagar *et al.,* 2018). All trait expressions depend on the genotype and environment, hence the genotypic and phenotypic coefficients of variability were determined for all traits studied (Nagar *et al.,* 2018). The heritability estimates and genetic advancements were determined in all traits to establish any possible genetic improvement upon selection of desired nutritional traits (Nagar *et al.,* 2018).

The phenotypic, genotypic and environmental variances and coefficients of variation were calculated according to the formula described by Burto and Devane (1953) and cited by Singh *et al.* (2017), as follows:

Environmental variance ($\delta^2 e$) = MSE

Genotypic variance ($\delta^2 g$) = $\frac{-\text{MSG} - \text{MSE}}{\text{r}}$

Phenotypic variance ($\delta^2 p$) = $\delta^2 g + \delta^2 e$

where MSG is mean square due to genotype, MSE is mean square of error (environmental variance) and (r) is the number of replications.

Phenotypic coefficient of variation (PCV) = $\sqrt{\frac{\delta^2 p}{x}} \times 100$

Genotypic coefficient of variation (GCV) = $\sqrt{\frac{\delta^2 g}{x}} \times 100$

Where;

$\delta^2 p$ = phenotypic variation; $\delta^2 g$ = genotypic variation; x = grand mean of the character studied.

Estimation of heritability in broad sense: Broad sense heritability (h^2) expressed as the percentage of the ratio of the genotypic variance ($\delta^2 g$) to the phenotypic variance ($\delta^2 p$), according to Allard (1960), was calculated with the following formula:

$H^2 = \frac{\delta^2 g}{\delta^2 p} \times 100$

Genetic advance (GA) was estimated as per formula given by Allard (1960) and cited by Meena *et al.* (2015).

$GA = k \times \sqrt{\frac{\delta^2 p \times \delta^2 g}{\delta^2 p}}$

where:

GA = expected genetic advance; $\delta^2 p$ = phenotypic variation; $\delta^2 g$ = genotypic variation; k= the standard selection differential at 5% selection intensity (k = 2.063).

Data analysis

Data were subjected to ANOVA using the GenStat 15th edition. ANOVA was combined for both growing seasons and 9 fruits (n=9) were analyzed for each parameter per landrace. Means were separated using Tukey's LSD at the 5% significance level. Correlations and principal component analysis (PCA) were implemented to determine multi-character variation using the GenStat 15th edition. Cluster analysis was performed on the genetic distance matrix by using the hierarchical cluster analysis (HCA) method through a biplot and dendrogram to study the relationship among landraces.

Results

There were significant ($P < 0.05$) differences among the landraces with regard to proximate and mineral element composition (Tables 2 and 3). This provides a satisfying pool of germplasm to select from for the improvement of mineral nutrient quantity and quality through breeding processes such as biofortification and hybridising.

Proximate and mineral element composition

The proximate analysis of the 14 landraces studied is presented in Table 2, which revealed significant variations (P < 0.01) in respect of the ash, fat, acid detergent fibre, neutral detergent fibre and protein contents. Ash content was highest in DSI (32.70 g/100g) and lowest in NRB (7.53g/100g). KSP had significantly higher fat content (2.41g/100g) and followed in order by KRI (1.50g/100g), NqSC (1.50g/100g), NRC (1.35g/100g) and DSI (1.23g/100g). However, NSC (0.19g/100g) recorded the lowest fat content. Acid detergent fibre content was highest in KSP (30.34g/100g) but did not differ significantly with the values obtained for NSRC (28.09g/100g) and DSI (28.08g/100g). The landrace MSC recorded the lowest acid detergent fibre content of 15.35g/100g. the neutral detergent fibre was significantly higher in KSP (39.51 g/100g) followed by NSRC (37.25g/100g) and DSI (33.74g/100g) in that order while landrace MSC gave the lowest (21.60g/100g) neutral detergent fibre content. The results showed that the protein content differed significantly from 5.38g/100g in NqRC to 9.62g/100g in NRC. Although landrace NRC recorded a significantly higher value of protein content, it did not differ significantly from KSP (9.20g/100g).

Table 2. Proximate composition of *L. siceraria* landraces (g/100 g).

LR	Ash	Fat	ADF	NDF	Pro
KSP	26.62 abc	2.41 a	30.34 a	39.51 a	9.20 a
KSC	29.43 ab	1.19 bcd	24.25 b	28.72 cde	5.36 e
KRI	23.76 abc	1.50 b	23.55 b	31.08 cd	5.91 de
NRB	7.53 f	1.00 bcde	17.96 cdef	21.94 fg	7.32 bc
NRC	12.73 def	1.35 bc	19.38 cde	23.40 efg	9.62 a
MSC	13.29 def	0.87 cdef	15.35 f	20.11 g	7.09 bc
RSP	21.16 bcd	0.44 fg	23.46 b	27.77 def	6.62 cd
RRP	11.51 ef	0.43 fg	17.79 cdef	21.60 g	6.57 cd
NqRC	20.86 bcd	0.79 def	19.42 cd	22.94 efg	5.38 e
NSRP	18.17 cde	0.36 fg	15.80 def	21.91 fg	7.02 bc
NqSC	19.48 cde	1.50 b	20.87 bc	32.35 bcd	7.09 bc
NSC	13.02 def	0.19 g	15.68 ef	19.17 g	6.76 bcd
NSRC	25.22 abc	0.53 efg	28.09 a	37.25 ab	5.69 de
DSI	32.70 a	1.23 bcd	28.08 a	33.74 abc	7.81 b
Mean	19.68	0.984	21.43	27.25	6.961
P value	<.001	<.001	<.001	<.001	<.001
LSD	9.221	0.514	3.731	5.955	1.079
CV%	28.0	31.2	10.4	13.1	9.3

Mean values in the same column with different letter (s), differ significantly at (p < 0.05) according to Tukey's LSD. LR- landraces; – from Khangelani area with smooth, (KSP) pear-shaped; smooth, (KSC) curvilinear shape; and (KRI) rough isodiametric shape fruits; from Ndumo area (NRB) with rough fruits with brown seeds and (NRC) rough fruits with creamy seeds; from Mbazwana area (MSC) with smooth cylindrical-shape; from Rorke's Drift area (RSP) with smooth pear-shaped and (RRP) rough pear-shaped; from Nquthu area (NqRC) with rough curvilinear shape,(NSRP) with semi-rough pear-shaped, (NqSC) and (NSC) with smooth curvilinear shaped and (NSRC) semi-rough curvilinear shaped and from Dundee area (DSI) with smooth isodiametric shape. ADF- acid detergent fibre, NDF- neutral detergent fibre and Pro-protein.

Table 3 shows the mean performance among the 14 landraces assessed on the basis of their mineral element contents. The content of Ca ranged from 0.13g/100g (NSRP) to 0.44g/100g (KSP), ofmg varied from 0.08g/100g (NqRC and NSRP) to 0.22g/100g (KSP), K ranged from 2.80g/100g (NRB) to 9.69g/100g (DSI), P varied from 0.08g/100g (KRI) to 0.29g/100g (KSP), N varied from 0.85g/100g (KSC) to 1.53g/100g (NRC), Na ranged from 0.03mg/kg (RRP and NSRP) to 0.11mg/kg (KSP), Mn varied from 9.67mg/kg (RSP) to 19.00mg/kg (NRC), Fe varied from 23.70mg/kg (NqSC) to 828.70mg/kg (NRC), Zn varied from 0mg/kg (KSP and KRI) to 120.33mg/kg (NSRC), Cu varied from 0.33mg/kg (NSRP) to 10.87mg/kg (KSP), Al varied from 11.01mg/kg (RRP) to 525.53mg/kg (NRC) and B varied from 18.80mg/kg (NqRC) to 38.32mg/kg (KSP).

Table 3. Mineral element traits of *L. siceraria* landraces.

Macronutrient content (g/100 g)						Micronutrient content (mg/kg)						
LR	Ca	Mg	K	P	N	Na	Mn	Fe	Zn	Cu	Al	B
KSP	0.44 a	0.22 a	8.62 ab	0.29 a	1.47 a	0.11 a	17.33 abc	106.70 cde	0.00 d	10.67 a	38.93 cde	38.32 a
KSC	0.25 def	0.16 bc	7.83 abc	0.18 cde	0.85 e	0.06 cde	18.33 ab	169.70 bc	82.67 ab	6.33 bc	43.87 c	35.86 ab
KRI	0.21 ef	0.19 ab	7.04 bcd	0.08 g	0.94 de	0.08 bc	11.67 ef	102.70 cde	0.00 d	4.67 bcde	41.87 cd	31.73 b
NRB	0.21 ef	0.15 bcd	2.80 f	0.24 abc	1.17 bc	0.05 def	16.00 abcd	244.00 b	9.67 d	5.67 bc	119.85 b	20.63 c
NRC	0.28 de	0.19 ab	3.83 ef	0.26 ab	1.53 a	0.04 ef	19.00 a	828.70 a	57.00 bc	7.00 b	525.53 a	19.84 c
MSC	0.25 def	0.09 ef	3.78 ef	0.15 ef	1.13 bc	0.05 def	13.67 cdef	86.30 cde	31.33 cd	1.33 fg	34.42 cdef	19.47 c
RSP	0.27 def	0.11 def	5.64 cde	0.16 def	1.05 cd	0.04 ef	9.67 f	29.70 de	21.00 cd	2.67 defg	20.97 cdef	22.53 c
RRP	0.20 fg	0.13 cde	3.69 ef	0.21 bcd	1.05 cd	0.03 f	14.33 bcde	33.70 de	24.67 cd	4.33 bcde	11.01 f	21.68 c
NqRC	0.19 fg	0.08 f	4.13 ef	0.14 efg	0.86 e	0.06 de	10.33 ef	35.30 de	18.33 cd	4.33 bcde	19.47 def	18.80 c
NSRP	0.13 g	0.08 f	3.53 ef	0.14 efg	1.12 bc	0.03 f	12.00 def	37.30 de	22.33 cd	0.33 g	16.05 ef	20.13 c
NqSC	0.35 bc	0.12 cdef	4.81 def	0.15 ef	1.13 bc	0.07 cd	18.00 ab	23.70 e	24.33 cd	2.00 efg	11.09 f	20.41 c
NSC	0.30 cd	0.11 def	3.56 ef	0.17 de	1.08 bcd	0.05 def	18.33 ab	43.30 de	30.33 cd	5.67 bc	11.23 f	20.22 c
NSRC	0.38 ab	0.17 bc	8.21 ab	0.08 g	0.91 de	0.10 ab	12.00 def	131.70 cd	120.33 a	4.00 cdef	39.74 cd	37.22 a
DSI	0.22 ef	0.18 ab	9.69 a	0.11 fgh	1.25 b	0.08 bc	11.33 ef	31.00 de	116.00 a	5.33 bcd	36.82 cde	34.47 ab
Mean	0.26	0.14	5.51	0.16	1.114	0.06	14.43	136.00	39.90	4.60	69.30	25.81
P value	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
LSD	0.074	0.043	2.238	0.058	0.172	0.026	4.048	107.15	39.71	2.920	23.43	5.022
CV%	16.8	18.4	24.3	20.9	9.3	24.6	16.8	47.1	59.5	38.0	20.2	11.6

Mean values with different letter (s) within the same column are significantly different at ($p < 0.05$) according to Tukey's LSD. LR-landraces; from Khangelani area with smooth, (KSP) pear-shaped; smooth, (KSC) curvilinear shape; and (KRI) rough isodiametric shape fruits; from Ndumo area (NRB) with rough fruits with brown seeds and (NRC) rough fruits with creamy seeds; from Mbazwana area (MSC) with smooth cylindrical-shape; from Rorke's Drift area (RSP) with smooth pear-shaped and (RRP) rough pear-shaped; from Nquthu area (NqRC) with rough curvilinear shape (NSRP) with semi-rough pear-shaped, (NqSC) and (NSC) with smooth curvilinear shaped and (NSRC) semi-rough curvilinear shaped and from Dundee area (DSI) with smooth isodiametric shape. Ca-calcium;mg-magnesium; K-potassium; Na-sodium; P-phosphorus; N-nitrogen; Mn-manganese; Fe-iron; Zn-zinc; Cu-copper, Al-aluminium and B-boron.

Correlation among the proximate and mineral element composition of the L. siceraria landraces

Only positive correlations were significant among nutritional and mineral components (Table 4). ADF and NDF were positively correlated with each other and they both correlated positively with ash,mg, K, Na and B. NDF further correlated positively with Ca.mg had a positive correlation with fat, K, Na, Cu and B. K strongly correlated with ash, Na and B. Na was positively correlated with ash, Ca and B.

B also correlated positively with ash. P and N correlated positively with each other and they further correlated with protein. P correlated positively with Mn and Cu, which also correlated positively with fat. Al positively correlated with protein, N and Fe.

Principal component analysis

The first three informative principal components (PC1–3) were responsible for 80.3% cumulative variability, with each principal component having an eigenvalue greater than 1.0 (Table 5). The first principal component (PC1), with 42.1% of the total variation was positively associated with ash, fat, ADF, NDF, Ca,mg, K, Na, Cu and B. PC2, with 29.3% of the total variability was positively correlated with protein, P, N, Mn, Fe and Al. PC3, responsible for 8.9% of the total variability was positively associated with Zn.

Cluster analysis

To further understand the association among nutritional components and the landraces of different origins, a biplot was constructed using PC1 and PC2 (Fig. 1.), both of which were positively correlated with fat, protein, Ca,mg, P, Fe, Al, N and Cu.

Table 4. Correlation among the nutritional and mineral composition of the *L. siceraria* landraces.

Variables	Ash	Fat	ADF	NDF	Pro	Ca	Mg	K	Na	P	N	Mn	Fe	Zn	Cu	Al
Fat	0.472															
ADF	**0.824**	0.573														
NDF	**0.773**	0.592	**0.945**													
Pro	-0.179	0.350	0.092	0.106												
Ca	0.245	0.428	0.567	**0.654**	0.325											
Mg	0.404	**0.689**	**0.732**	**0.677**	0.442	0.494										
K	**0.925**	0.535	**0.937**	**0.875**	-0.023	0.428	**0.656**									
Na	**0.657**	0.579	**0.826**	**0.880**	0.047	**0.685**	**0.637**	**0.787**								
P	-0.394	0.366	-0.080	-0.141	**0.675**	0.263	0.280	-0.266	-0.158							
N	-0.179	0.350	0.092	0.106	**1.000**	0.326	0.442	-0.022	0.047	**0.674**						
Mn	-0.271	0.435	-0.130	-0.065	0.434	0.422	0.310	-0.164	-0.001	**0.640**	0.434					
Fe	-0.291	0.238	-0.070	-0.132	0.559	0.088	0.422	-0.179	-0.162	0.481	0.559	0.469				
Zn	0.495	-0.042	0.419	0.333	-0.114	0.133	0.250	0.540	0.261	-0.369	-0.114	-0.060	0.137			
Cu	0.221	**0.625**	0.524	0.386	0.437	0.491	**0.774**	0.410	0.488	**0.610**	0.436	0.479	0.369	0.018		
Al	-0.302	0.187	-0.096	-0.157	**0.611**	0.047	0.378	-0.206	-0.206	0.463	**0.611**	0.411	**0.988**	0.119	0.322	
B	**0.806**	0.561	**0.895**	**0.837**	-0.048	0.461	**0.739**	**0.939**	**0.799**	-0.142	-0.047	-0.026	-0.114	0.480	0.520	-0.186

Values ≥ 0.6 are deemed to be significantly correlated are in bold. Variables – ash; fat; ADF, acid detergent fibre; NDF, neutral detergent fibre; Pro, protein; Ca, calcium;mg, magnesium; K, potassium; Na, sodium; P, phosphorus; N, nitrogen; Mn, manganese; Fe, iron; Zn, zinc; Cu, copper; Al, aluminium; B, boron.

Table 5. Loadings of the variables for the first three principal components.

variables	PC1	PC2	PC3
Ash	**0.752**	-0.508	0.134
Fat	**0.731**	0.303	-0.231
ADF	**0.944**	-0.211	0.043
NDF	**0.916**	-0.225	-0.068
Pro	0.252	**0.818**	0.010
Ca	**0.664**	0.212	-0.303
Mg	**0.848**	0.341	0.124
K	**0.904**	-0.361	0.129
Na	**0.870**	-0.214	-0.188
P	0.070	**0.849**	-0.328
N	0.253	**0.818**	0.010
Mn	0.149	**0.699**	-0.204
Fe	0.082	**0.790**	0.526
Zn	0.395	-0.258	**0.721**
Cu	**0.668**	0.494	-0.172
Al	0.039	**0.796**	0.548
B	**0.908**	-0.276	0.053
Eigenvalue	7.153	4.975	1.518
Variability (%)	42.076	29.266	8.928
Cumulative%	42.076	71.342	80.270

PC1–3: Principal components 1–3. Values ≥ 0.6 are deemed to be significant are in bold. Variables – ash; fat; ADF, acid detergent fibre; NDF, neutral detergent fibre; Pro, protein; Ca, calcium;mg, magnesium; K, potassium; Na, sodium; P, phosphorus; N, nitrogen; Mn, manganese; Fe, iron; Zn, zinc; Cu, copper; Al, aluminium; B, boron.

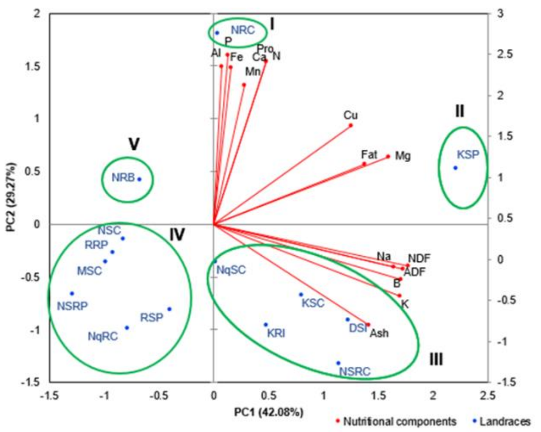

Fig. 1. Biplot of *L. siceraria* landraces and nutritional components. The blue marker indicates landraces-from Khangelani area with smooth, (KSP) pear-shaped; smooth, (KSC) curvilinear shape; and (KRI) rough isodiametric shape fruits; from Ndumo area (NRB) with rough fruits with brown seeds and (NRC) rough fruits with creamy seeds; from Mbazwana area (MSC) with smooth cylindrical-shape; from Rorke's Drift area (RSP) with smooth pear-shaped and (RRP) rough pear-shaped; from Nquthu area (NqRC) with rough curvilinear shape,(NSRP) with semi-rough pear-shaped, (NqSC) and (NSC) with smooth curvilinear shaped and (NSRC) semi-rough curvilinear shaped and from Dundee area (DSI) with smooth isodiametric shape. The red marker indicates nutritional components–ash; fat; ADF, acid detergent

fibre; NDF, neutral detergent fibre; Pro, protein; Ca, calcium;mg, magnesium; K, potassium; Na, sodium; P, phosphorus; N, nitrogen; Mn, manganese; Fe, iron; Zn, zinc; Cu, copper; Al, aluminium; B, boron.

In a biplot, landraces formed five distinct clusters in close relation with different nutritional components (Fig. 1.). Clusters I, II and V comprised of NRC, KSP and NRB as singletons, respectively. Cluster III consisted of NqSC, KSC, KRI, NSRC and DSI; whereas Cluster IV grouped landraces NSRC, RRP, MSC, NSRP, NqRC and RSP. All nutritional components were positively associated with PC1. In a dendrogram landraces grouped themselves into two main clusters (Fig. 2). Cluster I was made up of DSI from Dundee with smooth isodiametric shaped fruits. Cluster II comprised of two sub-clusters that grouped landraces primarily according to their origin and then their morphological traits.

Sub-cluster IIa had landraces from Rorke's Drift (RSP and RRP) and Nquthu (NqSC, NSC, NqRC and NSRP) with pear-shaped and curvilinear fruits. These locations are found in relatively dry areas with very cold winter (temperature range) and hot summer (temperature range) temperatures.

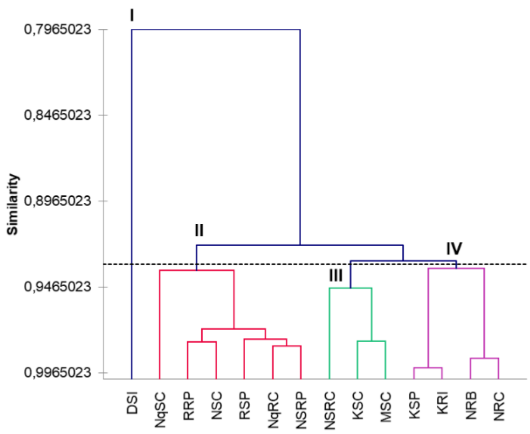

Fig. 2. Hierarchical cluster showing similarities amongst nutritional traits *L. siceraria* landraces using the complete linkage method. Landraces- from Khangelani area with smooth, (KSP) pear-shaped; smooth, (KSC) curvilinear shape; and (KRI) rough isodiametric shape fruits; from Ndumo area (NRB) with rough fruits with brown seeds and (NRC) rough fruits with creamy seeds; from Mbazwana area (MSC) with smooth cylindrical-shape; from Rorke's Drift area (RSP) with smooth pear-shaped and (RRP) rough pear-shaped; from Nquthu area (NqRC) with rough curvilinear shape,(NSRP) with semi-rough pear-shaped, (NqSC) and (NSC) with smooth curvilinear shaped and (NSRC) semi-rough curvilinear shaped and from Dundee area (DSI) with smooth isodiametric shape.

Sub-cluster IIb grouped landraces from Khangelani (KRI, KSC and KSP), Mbazwana (MSC), Ndumo (NRB and NRC); but associated with a landrace from Nquthu (NSRC). These areas, apart from Nquthu, are located in coastal and humid regions with relatively high temperatures both in winter (temperature range) and summer (temperature range). Morphological traits of these landraces ranged from semi-rough, curvilinear fruit (NSRC); rough fruit with isodiametric (KRI and NRB) and oblong (NRC) shapes; and smooth curvilinear (KSC and MSC) and pear-shaped (KSP) fruits.

Genetic parameters

The phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability, and genetic advancement for nutritional traits of the landraces from different origins are presented in Table 6. The PCV was higher than GCV for all nutritional traits. However, the difference between PCV and GCV was not significant, suggesting that the environment had a big impact on the expression and availability of these traits (Jain *et al.,* 2017). The highest GCV (>15%) was recorded for Al, followed by Zn, Fe and ash. This indicates a relatively high genetic variability of these nutritional traits among landraces of different origins. A similar record was evident for PCV. Nutritional traits were subjected to the estimate of heritability using the broad sense method. The heritability estimate ranged from 42.4% (Fe) to 98.9% (Al). High heritability estimates (more than 50%) were noted for all nutritional traits except for Fe. Nutrients were then expressed in the following descending order: Al; B; ADF; protein; nitrogen; fat; NDF; Ca; P; K;mg; Zn; Na; Cu; Mn and ash. All nutritional components had high genetic advance values of more than one. The highest genetic advance was recorded for Al (2.1) whereas the lowest was for Fe (1.3).

Table 6. Genetic parameters for nutritional traits of *L. siceraria* landraces.

Variables	δ²g	δ²e	δ²p	GM	PCV	GCV	ECV%	H2	GA
Ash	44.8	30.4	75.2	19.7	19.5	15.1	12.4	59.6	1.6
Fat	0.3	0.1	0.4	1.0	6.6	5.8	3.1	77.6	1.8
ADF	23.0	5.0	28.0	21.4	11.4	10.4	4.8	82.2	1.9
NDF	39.9	12.7	52.6	27.3	13.9	12.1	6.8	75.9	1.8
Pro	1.5	0.4	1.9	7.0	5.2	4.6	2.4	78.0	1.8
Ca	0.0	0.0	0.0	0.3	1.8	1.5	0.9	75.8	1.8
Mg	0.0	0.0	0.0	0.1	1.3	1.1	0.7	71.0	1.7
K	4.7	1.8	6.5	5.5	10.8	9.2	5.7	72.4	1.8
Na	0.0	0.0	0.0	0.1	1.1	0.9	0.6	70.1	1.7
P	0.0	0.0	0.0	0.2	1.7	1.4	0.9	73.3	1.8
N	0.0	0.0	0.0	1.1	2.1	1.8	1.0	78.0	1.8
Mn	9.1	5.9	15.0	14.4	10.2	8.0	6.4	60.9	1.6
Fe	3015.7	4104.0	7119.7	136.0	72.4	47.1	54.9	42.4	1.3
Zn	1371.6	563.7	1935.3	39.9	69.6	58.6	37.6	70.9	1.7
Cu	5.8	3.0	8.8	4.6	13.8	11.2	8.1	65.4	1.7
Al	17933.3	196.3	18129.6	69.3	161.7	160.9	16.8	98.9	2.1
B	56.2	9.0	65.2	25.8	15.9	14.8	5.9	86.2	1.9

Genetic parameters – δ²g, genotypic variance; δ²e, environmental variance; δ²p, phenotypic variance; GCV, genotypic coefficient of variation; PCV, phenotypic coefficient of variation; H2, broad sense heritability; GA, genetic advancement. Variables – ash; fat; ADF, acid detergent fibre; NDF, neutral detergent fibre; Pro, protein; Ca, calcium;mg, magnesium; K, potassium; Na, sodium; P, phosphorus; N, nitrogen; Mn, manganese; Fe, iron; Zn, zinc; Cu, copper; Al, aluminium; B, boron.

Discussion

Proximate composition of the L. siceraria landraces

A significant variation in proximate and mineral composition of *Lagenaria siceraria* landraces from northern KwaZulu-Natal is similar to that of landraces studied in India (Upaganlawar and Balaraman, 2009; Aliu *et al.,* 2012) and Egypt (Ahmed *et al.,* 2016).

The ash content range and average of the study material was significantly greater than the corresponding ranges and averages among *Cucurbita maxima* cultivars from Poland (0.59–1.35g/100g and 1.07g/100g) (Czech and Stepniowska, 2018) and Cameroon (0.3–1.3g/100g and 0.84g/100g) (Ponka *et al.,* 2015). The different genus and nutritional analysis methods are no doubt the reasons for these variation. The *C. maxima* cultivars from Cameroon were cooked, and this may have denatured and leached out the nutritional content of vegetables significantly (Mepba *et al.,* 2007). The range of ash content of *L. siceraria* fruit pulp from the current study was higher than the range that (2.93–4.01g/100g) recorded among *L. siceraria* seeds from Sudan (Mariod *et al.,* 2015). Landraces with high ash content indicate the presence of high mineral content, which is essential for human growth and development (Czech and Stepniowska, 2018).

The fat content of the fruit pulp from the current study was less than those of *L. siceraria* seeds from Sudan (24.11–26.32g/100g) (Mariod *et al.,* 2015) and Nigeria (38.13–43.65g/100g) (Essien *et al.,* 2015). However, *Cucumis sativus* cultivars from Nigeria recorded a lower fat content, varying from 0.12 to 0.30mg/100 g with an average of 0.22mg/100 g (Abbey *et al.,* 2017). ADF and NDF content averages recorded among the study material were higher than the 15.67 and 21.16g/100g among *L. siceraria* accessions from India (Upaganlawar and Balarama, 2009) as well as 14.90 and 17.70g/100g respectively of *Cucurbita maxima* from Poland (Peksa *et al.,* 2016). The elevated neutral detergent fibre, which is easily digestible, makes the *L. siceraria* treat constipation and avoiding haemorrhoids (Barot *et al.,* 2015).

The protein content range and mean of the current study were higher than ranges and averages among the *Cucurbita maxima* from Cameroon (5.36–9.62g/100g and 1.07g/100g) (Ponka *et al.,* 2015) and Poland (0.85–1.68g/100g and 1.26g/100g) (Czech and Stepniowska, 2018). The results of the current study are in the lower range when compared with the reported range and mean value (8.29–12.56g/100g and 9.67g/100g) in *Cucurbita maxima* accessions consumed in Nigeria (Blessing *et al.,* 2009).

Protein is important to the human body, which comprise approximately 45% of protein (Ponka *et al.,* 2015). Protein is essential for tissue repair, nutrient transport, and the building and functioning of muscles (Ponka *et al.,* 2015).

Mineral element composition of the L. siceraria landraces

The range and mean obtained for Ca from the current study proved to be higher than the range and mean reported in *Cucumis sativus* cultivars (0.020–0.025g/100g and 0.022g/100g) from Nigeria (Abbey *et al.,* 2017). A lower range and average of Ca content (0.06–0.26g/100g and 0.17g/100g) in *Cucurbita maxima* and *Cucurbita moschata* morphotypes were reported from Cameroon (Mbogne *et al.,* 2015). Calcium is essential for healthy bones and teeth, vital for muscle functioning, boosts the immune system, and regulates blood pressure and clotting (Gharibzahedi and Jafari, 2017). The magnesium content of the investigated landraces was very low compared to those reported for some commonly consumed cucurbits such as *Momordica charantia* genotypes (0.25–0.36g/100g with an average of 0.29g/100g) from Turkey (Karaman *et al.,* 2018), as well as *Cucurbita maxima* and *Cucurbita moschata* morphotypes (0.11–0.29g/100g with a mean of 0.18g/100g) from Cameroon (Mbogne *et al.,* 2015).

These *Momordica charantia* genotypes were grown in a greenhouse in a controlled environment when compared to the field–grown *L. siceraria* landraces of the current study, thus explaining their superiority resulting from an environment calibrated for optimum results. The *Cucurbita maxima* and *Cucurbita moschata* morphotypes were grown in soils rich in volcanic ash, which increases the soil fertility drastically, thus explaining the high mineral content present in these morphotypes (Mbogne *et al.,* 2015). The *Cucurbita maxima* and *Cucurbita moschata* morphotypes also received 1500 to 2000mm of annual rainfall (Mbogne *et al.,* 2015), which is higher than the annual rainfall received by the *L. siceraria* landraces of the current study at 299.95–350.02mm (Naidoo *et al.,* 2016). A similar study on *Cucurbita pepo* from Nigeria by Adnan *et al.* (2017) recorded a lowermg content, averaging 0.45mg/100g.mg is vital for protein synthesis and a healthy immune system, and relieves constipation (Gharibzahedi and Jafari, 2017).

The K content range and mean value were higher than the range and mean value (1.88–3.17g/100g and 2.46g/100g) reported by Mbogne *et al.* (2015) for *Cucurbita maxima* and *Cucurbita moschata* morphotypes from Cameroon, as well as (1.29–2.75g/100g and 1.78g/100g) for *Cucurbita maxima* cultivars from Cameroon by Ponka *et al.* (2015). A study on *L. siceraria* seeds by Mariod *et al.* (2015) obtained a lower K content range and mean (23118–33023mg/kg and 29385.9mg/kg) than the *L. siceraria* fruit pulp of the current investigation. K aids in fluid balance, and regulates blood pressure and waste elimination (Gharibzahedi and Jafari, 2017). The range (0.08–0.29g/100g) and mean (0.17g/100g) of phosphorus (P) content of the fruit pulp from the current study was lower than the range and mean of *L. siceraria* seeds from Sudan (0.57–0.72g/100g and 0.66g/100g) recorded by Mariod *et al.* (2015) and *Cucurbita maxima* accessions (0.23–0.36g/100g and 0.29g/100g) from Cameroon by (Ponka *et al.,* 2017). A similar study on *L. siceraria* varieties from India obtained a higher P content average at 0.19g/100g (Barot *et al.,* 2015). Phosphorus is vital for kidney performance and assists in protein synthesis, cell growth, maintenance and reparation, as well as ATP and energy production (Gharibzahedi and Jafari, 2017).

Nitrogen (N) content of the study material was lower than that of a comparable study on *Cucurbita pepo* from Slovakia, varying from 2.0 – 7.2g/100g (Kostalova *et al.,* 2010). Nitrogen is essential for boosting the immune system, and fighting infectious agents and malignant tumours (Bogdan *et al.,* 2000). The results show that the range and mean (0.03–0.11mg/kg and 0.06mg/kg) was higher than the range and mean (2.43–7.01mg/100g and 4.29mg/100g) of *Cucumis sativus* from Nigeria (Abbey *et al.,* 2017) and *L. siceraria* landrace seeds (17.64–36.70mg/kg and 21.98mg/kg) from Sudan (Mariod *et al.,* 2015). A study on *L. siceraria* varieties from India recorded a lower Na content, with an average of 36.68mg/100g (Barot *et al.,* 2015). Sodium is essential for electrolyte balance, healthy heart functioning, metabolic activities, and nerve transition (Gharibzahedi and Jafari, 2017). The range and mean obtained for manganese (Mn) (9.67–19.00mg/kg and 14.43mg/kg) from the current study proved to be higher than the range and mean for *Cucumis sativus* (0.08–0.81mg/100 g and 0.38mg/100g) from Nigeria documented by Abbey *et al. (*2017) and *Cucurbita maxima* (0.7–1.6g/100g with and 1.1mg/100g) from Cameroon (Ponka *et al.,* 2017). The average content of Mn was higher than the one reported by Upaganlawar and Balaraman (2009), (0.31mg/100g) and Ahmed *et al. (*2017) (0.032mg/100g) on *L. siceraria* from India and Pakistan, respectively. *Cucurbita maxima* from Colombia also recorded a lower Mn content average at 0.02mg/100g (Leterme *et al.,* 2006). Manganese is essential for healthy bone structure development and brain and nervous system functioning, and aids against osteoporosis (Gharibzahedi and Jafari, 2017).

Landraces from this study were fortified with Fe content than varieties studied in India (23.3mg/kg) (Upaganlawar and Balaraman, 2009). Iron is important for the formation of haemoglobin in red blood cells which transports oxygen from the lungs to the cells throughout the body and is essential for energy metabolism (Gharibzahedi and Jafari, 2017). A study on *L. siceraria* from India recorded a lower Zn content compared to the study material, averaging at 7mg/kg (Rahman, 2003). Also in the current study greater amounts were reported compared to those reported for some commonly consumed cucurbits, for example, *Cucumis sativus* (2.8–4.5mg/kg with an average of 3.7mg/kg) from Nigeria (Abbey *et al.,* 2017) and *Cucurbita pepo* accessions (0.67–2.15mg/kg with an average content of 1.1mg/kg) from Kolova (Aliu *et al.,* 2012). Zinc is an integral part of many enzymes; it is vital for genetic material and protein synthesis and for sexual maturation and healthy fetal development, and improves digestion (Gharibzahedi and Jafari, 2017).

The copper (Cu) content of the investigated material was lower compared to studies on *Cucurbita pepo*, which recorded a higher Cu content range of (0.1-1.3mg/kg with a lower mean of 3.1mg/kg) from Spain by Martinez-Valdivieso *et al.* (2014) and (0.56–3.50mg/kg with a mean of 1.17mg/kg) from Kolova (Aliu *et al.,* 2012). Copper is essential for the production of red blood cells and protein (Stern *et al.,* 2007). It is also vital for iron breakdown and digestion, and is important as an antioxidant defence and for healthy immune system function (Bosta *et al.,* 2016). The Al content of the current study was noticeably higher than that of ryegrass with a mean of 0.2mg/kg (Pontigo *et al.,* 2017). Aluminium has no beneficial biological function in humans, but it is detrimental to human health as the most common contaminants contain aluminium (Strunecka *et al.,* 2016). Boron content from the current study on the *L. siceraria* landraces from northern KwaZulu-Natal ranged from 18.80–38.32mg/kg with an average of 2.5mg/kg. Boron is essential for regulating oestrogen in post-menopausal women for optimum mental performance and healthy bones (Gharibzahedi and Jafari, 2017).

Correlation in proximate and mineral elements of L. siceraria

The findings of the current study contradict the findings on *Luffa acutangula* and *Momordica charantia* from Pakistan (Hussain *et al.,* 2009). According to Hussain *et al. (*2009), protein correlated positively with fat (0.3) and ash (0.4). However, these correlations were not recorded for the current study. Magnesium correlated with fat, potassium, sodium, copper and boron. This suggests that when selecting for genotypes with high magnesium content, those genotypes will subsequently be rich in fat and essential salts as well as being genotypes that facilitate faster digestion as a result of high copper content (Bosta *et al.,* 2016). In a comparable study on *Cucurbita moschata* genotypes from New Delhi, India, magnesium correlated positively with sodium (0.464) and copper (0.216) (Nagar *et al.,* 2018). In the current study phosphorus correlated positively with nitrogen (0.640) and copper (0.610). This assures that upon selecting genotypes with high phosphorus, the selected genotypes will also contain high nitrogen and copper content. A comparable study on *Momordica charantia* genotypes from India noted similar results, with phosphorus correlating positively with copper (0.454) (Dalamu, 2011).

Principal component and cluster analysis

Nutritional variability in PC1, PC2 and PC3 in the current study was comparable to variability in PC1 (48.34%), PC2 (23.04%) and PC3 (19.07%) among several leafy vegetables (Kumar *et al.,* 2018). The nutritional traits of the current study; ash, fat, acid detergent fibre, neutral detergent fibre, calcium, magnesium, potassium, sodium, copper and boron correlated positively with the first principal component (PC1). These traits contributed 42.076% of the total variability. A study on *Cantharellus cibarius* obtained similar findings as K,mg, Na and Cu correlated positively with PC1, accounting for 66% of the total variability (Drewnowska and Falandysz, 2015).

The nutritional traits of protein, phosphorus, nitrogen, manganese, iron and aluminium correlated positively with second principal component (PC2). These traits contributed 29.266% to the total variability. A study on *Cyperus esculentus* documented similar results with protein, phosphorus and aluminium correlating positively with PC2 and contributing 21.17% to the total variability (Bado *et al.,* 2015). A study on different leafy vegetables also documented positive correlation of potassium (0.7407) with PC1 (Kumar *et al.,* 2018) as in the current study. Positive correlation of calcium in PC1 and phosphorus in PC2 among *L. siceraria* landraces were in PC2 and PC3, respectively (Kumar *et al.,* 2018). However, a study on *Abelmoschus esculentus* contradicts the findings of the current study as Ca,mg, K, Na and Cu were all negatively correlated with PC1 (Dos Santos *et al.,* 2013)

The cluster analysis displayed the presence of diversity among the 14 landraces in terms of the nutritional traits studied. The dendrogram (Fig. 2.) showed four distinct clusters. The genetic variances and heritability estimates revealed positive results in terms of high variability among the germplasm with nutritional traits that are highly heritable - which is ideal for genetic manipulation and future breeding programmes in the quest to achieve the most nutritional *L. siceraria* landraces.

A total variance of 71.4% for two principal components of a biplot among *L. siceraria* landraces was comparable to the 66.2% in *Cucurbita maxima* and *Cucurbita moschata* morphotypes (Mbogne *et al.,* 2015) and 79.7% amongst *Abelmoschus esculentus* cultivars (dos Santos *et al.,* 2013). Grouping of *L. siceraria* landraces in the dendrogram according to their fruit morphology and area of origin was similar to the grouping of *Cucurbita maxima* germplasm (Kazminska *et al.,* 2018).

Genetic parameters

In this study the phenotypic coefficient of variance (PCV) was slightly higher than the genotypic coefficient of variation (GCV), suggesting that the environment played a vital role in the expression of these nutritional traits (Jain *et al.,* 2017). A high to moderate (>15%) phenotypic coefficient of variation was noted in the current study for aluminium (160.9%), iron (72.4%), zinc (69.6%), ash (19.5%), and boron (15.9%). Similar findings were documented on *Momordica charantia* genotypes from India, where iron recorded a lower PCV at 25.3% (Dalamu, 2011). The highest value for broad sense heritability estimate was noted for aluminium, boron, ADF, protein, nitrogen, fat, NDF, calcium, phosphorus, potassium, magnesium, zinc, sodium, copper, manganese and ash. A comparable study yielded similar results and the following highest heritability estimates were noted: calcium (99.9%), iron (99.7%), sodium (99.2%), potassium (97.5%), phosphorus (95.5%), zinc (93.3%) and manganese (90.0%) (Dalamu 2011). The current study recorded higher genetic advances for potassium (1.8) and phosphorus (1.8) than recorded by Dalamu (2011), for *M. charantia.*

Conclusion

The present study has reported that all 14 landraces are good means of supplementing diet—particularly KSP, NRC and DSI—as they recorded the highest ash, fat, ADF, NDF, protein content and KSP outperformed all 14 landraces in containing high amounts of mineral elements (Ca,mg, P, N, Na, Cu and B).

Therefore, these three landraces are recommended for their nutritional composition in future breeding programmes. Furthermore, relatively high nutritional composition is indicative of the great potential these landraces have as an alternative food source and for maintaining good health.

Nutritional traits correlated only positively with each other, this is an ideal outcome for progressive studies, particularly in plant breeding as this means that when selecting for nutritional traits of interest, other beneficial nutritional traits will also be selected. Among genetic parameters, the phenotypic coefficient of variation was higher than the genotypic coefficient variation for most traits. These findings emphasize the influence of the environment on the expression of genotypes, hence the evident diversity among landraces of different geographic origins.

The heritability and genetic advance were significantly high for nutritional traits. Considering all these results, the landraces studied here are strong contenders for desirable, heritable and poorly investigated parental material (germplasm) for future plant breeding and food security programmes.

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