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RESEARCH ARTICLE

Determination of the Best Performing Sri Lankan Maize Landraces Based on the Kernel Nutritional Composition

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ABSTRACT

Maize (Zea mays L.) is one of the most widely cultivated cereal crops in the world as well as in Sri Lanka. Data on the nutritional composition of maize is beneficial for the food and feed industry, but there is a lack of information regarding this avenue in Sri Lanka. Therefore, this study aimed to investigate the suitable landraces with higher nutritional composition among the different landraces by evaluating nutritional parameters using the rank summation index. The maize kernels derived from 42 local landraces were used and the responses were with varieties Bhadra (Control) and Pacific. The proximate composition was analyzed using Near-infrared spectroscopy (NIR) and carbohydrate content and energy were determined using the calculation method. Subsequently, the data were analyzed by performing ANOVA and the rank summation index (RSI) to identify the best performer among the landraces. The results revealed that there were significant differences (p<0.05) among the nutritional components for moisture, ash, fiber, fat, protein, carbohydrates, and energy among the tested landraces. Accordingly, the maize landraces SEU 22, SEU 31, and SEU 2 were identified as the superior germplasms regarding nutritional composition compared with Bhadra, as they exhibited the lowest RSI of 85, 88, and 89, respectively. Therefore, these maize landraces were recommended for future breeding programs for the development of nutritionally enriched maize grains and for sustainable production where land limitation is a challenge.

***Keywords**: Maize landraces; NIR spectroscopy; Nutritional composition; Rank summation index*

INTRODUCTION

Maize (*Zea mays* L.) is one of the most widely cultivated cereal crops in the world as well as in Sri Lanka followed by rice and wheat (FAOSTAT, 2014). It contributes to the food and feed industries (Huma *et al.*, 2019) and is predominantly used in biofuel and biogas production (Amer *et al.*, 2021). It can be cultivated in flooded and rain-fed farming systems in tropical temperate and semi-arid regions as cereal, fodder, and grain crops (Alvi *et al.*, 2003). Maize in Sri Lanka is the second most important cereal crop in terms of the extent of cultivation and human and animal consumption. In 2020, maize production was 313 thousand MT, which was cultivated in 23,000 to 28,000 ha from Anuradhapura, Ampara, Badulla, Monaragala, Matale, and Batticaloa districts. The rural farming community is the main source of demand for maize, which is consumed either as kernels or fresh cobs. In addition, maize grains and other maize-based food products are used by food industries in Sri Lanka. The annual maize requirement is scaled up to 600,000 MT of which local production meets around 42%, whereas the rest is imported. Maize is a good source of animal feed and the local dairy sector requires around 200,000 MT, while the poultry feed requirement is around 400,000 MT (Premarathne and Samarasinghe, 2020).

Maize is used as the major nutrient source for the food and feed industry, which could be produced comparatively at a reasonable cost. As such, consuming green maize is one of the most important ways for the human body to acquire nutrients necessary for its normal functioning (Qamar *et al.*, 2015). Furthermore, grains are rich in nutrients and are utilized for the production of a variety of industrial products (Afzal *et al.*, 2009) and they are crucial for the extraction of oil, starch, and glucose (Niaz and Dawar, 2009). However, such a nutritional composition tends to vary among the varieties and germplasms (Ullah *et al.*, 2010; Demeke, 2018; Adeniyi and Ariwoola, 2019). Therefore, it is necessary to develop varieties with improved nutritional composition to cater the demands of the food and feed industries.

To accelerate the adoption of newly developed varieties, breeders should take into consideration the concerns and preferences of farmers, consumers, and other actors at the early stage of cultivar development (De Groote *et al.*, 2002). Participatory plant breeding (PPB) approaches have been extensively used in cultivar development programs to address farmers' needs and their socioeconomic situation as well as consumers' preferences (Ribeiro *et al.*, 2017).

According to Sibiya *et al.* (2013), farmers preferred maize varieties with high yield and prolificacy, disease resistance, early maturity, white grain endosperm colour, and drying and shelling qualities. Also, Dao *et al.* (2015) stated that farmers preferred high-yielding, early-maturing, and drought-tolerant varieties. Etwire *et al.* (2013) reported that farmers preferred maize varieties that were early-maturing and drought-tolerant. In another study, Ribeiro *et al.* (2017) reported that farmers preferred maize varieties that were low soil nitrogen–tolerant and drought tolerant as well as disease- and pest-resistant.

In this regard, the nutritional compositions of kernels are also important for the selection of best maize landraces. However, the methods are used to determine the nutrient composition of the grains, the wet chemistry methods are more time-consuming and costly; therefore, researchers looked for ways to save costs and speed up processing. Hence, Near-infrared spectroscopy (NIRS) is one of the robust methods that can be used for quick analysis and has been widely utilized to determine the nutritional content of cereal grains and feedstuffs such as food fibre (Kays and Barton, 2002) and amino acid of grains (Fontaine *et al.*, 2002). However, it needs a high initial cost and skilled staff, yet it can analyze a large number of samples in a short amount of time, non-destructively, and with little or no supplies or chemicals (Lagombra and Harbers, 1991). Furthermore, NIR spectroscopy has been utilized for a selection of plants in breeding programmes, commodities exchange, agricultural production system investigation, and the development of inexpensive ration formulas (Deaville and Flinn, 2000). This analysis has the benefit of being simple and cost-effective in predicting product functioning regarding the spectra.

According to Okoli and Okoronkwo (2020), the cultivation of highly nutritious crops will not only improve the nutritional status of the country but also positively impact the overall livelihood of farmers. Maize breeders want to improve many targeted traits at the same time without impacting the performance of non-target traits. Index selection is one method of choice for many traits at once (Okoli, 2021). Mulamba and Mock (1978) recommended using the rank-summation index to determine the best-performer cultivars. The rank-summation index is calculated by ranking each cultivar according to each attribute and then summing the trait ranks for each cultivar. The cultivars with the lowest index values are selected for future usage.

Numerous benefits of the rank summation index include its ease of use and the absence of the requirement for estimates of genetic and phenotypic components (Hallauer and Carena, 2009). The concept of rank summation index was used in many research such as in the selection of maize hybrid varieties (Okoli 2021), stem borer resistance in maize (Oloyede-Kamiyo, 2019), the agronomic performance of drought-tolerant maize hybrids (Oyekunle and Badu-Apraku, 2017), the simultaneous selection in progenies of yellow passion fruit (Rosado *et al.*, 2012). Therefore, the rank summation index method has the potential to identify novel maize genotypes with improved characteristics in Sri Lanka.

The innovative efforts regarding the nutritional content, which is vital in the current context of global food security, become essential and justified as a result of the latent potentials of local landraces being revealed. Therefore, this study was carried out to compare the nutritional traits of different Sri Lankan maize landraces by using NIRS techniques and also used the rank summation index to identify the best landraces for crop improvement in future.

MATERIALS AND METHODS

Sampling site and collection

The present research study was conducted at the laboratory facilities at the Department of Biosystems Technology, Faculty of Technology, South Eastern University of Sri Lanka. Based on the preliminary Island-wide survey, it has been identified that Ampara, Monaragala and Badulla are the districts (Figure 1) that predominantly cultivated indigenous maize landraces for centuries. The landrace collection was performed through field visits, discussions and inspection of individual farmers in the said districts. Accordingly, 42 different maize landraces were collected and separated based on morphological characters (Mufeeth *et al.*, 2020). Subsequently, collected grain samples were placed separately in plastic containers (Figure 2) and stored under -18°C conditions to ensure the nutritional composition was intact until the laboratory analysis.

Nutritional analysis of maize landraces

The proximate chemical composition such as moisture, ash, fibre, protein and fat were determined using Near-infrared spectroscopy (FOSS NIRS DS2500, Denmark). The analysis was performed according to the protocol of Singh *et al.* (2018) with some modifications. Before starting the analysis in the NIR, the diagnostics test for hardware and performance was carried out. Then, 50 g of the sample was placed in a rotating cup made with NIR DS 2500, which fulfilled the requirement of ISO 12099 requiring a quartz window, which was placed in the sample compartment directly and closed the lid. Then the programme for Near-infrared spectral radiation in the spectrum of 400-2500 nm was selected to illuminate the sample. This multipoint reflectance measurement allowed for an accurate analysis of the sample for 1 minute. Readings were obtained by measuring the energy reflected from the samples by ISIscan Nova operating software. The analysis for each landrace was replicated three times. The carbohydrate content was calculated by subtracting the total percentage values of moisture, ash, protein, and fat from 100 (Hussain *et al.*, 2009; Sreerama *et al.*, 2012). Total energy values were obtained by multiplying the quantities of protein and carbohydrate by a factor of 4 kcal/g and fat by a factor of 9 kcal/g (Colak *et al.* 2009).

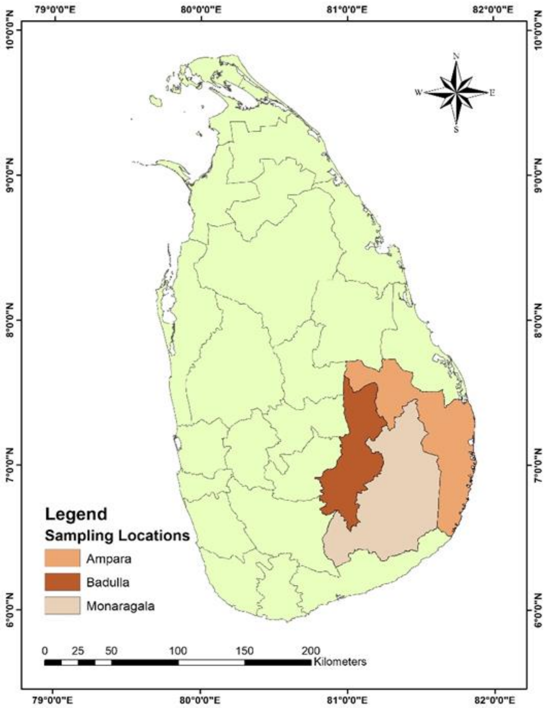

Figure 1: Sampling site of the maize landraces in three districts of Sri Lanka

Figure 2: Some of the collected maize landrace

Data analysis

The tested nutritional parameters were statistically analyzed following the Analysis of Variance (ANOVA) procedure using the SPSS software version 24.0. The means were compared using Tukey's post hoc test. Then, the rank summation index was used as previously described by Mulamba and Mock (1978) employing the nutritional traits and identifying the best landrace using Microsoft Excel Spreadsheet Software. Following the ranking, a selection index was calculated by adding the ranks of the maize landraces related to each characteristic that was studied. Cluster analysis was performed to distinguish similarities among the selected landraces by the Squared Euclidean distance method using SPSS software.

RESULTS AND DISCUSSION

The nutritional composition of maize landraces

The nutritional parameters of studied maize landraces are shown in Table 1. The ash contents of maize landraces were significantly different ($p<0.05$) among the tested landraces and ranged from 0.73 to 1.90% (Table 1). The highest ash content was obtained for SEU 17 (1.9%) followed by Bhadra (1.68%) whereas the lowest was denoted by SEU 40 (0.73%). The chemical analysis results of Ullah *et al*. (2010) found that the ash content ranges from 0.7 to 1.3% in maize grains of different varieties, whereas Aisha and El-Tinay (2004) examined the ash levels which were found to vary from 1.0% to 2.0%, which was similar to the findings of the present study. Further, the ash content ranged from 1.07 to 2.58% with the application of NIR Spectroscopy (Yang *et al.*, 2011). Also, the ash content of the maize varieties ranged from 1.23 to 3.13% in the Philippines (Marynold *et al.*, 2018). According to a study in Sri Lanka, the ash content of the maize variety was 2.06% (Gowri and Bhaminy, 2019).

The fiber content of maize landraces was found to be varying from 1.05 to 8.03% as shown in Table 1. There were significant differences (p<0.05) between the fibre content of tested maize landraces. This finding was supported by the finding of Marynold et al. (2018) conducted in the Philippines. The Variety SEU 32 (8.03%) had the highest value followed by SEU 38 (7.06%) in fiber content whereas the SEU 17 (1.05%) had the lowest in fiber content followed by Bhadra (1.88%) and Pacific (1.69%). Similarly, Ullah *et al.* (2010) found that the fibre content of maize varieties studied in Pakistan falls between 0.80 to 2.91% and similarly Ijabadeniyi and Adebolu (2005) reported that the fibre content of maize varieties grown in Nigeria was observed ranging from 2.07 to 2.77%. These findings were found to be slightly different from the current findings. The variations observed between the varieties might be attributed to genetic characteristics (Adeniyi and Ariwoola, 2019).

There were significant differences observed among the fat content of tested maize landraces (p<0.05). The highest fat content as shown in Table 1 was obtained for SEU 3 (4.82%) maize landrace followed by SEU 33 (4.75%) whereas the lowest was obtained for SEU 32 (2.44%). The fat content of the control variety (Bhadra) was obtained as 3.58%. According to the research conducted in Turkey, the fat content of the maize variety was 5.95% (Zeki *et al.*, 2022). The fat content of maize cultivars in Pakistan varieties varied from 3.21 to 7.71%, according to the research conducted by Ullah *et al.* (2010). According to a study in Sri Lanka, the fat content of the maize kernel was 6.47% (Gowri and Bhaminy, 2019). However, the fat content ranged from 2.04 to 4.47% as per the study by Langyan *et al.* (2021). The fat content of three maize varieties produced in Nigeria was reported to range from 4.77 to 5.0% by Ijabadeniyi and Adebolu (2005), which was consistent with the findings of the present study. Further, Yang *et al.* (2011) found that the fat contents were found to be ranging from 2.77 to 5.00% and were in accordance with the values of the current study.

The carbohydrate contents were significantly different among the tested landraces (p<0.05) and those ranging from 74.91 to 85.22% (Table 1). SEU 18 (85.22%) had the highest carbohydrate content while SEU 1 had the lowest (74.91%) content. The previous studies found carbohydrate content was in the range of 69.66 to 74.55% (Ullah *et al.*, 2010), and Ijabadeniyi and Adebolu (2005) found that carbohydrate content in maize cultivars in Nigeria was in the range of 65.63-70.23%. According to a study in Sri Lanka, the carbohydrate content of the maize kernel was 68.58% (Gowri and Bhaminy, 2019).

Table 1: Nutritional composition of kernels of collected maize landraces

Maize Landraces	Moisture (%)	Ash (%)	Fiber (%)	Fat (%)	Crude Protein (%)	Carbohydrates (%)	Energy (kcal/kg)
SEU 1	10.27 ± 0.32^{ab}	$1.17 \pm 0.23^{b-i}$	$2.85 \pm 0.23^{n-p}$	$3.6 \pm 0.26^{c-i}$	$10.04 \pm 0.12^{a-c}$	74.91 ± 0.7^{r}	3817.89 ± 9.49^{q}
SEU 2	$6.15 \pm 0.36^{m-r}$	$1.12 \pm 0.05^{c-i}$	$4.65 \pm 0.39^{e-g}$	$3.64 \pm 0.08^{b-i}$	$10.1 \pm 0.06^{a-c}$	$78.99 \pm 0.44^{j-o}$	3991.52 ± 8.38^{ab}
SEU 3	$8.56 \pm 0.19^{b-j}$	$0.86 \pm 0.07^{f-i}$	4.83 ± 0.10^{ef}	4.82 ± 0.12^{a}	$8.88 \pm 0.27^{c-i}$	$76.88 \pm 0.10^{p-r}$	$3964.25 \pm 4.42^{a-e}$
SEU 4	$7.97 \pm 0.29^{c-l}$	$1.35 \pm 0.12^{a-g}$	6.65 ± 0.11^{bc}	$2.63 \pm 0.12^{k-m}$	4.41 ± 0.25^{r}	$83.65 \pm 0.28^{a-c}$	$3855.09 \pm 10.21^{m-q}$
SEU 5	$8.1 \pm 0.08^{c-l}$	$1.22 \pm 0.05^{b-i}$	$3.05 \pm 0.06^{l-p}$	$2.89 \pm 0.07^{h-m}$	$7.5 \pm 0.2^{j-p}$	$80.29 \pm 0.41^{g-l}$	$3868.02 \pm 1.69^{j-q}$
SEU 6	$6.98 \pm 0.09^{i-p}$	$1.4 \pm 0.02^{a-e}$	$3.65 \pm 0.09^{h-n}$	$2.85 \pm 0.03^{h-m}$	$6.6 \pm 0.23^{m-q}$	$82.17 \pm 0.2^{c-g}$	$3904.93 \pm 4.17^{d-o}$
SEU 7	$8.56 \pm 0.49^{b-j}$	$0.96 \pm 0.07^{d-i}$	$4.23 \pm 0.17^{f-j}$	4.52 ± 0.04^{ab}	$8.94 \pm 0.4^{c-h}$	$77.02 \pm 0.06^{o-q}$	$3945.03 \pm 19.41^{a-h}$
SEU 8	$6.85 \pm 0.08^{j-q}$	$1.02 \pm 0.02^{d-i}$	$3.3 \pm 0.04^{k-0}$	$3.36 \pm 0.12^{d-l}$	$7.75 \pm 0.15^{h-n}$	$81.02 \pm 0.2^{g-i}$	$3952.19 \pm 8.42^{a-g}$
SEU 9	$8.44 \pm 0.31^{c-k}$	$0.87 \pm 0.08^{f-i}$	$3.56 \pm 0.14^{i-o}$	$3.73 \pm 0.35^{b-h}$	$7.76 \pm 0.18^{h-n}$	$79.20 \pm 0.23^{i-n}$	$3912.11 \pm 34.12^{c-n}$
SEU 10	$8.77 \pm 0.38^{a-h}$	$1.03 \pm 0.1^{d-i}$	$3.16 \pm 0.08^{k-o}$	$3.46 \pm 0.08^{c-k}$	$7.24 \pm 0.30^{l-p}$	$79.5 \pm 0.85^{h-n}$	$3877.81 \pm 15.86^{h-q}$
SEU 11	$6.93 \pm 0.04^{j-p}$	0.78 ± 0.06^{hi}	$3.57 \pm 0.12^{i-n}$	$3.53 \pm 0.15^{c-k}$	$6.63 \pm 0.13^{m-q}$	$82.12 \pm 0.18^{c-g}$	$3967.49 \pm 11.77^{a-d}$
SEU 12	$7.72 \pm 0.10^{f-n}$	$1.28 \pm 0.04^{b-h}$	$4.05 \pm 0.05^{f-k}$	$3.21 \pm 0.08^{f-m}$	$6.45 \pm 0.12^{o-q}$	$81.33 \pm 0.03^{b-h}$	$3897.82 \pm 1.34^{e-p}$
SEU 13	10.27 ± 0.18^{ab}	$1.03 \pm 0.04^{d-i}$	$4.53 \pm 0.22^{e-h}$	$4.26 \pm 0.15^{a-d}$	$7.4 \pm 0.21^{k-p}$	$77.03 \pm 0.08^{o-q}$	$3857.95 \pm 2.54^{l-q}$
SEU 14	$7.79 \pm 0.14^{e-n}$	$0.90 \pm 0.03^{e-i}$	$3.0 \pm 0.29^{m-p}$	$3.66 \pm 0.27^{b-i}$	$8.59 \pm 0.33^{e-k}$	$79.06 \pm 0.76^{i-n}$	$3934.03 \pm 6.83^{b-j}$
SEU 15	$9.33 \pm 0.18^{a-g}$	$0.99 \pm 0.09^{d-i}$	4.80 ± 0.20^{ef}	$3.96 \pm 0.04^{a-g}$	$9.88 \pm 0.08^{a-d}$	75.84 ± 0.21^{qr}	$3882.80 \pm 2.14^{h-q}$
SEU 16	$8.18 \pm 0.15^{c-l}$	$0.83 \pm 0.11^{g-i}$	$3.96 \pm 0.17^{f-l}$	$3.70 \pm 0.14^{b-h}$	$8.32 \pm 0.12^{f-l}$	$78.97 \pm 0.30^{j-0}$	$3922.72 \pm 6.01^{c-m}$
SEU 17	3.79 ± 0.61^{s}	1.9 ± 0.1^{a}	1.05 ± 0.05^{s}	$3.14 \pm 0.13^{f-m}$	$8.62 \pm 0.13^{d-k}$	$82.63 \pm 0.32^{c-e}$	$3933.08 \pm 11.23^{b-j}$

SEU 18	5.84±0.15^{p-r}	1.08±0.05^{c-i}	5.20±0.13^{de}	3.10±0.08^{g-m}	4.76±0.11^{r}	85.22±0.14^{a}	3977.52±11.05^{a-c}
SEU 19	8.67±0.20^{b-i}	1.02±0.1^{d-i}	3.45±0.11^{i-o}	3.10±0.05^{g-m}	8.87±0.23^{c-i}	78.34±0.2^{l-p}	3863.95±10.03^{k-q}
SEU 22	5.12±0.13^{rs}	1.66±0.13^{ab}	5.2±0.35^{de}	2.67±.12^{k-m}	9.15±0.10^{b-g}	81.4±0.48^{d-h}	3960.55±4.12^{a-f}
SEU 23	9.41±0.14^{a-f}	1.23±0.12^{b-i}	3.0±0.08^{m-p}	3.59±0.26^{c-i}	8.11±0.09^{g-l}	77.65±0.16^{n-q}	3850.30±14.16^{n-q}
SEU 24	8.68±0.15^{b-i}	0.9±0.09^{e-i}	5.29±0.09^{de}	4.35±0.25^{a-c}	7.65±0.35^{i-o}	78.42±0.14^{k-p}	3933.56±3.31^{b-j}
SEU 25	6.59±0.14^{l-r}	1.44±0.06^{a-d}	5.35±0.17^{de}	2.5±0.22^{im}	4.81±0.2^{r}	84.65±0.39^{ab}	3900.67±13.88^{d-p}
SEU 26	8.36±0.1^{c-k}	1.12±0.08^{c-i}	3.33±0.13^{j-o}	3.38±0.23^{d-l}	6.63±0.15^{m-q}	80.51±0.38^{f-j}	3886.77±11.02^{g-p}
SEU 27	7.52±0.18^{h-p}	1.00±0.08^{d-i}	4.28±0.23^{f-i}	3.44±0.21^{c-k}	7.83±0.1^{h-m}	80.22±0.22^{g-l}	3929.66±6.73^{b-k}
SEU 28	7.86±0.16^{d-m}	0.97±0.16^{d-i}	4.75±0.12^{e-g}	4.22±0.17^{a-e}	10.30±0.09^{ab}	76.64±0.23^{p-r}	3956.96±21.91^{a-f}
SEU 29	8.76±0.12^{a-h}	0.75±0.06^{i}	4.75±0.12^{e-g}	4.24±0.11^{a-d}	7.22±0.09^{l-p}	79.03±0.36^{j-n}	3930.71±2.98^{b-k}
SEU 30	6.13±0.12^{n-r}	0.76±0.05^{i}	4.05±0.17^{f-k}	3.71±0.03^{b-h}	6.54±0.17^{n-q}	82.86±0.08^{b-e}	4010.57±1.48^{a}
SEU 31	5.90±0.13^{p-r}	1.40±0.25^{a-e}	5.84±0.11^{cd}	3.41±0.22^{d-l}	6.52±0.28^{n-q}	82.77±0.37^{b-e}	3978.02±16.37^{a-c}
SEU 32	6.56±0.21^{l-r}	1.58±0.06^{a-e}	8.03±0.12^{a}	2.44±0.21^{m}	6.31±0.19^{pq}	83.10±0.67^{b-d}	3893.18±1.12^{f-p}
SEU 33	9.46±0.28^{a-e}	0.96±0.09^{d-i}	3.66±0.12^{h-n}	4.75±0.13^{a}	7.81±0.15^{h-m}	77.02±0.36^{o-q}	3919.74±8.40^{c-m}
SEU 34	8.47±0.1^{c-j}	1.01±0.09^{d-i}	2.65±0.12^{o-q}	3.37±0.21^{d-l}	9.41±0.24^{a-f}	77.75±0.06^{m-q}	3886.52±11.33^{g-p}
SEU 35	8.68±0.1^{b-i}	.99±0.09^{d-i}	4.23±0.17^{f-j}	3.64±0.12^{b-i}	9.7±0.17^{a-e}	76.99±0.11^{pq}	3892.36±14.15^{f-p}
SEU 36	10.46±0.21^{a}	1.11±0.08^{c-i}	2.22±0.1^{p-r}	4.05±0.17^{a-f}	7.55±0.26^{j-p}	76.83±0.39^{p-r}	3836.40±20.51^{pq}
SEU 37	9.3±0.29^{a-g}	0.98±0.08^{d-i}	3.62±0.27^{h-n}	3.97±0.09^{a-g}	9.54±0.1^{a-f}	76.21±0.55^{qr}	3884.96±10.55^{g-q}
SEU 38	7.68±0.01^{g-o}	1.34±0.13^{a-g}	7.06±0.11^{b}	2.75±0.12^{i-m}	4.94±0.11^{r}	83.28±0.10^{a-d}	3873.35±10.92^{b-j}
SEU 39	6.92±0.04^{j-p}	1.22±0.12^{b-i}	4.85±0.10^{ef}	3.32±0.07^{e-m}	5.57±0.15^{qr}	82.97±0.14^{b-e}	3938.90±6.44^{b-i}

SEU 40	7.80±0.12^{e-n}	0.73±0.07^{i}	4.51±0.05^{e-h}	4.34±0.05^{a-c}	7.45±0.24^{j-p}	79.68±0.32^{h-m}	3976.12±4.1^{a-c}
SEU 41	6.90±0.08^{j-p}	1.2±0.03^{b-i}	3.89±0.08^{g-m}	3.65±0.30^{b-i}	9.78±0.14^{a-e}	78.47±0.26^{k-p}	3957.74±12.16^{a-f}
SEU 42	9.62±0.23^{a-c}	0.95±0.06^{d-i}	4.04±0.12^{f-k}	3.85±0.15^{b-h}	8.70±0.03^{d-j}	77.0±0.30^{pq}	3860.59±1.18^{l-q}
SEU 43	9.53±0.29^{a-d}	0.95±0.06^{d-i}	3.49±0.2^{i-o}	3.22±0.15^{f-m}	7.76±0.18^{h-n}	78.54±0.32^{j-p}	3837.93±7.27^{o-q}
SEU 44	6.74±0.12^{k-r}	1.38±0.02^{a-f}	3.96±0.07^{f-l}	3.01±0.10^{h-m}	6.44±0.25^{o-q}	82.43±0.24^{c-f}	3923.77±9.60^{b-l}
Pacific	5.17±0.99^{q-s}	1.4±0.1^{a-e}	1.69±0.11^{rs}	3.4±0.10^{d-l}	10.0±0.43^{a-c}	79.91±0.26^{h-l}	3902.18±21.63^{b-j}
Bhadra	5.98±0.47^{o-r}	1.68±0.03^{ab}	1.88±0.10^{q-s}	3.58±0.07^{c-j}	10.64±0.32^{a}	80.34±0.18^{g-k}	3951.96±13.03^{a-g}
F (2, 43)	25.858	9.234	75.087	12.951	56.592	57.099	15.299
P-value	0.0001	0.0006	0.0002	0.0004	0.0006	0.0004	0.0001

The data represent the mean (±SE). The same letters denoted in the superscripts are not statistically different within a column at p= 0.05. (n = 3).

The crude protein content of tested maize landraces was significantly different ($P<0.05$) and it varied from 4.41 to 10.64% as shown in Table 1. The commercial variety Bhadra had the highest protein content (10.64%) followed by SEU 28 (10.3%) whereas SEU 4 (4.41%) had the lowest content (4.41%). Ijabadeniyi and Adebolu (2005), Ullah *et al.* (2010) and Langyan *et al.* (2021) found that the protein content of maize grains ranged from 8.83 to 15.54%, 7.71 to 14.60% and 10.67 to 11.27%, respectively. The findings of the above studies confirmed the current investigation. Similarly, Yang *et al.* (2011) found that protein content falls within the range of 7.6 to 9.4%. When compared to several popular legumes and oilseeds, maize has a low protein level, ranging from 9 to 12% depending on the variety and it is rich in methionine and cysteine amino acids but lacks in some amino acids like lysine and tryptophan (Akoja *et al.*, 2016). According to the study in Sri Lanka, the protein content of the maize kernel was 10.85% (Gowri and Bhaminy, 2019).

The energy values of maize varieties were significantly different ($p<0.05$) among the tested landraces and those varied from 3817.89 kcal/kg (SEU 1) to 4010.57 kcal/kg (SEU 30) (Table 1). The energy value of the variety Bhadra exerted to 3951.96 kcal/kg. The energy values of maize varieties grown in Pakistan varied from 3070.05 kcal/kg to 3940.66 kcal/kg (Ullah *et al.*, 2010). The studies of Kouakou *et al.* (2008) showed that the energy level of maize grains as of 3877.0 kcal/kg. These values were on par with the findings of the present investigation. In contrast, the study conducted by Ejigue *et al.* (2005) obtained an energy value of 4470 kcal/kg for yellow maize, which was higher than the values in the present study. The variations in energy levels were attributable to the intrinsic variances in the proximate composition.

Significant differences were observed among the moisture contents of all maize landraces ($p<0.05$). The highest moisture content was obtained for SEU 36 (10.46%) whereas the lowest was obtained for SEU 17 (3.79%). The moisture content of the control variety (Bhadra) was found to be 5.98%. Budiastraa *et al.* (2011) reported that the moisture contents varied from 3.95% to 12.65% with the application of NIR Spectroscopy. According to a study in Sri Lanka, the moisture content of the maize kernel was 12.05% (Gowri and Bhaminy, 2019). These findings were also in conformity with the results of the current investigation.

Rank summation index of nutritional composition

The results of RSI indicated wider variations in nutritional composition among the tested landraces (Table 2). Data indicated that landraces SEU 22, SEU 31 and SEU 2 had displayed the lowest RSI values of 85, 88 and 89, respectively which were superior to the elite commercial maize varieties, Bhadra (102) and Pacific (109). As per the analysis, the RSI value of the best cultivar would be the lowest. Breeders want to have a simple and accurate index to make rapid selections. The efficiency of the available indices must be evaluated to choose the best and most uncomplicated index that will produce high expected benefits (Oloyede-Kamiyo, 2019). It is vital to identify the selection criteria that promote changes in the desired direction as well as the breeding program's objects of interest (Reis *et al.*, 2004). As such, those maize landraces can be selected for future breeding programmes to produce nutritionally rich food products to decrease food insecurity.

In most crop breeding programmes, plant breeders must evaluate several factors while choosing improved genotypes. When a single attribute has to be enhanced, interrelated characters enhance selection efficiency. Selection for complicated qualities is particularly challenging, such as finding a genotype with appropriate scores for numerous attributes; as a result, approaches to make selection easier are required. The concurrent selection of characteristics, on the other hand, is an approach that allows for the combining of the advantages of numerous agronomically important qualities (Vilarinho *et al.*, 2003). Therefore, the selection index approach will aid in the objective selection among the subunits. Because selecting a single characteristic or several qualities is less effective than developing an index of combined traits (Cargnin *et al.*, 2007; Mohammadi *et al.*, 2013; Ghaed-Rohimi *et al.*, 2017).

De Paiva *et al.* (2002) confirmed the effectiveness of Mulamba and Mock's (1978) rank summation index approach in the selection of Barbados cherry progenies in comparison to the conventional method of selection among progenies and within progeny. The Mulamba and Mock indices provided the most precise estimates of genetic gain in superior alfalfa genotypes for productive, morphological, and chemical features, according to Vasconcelos *et al.* (2010). Cruz *et al.* (1993) and Costa *et al.* (2004) showed successful results employing the Mulamba and Mock indices in an experiment using corn and soybean.

The hierarchical cluster analysis was performed by incorporating the data of the nutritional parameters such as ash, fibre, protein, fat, carbohydrate, energy, and moisture content (Figure 3). Dendrogram indicated that two main groups of landraces result from nutritional traits. The landraces with lower RSI values (SEU 22, SEU 31 and SEU 2) cluster under group 01. Similarly, the elite commercial varieties (Bhadra and Pacific) were clustered in the same group with minimal distance. Most of the remainder of the landraces showed a far distance deviated from the selected germplasm. Both RSI and hierarchical cluster analysis tend to identify the same elite landraces having superior characteristics, suggesting that both analysis tools aid in the objective selection of germplasm.

Table 2: Rank summation index (RSI) of kernel nutritional parameters composition of tested maize landraces

Maize Landraces	Moisture (%)	R1	Ash (%)	R2	Fiber (%)	R3	Fat (%)	R4	Protein (%)	R5	CHO (%)	R6	Energy (kcal/kg)	R7	Rank Summation Index
SEU 1	10.27	42	1.17	17	2.85	39	3.60	20	10.04	4	74.91	44	3817.89	44	210
SEU 2	6.15	8	1.12	18	4.65	14	3.64	18	10.10	3	78.99	26	3991.52	2	89
SEU 3	8.56	29	0.86	39	4.83	10	4.82	1	8.88	13	76.88	39	3964.25	7	138
SEU 4	7.97	23	1.35	10	6.65	3	2.63	42	4.41	44	83.65	3	3855.09	40	165
SEU 5	8.10	24	1.22	14	3.05	36	2.89	38	7.50	27	80.29	18	3868.02	36	193
SEU 6	6.98	16	1.40	6	3.65	27	2.85	39	6.60	34	82.17	11	3904.93	24	157
SEU 7	8.56	29	0.96	32	4.23	18	4.52	3	8.94	12	77.02	35	3945.03	13	142
SEU 8	6.85	12	1.02	25	3.30	34	3.36	30	7.75	24	81.02	15	3952.19	11	151
SEU 9	8.44	27	0.87	38	3.56	30	3.73	13	7.76	22	79.20	23	3912.11	23	176
SEU 10	8.77	35	1.03	22	3.16	35	3.46	24	7.24	30	79.50	22	3877.81	34	202
SEU 11	6.93	15	0.78	41	3.57	29	3.53	23	6.63	32	82.12	12	3967.49	6	158
SEU 12	7.72	19	1.28	12	4.05	20	3.21	33	6.45	37	81.33	14	3897.82	27	162
SEU 13	10.27	42	1.03	22	4.53	15	4.26	6	7.40	29	77.03	34	3857.95	39	187
SEU 14	7.79	20	0.90	36	3.00	37	3.66	16	8.59	17	79.06	24	3934.03	15	165
SEU 15	9.33	37	0.99	28	4.80	11	3.96	11	9.88	6	75.84	43	3882.80	33	169
SEU 16	8.18	25	0.83	40	3.96	24	3.70	15	8.32	18	78.97	27	3922.72	21	170
SEU 17	3.79	1	1.90	1	1.05	44	3.14	34	8.62	16	82.63	9	3933.08	17	122
SEU 18	5.84	4	1.08	21	5.20	7	3.10	36	4.76	43	85.22	1	3977.52	4	116
SEU 19	8.67	31	1.02	24	3.45	32	3.10	35	8.87	14	78.34	31	3863.95	37	204
SEU 22	5.12	2	1.66	3	5.20	7	2.67	41	9.15	11	81.40	13	3960.55	8	85
SEU 23	9.41	38	1.23	13	3.00	37	3.59	21	8.11	19	77.65	33	3850.30	41	202
SEU 24	8.68	32	0.90	36	5.29	6	4.35	4	7.65	25	78.42	30	3933.56	16	149
SEU 25	6.59	10	1.44	5	5.35	5	2.50	43	4.81	42	84.65	2	3900.67	26	133

SEU 26	8.36	26	1.12	18	3.33	33	3.38	28	6.63	32	80.51	16	3886.77	30	183
SEU 27	7.52	17	1.00	27	4.28	17	3.44	25	7.83	20	80.22	19	3929.66	19	144
SEU 28	7.86	22	0.97	31	4.75	12	4.22	8	10.30	2	76.64	41	3956.96	10	126
SEU 29	8.76	34	0.75	43	4.75	12	4.24	7	7.22	31	79.03	25	3930.71	18	170
SEU 30	6.13	7	0.76	42	4.05	20	3.71	14	6.54	35	82.86	7	4010.57	1	126
SEU 31	5.90	5	1.40	6	5.84	4	3.41	26	6.52	36	82.77	8	3978.02	3	88
SEU 32	6.56	9	1.58	4	8.03	1	2.44	44	6.31	39	83.10	5	3893.18	28	130
SEU 33	9.46	39	0.96	32	3.66	26	4.75	2	7.81	21	77.02	35	3919.74	22	177
SEU 34	8.47	28	1.01	26	2.65	40	3.37	29	9.41	10	77.75	32	3886.52	31	196
SEU 35	8.68	32	0.99	29	4.23	18	3.64	18	9.70	8	76.99	38	3892.36	29	172
SEU 36	10.46	44	1.11	20	2.22	41	4.05	9	7.55	26	76.83	40	3836.40	43	223
SEU 37	9.30	36	0.98	30	3.62	28	3.97	10	9.54	9	76.21	42	3884.96	32	187
SEU 38	7.68	18	1.34	11	7.06	2	2.75	40	4.94	41	83.28	4	3873.35	35	151
SEU 39	6.92	14	1.22	14	4.85	9	3.32	31	5.57	40	82.97	6	3938.90	14	128
SEU 40	7.80	21	0.73	44	4.51	16	4.34	5	7.45	28	79.68	21	3976.12	5	140
SEU 41	6.90	13	1.20	16	3.89	25	3.65	17	9.78	7	78.47	29	3957.74	9	116
SEU 42	9.62	41	0.95	34	4.04	22	3.85	12	8.70	15	77.00	37	3860.59	38	199
SEU 43	9.53	40	0.95	34	3.49	31	3.22	32	7.76	23	78.54	28	3837.93	42	230
SEU 44	6.74	11	1.38	9	3.96	23	3.01	37	6.44	38	82.43	10	3923.77	20	148
Bhadra	5.98	6	1.68	2	1.88	42	3.58	22	10.64	1	80.34	17	3951.96	12	102
Pacific	5.17	3	1.40	6	1.69	43	3.40	27	10.00	5	79.91	20	3902.18	25	129

CHO - Carbohydrates
R1, R2, R3, R4, R5, R6 and R7 indicate the corresponding ranks for individual nutritional traits

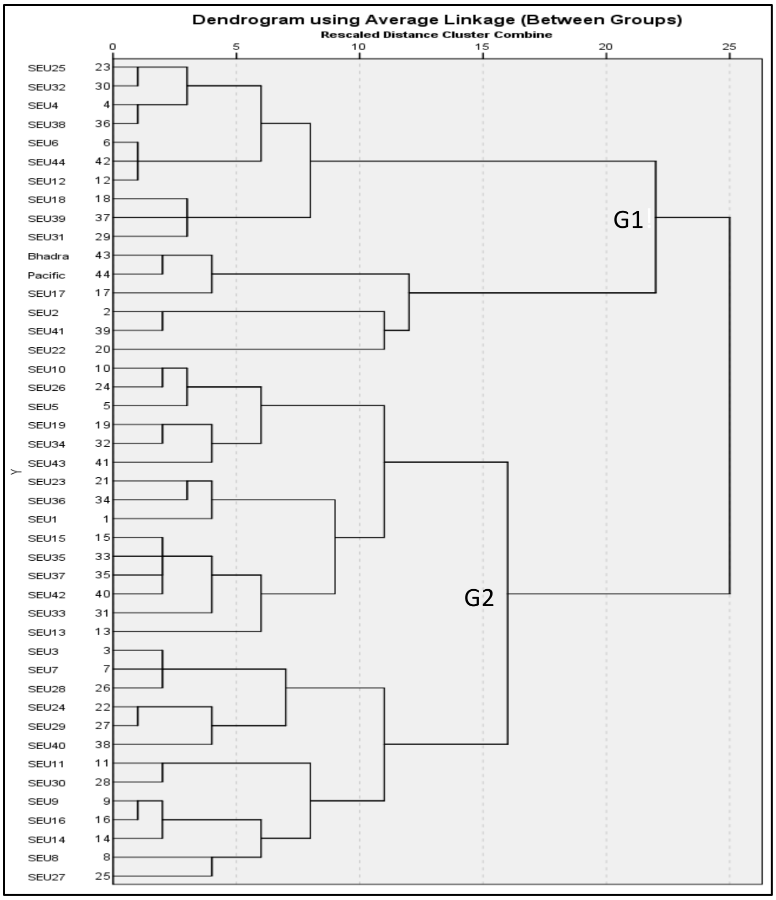

Figure 3: Hierarchical cluster analysis of maize landraces for all nutritional parameters

CONCLUSIONS

Maize stands out as the world's most productive grain crop, playing a crucial role in addressing food insecurity challenges in developing countries grappling with rapidly growing populations. The findings revealed that certain maize landraces, including SEU 22, SEU 31, and SEU 2, exhibited superior nutritional compositions when compared to Bhadra and Pacific varieties. Consequently, these specific maize landraces are recommended for future breeding programs aimed at developing maize varieties with enhanced nutritional content. Apart from the nutritional composition, we can use the criteria to select the best maize landraces such as high yield potential, disease resistance, drought-tolerant, early-maturing and pest-resistant.

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