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Grain morphological characterization and protein content of sixty-eight local rice (*Oryza sativa* L) cultivars from Cameroon

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Rice (*Oryza sativa* L.) cultivated in Cameroon is appreciated by consumers for its nutritive quality and good taste. Diversity of 68 local rice cultivars was investigated via grain morphology and protein content characterization. The size and shape of grains were determined and used with yield parameters to classify the cultivars and perform Principal Component Analysis (PCA). Total protein content and glutelin content of eight selected cultivars (CMRGNd, CMRGDn, CMRGTï, CMRTBa, CMRDWb, CMRDTc3, CMRDTx5 and CMRDTx6) were evaluated by Bradford assay and correlation analysis of all the parameters studied was performed. Long size grains (42) were predominant over extra-long (16), medium (9) and short (1) grains. Slender shaped grains (36) were distinguished as well as medium (28) and bold (4) grains. The 68 cultivars were grouped into four clusters independent of their origins. PCA revealed three principal components accounting for 74.4% of total variation. Highest total protein content was observed in CMRGNd (14.3%) and highest glutelin content in CMRGDn (10.1 mgEqvBSA/g DW). Pearson correlation of the different variables revealed no significant correlation between total protein and glutelin contents with the agro-morphological parameters evaluated in this study. This suggests that none of these parameters could be descriptor for protein content. Positive correlation between grain length and yield (r = 0.7) suggests grain length as yield descriptor.

Key words: Rice, diversity, grain morphology, protein, glutelin.

INTRODUCTION

Rice (*Oryza sativa* L.) is the second most consumed cereal in Cameroon after maize and is presently a staple food for both rural and urban populations. However, the national production estimated at about 360000 tons in 2017 (FAO, 2019), remains far below consumption that is estimated at about 635,000 tons (USDA, 2017). The deficit between demand and production results from several factors among which a non-effective distribution of high impact technologies and the low competitiveness of local rice. Domestic rice though, is dominated by imported rice and fails to compete both quantity and quality-wise with imported rice.

However, rice produced in Cameroon is appreciated by many; 90% of the national produce is exported to Nigeria in paddy form. While trying to identify the physico-chemical characteristics that determine the consumption preferences of local and imported rice in the North-west region, Fon and Fonchi (2016) obtained 83.9% of respondents confirming that locally produced rice tastes better than imported rice. Consumer demand for fine rice varieties is high due to good nutritional quality, palatability, aroma and taste. But quality can as well be considered from the view point of size, shape and appearance of grain (Cruz and Khush, 2000). IRRI classifies brown rice grain length into extra-long (>7.50 mm); long (6.61-7.50 mm); medium (5.51-6.60 mm); and short (≤5.50 mm). IRRI's Standard Evaluation System (SES) equally classifies shape as slender (length–width ratio >3.0), medium (ratio 2.1–3.0), bold (ratio 1.1–2.0) and round (ratio <1.1) (IRRI, 1996).

Scientific studies are indispensable to effectively demonstrate the quality of the local rice. In this light, Odenigbo et al. (2014) studied the gelatinization properties and amylose content of some local rice varieties and provided information on the physical, gelatinization, cooking and textural properties of TOX 3145, an improved rice variety cultivated in Cameroon. These studies focused on the cooking and eating quality and did not report the nutritional quality of the local rice. Protein content and composition are crucial to rice grain quality and nutritional value (Lin et al., 2005) but the genetic base of rice seed proteins in Cameroon's locally cultivated rice is relatively narrow.

The rice grain is composed of 12% water, 75–80% starch and 7% protein with a full complement of amino acids (Verma and Srivastav, 2017). Its high protein digestibility and excellent biological value make it an important part of consumers' daily nutrient intake. Yang et al. (2011) reported the digestibility of rice protein as being a major factor that influences cholesterol metabolism through the inhibition of cholesterol absorption. Rice protein hydrolysates are equally known to possess antioxidative and blood pressure regulating properties (Zhao et al., 2012; Phongthai et al., 2017). These physiological functions make rice suitable to prevent life style-related diseases such as malnutrition, obesity and high blood pressure which are adult risk factors. Besides, the enhancement of rice seed storage proteins to improve rice nutritive value has lately and gradually become an important target for rice quality breeding (Jiang et al., 2014). Data on characterization of grain and proteins of local Cameroon rice cultivars, which will be very useful in upscaling the potential of its production, is scanty. This study therefore explored Cameroon's locally cultivated rice to determine the quality of the cultivars cropped and provide additional rice diversity information.

MATERIALS AND METHODS

Establishment of an inventory of local rice cultivars

Sixty-eight cultivars from three agro-ecological zones of the country were used in this study (Table 1): sudano-sahelian zone (Garoua), humid forest with bimodal rainfall zone (Yaoundé) and western highlands zone (Dschang and Tonga). The cultivars collected in Yaoundé had recently been introduced from Benin while those from Garoua, Dschang and Tonga had been cultivated for long by local farmers over several campaigns.

Grain morphological characterization of cultivars

The morphology of grains was studied by measuring their dimensions (length and width) and determining the length/width ratio, which were used to characterise them following IRRI's standard evaluation system for rice (2013). They classify brown rice grain as extra-long (more than 7.5 mm), long (6.6 to 7.5 mm), medium (5.51 to 6.6 mm) and short (5.5mm or less) for size; and slender (over 3.0), medium (2.1 to 3.0), bold (1.1 to 2.0) and round (less than 1.1) for shape (length/width ratio) (IRRI, 1996).

Measurement of grain dimensions

Paddy samples were dehulled with a Satake rice dehuller machine (Satake, USA) and cleaned to eliminate dirt and husks. Length and width of three representative paddy and kernel grains from each sample were determined using a Vernier calliper. The grain shapes were then determined using the following equation:

Length to width ratio = Average grain length (mm)/Average grain width (mm).

Protein content evaluation

Samples were ground with a blender and sieved through a 5 mm mesh sieve to obtain fine powder. The powder was then stored at room temperature (25°C) in airtight bottles untill analysis.

Total protein extraction

Total proteins were extracted by mixing 0.1 g of rice powder with 1 mL of Tris urea buffer (0.05 M Tris-HCL, 5 M Urea, 2 % SDS, 1 % β-mercaptoethanol, and pH 8.0) and centrifuging at 10,000 rpm for 15 min (Tanaka et al., 2016). The supernatant was collected and the pellet rinsed with another 1 mL of Tris urea buffer. The new supernatant was collected into the previous and the proteins were quantified by Bradford assay (Bradford, 1976).

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Table 1. Rice cultivars used in this study.

Code	Variety name	Origin (locality)	Cycle (days)	N° tillers	Yield (Kg/h)	1000 GWt at 14% moisture
CMRYOr1	B1 ORYLUX 1	Yaoundé	119	12.4	7689.2504	24.0262
CMRYOr3	B2 ORYLUX 3	Yaoundé	119	15	7471.7740	22.3744
CMRYOr4	B3 ORYLUX 4	Yaoundé	119	12.6	10327.8066	23.1682
CMRYOr5	B4 ORYLUX 5	Yaoundé	131	14.2	7580.3924	22.7685
CMRYOr6	B5 ORYLUX 6	Yaoundé	105	24.8	4664.6814	22.8311
CMRYAr1	B6 ARICA 1	Yaoundé	133	20.4	6465.9251	23.7566
CMRYAr2	B7 ARICA 2	Yaoundé	111	7	8819.1999	23.2846
CMRYAr3	B8 ARICA 3	Yaoundé	111	11.6	9065.1237	23.9182
CMRYAr4	B9 ARICA 4	Yaoundé	105	6.4	2884.3836	20.3011
CMRYAr7	B12 ARICA 7	Yaoundé	112	5.6	3441.2896	22.5624
CMRYAr8	B13 ARICA 8	Yaoundé	133	13.2	6669.0641	22.2713
CMRYAr9	B 14 ARICA 9	Yaoundé	119	8.4	6628.4652	22.8311
CMRYAr10	B15 ARICA 10	Yaoundé	111	15.8	4886.5829	20.1414
CMRYAr11	B16 ARICA 11	Yaoundé	111	12	4977.8014	22.98023
CMRYAc1	B17 ARC-39-155-L-2	Yaoundé	119	11.6	5857.4306	24.6205
CMRYAc2	B18 ARC-37-16-1-5-G	Yaoundé	119	19	7798.2232	23.3664
CMRYAc3	B19 ARC-36-2-P-2	Yaoundé	119	11	6583.9304	23.7080
CMRYAc4	B20 ARC-39-135-VL-5	Yaoundé	112	13.6	6495.7222	23.6442
CMRYAc5	B21 ARC-39-130-EP-4	Yaoundé	112	13.4	3063.6420	22.0008
CMRYAc6	B22 ARC-39-145-EP-3	Yaoundé	112	8.2	6588.3679	22.1286
CMRYFl	B24 FL478-1-53	Yaoundé	112	6.4	5275.0568	23.5972
CMRYGc	B25 GOLD COAST FINGO	Yaoundé	119	9.8	6364.5332	21.7439
CMRYIr1	B26 IR4630-22-2	Yaoundé	133	24.4	5741.6468	22.3521
CMRYNl23	B28 NERICA-L-23	Yaoundé	111	11.6	6944.9369	22.6136
CMRYNl24	B29 NERICA-L-24	Yaoundé	111	10.4	6391.1240	22.3101
CMRYNl27	B30 NERICA-L-27	Yaoundé	112	10.8	4976.9713	23.1682
CMRYNl9	B31 NERICA-L-9	Yaoundé	119	12.8	7184.6219	23.0962
CMRYIr2	B32 IR64-SUBI	Yaoundé	112	5.8	3630.5247	22.1446
CMRDTx1	D13 TOX 3145-34-2-3	Dschang	119	8.6	7111.4402	25.9163
CMRDTx2	D14 TOX 3145-34-2-3-1	Dschang	119	20.6	12621.0426	24.6890
CMRDTx3	D15 TOX 3440-151-2-3	Dschang	113	13.2	6427.3875	23.3579
CMRDTx4	D16 TOX 3440-151-2-3	Dschang	107	9	7598.6249	26.0926
CMRDTx5	D17 TOX 3887-6-2-3	Dschang	107	9.2	4657.1479	25.6578
CMRDTx6	D18 TOX 40094-4-3	Dschang	115	16.8	15755.5428	24.7880
CMRDTc1	D20 TOC 2N 14-2	Dschang	114	14.4	4221.6066	26.1110
CMRDIr2	D26 IR 7167-33-2-3	Dschang	77	11	7978.0822	27.2030
CMRDIr3	D27 IR 155-79-135-3	Dschang	114	13.2	5847.0000	24.1402
CMRDWt	D28 WAT 311, WAS 7083-5-11	Dschang	114	10	5450.6507	24.2009
CMRDIt306	D30 ITA 306	Dschang	110	13.4	7513.4600	24.8605
CMRDFk60	D31 FKR 60	Dschang	114	10.6	6315.0885	23.3981
CMRDWb	D32 WAB	Dschang	114	15.8	13848.4079	22.9255
CMRDIb23	D35 IB 23	Dschang	114	8.8	6346.2671	22.5624
CMRDRv5	D36 RV 5	Dschang	112	9.2	5068.1764	24.3010
CMRTM16	T2 M 16	Tonga	115	13.2	8320.7283	23.3981
CMRTNl56	T3 NERICA-L-56	Tonga	115	13.8	7618.5760	25.5708
CMRTNl59	T4 NERICA-L-59	Tonga	115	10	8176.6444	24.2481
CMRTBa	T9 Bankou	Tonga	115	9.2	5393.0761	23.8159
CMRGIr46b	G14 IR 46	Garoua	114	10.4	7644.5798	23.5520
CMRGNe3	G3 NERICA 3	Garoua	110	3.2	1809.9551	23.2877
CMRGNl42	G19 NERICA-L-42	Garoua	114	13.8	7383.2482	20.7660

Table 1. Contd.

CMRGR48	G22 R48	Garoua	110	10.6	7432.5723	24.5873
CMRGTï	G25 TAÏTCHINGA	Garoua	127	15	11072.6567	22.8612
CMGNl60	G27 NERICA-L-60	Garoua	115	15.2	6509.0001	22.8928
CMRGRw	G28 RWISI	Garoua	115	21.8	5410.8288	24.1886
CMRGNe3	G18 NERICA 3	Garoua	110	6.8	3767.1202	23.70808
CMRGRw2	G32 RWISI (2)	Garoua	110	11.2	4010.5932	23.0137
CMRGDj	G33 DJOUNGA	Garoua	110	12	6513.3394	23.1225
CMRGNd	G35 NDOUNGOURI SAMORI	Garoua	115	12.6	11291.5231	23.6932
CMRGLa	G36 LASSIRI	Garoua	110	9.8	5700.4089	23.4834
CMRGDn	G38 DOUNGOURI SANTA	Garoua	107	10.6	4580.6372	24.2481
CMRGTx	G41 TOX	Garoua	93	17.8	8873.4296	24.3932
CMRG13	G13 Variété M	Garoua	114	14.6	10558.2449	21.1733

B, Benin; D, Dschang; G, Garoua; T, Tonga.

Glutelin extraction

Glutelins were extracted with 0.2 N acetic acid after elimination of albumins, globulins and prolamins with 35 mM KPi buffer (pH 7.6) (Nasri and Triki, 2007; Tanaka et al., 2016). One millilitre of inorganic potassium phosphate (KPi) buffer was added to 0.1 g of sample in the Eppendorf tube and mixed. The mixture was then placed on a rotating wheel at 34 rotations per minute (rpm) for 2 h 30 min for homogenization, and extraction was performed at 10,000 rpm for 15 min and the supernatant discarded. The pellet was then mixed with 1 mL of 0.2 N acetic acid and homogenized on the rotating wheel (34 rpm for 2 h 30 min) before centrifugation (10,000 rpm for 15 min). The supernatant was then collected into a new Eppendorf tube and quantified by Bradford assay. Glutelin content was expressed as milligrams equivalent of Bovine Serum Albumin per dry weight (mgEqvBSA/g DW).

Protein and glutelin data were analysed with SPSS software version 20. One way ANOVA test and Pearson correlation analysis were performed. The differences were considered as significant if $P < 0.05$, and highly significant if $P < 0.01$.

Statistical analyses

The data collected were subjected to multivariate analyses. The construction of the phylogenetic tree was done using software R. The Ward D method was used for calculating Euclidean distance. Principal component analysis (PCA) was performed using the SPAD V5 software.

RESULTS

Grain dimensions

Kernel sizes ranged from extra-long to short (Figure 1), with 16 extra-long cultivars, 42 long cultivars, 9 medium cultivars and 1 short cultivar. Kernel shapes were slender (36 cultivars), medium (28) and bold (4). It appeared that majority of the varieties from each of the localities were of long size (Yaoundé-56.6%, Dschang-57.9%, Garoua-60% and Tonga-75%), and slender shape (Yaoundé-66.7%, Dschang-52.6%, Garoua-53.3% and Tonga-50%).

Cluster and PCA analysis

Cultivars were grouped into four main clusters (Figure 2). Cluster 1 had six cultivars relatively low yielding (1810 to 3767 t/h) with varying sizes and shapes from extra-long and slender to long and medium. Cluster 2 had 34 cultivars with relatively high yields (6315 to 9065 t/h) and mainly slender and medium shaped grains, as well as many extra-long and long size grains with a few medium size and one short size grain cultivar. Cluster 3 had 8 cultivars with the highest yields (4752 to 15755 t/h) and mainly extra-long size and medium shape grains. Cluster 4 had 20 cultivars with low yields (4221,6 to 5858,2 t/h), mainly slender and medium in shape with one bold grain cultivar and many long size grain cultivars with a few extra-long and medium size grain cultivars.

PCA analysis demonstrated three components with Eigen value greater than 1 (Table 2): PC1, PC2 and PC3 which all contributed to 74.41 % of total variation. PC1 involved grain dimensions, PC2 involved agronomy parameters while PC3 involved yield components (Figure 3). Grain dimensions (paddy and kernel length and length/width ratio) which are associated to PC1 demonstrated a better distinction of the cultivars than other variables such as paddy and kernel width, number of tillers, thousand grain weight, cycle and yield.

Eight cultivars were selected for protein evaluation; four which were taught to be traditional and four improved cultivars which had PCA values similar to those of the traditional for comparison. Table 3 shows the eight selected varieties with their localities of origin and ecologies, and Figure 4 shows images of the paddy and kernels of these cultivars.

Total protein extraction and quantification

Protein contents were appreciably high, greater than the reported range of 7 to 10% (Figure 5). Highest protein

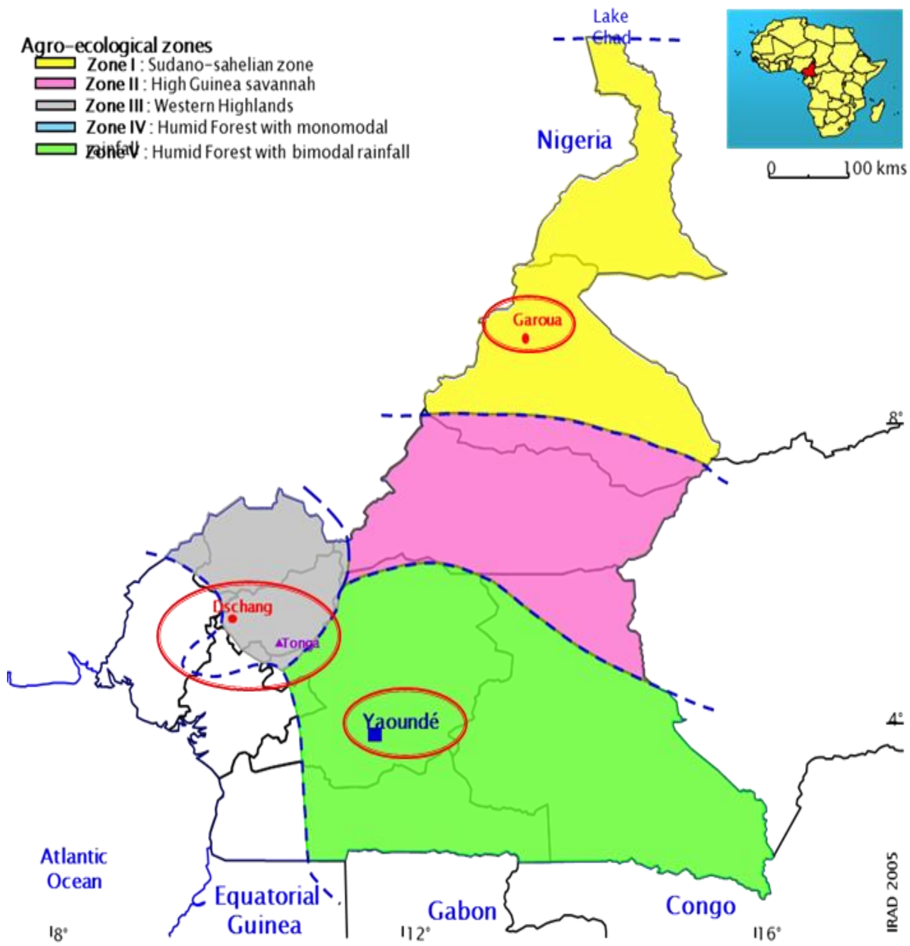

Figure 1. Cameroon agro-ecological zones.

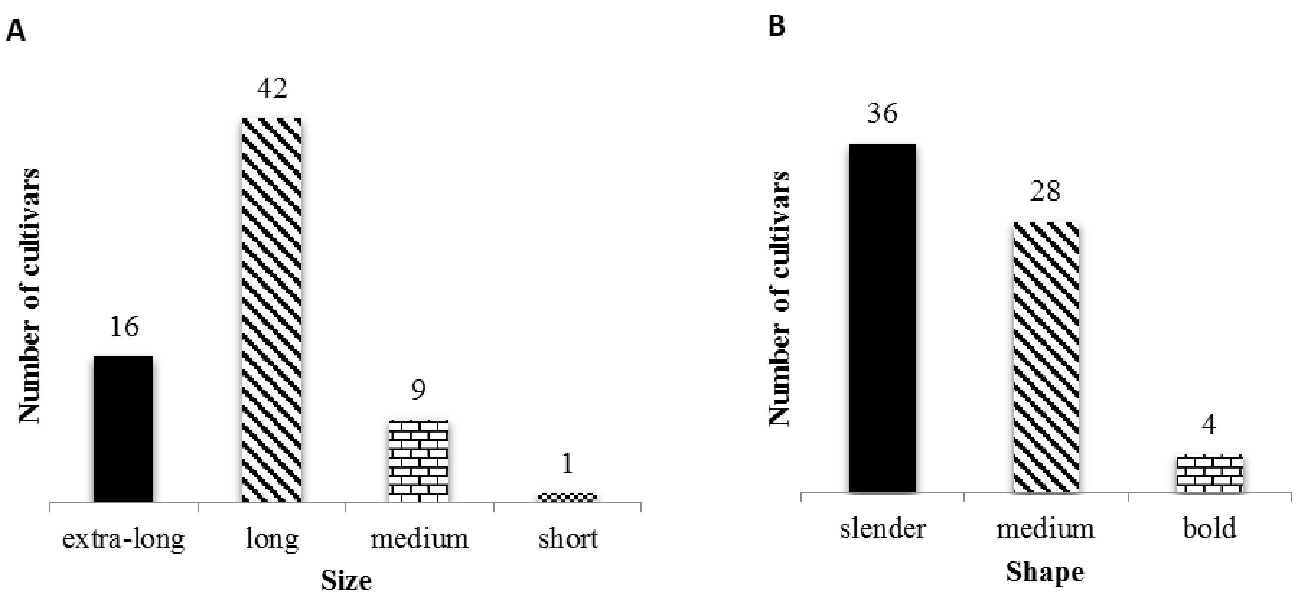

Figure 2. Kernel size (A) and shape (B) of cultivars collected.

Table 2. Principal Components for ten quantitative characters in 68 rice cultivars.

	Eigen value	Variance (%)	Cumulative (%)
PC1	4.6922	46.92	46.92
PC2	1.4182	14.18	61.10
PC3	1.3303	13.30	74.41

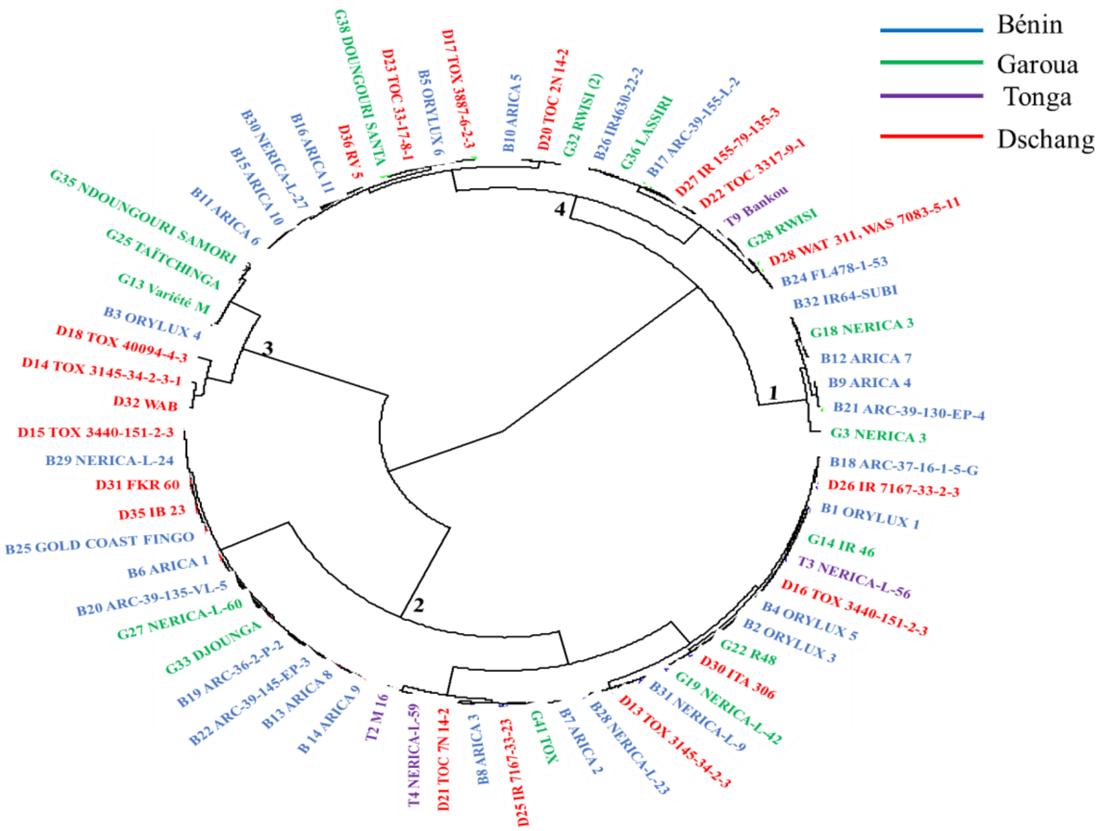

Figure 3. Dendrogram presenting the association between sixty-eight local rice varieties based on agro-morphological parameters.

Table 3. Origin and ecology of the rice varieties selected.

N°	Code	Variety	Origin	Ecology
Traditional varieties				
1	CMRGNd	G35 NDOUNGOURI SAMORI	Garoua	Rain fed upland
2	CMRGDn	G38 DOUNGOURI SANTA	Garoua	Rain fed upland
3	CMRTBa	T6 BANKOU	Tonga	Rain fed upland
4	CMRGTï	G25 TAÏTCHINGA	Garoua	Irrigated lowland
Improved varieties				
5	CMRDTx5	D17 TOX 3887-6-2-3	Dschang	Irrigate lowland
6	CMRDTc3	D22 TOC 3317-9-1	Dschang	Irrigated lowland
7	CMRDWb	D32 WAB	Dschang	Irrigated lowland
8	CMRDTx6	D18 TOX 40094-4-3	Dschang	Irrigated lowland

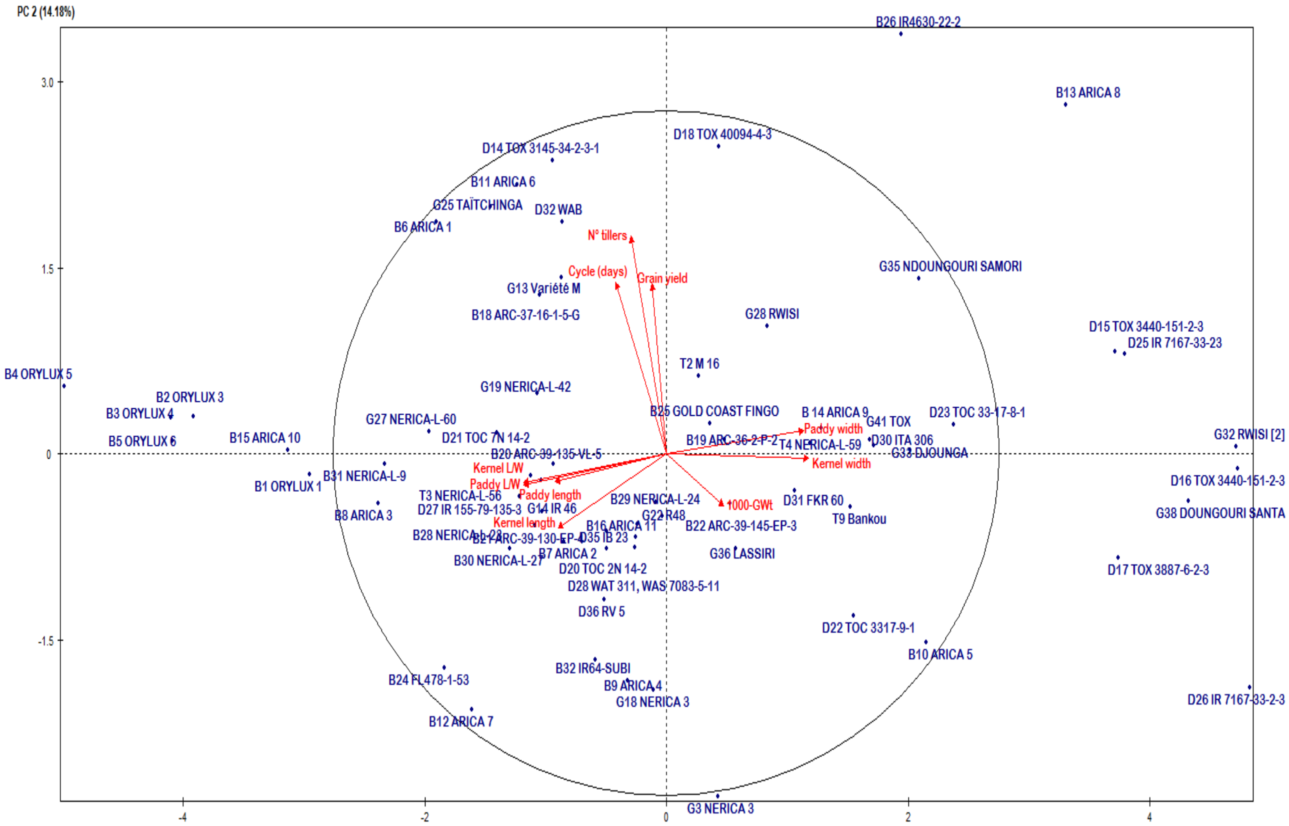

Figure 4. Principal component illustration of 68 local rice cultivars.

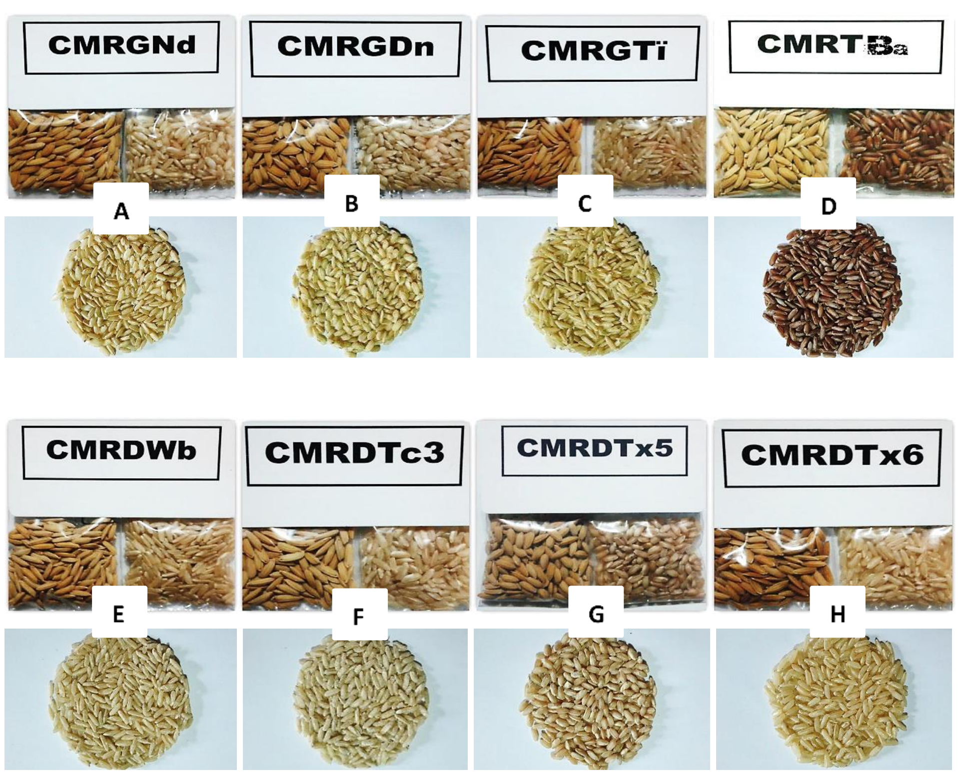

Figure 5. Samples selected for protein analysis.

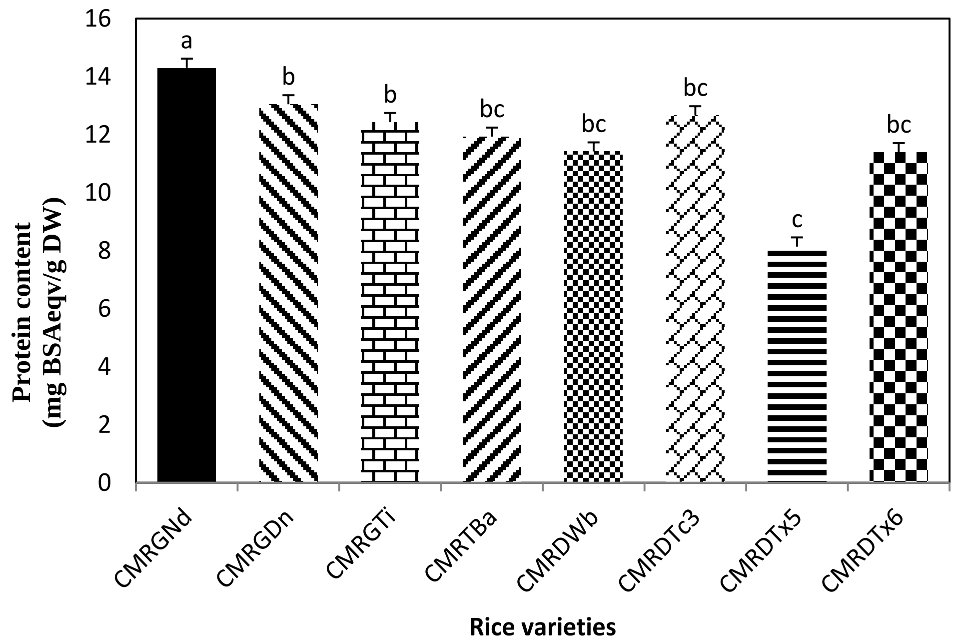

Figure 6. Total protein content of eight local rice cultivars.

Table 4. Glutelin contents (GC) and percentages (G %) of eight local rice varieties.

Variety	CMRGNd	CMRGDn	CMRGTï	CMRTBa	CMRDWb	CMRDTc3	CMRDTx5	CMRDTx6
GC (mg BSAeqv/g DW)	4.43	10.1	7.7	6.4	8.8	8.1	6.5	2.5
G %	30.9	77.7	62.1	53.8	73.3	63.8	80.2	29.1

content was obtained in CMRGNd (14.3%), followed by CMRGDn (13%) which was not significantly different from CMRGTï (12.2%). There was no significant difference between the protein contents of CMRTBa, CMRDWb, CMRDTc3 and CMRDTx6. The lowest protein content was exhibited by CMRDTx5 (8.%) which was the only variety with a protein content that fell within the reported range of 7-10%.

Glutelin extraction and quantification

Glutelin content ranged from 2.5 to 10.1 mgEqvBSA/g DW (Figure 6) and from 29.1 to 80.2% of total proteins (Table 4). Highest glutelin content was exhibited by CMRGDn (10.1 mgEqvBSA/g DW) followed by CMRDWb (8.8 mgEqvBSA/g DW), CMRDTc3 (8.1 mgEqvBSA/g DW) and CMRGTï (7.7 mgEqvBSA/g DW) which were not significantly different from each other. CMRDTx5 and CMRTBa had glutelin contents of 6.5 and 6.4 mgEqvBSA/g DW respectively, followed by CMRGNd (4.43 mgEqvBSA/g DW). Lowest glutelin content was observed in CMRDTx6 (0.25 mgEqvBSA/g DW).

Cluster analysis of the eight varieties using total protein and glutelin contents (Figure 7) presented two main clusters: A and B. cluster A branches into several sub clusters while cluster B branches to two varieties: CMRGNd and CMRDTx6. Cluster A branches at the highest level into cluster C which is linked to the variety CMRDTx5. Cluster C branches into cluster D and CMRGDn and cluster D gives cluster E and CMRTBa. Finally, cluster E gives CMRDWb and cluster F which contains the varieties CMRGTï and CMRDTc3.

Correlation results

A highly significant negative correlation (-0.863**) was observed between cycle duration and grain width, while cycle duration and grain length/width ratio showed a significant highly positive correlation (0.812*). Number of tillers presented a highly significant positive correlation with yield (0.921**), a significant negative correlation with grain width (-0.742*) and a significant positive correlation with grain length/width ratio (0.731*). Yield demonstrated a significant positive correlation with grain length (0.740*)

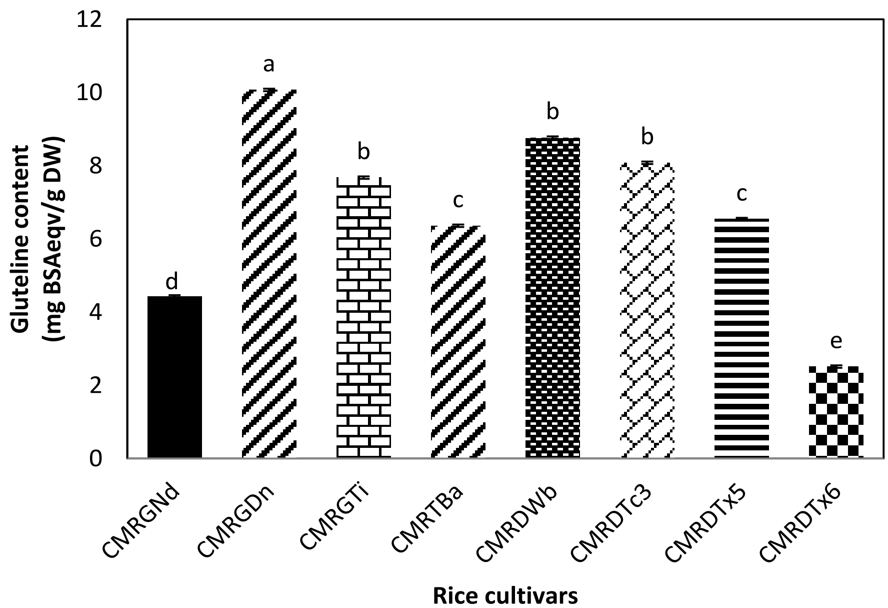

Figure 7. Glutelin content of eight local rice cultivars.

Table 5. Pearson correlation of variables involved in the study**.**

	Cycle	N° of tillers	Yield	Grain length (L)	Grain width (W)	Grain L/W ratio	Protein content	Glutelin content
Cycle	-							
N° of tillers	0.631	-						
Yield	0.552	0.921**	-					
Grain length (L)	0.602	0.593	0.740*	-				
Grain width (W)	-0.863**	-0.742*	-0.744*	-0.872**	-			
Grain L/W ratio	0.812*	0.731*	0.759*	0.927**	-0.989**	-		
Protein content	0.256	0.136	0.219	0.335	-0.117	0.185	-	
Glutelin content	-0.226	-0.344	-0.511	-0.182	0.239	-0.177	0.091	-

**Correlation is significant at the 0.01 level (2-tailed). *correlation is significant at the 0.05 level (2-tailed).

and length/width ratio (0.759*), and a significant negative correlation with grain width (-0.744*). Grain length demonstrated a highly significant negative correlation with grain width and a highly significant positive correlation with grain length/width ratio (-0.872** and 0.927** respectively) (Table 5). Grain width showed a highly significant negative correlation (-0.989**) with grain length/width ration but protein and glutelin content neither had significant correlation with either of the other variables nor with each other. These two put aside, grain width particularly demonstrated negative correlation with all other variables (Figure 8).

DISCUSSION

The size and shape categories distinguished in this study are in accordance with IRRI's Standard Evaluation System (SES) for rice (IRRI, 1996). Except the aroma, fine rice is generally appreciated for its long and slender grains. The predominance of long and slender rice grains (42 and 36 respectively out of 68) within the varieties studied is therefore indicative of the potential of these varieties for breeding programs and processing into fine rice for commercial purposes and represents a great exploitable potential for Cameroonian rice.

Cluster analysis with agro-morphological parameters yielded four clusters, with cultivars from different localities distributed within the same clusters, and cultivars from the same localities distributed in different clusters. This translates the variability that exists between varieties from the same environment and the similarity between varieties from different environments, which indicates that the decisive factors controlling these agro-morphological

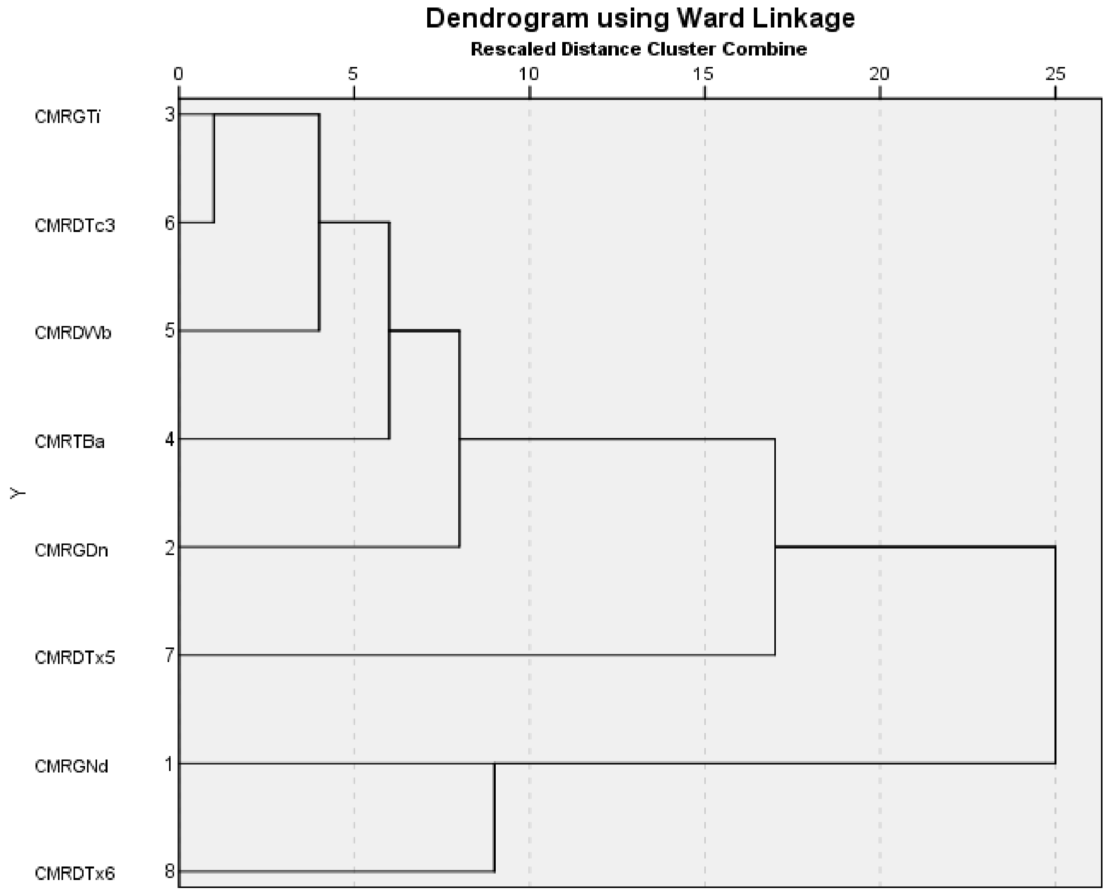

Figure 8. Dendrogram presenting the relationship between eight local rice varieties based on protein and glutelin content.

traits lie in the cropping systems and/or the rice genome. The high yielding cultivars were grouped together in cluster 3 and were mainly cultivars with slender shape, long size grains and high tiller number. Malaa et al. (2017) demonstrated farmers' preference for long grains (generally appreciated on market) and high tiller number of plants, which are associated to high yields. The high yields observed may thus be explained by the long size of the grains and the higher number of plant tillers. These high yields may as well be attributed to the genetic make-up of the cultivars, their environment and cropping conditions. In the same sense, low yields observed in cultivars grouped in cluster 1 may be explained by their low tiller number, genetic constitution and unfavourable environmental and cropping conditions. PCA analysis presented grain dimensions as the major contributors of the total variation, thereby presenting paddy length, width and length/width ratio as well as kernel length, width and length/width ratio as the major determinants of phenotypic diversity. This is in accordance with Rai et al. (2013) results on landraces of aromatic indica rice, which showed that grain length and width among other morphological characters are the major determinants of phenotypic diversity.

The protein contents of the varieties studied (8.1-14.3%) were higher than those reported by Juliano and Villareal (1993); Khush (1997) (7-10%). This might be because of adequate environmental conditions and cropping system. Buresova et al. (2010) reported that water supply, handling, application of fertilizer (soil nitrogen availability), environmental stress (such as salinity and alkalinity, temperatures and diseases), location of growing areas, growing conditions and time tend to increase grain protein content. Hence, these factors might have been adequate for the different cultivars studied. The higher protein content of the traditional varieties as compared to the improved varieties demonstrates their nutritional quality. Guo et al. (2007) reported that rice populations cropped in upland conditions had higher protein contents than those grown in lowland conditions. This explains the higher protein contents observed in CMRGNd and CMRGDn, which are upland varieties. CMRGNd, which showed highest protein content (14.3%), can be exploited to develop rice of better nutritional and technological quality. Rice protein is a major factor in determining texture (e.g. stickiness), pasting capacity, and sensory characteristics of rice. High protein content makes eating texture harder. This implies that CMRGNd, CMRGDn and CMRGTï, which demonstrated high protein content, would be adequate for cooking hard texture rice. In addition, these varieties shall be beneficial to farmers as they would provide increased returns due to less wastage during milling, which is associated to high storage proteins, as was reported by Leesawatwong et al. (2005). CMRTBa had a red pericarp, which is indicative of the presence of phenolic compounds which account for antioxidant property. Bhat and Riar (2017) obtained total protein contents of 7.24-8.85% with pigmented traditional cultivars from India. CMRTBa, which is equally a pigmented and traditional cultivar demonstrated a higher protein content (11.9%) and hence constitutes good genetic resource for breeding medicinal rice or developing a nutraceutical.

Glutelin is the most abundant and most nutritious of the four storage protein types present in rice appeared to be of significant differential content in the varieties selected. The quantities obtained were in accordance with the values reported by Kawakatsu et al. (2008), that is 60-80% of total proteins except for CMRTBa (53.8 %) and CMRDTx6 (29.1 %). CMRGDn, which showed the highest glutelin content (10.1 mgBSAEqv/g DW) is of particular interest for the development of a rice variety with better nutritional quality.

Classification of the eight selected varieties by cluster analysis based on total protein and glutelin content grouped together CMRGNd (traditional) and CMRDTx6 (improved) which are both characterized by high yields, with that of CMRGTx6 slightly higher. However, CMRGNd had higher protein and glutelin contents than CMRGTx6. This classification aligns with the one based on agro-morphology in which both varieties were grouped in the same cluster. CMRGTï (traditional) and CMRDTc3 (improved) were equally grouped in the same cluster; which is explained by their similar high protein and glutelin contents, the protein content of CMRGTï being slightly higher than that of CMRGTc3. Besides, CMRGTï presented a far greater yield than CMRTc3. With these two traditional varieties showing better traits than their improved counterparts, the quality of Cameroon's local and native varieties is clearly unveiled.

Positive correlation observed between cycle duration and grain length/width ratio might imply that slender grains are associated to a long cycle. Likewise, bold grains would be associated to a short cycle. In the same way, positive correlation observed between number of tillers, yield and grain length/width ratio would imply that we should expect high yield and slender grains from a variety that presents numerous tillers and low yield with bold grains from one that presents fewer tillers. Positive correlation observed between yield, grain length and grain length/width ratio may indicate that a variety characterised by long grains should normally be a high yielding one as opposed to one with short grains. A variety with slender grains should equally yield more than a variety with bold grains. Also, positive correlation between grain length and grain length/width ratio may indicate that long grains will generally be slender while short grains would be bold. Negative correlations observed between grain width and cycle; grain width and number of tillers may imply that a short cycle plant will yield short grains and long cycle plants will yield long grains. A variety with numerous tillers will provide long grains and a variety with few tillers will provide short grains.

Conclusion

The major findings suggest that Cameroon possesses high diversity in rice germplasms, most of which are improved varieties though a few native varieties still exist. The predominance of long, slender kernels and the high protein and glutelin contents of the varieties studied indicate the good quality of Cameroon's locally cultivated rice, especially those thought to be traditional. However, there is need to investigate the genetic make-up of these four thought traditional cultivars and confirm or not their nativity as well as provide relevant information for breeding programs.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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