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Phenotypic variation and genetic divergence studies in Cameroonian potato (*Solanum tuberosum* L.) genotypes

Mariette Anoumaa[1*], Eric Bertrand Kouam[2], Gabriel Kanmegne[1], Yanick Borel Kamga[1], Hervé Djomo Sime[1], Lisette Laure Chimi Nkombo[3], Théophile Fonkou[1]

[1]Department of Plant Biology, Faculty of Science, University of Dschang, Cameroon.
[2]Department of Crop Sciences, Faculty of Agronomy and Agricultural Science, University of Dschang, Cameroon.
[3]Department of crop production, Institute of Agricultural Research for Development, Dschang, Cameroon.

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ABSTRACT

Potato production in Cameroon is low and far from satisfying the demand. To enhance crop productivity, genetic improvement uses a phenotype-based selection strategy to choose parents based on their performance. Seventeen potato descriptors and six quantitative traits were used to determine the phenotypic variability and estimate genetic divergence among 138 potato accessions collected from farmers' fields in Cameroon. Accessions were grown during the rainy season under Dschang ecological conditions from September to November 2016 and March to May 2017. The relative index of phenotypic diversity estimated on the 17 qualitative traits using the relative diversity index of Shannon and Weaver was high (0.71) indicating high phenotypic diversity of the tested collection. Cluster analysis performed on dissimilarity estimates using the Euclidian distance revealed two main clusters; one showed the highest total tuber yield, whereas the other showed the highest dry matter content and included the indigenous genotypes. All the quantitative traits had high heritability. High genetic coefficients of variation and high heritability together with high genetic advance were observed for total tuber yield, total tuber number, plant height, and mean stem number. These traits can be used for breeding.

1. INTRODUCTION

Potato (*Solanum tuberosum* L.) contributes to the livelihood of millions of people worldwide [1]. It is appreciated for its high content of carbohydrates (19%) and proteins (2%), low-fat content (0.1%), and numerous medicinal properties [2]. In Cameroon, potato is eaten locally, sold in markets, and, also, exported to neighboring countries [3]. Despite its importance, potato yield in Cameroon averaged 9 t.ha^{-1}; this yield is low and far from the potential yield of 25 t.ha^{-1} recorded in research stations [4]; this low yield is attributed to the lack of quality planting material. To improve potato production in Cameroon, the Institute of Agricultural Research for Development (IRAD) in collaboration with the International Potato Center (CIP) proposed high-yielding varieties (Cipira and Tubira) which were widely adopted by farmers. However, these varieties have lost their performance over time and become susceptible to diseases [5].

The most efficient way to enhance the productivity of crops is through genetic improvement. It uses a phenotype-based selection strategy where parents are chosen based on their performance and their genetic potential. Crop genetic improvement relies on the level of the existing diversity within the species. High variability provides possibilities of selections for improvement [6]. Our previous study showed high morphological diversity in 77 potato accessions using qualitative and quantitative characters including yield parameters [7]. Additional samples were collected later for further studies. The knowledge of the phenotypic diversity, as well as its characteristics related to the target area, is important for the conservation of the new collection and improvement. Many quantitative traits are highly influenced by the environment as well as interactions between the genotype and environment, making the selection difficult and time-consuming. Genetic divergence

*Corresponding Author
Mariette Anoumaa, Department of Plant Biology, Faculty of Science, University of Dschang, Dschang, Cameroon. E-mail: mariettanou @ yahoo.fr

parameters, such as heritability and genetic advance, offer the most suitable conditions for selection [8]. This study was therefore conducted to (1) analyze phenotypic variability and (2) estimate genetic divergences, heritability, and genetic advance in potato accessions in Cameroon, these being important considerations in enhancing potato breeding programs.

2. MATERIAL AND METHODS

2.1. Sampling of Plant Material

A total of 138 potato accessions were collected from farmers' fields in the Western Highlands zone of Cameroon. The potato collection was composed of 125 accessions of local varieties and 13 modern varieties (Supplementary Table). Some of the modern potato varieties were collected twice from different farmers. Local names used by farmers were also collected. A large number of accessions were called "mashed potato" or local varieties by farmers; a code was given in such accession to identify each of them. GPS (Global positioning system) data of the collection areas were recorded and mapped (Fig. 1).

2.2. Cropping and Data Collection

The experiment was carried out at the Experimental Farm of the University of Dschang (lat 5° 27′ N, long 10° 04′ E, alt 1,395 m a.s.l) in the Western Highlands zone of Cameroon. This zone is characterized by average annual temperature of 20.5°C ± 6°C, mean annual rainfall of 2,000 mm, relative humidity of 76.8%, and a sandy loam soil with pH of 5.2. The experiment was carried out during the rainy season, from September to November 2016 and March to May 2017. For each accession, tubers were planted on 2.8 m^2 plots using a randomized block design with three replications. All farming practices applied in this study followed the procedure previously described [7]. Data were collected on 17 qualitative and 06 quantitative traits (Table 1) as previously described [7]. Quantitative traits were recorded on 04 randomly selected plants in each replication during the years 2016 and 2017.

2.3. Data Analysis

To determine the phenotypic diversity of the studied potato collection and to reveal the degree of polymorphism of the morphological characters, the relative index of phenotypic diversity was estimated on the qualitative data using the relative diversity index of Shannon and Weaver [9], each trait being defined as a separate phenotypic class. The Shannon and Weaver index was calculated using the following formula: $H = -\sum_{i=1}^{n} PiLnPi$ where H is the Shannon and Weaver diversity index and P_i is the frequency of each phenotypic class i of a given trait. The index (H) is converted into a relative index of phenotypic diversity (H') using the following formula: $H' = -\sum_{i=1}^{n} PiLnPi / Ln(n)$, where $Ln(n)$ is the maximum value of the index (H) and n the number of phenotypic classes of each trait. Student's *t*-test was used to determine the difference of mean diversity index between local and modern varieties. With the 23 morphoagronomic traits, cluster analysis was performed on dissimilarity estimates using the Euclidian distance, from which a dendrogram representing the relationship among the accessions was obtained. Clusters were inferred using the Ward method [10]. Common or local names were characterized and associated with clusters as well as with phenotypic traits. Genetic parameters were estimated using 06 quantitative traits to estimate genetic variability among accessions and determine genetic and environmental effects on various characters. Analysis of variance was performed using Genstat package v. 20 [11] to assess variation between accessions. The random model was used to calculate the expected mean squares for the genotype, genotype *x* year, and environmental variances [12].

Genotypic (σ_g^2) and phenotypic (σ_p^2) variances were estimated using mean squares: $\sigma_g^2 = \left(MS_g - MS_e\right)/r$, where MS_g is mean square of accession, MS_e is mean square of error, and r is the number of replications.

$$\sigma_p^2 = \sigma_g^2 + \frac{\sigma_{ge}^2}{m} + \frac{\sigma_e^2}{mr}, \text{ where } \sigma_e^2 = MS_e \qquad [13]$$

Genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), broad-sense heritability (h_B^2), and expected genetic advance (GA) were calculated using the following formulae [14]:

$$GCV = \frac{\sqrt{\sigma_g^2}}{x} \times 100$$

$$PCV = \frac{\sqrt{\sigma_p^2}}{x} \times 100$$

$$h_B^2 = \sigma_g^2 / \sigma_p^2$$

$$GA = \frac{\sigma_p}{x}.k.h_B^2 \times 100,$$

where x is mean of the trait, $\sigma_p = \sqrt{\sigma_p^2}$ is phenotypic standard deviation, and k = 1.76 is the standardized selection differential constant at 10% selection intensity.

3. RESULTS AND DISCUSSION

3.1. Diversity Index of Potato Accessions as Revealed by Morphological Characteristics

Table 2 presents the relative diversity index (*H*') of potato accessions as revealed by 17 morphological traits. The mean relative diversity index (*H*'mean) of all potato accessions was high (0.71). Time to maturity was a monomorphic character (*H*' = 0) for the entire potato collection studied showing very early maturity. This may be due to environmental conditions in the experimental site which may have reduced time to maturity in many genotypes. Although the time to maturity depends on the cultivar, it is highly affected by temperature. The temperature at the experimental site was 20.5°C ± 6°C. According to Kooman [15], the senescence

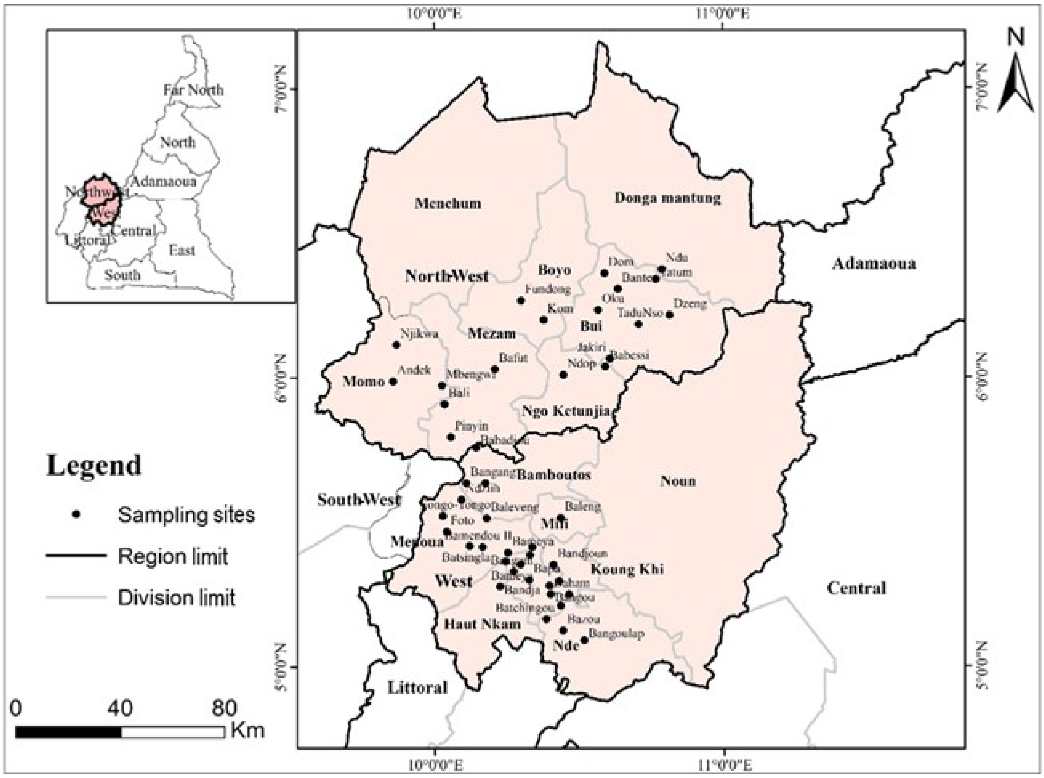

Figure 1: Map of the Western Highlands of Cameroon showing the sampling sites.

Table 1: Description of the qualitative and quantitative traits.

N°	Qualitative traits	Description
1	Growth habit	(1) Extremely-erect; (3) erect; (5) semierect; (7) decumbent
2	Foliage cover	(1) Poor; (3) moderate; (5) abundant
3	Predominant sprout color	(1) White-green; (3) pink; (5) red; (7) violet; (9) purple; (11) brown
4	Secondary sprout color	(0) Absent; (1) cream; (3) green; (5) purple
5	Distribution of the secondary sprout color	(0) Absent; (1) at the apex; (3) scartted; (5) at the base
6	Degree of flowering	(0) No buds; (1) buds abortion; (3) scarce; (5) moderate; (7) abondant
7	Time to maturity	(1) Very early (shorter than 80 days); (3) early (between 80 and 100 days); (5) moderate (between 101 and 110 days); (7) late (between 111 and 120 days); (9) very late (later than 120 days)
8	Tuber shape	(1) Obovate (compressed); (3) round; (5) ovate; (7) obovate; (9) elliptic; (11) oblong; (13) long-oblong
9	Tuber skin color	(1) White-cream; (3) yellow; (5) brown; (7) pink; (9) red
10	Tuber flesh color	(1) White; (3) cream; (5) yellow; (7) deep yellow
11	Eye depth	(1) Protruding; (3) shallow; (5) slightly deep; (7) deep; (9) very deep
12	Eye distribution	(1) Predominantly apical; (3) evenly distributed
13	Eye color	(1) White-cream; (3) yellow; (5) brown; (7) pink; (9) red
14	Note of eye per tuber	(1) Few (less than 8); (3) intermediate; (5) many (more than 15)
15	Dormancy period	(1) Very short (shorter than 30 days); (3) short (between 30 and 60 days); (5) medium (between 61 and 90 days); (7) long (between 91 and 120 days); (9) very long (longer than 120 days)
16	Flower color	(1) White; (3) light pink; (5) pink; (7) light violet; (9) deep violet; (11) light blue; (13) purple
17	Stamen formation	(0) No flower; (1) normal; (3) shrivelled
N°	**Quantitative traits**	**Description**
1	Plant height	Measurements of the distance between the top point of the plant and the ground surface at maturity in meters
2	Total tuber yield	Weight of tubers in tons per hectare
3	Total tubers number	Total number of tubers per plant
4	Percentage of marketable tubers	Number of marketable tubers expressed as a percentage of the total number of tubers per plant
5	Mean stem number	Main stem number per plant
6	Dry matter content	Dry matter content in potato tubers

Table 2: Relative diversity index of morphological traits.

Trait	Whole collection			Modern varieties			Local varieties		
	No	Ne	H'	No	Ne	H'	No	Ne	H'
Time to maturity	1	1.00	0.00	1	1.00	0.00	1	1.00	0.00
Dormancy period	5	2.33	0.69	4	3.76	0.98	4	2.08	0.68
Eye dept	5	3.85	0.89	4	2.25	0.75	5	3.80	0.88
Eye distribution	2	1.77	0.90	2	1.75	0.90	2	1.65	0.84
Note on eye per tuber	3	1.37	0.45	2	1.60	0.56	3	1.34	0.47
Degree of flowering	5	3.10	0.83	5	3.28	0.83	5	3.01	0.82
Growth habit	4	2.58	0.81	4	3.46	0.94	4	2.46	0.78
Foliage cover	3	2.24	0.86	3	2.72	0.95	3	2.14	0.83
Tuber skin color	4	1.79	0.58	3	2.25	0.80	4	1.70	0.55
Eye color	5	1.86	0.54	2	2.00	1.00	5	1.77	0.52
Tuber shape	8	3.27	0.72	5	4.57	0.97	8	3.01	0.67
Tuber flesh color	4	2.90	0.84	3	2.61	0.93	4	2.88	0.84
Predominant sprout color	5	2.80	0.78	5	2.98	0.81	5	2.61	0.75
Secondary sprout color	5	2.64	0.77	4	3.05	0.87	5	2.51	0.74
Distribution of the secondary sprout color	3	2.19	0.83	3	2.25	0.80	3	2.12	0.82
Color of corolla	8	3.10	0.69	3	2.17	0.79	8	3.10	0.70
Stamen formation	3	2.55	0.91	3	2.17	0.79	3	2.55	0.92
H' mean			0.71			0.80			0.70

No = number of observed phenotsypic classes; Ne = number of effective phenotypic classes; H'= relative diversity index.

rate increases with temperature. Foliar development reduces at high temperatures. Ingram and McCloud [16] reported that a leaf formed was estimated to be functional for about 23 days at 20°C but 12 days at 30°C. The other 16 traits apart from time to maturity were polymorphic with relative diversity indices ranging between 0.45 for note on eye per tuber and 0.91 for stamen formation. For eye color, all phenotypic classes presented equal frequencies in modern varieties (Table 2). Student's *t*-test showed a higher mean diversity index (0.80) ($p < 0.0001$) within the group of modern varieties as compared to that of local varieties (0.70). The Shannon–Weaver diversity index has been widely used to estimate diversity based on morphological traits in wheat [17,18]. This work revealed a high mean diversity index, reflecting important morphological diversity of the potato collection studied, due to the presence of a high number of polymorphic characters.

3.2. Cluster Analysis of Potato Accessions and Characteristics of Local Names

Phenotypic variations among potato genotypes were previously reported in India [19] and Ethiopia [20]. The 23 characters including 17 qualitative and 06 quantitative traits revealed two clusters of potato accessions in the dendrogram (Fig. 2).

Accessions of cluster I were exclusively local varieties and had the highest dry matter content (22.25%) and lowest mean values for total tuber yield (8.56 t.ha^{-1}), percentage of marketable tubers (83.35%), and height (51.61 cm) as compared to those of cluster II ($p < 0.001$). Accessions in cluster I had a very short to medium dormancy period (less than 91 days) and intermediate to many eyes per tuber evenly distributed on the tuber. All the accessions of this cluster are commonly called "mashed potato" varieties by farmers. "Mashed potato" is a potato meal which is made by mashing potato mixed with black common bean and red palm oil, with yellow pepper as the spice. The meal is highly appreciated by people of the Western Highlands zone of the country, and the suitable material to get the expected texture is potato tubers with low water content. "Mashed potato" as the variety's name is related to the high dry matter content in the tuber. The high dry matter content observed in these varieties justifies their potential uses for breeding. Cluster I was further divided into two subclusters.

Subcluster Ia included nine (09) accessions (Fig. 2). The growth habit is extremely erect with poor leaf coverage. The eyes are shallow or protruding. The sprout color is white-green, and the secondary color is absent. Only two accessions produce flowers, and the color is light purple or pink; the degree of flowering is rare or moderate, and the stamen formation is shriveled or normal.

Subcluster Ib included 51 accessions (Fig. 2). The habit is semierect, and the leaf cover is poor, moderate, or dense. The predominant sprout color is purple with a green secondary color distributed at the apex. Flowering is absent. This subcluster included Tezelfo which is one of the oldest indigenous potato varieties introduced into the country early in the 20th century by missionaries and colonial explorers [3].

Cluster II included modern as well as local varieties (Fig. 2). This cluster showed the highest mean values of total tuber yield (14.45 t.ha^{-1}), percentage of marketable tubers (88.62%), and plant height (75.86 cm), but the lowest mean value dry matter content (18.86%) as compared to cluster I. High tuber yield in modern varieties explains farmers' tendency to abandon local varieties in favor

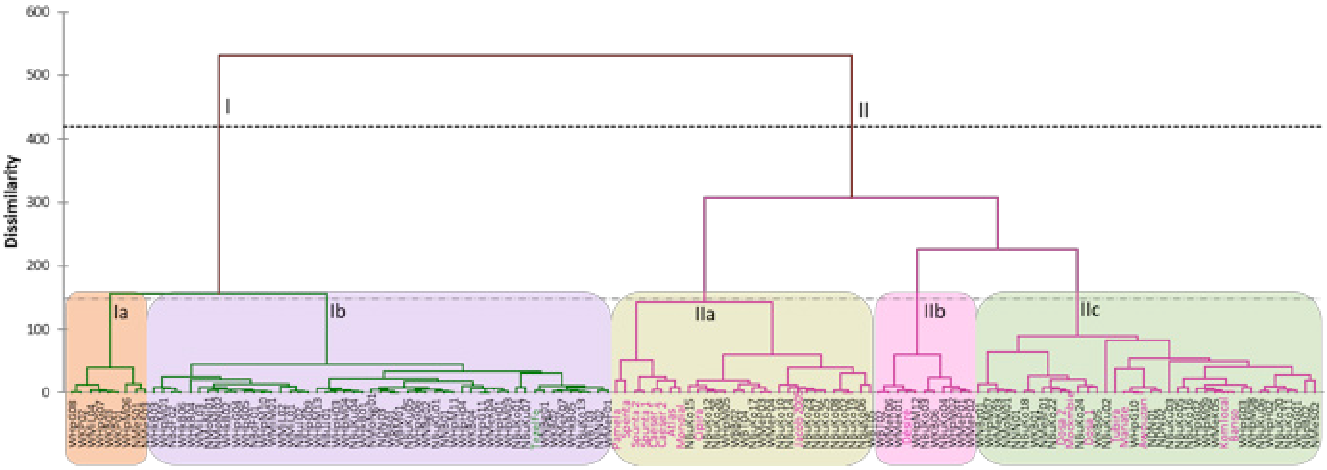

Figure 2: Dendrogram showing the relationship between 138 potato accessions based on 23 morphoagronomic characters

of modern varieties. Clustering of local varieties with modern varieties suggests misidentification of varieties looking alike as reported on vegetatively propagated crops [21]. This cluster was subdivided into three subclusters.

Subcluster IIa comprised 28 (Fig. 2) including 08 European varieties (Atlas, Caieser, Mondial, Pamela, Spenta, and Spunta), which are currently imported by seed multipliers, and two (02) varieties (Cipira and Jacob 2005) which were released in 1992 by the collaboration between the IRAD-CIP. The habit is erect or semierect, and the leaf cover is poor or moderate. The eyes are shallow or protruding. The sprout color is diverse. The Caieser, Jacob 2005, and Cipira varieties produced flowers, with white color and normal stamen formation. The sprout's predominant color is white-green, and the secondary color is purple, brown, or absent. The degree of flowering is scarce, moderate, or abundant with white flowers and normal stamen formation. Cipira and the 10 other accessions clustering together showed an obovate tuber shape, while Jacob 2005 and 11 accessions of the same cluster showed an oblong tuber shape.

Subcluster IIb included eleven (11) among which is Desiree (Fig. 2), another currently imported variety from Europe by seed multipliers. Accessions of this subcluster have a dormancy period that varies from very short to medium (less than 91 days). The port is erect or semierect, and the leaf cover is poor or dense. The shape of the tuber is spherical, elliptical, or oblong. The tuber skin and eye color are red. The predominant sprout color is red, and the secondary color is green or absent. The majority produced purple flowers with a scarce degree of flowering and normal stamen formation.

Subcluster IIc comprised 38 accessions including Dosa, Mockmbie, Tubira, Manaté, Awouzan, Kom local, and Banso (Fig. 2). The diversity in this subcluster is high. The habit is erect or semierect, and the leaf cover moderate or dense. The shape of the tuber is very diverse. The skin and eyes of the tuber are white-cream or yellow, except for two varieties (WKB01 and NBuKo18) which showed pink eyes. All accessions in this subcluster produced flowers. Dosa and Mockmbie are of the same variety. Mockmbie is a village in the Menoua division, West region of Cameroon. The Dosa variety was called Mockmbie for the first time by potato traders who discovered the variety during their first time in Mockmbie village; this name has spread over the Western Highlands zone of the country. The Dosa variety and the seven accessions which cluster together (Fig. 2) showed a short dormancy period (between 30 and 60 days), a scarce degree of flowering, white flowers, and normal stamen formation; the tuber presents an oblong shape, deep eyes, and yellow flesh; the predominant sprout color is violet with a green secondary sprout color distributed at the apex. Tubira is another variety released by the IRAD-CIP collaboration; this variety is on its own with a short dormancy period (between 30 and 60 days), abundant degree of flowering, white flowers, and normal stamen formation; the tuber presents an oblong shape, slightly deep eyes, and white flesh; the predominant sprout color is purple with a cream secondary sprout color scattered on the sprout. Awouzan, Manaté, and three other accessions within the same cluster are the same variety. This variety showed a very short dormancy period (shorter than 30 days), an abundant degree of flowering, light-violet flowers, and shriveled stamens; the tuber presents an obovate shape, deep eyes, yellow skin, and white flesh; the predominant sprout color is pink with a cream secondary sprout color distributed at the apex. "Manaté" means "variety that rushes" in Bangang (West region of Cameroon, Bamboutos division) local language. This name is related to the early germination characteristic of the variety. The synonym Awouzan is used by the people of Fongo-Tongo and Foto (West region of Cameroon, Menoua division); the origin of this other name is not known. The Banso and Kom local varieties clustered with nine other accessions represent the same variety (Fig. 2). These accessions present a very short dormancy period (shorter than 30 days), an abundant degree of flowering, and light-violet flowers with shriveled stamens; the tuber presents an oblong shape, very deep eyes evenly distributed, and yellow skin and cream flesh; the predominant sprout color is deep violet with a cream secondary sprout color distributed at the apex. The names Banso and Kom local, given to this variety, are related to the names of the localities where the variety was discovered by potato traders: the Banso

Table 3: Estimation of genetic variables for 06 agronomic traits in potato accessions.

Traits	Mean	σ_g^2	σ_{ge}^2	σ_e^2	σ_p^2	GCV (%)	PCV (%)	h_B (%)	GA	GAM (%)
Total tuber yield (t.ha^{-1})	10.08	20.12	7.40	1.82	24.12	44.51	48.74	83.40	7.21	71.54
Total tubers number	8.10	11.87	0.15	1.40	12.18	42.54	43.09	97.46	5.99	73.92
Percentage of marketable tubers	87.03	51.62	0.38	27.87	56.46	8.26	8.63	91.44	12.09	13.89
Plant height (cm)	66.69	295.19	6.07	10.06	299.90	25.76	25.97	98.43	17.32	25.98
Mean stem number	1.75	0.23	0.05	0.03	0.26	27.06	28.94	87.44	0.78	44.54
Dry matter content (%)	20.33	5.08	0.02	0.04	5.10	11.09	11.11	99.64	3.96	19.48

locality in the Bui division and Kom locality in the Boyo division (North-West region of Cameroon).

3.3. Analysis of Genetic Variability Parameters

Variability plays an important role in crop breeding. Diverse material ensures better chances of producing desirable crop plants. Estimates of the variance components, genotypic and phenotypic coefficients of variation (GCV and PCV), broad-sense heritability (h_B), and genetic advance (GAM) for 06 agronomical traits of potato were estimated and are shown in Table 3. The phenotypic variance was higher than the genotypic variance for all the traits. This suggests the influence of the environment on the expression of these characters as previously reported by Asefa *et al*. [20]. Studies on several crop species suggested that traits with high estimates of GCV have a high probability for improvement through selection, whereas improvement of traits with low estimates of GCV is difficult through selection due to the environment's masking effect [22,23]. In this study, genotypic and phenotypic coefficients of variation were high (>20%) for most of the traits. Dry matter content showed moderate (10% to 20%) genetic coefficients of variation. This indicates the limitation of selection for the improvement of this character. The percentage of marketable tubers showed low and low (<10%) phenotypic and genotypic coefficients of variation, indicating a highly pronounced effect of the environment in the expression of this trait. Heritability indicates the level of environment influence on the expression of a trait. It helps the breeder to know the possibility and extent to which improvement of a trait is possible through selection [24]. In general, estimates of heritability of more than 70% are accepted as usable in plant breeding programs [25]. The present study showed high heritability (>80%) for all the traits. High heritability was previously reported for a majority of traits in 11 potato genotypes at three locations for 2 years in Turkey [26]. However, high heritability may not always associate with high genetic advance. Genetic advance shows the degree of the gain obtained in a character under a particular selection pressure; hence, the heritability value alone would not be of practical importance because it may not provide clear predictability of the breeding value. Heritability should then be considered together with the genetic advance in predicting the resultant effect of selection [27]. High heritability coupled with high genetic advance has been reported for many characters in *Zea mays* [28], *Ipomoea batatas* [29], and *Jatropha curcas* [30]. In this study, genetic advance as a percentage of the mean at 10% selection intensity was high (>20%) for the majority of traits from the percentage of marketable tubers and dry matter content. High heritability combined with high genetic advance for the total tuber yield, total number of tubers, plant height, and mean stem number indicates that these traits were governed by additive gene action and can be improved through simple selection. High genetic advance for tuber yield, tuber number, and plant height was reported with 28 potato genotypes in Bangladesh [31]. High heritability coupled with low genetic advance observed for the percentage of marketable tubers and dry matter content indicates the predominance of nonadditive gene actions which is important to select for specific combination ability, taking advantage of hybrid vigor [32,33]. Sardana *et al.* [34] suggested that high heritability leads to increased genetic gain only if sufficient genetic variability existed in the germplasm. As reported in this study, Regassa and Basavaraj [19] obtained low genetic advance in dry matter content when analyzing 100 potato genotypes in India. However, low values of heritability and genetic advance were obtained for most of the characters studied in 21 potato genotypes for 2 years in Turkey [12]. The divergence between the values reported might be due to the differences in sampling the genotypes and environments.

4. CONCLUSION

This study aimed at determining the phenotypic characteristics and genetic variability estimates in 138 potato accessions from Cameroon. The results showed high levels of variation among the 138 potato accessions cultivated in the Western Highlands zone of Cameroon for 23 qualitative and quantitative characters. This study showed the existence of a unique set of indigenous varieties exhibiting particular characteristics of the area which are related to organoleptic properties and adaptability to environmental conditions. This could serve as a point of support for the genetic improvement of locally adapted potato varieties. Local names associated with many genotypes were related to some morphological traits such as the tuber dormancy period, organoleptic properties of the tuber, and the name of the area where the genotype was discovered by traders for the first time. Total tuber yield, total tuber number, plant height, and mean stem number exhibited high heritability coupled with high genetic advance. These characters could easily be improved through selection.

5. ACKNOWLEDGMENTS

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6. CONFLICT OF INTEREST

The authors report no financial or any other conflicts of interest in this work.

7. AUTHORS' CONTRIBUTIONS

All authors made substantial contributions to conception and design, data acquisition, or data analysis and interpretation of and took part in drafting the article or revising it critically for important intellectual content or gave final approval of the version to be published, agreed to submit to this journal, and agree to be accountable for all aspects of the work. All the authors are eligible to be authors as per the International Committee of Medical Journal Editors (ICMJE) requirements/guidelines.

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9. ETHICAL APPROVALS

This study does not involve experiments on animals or human subjects.

10. DATA AVAILABILITY

All data generated and analyzed are included within this research article.

11. PUBLISHER'S NOTE

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Supplementary table : passport data of the 138 potato accessions collected in the western highlands zone of Cameroon

N°	Accession code/name	Type	village	Latitude	Longitude	Elevation (m)
1	Atlas	modern	Balatsit III	N 5°21'15.8"	E 10°17'48.4"	1590
2	Caieser 1	modern	Ndziih	N 5°34'42.5"	E 10°5'32.7"	1859
3	Caieser 2	modern	Tadu	N 6°11'1.8"	E 10°42'22.9"	1923
4	Cipira 1	modern	Bangang	N 5°38'8.4"	E 10°6'32.1"	2377
5	Jacob 2005	modern	Pinyin	N 5°47'41.3"	E 10°3'20.4"	1713
6	Desiree	modern	Ndziih	N 5°25'6.3"	E 10°7'12"	1524
7	Dosa 1	modern	Ndziih	N 5°34'42.5"	E 10°5'32.7"	1859
8	Dosa 2	modern	Bangang	N 5°38'8.4"	E 10°6'32.1"	2377
9	Mondial 1	modern	Ndziih	N 5°34'42.5"	E 10°5'32.7"	1859
10	Mondial 2	modern	Bangang	N 5°38'8.4"	E 10°6'32.1"	2377
11	Kom local	local	Kom	N 6°12'0.4"	E 10°22'41.9"	1494
12	NBoB02	local	Kom	N 6°12'0.4"	E 10°22'41.9"	1494
13	NBoF01	local	Fundong	N 6°16'1.8"	E 10°18'0.7"	1629
14	NBoF02	local	Fundong	N 6°16'1.8"	E 10°18'0.7"	1629
15	NBuJ01	local	Jakiri	N 6°3'54.9"	E 10°36'23.9"	1680
16	NBuJ02	local	Jakiri	N 6°3'54.9"	E 10°36'23.9"	1680
17	NBuKo01	local	Banten	N 6°18'23.8"	E 10°38'5.2"	2114
18	NBuKo02	local	Banten	N 6°18'23.8"	E 10°38'5.2"	2114
19	NBuKo03	local	Banten	N 6°18'23.8"	E 10°38'5.2"	2114
20	NBuKo04	local	Banten	N 6°18'23.8"	E 10°38'5.2"	2114
21	NBuKo05	local	Banten	N 6°18'23.8"	E 10°38'5.2"	2114
22	NBuKo06	local	Banten	N 6°18'23.8"	E 10°38'5.2"	2114
23	NBuKo07	local	Banten	N 6°18'23.8"	E 10°38'5.2"	2114
24	NBuKo08	local	Banten	N 6°18'23.8"	E 10°38'5.2"	2114
25	NBuKo09	Banso	Nso	N 6°11'1.8"	E 10°42'22.9"	1923
26	NBuKo10	local	Nso	N 6°11'1.8"	E 10°42'22.9"	1923
27	NBuKo11	local	Nso	N 6°11'1.8"	E 10°42'22.9"	1923
28	NBuKo12	local	Nso	N 6°11'1.8"	E 10°42'22.9"	1923
29	NBuKo13	local	Nso	N 6°11'1.8"	E 10°42'22.9"	1923
30	NBuKo14	local	Nso	N 6°11'1.8"	E 10°42'22.9"	1923
31	NBuKo15	local	Nso	N 6°11'1.8"	E 10°42'22.9"	1923
32	NBuKo16	local	Nso	N 6°11'1.8"	E 10°42'22.9"	1923
33	NBuKo17	local	Nso	N 6°11'1.8"	E 10°42'22.9"	1923
34	NBuKo18	local	Nso	N 6°11'1.8"	E 10°42'22.9"	1923
35	NBuKo19	local	Nso	N 6°11'1.8"	E 10°42'22.9"	1923
36	NBuKo20	local	Nso	N 6°11'1.8"	E 10°42'22.9"	1923
37	NBuKo22	local	Tadu	N 6°14'11.7"	E 10°35'54.7"	2050
38	NBuKo23	local	Tadu	N 6°14'11.7"	E 10°35'54.7"	2050
39	NBuKo24	local	Tadu	N 6°14'11.7"	E 10°35'54.7"	2050
40	NBuKu01	local	Dzeng	N 6°12'57.6"	E 10°48'46.8"	2135
41	NBuKu02	local	Dzeng	N 6°12'57.6"	E 10°48'46.8"	2135
42	NBuKu03	local	Dzeng	N 6°12'57.6"	E 10°48'46.8"	2135
43	NBuKu04	local	Tatum	N 6°20'24.5"	E 10°45'58.1"	2028

Table Continued

N°	Accession code/name	Type	village	Latitude	Longitude	Elevation (m)
44	NBuKu05	local	Dom	N 6°21'40.3"	E 10°35'19.2"	1542
45	NBuKu06	local	Oku	N 6°14'2"	E 10°33'59.3"	2121
46	NBuKu07	local	Oku	N 6°14'2"	E 10°33'59.3"	2121
47	NDN01	local	Ndu	N 6°22'26.8"	E 10°47'14.4"	2014
48	NDN02	local	Ndu	N 6°22'26.8"	E 10°47'14.4"	2014
49	NDN03	local	Ndu	N 6°22'26.8"	E 10°47'14.4"	2014
50	NMeBf01	local	Bafut	N 6°1'46.2"	E 10°12'32.3"	1240
51	Mockmbie	local	Bali	N 5°54'31.4"	E 10°2'2.8"	1339
52	NMeS01	local	Pinyin	N 5°47'41.3"	E 10°3'20.4"	1713
53	NMeS02	local	Pinyin	N 5°47'41.3"	E 10°3'20.4"	1713
54	NMeS03	local	Pinyin	N 5°47'41.3"	E 10°3'20.4"	1713
55	NMoM01	local	Mbengwi	N 5°58'24"	E 10°1'34.4"	1278
56	NMoNg01	local	Andek	N 5°59'16.4"	E 9°51'23.5"	1440
57	NMoNj01	local	Njikwa	N 6°6'52.3"	E 9°52'7.7"	1434
58	NMoNj02	local	Njikwa	N 6°6'52.3"	E 9°52'7.7"	1434
59	NNB01	local	Babessi	N 6°2'17"	E 10°35'28.5"	1206
60	NNN01	local	Ndop	N 6°0'35.8"	E 10°26'43.3"	1198
61	NNN02	local	Ndop	N 6°0'35.8"	E 10°26'43.3"	1198
62	Pamela	modern	Balatsit III	N 5°21'15.8"	E 10°17'48.4"	1590
63	Spenta 1	modern	Ndziih	N 5°34'42.5"	E 10°5'32.7"	1859
64	NBuKo25	local	Tadu	N 6°11'1.8"	E 10°42'22.9"	1923
65	Spunta 1	modern	Ndziih	N 5°34'42.5"	E 10°5'32.7"	1859
66	Spunta 2	modern	Pinyin	N 5°47'41.3"	E 10°3'20.4"	1713
67	Tubira	modern	Tadu	N 6°14'11.7"	E 10°35'54.7"	2050
68	WBB01	local	Babadjou	N 5°45'34.6"	E 10°8'36.2"	1743
69	WBB02	local	Babadjou	N 5°45'34.6"	E 10°8'36.2"	1743
70	WBM01	local	Balatchi	N 5°38'6.5"	E 10°10'31.8"	1745
71	Manate	local	Bangang	N 5°38'8.4"	E 10°6'32.1"	2377
72	WBT02	local	Bangang	N 5°38'8.4"	E 10°6'32.1"	2377
73	WBT03	local	Bangang	N 5°38'8.4"	E 10°6'32.1"	2377
74	WBT04	local	Bangang	N 5°38'8.4"	E 10°6'32.1"	2377
75	WBT05	local	Batcham	N 5°38'8.4"	E 10°6'32.1"	2377
76	WHkB01	local	Bandja	N 5°16'39.5"	E 10°13'31.2"	1281
77	WHkB02	local	Bandja	N 5°16'39.5"	E 10°13'31.2"	1281
78	WHkB03	local	Bandja	N 5°16'39.5"	E 10°13'31.2"	1281
79	WHkB04	local	Bandja	N 5°16'39.5"	E 10°13'31.2"	1281
80	WHkB05	local	Fotouni	N 5°21'52.9"	E 10°14'38.9"	1576
81	WHkB06	local	Fotouni	N 5°21'52.9"	E 10°14'38.9"	1576
82	WHpG01	local	Baloumngou	N 5°12'42.9"	E 10°26'5.4"	1424
83	WHpG02	local	Bangou	N 5°12'42.9"	E 10°26'5.4"	1424
84	WHpG03	local	Baloumngou	N 5°12'42.9"	E 10°26'5.4"	1424
85	WHpG04	local	Bangou	N 5°15'3.3"	E 10°24'1.3"	1829
86	WHpG05	local	Bangou	N 5°15'3.3"	E 10°24'1.3"	1829
87	WHpG06	local	Bangou	N 5°15'3.3"	E 10°24'1.3"	1829

Table continued

N°	Accession code/name	Type	village	Latitude	Longitude	Elevation (m)
88	WHpG07	local	Bapa	N 5°18'1.3"	E 10°19'37.3"	1685
89	WHpG08	local	Bapa	N 5°18'1.3"	E 10°19'37.3"	1685
90	WHpG09	local	Bapa	N 5°18'1.3"	E 10°19'37.3"	1685
91	WHpG10	local	Bapa	N 5°18'1.3"	E 10°19'37.3"	1685
92	WHpG11	local	Bapa	N 5°18'1.3"	E 10°19'37.3"	1685
93	WHpH01	local	Baham	N 5°16'49.4"	E 10°23'46"	1828
94	WHpH02	local	Baham	N 5°16'49.4"	E 10°23'46"	1828
95	WHpH03	local	Baham	N 5°16'49.4"	E 10°23'46"	1828
96	WHpH04	local	Baham	N 5°16'49.4"	E 10°23'46"	1828
97	WHpM01	local	Bameya	N 5°23'41.4"	E 10°15'9.9"	1528
98	WHpM02	local	Bameya	N 5°23'41.4"	E 10°15'9.9"	1528
99	WHpM03	local	Bameya	N 5°23'41.4"	E 10°15'9.9"	1528
100	WHpM04	local	Bameya	N 5°23'41.4"	E 10°15'9.9"	1528
101	WHpM05	local	Badang	N 5°23'13.9"	E 10°19'44.5"	1611
102	WHpM06	local	Balatsit III	N 5°23'13.9"	E 10°19'44.5"	1611
103	WHpM07	local	Balatsit III	N 5°21'15.8"	E 10°17'48.4"	1590
104	WHpM08	local	Balatsit III	N 5°21'15.8"	E 10°17'48.4"	1590
105	WHpM09	local	Balatsit III	N 5°21'15.8"	E 10°17'48.4"	1590
106	WHpM10	local	Bameya	N 5°21'15.8"	E 10°17'48.4"	1590
107	WHpM11	local	Bameya	N 5°21'15.8"	E 10°17'48.4"	1590
108	WHpM12	local	Balatsit III	N 5°24'51.7"	E 10°20'12.4"	1563
109	WHpM13	local	Bangam	N 5°19'46.3"	E 10°16'22.7"	1670
110	WKB01	local	Bayangam	N 5°15'0.6"	E 10°27'46"	1555
111	WKB02	local	Bayangam	N 5°17'47.1"	E 10°25'46.6"	1648
112	WKB03	local	Bayangam	N 5°17'47.1"	E 10°25'46.6"	1648
113	WKB04	local	Bayangam	N 5°17'47.1"	E 10°25'46.6"	1648
114	WKB05	local	Bayangam	N 5°17'47.1"	E 10°25'46.6"	1648
115	WKB06	local	Bayangam	N 5°17'47.1"	E 10°25'46.6"	1648
116	WKP01	local	Bandjoun	N 5°21'11"	E 10°24'35.5"	1522
117	WKP02	local	Bandjoun	N 5°21'11"	E 10°24'35.5"	1522
118	Awouzan	local	Foto	N 5°28'3.8"	E 10°2'27.5"	1395
119	WMeF01	local	Fongo-Tongo	N 5°31'18.5"	E 10°1'42.6"	1556
120	WMeK01	local	Ndziih	N 5°34'42.5"	E 10°5'32.7"	1859
121	Tezelfo	local	Ndziih	N 5°34'42.5"	E 10°5'32.7"	1859
122	WMeK03	local	Nkong-Ni	N 5°34'42.5"	E 10°5'32.7"	1859
123	WMeK04	local	Batsingla	N 5°25'6.3"	E 10°7'12"	1524
124	WMeK05	local	Batsingla	N 5°25'6.3"	E 10°7'12"	1524
125	WMeK06	local	Baleveng	N 5°30'48.1"	E 10°10'45.7"	1421
126	WMeK07	local	Baleveng	N 5°30'48.1"	E 10°10'45.7"	1421
127	WMeP01	local	Bamendou II	N 5°24'52.6"	E 10°9'53.6"	1631
128	WMeP02	local	Bamendou II	N 5°24'52.6"	E 10°9'53.6"	1631
129	WMeP03	local	Bamendou II	N 5°24'52.6"	E 10°9'53.6"	1631
130	WMeP04	local	Bamendou II	N 5°24'52.6"	E 10°9'53.6"	1631
131	WMiL01	local	Baleng	N 5°30'54.2"	E 10°26'4.5"	1340

Table continued

N°	Accession code/name	Type	village	Latitude	Longitude	Elevation (m)
132	WMiL02	local	Baleng	N 5°30'54.2"	E 10°26'4.5"	1340
133	WMiL03	local	Baleng	N 5°30'54.2"	E 10°26'4.5"	1340
134	WMiL04	local	Baleng	N 5°30'54.2"	E 10°26'4.5"	1340
135	WMiM01	local	Bamoungoum	N 5°27'36"	E 10°22'59.6"	1345
136	WNBg01	local	Bangoulap	N 5°5'28.9"	E 10°30'58.1"	1472
137	WNBg02	local	Batchingou	N 5°9'51.9"	E 10°23'8.7"	1382
138	WNBz01	local	Bazou	N 5°7'31.6"	E 10°26'33"	1480