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Genetic Variability, Heritability and Correlation of Some Morphological and Yield Components Traits in Potato (*Solanum tuberosum* L.) Collections

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Abstract

The study was conducted with the main objective to evaluate the genetic variability, heritability, and clustering pattern exploration of morphological and yield related traits in potato (*Solanum tuberosum* L.) collections in the bimodal rainfall agroecological zone of Cameroon using a Randomized Complete Block Design (RCBD) with three replications. The data obtained on morphological and yield traits were subjected to analysis of variance (ANOVA). The results showed that the viability rate of the collections varied from 77.78% to 96.55% respectively for the *Maffo* and *Desiree collections*, while the greatest number of tubers per plant varied from 4 to 18 respectively for *Synergie* and *Desiree*. The emergence rate varies from 60% to 1.66% respectively for *Maffo* et *Doza* collections. However, *Desiree* presents the highest TL (96.55) while *Maffo* shows the lowest value (77.78%). The yield per hectare varied from 1.14 to 9.3 t/h for *Maffo* and *Doza* respectively. For all the characteristics observed, Phenotypic Coefficients of Variation (PCV) were higher than Genotypic Coefficients of Variation (GCV) suggesting the role of environment in the expression of traits under observation. The highest GCV

and PCV 47.55 and 58.94 respectively were observed for Diameter at the collar (DC). Most of the traits showed high GAM (>20%) except Average Tuber Length (ATL) with a moderate value (19.8). In terms of vegetative development, the *Desiree* variety showed the highest performance. Based on the growth and yield results, *Doza* seems to be the most recommendable crop in the study area.

Keywords

Agroecological Zone, Genetic Variability, Heritability, *Solanum tuberosum*, Yield

1. Introduction

Potato (*Solanum tuberosum* L.) is an annual herbaceous, self-pollinated species that belongs to the family *Solanaceae* cultivated throughout the world [1]. The ranks as the most important food crop in the world after rice, wheat, and maize [2].

Over the last decade, Cameroonian national potato production has increased from 200,000 tons in 2011 to approximately 400,000 tons in 2020 [3]. Potato is not only a widely used vegetable but also used for making processed foods and for manufacturing starch, and alcoholic beverages [1]. It is commonly produced for its tuber, which mainly contains carbohydrates [4]. According to its important years, potato breeding has focused on tuber quality which should be a priority in breeding programs. However, the quality of these tubers varied according to the genotypes [5]. Beyond quality, yields in terms of tubers per hectare which are strongly influenced by climatic variations are also important [6]. By analyzing the Spatio-Temporal Rainfall Variability in Cameroon over the period 1950 to 2019, a previous study showed a reduction in temperatures in the different regions of the country [7]. The decreases observed for the northern regions of Cameroon are between −5.4% (Adamawa) and −7.4% (Far North). Those of western regions oscillate between −7.5% (South-West) and −12.5% (West) [7]. However, according to their environmental conditions, potatoes (*Solanum tuberosum*), maize (*Zea mays*), and beans (*Phaseolus vulgaris*) are the principal food crops of the Western Highlands [8]. These crops, which adapt easily in this zone, would undergo variation once grown in other agro-ecological zones of Cameroon. This would pose a problem of adaptability and selection of the best genotypes suited to the soil and climate conditions. In order to increase potato production in Cameroon, it would be possible, thanks to the genetic diversity of this species, to find varieties that can withstand climatic variations in general and adapt to the soil and climatic conditions of the other agroecological zones of Cameroon specifically. However, to the best of our knowledge, there is no scientific study to date on the response of potato varieties in all the agroecological zones of Cameroon. The present study aimed to analyze the Genetic Variability,

Heritability and Correlation of some Yield Components in potato (*Solanum tuberosum* L.) collections at Leboudi II in the bimodal rainfall forest zone of Cameroon.

2. Material and Methods

2.1. Experimental Site and Experimental Design

The work was carried out at Leboudi II (OKOLA district, Lékié Department, Centre Region of Cameroon). This locality belongs to agroecological zone V or forest zone with bimodal rainfall. Rainfall is generally in the order of 1500 to 2000 mm/year with two distinct wet seasons. Over the year, the average temperature is 23°C for an altitude of 797 m [9].

The experimental design consisted of four completely randomized blocks with three replications. The varieties studied were: *Desiree*, *Banso*, *Panamera*, *Synergie*, *Maffo*, *Doza*, *and Cypira*. Any variety was separated from the others by 0.5m aisles. Each block measured approximately 5m x 3m and consisted of seven (07) ridges each containing six (06) seedlings, separated from the others by a distance of twenty (20) cm.

Furthermore, the choice of the different potato collections was based on the varietal preferences of the growers and consumers, their availability and accessibility. It should be noted that each of these collections was all taken from growers in the of Bafou and Bamboutos localities of the Western Highlands of Cameroon.

Forty-eight hours (48) after the preparation of the experimental site, the potato tubers of the pre-germinated collections were planted. The maintenance consisted of weeding, followed by hoeing on the different ridges and around the experimental site. Watering was provided by rainfall in the locality.

2.2. Data Collection

Genetic traits of the seven genotypes of potatoes were evaluated based on morphological and yield parameters. Morphological parameters include plant height (PH), collar diameter (DC), emergence rate (TL), and viability rate (TV) evaluated 41 days after sowing. For the yield parameters, a total number of tubers (TNT), average tuber weight (AWT), average tuber volume (AVT), average tuber length (ALT), and number of tuber per plant (NTP) were determined.

The following parameters have been calculated as genetic parameters: grand mean, standard error of mean (SEM), critical difference (CD) 5%, critical difference (CD) 1%, environmental variance (VE), genotypic variance (VG), phenotypic variance (VP), environmental coefficient of variance (ECV), genotypic coefficient of variance (GCV), phenotypic coefficient of variance (PCV), broad sense heritability (H^2), genetic advance (GA) and genetic advance as a percentage of mean (GAM) [10] [11].

2.3. Statistical Analysis

The data obtained were subjected to ANOVA with the software R (version 3.5.1)

for the multiple comparisons of the means and their ranking, the Least Significance Test at the 5% threshold.

Principal component analysis and hierarchical cluster analysis (HCA) were performed by the variability package of the software R (version 3.5.1). The classification of the collections has been done by ascendant classification. The biplot has been constructed to bring together varieties and parameters as in [12].

3. Results and Discussion

3.1. Agromorphological Variability of Potato

3.1.1. Total Number of Plants per Tuber

The number of plants per tuber varies from 1 (*Synergie*) to 8 (*Desiree*). This parameter showed a significant difference between collections at the 5% level (**Figure 1**).

3.1.2. Collar Diameter

The collar diameter varied from 0.2 to 0.7 cm for *Synergie* and *Desiree* respectively. The collar diameter shows a significant difference between collections at $p < 0.05$ (**Figure 2**).

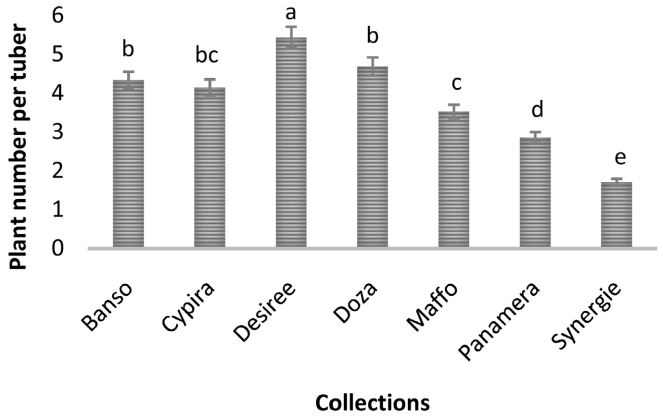

Figure 1. Total number plant per tuber. Histogram bars followed by the same letter are not significantly different at the 5% level.

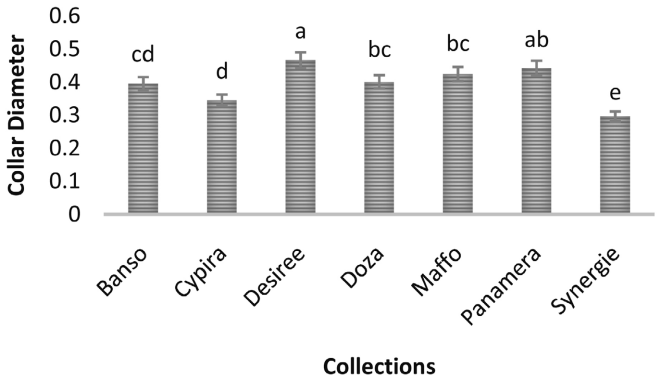

Figure 2. Collar diameter of the study collections. Histogram bars followed by the same letter are not significantly different at the 5% level.

3.1.3. Plant Height

The average plant height varies from 10 to 80 cm in *Synergie* and *Desiree* respectively. It shows a significant difference between the seven collections at $p < 0.05$ (Figure 3).

3.2. Productivity of Potato Collections

3.2.1. Number of Tubers per Plant

The number of tubers harvested varies from 15 to 45 for *Synergie* and *Desiree*, respectively. The analysis of the data shows a significant difference between collections at $p < 0.05$ (Figure 4).

3.2.2. Tuber Weight

The weight values range from 0.2 kg to 0.5 kg for *Maffo* and *Doza*, respectively. Data analysis shows a significant difference between the collections at $p < 0.05$ (Figure 5).

3.2.3. Tuber Volume

The volume of the tubers is between 45 and 98 ml for *Maffo* and *Cypira*, respectively (Figure 6). The data analysis showed a significant difference between the collections at $p < 0.05$.

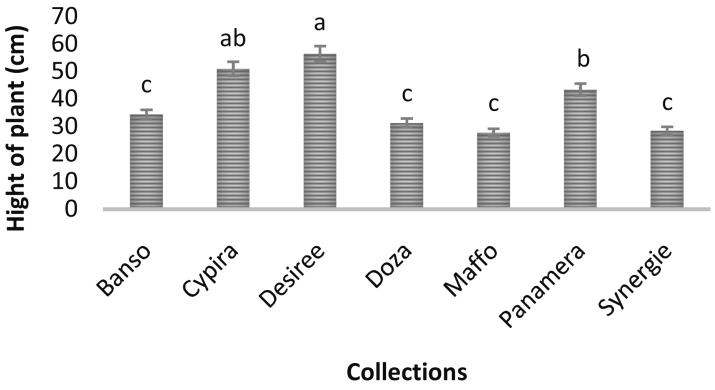

Figure 3. Plant height of the potato collections. Histogram bars followed by the same letter are not significantly different at the 5% level.

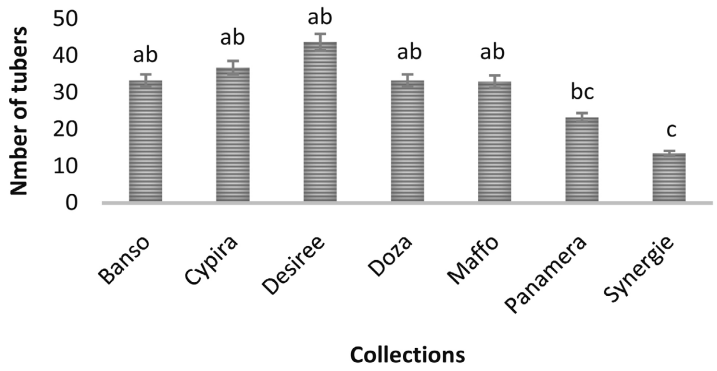

Figure 4. The number of tubers of collections. Histogram bars followed by the same letter are not significantly different at the 5% level.

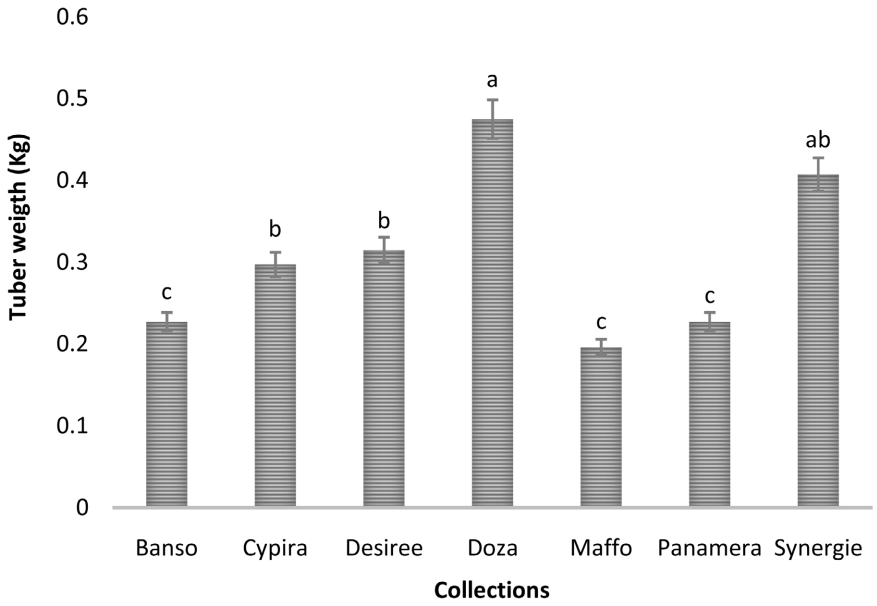

Figure 5. Tuber weight (kg) of potato collections. Histogram bars followed by the same letter are not significantly different at the 5% level.

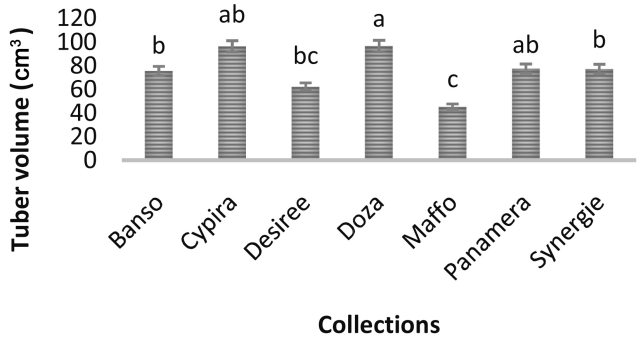

Figure 6. Average tuber volume of potato collections. Histogram bars followed by the same letter are not significantly different at the 5% level.

3.2.4. Tuber Length

The average length of tubers varies between 4.6 to 7.07 cm for *Maffo* and *Doza*, respectively. Data analysis has shown significant differences between collections (**Figure 7**).

The emergence rate (TL) varies from 60 à 91.66% respectively for Maffo et Doza collections. However, Desiree presents the highest TV (96.55%) while Maffo shows the lowest value (77.78%). The yield per hectare of the collection varied from 1.14 to 9.3 t for *Maffo* and Doza respectively (**Table 1**).

4. Genetic Parameters

4.1. Estimation of Principal Component Analysis

To determine the nature and degree of divergence between our collections, a PCA and hierarchical clustering (HC) were performed. Only the first two axes of

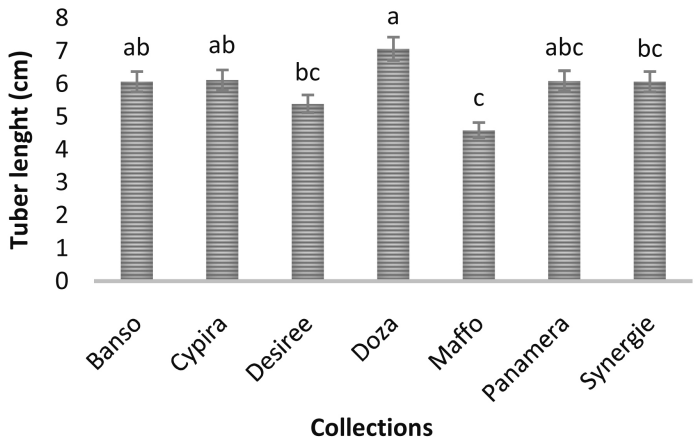

Figure 7. Tuber length (cm) of potato collections. Histogram bars followed by the same letter are not significantly different at the 5% level.

Table 1. Emergence rate viability rate and yield parameters of potatoes.

Varieties	TL (%)	TV (%)	Yield (tons)
Desiree	95	96.55	6.2
Banso	95	89.47	4.4
Panamera	82.6	86.84	1.58
Synergie	78.6	91.67	7.2
Maffo	60	77.78	1.14
Doza	91.66	84.09	9.3
Cypira	84.61	81.82	5.1

TL: Emergence rate, TV: Viability rate.

the principal component analysis (Figure 8) expressing nearly 72% were taken into account. Axis 1, which contains 39.2%, is associated with the characters TL, Yield, AWT, AVT, and ALT.

Axis 2 which counts 32.8% associated with the variables such as TNT, NFP, DC and P_High. The combination between variables and collections showed that *Desiree* can be selected based on parameters such as TNT, NTP, DC, and PH while *Doza* can be selected based on TL, Yield, AWT, AVT, ALT (Figure 8).

4.2. Estimates of Variance Components

The variability components of potatoes namely genotypic and phenotypic variance and coefficient of variations, heritability in a broad sense, and genetic advance as a percent of mean were estimated for seven traits (Table 2).

Phenotypic variance ranged from 0.015 to 141.54 respectively for AWT and TNT, while genotypic variance ranged from 0.0091 to 80.9 respectively for the same trait. All our studies traits showed that phenotypic variance is higher than genotypic variance (Table 2)

Briefly, the result exhibited those genotypic coefficients of variance (σ^2 g)

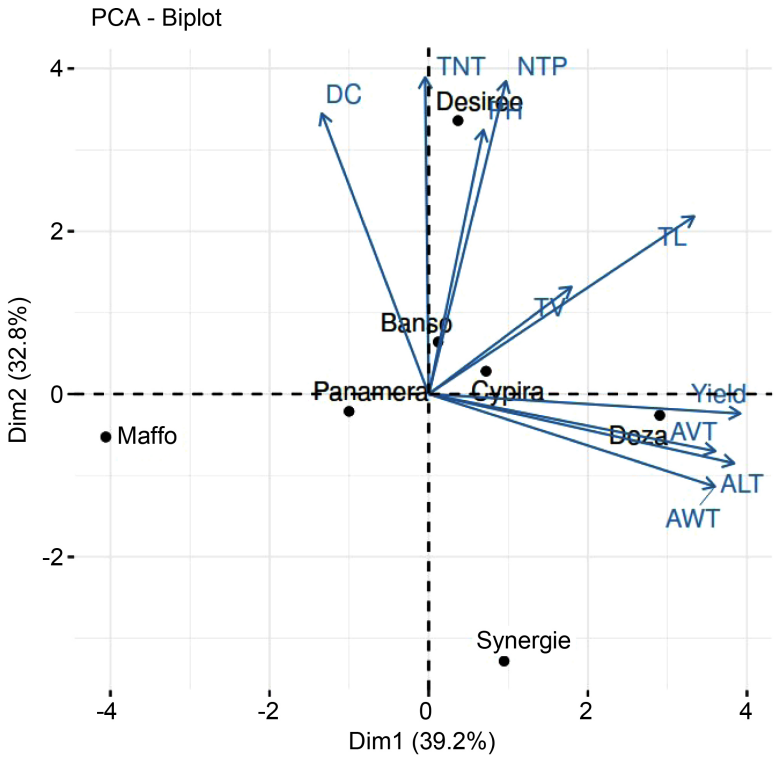

Figure 8. PCA shows the combinations between variables and collections. TNT: total number of tubers, AWT: average weight of tuber, AVT: average volume of tuber, ALT: average length of tuber, NTP: number of tuber per plant; DC: diameter at the collar, PH: plant height, TL: emergence rate, TV: viability rate.

varied from 12.01% to 47.55%. The length of tubers has the lowest coefficients while the DC has the highest coefficients. Phenotypic coefficients of variance ranged from 15.03% to 58.94% and the highest PCV was obtained from DC and the lowest from ALT. The phenotypic coefficient of variation (PCV) was relatively greater than the genotypic coefficient of variation (GCV) for all traits. The environmental coefficient of variance ranged from 9.02 to 34.84 for the same traits.

The Relative Difference (RD) is the estimation of the ratio of GCV in association with the respective PCV and the estimated RD values varied from 0.11% to 24.59% for AWT and AVT respectively (Table 2).

4.3. Estimate of Broad Sense Heritability and Genetic Advance

The estimated broad sense heritability (H^2) varied from 49% to 65%. The highest heritability was recorded for DC (65%) followed by ATL (64%) and AWT (61%) (Table 2) and the lowest for 49% (AVT). Generally, moderate ($30\% \leq h^2 \leq 60\%$) heritability values were marked for AVT (49%), TNT (57%), and NTP (60%) whereas the rest of the traits expressed high ($H^2 \geq 60\%$) heritability values. Genetic Advance as percentage of mean (GAM) ranged from 19.8% to 79.03% respectively for ATL and DC.

Table 2. Genetic parameters of potatoes under the bimodal rainfall forest zone of Cameroon.

Genetic parameter	TNT	NTP	AWT	AVT	ATL	DC
Maximum	53	18	0.7	153	7.7	0.92
Minimum	6	2	0.18	42	3.5	0.12
Grand Mean	30.9643	10.14	0.31	76	5.92	0.39
Standard Error of Mean (SEM)	3.9	1.3	0.04	8.25	0.27	0.07
Critical Difference (CD) 5%	11.59	3.85	0.11	24.51	0.8	0.19
Critical Difference (CD) 1%	15.88	5.27	0.15	33.58	1.1	0.25
Environmental Variance	60.84	6.7	0.0057	272.17	0.29	0.02
Genotypic Variance	80.8	10.24	0.0091	260.07	0.51	0.035
Phenotypic Variance	141.64	16.94	0.015	532.24	0.79	0.054
Environmental Coefficient of Variance	25.19	25.52	24.55	21.7	9.02	34.87
Genotypic Coefficient of Variance	29.03	31.55	31.11	21.21	12.02	47.55
Phenotypic Coefficient of Variance	38.43	40.56	39.68	30.34	15.03	58.94
Heritability (Broad Sense)	0.57	0.6	0.6149	0.49	0.64	0.65
Genetic Advance (GA)	13.99	5.12	0.154	23.22	1.17	0.31
Genetic Advance as Percentage of Mean (GAM)	45.16	50.52	50.26	30.54	19.8	79.03

TNT: total number of tubers, NTP: number of tuber per plant, AWT: average weight of tuber, AVT: average volume of tuber, ALT: average length of tuber; DC: diameter at the collar.

4.4. Analysis of Correlation Coefficients

The Pearson correlation between the 10 traits showed that Tuber weight (AWT) was strongly and positively correlated with yield (r = 0.8) (**Figure 9**). A strong positive correlation was also observed between the total number of tubers (TNT) and the number of tubers per plant (TNP). Furthermore, a positive correlation was observed between tuber volume (AVT). On the other hand, DC was negatively correlated with tuber weight, tuber volume, and yield (**Figure 9**).

4.5. Cluster Analysis

The hierarchical ascending classification gives a structuring of the 8 potato collections in the bimodal rainfall zone of Cameroon into 3 groups using 6 morphological and 04 yield parameters (**Figure 10**). Group II contains a single variety (*Maffo*) while groups I and III consist of 2 (*Desirée* and *Sypira*) and 4 (*Doza*, *Synergire*, *Panamera* and *Banso*) collections respectively.

5. Discussion

5.1. Agromorphological Parameters

The number of tuber plants showed a significant difference between the collections studied. The results obtained in this work are close to those obtained in the Western Region of Cameroon in which the number of tillers per plant varied

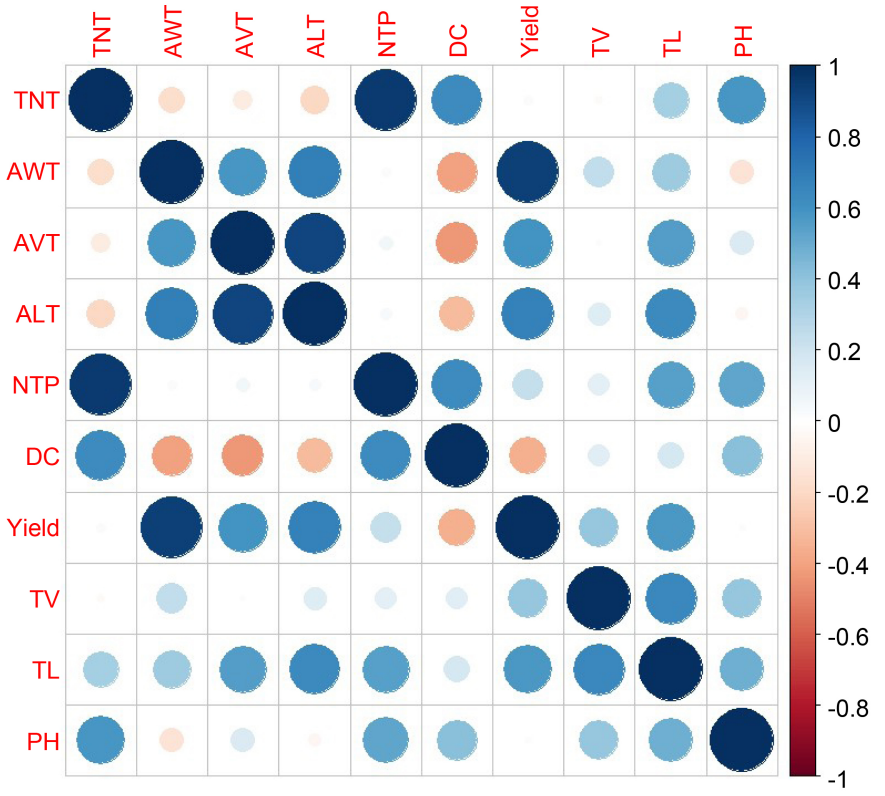

Figure 9. Correlation coefficients among characters. TNT: total number of tubers, AWT: average weight of tuber, AVT: average volume of tuber, ALT: average length of tuber, NTP: number of tuber per plant; DC: diameter at the collar, PH: plant height, TL: emergence rate, TV: viability rate.

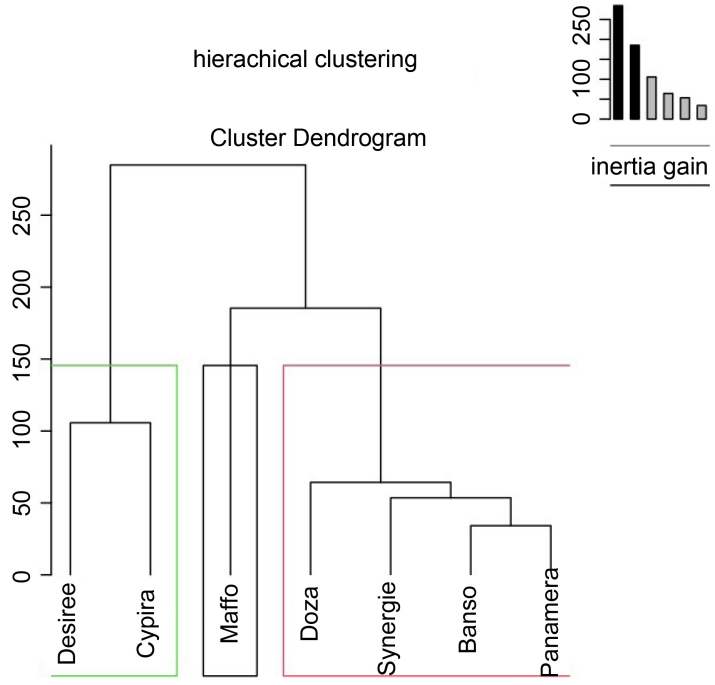

Figure 10. Dendrogram of potato collections based on using 6 morphological and 4 yield parameters.

between three and seven [13]. The height of the plants, which indicates plant biomass, varies from 4.5 cm to 80 cm respectively in *Maffo* and *Desiree*. Other researchers obtained values between 34 and 51 cm [13]. In addition, the values of the diameter at the collar obtained ranged from 0.2 cm for *Synergie* to 0.7 cm for *Desiree* compared to those obtained in the West Cameroon region, which ranged from 0.65 cm to 0.91 cm [13]. This would be due to the soil and climate conditions of the two cultivation zones. The differences observed in the different growth parameters in each variety can be explained by the effect of the variety on the vegetative growth of the different plants and the yield of each variety. Indeed, in their work, they demonstrate and confirm the influence of variety on the growth and development of plants. These results are also further confirmed by [14].

5.2. Productivity of Potato Varieties

The highest number of tubers per plant (15) was observed in *Desiree* in contrast to the *Synergie* variety whose average number was 4 tubers per plant. These results are similar to those obtained on the characterization of the potato in which the number of tubers per plant varied from 2 to 16 by [15]. Furthermore, the collection with the most tubers had a non-proportional mean weight [16] and observed significant differences in 24 potato genotypes due to genetic differences. The differences would also be due to environmental factors such as soil nutrient richness. Another work showed that the available potassium had the strongest correlation with potato tuber yield which is also correlated with soil water content [17]. The low production and productivity could be attributed to the infestation of disease on standing crops [18].

5.3. Genetic Parameters

The analysis of these results showed a positive correlation between the average weight of the tubers, the number of stems/plants, and the number of tubers. Traits with such a positive correlation with yield can optimize yield as a result of their simultaneous improvement [19].

The seven varieties studied were subdivided into three clusters. These are respectively *Desiree and Cypira* (cluster I), Maffo (cluster II) and *Doza*, *Panamera*, *Synergire*, and *Banso* (cluster III). As in this work, [15] clearly separated *Cypira* and *Doza* varieties into two clusters while [20] separated 146 samples into 27 groups based on 15 variables. This would be due to the environmental factors and the genotypes of the collections.

For all the variables, phenotypic coefficients of variation were higher than genotypic coefficients of variation suggesting the role of environment in the expression of traits under observation. These results are in line with those obtained by [21]. The average tuber length is intermediate, while the other parameters show GCV and PCV values above 20%. The highest GCV (47.55) and PCV (58.94) were calculated for DC. On the contrary, [22] obtained the highest value for the yield of tubers per plant and the number of tubers per plant. This highest

value indicates a high potential for effective selection.

The GAM raged from 19.8 (ATL) to 79 (DC). According to [23], the GAM was categorized as low (0 - 10%), moderate (10% - 20%), and high (>20%). Most of the traits showed high GAM (>20%) except ATL with a moderate value (19.8). The estimated values of heritability vary from 49 (AVT) to 65 (DC). These results are in line with those obtained by [11].

A moderate heritability and high GAM were observed for AVT, TNT, and NTP. ALT has presented a high heritability and a moderate GAM, while high heritability coupled with high GAM was observed for AWT and DC suggesting selection for these traits would give a good response. The same result has been obtained by [24] for the weight of the tuber and the number of tubers per vine on sweet potato. This result suggests that there may be the presence of additive gene action and selection will be rewarding for the improvement of such traits with a simple breeding method [10]. According to [11] the effectiveness of selection is realized more quickly in those characters which have high heritability and high genetic advance.

The relative difference (RD) is the estimation of the ratio of GCV in association with the respective PCV and the estimated RD values varied from 0.11% to 24.59% for AWT and AVT respectively. High values indicate an environmental influence. All the above observations based on morphological analysis showed a strong variability among the used material in this study. This variability may be confirmed by molecular analysis as in [25].

6. Conclusion

This study aimed to analyze the Genetic Variability, Heritability, and Correlation of some Yield and Yield Components in potato (*Solanum tuberosum* L.) collections in the bimodal rainfall forest zone of Cameroon. The number of tillers per plant varied from 3 to 7. The height of the plants, which indicates the plant biomass, varied from 4.5 cm to 80 cm in *Maffo* and *Desiree* respectively. The highest number of tubers (15) was observed in *Desiree*, in contrast to the *Synergie* collection, whose average number of tubers was 4 tubers. The heritability values ranged from 49% to 65%. A moderate heritability and high GAM were observed for AVT, TNT, and NTP. The Pearson correlation test between the agro-morphological traits observed showed a correlation between the variables studied. The differences observed in the different growth parameters in each of the collections can be explained by the effect of the collection on the vegetative growth of the individual plants and the yield of each collection.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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