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Morpho-Physiological Characterization of Potato (*Solanum Tuberosum*) Genotypes of the Andigenum and Phureja Group from the Working Collection of the Universidad De Nariño

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ABSTRACT: This study presents the morpho-physiological characterization of potato (*Solanum tuberosum*) genotypes from the Andigenum and Phureja groups, cultivated at the Nariño, Colombia. The research addresses the vital role of genetic diversity in agricultural sustainability and food security, highlighting the importance of genetic resources for crop improvement and ecosystem stability.

The study utilized a comprehensive morphological characterization based on both qualitative and quantitative descriptors to assess genetic variability within the university's potato collection. This approach allowed for the identification of duplicates, the enhancement of a morphological database, and insights into the genetic diversity of the collections. Using techniques like Multiple Correspondence Analysis (ACM) and Principal Component Analysis (PCA), distinct clusters of genotypes were identified, which were highly influenced by their ploidy levels.

Results indicated significant morphological variation between diploid Phureja and tetraploid Andigenum genotypes. Phureja genotypes showed greater similarity among themselves compared to the more diverse Andigenum group. This morphological diversity is importante for the identification of specific traits beneficial for breeding programs, such as resistance to environmental stresses and diseases.

The study underscores the importance of maintaining genetic diversity within potato germplasm collections, facilitating the selection of genotypes with desirable agronomic traits. The findings contribute significantly to the understanding of the genetic and morphological foundations necessary for the future genetic improvement of the potato, a staple food crop with profound implications for global food security. The geographic distribution of the genotypes also suggested a correlation between morphological traits and geographic locations, reinforcing the role of local adaptation in crop diversity and resilience.

KEYWORDS: Genetic Diversity, Agronomic Traits, Multivariate Analysis, Conservation Strategies and Ploidy Levels.

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INTRODUCTION

The potato crop (*Solanum tuberosum* L.) is native to the Andes of South America. This tuber is considered the most economically important tuber in the world and constitutes a food product that is grown in more than 100 countries and has grown in the global market due to its positive attributes, particularly for its high nutritional value and as a fundamental pillar for food security (Barandiarán, 2018). With a global production of more than 487 million tons per year in the last five years (FAOSTAT, 2018), potato ranks as the fifth most important crop in the world, after sugarcane, corn, wheat and rice. This crop grows in diverse soil types and climatic conditions and, despite its cultivated area remaining stable at around 19 million hectares since the 1990s, its overall productivity, which currently exceeds 19 tons ha-1, is steadily increasing.

Plant genetic resources are an invaluable heritage of humanity, and their loss is an irreversible process that threatens the stability of ecosystems, agricultural development, and food security in the world (Martínez, 1992). Therefore, it is necessary to preserve these resources through activities such as: characterization, collection, evaluation, regeneration, documentation, and exchange of seeds, thus avoiding the genetic erosion of many species. One of the principles of conservation is to maintain different individuals and achieve the maximum possible variability within the same species (Muñoz et al., 2012).

The genetic identity that living beings have to define them as unique is based on diversity among populations and within species. This diversity manifests differential responses in proportion to their genetic heterogeneity, and this principle is the methodological basis for conservation programs (Alba-Landa et al., 2008). To identify differences among individuals, there are tools that involve the use of statistical methods that group individuals with similar characteristics into certain categories, whether qualitative or quantitative (Ballesteros, 2011). These refer to multivariate methods used to make groupings based on data obtained through morphological characterization (Núñez-Colín & Escobedo-López, 2011).

On the other hand, phenotypic characterization is based on botanical morphology, which is the fundamental theory that maintains that the architecture and morphology of plants is the result of a process of adaptation of the species, because, in the processes of adaptation, there is a close relationship between the morphology of plants and their ecology. Thus, eco-morphology explores the interactions between the structure of organs and their environment. However, not all organ shapes can consistently describe a plant, and for this reason, characters known as descriptors or morphological markers must be chosen (Gómez, 2000).

Knowledge of genetic diversity facilitates the efficient use of germplasm, allows the identification and elimination of duplicates and helps in the establishment of core collections (Engels & Visser, 2007). Genetic diversity is the main input for the genetic improvement of a cultivated species; therefore, it is a prerequisite to increase yields and to stabilize production in the face of disease epidemics and fluctuating environmental conditions. Local and wild varieties are maintained in germplasm banks as genetic resources, however, their use in genetic improvement for yield has been limited (Bonierbale et al., 2004).

Morphological characterization is the first step in the description and classification of germplasm (Smith & Smith, 1989). Understanding morphological traits facilitates identification, selection of desirable attributes, design of new populations, transfer of their genes, and resistance to biotic and abiotic factors (Singh et al., 2014). In the characterization process, it is convenient to use traits with high heritability, therefore, little affected by the environment, which ensures that the genotype-environment interaction has a reduced effect on the variables that serve to characterize the different accessions. Variables that are affected by the environment are more commonly used for evaluation and require appropriate experimental designs to control for environmental effects and reduce experimental error.

In addition, descriptors should be associated with traits of high heritability and governed by few genes and low environmental influence, high taxonomic value, low complexity, and variation within the population (Engels, 1985).

In work with genetic resources, descriptors are encoded in so-called "descriptor states". The descriptor states are the different values that a descriptor can assume, which can be a numerical value, a scale, a code, or a qualifying adjective. For example, fruit colors or leaf shape (Carneiro, 2001). The descriptors of a species are selected on the basis of qualitative and quantitative characteristics, with prior knowledge of the variability of the characters within and between plants and may vary according to whether they are selected by plant breeders, botanists, geneticists or experts from other disciplines (Enriquez et al., 1991). It is relevant to consider botanical criteria, since morphological characters are selected independently of their genetic regulation (Furman et al., 1997).

However, it should be considered that for a characterization, the descriptor states should meet the following conditions: be easily observable, have a high discriminant action and low environmental influence (Barretta, 2001; Gómez, 2000). According to the above, through the collection of phenotypic information, the aim is to characterize the Phureja collection of the Universidad de Nariño, with the objective of identifying duplicates, completing a morphological database useful in genetic improvement works and to study the diversity and variability of the introductions that make up the collection.

Considering the above, this chapter presents the results of the morphological characterization of the genotypes of phureja (*Solanum tuberosum* group phureja and andigenum) that make up the working collection of the Universidad de Nariño and describes the variability of morphological characters based on a list of quantitative and qualitative descriptors for plant, stem, leaf, flower, and fruit.

MATERIALS AND METHODS

Location

The morphological characterization was carried out at the Experimental Botana Farm of the Universidad de Nariño, located in Corregimiento Botanilla, in the municipality of Pasto (Nariño) at an altitude of 2820 masl, 01°09'12"LN and 77°18'31"LO.

Plant material

We used 115 accessions of potato *Solanum tuberosum* group Phureja and Andigenum that make up the potato work collection of the Universidad de Nariño, of which 76 come from the Colombian Central Collection and 37 from the Universidad de Nariño. The germplasm used in this project has different ploidy levels. The 115 genotypes correspond to 57 accessions of the diploid potato group of the Phureja group, and 56 accessions belong to the Andigenum group (Supplementary Table 1).

Morphological descriptors

Based on the morphological descriptors described by the International Board for Plant Genetic Resources (Mackay et al. 1985) and those reported by the Universidad Nacional, Corpoica and CIP, a list of descriptors of qualitative and quantitative variables was constructed (Supplementary Table 2).

Morphological characterization was carried out on the basis of Huaman (2002) and Gómez (2000), who state that the information should be collected from plants propagated from tubers that are healthy and in full flowering (greater than 75%). All leaf descriptor data are recorded from organs located in the middle portion of the main stem. And the average values observed on at least two mature leaves are recorded.

The evaluations were carried out in a total of 10 replicates (10 plants for each accession). The mode and mean of qualitative and quantitative variables, respectively, were used in subsequent multivariate analyses.

Statistical analysis

The data corresponding to the qualitative variables were processed to eliminate those that were not representative for the analysis (no variation between categories). To determine if there was a significant association ($p<0.05$) between variables, contingency tables and chi-square tests were performed. After these analyses 31 categorical variables were used for Multiple Correspondence Analysis (MCA). On the other hand, quantitative variables were used to perform Principal Component Analysis (PCA). Variables were selected based on the Kaiser-Meyer-Olkin test (Costales et al., 2022). Descriptors that presented values lower than 0.5 were not considered in the subsequent analysis. Finally, a biplot graph was constructed to facilitate the interpretation of the results. From the coordinates of a general MCA of the evaluated variables, they were incorporated into the set of variables used in the PCA to perform a hierarchical clustering following the "Ward" method with all the evaluated genotypes. In addition, a correlation was made between the matrix of geographical distances of each genotype (obtained from latitude and longitude) and the matrix of Euclidean distances (obtained from morphological distances). The geographic relationship and morphological divergences and their degree of statistical significance were determined by Pearson correlation analysis. The procedures were performed using the statistical packages of the R v4.2.0 software (R Core Team, 2020) and the plots were made using the ggplot2 library (Wickham, 2016).

RESULTS

The ploidy level of genotypes has a significant impact on the phenotypic characteristics of potato materials, which influences the formation of clusters generated by multivariate analyses (Figure 1). Data dimensionality reduction techniques revealed that cytogenetic differences in germplasm generate significant patterns of clustering and separation of potato accessions according to their quantitative and qualitative characteristics (Figure 1).

The MCA results revealed a clear separation between diploid and tetraploid materials (Figure 1A). Phureja-type genotypes clustered more closely in the space of the two dimensions (18.8% of the cumulative variance), suggesting that they share common qualitative descriptors and fewer variables (Figure 1A). Thus, there is greater category variability among potato genotypes in the Andigenum group (Figure 1A). In fact, a group of genotypes tend to be concentrated at the right end of the dimension that represents the highest percentage of the total variability (Figure 1A). These materials are characterized by the absence of reproductive structures, and when present, the calyx lobes are gently arched, and the pistil and stamen morphology is of normal type (Figure 2A). Three characteristics most represent the composition of the second dimension, including the level of ploidy (phloidy and andigena) and the absence of pairs of secondary lateral leaflets - NPSL (Figure 2B). Thus, the absence of these leaf structures may be a morphological indicator of increased ploidy level of potato materials (Figure 2B). Although three phureja-type genotypes (UNR57, UNR65, UNR39) showed positive values in the second dimension (NPSL-absent), this change in leaf architecture could be an initial indicator of the increase in the number of homologous chromosomes. Additionally, the perceptual map of the variables demonstrates the high degree of association between ploidy level and NPSL categories (Supplementary Figure 2A).

On the other hand, the two principal dimensions of the PCA, which together explain 60.6% of the cumulative variance, reveal significant patterns on the population structure of potato genotypes (Figure 1B). The dominant relationships representing the principal component (46.7%) also represent the attributes that characterize potato materials by their ploidy level among the phureja and andigenum potato groups (Figure 1B). Thus, the genome size of potato genotypes could be positively influencing characteristics such as number of flowers and branches per inflorescence, peduncle length, flowering time and physiological maturity (Figure 3A). In addition, these variables that were the most representative also showed high positive correlation values, with the exception of time to physiological maturity (Supplementary Figure 2B). This last trait may be controlled by other factors in addition to ploidy level, which seems to be negatively associated with the other morphological attributes evaluated (Supplementary Figure 2B). The second component of PCA is mainly represented by canopy cover, however, this trait is not particular to phureja or andigena potato genotypes (Figure 3B). Nevertheless, the increase in the number of homologous chromosomes in potato germplasm has complex effects mainly on reproductive and physiological attributes (Figure 3), the molecular mechanisms of which are so far unknown.

The dendogram revealed three clearly defined groups that were grouped by their morpho-physiological characters (Figure 4). The phenotypic characteristics are influenced by the ploidy level of the materials. The group with the highest number of individuals corresponds to the set of exclusively andigenum materials with 60 accessions (Figure 4). The second group is predominantly phurejas with 40 accessions, of which two genotypes (UNR113 and UNR135) are classified in their passport as andigenum (Figure 4). A third group, which is more distant from the other two, is represented by 14 andigena-type genotypes and 1 phureja-type genotype (Figure 4). This group of genotypes is characterized by the absence of reproductive structures (Figure 1A-2A) and are valuable germplasm to further investigate their karyotypic structure. On the other hand, the formation of independent subgroups of the genotypes of each type could also indicate a measure of intragroup diversity (Figure 4). Values of similarity or differences between individuals provide valuable information about possible genetic distances.

The separation of the set of genotypes by their morpho-physiological attributes may reflect differences in terms of geographic origin (Figure 5). Pearson's correlation between the Euclidean and geographic distance matrices resulted in a coefficient of 0.37 (Figure 5). Although not extremely high, the correlation coefficient reveals a positive and significant relationship ((p<2.2^{-16}) between spatial distances and distances based on phenotypic attributes.

DISCUSSION

Multivariate analysis provides a deeper understanding of the structure and variability of the potato genotype collection at the Universidad de Nariño. The results demonstrate the impact of ploidy level on phenotypic characteristics of potato germplasm. The groupings based on MCA and PCA results support the idea that cytogenetic differences play a fundamental role in the phenotypic diversity of this species. In addition, there is ample evidence demonstrating the effects of ploidy level on morphological and physiological characteristics of potato (Kyriakidou et al., 2020; Ortiz & Mihovilovich, 2020) and other plant species(Neill & Contreras, 2022; Revathi & Beena, 2022; Souza et al., 2022).

Phureja-type genotypes were more clustered in the two-dimensional space of the MCL compared to plants of the andigenum group. Andigena potato populations tended to be more morphologically diverse than phureja populations, considering the group of categorical descriptors. These results are in agreement with molecular diversity studies, which reveal that andigena plants present greater genetic variability compared to diploid populations (Berdugo-Cely et al., 2017).

Quantitative and qualitative attributes were highlighted as the main contributors to the characterization of phureja and andigena genotypes. The absence of reproductive structures was the most informative characteristic for discriminating a group of 15 andigena potato genotypes. The absence of flowers or fruits in the potato crop may be of great agronomic value. The removal of nutrient sink organs can have a positive effect on the redistribution of photoassimilates in the plant. Agronomic practices such as flower removal contribute to substantial increases in the number, weight and quality of potato tubers(Gebregwergis et al., 2019, 2021; Jansky & Thompson, 1990). The same competition for the products of photosynthesis was recorded in *Helianthus tuberosus* plants (Gao et al., 2020). Control of the relationship between source and sink organs is an important feature of agronomic management and breeding. Knowledge of the genetic basis of the absence of reproductive structures may have direct implications for potato breeding, as well as contribute to knowledge about the genetic control of plant development.

On the other hand, the morphological attribute most associated with andigena potatoes was the absence of pairs of secondary lateral leaflets on the petioles. Apparently, the formation of these leaf structures is repressed due to the increase in genome size in potato. In favor of this hypothesis, experiments by Sree et al. (1983) show that increasing the ploidy level in potato causes the formation of very poorly developed or even absent secondary leaflets. In addition, haploid plants obtained from interspecific hybrids showed the presence of small secondary leaflets on potato leaves (Dolnicar & Bohanec, 2000). These studies suggest effects of individual minor genes that could favor their expression in the haploid state. However, these results differ from studies showing that polyploid plants produce secondary leaflets. Heterotic effects were expressed by hexaploid and tetraploid interspecific hybrids, which generally produce a greater number of primary and secondary leaflets (Cardi, 1998). In addition, secondary lateral leaflets have been important characters in the classification of cultivated potato populations for more than two decades. The absence of secondary leaflets is a characteristic feature of potato groups such as Ajanhuiri, Curtilobum, Juzepczukii, generally absent in groups such as Chilotanum, and may be present or absent in groups such as Andigena, Chaucha, Phureja and Stenotomum (Huamán & Spooner, 2002). There is no recent literature to ensure that this attribute is a particular characteristic of Andigena population, and the underlying causes of this phenotypic trait are a complete enigma.

The increase of homologous chromosomes in potato plants has a direct effect on the increase of flowering time and physiological maturity. Generally, plants of the tuberosum group flower only when grown under long days (Ghislain & Douches, 2020). Some early maturing genotypes do not even flower under any conditions (Ghislain & Douches, 2020). On the other hand, andigena potato is characterized by a later vegetative period than diploid cultivars(Ignacio - Cárdenas et al., 2022). Recent studies seek to dissect the genetic control of this important attribute. On the one hand, interspecific crosses suggest that physiological maturity is governed by minor genes that were carried by *S. phureja* genotypes(Ruiz et al., 2022). While other authors claim that harvest time is controlled by a dominant allele with additive effects (Ortiz & Mihovilovich, 2020). Recent findings in other crops claim that plant development time may also be associated with whole genome size. In corn, the increase in DNA content causes a longer delay in phenotypic development, probably due to an increase in the timing of the S-phase of the cell cycle (DNA synthesis), consequently in the rate of cell division and tissue growth(Jian et al., 2017). We do not rule out that andigenic plants have a longer cell cycle and have an effect on the periods of phenotypic stages.

Variables that had inverse correlation to the time to physiological maturity but characterize the andigenic populations include peduncle length, number of flowers per inflorescence, and number of inflorescences per raceme. Superior performance in these traits is due to the masking of deleterious genes in the andigenic potato crop (Blasio et al., 2022). The phureja plant group has fairly stable had characteristics very similar to the [sic]

The phureja plant group exhibits remarkable cohesion in terms of clustering, with most genotypes forming a distinct cluster. However, the presence of the Phu-UNR18 genotypes in the andigena group cluster suggests that they are duplicates of the And-UNR145 and And-UNR146 genotypes, due to the similarity in their morphological profiles (Figure 4). Similar results were obtained with the genotypes And-UNR113 and And-UNR135, which were clustered with germplasm from the phureja group. This finding raises questions about the true diversity of these materials and their taxonomic assignment. No significant genetic distance could be established between these apparently close genotypes, according to the criteria evaluated in the present study. Likewise, a coincidence in the geographic coordinates of these materials was observed (Supplementary Table 1), which could indicate their common origin or a similar distribution history in a geographic context of the Nariño region. These findings highlight the need for a more detailed and comprehensive analysis to clarify the genetic relationship contributing to the phenotypic discrepancy between these genotypes, as well as to elucidate their taxonomy and molecular diversity.

Overall, a positive and significant relationship was observed between geographic distances and Euclidean distances among the 115 potato genotypes. This finding highlights the influence of geographic location on phenotypic and genetic variation in populations. genotypes that are genetically similar also tend to have geographic proximity. The results demonstrate that increasing the geographic distance between genotypes also increases the distance their divergence in terms of phenotypic characteristics. This result is consistent with the concept of geographic genetic structure, where populations that are closer geographically tend to be more genetically similar due to factors such as seed propagation, limited pollen dispersal, and local adaptation to environmental conditions (Aksoy et al., 2021; Rachappanavar, 2023; Rio & Bamberg, 2021; Salimi et al., 2016). These results also have important implications for potato conservation and breeding, as they highlight the importance of considering geographic variation when selecting genotypes for breeding and conservation programs, in order to preserve genetic and adaptive diversity in potato populations.

Figures

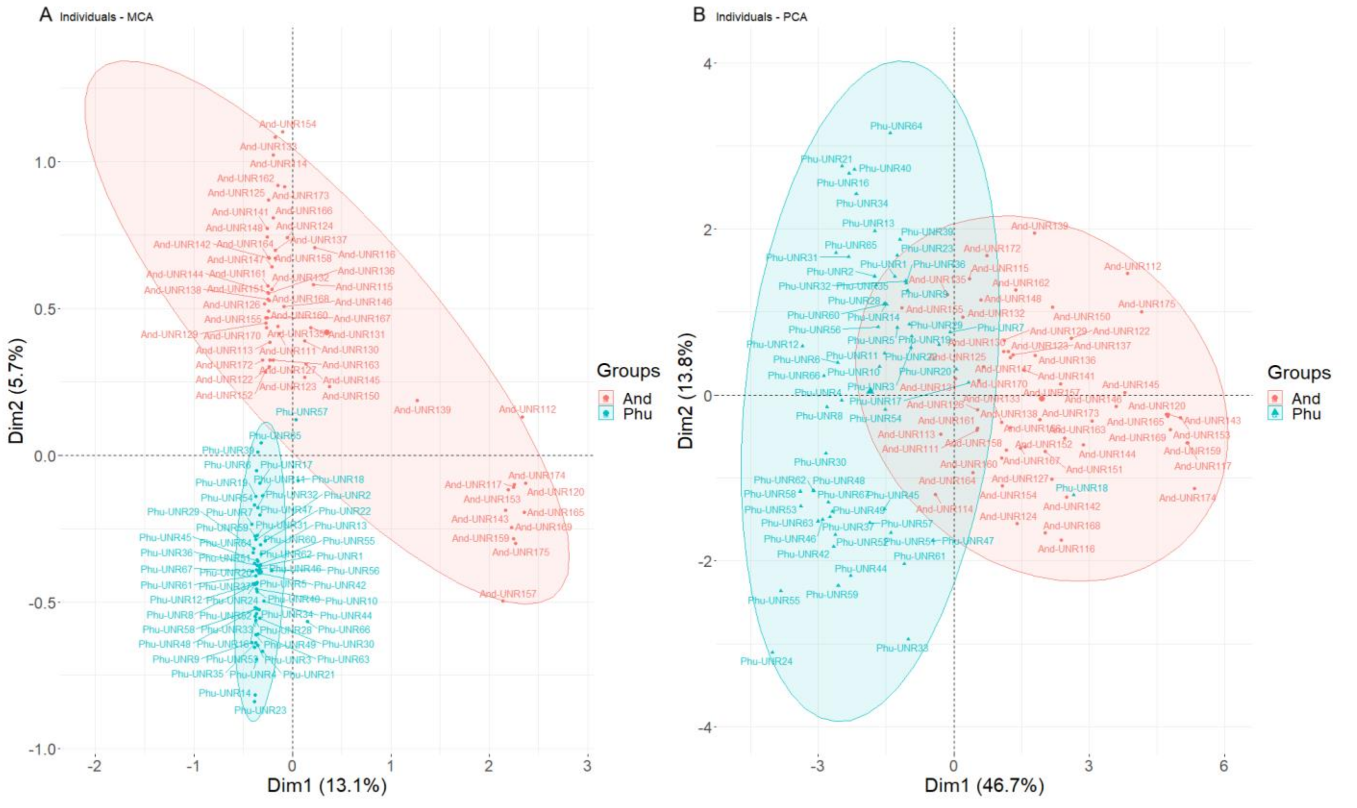


Figure 1. Multivariate analysis of the qualitative and quantitative descriptors of the 115 genotypes evaluated (A) Multiple Correspondence Analysis (B) Principal Component Analysis.

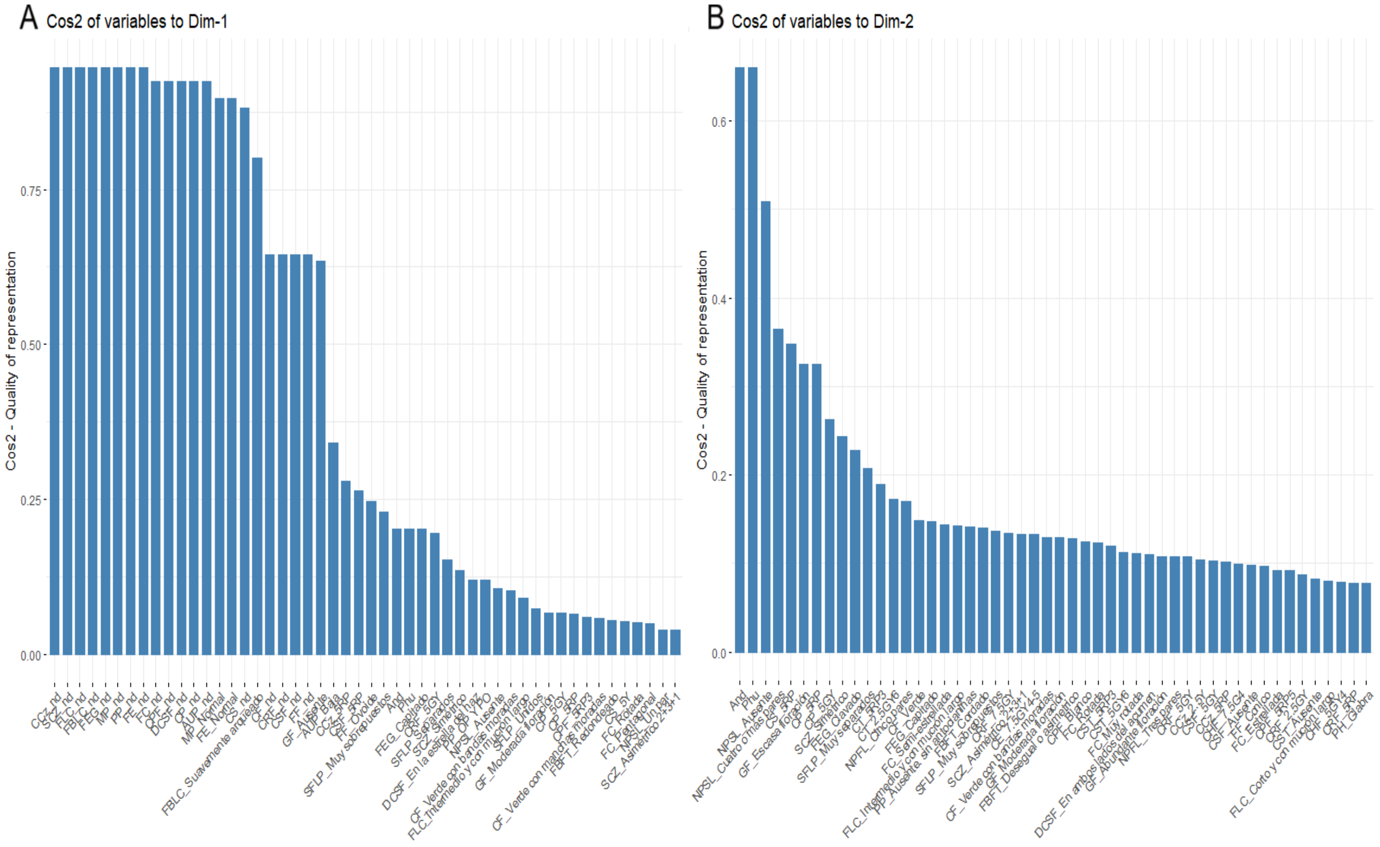


Figure 2. Quality of representation (Cos2) of the variables in the Multiple Correspondence Analysis. (A) The 50 most representative variables for the first dimension. (B) The 50 most representative variables for the second dimension.

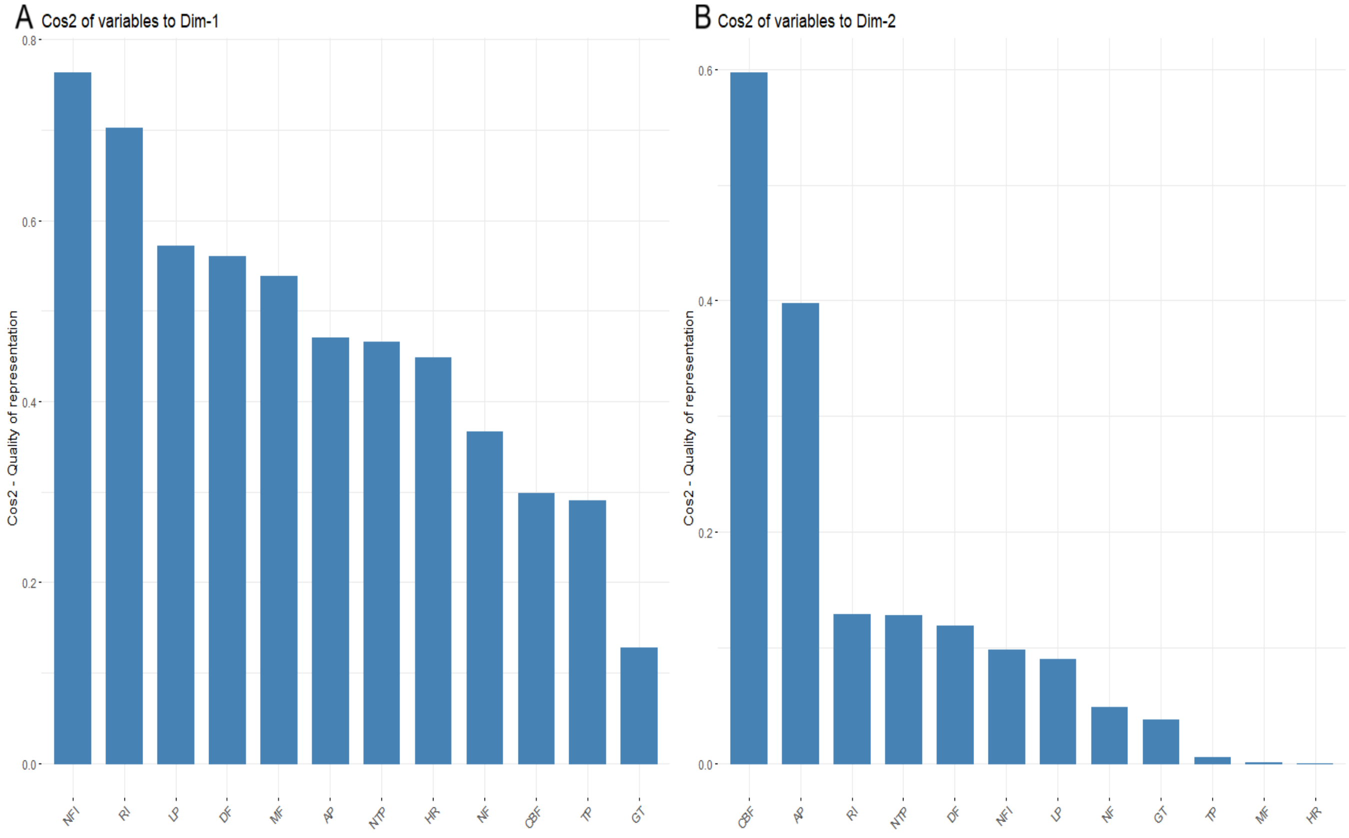


Figure 3. Quality of representation (Cos2) of the variables in the Principal Component Analysis. (A) The most representative variables for the first dimension. (B) The most representative variables for the second dimension.

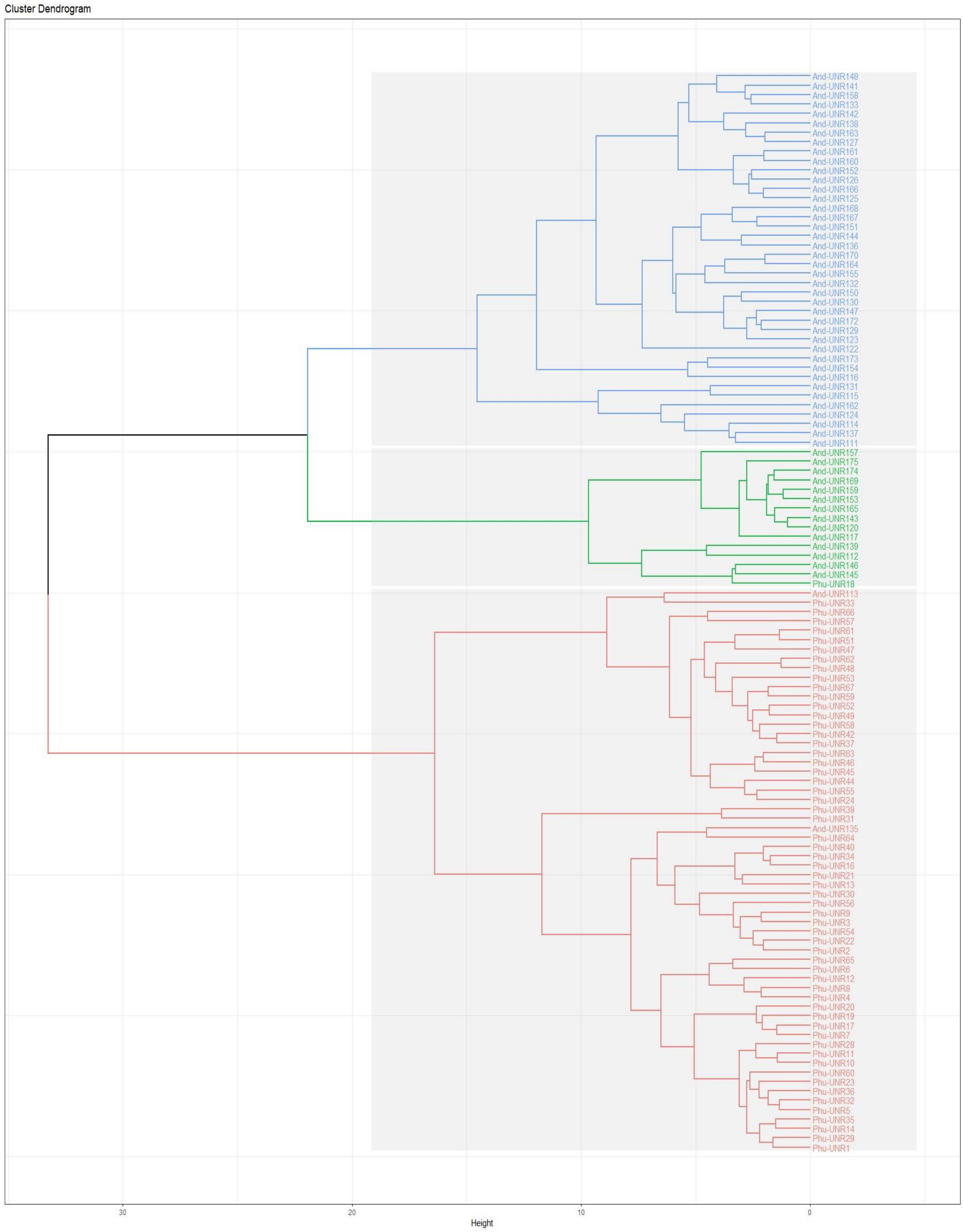


Figure 4 Hierarchical clustering of the 115 genotypes evaluated using the Euclidean distances obtained from the Principal Component Analysis and the coordinates obtained from the Multiple Correspondence Analysis. Three distinct groups were formed according to the distance between genotypes.

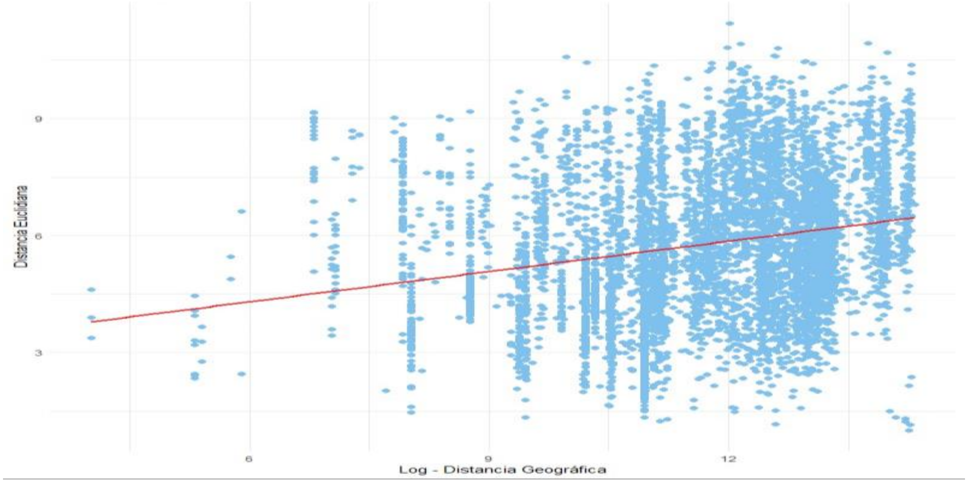
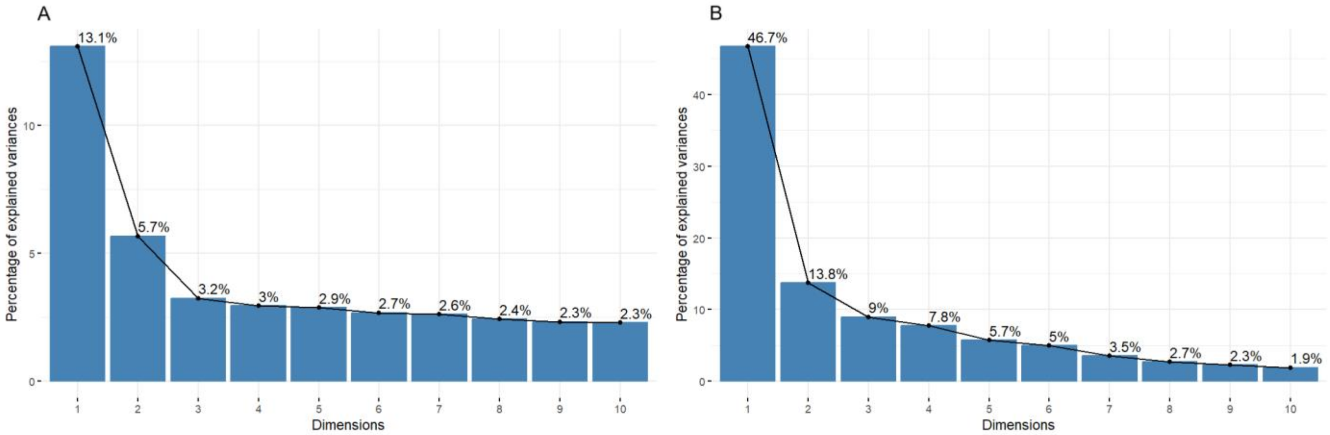
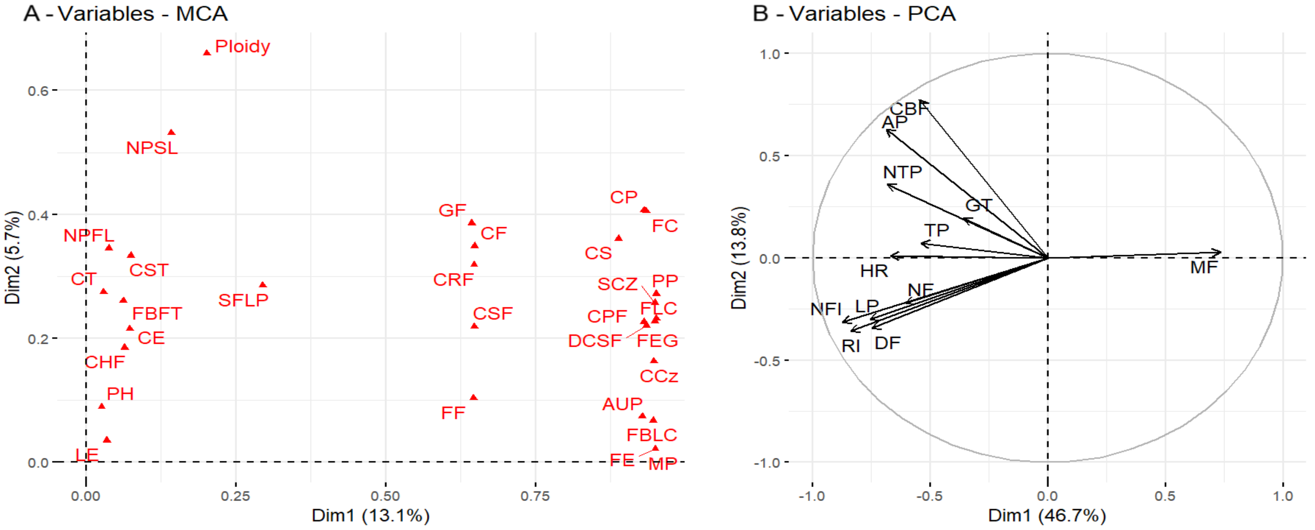


Figure 5. Correlation between the values of the geographic distance matrix and the values of the Euclidean distance matrix. The geographic distance values were transformed using the logarithm (*log*) function. There is a positive (0.37) and significant ($p<2.2^{-16}$) relationship between the two variables, according to Pearson's correlation test.

Supplementary Material



Supplementary Figure 1. Proportion of the total variance explained by the dimensions of the Multiple Correspondence Analysis (MCA) and Principal Component Analysis (PCA). (A) Percentage of variance explained by the first 10 MCA dimensions. (B) Percentage of variance explained by the first 10 dimensions of the PCA.



Supplementary Figure 2. Relationship between variables in the space of the two main dimensions of the Multiple Correspondence Analysis (A) and the Principal Component Analysis (B).

Supplementary Table 1. Passport data of 115 creole potato genotypes (*Solanum tuberosum* phureja group and Andigenum).

ID	Latitude	Longitude	Group	Country (Department)	Municipality	Vereda	Altitude (masl)	Donor
Phu-UNR1	0°56´14,28"	77°46´56,75"	Phureja	Colombia (Nariño)	Cumbal	Panam	3089	Maximil Quilisma
Phu-UNR2	0°56´14,28"	77°46´56,75"	Phureja	Colombia (Nariño)	Cumbal	Panam	3090	Maximil Quilisma
Phu-UNR3	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2710	C.I. Corpoica
Phu-UNR4	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2712	C.I. Corpoica Obonuco
Phu-UNR5	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2713	C.I. Corpoica Obonuco
Phu-UNR6	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2714	C.I. Corpoica Obonuco
Phu-UNR7	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2715	C.I. Corpoica Obonuco
Phu-UNR8	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2716	C.I. Corpoica Obonuco
Phu-UNR9	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2717	C.I. Corpoica Obonuco
Phu-UNR10	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2718	C.I. Corpoica Obonuco
Phu-UNR11	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2719	C.I. Corpoica Obonuco
Phu-UNR12	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2720	C.I. Corpoica Obonuco
Phu-UNR13	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2721	C.I. Corpoica Obonuco
Phu-UNR14	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2722	C.I. Corpoica Obonuco
Phu-UNR16	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2724	C.I. Corpoica Obonuco
Phu-UNR17	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2727	C.I. Corpoica Obonuco
Phu-UNR18	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2728	C.I. Corpoica Obonuco

Phu-UNR19	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2730	C.I. Corpoica Obonuco
Phu-UNR20	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2732	C.I. Corpoica Obonuco
Phu-UNR21	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2733	C.I. Corpoica Obonuco
Phu-UNR22	0°56´14,28"	77°46´56,75"	Phureja	Colombia (Nariño)	Cumbal	Panam	3090	Maximil Quilisma
Phu-UNR23	0°56´14,28"	77°46´56,75"	Phureja	Colombia (Nariño)	Cumbal	Panam	3090	Maximil Quilisma
Phu-UNR24	0°55´55.52"	77°50´22,35"	Phureja	Colombia (Nariño)	Cumbal	Laguna	3109	Juan Carlos Cumbal
Phu-UNR28	0°56´14,28"	77°46´56,75"	Phureja	Colombia (Nariño)	Cumbal	Panam	3090	Maximil Quilisma
Phu-UNR29	0°56´14,28"	77°46´56,75"	Phureja	Colombia (Nariño)	Cumbal	Panam	3090	Maximil Quilisma
Phu-UNR30	0°56´14,28"	77°46´56,75"	Phureja	Colombia (Nariño)	Cumbal	Panam	3090	Maximil Quilisma
Phu-UNR31	0°56´14,28"	77°46´56,75"	Phureja	Colombia (Nariño)	Cumbal	Panam	3090	Maximil Quilisma
Phu-UNR32	0°56´14,28"	77°46´56,75"	Phureja	Colombia (Nariño)	Cumbal	Panam	3090	Maximil Quilisma
Phu-UNR33	0°56´14,28"	77°46´56,75"	Phureja	Colombia (Nariño)	Cumbal	Panam	3090	Maximil Quilisma
Phu-UNR34	0°56´14,28"	77°46´56,75"	Phureja	Colombia (Nariño)	Cumbal	Panam	3090	Maximil Quilisma
Phu-UNR35	0°56´14,28"	77°46´56,75"	Phureja	Colombia (Nariño)	Cumbal	Panam	3090	Maximil Quilisma
Phu-UNR36	0°56´14,28"	77°46´56,75"	Phureja	Colombia (Nariño)	Cumbal	Panam	3090	Maximil Quilisma
Phu-UNR37	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2711	C.I. Corpoica Obonuco
Phu-UNR39	0°56´14,28"	77°46´56,75"	Phureja	Colombia (Nariño)	Cumbal	Panam	3090	Maximil Quilisma
Phu-UNR40	0°56´14,28"	77°46´56,75"	Phureja	Colombia (Nariño)	Cumbal	Panam	3090	Maximil Quilisma
Phu-UNR42	1°05´47,4"	77°16´12.53"	Phureja	Colombia (Nariño)	Pasto	Jurado	2806	Silvio Gelud Rosero
Phu-UNR44	1°07´1,91"	77°36´24.44"	Phureja	Colombia (Nariño)	Guachucal	Santa Isabell	3103	Hector Guerrero
Phu-UNR45	00°50´55,79"	77°30´25.51"	Phureja	Colombia (Nariño)	Cordoba	El Salado	2897	Sigifredo Cuaran
Phu-UNR46	0°55´55.52"	77°50´22,35"	Phureja	Colombia (Nariño)	Cumbal	Laguna	3109	Juan Carlos Cumbal
Phu-UNR47	00°50´22,79"	77°30´25.98"	Phureja	Colombia (Nariño)	Cumbal	Laguna	3109	Juan Carlos Cumbal

Phu-UNR48	0°55´55.52"	77°50´22,35"	Phureja	Colombia (Nariño)	Cordoba	El Salado	2890	Manuel Valenzuela
Phu-UNR49	00°50´55,79"	77°30´25.51"	Phureja	Colombia (Nariño)	Cordoba	El Salado	2897	Sigifredo Cuaran
Phu-UNR51	1°07´1,91"	77°36´24.44"	Phureja	Colombia (Nariño)	Guachucal	Santa Isabell	3103	Hector Guerrero
Phu-UNR52	1°07´1,91"	77°36´24.44"	Phureja	Colombia (Nariño)	Guachucal	Santa Isabell	3103	Hector Guerrero
Phu-UNR53	1°07´1,06"	77°10´29,29"	Phureja	Colombia (Nariño)	Pasto	El Encano	2840	Jesus Reyes Jojoa
Phu-UNR54	1°07´1,06"	77°10´29,29"	Phureja	Colombia (Nariño)	Pasto	El Encano	2840	Jesus Reyes Jojoa
Phu-UNR55	1°05´11,81"	77°10´2,34"	Phureja	Colombia (Nariño)	Pasto	El Encano	2894	Roberto Jojoa
Phu-UNR56	1°07´1,06"	77°10´29,29"	Phureja	Colombia (Nariño)	Pasto	El Encano	2840	Jesus Reyes Jojoa
Phu-UNR57	0°50´25,79"	77°30´24.29"	Phureja	Colombia (Nariño)	Cordoba	Tandaup	2905	Guillermo Caipe
Phu-UNR58	1°05´47,4"	77°16´12.53"	Phureja	Colombia (Nariño)	Pasto	Jurado	2806	Silvio Gelud Rosero
Phu-UNR59	0°50´25,79"	77°30´24.29"	Phureja	Colombia (Nariño)	Cordoba	Tandaup	2905	Guillermo Caipe
Phu-UNR60	1°05´47,4"	77°16´12.53"	Phureja	Colombia (Nariño)	Pasto	Jurado	2806	Silvio Gelud Rosero
Phu-UNR61	00°50´55,79"	77°30´25.51"	Phureja	Colombia (Nariño)	Cordoba	El Salado	2897	Sigifredo Cuaran
Phu-UNR62	1°05´11,81"	77°10´2,34"	Phureja	Colombia (Nariño)	Pasto	El Encano	2894	Roberto Jojoa
Phu-UNR63	0°50´25,79"	77°30´24.29"	Phureja	Colombia (Nariño)	Cordoba	Tandaup	2905	Guillermo Caipe
Phu-UNR64	1°05´11,81"	77°10´2,34"	Phureja	Colombia (Nariño)	Pasto	El Encano	2894	Roberto Jojoa
Phu-UNR65	1°12’52.48”	77°16’41.22”	Phureja	Colombia (Nariño)	Pasto	Obonuco	2710	C.I. Corpoica Obonuco
Phu-UNR66	0°55´55.52"	77°50´22,35"	Phureja	Colombia (Nariño)	Cumbal	Laguna	3109	Juan Carlos Cumbal
Phu-UNR67	0°55´55.52"	77°50´22,35"	Phureja	Colombia (Nariño)	Cumbal	Laguna	3109	Juan Carlos Cumbal
And-UNR111	16°29"33"	68°07"20"	Andigenum	Bolivia (La Paz)	No data	No data	3600	C.I. Corpoica Tibaitata
And-UNR112	16°29"57"	68°02"57"	Andigenum	Bolivia (No data)	No data	No data	3800	C.I. Corpoica Tibaitata

And-UNR113	16°01"12"	68°42"02"	Andigenum	Bolivia (Potosí)	No data	Estación Experimental De Belén	3500	C.I. Corpoica Tibaitata
And-UNR114	19°39"09"	65°17"16"	Andigenum	Bolivia (Potosí)	Saavedra	Chinoli	3500	C.I. Corpoica Tibaitata
And-UNR115	15°48"17"	70°01"58"	Andigenum	Perú (Puno)	No data	La Huerta	4000	C.I. Corpoica Tibaitata
And-UNR116	8°05"47"	78°08"46"	Andigenum	Perú (La Libertad)	Santiago de chuco	Cachicadan	2700	C.I. Corpoica Tibaitata
And-UNR117	7°09"19"	78°31"09"	Andigenum	Perú (Cajamarca)	No data	Local Market	3000	C.I. Corpoica Tibaitata
And-UNR120	21°31"58"	64°44"03"	Andigenum	Bolivia (Torija)	No data	Local Market	1985	C.I. Corpoica Tibaitata
And-UNR122	13°03"04"	76°51"02"	Andigenum	Perú (Huancavelica)	No data	Taya Caja Pampas-Marcopata	3350	C.I. Corpoica Tibaitata
And-UNR123	11°26"08"	74°08"31"	Andigenum	Perú (Ayacucho)	No data	Quinua Km 13	3320	C.I. Corpoica Tibaitata
And-UNR124	12°44"06"	74°39"58"	Andigenum	Perú (Huancavelica)	Paucara	No data	3940	C.I. Corpoica Tibaitata
And-UNR125	12°44"06"	74°39"58"	Andigenum	Perú (Huancavelica)	Paucara	No data	3940	C.I. Corpoica Tibaitata
And-UNR126	12°43"23"	74°40"01"	Andigenum	Perú (Huancavelica)	No data	No data	4100	C.I. Corpoica Tibaitata
And-UNR127	10°29"13"	76°30"51"	Andigenum	Perú (Pasco)	Daniel alcides carrion	Yaua Huaca	3400	C.I. Corpoica Tibaitata
And-UNR129	5°38"00"	72°54"59"	Andigenum	Colombia (Boyacá)	Sogamoso	Primera Chorrera	3300	C.I. Corpoica Tibaitata
And-UNR130	4°31"50"	75°38"25"	Andigenum	Colombia (Quindío)	Calarcá (from nariño)	Local Market	1619	C.I. Corpoica Tibaitata
And-UNR131	4°31"50"	75°38"25"	Andigenum	Colombia (Quindío)	Calarcá (from nariño)	No data	1619	C.I. Corpoica Tibaitata
And-UNR132	5°37"00"	72°52"00"	Andigenum	Colombia (Boyacá)	Sogamoso	Las Cintas	3380	C.I. Corpoica Tibaitata
And-UNR133	5°34"19"	72°49"59"	Andigenum	Colombia (Boyacá)	Aquitania	Valle De Toquilla	3085	C.I. Corpoica Tibaitata

And-UNR135	6°19"04"	72°33"35"	Andigenum	Colombia (Boyacá)	Boavita	Local Market De La Uvita	2220	C.I. Corpoica Tibaitata
And-UNR136	6°22"59"	72°27"17"	Andigenum	Colombia (Boyacá)	El cocuy	El Carrizal	3150	C.I. Corpoica Tibaitata
And-UNR137	6°33"10"	72°29"58"	Andigenum	Colombia (Boyacá)	Chiscas	El Rinconcito	3000	C.I. Corpoica Tibaitata
And-UNR138	7°12"15"	72°45"25"	Andigenum	Colombia (Norte De Santander)	Silos	Tutepa (Km 2 Laguna De Chitaga)	2450	C.I. Corpoica Tibaitata
And-UNR139	6°58"21"	72°50"54"	Andigenum	Colombia (Santander)	Guaca	Camara	2420	C.I. Corpoica Tibaitata
And-UNR141	0°49"50"	77°38"22"	Andigenum	Colombia (Nariño)	Ipiales	Teques	3200	C.I. Corpoica Tibaitata
And-UNR142	0°49"50"	77°38"22"	Andigenum	Colombia (Nariño)	Ipiales	Teques	3200	C.I. Corpoica Tibaitata
And-UNR143	1°11"48"	77°16"16"	Andigenum	Colombia (Nariño)	Pasto	Local Market	3250	C.I. Corpoica Tibaitata
And-UNR144	0°55"10"	77°49"36"	Andigenum	Colombia (Nariño)	Cumbal	Tasma 3 Km from Cumbal, Road to La Laguna	3200	C.I. Corpoica Tibaitata
And-UNR145	1°11"58"	77°18"09"	Andigenum	Colombia (Nariño)	Pasto	Granja De Obonuco	2800	C.I. Corpoica Tibaitata
And-UNR146	1°11"58"	77°18"09"	Andigenum	Colombia (Nariño)	Pasto	Granja De Obonuco	2800	C.I. Corpoica Tibaitata
And-UNR147	2°30"42"	76°17"22"	Andigenum	Colombia (Nariño)	Popayán	Malvaza	1760	C.I. Corpoica Tibaitata
And-UNR148	2°26"49"	76°36"10"	Andigenum	Colombia (Cauca)	Popayán	Local Market	1760	C.I. Corpoica Tibaitata
And-UNR150	2°30"35"	76°24"05"	Andigenum	Colombia (Cauca)	Totoro	Road to San Pedro	3220	C.I. Corpoica Tibaitata
And-UNR151	2°01"56"	76°40"21"	Andigenum	Colombia (Cauca)	La vega	Guachicono	2200	C.I. Corpoica Obonuco
And-UNR152	1°54"00"	76°40"19"	Andigenum	Colombia (Cauca)	San sebastián	Corregimiento Valencia	2900	C.I. Corpoica Tibaitata
And-UNR153	1°54"00"	76°40"19"	Andigenum	Colombia (Cauca)	San sebastián	Corregimiento Valencia	2900	C.I. Corpoica Tibaitata

And-UNR154	2°33"13"	76°12"35"	Andigenum	Colombia (Cauca)	Silvia	Paramo De Las Delicias	3000	C.I. Corpoica Tibaitata
And-UNR155	5°11"46"	76°53"11"	Andigenum	Colombia (Cundinamarca)	Tausa	Km 24 road from Zipaquira to San Calletano	3380	C.I. Corpoica Tibaitata
And-UNR157	5°21"59"	73°31"16"	Andigenum	Colombia (Boyacá)	Ventaquemada	Puente De Piedra/ Old Road to Tunja	2880	C.I. Corpoica Tibaitata
And-UNR158	4°30"32"	74°06"50"	Andigenum	Colombia (Cundinamarca)	Usme	Las Mercedes/Road to Paramo Del Sumapaz	3350	C.I. Corpoica Tibaitata
And-UNR159	4°30"32"	74°06"50"	Andigenum	Colombia (Cundinamarca)	Usme	Las Mercedes/Road to Paramo Del Sumapaz	3350	C.I. Corpoica Tibaitata
And-UNR160	4°24"21"	73°56"47"	Andigenum	Colombia (Cundinamarca)	Caqueza	From De Une	1840	C.I. Corpoica Tibaitata
And-UNR161	4°20"20"	73°56"20"	Andigenum	Colombia (Cundinamarca)	Fosca	La Placita	1840	C.I. Corpoica Tibaitata
And-UNR162	5°04"19"	75°31"27"	Andigenum	Colombia (Caldas)	Manizales	Local Market	2180	C.I. Corpoica Tibaitata
And-UNR163	5°45"42"	74°27"53"	Andigenum	Colombia (Cundinamarca)	Anolaima	No data	1800	C.I. Corpoica Tibaitata
And-UNR164	1°09"57"	77°08"21"	Andigenum	Colombia (Nariño)	El encano	San José	2820	C.I. Corpoica Tibaitata
And-UNR165	1°05"05"	77°35"39"	Andigenum	Colombia (Nariño)	Tuquerres	Corregimiento Pinzón	3000	C.I. Corpoica Tibaitata
And-UNR166	0°57"27"	77°46"22"	Andigenum	Colombia (Nariño)	Cumbal	Laguna De San Diego	3430	C.I. Corpoica Tibaitata
And-UNR167	0°49"26"	77°38"31"	Andigenum	Colombia (Nariño)	Ipiales	Quitiaques	3200	C.I. Corpoica Tibaitata
And-UNR168	3°32"20"	76°17"51"	Andigenum	Colombia (Valle Del Cauca)	Palmira	Km 44 Road to Ataco	2900	C.I. Corpoica Tibaitata
And-UNR169	1°54"00"	76°40"19"	Andigenum	Colombia (Cauca)	No data	Corregimiento De Valencia	2930	C.I. Corpoica Tibaitata

And-UNR170	5°56"51"	75°18"28"	Andigenum	Colombia (Antioquia)	La unión	San Juan	2475	C.I. Corpoica Tibaitata
And-UNR172	6°01"18"	75°25"55"	Andigenum	Colombia (Antioquia)	La ceja	Local Market	2110	C.I. Corpoica Tibaitata
And-UNR173	1°42"32"	78°38"42"	Andigenum	Ecuador (No data)	Chuina	San Luis	2200	C.I. Corpoica Tibaitata
And-UNR174	6°27"08"	75°32"33"	Andigenum	Colombia (Antioquia)	San pedro	El Espinal	2570	C.I. Corpoica Tibaitata
And-UNR175	1°11"58"	77°18"09"	Andigenum	Colombia (Nariño)	Pasto	Obonuco Experimental Farm	3000	C.I. Corpoica Tibaitata

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