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Common bean (*Phaseolus vulgaris*) mulatinho type accessions conserved *ex situ* in Brazil

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ABSTRACT. Conservation of seeds *ex situ* is an important strategy for maintaining genetic resources. Mulatinho type common beans are widely cultivated and consumed in regions with extreme climatic conditions with semi-arid characteristics, including low fertility soils, and a dry and hot climate, such as in northern Minas Gerais state and the northeast region of Brazil. This bean type also has socio-economic importance, as a protein source for the food security of families. Part of the harvest is consumed and another part is selected as seed and stored for the next crop. Our objective was to create a reduced collection ensuring the conservation of distinct alleles , based on information on morphologic, agronomic, and ecogeographic characteristics to help support *ex situ* and *on farm* seed conservation programs. Two greenhouse studies were conducted at the Embrapa facility, located in Santo Antônio de Goiás, Brazil. Morphologic and agronomic descriptors, both qualitative and quantitative, were transformed into binary variables through the creation of fictitious variables. Descriptors were used to estimate the coefficient of similarity between two accessions and obtain the dissimilarity distance between the semi-partial correlation squared values. Experiment I was comprised of genetic material from 745 accessions of common beans and was planted in pots with three plants for each accession. In Experiment II, 240 accessions were selected from Experiment I, using four pots with three plants for each accession. The phenotypic data in this reduced group showed increased phenotypic dissimilarity, contributing information for research in plant breeding and for farmers who may need seeds. The mulatinho type common beans types can be reduced to 96 accessions, maintaining the conservation of distinct alleles, with a significantly higher mean number of pods and seeds, and of plant mass, compared to the initial collection of 745 accessions.

Key words: *Phaseolus vulgaris*; Genetic variability; Conservation

INTRODUCTION

The growing conditions of common beans (*Phaseolus vulgaris*) are characterized by high biotic and abiotic risks, which contribute to low yields, since it is one of the annual crops that is most sensitive to climatic adversities and pests (Assefa et al., 2019). Because common beans are often grown on small farms with little access to technology, the farmers normally do not use improved seeds, and the genetic material is the result of the year after year production, in which farmers select the materials of interest in order to meet the production goals in the particular region (Portugal et al., 2015). These crops are managed for several cycles and generations; the farming families know their productive potential and the cultural treatments to obtain the best production results. According to Curado et al. (2020), the multiplication of these materials is a reality for these families that perform the phenotypic selection of the best genotypes, over the seasons of a population provided based on desirable characteristics in relation to the plant, ear or grain, to serve as a production matrix.

The common bean stands out for its economic aspect and its importance as a factor of food and nutritional security and sovereignty. The cultivation of common beans assumes fundamental importance in impoverished regions of the country and that normally deal with extreme climatic adversities. In these situations, the cultivation of common beans is carried out not only for its economic potential, but also for its social, cultural and food value (Manos et al., 2012; Ferrari and Ramos Junior, 2015).

The mulatinho group is important for both cultivation and the potential to select useful characteristics for growing under extreme climatic and environmental variations. Traditional growing environments with predominance of low fertility soils and dry and hot climate, includes northern Minas Gerais State and the Northeastern region of Brazil (Melo et al., 2008). The morphophysiological characteristics of this group of beans are related to the development of plants resistant to high temperatures and water stress. We sought to identify the most relevant characteristics associated with this resistance under high temperature conditions, to find plants that have mechanisms that will avoid significant loss of their productive potential. The mulatinho group bean has a prominent role among the groups of beans because of its rusticity and high adaptability to the edaphoclimatic conditions of Northeastern Brazil, especially the BRS Agreste cultivar (Manos et al., 2012). The main characteristics of the common bean cultivar BRS Agreste are its medium size, light brown color, white colored halo, opaque grain, and good culinary quality. The plant is erect and develops based on plant breeding, since there is diversity in the characteristics of traditional varieties. The flower color varies, but it is typically violet (Ferrari and Ramos Junior, 2015).

In Northeast Brazil, the region that suffers most from high temperatures and lack of rain, common beans account for over 50% of the planted area (IBGE, 2021). According to Faria et al. (2020), this region that most demands the type of mulatinho grain. This type of beans is still widely used in the region because it presents good culinary quality and is widely used in traditional dishes. This type has already had the preference of the entire Northeastern market and has reached levels of yield never achieved with other types of grain in this region (Costa and Lopes, 1999; Ferrari and Ramos Junior, 2015).

For conservation of genetic resources in cold and dry regions, *ex situ* conservation has historically been highlighted for preventing genetic erosion processes, becoming an essential tool for the protection of plant genetic heritage. In addition to plant breeding programs that aim for high performance and greater productivity, the conservation of genetic resources has great relevance to food security by the continuous use of the most important plant species for human consumption (Santonieri and Bustamante, 2016). According to Santonieri and Bustamante (2016), *ex situ* conservation can be characterized as “static”, since it characterizes limited access of this biodiversity by farmers, and this hinders the co-evolutionary process of the seed, preventing the adaptability achieved over years of cultivation by farmers.

The strategy of building local seed bands was established in different regions of Brazil, particular the Brazilian semiarid region, and the aim was conservation of local genetic resources. These seed banks go through the process of duplicating the genetic material, though there can be loss of seed viability, and sometimes loss of seeds (Padua, 2018). In face of climate changes, *on farm* conservation, which is characterized by the continuous management and cultivation of plant populations by traditional and/or local communities, and *ex situ* conservation will ensure the reduction of genetic erosion and the maintenance of genetic diversity. According to Clemente et al. (2008), *on farm* conservation is a complementary strategy to *ex situ* conservation because it allows for the conservation of evolutionary and adaptive processes, thus providing new genetic materials.

The characterization of accessions in Active Germplasm Banks (AGB) is an essential tool to support research on conventional and participatory plant breeding. The Active Germplasm Bank (BAG) is located at Embrapa Arroz e Feijão (EMBRAPA Rice and Bean), in Santo Antônio de Goiás. The increased use of greater diversity of common beans by farmers, whether by reintroducing seeds through access to the germplasm bank or by materials kept in the field, can become an important resource as long as it is accessible to farmers. For the farmer to properly use the genetic resource of a germplasm bank, it is also important that the farmer be part of the selection process and have information about the genetic variability and divergence within a species (Rana et al., 2015).

The conservation of mulatinho beans is an important strategy for the development of food security for farming families living in northeastern Brazil, which has dry climatic characteristics and high temperatures, and the knowledge of their genetic diversity allows the selection of interesting characteristics adapted to this region. Thus, due to the relevance of this beans type to the farmers and the Brazilian society, the objective of this study was to develop a collection of common mulatinho beans, with information on their morpho-agronomic and ecogeographic characteristics, to strengthen *ex situ* and *on farm* seed conservation programs through the expansion of the AGB database.

MATERIAL AND METHODS

Genetic material

The accessions used in this research are part of the collection of the beans registered with AGB Rice and Beans. Since the establishment of AGB Rice and Beans in 1975, several collection expeditions have been carried out over the years across various Brazilian states. In addition, different research institutions, both national and international, have donated a copy of their collection to expand the AGB database, totaling approximately 18,000 accessions of rice and 15,000 accessions of beans. Further information regarding the AGB can be found on the Embrapa website (https://www.embrapa.br/arroz-e-feijao/infraestrutura/banco-ativo-de-germoplasma) and the Alelo website (http://alelobag.cenargen.embrapa.br/AleloConsultas/Home/index.do), where the information concerning the accessions is registered.

The Embrapa AGB Rice and Beans bank were formed more than 40 years ago through both expeditions to collect materials and exchanges with other institutions, such as International Center for Tropical Agriculture (CIAT). These actions were institutional at the time of the formation of the official germplasm banks, both nationally and internationally, and they are within global agreements in which Brazil participated. The BRS Agreste cultivar was used as a reference variety in the two experiments conducted here, and this cultivar has already been described in detail in comparison with other bean cultivars (Melo et al., 2008; Gomes, 2015). The collection used in Experiment I was that of the common mulatinho bean type that is composed of 745 accessions. From the initial selection of accessions that are described below, the 240 most diverse and productive accessions were selected to be used in the Experiment II.

Experiments I and II

Two experiments were conducted in the greenhouse at the Fazenda Capivara of Embrapa Rice and Beans, located in the city of Santo Antônio de Goiás, Brazil (16º28' S, 49º17' W and altitude of 823 m). The greenhouse had 600 m^2 area, and it was equipped with an automated nebulization system, micro sprinkler, and drip irrigation for the pots, covered with a 50% retention sunshade screen. According to the Köppen's classification, the region had an Aw climate, which is characterized by tropical climate of savanna, megathermic, with a dry winter season. The mean annual air temperature was 22.6 ºC, while June presented the lowest average temperature (14.1 ºC) and September the highest (31.3 ºC).

In Experiment I, the plants were sown on May 31, 2013, and harvested between August 17 and September 15, 2013. Each experimental unit was comprised of one pot of 5

L for each accession, containing three plants per pot. The pot was filled with subsoil and its fertility is described in table S1 in appendix. No fertilizer was added during experiment I, so that accessions with productive potential in low input conditions could be selected.

In Experiment II, four pots with three plants each were used for each selected accession, totaling 12 plants per accession. The soil from Experiment I was reused in Experiment II, which consisted of a rice and beans crop rotation. In 2014, the soil was used a 4th time at the time of the experiment for the cultivation of common beans. Fertilizer was added after planting at a rate of 36 g pot^{-1}, using 04-30-10 (N-P_2O_5-K_2O) fertilizer. Mites were controlled by applying 18 g L^{-1} of abamecin (1 mL of product mixed with 1 L of water) on September 16 and 19, 2014. The application was carried out through a spray of 20L inside the greenhouse, totaling 2.4 mL of the solution per plant.

Characterization of the genetic material

The AGB characterization was defined according to the determinations of van Schoonhoven (1987) with standardized descriptors. For common beans, 37 morphological and agronomic descriptors are used internationally, 18 of which are the most common for the crop (Long et al., 2020). The leaf color was evaluated during the seedling phase. The leaves were also evaluated for roughness, classified as smooth or rough leaves. The size of the leaves was defined as small, normal, or non-standard (i.e. bigger than normal). The pigmentation of the cotyledon, hypocotyl, and stem were evaluated by checking the absence or presence of anthocyanin.

The date of initial and final flowering was recorded, and the number of days during the flowering stage was estimated. The initial flowering date was determined by the number of days after planting it took for 50% of the plot plants flowers had opened. The flower color was assessed in the early hours of the morning and again when they were completely opened. Plant growth practices were also evaluated. At physiologic maturity, the primary and secondary color of the pods and color uniformity were recorded, as well as the shape of the pod secondary color in relation to the pod profile, and was classified as straight, semi-arched, arched, and curved.

All accessions were beige in color, as they were part of the mulatinho group, and thus, they were classified in relation to the brightness during Experiment I. The number of pods per plant, seeds per plant, mass of seeds were evaluated per plant, while number of seeds and weight was also evaluated for each access, totaling of 18 descriptors with 12 that were qualitative and 6 that were qualitative. For all accesses, the goal after reducing the number of accessions was to morphologically characterize seed descriptors, such as shape and degree of grain flatness, in addition to the descriptors mentioned above in Experiment I.

Data analysis

Descriptive statistics and multivariate analysis were conducted. For the latter, the variables were converted into multi-categorical variables, generating a matrix of zeros and ones. For quantitative variables, based on the normal theoretical curve, the intervals provided by the mean (X) and standard deviation (S) were used to compose the fictitious variables. In this case, the morphologic and agronomic descriptors, both qualitative and quantitative, were transformed into binary variables through the creation of fictitious variables (Rana et al., 2015).

When a qualitative variable has more than two levels, it is possible to transform it into binary variables through the creation of fictitious variables (Johnson and Wichern 2002). The vectors of the binary variables generate a table with dual entry. This table is then used to estimate the coefficient of similarity between two accessions and obtain the dissimilarity distance between the semi-partial correlation squared (SPRSQ) values (Johnson and Wichern 2002; Rana et al., 2015).

During the Experiment II, the genetic diversity was analyzed to assess the degree of similarity between accessions. The genetic diversity was calculated from the morphological, morphological and ecogeographic descriptors raised. Through the 86 fictitious variables that were applied to Ward's method. The statistical analyses were conducted using the SAS® software, v9.2 (SAS Institute Inc., 2011), and the accessions were grouped based on the multivariate analysis, following the methodology described by Ward (1963). The Ward method was used to minimize internal differences in groups and to avoid problems with "chaining" the observations found in the individual bonding method. On the other hand, the Ward method allows for obtaining clusters with well-defined regions and determining nearby accesses with similar characteristics (Oliveira et al., 2008). Genetic diversity was used to measure the degree of similarity between accessions. It is possible to demonstrate how the data behaved with this method, that is, the existence of some pattern or degree of organization within the set of accessions evaluated here (Rana et al., 2015). Lastly, dendrograms resulting from the grouping application to the dissimilarity matrix were obtained.

A study was carried out based on the frequency of main characteristics, comparing the behavior of the accessions. A t-test was conducted to compare to number of pods (NP), number of seeds (NS), and weight of each plot, and this was performed with a statistical significance of 99%, similar to the statistical analysis performed by Ribeiro et al. (2014).

Ecogeographic data

The ecogeographic data of all accesses were known and were registered at the AGB from moment of seed collection and storage, and they were referenced by the geographic region, state, latitude, longitude, and altitude of the place of origin of mulatinho beans collection, in addition to the name used locally. This data was used to create maps that depict the distribution of the accessions of mulatinho type common beans in the Brazilian territory and provide visual information on the proportion of the accession distribution. The distribution was determined after the characterization and selection of materials that have genetic variability, and in this way, they guarantee the wealth of accession alleles for the mulatinho type common beans accessions at AGB Rice and Beans.

RESULTS AND DISCUSSION

Identification and elimination of redundant accessions

In the initial data from the 745 accessions of mulatinho beans collected, the most frequent names were Bico de Ouro, Mulatinho, Mulatinho Vagem Roxa, and Rosinha. These names were given by the farmers who own the seeds. At the time of seed collection, this information was recorded and made up the AGB Rice and Bean database. Regional names are important to link the collected material with its morphogenetic characterization. The observed frequency of these varieties was noted and is listed in Table 1.

Table 1. List of the most frequent variety names in the collection of common beans of the mulatinho type of AGB Rice and Bean in different regions of Brazil.

Name	Frequency	Region
Bico de Ouro	53	Northeast, Southeast, Midwest, and South
Mulatinho	118	Northeast, Southeast, South, and Midwest
Mulatinho Vagem Roxa	32	Northeast, Southeast, South, and Midwest
Rosinha	111	Northeast, Southeast, South, and Midwest

As expected, accessions with similar characteristics but with different names were found, as they were from the same commercial type of the common bean. Initially, 744 grouping steps were obtained (from 745 accessions) (Supplementary 1). It was determined that 441 of the 745 accessions could be characterized by 86 fictitious variables (Supplementary 2) (SPRSQ = 0.0001). During the first grouping steps, the accessions were similar to each other, presenting redundancies in the base collection, and that is to say, the 441 accessions were similar with respect to the characteristics that were evaluated. It was noted that the accessions gathered in the first grouping steps, values of the coefficient agglomeration were less than 0.0014, as shown in Table 2.

Table 2. Agglomeration coefficient of the hierarchical analysis of the first 50 steps of the grouping of 240 traditional bean accessions of the mulatinho commercial group, using the Ward method (EMBRAPA, 2014).

Step	Combined grouping Access / grouping		Agglomeration coefficient	Step	Combined grouping Access / grouping		Agglomeration coefficient
1	G093	G108	0.0005	26	G096	G203	0.001
2	G167	G183	0.0006	27	G095	G103	0.001
3	G049	G074	0.0007	28	CL226	G215	0.001
4	G004	G008	0.0007	29	G073	G104	0.0011
5	G106	G107	0.0007	30	G148	G214	0.0011
6	G070	G072	0.0007	31	G197	CL230	0.0011
7	G068	G075	0.0007	32	G063	CL222	0.0011
8	G134	G160	0.0008	33	CL233	CL223	0.0011
9	G051	G077	0.0008	34	CL237	G211	0.0011
10	G201	G213	0.0008	35	G132	G179	0.0012
11	G058	G235	0.0008	36	G056	G142	0.0012
12	G209	G217	0.0008	37	G050	CL235	0.0012
13	G065	G078	0.0008	38	CL214	G220	0.0012
14	G198	G200	0.0008	39	G188	G191	0.0012
15	G048	CL239	0.0009	40	CL224	G174	0.0013
16	G128	G159	0.0009	41	G150	G172	0.0013
17	G071	CL232	0.0009	42	G025	G083	0.0013

Possible redundancies were observed in 18 groups (SPRSQ = 0.0194), based on the Ward method. In this case, the most divergent and productive materials were found within the group of 240 accessions. Supplementary 2 shows the frequency of most of the evaluated characteristics of the initial collection that was maintained. The variables were reduced to those that appeared in 50% of the evaluated accessions within the group of 240 accessions (Supplementary 3). The 240 accessions represented one third of the initial collection of mulatinho type common beans. From the 186 fictitious variables evaluated in Experiment II, it was possible to organize the accesses in different stages that were grouped using the Ward method (Supplementary 4).

The first group included the majority of the accessions (SPRSQ = 0.0014), approximately 40% of the total accessions, and it was the group characterized by the lowest level of phenotypic divergence. The variability between accessions showed little or no redundancy, since 79 of the accesses were represented by individual accesses (Figure 1). These results suggest that the 240 accessions could be summarized by 96 accessions, ensuring the conservation of distinct alleles that were present in the group.

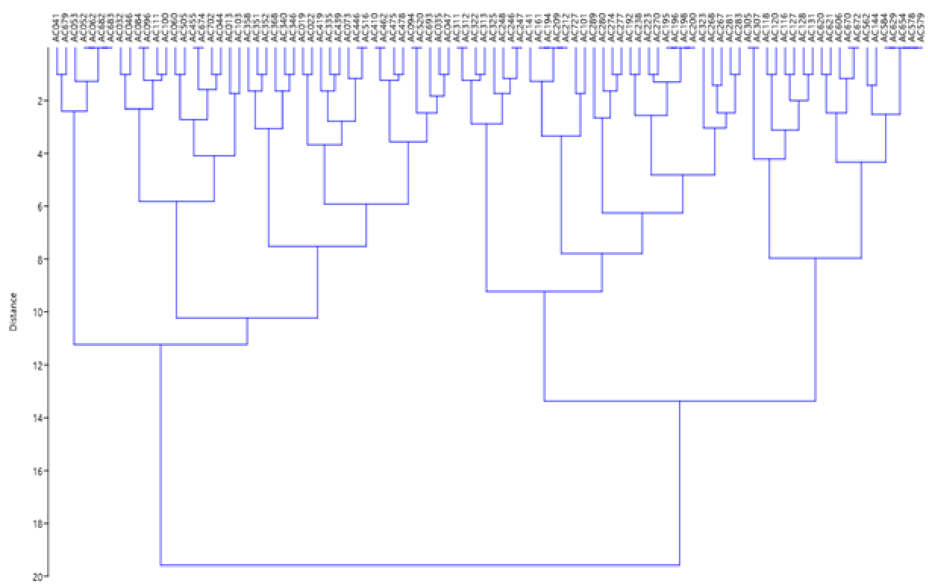

Figure 1. Grouping of the 96 selected mulatinho bean accessions that characterize the AGB common bean collection.

Characterization of accessions

The diversity of results for the accessions stored in the AGB are presented in Table 3. The survey of the morphologic and agronomic characteristics were used to eliminate redundant accessions and to determine the existing diversity in the AGB.

The initial flowering of the accessions varied between 36 and 49 days, and the flowering interval lasted between 10 and 22 days. The flowering interval provides information about the plant growth, presented in Table 3. Both the average number of pods and the number and weight of 100 grains in the 240 accessions selected were significantly greater than the base collection of 745 accessions. The 240 accessions were obtained by the positive coincidences for the number of pods and the number and weight of seeds of the plot (Table 4).

Table 3. Distribution of mulatinho bean accessions characterized in the seedling, flowering, and maturation phases.

Characteristic		**Experiment I (745 accessions)**	**Experiment II (240 accessions)**	**Final selection (96 accessions)**
Cotyledon pigmentation	Absent	77	65	42
	Present	635	142	35
	Miscellaneous	33	33	19
Hypocotyl pigmentation	Absent	276	66	36
	Present	440	145	44
	Miscellaneous	29	29	16
Stem pigmentation	Absent	285	181	66
	Present	455	59	30
Leaf color	Light green	163	99	42
	Green	528	114	39
	Dark green	51	24	15
	Miscellaneousa	3	3	-
Leaf roughness	Smooth	469	144	55
	Rough	276	96	41
Leaf size	Big	23	11	2
	Normal	618	225	94
	Small	104	4	-
Flower color	White	254	78	40
	Pink	37	3	3
	Violet	432	155	50
	Miscellaneous	22	4	3
Growth practice	Determinate	272	47	26
	Indeterminate	421	190	71
	Intermediate	52	3	-
Uniformity of the pod color	Uniform	601	129	52
	Non-uniform	144	111	44
Primary color of the pod	Yellow	243	43	43
	Purple	169	66	18
	Brown	48	10	3
	Pink	141	10	45
	Miscellaneous	144	111	24
Secondary color of the pod	Yellow	14	1	1
	Purple	31	27	13
	Brown	190	5	2
	Pink	107	10	3
	No color	403	197	77
Pod profile	Straight	119	33	22
	Arched	559	194	74
	Miscellaneous	67	13	
Seed brightness	Opaque	539	188	75
	Intermediate	177	44	20
	Bright	29	8	1
Shape of seed	Elliptic	-	124	50
	Spherical	-	14	5
	Oblong	-	102	41
Flattening degree	Semi-flattened	-	161	64
	Flattened	-	57	23
	Full	-	22	9

Considering all accessions together, the number of pods (NP) was 21.5, whereas the first selection of 240 accessions presented 29.5 units ($P < 0.001$), and the observations resulted in a similar value of 29.25 for the 96 accesses ($P > 0.05$). For the number of seeds (NS), the initial value was 88.2 seeds, followed by a greater value of 125.9 seeds for the 240 accessions (P < 0.001) and a similar value of 124.9 seeds for the last accessions selection (P > 0.05). Finally, the weight in grams in the initial selection of accesses was 18.2g of 100 grains, which was lower than that found for 240 accesses, totaling 29.25g (P < 0.001). This was similar to the value of 24.81g found for a total of 96 final accesses (P > 0.05).

Table 4. Agronomic parameters of mulatinho type common bean accessions, including number of pods (NP), number of seeds (NS), and weight of 100 grains of the 745, 240, and 96 selected accessions.

	740 accessions			240 accessions			96 accessions		
Parameter	**NP**	**NS**	**Weight (g)**	**NP**	**NS**	**Weight (g)**	**NP**	**NS**	**Weight (g)**
Average	21.5	88.2	18.2	29.5**	125.9**	24.7**	29.25	124.9	24.81
Minimum	3.0	7.0	2.3	22.0	92.0	20.5	22	20.5	21.81
Maximum	52.0	204.0	38.7	52.0	204.0	38.7	49	167	38.69
Standard deviation	8.3	36.5	6.3	5.1	20.4	3.1	4.77	20.3	3.08

For all accessions together, the average NP was 21.5. For the first selection of 240 accessions, the NP significantly increased to 29.5, and it was similar to the final 96 selected accessions (NP of 29.25). The NS was 88.2 for the 740 accessions, followed by a significant increase for the 240 accessions (NP of 125.9). The NS was not significantly different between the 240 and 96 accessions. Similarly, the seed weight was significantly greater in the 240 group compared to the 740 accessions, but it was equivalent to the 96 accessions.

Ecogeographic data

The geographic distribution of the base collection comprised 745 accessions, being the initial population, and then, the 240 first selection and the final 96 accessions selected to comprise the final reduced collection of mulatinho beans (Figure 2). The geographic distribution of the initial population was concentrated in two regions, 42% in the Northeast and 44% in the Southeast, especially in the state of Minas Gerais. After characterizing and selecting the 240 accessions, the distribution increased to 47% in the Northeast, while the Southeast remained at 44%. In contrast, there was a decrease from 9 to 6% in the Midwest region.

For the 96 accessions selection, the Northeast region represented 44%, the Southeast 46%, the Midwest 8%, and the South 2%. The frequency of accessions remains significantly in the Southeastern region in the Minas Gerais state with a total of 42 accessions, while in the Northeast region, 31 accessions were from the state of Bahia and 11 in the state of Alagoas. Overall, a proportion is maintained among the accessions selected, maintaining the representativeness of the geographic distribution of the collected material.

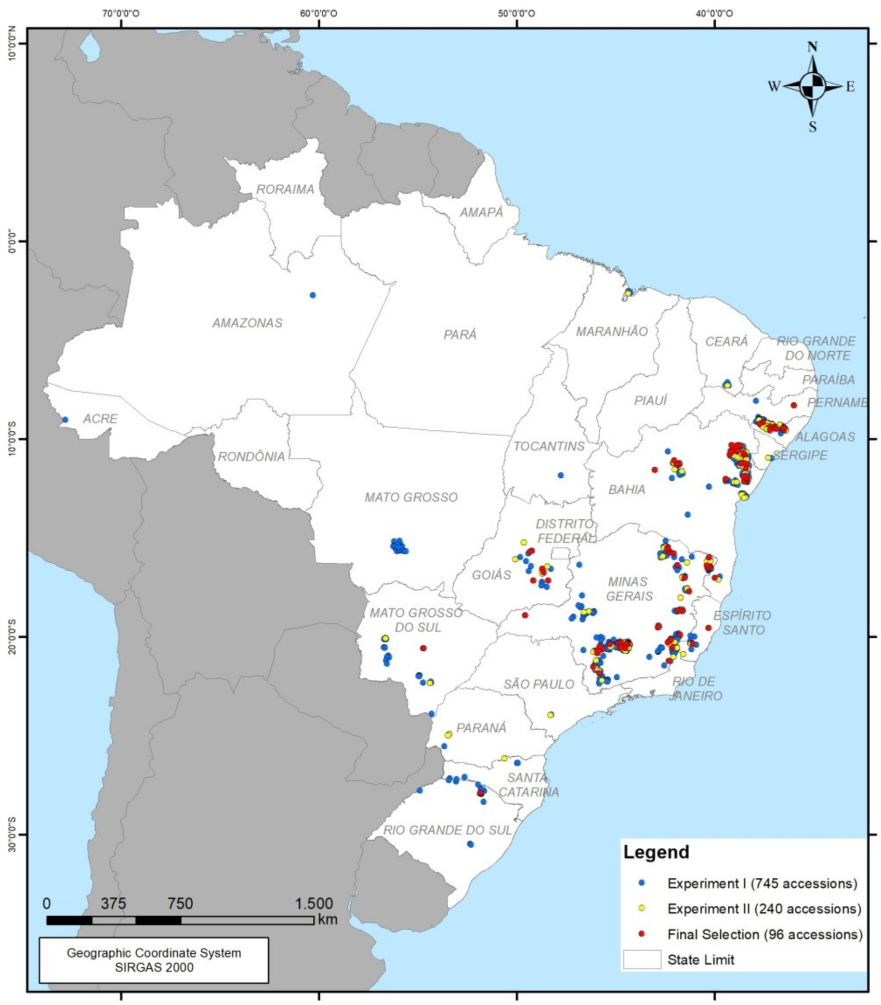

Figure 2. Distribution of accessions of AGB of mulatinho type common bean stored before and after the experiment.

DISCUSSION

The collection of 745 accessions across Brazil can be well represented by the characteristics of 96 accessions. This is one of the first studies that has characterized these accessions of mulatinho type common beans in the world. Most previous studies involving common beans were of characterization of accessions in Europe, particularly Portugal (Leitão et al., 2017), Slovenia (Sinkovič et al., 2017), India (Rana et al, 2015), Brazil (Chiorato et al. 2006; Oliveira et al. 2008; Santos et al 2019), the Andes and Mesoamerica (Becerra et al., 2011; Leitão et al., 2017).

The collection of seeds for the AGB database collections have become increasingly important for the Brazilian society. With *ex situ* conservation, it is possible to gather the genetic diversity of one or many species of interest in one place, and without this conservation, they could disappear, as occurs in nature. This is a safe and reliable alternative that allows for multiplication and study of different periods for conserved genetic material with easy access to germplasm (Brouwer et al. 2016).

Under *on farm* conservation conditions, the presence of more than one genetic material is a common practice among family farmers who have heterogeneous plants to guarantee variability and resistance to climatic adversities, since an accession is a mixture of pure strain. According to Assefa et al., (2019), the common bean presents great morphologic variability, and these differences allow for both genetic improvement and for farmers from different locations to obtain and select common bean materials adapted to the various prevailing production systems in the country, which can be resistant to the main biotic stresses of the crop.

The morphologic and agronomic characterization is an efficient methodology to separate duplicate accessions of common bean, even without the utilization of molecular methods (IPGRI, 2007; IBPGR, 1982). The characterized material can be used by the conventional plant breeding community or those who perform participatory breeding, as well as those interested in information generated in the work of reintroducing seeds that were lost by farmers. By the morphologic and agronomic characterization, their phenotypic expression can be related to edapho-climatic factors, region, and other local conditions, aiming at the selection of specific accessions for certain characteristics.

The importance of characterizing the accessions is related to the objectives of its users. According to Rangel et al. (2019), characterization and evaluation of accessions is essential because it increases the utilization of germplasm in plant breeding programs. This makes it possible to identify and genetically separate the accessions that make up the germplasm collection, fosters the catalog of accession descriptors with essential information for the collection management, and facilitates and stimulates the use of these accessions in the genetic improvement of plants, or directly in agriculture.

For the final 96 selected accessions, an average of 3.09 pods per plant was observed, presenting 4.33 seeds per pod and weight of 100 seeds of 19.95 g. The results of this study in comparison with other studies that evaluated accessions of common beans highlight that the mulatinho group presents values similar to other beans of the so-called special group.

When comparing to commercial groups such as Carioca, in general, these results are lower. Alves et al. (2020) worked with two common beans cultivars, a commercial Carioca group and another special bean, and they reported an average 12 pods per plant and 4.1 seeds per pod, producing about 27.6 g per 100 seeds for the commercial group (BRS Estilo, BRS MG majestoso, BRS Ametista, BRS Notavel, and BRS Cometa). As for the special commercial group (BRS Mg Realce, BRS Embaixador, MRS FC 305, BRS Executivo, and BR), the number of pods and seeds were lower, but they had greater weight. In a similar study evaluating other varieties of the Carioca group grown in the winter (Pérola, BRS Estilo, BRSMG Madrepérola, BRS Notável, IAC Alvorada, IAC Imperador, IAC Milênio, IPR 139 (Juriti Claro), IPR Andorinha, TAA Bola Cheia, TAA Dama, TAA Gol, and ANfc 9), Santis et al. (2019) reported 11 pods per plant, 4.3 seeds per pod, and 29.2 g per 100 seeds.

The participatory plant breeding, rescuing accessions in the community, reveals a wide variety of unknown genetic materials, which presented different characteristics and particularities when evaluated agronomically. In consideration of the volume of information generated, efficient methods are needed to define the relevant groups within the wide range of materials. Oliveira et al. (2008) worked with 126 accessions of Carioca group common beans, and they reported that the clusters (based on the Ward method) occurred as expected, as it was possible to illustrate the influence of the database on the final result. In this study, both the 745 accessions of mulatinho group common beans and the 96 accessions that represents this group highlight the efficiency of this method.

The ecogeographic data for each accession also revealed that the states with the greatest representation in the final collection of mulatinho beans were Minas Gerais, Alagoas, and Bahia. Based on previous evaluation of the region, it is possible to see the importance of mulatinho beans for the producer and consumer community. In a study from 1980, Oliveira et al. (1980) highlighted the composition of mulatinho in 15% of the plantations in the Northwest region of Minas Gerais and 21% in both Jequitinhonha and Rio Doce. At the time, this characteristic may have been relevant for strengthening the evaluated group, which reflects the current state of Minas Gerais as one of the primary states in maintaining accessions for this cultivar in Brazil.

There is a preference for common beans with light colors in the states of Bahia and Pernambuco, such as the Mulatinho. The most well-known varieties in this region are the ‘Rim de Porco’, ‘Vagem Roxa’, and ‘Favinha’. The first common bean cultivar of the Mulatinho type was developed by the Agronomic Institute of Pernambuco in 1974, originated from the crossing between the cultivars “Costa Rica” and “L.3.0.50”, and it presents resistance to leaf rust and common mosaic, called IPA 74-19 (Miranda et al., 1979).

Embrapa released the cultivar Bambuí of mulatinho type common bean in 1993, the A 774 strain named “BRS Marfim” in 1996, and “BRS Agreste” in 2008. Oliveira et al. (2008) evaluated 11 strains and two varieties of the commercial group Mulatinho common bean in different cities of Northeastern Brazil, and they reported that grain yield ranged from 1,705 to 3,253 kg ha^{-1}. According to the authors, this variation was primarily due to rainfall distribution during the growing season and the different soil types, indicating variation in environmental conditions where the experiments were conducted.

The characterization of different accessions with genetic diversity can indicate tolerance to different types of stress. This should be used as a strategy to ensure the sustainability of the production processes and, thus, the food security in the communities. A fact that is becoming more evident in studies of genetic resources is the importance of maintaining biodiversity, which is due to *on farm* conservation by the producers. The genetic diversity is the key to societal development, nutrition, and well-being (Barbieri et al., 2015).

Based on characterization of the accessions of Mulatinho common beans, it is possible to identify rescue materials more adapted to these extreme climatic conditions, facilitating the dialogue among farmers who produce beans in areas that are disadvantaged by the climate. The phenotypic data obtained in this work expanded the information of Mulatinho beans, evidencing the degree of phenotypic dissimilarity and contributing to organization of the information to expand its use by plant breeders. Moreover, this allows for the information to serve for the elaboration and characterization of thematic collections that will assist in works for tolerance to the stresses arising from climate change, such as high temperatures and water deficiency.

In this sense, research on genetic resources, allowing for work carried out in the scientific community with common bean producers in different regions to converge, may contribute to both integrated conservation (*ex situ* and *on farm* conservation) and the establishment of fair agriculture, based on the principles of sustainable development and adapted to climate change. For this, it is necessary to provide dialogue and exchange information between germplasm bank curators, researches, civil society entities, guardians of agro-biodiversity who work in *on farm* conservation. Genetic diversity studies as performed by Almeida et al. (2020) are important for deepening the knowledge about the population and genetic evolution of conserved accessions in farmers' fields and those that were stored *ex situ*. In this same work, the authors show how much beans of the Carioca variety are influenced by Andean beans, a phenomenon called allelic introgression in which the gene is persistent in the variety's genome.

There were at least 745 mulatinho group common bean accessions in Brazil. Of this total, 96 accessions could be selected to determine the group characteristics. Minas Gerais and the states in the Northeast were the states that presented the greatest abundance of mulatinho group common beans accessions. With expanded characterization information on mulatinho common beans accessions, it is possible to more efficiently identify and rescue materials that are better adapted to extreme weather conditions. This facilitates the dialogue among researches in the area of plant breeding, in the reintroduction of seeds, and for farmers that grow beans in areas that are disadvantaged by the climate.

Research projects in the area of genetic resources, which allow for the proposed work to be carried out between the scientific community and common bean producers in different regions, may contribute not only to integrated conservation (*ex situ* and *on farm* conservation) but also the establishment of fair agriculture based on the principles of sustainable development and climate change. For this, an effort will be necessary to provide dialogue and exchange information between germplasm bank curators, research groups, civil society entities, and guardians of agro-biodiversity who work in *on farm* conservation.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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