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RESEARCH ARTICLE

Genetic variation of the *Ananas* genus with ornamental potential

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Abstract Brazil is one of the main centers of origin of pineapple species presenting the largest genetic variation of the *Ananas* genus. Embrapa Cassava and Fruits is a Brazilian Agricultural Research Corporation and has an ex-situ collection of 678 accessions of the *Ananas* genus and some other Bromeliaceae. The use of ornamental pineapple has increased in the last years demanding new varieties, mainly for the external market, due to the originality and colors of its tiny fruits. The main aim of the present study was describing accessions from the pineapple gene bank in order to quantify their genetic variation and identify possible progenitors to be used in breeding programs of ornamental pineapples. Eighty-nine accessions of *Ananas comosus* var. *comosus*, *A. comosus* var. *bracteatus* (Lindl.) Coppens et Leal, *A. comosus* var. *ananassoides* (Baker) Coppens et Leal, *A. comosus* var. *erectifolius* (L. B. Smith) Coppens et Leal, *A. comosus* var. *parguasensis* (Camargo et L. B. Smith) Coppens et Leal and *A. macrodontes* Morren were evaluated with 25 morphological descriptors. According to the results, the evaluated accessions were separated into the following categories: landscape plants, cut flower, potted plants, minifruits, foliage and hedge. The genetic distance among accessions was determined using the combined qualitative and quantitative data by the Gower algorithm. The pre-selected accessions presented genetic variation and ornamental potential for different uses. The multicategory analysis formed seven clusters through a classification method based on the average Euclidean distance between all accessions using the cut-point of genetic dissimilarity ($D\ dg = 0.35$). The genotypes *A. comosus* var. *erectifolius* were selected to be used as landscape plants, cut flower, minifruits and potted plants. Accessions of *A. comosus* var. *bracteatus* and *A. macrodontes* were selected as landscape plants and hedge. The highest variation was observed in *A. comosus* var. *ananassoides* genotypes, which presented high potential for use as cut flowers.

Keywords *Ananas* · Genetic diversity · Morphological descriptors · Ornamental plants · Pineapple · Pre-breeding

Everton H. Souza and Fernanda Vidigal Duarte Souza contributed equally to this work.

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Introduction

Pineapple species are members of the family of Bromeliaceae, is the sixth most economically exploited tropical fruit in the world. It obtained an output of 18.4 million tonnes in 2009 (FAO 2011).

Potential uses have been explored for species of the genus *Ananas*, including the production of fibers for the manufacture of rustic material, such as ropes and fabric; the use in the automotive industry as a source of nanocellulose plastic, more resistant to heat, gasoline and water and he envisions using it for dashboards, bumpers and body panels (Mohanty et al. 2000; Zah et al. 2007; Leão et al. 2009); manufacture of paper (Marques et al. 2007); proteolytic enzymes (Maurer 2001) and secondary metabolites with antioxidant and biological activities of great value for the pharmaceutical, cosmetic and food industry (Harvey 2000; Manetti et al. 2009); besides its great ornamental potential (Duval et al. 2001a; Souza et al. 2006, 2007, 2009; Coppens D'Eeckenbrugge and Duval 2009; Sanewski 2009).

Ornamental use has increased in recent years and generating demand, due to the exotic and colorful aspect of the small pineapple fruits (Souza et al. 2009).

Searching for new varieties has increased recently, since the trade of ornamental pineapples is limited to two varieties, namely, one genotype of *A. comosus* var. *erectifolius* and another of *A. comosus* var. *bracteatus.*

Brazil is the center of origin and genetic diversity of the genus and Embrapa Cassava and Fruits, a Brazilian Agricultural Research Corporation, maintains a Active Germplasm Bank (AGB) located in Cruz das Almas city, Bahia, Brazil, with 678 accessions, distributed into botanic species and varieties of the genus *Ananas* and other Bromeliaceae (Souza et al. 2009).

This collection has potential to identify and generate new varieties, mainly considering the significant genetic variation of the genus. Studies on this variation may provide the support for a genetic breeding program aiming to generate new ornamental hybrids of pineapple.

Therefore, the characterization of these accessions is crucial to identify the ornamental potential of the collection. The studies on the identification, characterization and evaluation of pineapple germplasm provide important data on the accessions evaluated, highlighting the relevance of maintenance an active germplasm bank, in which the genetic variation of certain species can be used for different purposes, including ornamentation.

Previous studies by Souza et al. (2006, 2007, 2009) presented the characteristics that must be considered to identify and select ornamental pineapple plants, including plant size, length and color of the leaves and length, diameter, morphology and color of syncarps. Based on that study, 89 accessions with ornamental potential use were selected.

The identification of a certain accession with potential to be used as potted plant, or for landscape plants, foliage, inflorescence cutting or even as ornamental minifruits depends on the set of characteristics related to each of these categories. Besides, these accessions may be potential parents in breeding programs for the generation of hybrids with the desired characteristics, even without presenting all the desirable characteristics for a certain use.

Therefore, this work aimed at describing accessions from the pineapple active germplasm bank with ornamental potential. Also, the purpose was to estimate their genetic variation and classification into the different categories of ornamental use, identifying possible parents for genetic breeding targeting ornamental hybrids.

Materials and methods

This study was conducted at the pineapple Active Germplasm Bank (pineapple AGB) of the Embrapa Cassava & Fruits, located at 12°40′ south latitude and 39°06′ west longitude, in the municipality of Cruz das Almas, Bahia, Brazil.

According to the Köppen classification, the climate in Cruz das Almas is a transition between the Am and Aw zones, with average annual rainfall of 1.143 mm, average temperature of 24.28°C and relative humidity of 60.47%. The soil of the experimental area is a typical dystrophic Yellow Latosol, A moderate, sandy clay loam texture, kaolinite, hypoferric, transition zone between subperennial and semideciduous rainforest, with slope of 0–3%.

A total of 89 accessions of pineapple species, varieties and inter-varieties hybrids with ornamental potential were previously selected for this study and are presented in Table 1. The accessions were planted in 1.0 × 0.8 m plots, with four replications, each corresponding to one plant.

Table 1 Accessions identified and characterized in the pineapple AGB of the Embrapa Cassava & Fruits which hold ornamental potential and their respective species and provenance

Number	Name of the accession	Proven.	Number	Name of the accession	Proven.
Ananas comosus var. *comosus*					
AGB 16	Roxo de Tefé	BR/AM	AGB 382	LBB-605	BR/MA
AGB 28	Branco	BR/AM	AGB 458	LBB-1408	BR/AC
AGB 101	FRF-747	BR/AP	AGB 511	G-42	FG
AGB 137	Arroba Tarauacá	BR/AC	AGB 693	FRF-1015	BR/AM
AGB 380	LBB-608	BR/MA	AGB 772	GF-492	FG
Ananas comosus var. *erectifolius*					
AGB 739	Curauá Roxo	BR/PA	AGB 804	FFR-1387	BR/RN
AGB 750	FRF-1392	BR/CE			
Ananas comosus var. *ananassoides*					
AGB 25	Ananaí	BR/MT	AGB 385	LBB-540	BR/GO
AGB 174	FRF-52 (A. do Índio)	BR/DF	AGB 464	LBB-1427	BR/MT
AGB 198	FRF-249	BR/RO	AGB 465	LBB-1446	BR/MT
AGB 207	FRF-224	BR/RO	AGB 469	LBB-1437	BR/MT
AGB 208	FRF-221	BR/RO	AGB 470	LBB-1438	BR/MT
AGB 229	FRF-367	BR/MS	AGB 471	LBB-1442	BR/MT
AGB 230	FRF-372	BR/MS	AGB 472	LBB-1439	BR/MT
AGB 232	FRF-393	BR/MT	AGB 475	LBB-1447	BR/MT
AGB 270	LC-7241	BR/MT	AGB 477	LBB-1440	BR/MT
AGB 315	D C G-876	BR/DF	AGB 479	LBB-1448	BR/MT
AGB 323	GHAV e JMTM-11	BR/MT	AGB 487	LBB-1455	BR/MT
AGB 324	Valls 9385	BR/MT	AGB 523	G-35	FG
AGB 325	ARM-955	BR/MT	AGB 526	G-44	FG
AGB 330	FRF-667	BR/PA	AGB 703	CI-33	FG
AGB 378	LBB-639	BR/PI			
Ananas comosus var. *parguasensis*					
AGB 211	FRF-755	BR/AP	AGB 391	FRF-813	BR/AP
AGB 327	FRF-691	BR/PA	AGB 404	FRF-724	BR/AP
AGB 337	FRF-812	BR/AP	AGB 775	GF-491	FG
AGB 388	FRF-756	BR/AP			
Ananas comosus var. *bracteatus*					
AGB 2	Ananás São Bento	BR/SP	AGB 128	FRF-32	BR/GO
AGB 3	Ananás Verm. do Mato	BR/SP	AGB 210	FRF-1217	BR/PR
AGB 17	Ananás tricolor	BR/SP	AGB 408	FRF-1203	BR/RS
AGB 20	Ananás Branco do Mato	BR/SP	AGB 495	FRF-1209	BR/RS
AGB 35	Ananás Santo Amaro	BR/BA	AGB 510	FRF-1261	BR/SP
AGB 45	Ananás Minas Gerais	BR/MG	AGB 543	FRF-1213	BR/RS
AGB 47	Selvagem 5	BR/RS	AGB 584	FRF-1214	BR/SC
AGB 56	BGA-12	BR/BA	AGB 663	FRF-1419	BR/MG
AGB 97	Silvestre 166	BR/DF	AGB 690	FRF-1212	BR/RS
AGB 110	FRF-414	BR/ES	AGB 692	FRF-1136	BR/SP
AGB 119	FRF-16A	BR/PR	AGB 776	BR-725	FG
AGB 123	FRF-19	BR/GO	AGB 808	FRF-1393	BR/CE
AGB 126	FRF-22	BR/GO			

Table 1 continued

Number	Name of the accession	Proven.	Number	Name of the accession	Proven.
Ananas macrodontes					
AGB 81	Silvestre 25	BR/DF	AGB 299	FRF-327	BR/MS
AGB 83	I-26 803	BR/DF	AGB 719	FRF-1239	BR/BA
Hybrids					
AGB 18	*Pseudananas* × Rondon	BR/SP	AGB 148	S. Cay. × Ananai	BR/BA
AGB 146	A. S. Bento × Loc. de Tefé	BR/BA	AGB 152	S. Cay. × Ananás S. Bento	BR/BA
Ananas sp.					
AGB 195	GPS-389	BR/AP	AGB 393	FRF-814	BR/AP
AGB 197	FRF-202	BR/RO	AGB 396	FRF-818	BR/AP
AGB 351	FRF-719	BR/PA	AGB 507	G-69	FG
AGB 377	LBB-550	BR/GO			

BR Brazil/States, *FG* French Guiana. Brazilian states: *AC* Acre, *AP* Amapá, *AM* Amazonas, *BA* Bahia, *CE* Ceará, *DF* Distrito Federal, *ES* Espírito Santo, *GO* Goiás, *MA* Maranhão, *MT* Mato Grosso, *MS* Mato Grosso do Sul, *MG* Minas Gerais, *PA* Pará, *PR* Paraná, *PI* Piauí, *RO* Rondônia, *RN* Rio Grande do Norte, *RS* Rio Grande do Sul, *SC* Santa Catarina, *SP* São Paulo

Twenty-five morphological descriptors were used. Eleven of them were quantitative and fourteen, qualitative. The list of the descriptors can be found in "International Board for Plant Genetic Resources" (IBPGR 1991).

The following characteristics are considered for the classification of accessions into use categories:

Potted plants plant height lower than 65.00 cm, canopy diameter narrower than 80.00 cm, leaf length less than 60.00 cm, crown/syncarp ratio close to 1, syncarp length less than 5.00 cm, syncarp diameter less than 3.00 cm, crown length less than 5.00 cm, peduncle length less than 30.00 cm and absence of spines;

Cut flower crown/syncarp ratio close to 1, syncarp length less than 8.00 cm and syncarp diameter less than 6.00 cm, peduncle length exceeding 40.00 cm, peduncle diameter less than 1.50 cm and crown length less than 7.00 cm;

Minifruits syncarp length less than 5.00 cm, crown/syncarp ratio close to 1 and crown length less than 4.50 cm;

Landscape plants wide category that includes potted plants, cut flower and minifruits. An important characteristic of this category is the formation of clumps, which can be observed in the tillering capacity of the material evaluated.

Foliage leaf length exceeding 1.00 m, leaf width exceeding 5.00 cm, presence of variegation (desirable, but not mandatory), intense color and absence of spines;

Hedge plant height exceeding 80.00 cm, formation of clumps, leaf length exceeding 80.00 cm, leaf width exceeding 5.00 cm and presence of spines.

Analyses of variance were carried out and the following descriptive statistics were calculated: average, maximum value, minimum value, variation coefficient, *F* test and average square. A completely randomized experimental design was used, the averages were compared by the Scott-Knott test at 1% probability using the statistical SAS software system (SAS Institute 2004).

The Singh criterion (1981) was employed to calculate the relative contribution of each quantitative variable, based on Mahalanobis distance, and the analysis was carried out by the Genes software system (Cruz and Regazzi 1997).

A joint analysis of the qualitative and quantitative data was carried out to determine the genetic distance based on the Gower algorithm (1971).

The hierarchical clusterings of the accessions were achieved by the UPGMA methods (Unweighted Pair-Group Method Using an Arithmetic Average) based on the average Euclidean distance between all the accessions. The validation of the clusterings was determined by the cophenetic correlation coefficient (r) (Sokal and Rohlf 1962).

The statistical software system (R Development Core TeaM. 2006) was used for the analyses of genetic distance, hierarchical clusterings and cophenetic correlation. The cophenetic correlation was calculated by the *t* and Mantel tests (10,000 permutations). The dendrogram was generated based on the distance matrix by the MEGA 4 software system (Tamura et al. 2007).

Results and discussion

The application of morphological descriptors to characterize pre-selected accessions of pineapple trees revealed the wide variation of the pineapple germplasm active bank and allowed the identification of accessions with great ornamental potential for different uses, aggregating value to the germplasm preserved (Table 2).

The Singh method (1981) was used to assess the relative importance of the 11 quantitative descriptors. It was also determined, by this method, that four of them provided 98.59% of the genetic divergence, while seven of them provided only 1.41%. Canopy diameter was the variable with the highest contribution, 53.31%, followed by plant height (19.57%), leaf length (15.28%) and peduncle length (10.43%). These results indicate the existence of significant genetic variation for these characters in the genotypes evaluated. In general, the length and diameter of the fruit, length and diameter of the inflorescence, crown length, leaf width and peduncle diameter did not contribute to explain the variation observed among the genotypes (Table 3).

The multi-category analysis carried out with the 89 accessions allowed the formation of seven groups (Fig. 1) by the UPGMA clustering method, based on the average Euclidean distance, using the average genetic dissimilarity as the cutting point ($D\ dg = 0.35$).

The cophenetic correlation coefficient of the dendrogram ($r = 0.81$, $P < 0.0001$, 10,000 permutations) revealed good adjustment between the graphic representation of the distances and its original matrix (Rohlf and Fisher 1968).

The group G1 is formed by only one accession of *A. comosus* var. *comosus* called 'Arroba Tarauacá', which was selected mainly because of its great height and the purplish color of its leaves and fruits. Its leaves present average length of 126.50 cm and width of 8.15 cm, its habit is decumbent and its fruits are used for food (Table 4). This accession, although presenting some interesting characteristics, was not recommended as a parent, mainly due to the size of its fruit (Fig. 2a).

The accessions of *A. comosus* var. *comosus* are known as pineapple, ananás and nanas and are 65% of all accessions of the AGB of pineapple of the Embrapa Cassava & Fruits. This variety presented the highest variation among the accessions evaluated, showed in Fig. 1, in which the variety was identified to form part of different groups. Duval et al. (2000, 2001b) report high genetic variation for this variety, especially in the Western Amazon and Eastern Guiana.

Some accessions accessions that form part of the bank were included in this work due to their attractive colors and relevant characteristics for ornamental purposes. They are mainly used in landscape plants and/or foliage. Out of the 411 accessions that form the bank, only 10 were selected, including the accession Roxo de Tefé (AGB 16), because of its long (61.33 cm) and wide (4.07 cm) leaves, reddish color and the large distribution of anthocyanin (Table 4; Fig. 2b). The accession Branco (AGB 28) also stood out, with its olive-green inflorescence, which is very different from ordinary pineapples (Fig. 2c), good development, with 7.15 cm in length and 4.95 cm in diameter, open habit and well formed syncarp, whose average length is 8.40 cm and diameter, 5.95 cm (Table 5; Fig. 2d).

All accessions of *A. comosus* var. *erectifolius* formed the group G2 better known as curaguá, carauá, curaná, kulaiwat, coma-pitte, pitte, lucidus and curauá (Coppens D'Eeckenbrugge and Duval 2009). The last two names are the most commonly used in Brazil.

No significant differences were observed for the three accessions evaluated, with all plants studied have erect habit, a characteristic that gives name to the variety, smooth and purplish leaves with average length of 65.00 cm and width of 3.50 cm (Table 4). The peduncle is long, straight, without deformities, with approximately 40.00 cm in length and 0.80 cm in diameter (Table 2). Due to these characteristics, the *A. comosus* var. *erectifolius* has already been used and marketed as cut flower (Brainer and Oliveira 2007). The inflorescence has small and smooth floral bracts

Table 2 Descriptive statistics for 11 descriptors of ornamental pineapple trees, in different botanic varieties

	N	HEI (cm)	CAN (cm)	LLE (cm)	LWI (cm)	LPE (cm)	DPE (cm)
Ananas comosus var. *bracteatus*	25 (100)	93.76 ± 13.16a	151.70 ± 15.06a	94.68 ± 9.59a	4.58 ± 0.41a	25.31 ± 4.92b	1.83 ± 0.32a
A. comosus var. *erectifolius*	3 (12)	77.31 ± 7.88b	80.19 ± 8.89b	64.33 ± 16.21b	3.46 ± 3.46b	39.64 ± 1.92a	0.83 ± 0.16b
A. comosus var. *ananassoides*	29 (116)	64.90 ± 16.58b	106.01 ± 26.65b	72.05 ± 17.72b	2.88 ± 0.77b	49.83 ± 16.38a	0.85 ± 0.34b
A. comosus var. *parguasensis*	7 (28)	62.50 ± 15.33b	102.56 ± 20.92b	70.32 ± 9.66b	4.03 ± 0.75a	28.77 ± 9.08b	1.17 ± 0.22b
A. comosus var. *comosus*	10 (40)	76.12 ± 18.97b	125.92 ± 47.22a	84.92 ± 19.87a	4.82 ± 1.63a	28.24 ± 11.15b	2.00 ± 0.45a
Ananas sp.	7 (28)	63.76 ± 16.71b	98.98 ± 21.46b	73.86 ± 21.84b	3.74 ± 0.75b	35.05 ± 8.97b	1.20 ± 0.67b
Hybrids	4 (16)	70.52 ± 18.86b	123.44 ± 7.52a	81.54 ± 13.34a	4.08 ± 0.55a	24.69 ± 12.49b	1.63 ± 0.22a
A. macrodontes	4 (16)	74.50 ± 1.73b	138.64 ± 8.43a	85.83 ± 9.61a	3.97 ± 0.47a	28.06 ± 0.77b	2.05 ± 0.53a
Mean		75.09	121.63	80.64	3.85	35.24	1.39
CV (%)		20.60	20.70	19.15	21.05	32.56	27.04
Fc		8.26**	9.54**	5.53**	11.23**	10.99**	20.47**
AS		1977.50	6046.39	1318.44	7.39	1447.56	2.92

	N	LIN (cm)	DIN (cm)	LSY (cm)	DSY (cm)	LCR (cm)
Ananas comosus var. *bracteatus*	25 (100)	7.21 ± 1.80a	5.01 ± 0.62b	9.00 ± 3.08a	6.23 ± 0.90a	4.79 ± 1.29a
A. comosus var. *erectifolius*	3 (12)	3.54 ± 1.05b	1.82 ± 0.57d	4.81 ± 0.77b	3.63 ± 1.07b	2.96 ± 0.27a
A. comosus var. *ananassoides*	29 (116)	3.58 ± 1.20b	2.40 ± 0.72d	5.15 ± 1.65b	3.54 ± 0.97b	2.15 ± 1.38b
A. comosus var. *parguasensis*	7 (28)	4.53 ± 1.73b	3.11 ± 0.78c	5.20 ± 1.86b	4.34 ± 0.55b	4.21 ± 1.30a
A. comosus var. *comosus*	10 (40)	6.02 ± 2.48a	4.53 ± 1.73b	9.27 ± 3.91a	6.28 ± 1.54a	4.48 ± 1.88a
Ananas sp.	7 (28)	4.41 ± 1.33b	3.10 ± 0.41c	5.42 ± 1.42b	4.55 ± 0.76b	3.67 ± 0.77a
Hybrids	4 (16)	6.30 ± 0.70a	4.36 ± 0.18b	9.21 ± 3.13a	6.32 ± 0.95a	4.12 ± 1.50a
A. macrodontes	4 (16)	7.14 ± 0.93a	6.13 ± 0.79a	9.73 ± 1.50a	7.29 ± 0.80a	0.00c
Mean		5.29	3.72	7.09	5.04	3.25
CV (%)		30.27	21.18	35.44	19.68	38.81
Fc		12.16**	32.19*	8.00**	22.33**	12.65**
AS		31.27	19.97	50.57	22.01	22.77

Means and standard error

Means followed by the same letter are not significantly different by the Scott-Knott test at 1% probability

CV (%) coefficient of variation, *Fc* value of the calculated *F* test, *AS* average square

N accessions number (plant), *HEI* plant height, *CAN* canopy diameter, *LLE* leaf length 'D', *LWI* leaf width 'D', *LPE* peduncle length, *DPE* peduncle diameter, *LIN* inflorescence length, *DIN* inflorescence diameter, *SYL* syncarp length after closure of the last flower, *SYD* syncarp diameter after closure of the last flower, *LCR* crown length

** ($P < 0.01$)

(Fig. 2e), the syncarp is small, ovoid, with approximately 4.80 cm in length and 3.60 cm in diameter, slightly larger than the inflorescence, with scarce and fibrous pulp which make this variety unsuitable to be used as food (Table 5; Fig. 2f).

The *A. comosus* var. *erectifolius* differs from *A. comosus* var. *ananassoides* because it does not present long spines in the edges of the leaves (Souza et al. 2007). The absence of spines and the erect form of the leaves probably result from artificial selection aimed at enhancing larger fiber production and easy leaf manipulation (Coppens D'Eeckenbrugge and Duval 2009).

The genotypes of this variety have characteristics for different uses. The variety is appropriate for landscape plants, since it forms massive. The plants can also be used as cut flower, due to their long and erect peduncle with small syncarp, and minifruits.

Table 3 Relative contribution (%) of each plant descriptor in the genetic variation data based on the Singh criterion (1981) and Mahalanobis distance

Descriptors	*S.j*[a]	*S.j*[a] (%)
Canopy diameter	2,212,402.60	53.31
Plant height	812,171.74	19.57
Leaf length 'D'	634,131.92	15.28
Peduncle length	432,852.70	10.43
Syncarp length after closure of the last flower	24,071.33	0.58
Inflorescence length	11,205.44	0.27
Crown length	9,132.57	0.22
Syncarp diameter after closure of the last flower	5,809.34	0.14
Inflorescence diameter	4.565.13	0.11
Leaf width 'D'	2,074.93	0.05
Peduncle diameter	832.32	0.02

[a] $S.j$ = contribution of the variable x for the value of the Euclidean distance between the genotypes i and i

This variety stands out for its direct use, which has already been taking place, without breeding programs. Nowadays, this variety is largely exported to Europe as cut flower and is responsible for 75% of the exports of ornamental pineapple (Brainer and Oliveira 2007).

Besides its ornamental use, this variety is widely used for the extraction of fibers of excellent quality, when compared to hemp, sisal, linen, jute, ramie and abaca (Leão et al. 2009). Nowadays, it is cultivated near Belém do Pará (Brazil), for fiber extraction and the manufacture of hammocks, fishing nets (Leal and Amaya 1991) and upholstery of trucks and cars.

The group G3 is formed by two accessions of *A. comosus* var. *parguasensis, Ananas* sp. and 25 accessions of *A. comosus* var. *ananassoides*.

In Brazil, *A. comosus* var. *parguasensis* is called ananaí, kurupira-naná and gravatá. These pineapples grow in places preferably humid and shady, in clearings, gardens or dense forests. They cannot resist in dry places with intense solar radiation.

The leaves presented an average length of 70.32 cm, with usually wavy edges (Table 2). The accessions GF-491 (AGB 775) and FRF-813 (AGB 391) present anthocyanin distribution in their leaves (Fig. 2h, i), which gives them an interesting aspect for landscape plants use. In their natural habitat, their leaves reach up to 2.00 m long, and their limbo is very broad (Coppens D'Eeckenbrugge and Duval 2009). Their most remarkable difference from *A. comosus* var. *ananassoides* is the orientation of some spines in the base of the wide leaves, slightly constricted at the base. Often, it is difficult to distinguish the two varieties due to their similar characteristics.

The syncarps are small, measuring on average 5.20 cm in length, predominantly globoid. The peduncle is generally winding, long and thin. The accession FRF-691 (AGB 327) presented peduncle with average length of 41.00 cm and 0.95 cm in diameter. It is targeted at breeding for cut flower, and can also be used as pot plant due to its low height, below 40.00 cm (Fig. 2g), which is a small size, considering ordinary pineapples (Tables 4, 5).

Nearly 31% of the accessions studied are *A. comosus* var. *ananassoides,* a variety with wide genetic variation. This variety has genotypes with ornamental characteristics, although some of them are considered undesirable, such as the presence of spines. Duval et al. (1997) report that most populations are monoclonal, but some of them are polyclonal and present morphological variations of sexual origin. The plants generally present an average size, with long and narrow leaves, of up to 1.00 m in length and ascending spines. The habit ranges from open to decumbent, and most accessions are decumbent.

The accessions Ananaí (AGB 25) and CI-33 (AGB 703) have potential for potted plant due to their reduced size and decumbent habit. However, their use in landscape plants in the form of massive is very interesting. These accessions are called abacaxi-de-salão and used to be classified as *A. nanus* (Fig. 2j, k) in the former taxonomy. They are marketed in Europe and United States in spite of the presence of spines. The use of this accession as a parent is interesting because of the small size of the fruit, approximately 2.00 cm, a characteristic highly desirable for ornamental pineapple. Some pineapples are

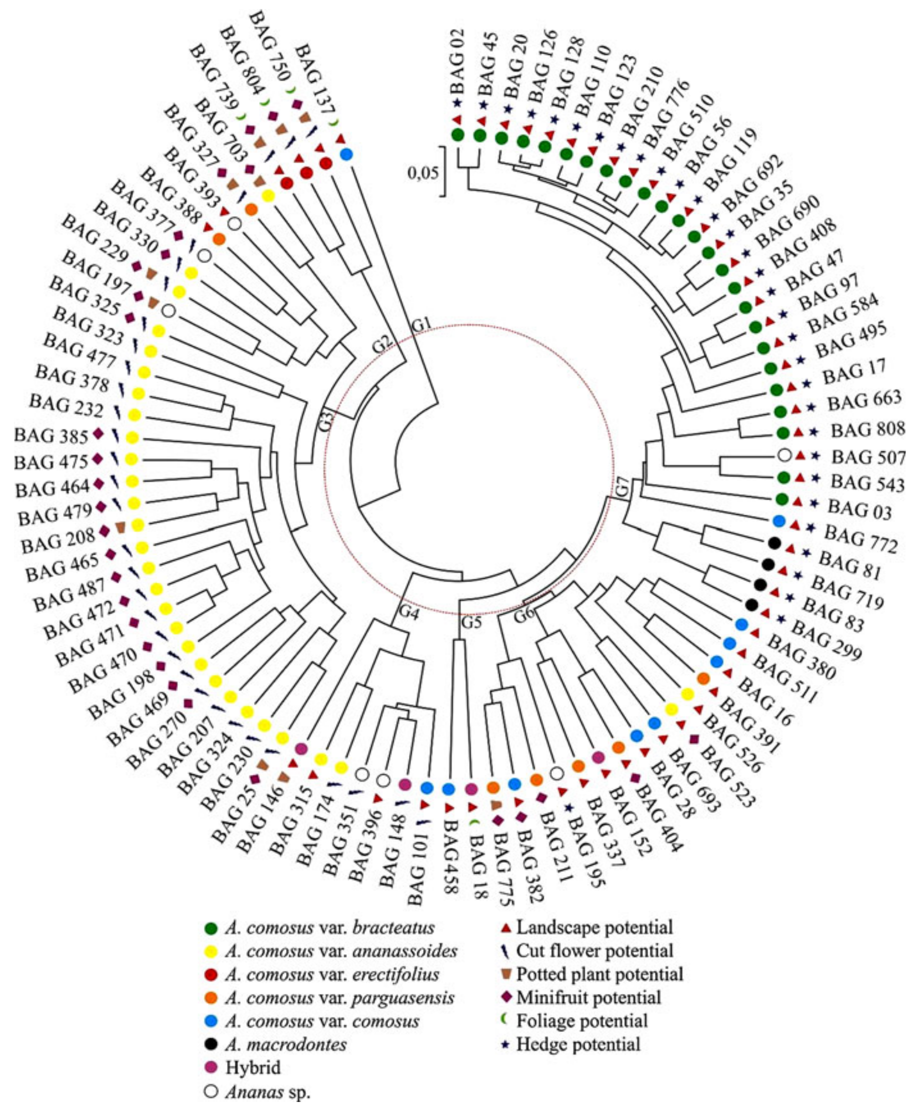

Fig. 1 Dendrogram of the genetic dissimilarities among 89 accessions of pineapple trees, achieved by the UPGMA method based on the Gower algorithm, from twenty-five qualitative and quantitative characters

ornamental, but produce large fruits, such as the *A. comosus* var. *bracteatus*, which complicates the post-harvest management and increases the cost of transport. The crossing of these genotypes with varieties of very small fruits could determine interesting ornamental variants.

The inflorescences of *A. comosus* var. *ananassoides* are generally small, with about 2.00–3.00 cm, reaching up to 7.13 cm in length, which is the case of the accession FRF-52 Ananás do Índio (BGA 174) (Table 5). This is an important characteristic when the the intended use is cut flower, possibly at bud stage or complete fruit (syncarp and crown). The employment of ornamental pineapple for cut at bud stage may be innovative in the flower market and may allow using of many genotypes which are not interesting as complete fruits, but have very attractive buds with a singular beauty, providing differentiated floral arrangements. The shape of the syncarp can be ovoid, globular and cylindrical. They have different colors, but most of them are pinkish. However, the accessions G-35 (AGB 523) and G-44 (AGB 526) were dark purple (Fig. 2m) (Table 5).

The length of the peduncle (stem) is an important characteristic to select genotypes for cut plant, since the market demands stems longer than 40.00 cm. 70.5% of the accessions evaluated presented peduncles longer than that, which points out the great

Table 4 Quantitative and qualitative characteristics of the plant in 89 accessions of the pineapple AGB of the Embrapa Cassava & Fruits with ornamental potential

Genotype	Characteristics of the plants										
	HAB	HEI	CAN	LLE	LWI	LVA	COL	ANT	STO	SPI	CTH
AGB 02	OPE	97.00a	153.75c	104.75a	5.25b	VRM	DGR	PIK	ABS	PRE	DLF
AGB 03	OPE	90.50a	144.00c	85.00b	4.40b	VRM	DGR	GRE	ABS	PRE	DLF
AGB 16	OPE	61.33c	120.00e	61.33c	4.07b	VPM	ANT	PUR	ABS	PRE	ILF
AGB 17	DEC	89.50a	187.00b	102.50a	4.90b	VWM	ANT	PIK	ABS	PRE	DLF
AGB 18	DEC	63.00c	128.33d	75.67c	4.20b	VRM	ANT	PUR	ABS	ABS	ABS
AGB 20	OPE	85.00b	152.25c	99.25a	4.40b	VRM	ANT	PIK	ABS	PRE	DLF
AGB 25	DEC	41.75d	73.25f	48.25d	2.23c	WVE	ANT	GRE	ABS	PRE	ILF
AGB 28	OPE	92.00a	134.00d	84.50b	5.40b	WVE	LGR	ABS	ABS	PRE	ILF
AGB 35	OPE	101.50a	141.25c	88.00b	4.48b	VRM	LGR	PIK	ABS	PRE	DLF
AGB 45	OPE	85.00b	153.33c	95.00	4.40b	WVE	ANT	PIK	ABS	PRE	DLF
AGB 47	OPE	102.60a	137.60d	70.33c	4.00b	VRM	DGR	PIK	ABS	PRE	DLF
AGB 56	OPE	112.00a	162.00c	109.50a	5.13b	VRM	ANT	PIK	ABS	PRE	DLF
AGB 81	OPE	74.00b	133.25d	74.00c	4.03b	WVE	DGR	ABS	PRE	PRE	DLF
AGB 83	OPE	73.00b	143.30c	85.33b	3.50c	WVE	ANT	PIK	PRE	PRE	DLF
AGB 97	OPE	105.25a	155.25c	95.25a	4.28b	VRM	ANT	PIK	ABS	PRE	DLF
AGB 101	OPE	80.67b	96.67e	75.33c	3.07c	WVE	LGR	ABS	ABS	PRE	ILF
AGB 110	OPE	99.75a	166.25c	104.00a	4.33b	VRM	ANT	PIK	ABS	PRE	DLF
AGB 119	OPE	106.00a	182.75b	104.00a	4.48b	VRM	ANT	PIK	ABS	PRE	DLF
AGB 123	OPE	109.50a	160.75c	99.25a	4.40b	VRM	ANT	PIK	ABS	PRE	DLF
AGB 126	OPE	85.33b	157.33c	93.00a	4.07b	VRM	ANT	PIK	ABS	PRE	DLF
AGB 128	OPE	85.33b	143.67c	89.00b	4.13b	VRM	ANT	PIK	ABS	PRE	DLF
AGB 137	DEC	89.50a	237.00a	126.50a	8.15a	WVE	ANT	PUR	ABS	PRE	ILF
AGB 146	OPE	47.33d	80.10f	66.00c	3.33c	WVE	LGR	ABS	ABS	PRE	ILF
AGB 148	OPE	85.25b	130.25d	88.50b	4.15b	WVE	LGR	ABS	ABS	PRE	ILF
AGB 152	OPE	86.50b	121.50e	96.00a	4.65b	WVE	LGR	ABS	ABS	PRE	DLF
AGB 174	OPE	81.75b	154.50c	102.75a	5.38b	WVE	DGR	ABS	ABS	PRE	ILF
AGB 195	DEC	46.00d	110.67e	68.33c	2.60c	WVE	ANT	PIK	ABS	PRE	ILF
AGB 197	UND	45.50d	59.75f	35.00d	3.08c	WVE	LGR	ABS	ABS	PRE	ILF
AGB 198	OPE	74.00b	94.50e	74.00c	2.55c	WVE	ANT	PIK	ABS	PRE	DLF
AGB 207	DEC	68.75b	117.75e	65.50c	3.55c	WVE	ANT	PUR	ABS	PRE	ILF
AGB 208	DEC	58.25c	80.00f	53.75d	2.43c	VPM	ANT	PIK	ABS	PRE	DLF
AGB 210	OPE	88.75a	151.25c	97.75a	4.13b	VRM	ANT	GRE	ABS	PRE	DLF
AGB 211	OPE	60.00c	102.67e	65.00c	2.87c	VGM	ANT	PIK	ABS	PRE	DLF
AGB 229	OPE	38.50d	77.00f	56.50d	2.30c	WVE	LGR	ABS	ABS	PRE	ILF
AGB 230	OPE	76.50b	135.00d	80.00b	2.15c	WVE	ANT	PIK	ABS	PRE	ILF
AGB 232	DEC	66.00b	127.00d	88.50b	2.75c	VRM	LGR	PIK	ABS	PRE	DLF
AGB 270	DEC	68.50b	97.75e	62.50c	2.13c	VPM	ANT	PUR	ABS	PRE	DLF
AGB 299	OPE	74.00b	148.00c	97.50a	3.75c	WVE	DGR	ABS	PRE	PRE	DLF
AGB 315	OPE	85.67b	158.00c	99.33a	4.77b	WVE	LGR	ABS	ABS	PRE	ILF
AGB 323	DEC	107.50a	100.50e	68.00c	2.65c	WVE	ANT	PUR	ABS	PRE	DLF
AGB 324	OPE	58.00c	79.00f	62.50c	2.25c	WVE	ANT	GRE	ABS	PRE	ILF
AGB 325	DEC	86.50b	145.50c	89.50b	2.50c	WVE	ANT	PUR	ABS	PRE	ILF

Table 4 continued

Genotype	Characteristics of the plants									
	HAB	HEI	CAN	LLE	LWI	LVA	COL	ANT	STO	SPI	CTH
AGB 327	DEC	39.50d	68.50f	58.50d	3.35c	WVE	LGR	ABS	ABS	PRE	ILF
AGB 330	OPE	42.00d	69.33f	46.67d	2.37c	VPM	LGR	ABS	ABS	PRE	DLF
AGB 337	OPE	79.50b	132.50d	85.50b	4.85b	WVE	ANT	PUR	ABS	PRE	ILF
AGB 351	OPE	91.00a	116.00e	89.50b	3.95b	WVE	LGR	ABS	ABS	PRE	ILF
AGB 377	OPE	61.25c	82.00f	65.25c	3.63c	WVE	LGR	ABS	ABS	PRE	ILF
AGB 378	DEC	7800b	126.50d	85.00b	2.25c	WVE	LGR	ABS	ABS	PRE	DLF
AGB 380	OPE	103.50a	167.50c	100.50a	5.00b	VRM	LGR	PUR	ABS	PRE	ILF
AGB 382	OPE	90.67a	108.00e	95.00a	3.57c	VGM	ANT	GRE	ABS	PRE	DLF
AGB 385	DEC	41.25d	73.25f	47.75d	1.98c	VRM	ANT	GRE	ABS	PRE	DLF
AGB 388	OPE	71.50b	107.25e	66.25c	3.80b	WVE	LGR	ABS	ABS	PRE	DLF
AGB 391	OPE	71.50b	121.00e	81.50b	4.88b	VPM	ANT	PUR	ABS	PRE	DLF
AGB 393	OPE	80.00b	95.00e	104.00a	4.53b	WVE	LGR	PIK	ABS	PRE	ILF
AGB 396	OPE	60.33c	114.67e	71.67c	3.70c	WVE	LGR	ABS	ABS	PRE	DLF
AGB 404	OPE	71.50b	96.50e	69.50c	4.15b	WVE	LGR	ABS	ABS	PRE	DLF
AGB 408	OPE	104.75a	152.00c	103.00a	5.00b	VPM	LGR	GRE	ABS	PRE	DLF
AGB 458	DEC	80.50b	98.50e	93.00a	7.10a	VRM	ANT	PUR	ABS	PRE	DLF
AGB 464	DEC	57.00c	98.00e	65.50c	3.05c	VPM	ANT	PIK	ABS	PRE	ILF
AGB 465	DEC	71.33b	106.67e	79.67b	2.70c	VPM	ANT	PUR	ABS	PRE	DLF
AGB 469	DEC	48.50d	112.50e	79.00b	2.35c	VPM	ANT	PUR	ABS	PRE	DLF
AGB 470	DEC	68.75b	130.50d	82.25b	3.15c	VPM	ANT	PIK	ABS	PRE	DLF
AGB 471	DEC	77.50b	119.50e	84.50b	2.68c	VPM	LGR	PIK	ABS	PRE	DLF
AGB 472	DEC	74.25b	102.50e	87.00b	3.10c	VPM	ANT	PIK	ABS	PRE	ILF
AGB 475	DEC	56.67c	108.67e	76.67c	3.40c	VPM	LGR	PIK	ABS	PRE	DLF
AGB 477	DEC	79.50b	136.00d	88.00b	2.75c	VPM	LGR	PIK	ABS	PRE	DLF
AGB 479	DEC	54.67c	94.67e	58.33d	3.27c	WVE	ANT	PIK	ABS	PRE	DLF
AGB 487	DEC	67.50b	120.00e	102.50a	2.95c	WVE	ANT	PIK	ABS	PRE	ILF
AGB 495	OPE	107.25a	155.00c	96.00a	4.60b	VRM	ANT	GRE	ABS	PRE	DLF
AGB 507	OPE	62.25c	114.75e	83.25b	4.73b	VRM	ANT	GRE	ABS	PRE	DLF
AGB 510	OPE	91.00a	146.00c	94.00a	4.48b	VRM	ANT	GRE	ABS	PRE	DLF
AGB 511	OPE	64.50c	126.00d	85.50b	4.50b	WVE	ANT	PUR	ABS	PRE	ILF
AGB 523	OPE	63.00c	106.00e	68.00c	3.10c	VRM	ANT	PIK	ABS	PRE	DLF
AGB 526	OPE	51.33c	65.67f	47.67d	3.80b	WVE	ANT	PUR	ABS	PRE	ILF
AGB 543	OPE	97.00a	158.00c	92.50a	4.73b	WVE	ANT	PIK	ABS	PRE	DLF
AGB 584	OPE	93.00a	141.00c	95.00a	5.00b	VRM	ANT	PIK	ABS	PRE	DLF
AGB 663	OPE	63.67c	122.33e	77.33c	4.10b	VRM	ANT	GRE	ABS	PRE	DLF
AGB 690	OPE	96.50a	152.75c	102.00a	4.80b	VRM	LGR	GRE	ABS	PRE	DLF
AGB 692	OPE	105.50a	135.50d	105.00a	5.00b	VRM	ANT	GRE	ABS	PRE	DLF
AGB 693	OPE	47.00d	105.00e	62.50c	3.90b	VPM	ANT	PUR	ABS	PRE	DLF
AGB 703	DEC	39.25d	64.50f	39.75d	2.63c	WVE	LGR	ABS	ABS	PRE	ILF
AGB 719	OPE	77.00b	130.00d	86.50b	4.60b	VRM	ANT	GRE	PRE	PRE	DLF
AGB 739	ERE	84.67b	90.33f	83.00b	4.10b	WVE	ANT	PUR	ABS	ABS	ABS
AGB 750	ERE	78.25b	76.50f	53.75d	3.03c	VRM	ANT	GRE	ABS	ABS	ABS
AGB 772	OPE	51.50c	66.50f	67.00c	3.75c	VRM	ANT	GRE	ABS	PRE	DLF

Table 4 continued

Genotype	Characteristics of the plants										
	HAB	HEI	CAN	LLE	LWI	LVA	COL	ANT	STO	SPI	CTH
AGB 775	OPE	44.00d	80.00f	66.00c	4.35b	WVE	ANT	GRE	ABS	PRE	DLF
AGB 776	OPE	92.50a	150.00c	94.50a	4.78b	VPM	ANT	GRE	ABS	PRE	DLF
AGB 804	ERE	69.00b	73.75f	56.25d	3.25c	VGM	ANT	PUR	ABS	ABS	ABS
AGB 808	OPE	64.00c	121.50e	76.50c	4.00b	VRM	ANT	GRE	ABS	PRE	DLF

Averages followed by the same letter do not differ by the Scott-Knott test at 1% probability

HAB plant habit, *HEI* plant height (cm), *CAN* canopy diameter (cm), *LLE* leaf length 'D' (cm), *LWI* leaf width 'D' (cm), *LVA* leaf variegation, *COL* color of the leaves, *ANT* presence of anthocyanin, *STO* stolon, *SPI* spinescence, *CTH* color of the spines, *ABS* absent, *PUR* purple, *DEC* decumbent, *DLF* different from leaf, *ERE* erect, *ILF* similar to leaf, *LGR* light green, *OPE* open, *PRE* present, *PIK* pink, *UND* undetermined, *GRE* green, *VGM* variegation with green margin, *VPM* variegation with purple margin, *VRM* variegation with red margin, *VWM* variegation with white margin, *WVE* without variegation

potential of this variety to be used as parent in crossings targeting hybrids for this purpose. The average length observed in the accessions evaluated was 50.55 cm, while the variation was from 10.95 cm in the accession G-35 (AGB 523) to 80.50 cm in the accession FRF-372 (AGB 230) (Table 5).

For the diameter of the peduncle, the average observed was 0.78 cm, varying from 0.45 to 1.83 cm (Tables 2, 5). Thin peduncles with good resistance to syncarp dropping are desirable, since weight affects the cost of transport, mainly for export.

Concerning the shape of the peduncle, it is worth mentioning that the European market demands erect peduncles without any deformation, although sinuous peduncles are interesting for floral arrangements. The results of this work demonstrated that 35.3% of the characterized accessions have erect peduncles while 64.7% have sinuous peduncles.

Cut flowers must present well formed and small syncarps, with intense color and crown/syncarp relation lower or equal to one. Syncarps lower than 5.00 cm in diameter were recorded in 12 accessions.

Groups G4, G5 and G6 comprise accessions of *A. comosus* var. *ananassoides*, *A. comosus* var. *parguasensis*, *A. comosus* var. *comosus*, *Ananas* sp. and hybrids from crossings previously carried out for genetic breeding for food use. These accessions stood out mainly due to their ornamental characteristics and were thus included in the evaluation proposed in this work.

The hybrid resulting from the crossing between *A. comosus* var. *bracteatus* and *A. comosus* var. *comosus*, the Ananás S. Bento × Local de Tefé, presents a strong ornamental potential for landscape plants, with open habit, average height of 47.33 cm, reddish syncarps, greenish crown and great contrast for ornamentation (Table 4). The plant presents few spines distributed along the leaves, the crown is small (4.37 cm) and the syncarp is cylindrical, forming an extremely attractive fruit, mainly by the contrast with the greenish crown (Table 5; Fig. 3a).

The accession Smooth Cayenne × Ananaí (AGB 148) is a hybrid resulting from the crossing of *A. comosus* var. *comosus* and *A. comosus* var. *ananassoides. This* accession presents a long and erect peduncle (42.75 cm), and a light pink cylindrical syncarp with average length of 8.23 cm (Table 5). Its leaves are long (88.50 cm) and thin (4.14 cm), with few spines distributed along them, a characteristic probably inherited from the parent Ananaí (Table 4; Fig. 3b).

The accession *Pseudananas* × Rondon (AGB 146) is a hybrid resulting from the crossing of *A. macrodontes* and *A. comosus* var. *comosus,* whose leaves are long (101.00 cm), wide (5.80 cm), glossy and free from spines, with great concentration of anthocyanin (Table 4). Its inflorescence is purplish-red, large and extremely attractive (Fig. 3c). Its syncarp is long (13.83 cm), dark red and trapezoidal, with wide base at fruit stage. The crown is very small (1.93 cm) and almost absent (Table 5; Fig. 3d).

The accessions of *Ananas* sp. are distributed into different groups, which demonstrates that it is difficult to classify the genus taxonomically. These accessions do not show a clear classification pattern, and further research works on molecular markers are needed. Most of them are similar to the *A. comosus* var.

Fig. 2 Genetic variation among pineapple trees with ornamental potential. **a–d** *A. comosus* var. *comosus*; **a** Arroba Tarauacá (AGB 137); **b** Roxo de Tefé (AGB 16); **c** detail of the inflorescence, accession Branco (AGB 28); **d** Branco (AGB 28). **e–f** *A. comosus* var. *erectifolius*; **e** detail of the bud, accession FFR-1387 (AGB 804); **f** Curauá Roxo (AGB 739). **g–i** *A. comosus* var. *parguasensis*; **g** FRF-691 (AGB 327); **h** GF-491 (AGB 775); **i** FRF-813 (AGB 391). **j–r** *A. comosus* var. *ananassoides*; **j** Ananaí (AGB 25); **k** CI-33 (AGB 703); **l** LBB-1446 (AGB 465); **m** G-44 (AGB 526); **n** FRF-372 (AGB 330); **o** DCG-876 (AGB 315); **p** detail of the bud of the accession Valls 9385 (AGB 324); **q** detail of the bud, accession GHAV E JMTM-11 (AGB 323) and **r** detail of the sinuous peduncle, accession Valls 9385 (AGB 324). *Bar* = 1.00 cm

Table 5 Quantitative and qualitative characteristics of peduncle, inflorescence, syncarp and crown in 89 accessions of the pineapple AGB of the Embrapa Cassava & Fruits with ornamental potential

Genotype	Characteristics of the peduncle, inflorescence, syncarp and crown													
	LPE	DPE	SPE	CPE	LIN	DIN	SYL	SYD	LCR	SSY	PBC	CBC	CSF	CSD
AGB 02	19.88h	1.65d	ERE	DPI	7.58c	5.50c	5.55e	5.75b	5.55c	TRA	ABS	ABS	LPI	DPI
AGB 03	28.00f	1.70c	ERE	DRE	7.00c	4.45d	10.25c	5.90b	3.35e	OVO	ABS	ABS	DRE	BUR
AGB 16	19.00h	2.07b	ERE	DRE	6.77c	4.47d	7.50e	5.83b	4.73c	CYL	ABS	ABS	LPU	DPI
AGB 17	28.25f	1.45d	ERE	DPI	6.48c	4.60d	7.30e	5.73b	6.85b	TRA	ABS	ABS	DPI	DPI
AGB 18	23.00 g	1.70c	ERE	DPI	6.73c	4.13e	13.83b	7.73b	1.93f	TRA	ABS	ABS	DRE	DGR
AGB 20	27.25f	2.00b	ERE	DPI	6.05d	4.70d	7.27e	6.40b	4.90c	TRA	ABS	ABS	DPI	DPI
AGB 25	45.75d	0.45 h	ERE	LPI	2.88f	1.58 h	3.95f	2.75c	2.80e	CYL	ABS	ABS	CRE	CRE
AGB 28	28.50f	2.35a	ERE	LGR	7.15c	4.95d	8.40d	5.95b	4.15d	TRA	ABS	ABS	LGR	LGR
AGB 35	25.50 g	2.00b	ERE	DPI	5.65d	5.00d	8.83d	7.40b	4.45d	TRA	ABS	ABS	DPI	DPI
AGB 45	27.00 g	1.87c	ERE	DPI	6.00d	5.37c	7.20e	6.73b	5.60c	TRA	ABS	ABS	LPI	DPI
AGB 47	20.67 h	1.87c	ERE	DPI	9.03b	5.53c	8.63d	6.37b	4.93c	TRA	ABS	ABS	LPI	LPI
AGB 56	29.00f	2.20b	ERE	DPI	5.50d	4.43d	11.88c	6.45b	8.23a	TRA	ABS	ABS	DPI	DPI
AGB 81	28.75f	2.48a	ERE	DRE	8.08b	7.23b	9.15d	8.43a	0.00 g	TRA	ABS	ABS	DRE	DGR
AGB 83	27.00 g	1.27e	ERE	LPI	6.40c	6.00c	8.07d	6.60b	0.00 g	OVO	ABS	ABS	ORA	LPI
AGB 97	18.75 h	2.20b	ERE	DPI	6.65c	5.98c	7.60d	7.38b	4.20d	TRA	ABS	ABS	LPI	LPI
AGB 101	47.00d	2.20b	ERE	LPI	5.83d	5.03d	9.00d	6.17b	6.77b	OVO	PRE	LPI	LPI	LPI
AGB 110	23.75 g	1.63d	ERE	DPI	4.88e	4.45d	7.10e	5.28b	3.60e	TRA	ABS	ABS	DPI	DPI
AGB 119	31.50f	2.10b	ERE	DPI	6.68c	5.38c	11.05c	6.93b	5.53c	TRA	ABS	ABS	DPI	DPI
AGB 123	26.25 g	2.00b	ERE	DPI	5.55d	4.75d	8.08d	6.18b	3.50e	TRA	ABS	ABS	DPI	DPI
AGB 126	22.33 g	1.80c	ERE	DPI	5.93d	4.77d	9.07d	6.17b	3.27e	TRA	ABS	ABS	DPI	DPI
AGB 128	28.33f	1.87c	ERE	DPI	6.07d	4.70d	8.73d	5.73b	4.03d	TRA	ABS	ABS	DPI	DPI
AGB 137	15.00 h	2.55a	ERE	LPU	11.50a	8.25a	17.75a	9.75a	4.25d	CON	ABS	ABS	DPU	DPI
AGB 146	15.00 h	1.37e	ERE	LRE	7.00c	4.53d	7.87d	6.03b	4.37d	CYL	PRE	DGR	DRE	LRE
AGB 148	42.75d	1.90c	LSI	LPI	6.03d	4.48d	8.23d	5.63b	5.03c	CYL	PRE	LPI	LPI	LPI
AGB 152	18.00 h	1.55d	ERE	DPI	5.45d	4.30e	6.90e	5.90b	5.15c	OVO	ABS	ABS	DRE	DPI
AGB 174	38.25e	1.70c	ERE	LPI	7.13c	3.88e	7.83d	5.18b	3.75d	CYL	ABS	ABS	LPI	LPI
AGB 195	38.33e	0.70 g	ERE	DPI	3.63e	2.67f	3.47f	3.90c	4.97c	GLO	ABS	ABS	DPU	DPI
AGB 197	31.25f	0.55 h	LSI	LPI	3.88e	2.60f	3.80f	3.40c	3.18e	TRA	ABS	ABS	LPI	LPI
AGB 198	42.00e	0.80 g	ERE	LPI	2.40f	1.85 h	5.00e	2.80c	2.05f	OVO	ABS	ABS	LPI	LPI
AGB 207	48.50d	0.83 g	LSI	LPI	4.25e	2.48 g	6.43e	3.93c	2.65e	CYL	ABS	ABS	DGR	DGR
AGB 208	33.25f	0.65 h	LSI	LPI	2.80f	1.90 h	3.63f	3.08c	1.30f	GLO	ABS	ABS	LPI	DGR
AGB 210	23.00 g	1.68c	ERE	DPI	8.10b	5.25c	8.70d	6.33b	5.35c	TRA	ABS	ABS	DPI	DPI
AGB 211	33.67f	1.13f	ERE	LRE	4.07e	3.60f	4.83f	4.57c	3.10e	GLO	ABS	ABS	LPU	DPI
AGB 229	39.50e	0.80 g	ERE	LPI	3.55e	2.35 g	2.90f	3.05c	1.55f	CYL	ABS	ABS	LPI	LPI
AGB 230	80.50a	0.85 g	ERE	LPI	3.95e	2.50 g	5.80e	3.80c	2.00f	CYL	ABS	ABS	CRE	CRE
AGB 232	58.50c	0.95f	LSI	LPI	3.25f	2.40 g	6.80e	4.50c	3.60e	CYL	ABS	ABS	CRE	CRE
AGB 270	51.50d	0.63 h	ERE	LPI	2.78f	1.93 h	4.38f	2.98c	1.33f	CYL	ABS	ABS	DPI	DPI
AGB 299	28.00f	2.20b	ERE	LPI	7.80c	5.35c	11.60c	7.25b	0.00 g	CYL	ABS	ABS	LPI	LPI
AGB 315	36.67e	1.57d	ERE	LPI	6.57c	3.77e	6.63e	4.47c	2.53e	CYL	ABS	ABS	DPI	DPI
AGB 323	52.00d	1.05f	LSI	DPU	5.60d	4.23e	7.88d	4.65c	3.08e	OVO	ABS	ABS	DPI	DPI
AGB 324	65.00b	0.65 h	MSI	LPI	4.85e	2.25 g	8.40d	3.25c	1.85f	CYL	ABS	ABS	DPI	DPI
AGB 325	76.50a	1.00f	MSI	DPI	3.90e	2.90f	5.00e	3.30c	0.35 g	CYL	ABS	ABS	DPI	LPI

Table 5 continued

Genotype	Characteristics of the peduncle, inflorescence, syncarp and crown												
	LPE	DPE	SPE	CPE	LIN	DIN	SYL	SYD	LCR	SSY	PBC	CBC	CSF	CSD
AGB 327	41.00e	0.95f	ERE	LGR	2.15f	1.75 h	3.05f	3.80c	6.90b	GLO	ABS	ABS	YEL	ORA
AGB 330	38.00e	0.50 h	LSI	DPI	2.30f	1.80 h	2.93f	2.60c	1.60f	OVO	ABS	ABS	LPI	CRE
AGB 337	25.50 g	1.40e	ERE	LRE	7.50c	4.15e	8.05d	5.05b	4.60d	OVO	ABS	ABS	LPU	DGR
AGB 351	50.00d	2.45a	ERE	LPI	4.2e	3.35f	6.95e	5.10b	3.00e	CYL	PRE	LPI	DPI	LPI
AGB 377	39.75e	0.60 h	LSI	LPI	3.00f	2.95f	4.65f	4.20c	3.45e	CYL	ABS	ABS	DRE	DGR
AGB 378	67.00b	0.90 g	LSI	LPI	3.30f	2.15 g	6.10e	4.00c	2.30e	CYL	ABS	ABS	LPI	LGR
AGB 380	48.50d	2.00b	ERE	DPI	7.80c	4.25e	10.15c	6.00b	2.95e	OVO	ABS	ABS	LPI	LPI
AGB 382	28.33f	1.73c	ERE	LRE	2.80f	2.87f	4.03f	4.50c	8.20a	GLO	ABS	ABS	DGR	DGR
AGB 385	51.25d	0.48 h	MSI	LPI	2.53f	1.88 h	3.88f	2.78c	1.00f	OVO	ABS	ABS	YEL	YEL
AGB 388	30.25f	1.05f	ERE	LPI	4.53e	3.33f	6.23e	4.60c	3.18e	GLO	ABS	ABS	LPU	DGR
AGB 391	18.50 h	1.45d	ERE	DRE	5.93d	3.13f	6.53e	4.73c	4.05d	CYL	ABS	ABS	DRE	LGR
AGB 393	31.67f	1.43d	LSI	LPI	3.70e	3.03f	6.00e	5.57b	4.57d	GLO	ABS	ABS	LPU	DPI
AGB 396	33.33f	1.33e	ERE	LPI	6.70c	3.73e	6.47e	4.63c	3.33e	CYL	PRE	LPI	LPI	LPI
AGB 404	36.00e	1.30e	ERE	LGR	4.05e	3.30f	4.70f	4.15c	4.15d	OVO	ABS	ABS	LGR	LGR
AGB 408	31.00f	1.98b	ERE	DPI	10.30a	5.83c	10.98c	7.08b	4.60d	TRA	ABS	ABS	DPI	DPI
AGB 458	24.00 g	2.50a	ERE	DPU	4.00e	3.30f	13.75b	8.20a	1.85f	TRA	ABS	ABS	LPU	DGR
AGB 464	57.00c	0.55 h	LSI	DPI	3.10f	2.30 g	3.80f	3.20c	2.05f	OVO	ABS	ABS	ORA	DGR
AGB 465	51.33d	0.70 g	MSI	DPI	2.07	1.77 h	3.40f	2.73c	2.13f	OVO	ABS	ABS	YEL	LPI
AGB 469	46.50d	0.85 g	ERE	LPI	3.10f	2.65f	4.15f	3.30c	0.10 g	GLO	ABS	ABS	DGR	DGR
AGB 470	72.75a	0.90 g	MSI	LPI	3.58e	2.30 g	4.90f	3.00c	1.63f	OVO	ABS	ABS	LPI	LPI
AGB 471	63.25b	0.70 g	MSI	LPI	3.18f	1.95 h	4.83f	3.25c	1.28f	OVO	ABS	ABS	LPI	LPI
AGB 472	39.00e	0.53 h	LSI	LPI	2.88f	2.10 g	3.20f	2.55c	1.18f	OVO	ABS	ABS	LPI	LPI
AGB 475	57.00c	0.77 g	LSI	LPI	3.40f	2.47 g	3.63f	3.23c	2.13f	OVO	ABS	ABS	ORA	DPI
AGB 477	56.00c	0.78 g	LSI	LPI	3.93e	2.33 g	6.90e	3.50c	2.48e	CYL	ABS	ABS	LPI	ORA
AGB 479	38.67e	0.67 h	LSI	LPI	2.93f	2.27 g	3.90f	3.03c	1.67f	OVO	ABS	ABS	LPI	CRE
AGB 487	77.00a	1.00f	MSI	LPI	3.40f	2.50 g	4.90f	3.15c	0.80 g	CYL	ABS	ABS	LPI	LPI
AGB 495	26.25 g	1.78c	ERE	DPI	7.88c	5.48	8.03d	5.25b	4.93c	TRA	ABS	ABS	DRE	DPI
AGB 507	21.00 h	1.33e	ERE	DPI	5.78d	3.38f	6.58e	5.08b	3.23e	GLO	ABS	ABS	LPI	LGR
AGB 510	30.00f	1.83c	ERE	DPI	9.80a	5.10c	11.53c	6.75b	4.43d	TRA	ABS	ABS	DPI	DPI
AGB 511	25.50 g	1.20e	ERE	DRE	4.60e	4.20e	8.80d	5.75b	3.75d	CYL	ABS	ABS	DPU	BUR
AGB 523	10.95 h	1.10f	ERE	LPU	4.60e	3.35f	5.00e	4.05c	1.60f	OVO	ABS	ABS	BUR	DPI
AGB 526	29.33f	1.83c	ERE	DRE	3.27f	2.90f	8.27d	7.26b	7.43b	GLO	ABS	ABS	DPU	DPI
AGB 543	29.25f	2.10b	ERE	LRE	9.80a	5.70c	19.25a	7.48b	5.00c	CYL	ABS	ABS	DRE	DGR
AGB 584	24.50 g	2.15b	ERE	DPI	8.65b	5.50c	11.00c	7.20b	6.85b	TRA	ABS	ABS	DPI	LPI
AGB 663	14.00 h	0.97f	ERE	LPI	4.10e	3.57f	6.03e	4.80c	2.07f	TRA	ABS	ABS	LPI	DPI
AGB 690	27.00 g	1.95c	ERE	DPI	9.10b	5.35c	9.75c	6.25b	4.95c	TRA	ABS	ABS	DPI	DPI
AGB 692	31.00f	2.20b	ERE	DPI	10.00a	5.55c	11.40c	6.65b	4.85c	TRA	ABS	ABS	DPI	DPI
AGB 693	20.00 h	1.35e	ERE	LPU	5.75d	4.20e	6.50e	5.50b	3.00e	OVO	ABS	ABS	DPU	DPI
AGB 703	34.25f	0.58 h	ERE	LGR	2.38f	0.80 h	4.33f	3.30c	4.13d	GLO	ABS	ABS	LGR	LGR
AGB 719	28.50f	2.25b	ERE	DPI	6.30c	5.95c	10.10c	6.90b	0.00 g	TRA	ABS	ABS	DRE	DGR
AGB 739	40.17e	0.70 g	ERE	DRE	4.13e	1.33 h	5.00e	4.47c	3.07e	OVO	ABS	ABS	DRE	LRE
AGB 750	41.00e	0.78 g	ERE	DRE	2.33f	1.68 h	4.30f	2.93c	3.15e	OVO	ABS	ABS	DRE	ORA
AGB 772	26.50 g	2.05b	ERE	DPI	4.05e	3.80e	6.85e	5.15b	5.15c	GLO	ABS	ABS	LPI	ORA

Table 5 continued

Genotype	Characteristics of the peduncle, inflorescence, syncarp and crown												
	LPE	DPE	SPE	CPE	LIN	DIN	SYL	SYD	LCR	SSY	PBC	CBC	CSF	CSD
AGB 775	16.50 h	0.90 g	ERE	LRE	3.50e	2.50 g	3.00f	3.50c	3.50e	GLO	ABS	ABS	DGR	DGR
AGB 776	31.25f	1.75c	ERE	DPI	7.50c	4.88d	8.95d	6.33b	5.10c	TRA	ABS	ABS	DPI	DPI
AGB 804	41.50e	1.00f	ERE	DRE	4.15e	2.45 g	4.43f	3.10c	2.65e	OVO	ABS	ABS	DRE	DGR
AGB 808	15.50 h	1.05f	ERE	LPI	5.20d	3.80e	5.45e	4.30c	3.75d	TRA	ABS	ABS	DPI	DPI

Averages followed by the same letter do not differ by the Scott-Knott test at 1% probability

LPE peduncle length, *DPE* peduncle diameter, *SPE* shape of the peduncle, *CPE* color of the bractea of the peduncle, *LIN* inflorescence length (cm), *DIN* inflorescence diameter (cm), *SYL* syncarp length after closure of the last flower (cm), *SYD* syncarp diameter after closure of the last flower (cm), *LCR* crown length after closure of the last flower (cm), *SSY* shape of the syncarp at 30 days, *PBC* presence of bractea under the crown, *CBC* color of the bractea under the crown, *CSF* color of the syncarp after closure of the last flower, *CSD* color of the syncarp at 30 days, *ABS* absent, *BUR* burgundy, *CON* conical, *CRE* creamy white, *CYL* cylindrical, *DGR* dark green, *DPI* dark pink, *DPU* dark purple, *DRE* dark red, *ERE* erect, *GLO* globose, *LGR* light green, *LPI* light pink, *LPU* light purple, *LRE* light red, *MSI* highly sinuous, *ORA* orange, *OVO* ovoid, *PRE* present, *LSI* little sinuous, *TRA* trapezoid with wide base, *YEL* yellowish

ananassoides or *A. comosus* var. *parguasensis*, although they do not meet certain conditions which are peculiar to these varieties. They may be natural hybrids among these varieties, but only further studies can corroborate this hypothesis.

The accession GPS-389 (AGB 195) is globoid, with small syncarp (3.47 cm in length and 3.90 cm in diameter) and characteristics similar to those of *A. comosus* var. *parguasensis* (Table 5). This accession has potential to be used as minifruits or for landscape plants (Fig. 3e).

The accession FRF-202 (AGB 197) is the most differentiated among those evaluated from the germplasm active bank because its habit is different from all the three found on the list of morphological descriptors for pineapple. The leaves are small (35.00 cm), green, with wavy margins and small spines (Table 4). The inflorescences and syncarps are light pink and small (Table 5). This accession can be used in landscape plants, due to its unusual type of growth that forms massive and its high tillering. Due to the beauty of its fruits and absence of peduncle, its use as minifruits may be interesting (Fig. 3f).

The group G7 is formed by accessions of *A. comosus* var. *bracteatus,* accessions of the species *A. macrodontes, one* accession of *A. comosus* var. *comosus,* GF-492 (AGB 772) and one accession *Ananas* sp. G-69 (AGB 507).

The *A. comosus* var. *bracteatus*, also known as ananás-de-cerca, ananás selvagem, ananás-do-mato and karaguata-ruha, is mainly distributed in the southern Brazil, Northern Argentina and Paraguay.

It was observed that all of the accessions evaluated in this group were larger than 125.00 cm, presenting normal growth habit and vigorous plants, forming large clumps, due to the abundant tillering. They are used as hedge in some regions, mainly because of the presence of large and aggressive spines along their leaves (Coppens D'Eeckenbrugge and Duval 2009).

The variation found is related to the color of the leaves and color, size and shape of the syncarp. Ananás Tricolor (AGB 17) has green leaves, white margins and pink spines (Fig. 3g). The accession Ananás vermelho do mato (AGB 03) presents darker leaves close to purplish red, with average size of 90.00 cm (Fig. 3k), while the other accessions presented green leaves with red spots.

In most accessions, the syncarp is dark pink, trapezoidal with wide base, measuring about 15.00 cm, excepting the accession Ananás vermelho do mato, which is reddish, ovoid, measures 9.00 cm and is extremely ornamental.

The accession Silvestre 166 (AGB 97) has a light pink syncarp and is smaller (7.10 cm) than the other accessions of this variety.

The *A. comosus* var. *bracteatus* has accessions with thick peduncles and colorful syncarps. They are generally medium to large size, with juicy and edible pulp, whose flavor is not so appreciated as that of the other varieties cultivated for fresh consumption. There are records of its use in juices, in spite of the common presence of seeds (Coppens D'Eeckenbrugge and Duval 2009).

◀**Fig. 3** Genetic variation among pineapple trees with ornamental potential. **a–d** hybrids; **a** Ananás S. Bento × Local de Tefé (AGB 146), **b** Smooth Cayenne × Ananaí (AGB 148); **c** detail of the inflorescence, accession *Pseudananas* × Rondon (AGB 18); **d** *Pseudananas* × Rondon (AGB 18). **e–f** *Ananas* sp.; **e** GPS-389 (AGB 195); **f** FRF-202 (AGB 197). **g–m** *A. comosus* var. *bracteatus*; **g** detail of the inflorescence and leaves, accession Ananás Tricolor (AGB 17); **h** detail of the syncarps, accession FRF-1213 (AGB 543); **i** bud, accession FRF-16A (AGB 119); **j** detail of the cylindrical syncarp, accession FRF-1213 (AGB 543); **k** Ananás Vermelho do Mato (AGB 03); **l** BGA-12 (AGB 56); **m** Selvagem 5 (AGB 47). **n–p** *A. macrodontes*; **n** I-26 803 (AGB 83); **o** FRF-327 (AGB 299); **p** detail of the inflorescence and leaves, with the presence of spines, accession Silvestre 25 (AGB 81). *Bar* = 1.00 cm

In Northeastern Brazil, these pineapples, better known as 'Gravatás', are used at Christmas season for table decoration, mainly in rural communities. They are commonly found in street markets during that season, at very low cost, in spite of their beauty and durability.

Its use as ornamental plant is incipient in Brazil, but in other parts of the world it has been cultivated and marketed for this purpose.

Out of the 25 accessions of the *A. comosus* var. *bracteatus* evaluated in this study, only four presented variation, which demonstrates the need for molecular studies for the characterization of the other accessions and probable identification of duplicates. Duval et al. (2000, 2001b) reported that this variety presents little variation, due to its very narrow genetic base.

The species *A. macrodontes,* known as *Pseudananas sagenarius* in the former classification, has genotypes popularly known as gravatá-de-rede, gravatá-de-cerca-brava, nana-cabaça and yvira. It is a rustic, exuberant and vigorous plant that can reach 2.00 meters of height (Coppens D'Eeckenbrugge and Duval 2009). Outstanding characteristics in the species are the absence of crown and its propagation, by stretching below ground by means of stolons. For the four accessions evaluated, the maxiumm height achieved was 77.00 cm, recorded in the accession FRF-1239 (AGB 719) (Table 4). The plants were not in their natural habitat, which may explain their reduced size.

The leaves are bowed, arranged in a rosette, with approximately 85.00 cm in length and 4.00 cm in width, coriaceous, with aggressive spines of the antrorse and retrorse type (Table 4). The lack of systematic cultivation of accessions of this species is the greatest hindrance for its exploration as ornamental plant. Its aggressiveness complicates the management and the phytotechnical procedures necessary for the culture.

The stems are erect, considered short and thick, with average length of 28.00 cm and diameter of 2.00 cm. The syncarps presented an average of 9.73 cm in length and 7.29 cm in diameter (Table 2). These data agree with the descriptions of this genus recorded by Leme and Siqueira Filho (2006).

The color, size and shape of the syncarps presented variation. The accession Silvestre 25 (AGB 81) has green leaves and pink spines, trapezoidal syncarp with wide base and intense red color. This accession of this species is the most indicated for ornamental pineapple breeding (Fig. 3p).

Another accession evaluated, I-26 803 (AGB 83), presents light pink ovoid syncarp, which can be observed in Fig. 3n.

There are records of the use of this variety for hedge, mainly due to the presence of spines distributed throughout the plants (Coppens D'Eeckenbrugge and Duval 2009).

Morphological characterization performed in this study allowed for some inferences on the pineapple taxonomy, considered one of the most complicated of the Bromeliaceae family, probably due to the agricultural profile of the genus. The current classification divides the genus in two species: *Ananas comosus* with five botanical varieties (*A. comosus* var. *ananassoides*, *A. comosus* var. *bracteatus*, *A. comosus* var. *erectifolius*, *A. comosus* var. *parguasensis* and *A. comosus* var. *comosus*) and *A. macrodontes* (Coppens D'Eeckenbrugge and Leal 2003). The most significant difference in relation to the previous taxonomy refers to the five botanical varieties which were earlier considered species (Smith and Downs 1979), ignoring the absence of incompatibility barriers between them, among other attributes required for this classification (Leal et al. 1998).

The seven groups formed in this study and the species distribution considering their site of origin adjusts better to the current taxonomy, and also considering previous results obtained by this research group where hybridizations were possible among all varieties of *A. comosus* (Souza 2010), including the interspecific hybridization with *A. macrodontes* and *A. comosus* var. *comosus*.

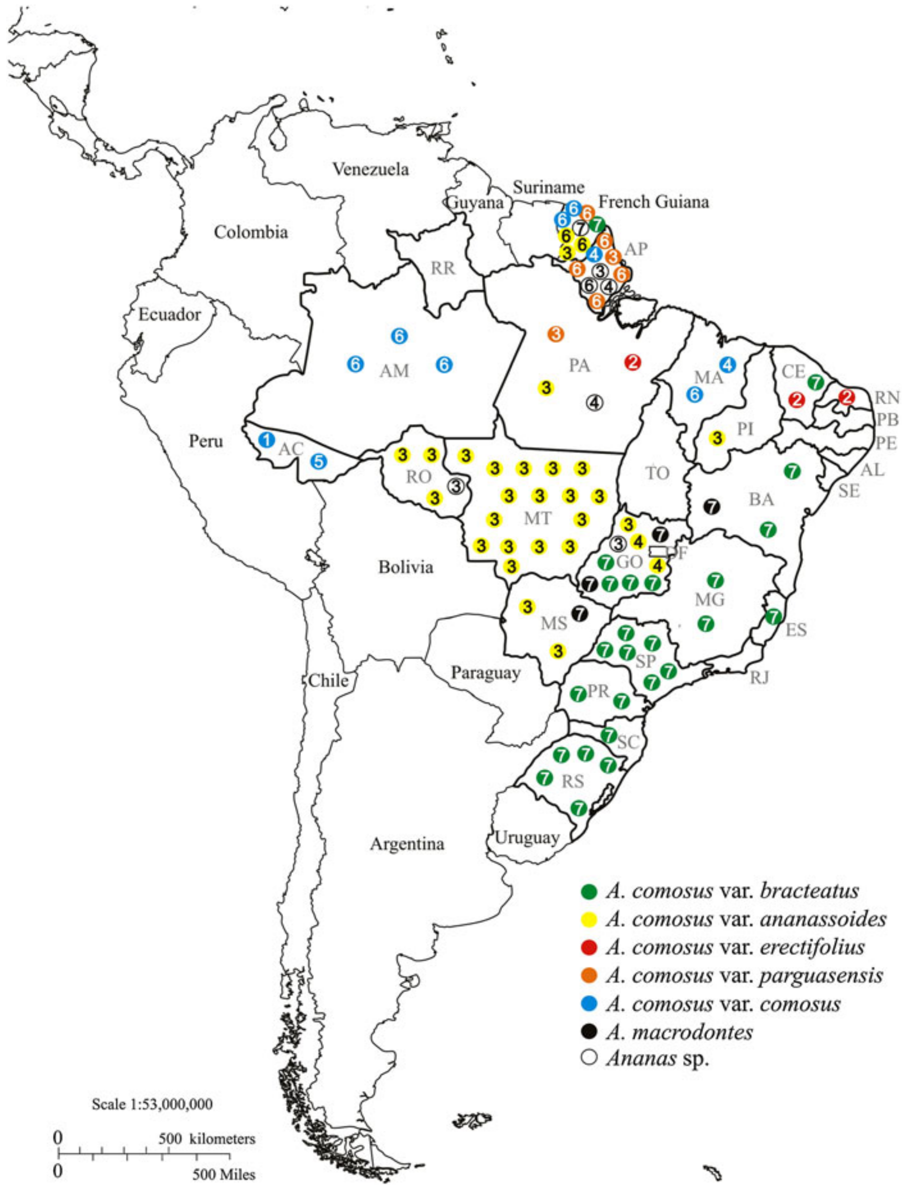

Fig. 4 Location of accesses based on passport data showing the botanical variety (*colorful circles*) and grouping (*number*) achieved by the UPGMA method based on the Gower algorithm, from twenty-five qualitative and quantitative characters (*1* G1 group; *2* G2 group; *3* G3 group; *4* G4 group; *5* G5 group; *6* G6 group; *7* G7 group). Brazilian states: *AC* Acre, *AL* Alagoas, *AP* Amapá, *AM* Amazonas, *BA* Bahia, *CE* Ceará, *DF* Distrito Federal, *ES* Espírito Santo, *GO* Goiás, *MA* Maranhão, *MT* Mato Grosso, *MS* Mato Grosso do Sul, *MG* Minas Gerais, *PA* Pará, *PB* Paraíba, *PR* Paraná, *PE* Pernambuco, *PI* Piauí, *RJ* Rio de Janeiro, *RN* Rio Grande do Norte, *RS* Rio Grande do Sul, *RO* Rondônia, *RR* Roraima, *SC* Santa Catarina, *SP* São Paulo, *SE* Sergipe, *TO* Tocantins

The group formed by accessions and their site of origin, according to passport data, seems to support the hypothesis of Leal and Antoni (1981) that the center of origin of the genus may have been the Northern part of South America and that the early domestication probably occurred in the Guianas and Northeastern of Brazil. The accessions are presented in the map (Fig. 4), according to the groups formed and site of collection. In these regions it is possible to see the presence of the botanical varieties *A. comosus* var. *comosus*, *A. comosus* var. *ananassoides*, *A. comosus* var. *parguasensis* and *A. comosus* var. *bracteatus* (representatives of G4, G6 and G7 groups) and *A. comosus* var. *erectifolius* (G2), showing a greater variation of wild and cultivated forms than the variation found in the Western Central, Southern and Southeastern regions of Brazil, with most of them being *A. comosus* var. *ananassoides* (G3), *A. comosus* var. *bracteatus* and the species *A. macrodontes* (G7). According to these authors, the Southeastern region of Brazil could be a secondary center of origin of these species. This difference observed in the genetic variation between these two regions corroborate with the results obtained in the present work, reinforcing this theory.

On the other hand, the formation of groups G4 and G6 showed a morphological similarity among different accessions from different botanical varieties, with most of them in two groups, including some hybrids. The *A. comosus* var. *ananassoides,* which shows a wide range of morphological and adaptive variations from forest type to savannah, were concentrated basically on G3, but may be found in other groups with another botanical varieties, mainly with *A. comosus* var. *comosus.*

These two varieties show the highest genetic variation inside the genus, justifying their distribution in many regions in the country. The accession AGB 377, included in this group as *Ananas* sp., is probably a *A. comosus* var. *ananassoides* since the passport data recorded its origin in the savannah where the occurrence of *A. comosus* var. *parguasensis* is not observed. The other accessions of *Ananas* sp. (AGB 393 and AGB 197) were originated from the Northern region, where *A. comosus* var. *ananassoides* and *A. comosus* var. *parguasensis* are present and, therefore, more studies are needed for their correct classification. The AGB 197 is the only accessions that does not hybridize with any other accession and, currently, several studies are ongoing to clarify this matter (Souza et al. 2011).

Conclusions

The pre-selected accessions from the pineapple AGB presented wide genetic variation and can be classified into different ornamental use categories;

The widest genetic variation observed inside the variety is recorded among the accessions of *A. comosus* var. *ananassoides*, which have striking characteristics for use as cut flower;

The *A. comosus* var. *erectifolius* form the group G2 and can be used for landscape plants, cut flower, pot plant and minifruits;

The accessions *A. comosus* var. *bracteatus* and *A. macrodontes* are selected for landscape plants and hedge;

Different accessions of the varieties studied can be used as parents in the genetic breeding program for the generation of pineapple ornamental hybrids.

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