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DIVERSITY OF PINEAPPLE GENETIC RESOURCES IN CUBA: THREATS AND ACTIONS FOR MINIMIZING LOSSES

DIVERSIDAD DE LOS RECURSOS FITOGENÉTICOS DE PIÑA EN CUBA: AMENAZAS Y ACCIONES PARA MINIMIZAR SU PÉRDIDA

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SUMMARY

Conservation of plant genetic resources (PGR) is essential to preserve diversity and to provide genes for plant breeding. This paper assesses the current status of pineapple PGR diversity in Cuba and actions are proposed to minimize the loss of diversity. *In situ* diversity was evaluated through field trips to different locations across the country, evidence was found that pineapple germplasm diversity is low. Only three (Spanish, Cayenne and Pernambuco) out of the five horticultural groups of this crop are presently planted at Cuba. Red Spanish is the predominant cultivar, and White Pineapple is an endangered one. The highest diversity was found at the Eastern region, where it was possible to find at least two different cultivars from each of these three groups. The *ex situ* pineapple collection contains 56 accessions, 45 % belong to the Spanish group, 20 % to Cayenne and 14 % to Pernambuco, while the rest are hybrids, improved cultivars and other related species. Threats of diversity loss were identified by the Research-Action-Participation method. Farmers and experts agreed that growing of the most common cultivars is being abandoned and consequently, there is high risk of loss of *in situ* diversity. Results document the low diversity of pineapple genetic resources in the country and the need to use *in situ* and *ex situ* conservation approaches as complementary strategies for germplasm preservation for future generations.

Index words: *Ananas comosus*, *ex situ* conservation, germplasm, *in situ* conservation.

RESUMEN

La conservación de los recursos fitogenéticos (RFG) es esencial para preservar la diversidad y proporcionar genes para el mejoramiento de plantas. Este trabajo evalúa el estado actual de la diversidad de RFG de piña en Cuba y propone acciones para minimizar su pérdida. La diversidad *in situ* se evaluó a través de prospecciones en diferentes lugares del país, lo que evidenció que la diversidad del germoplasma de la piña es baja. Sólo tres (Español, Cayena y Pernambucano) de los cinco grupos hortícolas de este cultivo se cultivan en la isla. Española Roja es el cultivar predominante y Piña Blanca está en peligro de extinción. La diversidad fue mayor en la región oriental, donde fue posible encontrar al menos dos cultivares diferentes de cada uno de estos tres grupos. La colección *ex situ* de piña contiene 56 accesiones, de las cuales 45 % pertenecen al grupo Española, 20 % a Cayena y 14 % a Pernambuco, mientras que el resto son híbridos, cultivares mejorados y otras especies relacionadas. Las amenazas de pérdida de diversidad fueron identificadas por el método de Investigación-Acción-Participación. Agricultores y expertos coincidieron en que se abandona el cultivo de los cultivares más comunes y, por consiguiente, existe un alto riesgo de pérdida de diversidad *in situ*. Los resultados documentan la baja diversidad de recursos genéticos de piña en el país y la necesidad de utilizar enfoques de conservación tanto *in situ* como *ex situ* como estrategias complementarias para la preservación del germoplasma para las generaciones futuras.

Palabras clave: *Ananas comosus*, conservación *ex situ*, germoplasma, conservación *in situ*.

INTRODUCTION

Conservation and sustainable management of plant genetic resources for food and agriculture (PGRFA) are necessary to guarantee food security for future generations. In the PGRFA context, genetic resource conservation can be performed both *in situ* and *ex situ*, and both are complementary approaches. *In situ* conservation refers to the preservation of natural ecosystems and habitats to guarantee continuity of evolutionary processes is guaranteed; this could include the preservation of traditional cultivars ("on farm" conservation), and associated traditional agricultural methods and knowledge of local farmers. Local producers have played a key role in the creation, maintenance and promotion of genetic diversity, and they have developed skills to meet their specific needs like quality, resistance to pests and pathogens, and adaptation to different soils, water availability and varying climate (Vernooy and Halewood, 2015). *Ex situ* conservation refers to the storage of genetic material in germplasm collections (*e.g.* vegetative field collections, seeds or *in vitro* culture banks).

Pineapple (*Ananas comosus* L. Merrill, 2n = 2x = 50) is a species of the Bromeliaceae family native to South America and it is currently grown in tropical, subtropical and mild climate regions worldwide (Rohrbach *et al.*, 2003;

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Smith and Downs, 1979). Coppens d'Eeckenbrugge and Leal (2003) revised pineapple taxonomy and proposed one genus, *Ananas*, with two species *A. comosus* (L.) Merr. (diploid, 2n = 2x = 50) and *A. macrodontes* Morren (tetraploid, 2n = 4x = 100). *A. comosus* includes five botanical varieties: *comosus, ananassoides, parguazensis, erectifolius* and *bracteatus*. The cultivated pineapple varieties are included in var. *comosus* and they are usually classified into five phenotypic groups: Spanish, Queen, Abacaxi or Pernambuco, Cayenne and Maipure or Perolera (Paull and Duarte, 2011; Py *et al.*, 1987). The groups can be easily distinguished with molecular markers (Rodríguez *et al.*, 2013). In terms of production, pineapple is the third most important tropical fruit, after banana (*Musa × paradisiaca*) and mango (*Mangifera indica*), with around 25 million tons produced worldwide in 2014 (FAOSTAT, 2015).

Pineapple is not native to Cuba but it was present in the island since pre-Columbian times. It was introduced from other areas of the Caribbean and continental America, and it is an important fruit crop in the country with a production of almost 90,000 t in 2013 (FAOSTAT, 2015). Cuban researchers had previously surveyed the national territory to locate and catalogue the largest possible number of native pineapple genotypes and related species from the Bromeliaceae family (Isidrón *et al.*, 2003). These efforts followed the broad objective of preserving, to the greatest possible extent, the genetic diversity of this crop. Despite the long history of pineapple cultivation on the island, some of the biodiversity of this species remains unpreserved, and scattered as rare varieties growing in the wild throughout the country or as small plantations of locally adapted ecotypes. In addition, threats to the diversity of pineapple have increased in recent years. Participatory research-action methods (RAP) (Pérez, 1990) were used in this research as an effective tool for the management and recovery of local genetic resources. The present work assessed the current state of genetic resources of pineapple in Cuba, identified the main threats to its diversity and proposed actions that reduce threats and promotes secure pineapple conservation.

MATERIALS AND METHODS

Field trips for prospecting pineapple varieties were carried out from 2000 to 2008 across the country (Table 1). The survey covered most pineapple producers from each territory. Propagules, like slips or ground suckers, and fruit crowns were collected for conservation purposes and propagation studies. Plant material was photographed and precise location of the collection sites was determined with topographical and physical maps. Voucher samples were stored in the national germplasm collection at the Bioplant Center, Ciego de Ávila province located at 21º 47' N and 78º 17' E, at 80 m above sea level.

Accessions were identified by the collection curators, and common names used by farmers were also recorded. Plants were classified into horticultural groups according to reported classification criteria (Cerrato, 2013; de Matos

Table 1. Region, province and municipality of each surveyed location.

	Province	Municipality		Province	Municipality		Province	Municipality
WESTERN	Pinar del Río	La Palma	CENTRAL	Villa Clara	Santo Domingo	EASTERN	Granma	Cienaguilla
		Viñales			Corralillo			
		Rosario			Caibarién			
	Artemisa	San Cristóbal		Cienfuegos	Rodas		Holguín	Gibara
		Candelaria			Abreu			Moa
		San Antonio			Aguada de Pasajeros			Frank País
		Alquizar						
		Artemisa						
	Mayabeque	Madruga		Camagüey	Morón		Santiago de Cuba	Caney
		Jaruco			Florencia			
	Matanzas	Bolondrón		Ciego de Ávila	Cascorro		Guantánamo	Baracoa
		Jagüey Grande			Esmeralda			Niceto Pérez
		Los Arabos						
		La Fe						
Special municipality Isla de la Juventud		Gerona						

and Reinhardt, 2009; Morton, 1987; Py *et al.*, 1987; Sandoval and Torres, 2011). Classification relied on plant and fruit morphological characteristics. The presence of cultivars per horticultural group was determined in each municipality, province and region. *Ex situ* diversity was assessed by calculating the percentage of each cultivar in the germplasm collection, according to its horticultural group and origin.

Research-Action-Participation method (RAP) (Pérez, 1990) was used to identify threats to the genetic diversity of pineapple germplasm conserved *in situ* and *ex situ*. The RAP method included three stages: Phase I: creation of the working group (AE group) with five experts among professionals and farmers with extensive expertise and knowledge on traditional pineapple cultivation; Phase II: data collection from focused and semi-structured interviews, farmer testimonies and field notes that concentrated on the conditions of traditional management of the crop (i.e. the origin of planted propagules, pest presence and age of plantations, among others) and the peasant knowledge on the varieties used; and Phase III: identification of the main causes for the loss of traditional cultivars and proposal of actions to improve conservation of the pineapple resources within the country. Three workshops were held, one at each geographic region with the participation of the AE group and local producers. The collected information was compiled, and it was accepted by consensus when more than the 20 % of the participants agreed on each issue.

RESULTS AND DISCUSSION

Field trips across the island revealed that only three out of the five horticultural groups of pineapple are presently sowed in the country: Spanish, Cayenne and Pernambuco (Table 2). Cultivars classified within the Red Spanish group showed the following characteristics: Red Spanish plants are medium-size, with spiny or half spiny dark green leaves; the fruit is medium-size (1.2-2 kg), orange, aromatic and sweet, with moderate sugar content but low acidity; floral bracts are an intense bright red color; and it is vigorous and tolerant to high temperature, drought, internal browning, butt rot, wilt and Phytophthora (Py *et al.*, 1987). Accessions classified into the Cayenne Group were allocated according to Cerrato (2013), de Matos and Reinhardt (2009) and Sandoval and Torres (2011), who described them as medium-sized plants up to 1 m tall, with short, broad, dark green leaves with reddish spots, with no spines at the edges except for the apical portion and sometimes at the base of the leaves. The reddish-orange Cayenne ripe fruit is of large size and cylindrical shape, and its pulp varies from pale yellow to golden yellow. The accessions classified into the Pernambuco Group, were medium-sized plants, with light green leaves that have short spines, straight and very united. Its fruits were pyramidal shape, with small eyes and ripe yellowish-green. The Pernambuco pulp ranges from pale yellow to very pale white with excellent flavor, it is very sweet and has low acidity; these observations coincide with the specifications presented by Morton (1987), Py *et al.* (1987) and De Matos and Reinhardt (2009).

The 14 different cultivars found in the prospected areas are listed in Table 2. Cultivars belonging to the Spanish group were the most widely distributed in all regions; thus, demonstrating its great acceptance among farmers. This observation was in agreement with previous reports (Isidrón *et al.*, 2006) where Red Spanish was referred as the "queen" of the Cuban country side.

The Eastern region exhibits the largest diversity of locally cultivated pineapple and contains at least two cultivars from each of the three extant horticultural groups. Spanish was the most predominant group, while Pernambuco and Cayenne were found at much lower frequencies (Figure 1). Interestingly, the Spanish cultivars feature long and abundant spines, as well as small fruits, but its outstanding plant adaptability under island conditions justifies its popularity among farmers (Isidrón *et al.*, 2003; Ramírez, 1981). Fruits from the other horticultural groups are generally more popular among customers than the Spanish group, but farmers disfavors them because of their highly demanding agronomic management.

The higher pineapple diversity found in the Eastern region could be related to low-technology agriculture and larger incidence of subsistence farming. Other authors have also reported higher diversity for other traditional crops such as maize (*Zea mays* L.) in the Eastern region (Fernández *et al.*, 2011). Local geography may also influence *in situ* preservation of pineapple genetic resources because rural settlements tend to be geographically isolated, and the limited road infrastructure hinders access to regional markets. Therefore, local preferences, traditions and non-commercial demand determine the choice of a particular pineapple variety. This situation favors the preservation of plant genetic resources for food and agriculture. For instance, at the Cienaguilla zone from the Granma province, the Baronne Rothschild variety is still found interspersed between plots of other cultivars, despite its spiny leaves and susceptibility to fungi. Likewise, the Cabezona cultivar is still well appreciated for its large fruit size (up to 5 kg) in some areas of Gibara at Holguín province, despite its softness, which complicates post-harvest processing.

More than 50 different pineapple cultivars have been reported by Coppens d'Eeckenbrugge and Leal (2001); most of them are sown in America. However, this study identified only 14 cultivars in Cuba, which signals a serious loss in diversity and limits the possible breeding actions due to

Table 2. Name, horticultural group and provenance of the pineapple cultivars collected.

Province		Place of collection	Accession name and main cultivars	Horticultural group
WESTERN	Pinar del Río	La Palma	Red Spanish Pinareña	Spanish
		Viñales	Red Spanish Camagüeyana	Spanish
		Rosario	Red Spanish Camagüeyana	Spanish
	Artemisa	San Cristóbal	Red Spanish Camagüeyana	Spanish
		Candelaria	Red Spanish Camagüeyana†	Spanish
		San Antonio	Red Spanish Camagüeyana	Spanish
		Alquízar	Red Spanish Pinareña and White Pineapple	Spanish and Pernambuco
		Artemisa	Red Spanish Pinareña and Camagüeyana	Spanish
	Mayabeque	Madruga	Red Spanish Pinareña	Spanish
		Jaruco	Red Spanish Pinareña	Spanish
	Matanzas	Bolondrón	Red Spanish Pinareña, White Pineapple† and Smooth Cayenne†	Spanish, Pernambuco and Cayenne
		Jagüey Grande	Red Spanish Pinareña and White Pineapple	Spanish, Pernambuco
		Los Arabos	Red Spanish Pinareña and Camagüeyana	Spanish
CENTRAL	Villa Clara	Santo Domingo	Red Spanish Camagüeyana	Spanish
		Corralillo	Red Spanish Camagüeyana	Spanish
		Caibarién	Red Spanish Camagüeyana	Spanish
	Cienfuegos	Rodas	Red Spanish Camagüeyana, Cayenne and White Pineapple†	Spanish, Cayenne and Pernambuco
		Abreu	Red Spanish Camagüeyana	Spanish
		Aguada de Pasajeros	Red Spanish Camagüeyana	Spanish
	Ciego de Ávila	Morón	Smooth Cayenne Serrana†, Red Spanish Camagüeyana†	Cayenne and Spanish
		Florencia	Red Spanish Camagüeyana†	Spanish
	Camagüey	Cascorro	Red Spanish Camagüeyana	Spanish
		Esmeralda	White Pineapple	Pernambuco
EASTERN	Granma	Cienaguilla	Red Spanish Camagüeyana and Baronne Rothschild	Spanish and Cayenne
	Holguín	Gibara	Cabezona†	Spanish
		Moa	Red Spanish Camagüeyana, White Pineapple, Smooth Cayenne	Spanish, Pernambuco and Cayenne
		Frank País	Spanish Purple†, White Pineapple and Mocaena†	Spanish and Pernambuco
	Santiago de Cuba	Santiago de Cuba	White Pineapple†, Red Spanish one smooth edge, Colorada del Ramón and Colorada del Caney†	Pernambuco and Spanish
	Guantánamo	Baracoa	Red Spanish Pinareña, Cabezona, White Pineapple and Ocaena	Spanish, Pernambuco and Cayenne
		Niceto Pérez	Spanish Purple† and Cubana†	Spanish and Pernambuco
Special municipality Isla de la Juventud		La Fe	Smooth Cayenne	Cayenne
			Red Spanish Camagüeyana†	Spanish
		Gerona	Red Spanish Camagüeyana	Spanish

†Main cultivars.

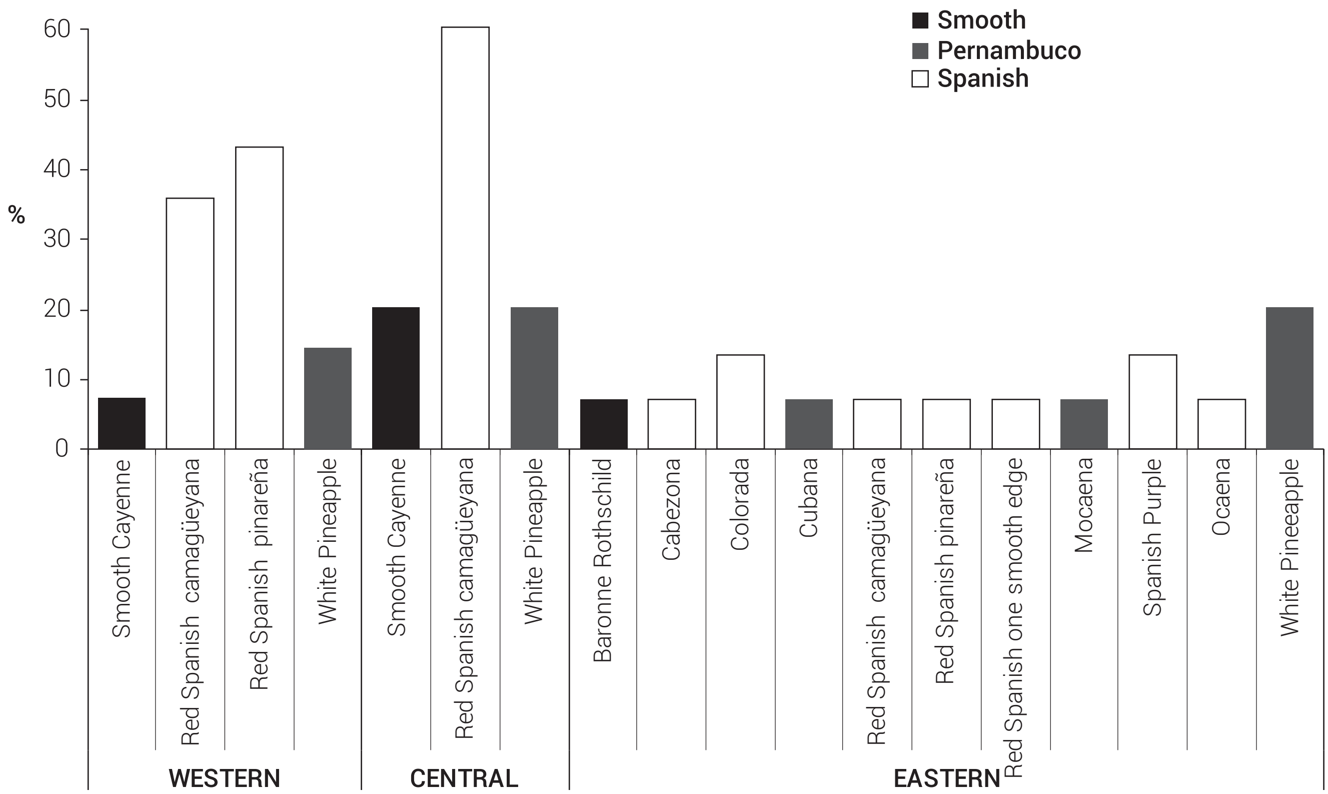

Figure 1. Diversity of pineapple in the three studied regions of Cuba.

insufficient genetic background.

Improvement programs have been undertaken to broaden the genetic base of pineapple. Benega *et al.* (1997) obtained several hybrids which combined the resistance of Red Spanish Pinareña with the productivity and desirable fruit traits of Smooth Cayenne Serrana; however, the introduction of those materials has been limited. The low diversity in the genetic resources of pineapple and the clear predominance of Spanish were previously reported (Isidrón *et al.*, 2003) and suggest that no successful actions have been carried out in the last decade.

As a result of the present work the number of accessions in the pineapple *ex situ* collection was increased by more than 50 %. After including the new cultivars collected during field trips, the germplasm collection now contains 56 accessions, 86 % of them were collected in Cuba itself and 14 % came from other countries through germplasm interchange actions. Over 30 accessions, including specimens from Cayenne, Pernambuco and Perolera horticultural groups, and other closely related species were introduced between 1988 and 1999 from Brazil, Martinique, Mexico, Colombia, Puerto Rico, Hawaii, France, the Dominican Republic, Panama, Kenya, Ecuador and Costa Rica. The Spanish horticultural group accounts for 45 % of the total number of accessions, Cayenne accounts for 20 %, Pernambuco for 14 % and the rest are species from the same family and cultivars generated during genetic improvement programs (Table 3). Some specimens from the *ex situ* collection have been affected by adverse climatological events. The loss of these genetic resources represents a significant reduction in diversity. Some of the lost cultivars have been recovered by farmers, showing the importance of implementing complementary *in situ* and *ex situ* strategies.

The Research-Action-Participation method in this research identified threats to pineapple diversity in Cuba. The abandonment of cultivars was the most frequently identified threats by 50.84 % of producers and the whole AE expert group (Table 4). Susceptibility to fungal diseases, low yields and relatively low number of produced propagules were the main causes for this situation. The threat of extinction is very high for cultivars from the Pernambuco horticultural group; for example, White Pineapple is often replaced by *cv.* Red Spanish. Several plantations within the Cayenne horticultural group have gradually disappeared in the Pinar Río and La Habana provinces (Western region) due to low propagation rates and susceptibility to several biotic and abiotic factors. The diversity of planted pineapple cultivars has also decreased in Ciego de Ávila province, where only *cv.* MD-2 is used. A similar case related to the Spanish horticultural group is *cv.* Cabezona, which is now only found in small plantations at Gibara and Guantánamo, even though

Table 3. List of accessions of pineapple cultivars and closely related species of the Bromelieaceae family conserved *ex situ* in Cuba after adding the specimens collected during the present work.

N_0. BG.[†]	Name	Genus	Species	Horticultural group	Origin
001[††]	Red Spanish Pinareña	*Ananas*	*comosus*	Spanish	Cuba (Ciego de Ávila)
003	Red Spanish Colorada Caney	*Ananas*	*comosus*	Spanish	Cuba (Caney)
004	Red Spanish Colorada Ramón	*Ananas*	*comosus*	Spanish	Cuba (Stgo. de Cuba)
005	Cabezona	*Ananas*	*comosus*	Spanish	Cuba (Holguín)
007	Red Spanish del Caney	*Ananas*	*comosus*	Spanish	Cuba (Caney)
008	Red Spanish one smooth edge	*Ananas*	*comosus*	Spanish	Cuba (Caney)
009[††]	Red Spanish M 35	*Ananas*	*comosus*	Spanish	Cuba (Radiations 35Gy)
010[††]	Red Spanish	*Ananas*	*comosus*	Spanish	Cuba (Ceiba Agua)
012[††]	Red Spanish P3R5	*Ananas*	*comosus*	Spanish	Cuba (Somaclonal var.)
016[††]	Smooth Cayenne	*Ananas*	*comosus*	Cayenne	Cuba (Cienaguilla)
017	Red Spanish	*Ananas*	*comosus*	Spanish	Cuba (San Cristóbal)
018	Smooth Cayenne serrana	*Ananas*	*comosus*	Cayenne	Cuba (Morón)
019	Baronne Rothschild	*Ananas*	*comosus*	Cayenne	Cuba (Granma)
023	Red Spanish	*Ananas*	*comosus*	Spanish	Cuba (Niceto Pérez)
025	Cubana	*Ananas*	*comosus*	Pernambuco	Cuba (Baracoa)
027	Red Spanish	*Ananas*	*comosus*	Spanish	Cuba (Cienaguilla)
029[††]	Mocaena	*Ananas*	*comosus*	Cayenne	Cuba (INCA)
030[††]	Champaka	*Ananas*	*comosus*	Cayenne	Brazil
033[††]	Puerto Rico	*Ananas*	*comosus*	-	Puerto Rico
037[††]	Cayenne Hawai	*Ananas*	*comosus*	Cayenne	Hawai
038[††]	Mocaena	*Ananas*	*comosus*	Cayenne	Cuba (Baracoa)
039	White Pineapple serrana	*Ananas*	*comosus*	Pernambuco	Cuba (Morón)
040	White Pineapple Caney	*Ananas*	*comosus*	Pernambuco	Cuba (Stgo. de Cuba)
041	Cubana Caney	*Ananas*	*comosus*	Pernambuco	Cuba (Caney)
042[††]	Smooth Cayenne	*Ananas*	*comosus*	Cayenne	Cuba (Ceiba del Agua)
044	Red Spanish Florencia	*Ananas*	*comosus*	Spanish	Cuba (Florencia)
046	Red Spanish	*Ananas*	*comosus*	Spanish	Cuba (Rosario)
050[††]	China	*Ananas*	*comosus*	?	Cuba (INCA)
053[††]	Branco	*Ananas*	*bracteatus*	-	Brazil
058[††]	Piña de ratón	*Bromelia*	*pinguin*	-	Cuba (La Habana)
059[††]	*Bromelia pinguin*	*Bromelia*	*pinguin*	-	Colombia
060[††]	*Bromelia karatas*	*Bromelia*	*karatas*	-	Colombia
061[††]	Curujey	*Tillandsia*	*fasiculata*	-	Cuba (UNAH)
062[††]	Jupi	*Ananas*	*comosus*	Pernambuco	Brazil
065	White Pineapple	*Ananas*	*comosus*	Pernambuco	Cuba (Baracoa)
070	Red Spanish	*Ananas*	*comosus*	Spanish	Cuba (Rodas)
071	White Pineapple	*Ananas*	*comosus*	Pernambuco	Cuba (Rodas)
072	Smooth Cayenne	*Ananas*	*comosus*	Cayenne	Cuba (Rodas)
073	Red Spanish	*Ananas*	*comosus*	Spanish	Cuba (Abreus)
075	Spanish Purple	*Ananas*	*comosus*	Spanish	Cuba (Holguín)

Table 3. Continuity...

N_0. BG.†	Name	Genus	Species	Horticultural group	Origin
077	Red Spanish	*Ananas*	*comosus*	Spanish	Cuba (Aguada)
081	Red Spanish	*Ananas*	*comosus*	Spanish	Cuba (Jagüey)
082	Red Spanish	*Ananas*	*comosus*	Spanish	Cuba (Baracoa)
084	Red Spanish	*Ananas*	*comosus*	Spanish	Cuba (Arabos)
086	Red Spanish (18)	*Ananas*	*comosus*	Spanish	Cuba (Villa Clara)
093	Ocaena	*Ananas*	*comosus*	Spanish	Cuba (Baracoa)
097††	Hybrid CBCE-003	*Ananas*	*comosus*	-	Cuba (Improvement prog.)
098††	Hybrid CBCE-021	*Ananas*	*comosus*	-	Cuba (Improvement prog.)
099††	Hybrid CBCE-054	*Ananas*	*comosus*	-	Cuba (Improvement prog.)
109	MD-2	*Ananas*	*comosus*	Cayenne	Costa Rica
118	Red Spanish	*Ananas*	*comosus*	Spanish	Cuba (Viñales)
121	Smooth Cayenne	*Ananas*	*comosus*	Cayenne	Cuba (Nueva Gerona)
133	White Pineapple	*Ananas*	*comosus*	Pernambuco	Cuba (Bolondrón)
134	Red Spanish	*Ananas*	*comosus*	Spanish	Cuba (Bolondrón)

†No. BG: entry number at the germplasm collection; ††present accessions; var: variety; Stgo: Santiago; prog: program.

it was once extensively planted at Santo Domingo (Villa Clara), Gibara (Holguín) and Niceto Pérez (Guantánamo).

Abandonment of traditional pineapple cultivation was the second most frequently identified threat by farmers (30.91 %) and experts (60 %). As educational standards increase, descendants of private farmers were no pursued cultivation of this crop. Another identified threat to the germplasm was erosion of cultivars during *in situ-ex situ* conservation of variability (25.45 % and 100 % according to producer and expert criteria, respectively), followed by vulnerability of cultivars to adverse natural conditions (20 % by producers and 40 % by EP group). These considerations agreed with those of Longar (2007).

Part of the genetic erosion of the pineapple genetic resources in the island has been the funding shortfalls which precluded the appropriate management of the germplasm collection. For instance, the Primavera cultivar and other accessions from the Cayenne group as Smooth Cayenne from Ecuador, Guinea and Mexico have been lost due to inadequate germplasm management procedures.

This study confirmed that the knowledge of some farmers about appropriate agricultural practices for this crop is rather limited; for example, the use of irregular planting densities within their plantations. In accordance with Hepton (2003), the grading of planting material by size is critical to provide uniform plants at flowering and to force efficiency at harvest time. Often, farmers do not remove side shoots and old leaves, limiting physical access to the furrows and, therefore, complicating normal agronomical and harvesting operations, especially in older plantations. Additionally, flowering is not usually induced, which affects the uniformity of fructification.

The importance of training and capacitation of growers is key to optimize yield and to promote food security in developing countries (FAO, 2010; Ortiz and de la Fé, 2012). The workshops organized in the Western and Central regions attempted to educate attendees on the need to exchange and introduce new cultivars. These regions exhibited the lowest pineapple diversity in the country and contained the largest pineapple producers, usually single-cultivar, state-managed farms. In general, the interviews and meetings with farmers and agricultural communities provided opportunities for discussing the advantages of cultivar exchange and PGRFA conservation programs, and it is in agreement with Longar (2007) criteria. Special emphasis was placed on rare, endangered cultivars such as Baronne Rothschild, Cabezona and White Pineapple that only exist as small populations in a restricted number of geographical locations. Rodríguez *et al.* (2013) determined the genetic identity of these accessions using molecular markers methods.

Based on analysis of threats to pineapple diversity, the following actions were proposed by farmers and experts to increase the conservation of pineapple genetic resources on the island:

1. Encourage the propagation of endangered cultivars and closely related species, especially where propagule availability is limited.
2. Establish strategies for conservation *ex situ* (including

Table 4. Main criteria provided by farmers and experts, collected in interviews and workshops developed in field prospections, involving threats of genetic erosion of pineapple in Cuba.

Threats to genetic erosion of pineapple germplasm	West	Central	East	Total Producers	PE[†]
	Percentage of identification of threats (%)				
Abandonment of cultivars	23.64	14.5	12.7	50.84	100
Vulnerability of cultivars against adverse natural conditions	9.09	1.82	9.09	20.00	40
Abandonment of the tradition of pineapple cultivation by the farmer	21.82	5.45	3.64	30.91	60
Erosion of cultivars during *in situ*-*ex situ* conservation of single variability	20	3.64	1.82	25.45	100
Scarce real possibility for the replacement of lost cultivars from the *ex situ* collection			-		80
Scarce real possibility for the introduction of new cultivars to the *ex situ* collection			-		60

[†]PE: expert group composed by selected producers and professionals.

both *in vitro* and *in vivo*) and *in situ* that supports efforts that revert the erosion of genetic diversity in the affected agricultural systems, and enrich these collections to the maximum possible extent.

3. Promote community involvement in the protection and management of the agricultural diversity, of which they become de facto custodians, and encourage the exchange of germplasm and local know-how to ensure the preservation of cultural traditions that guarantee the conservation and use of agricultural diversity.
4. Produce educational literature and booklets written in easily accessible style according to the objectives.
5. Encourage the writing and submission of grant applications to national and international funding agencies to guarantee financing of field trips for collection of new specimens, operation of *ex situ* collections and training of farmers in the management and mitigation of threats to the genetic resources of pineapple.
6. Advocate for changes to the national quarantine program for plant materials, so that it becomes easier to import new accessions from foreign *ex situ* collections to support future genetic improvement programs.

The actions proposed here will contribute to more efficient management of existing germplasm and convenient protection of pineapple genetic resources in the country. Farmers and curators of germplasm banks involvement has been, and it will continue to be, essential to the preservation of biodiversity.

CONCLUSIONS

The pineapple germplasm diversity present in Cuba is insufficient for conservation and plant breeding of the species. The collecting missions revealed that the pineapple horticultural groups present in Cuba are Spanish, Cayenne and Pernambuco, and within these, only 14 cultivars could be identified. Cultivars belonging to the Spanish group were found to be widely widespread. The distribution of cultivars varied according to each prospected geographic zone, being the Eastern region of the country the most diverse, with at least two cultivars from each horticultural group. The main threats to pineapple diversity in Cuba are the abandonment of cultivars, erosion of cultivars during *in situ* and *ex situ* conservation of variability, and the scarce real possibility for replacement of lost cultivars from the *ex situ* collection. As a result of the application of the Research-Action-Participation method farmers and experts proposed some specific actions to mitigate the loss of genetic resources. Some of them are propagation of endangered pineapple cultivars, establishment of strategies for *ex situ* and *in situ* conservation, involvement of the community in the protection and management of the pineapple diversity, and adjustment of national quarantine programs to permit the importation of new accessions from foreign *ex situ* collections. The implementation of the proposed mitigation actions could contribute to protect better the genetic resources of this valuable crop, and requires future supervision by the curators and competent authorities.

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