PHENOLOGY AND MORPHOLOGICAL DIVERSITY OF SWEET POTATO (*Ipomoea batatas*) LANDRACES OF THE VALE DO RIBEIRA

Elizabeth Ann Veasey[1]*; Jurema Rosa de Queiroz Silva[2]; Mariana Silva Rosa[3]; Aline Borges[4]; Eduardo de Andrade Bressan[5]; Nivaldo Peroni[6]

[1]*USP/ESALQ - Depto. de Genética, C.P. 83 - 13400-970 - Piracicaba, SP - Brasil.*
[2]*USP/CENA - Programa de Pós-Graduação em Biologia na Agricultura e no Ambiente.*
[3]*USP/ESALQ - Graduanda em Engenharia Agronômica.*
[4]*USP/ESALQ - Graduanda em Ciências Biológicas.*
[5]*USP/ESALQ/CENA - Programa de Pós-Graduação Interunidades em Ecologia Aplicada.*
[6]*UNICAMP/Instituto de Biologia, Museu de História Natural, Rua Monteiro Lobato, 255 - 13083-970 - Campinas, SP - Brasil.*
Corresponding author <eaveasey@esalq.usp.br>

ABSTRACT: The phenotypic diversity of sweet potato (*Ipomoea batatas*) landraces was assessed using morphological traits, verifying how this diversity is distributed among the households and settlements of the Vale do Ribeira, Brazil. A total of 74 accessions, involving 53 landraces, collected from 30 households distributed among 18 settlements that practice traditional agriculture in the municipalities of Iguape, Ilha Comprida, and Cananeia, as well as four commercial varieties acquired in markets of Iguape and Piracicaba, were evaluated under an *ex situ* experimental condition in Piracicaba, SP, Brazil. Nine phenological and floral descriptors, nine morphological vegetative aerial descriptors and five storage root traits were recorded. The 14 aerial vegetative and root descriptors were evaluated as binary data, totaling 74 attributes. Cluster analyses were made using the Jaccard similarity index and the UPGMA (unweighted pair group method with arithmetic mean) agglomerative method. Binary data was also submitted to a variance analysis (AMOVA). No defined groups were observed, indicating that the diversity of the landraces is not structured in space, but considerable morphological variation was found in this area (Jaccard similarity index varying from 0.12 to 1.0). Most of the variability occurred within households (64.4%), followed by the distribution among households within settlements (27.1%) and among settlements (8.4%). Thus, the traditional agriculturists of Vale do Ribeira maintain a high morphological diversity for sweet potato within their households, which can be assumed to be produced by the outcrossing mating system of this species and somatic mutation events, as well as the exchange system at local and regional levels.
Key words: local varieties, morphology, phenotypic diversity, traditional agriculture, variability

FENOLOGIA E DIVERSIDADE MORFOLÓGICA DE ETNOVARIEDADES DE BATATA-DOCE (*Ipomoea batatas*) DO VALE DO RIBEIRA

RESUMO: Avaliou-se a diversidade fenotípica de etnovariedades de batata-doce através de descritores morfológicos, visando verificar como esta diversidade está distribuída em nível de roças e comunidades do Vale do Ribeira, SP, Brasil. Foram avaliados, no total, 74 acessos, envolvendo 53 etnovariedades, coletadas em 30 roças, distribuídas em 18 comunidades de agricultores que praticam agricultura tradicional nos municípios de Iguape, Ilha Comprida e Cananéia, somadas a quatro variedades comerciais adquiridas em varejões de Iguape e Piracicaba. A avaliação foi realizada em condições experimentais *ex situ* em Piracicaba, SP. Foram avaliados nove descritores fenológicos e florais, nove descritores morfológicos da parte aérea e cinco da raiz. Os 14 descritores de parte aérea e raiz foram transformados em dados binários, totalizando 74 atributos. Foi realizada uma análise de agrupamento, empregando-se o coeficiente de similaridade de Jaccard e o método aglomerativo UPGMA (unweighted pair group method with arithmetic mean). Os dados binários foram também submetidos a uma análise de variância (AMOVA). Não se detectou formação de grupos definidos, indicando que não há estruturação espacial da diversidade para as etnovariedades, mas observou-se grande variação

morfológica (índice de Jaccard variando de 0,12 a 1,0) na região estudada. A maior parte da variabilidade encontra-se distribuída dentro de roças (64,4%), seguida pela distribuição entre roças dentro de comunidades (27,1%) e entre comunidades (8,4%). Portanto, os agricultores tradicionais no Vale do Ribeira cultivam em suas roças grande diversidade morfológica de batata-doce, cuja origem pode ter sido gerada pelo sistema reprodutivo da espécie por alogamia, por eventuais mutações somáticas e pelo amplo sistema de trocas entre agricultores em âmbito local e regional.
Palavras-chave: agricultura tradicional, diversidade fenotípica, morfologia, variabilidade, variedades tradicionais

INTRODUCTION

Sweet potato (*Ipomoea batatas* L. Lam), an autohexaploid species (2n = 6x = 90) belonging to the Convolvulaceae family, is native of tropical America and normally propagated by asexual means (Chen et al., 1992). The exact location of its botanical origin is unknown but Central America is considered the primary diversity center, while South America (Peru, Ecuador) is considered the secondary center of diversity (Zhang et al., 2000), as also is the Brazilian territory (Austin, 1988).

Sweet potato is one of the subsistence crops used in traditional shifting cultivation in Brazil, known as slash-and-burn agriculture (Peroni & Hanazaki, 2002). The history of this farming practice goes back to the Brazilian pre-colonial period where cultivation techniques have and still are being modified and adapted over time (Peroni & Martins, 2000). A common characteristic of this practice is the planting of a heterogeneous set of species, allowing for the coexistence of a high inter and intraspecific diversity (Martins, 2001). Also, indispensable in traditional farming is the perceptive selection made by the farmer himself (Nazarea, 1998) and the adapting capacity of a species or landrace to climatic, geographical and cultural variants, since under these systems the farmers are interested in diversity and a population structure that will permit maximization of local adaptation (Soleri & Smith, 1995).

Although a species with a long history of common use by the people of the Americas, the characterization of its morphological diversity has been restricted to germplasm bank collections (Ritschel & Huamán, 2002; Daros et al., 2002; Oliveira et al., 2000; Huamán et al., 1999; Mok & Schmiediche, 1999; Ritschel et al., 1998; Contreras et al., 1995). A common characteristic of these studies has been the observation of high phenotypical variability, as well as the occurrence of duplicates.

The objective of this work was to characterize the phenotypical diversity of sweet potato landraces collected in swidden agriculture systems of the Vale do Ribeira, in the municipalities of Iguape, Cananeia and Ilha Comprida, providing answers to the following questions: is there any morphological diversity for this crop in this region, considering it is a vegetative reproductive crop?; if the first answer is yes, what is the magnitude of this diversity and is it structured in space?; and how is this diversity distributed among and within households and settlements of the Vale do Ribeira?

MATERIAL AND METHODS

Fifty three sweet potato landraces collected from 30 households, distributed in 18 settlements or villages, that practise traditional agriculture in areas previously covered by the Atlantic Forest of the Vale do Ribeira, State of São Paulo, Brazil, in the municipalites of Iguape (24º42'S, 47º33'W), Cananeia (25º00'S, 47º55'W) and Ilha Comprida (24º53'S, 47º47'W) (Bressan et al., 2005), as well as four commercial varieties acquired in markets of Iguape and Piracicaba (Table 1, Figure 1) were evaluated in this study.

The collection strategy consisted of visiting the households at random in the main settlements of the municipalities of Iguape, Cananéia and Ilha Comprida. Each household provided one or more tubers or vines from each sweet potato variety they were cultivating. On average, there were 1.8 sweet potato landrace collected per household, distributed in the following manner: 17 households cultivated and provided one sweet potato landrace, seven cultivated two landraces, four cultivated three landraces, one (from Pontal de Icapara) cultivated four landraces and one household (from Agrossolar) cultivated six landraces. More than one vine or tuber was collected from landraces of the Iguape municipality, in this order: two vines collected from landraces nº 3, 4, 12, 14, 21 and 23; three from nº 6 and 7; five from nº 9; and eight from nº 5 (Table 1). These extra vines or tubers were considered clones or replications, for assessment of the intravariety variability. Thus, a total of 74 plants or accessions were evaluated, plus four commercial varieties. These accessions were planted in the field under *ex situ* conditions in Piracicaba, SP (22º42'S, 47º38'W), with 1.50m spacing between plants and 1.50m between rows, with one plant per plot without replications. Prior to establishing the plants in the field, they were multiplied in pots in the greenhouse, where part of the assessment was undertaken.

Table 1 - Sweet potato landraces and respective accession numbers and identification, replications (number of vines or tubers collected/accession), municipalities, settlements, households and folk names.

Nº	Landrace	Accessions	Municipality	Settlement	Households	Folk name
1	DGB 1	1	Iguape	Icapara	H 1	3 months purple potato
2	DGB 2	1	Iguape	Icapara	H 2	Butter potato
3	DGB 3	2	Iguape	Icapara	H 3	Purple potato
4	DGB 4	2	Iguape	Icapara	H 3	-[1]
5	DGB 5	8	Iguape	Pontal de Icapara	H 4	Native/"Sambaqui"
6	DGB 6	3	Iguape	Pontal de Icapara	H 4	"Vargem Grande Paulista"
7	DGB 7	3	Iguape	Pontal de Icapara	H 4	"Vargem Grande Paulista"
8	DGB 8	1	Iguape	Pontal de Icapara	H 4	-
9	DGB 9	5	Iguape	Praia do Leste	H 5	-
10	DGB 10	1	Iguape	Praia do Leste	H 6	Purple potato
11	DGB 11	1	Iguape	Praia do Leste	H 6	White potato
12	DGB 12	2	Iguape	Vila Nova	H 7	Punpkin potato
13	DGB 13	1	Iguape	Momuna	H 8	White potato
14	DGB 14	2	Iguape	Momuna	H 9	Milk potato
15	DGB 15	1	Iguape	Momuna	H 10	White potato(One year)
16	DGB 16	1	Iguape	Momuna	H 10	Purple potato
17	DGB 17	1	Iguape	Momuna	H 10	3 months potato
18	DGB 18	1	Iguape	Momuna	H 11	Purple potato
19	DGB 19	1	Iguape	Momuna	H 11	Little purple potato
20	DGB 20	1	Iguape	Momuna	H 12	Yellow potato
21	DGB 21	2	Iguape	Momuna	H 13	White potato(3 months)
22	DGB 22	1	Iguape	Momuna	H 14	3 months potato
23	DGB 23	2	Iguape	Cavalcanti	H 15	White potato
24	DGB 24	1	Iguape	Peropava	H 16	White potato
25	DGB 25	1	Iguape	Peropava	H 16	White potato (3 months)
26	DGB 26	1	Iguape	Peropava	H 16	"Copinha"
27	DGB 32	1	Cananéia	Agrossolar	H 17	Rio Grande potato
28	DGB 33	1	Cananéia	Agrossolar	H 17	Wounded heart
29	DGB 34	1	Cananéia	Agrossolar	H 17	Black potato
30	DGB 35	1	Cananéia	Agrossolar	H 17	Purple potato
31	DGB 36	1	Cananéia	Agrossolar	H 17	White potato "toothacke"
32	DGB 38	1	Cananéia	Agrossolar	H 17	Purple skin potato
33	DGB 39	1	Cananéia	S.P.Bagre	H 18	Purple potato
34	DGB 40	1	Cananéia	S.P.Bagre	H 18	White potato
35	DGB 41	1	Cananéia	S.P.Bagre	H 19	Purple potato
36	DGB 42	1	Cananéia	Aroeira	H 20	White potato
37	DGB 43	1	Cananéia	Porto Cubatão	H 21	Purple potato
38	DGB 44	1	Cananéia	Rio Branco	H 22	Potato
39	DGB 45	1	Cananéia	Rio Branco	H 22	Native/"Sambaqui"
40	DGB 46	1	Cananéia	Aldeia Tecoatapaji	H 23	Potato
41	DGB 47	1	Cananéia	Rio Branco	H 24	Purple potato
42	DGB 48	1	Cananéia	Rio Branco	H 24	White potato
43	DGB 49	1	Cananéia	Palmeiras	H 25	White potato

Continue...

Table 1 - Continuation.

44	DGB 51	1	Cananéia	Mandira	H 26	Purple potato (3 months)
45	DGB 52	1	Cananéia	Ex-colônia	H 27	White potato
46	DGB 53	1	Cananéia	Ex-colônia	H 27	Purple potato
47	DGB 54	1	Cananéia	Ex-colônia	H 27	Yellow potato
48	DGB 55	1	Cananéia	Santa Maria	H 28	Purple "running" potato
49	DGB 56	1	Cananéia	Santa Maria	H 28	White potato
50	DGB 57	1	Ilha Comprida	Pedrinhas	H 29	White potato
51	DGB 58	1	Ilha Comprida	Pedrinhas	H 30	Secret potato
52	DGB 59	1	Ilha Comprida	Pedrinhas	H 30	Punpkin potato
53	DGB 61	1	Ilha Comprida	Pedrinhas	H 30	Cecília potato
-	Sub-Total[2]	74	3	18	30	-
54	DGB 28	1	Iguape	Market	Com.	Purple potato
55	DGB 29	1	Piracicaba	Market	Com.	White potato
56	DGB 30	1	Piracicaba	Market	Com.	Purple potato
57	DGB 31	1	Piracicaba	Market	Com.	-
Total	-	78	-	-	-	

[1]Landraces without a common name given by the farmer; [2]List referring to the landraces of Vale do Ribeira.

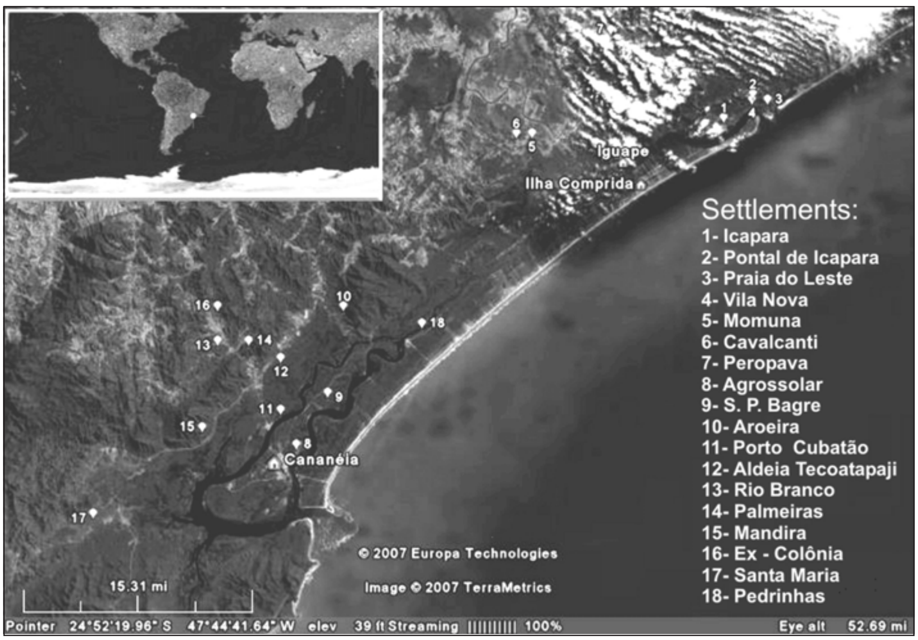

Figure 1 - Map showing the sites for each settlement visited in the Vale do Ribeira, within the municipalities of Iguape, Ilha Comprida and Cananéia.

Sweet potato phenology was evaluated in the field recording the date of flowering initiation (emergence of at least one opened flower per plant) and flowering period from December 2003 to October 2004, with weekly visits to the field plots (one plant per plot). Seven floral descriptors (Huamán, 1991) were also evaluated during these visits (Table 2), with three flowers examined per plant.

Nine aerial vegetative morphological and five storage root traits were evaluated in accordance with Huamán (1991), with some adaptations (Table 3). The aerial vegetative morphological descriptors were evaluated in the greenhouse, 90 days after sprouting, when sufficient vegetative growth (young and adult leaves, vines) was available. Root assessments (three storage roots per plant) were carried out during the field planting in December 2004, when roots were collected for

Table 2 - Descriptors used to assess the phenology and floral traits in sweet potato landraces of the Vale do Ribeira.

Descriptors[1]	Observed phenotypic classes
1) Flowering initiation date	Marked when at least one opened flower was observed per plant, in weekly visits to the field
2) Flowering period	In weekly visits to the field, all flowering plots were marked.
3) Flower color	1-White limb with purple center; 2-White limb with pale purple center; 3-Pale purple limb with purple center; 4-Purple limb and center; 5- Pale purple limb and pale purple center.
4) Shape of limb	1-Semi-stellate; 2-Pentagonal; 3-Rounded.
5) Sepal color	1-Green; 2-Green with purple spots; 3-Totally pigmented - pale purple; 4- Totally pigmented - dark purple.
6) Color of stigma	1-White; 2-Pale purple.
7) Color of style	1-White; 2-White with purple at the top; 3- Purple.
8) Color of filament	1-White with purple at the base; 2-Purple.
9) Stigma exertion	1-Inserted (shorter than the longest anther); 2-Same height as highest anther; 3-Slightly exerted; 4-Exerted (longer than longest anther).

[1]Adapted from Huamán (1991).

Table 3 - Descriptors used to assess the aerial vegetative traits (1 to 9) and storage root traits (10 to 14) in sweet potato landraces of the Vale do Ribeira.

Descriptors[1]	Observed phenotypic classes
1) Vine pigmentation	1-Green; 2-Green with few purple spots; 3-Green with many purple spots; 4-Mostly purple; 5-Totally purple.
2) Vine tip pubescence	1-Absent; 2-Sparse; 3-Moderate; 4-Heavy.
3) Leaf lobes type	1-No lateral lobes (entire); 2-Very slight (teeth); 3-Slight; 4-Moderate; 5-Deep.
4) Shape of central leaf lobe	1-Triangular; 2-Semi-circular; 3-Semi-elliptic; 4-Elliptic.
5) Abaxial leaf vein pigmentation	1-Green; 2-Purple spot in the base of main rib; 3-Main rib partially purple; 4-All veins partially purple; 5-All veins mostly or totally purple; 6-All veins dark purple; 7-All veins slightly purple.
6) Mature leaf color	1-Green; 2-Green with purple edge; 3-Green with purple veins on upper surface.
7) Immature leaf color	1-Green; 2-Green with purple edge; 3-Green with purple veins on upper surface; 4-Slightly purple; 5-Mostly purple; 6-Purple both surfaces; 7-Dark purple both surfaces.
8) Petiole pigmentation	1-Green; 2-Green with purple near leaf; 3-Green with purple at both ends; 4-Green with purple spots throughout petiole; 5-Green with purple stripes; 6-Mostly purple; 7-Totally purple.
9) Leaf lobes number	1; 3; 5; 7.
10) Storage root cortex thickness	1-Very thin (< 1mm).
11) Storage root skin color	1-White; 2-Cream; 3-Yellow; 4-Orange; 5-Pink; 6-Purple; 7-Dark purple.
12) Predominant storage root flesh color	1-White; 2-Cream; 3-Yellow; 4-Pale orange; 5-Purple.
13) Secondary storage root flesh color	1-Absent; 2-White; 3-Cream; 4-Yellow; 5-Brown orange; 6-Pink; 7-Purple.
14) Distribution of secondary flesh color	1-Absent; 2-Broad ring in cortex; 3- Scattered spots in flesh; 4- Narrow ring in cortex; 5-Ring and other areas in flesh; 6-In longitudinal sections.

[1]Adapted from Huamán (1991).

multiplication of the varieties. Subsequently, the storage roots of each individual plant underwent pot culture in the greenhouse for a second multiplication phase.

Descriptive statistical analyses were carried out for all the morphological characters. With the exception of the floral and phenological traits, as not all varieties flowered in the evaluation period, the vegetative aerial and root storage morphological traits were converted into binary data (present = 1 and absence = 0, for each phenotypic class evaluated within each trait). With the binary data a matrix of Jaccard's similarity coefficient for the 74 accessions, including the 53 landraces, was obtained and a cluster analysis performed using the agglomerative hierarchic method UPGMA, and the NTSYS-pc (Rohlf, 1992) software.

Binary data were also submitted to an analysis of variance (AMOVA) to verify the partition of variability among settlements, among households within settlements and within households, utilizing the Arlequin software (Schneider et al., 2000). Arlequin is an exploratory population genetics software, designed to handle different types of molecular data (RFLPs, DNA sequences, microsatellites), while retaining the capacity of analyzing conventional (non-molecular or frequency-type) genetic data. For this analysis, all 74 accessions were considered, including the 53 landraces and their replications (presumed clones).

RESULTS AND DISCUSSION

The sweet potato landraces, also called local varieties, grown by traditional farmers of the Vale do Ribeira, exhibited high morphological variability, with the Jaccard similarity index varying from 0.12 to 1.0. A wide range in flowering initiation periods was observed for the 53 landraces. Flowering initiation started in January 2004 and went on until September 2004, reaching its peak in April, May and June (Figure 1). Some differences were observed in the flowering of landraces collected in the municipality of Iguape when compared to those from Cananeia and Ilha Comprida. Landraces from Iguape ceased flowering in June 2004, whereas those from Cananeia and Ilha Comprida continued flowering significantly until September (Figure 2). Also, while all landraces from Cananeia and Ilha Comprida flowered, seven landraces from Iguape did not flower, representing 13.2% of the total landraces. Rajendran & Amma (1996), evaluating 764 sweet potato accessions in Trivandrum, India, also observed absence of flowering in 13.9% of them. In Indonesia,

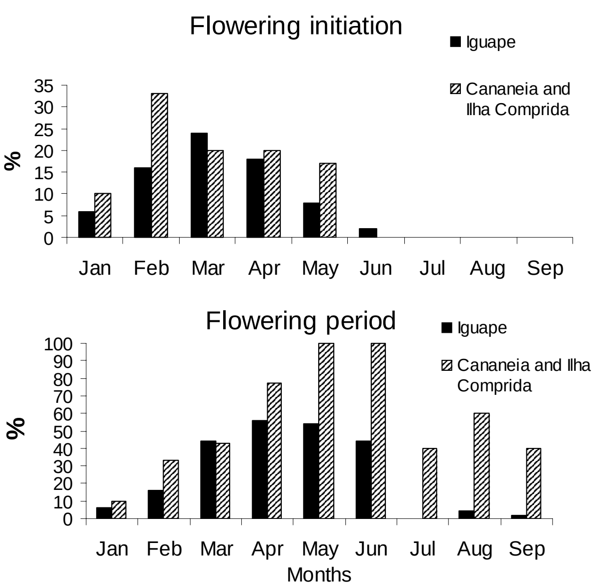

Figure 2 - Flowering initiation and flowering period of 53 landraces of sweet potato from the Vale do Ribeira.

Mok & Schmiediche (1999) reported that 40% of the accessions collected did not flower. Absence of seed production was observed in 37.3% of the accessions examined by Rajendran & Amma (1996).

The considerable variability observed in this study in the phenology of the accessions was enough to classify the landraces in early, intermediate and late varieties, which can be explored in plant breeding programs due to the correlation of this trait and the storage root harvest periods.

The predominant colors of the sweet potato flowers of the Vale do Ribeira were pale purple upon the limb and purple in the center (74%), followed by white limb with purple in the center (17%). The predominant sepal color was green (75%) and the shape of limb rounded (92%). Only 6% of the flowers presented pentagonal limb shapes and 2% a semi-stellate shape. The colors of the stigma were predominantly white (93%). Such descriptors can be utilized in inheritance studies as morphological markers. The position of the stigma in relation to the anthers of sweet potato was also evaluated. Thus, four types of occurrences were observed: inserted (stigma shorter than longest anther), stigma of the same height than highest anther, stigma slightly exerted and exerted (longer than longest anther). This variation in the position of the stigma indicates the occurrence of heterostyly in sweet potato, which probably reinforces the self-incompatibility system observed for this crop (Martin, 1968). Seed yield was not evaluated consistently in the present study, but seed production was observed to be more intense in some varieties. Harvested seed germinated promptly after scarification with sandpaper, indicating the presence of mechanical dormancy (Martin Jr., 1946) due to the seed coat of sweet potato seeds.

Although vegetative propagation is the method adopted by farmers, using the vines, an ethnobotanic survey in a parallel study with 46 agricultural households in the Vale do Ribeira, 91% of those interviewed observed the presence of flowers in the cultivated varieties of sweet potato. Although Martins (2001) observed the formation of sweet potato seed banks in the same region, no farmer noticed the presence of botanical seeds in this study. In the ethnobotanic survey, a deep degree of observational capability of the farmers about particular characteristics of the varieties was evident. Farmer's observations, men and women, are made predominantly in plants which are grown in home gardens, with old varieties as well as new varieties incorporated into the family unit through an exchange system. The home gardens are located near farmer's houses, with high organic matter accumulation, resulting in high fertility soils, ideal for the initial experimentation with the introduced varieties. The proximity of the home gardens to the family units makes the observations of the varieties a regular and meticulous activity. Before a more intense vegetative propagation in the swiddens, the individuals of new varieties are at first observed for the agronomic performance, and also for other characteristics, including the reproductive behavior. Being very conspicuous, the flowers of sweet potato are easily identified and observed for fructification and seed formation.

Although abiotic factors, such as photoperiodism, may influence the reproductive success of sweet potato, the fact that these farmers did not observe fructification and seeds in the Vale do Ribeira reinforce an idea that this can be related mainly to the biotic factors as barriers to reproduction in the prezygotic phases, including reproductive isolation by absence of pollinators and varieties with high level of self-incompatibility. As the propagation is mainly made by clones these can reinforce the incompatibility of the whole population. Further studies of genetic and reproductive ecology to observe the causes of the absence of effective seed production in this region are recommended.

The aerial vegetative descriptors with most variability, represented by the highest number of phenotypic classes with a significant percentage of individuals in each class, were the vine pigmentation, the vine tip pubescence, the leaf lobes type, the leaf lobes number and the petiole pigmentation (Figures 3 and 4). Most of the landraces displayed green vines with many purple spots (29%), principally those from Iguape, or with few purple spots (27%) or even mostly purple (25%); vine tip pubescence absent (33%); leaves with very slight lobes (36%); the central lobe of triangular shape (72%); and leaves with five lobes (45%) (Figure 3). The mature leaf color was mostly green (60%), with the abaxial leaf veins mostly or totally purple (45%), principally those from the Iguape municipality (Figure 4). The immature leaf color was mainly green with purple edges (50%) and the petiole pigmentation mainly green with purple stripes (29%).

As for the storage roots, there was a predominance of one or two main phenotype classes although many classes have been observed for each descriptor (Figure 5), except for the cortex thickness descriptor that was characterized as being very thin (< 1 mm) for all varieties. Most of the varieties presented a cream storage root skin color (46%) followed by pink (26%), white (9.5%) and purple colors (9.5%). The sweet potato collection maintained by the Empresa de Pesquisa Agricola de Santa Catarina (EPAGRI), Brazil, presented most of its accessions with a red color for the external skin (30%), followed by pink (27%) and white (26%), while cream color for this trait occurred in only 14% of the accessions (Ritschel et al., 1998). On the other hand, the storage root skin color was observed to be pink in 50% of the 14 sweet potato accessions of the State University of North Fluminense by Daros et al. (2002).

Most of the sweet potato landraces of the Vale do Ribeira also presented cream as the predominant (73%) and the secondary color of the storage root flesh (68%), presenting mostly narrows rings in cortex (73%) (Figure 5). Cream as the predominant storage root flesh color was also observed for 70% of the accessions by Ritschel et al. (1998) and for 50% of the accessions evaluated by Daros et al. (2002).

Evaluating 14 sweet potato accessions, Daros et al. (2002) observed high morphological variability, concluding that the most informative descriptors were

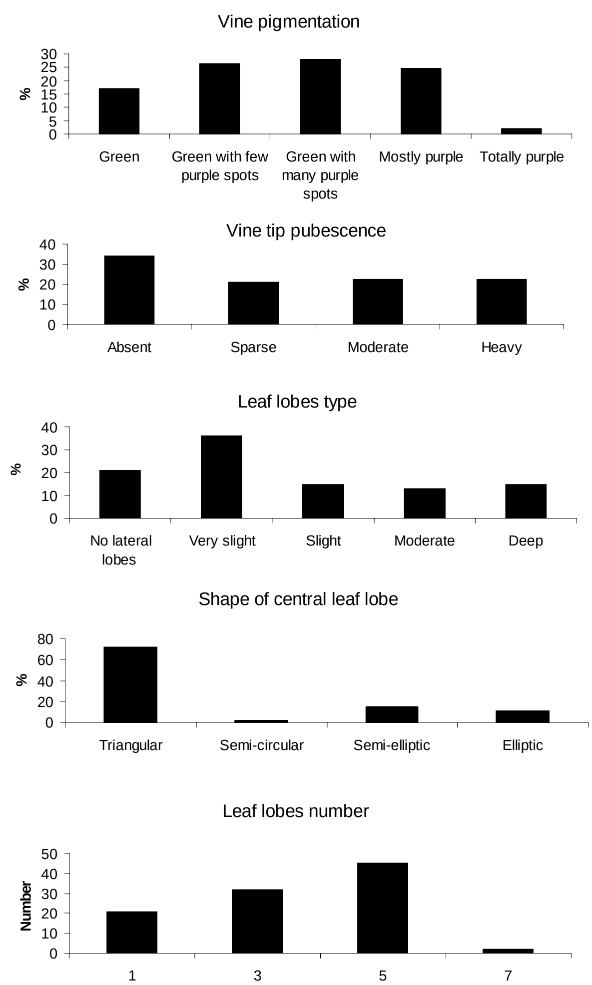

Figure 3 - Morphological vegetative aerial descriptors (vine pigmentation, vine tip pigmentation, leaf lobe types, shape of central leaf lobe and leaf lobe number) evaluated in 53 landraces of sweet potato from the Vale do Ribeira.

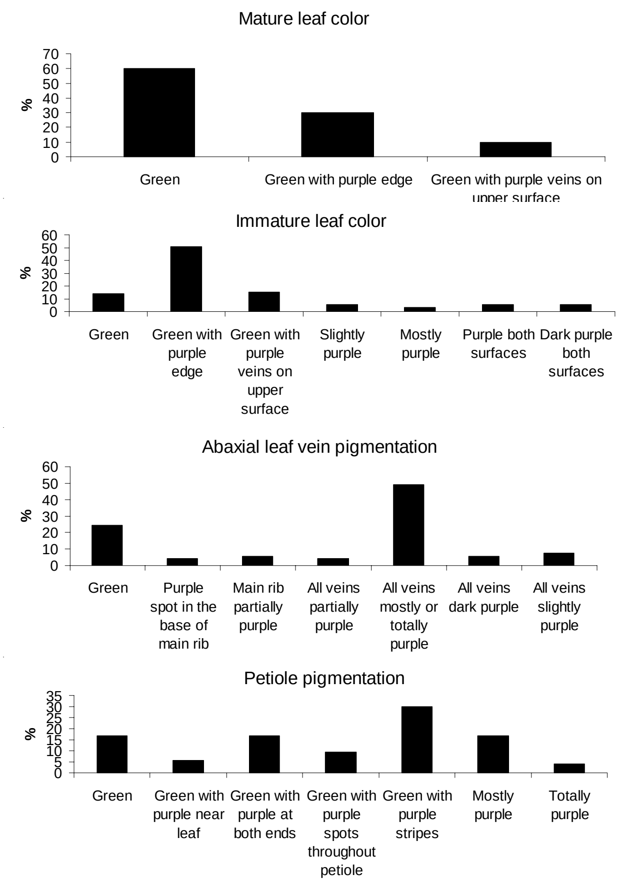

Figure 4 - Morphological vegetative aerial descriptors (mature leaf color, immature leaf color, abaxial leaf vein pigmentation, petiole pigmentation) evaluated in 53 landraces of sweet potato from the Vale do Ribeira.

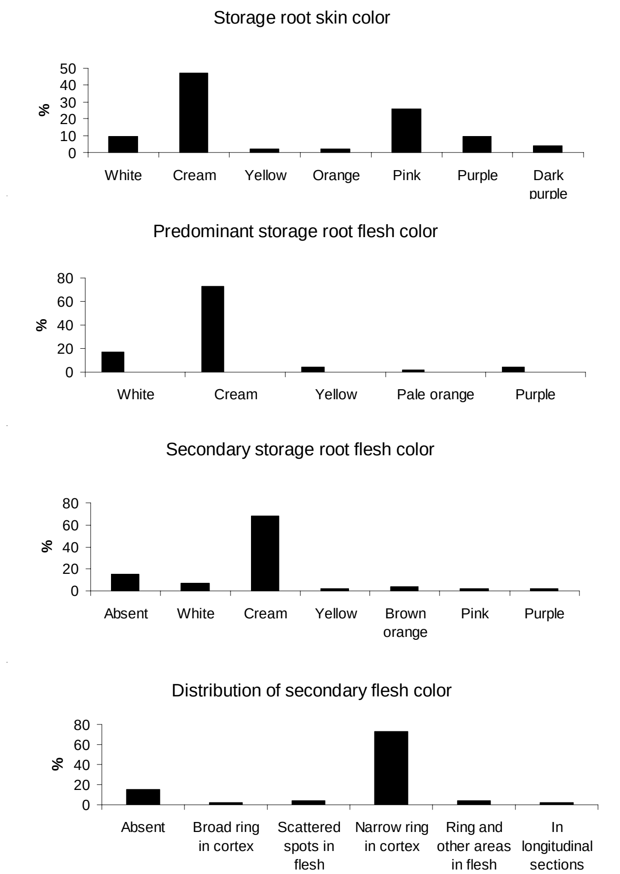

Figure 5 - Storage root morphological descriptors (skin color, predominant flesh color, secondary flesh color, distribution of secondary flesh color) evaluated in 53 landraces of sweet potato from the Vale do Ribeira.

the vine tip pubescence, the abaxial leaf vein pigmentation and the shape of the roots. Oliveira et al. (2000) also observed high genetic divergence between 51 clones of sweet potato originating from various Brazilian regions. The traits that most contributed to the diversity were: distribution of secondary flesh color, root shape, storage root surface defects and predominant storage root flesh color, in this order. The importance of the traits related to the storage root, which is the plant organ utilized for consumption, was confirmed here.

The dendrogram in the cluster analyses (Figure 6) showed no formation of any defined groups according to the community or even the municipality, indicating that the landraces are not space-structured. For example, the hypothesis that the landraces of the Momuna settlement should be classified in a separate group (from the other settlements) was not observed, as the Momuna landraces were present in many of the groups formed. There was a slight structural spacing for the Icapara and Pontal de Icapara landraces allocated in the same group (Figure 6). The four commercial varieties evaluated were not grouped separately from the landraces (data not shown).

The absence of structuring in the morphological diversity is influenced by two factors that act jointly: the time of use and cultivation of the varieties in each family unit and the space in which the varieties are distributed and exchanged in successive generations of agriculturists. According to an ethnobotanical data survey paralleling this study in a universe of 46 farmers interviewed in the region, the absence of structuring in the morphological diversity of sweet potato is probably influenced by the extensive exchange system, mainly between neighbors, occurring within a range of 10 km (82% of the 46 farmers interviewed) and also on a regional level, within a maximum distance of 30 to 50 km. The restriction to the spatial displacement is evident when the distances between the place of birth and establishment of the current residence is observed. Considering that the average age was 64.3 years ($26 < n < 89$), 54.39% of those interviewed were born less than 8 km from the current place of residence and, on average, the couples did not

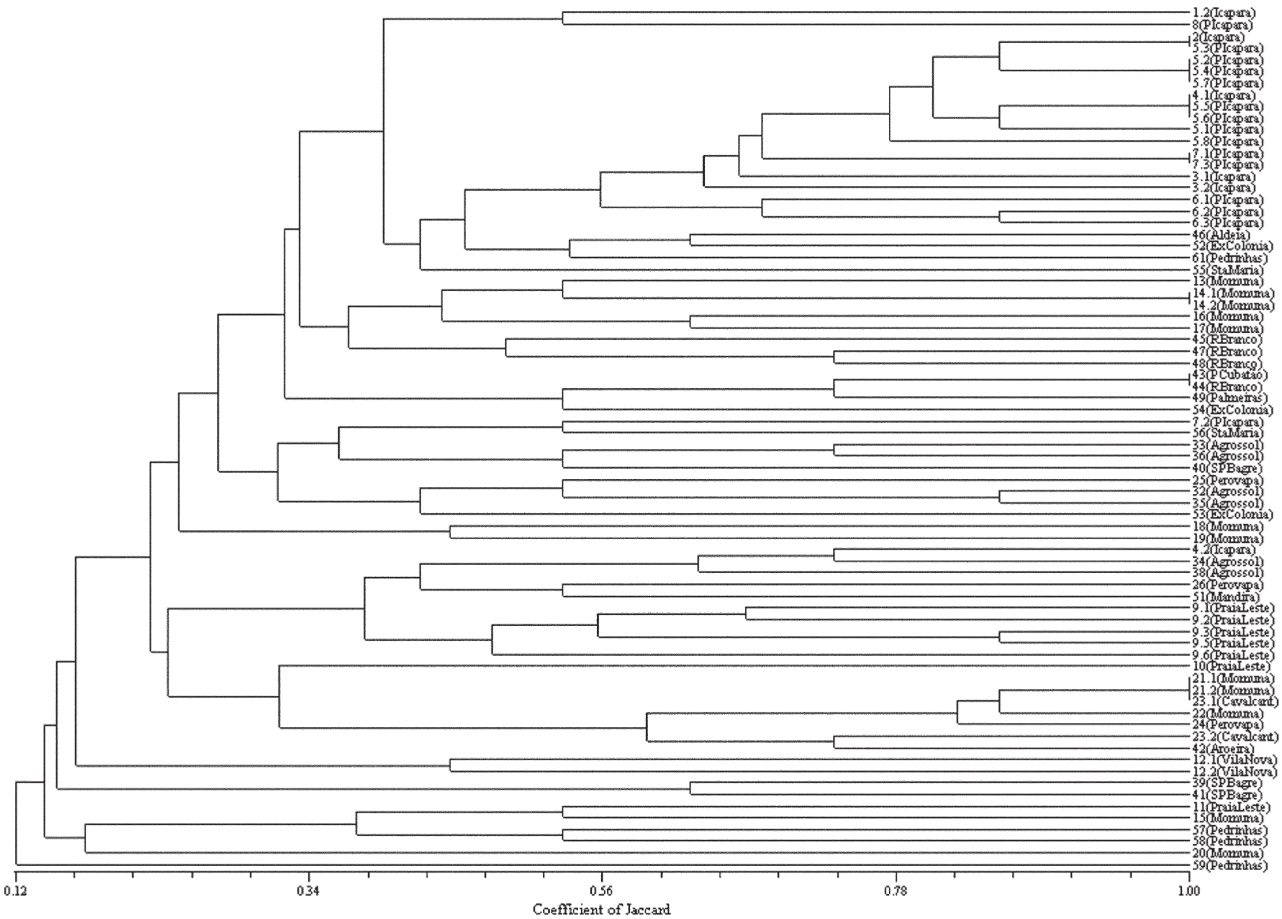

Figure 6 - Dendrogram obtained with the similarity coefficient of Jaccard and UPGMA using morphological descriptors for 74 sweet potato accessions from the Vale do Ribeira, collected in 18 settlements (in brackets).

move more than 13.5 km from where they were born. In the studied region, the isolation of the human populations only ceased at the beginning of the 1980's (Hogan et al., 1999), and exchanges have been occurring over time on a local basis. A similar pattern of no structural spacing was also observed by Naskar (1996), who did not find any correlation between morphological genetic divergence and geographical distribution for l8 cultivars of sweet potato in India, with cultivars of the same geographical origin allocated in different groups in the cluster analysis utilizing Mahalanobis generalized distance.

Among the agriculturists of the Vale do Ribeira, clear rules of reciprocity in the exchanges between varieties are not observed, but they occur informally when new varieties are introduced and also when harvest losses occur. Moreover, there are no rules of exchange based on blood relations such as observed between the Tukâno cassava growers in the Amazon, where exogamy rules are observed as well as matrilineal descendants, for example where the women take their varieties to their husband´s swiddens (Chernela, 1987). In the case of the agriculturists of the Vale do Ribeira, exchanges are more homogeneous, considering that when marriages occur the family varieties of the husband and wife can join to form new swiddens. As time goes by, the varieties from both wives and husbands families can enter the couple´s swidden continuously.

In relation to the time in which the varieties are cultivated in each place, 89% of agriculturists have already exchanged varieties although 49% could not define since when they were exchanged. Among the 51% that could define the time of exchange, 70% of the varieties are so old that the exactness of the time in which they have been cultivated in the swiddens is unknown. Thus, the spatial displacement that influences the space distribution of the varieties is highly influenced by the time in which the farmers have been cultivating a homogeneous set of varieties.

The absence of significant correlation between genetic distances, either with morphological or isozymatic markers, and geographic distances was also observed for four yam species and landraces (*Dioscorea alata, D. trifida, D. cayenensis* and *D. bulbifera*) collected in the same Vale do Ribeira settlements (Bressan, 2005). Peroni (2004) also observed that the structural spacing diversity for cassava landraces cultivated in the Vale do Ribeira was practically null. The author attributes this result to the flux of landraces due to the interchanges, and also to the origin of the landraces, mainly local. Peroni (2004) even makes an analogy between the metapopulation's model (Levins, 1969) and the explanatory model for the exchanges between agriculturists, which can also be extended to the exchange system of sweet potato landraces.

The Jaccard similarity index varying from 0.12 to 1.00 is indicative of a large diversity for the group of landraces from the Vale do Ribeira. Seven duplicates were observed, but only three contained accessions considered clones of the same landrace (5.2, 5.4, 5.7 from Pontal de Icapara; 7.1, 7.2 from Pontal de Icapara; and 14.1, 14.2 from Momuna) (Figure 6). The other four duplicates included accessions from different landraces, such as accession 43 from Porto Cubatão and 44 from Rio Branco, for example. Also, there were several accessions considered clones (vines of the same landrace) that were not duplicates, although most of them were grouped in the same or nearby clusters, showing their genetic proximity. Three examples are the accessions 5.1 to 5.8 from Pontal de Icapara, 6.1 to 6.3 also from Pontal de Icapara, and 9.1 to 9.6 from Praia do Leste. The low occurrence of duplicates among the landraces and the high amplitude for the Jaccard similarity index are strong indicators of the high genetic variability that is being maintained by traditional farmers of the Vale do Ribeira for sweet potato, cultivated under a system considered today as a type of *in situ* and *on farm* conservation (Jarvis et al., 2000).

Most of this morphological diversity, considering a total of 74 individual plants or accessions within 53 landraces, was distributed within the households (64.4%), while 27.1% of total variability was distributed among the households within settlements and only 8.4% was distributed between settlements (Table 4). This result was very similar to a parallel analysis of this same set of landraces with microsatellite markers, where 58.2% of the molecular variability was observed occurring within the households, 28.5% among households within settlements and 13.63% between settlements (Borges et al., 2006).

Utilizing AFLP (Amplified fragment length polymorphism) markers, Fajardo et al. (2002) also detected greater variability (79.8%) within groups in comparison with variability between groups (20.2) when comparing two groups, one with 14 genotypes from the New Ireland Island and another with 117 genotypes from New Guinea Island, collected in 26 farm plots in four provinces of Papua New Guinea. The same pattern of greater variability within rather than between traditional farm fields has been observed for cassava (Sambatti et al., 2000; Peroni, 2004) which like sweet potato is a crop of vegetative propagation and outcrossing mating system.

The higher diversity within households or within swiddens observed in this study is due as much to the presence of more than one variety in the same field, as also to intravarietal variability, as morphological variation was observed between most of the plants originating from vines of the same variety. These results are in accordance with the breeding system of sweet potato, considered an outcrossing species with self-incompatibility (Martin, 1968) and also vegetative reproduction mechanisms. Plarre (1995) attributes the large variability of 45 to 50 sweet potato clones originating from two localities of Irian Jaya, West New Guinea, knowing that this crop was introduced to the region after contacts with the Americas, to the occurrence of mutations and of segregation after seed setting and selection of seedlings, later multiplied as clones. The fact that farmers of the Vale do Ribeira had not detected the presence of sweet potato seeds, as discussed above, does not imply that these are not occurring in the region, but this hypothesis has yet to be tested.

The hypothesis that can be formulated arising from this study is that the great morphological variability occurring within the households implies the eventual occurrence of mutations, knowing that sweet

Table 4 - Analysis of variance (AMOVA) for binary transformed data from a total of 74 plants belonging to 53 sweet potato landraces obtained from 30 households in 18 settlements, for the extraction of components of morphological variation among settlements, households and among individuals within households.

Source of variation	DF	SS[1]	Variancecomponents	% Total[2]
Among settlements	17	237.3	0.677	8.4
Among households within settlements	12	107.0	2.176	27.1
Within small holdings	44	227.2	5.164	64.4
Total	73	571.4	8.017	

[1]Sum of squared deviations; [2]Percent of total variance.

potato presents a high frequency of somatic mutations (Love et al., 1978). In addition, anthropic factors should also be influencing this high variability within the households, such as the inclusion of new clones in the fields through the exchange system mentioned above and the possibility of hybridization occurring between them with the appearance of new individuals arising from seed (evolutionary effect of migration and gene flow), and from selection made by the agriculturist himself acting in his interest in maintaining divergent types in his plantings which is a characteristic of subsistence agriculture (Nazarea, 1998). Further studies concerning *in situ* phenological observations within the households of traditional farmers of the Vale do Ribeira should be conducted, in order to observe the presence or absence of seed production on an experimental basis. Also, further studies could be carried out with more extensive sampling within each landrace, collecting five to ten vines from each landrace, within each household, considering that higher variability was found within households, which together with the phenological observations, could provide more insights to the evolutionary dynamics of this crop.

CONCLUSION

The traditional farmers of the Vale do Ribeira are maintaining high morphological variability for sweet potato, with most of this variability occurring within households, followed by that existing among households within settlements.

ACKNOWLEDGMENTS

To the program Biota/FAPESP and CNPq for financial support for this research and FAPESP for the Post Doctoral grant to Nivaldo Peroni, and also the technicians Ronaldo Jose Rabello and Domingos de Salvio Amaral for their contribution in the field experiments and field collections, and to the agriculturists of the Vale do Ribeira who contributed with landraces samples from their households and provided valuable information acquired from years of practical experience.

REFERENCES

AUSTIN, D.F. The taxonomy, evolution and genetic diversity of sweetpotatoes and related wild species. In: SWEET POTATO PLANING CONFERENCE, 1., 1987, Lima. **Exploration, maintenance and utilization of sweet potato genetic resources - report**. Lima: CIP, 1988. 369p.

BORGES, A.; ROSA, M.S.; SILVA, J.R.Q.; BRESSAN, E.A.; SPIRONELLO, F.S.A.; VEASEY, E.A. Diversidade genética em etnovariedades de batata-doce (*Ipomoea batatas*) por meio de microssatélites (SSR). In: CONGRESSO BRASILEIRO DE GENÉTICA, 52., Foz do Iguaçu, 2006. **Anais.** Foz do Iguaçu, 2006. 1 CD-Rom.

BRESSAN, E.A. Diversidade isoenzimática e morfológica de inhame (*Dioscorea* spp.) coletados em roças de agricultura tradicional do Vale do Ribeira – SP. Piracicaba: USP/ESALQ, 2005. 172p. (Dissertação - Mestrado).

BRESSAN, E.A.; VEASEY, E.A.; PERONI, N.; FELIPIM, A.P.; SANTOS, M.P. Collecting yam (*Dioscorea* spp.) and sweet potato (*Ipomoea batatas*) germplasm in traditional agriculture small-holdings in the Vale do Ribeira, São Paulo, Brazil. **Plant Genetic Resources Newsletter**, v.144, p.8-13, 2005.

CHEN, L.O.; LO, H.S.; CHEN, T.H.; LEE, L. Peroxidase zymograms of sweet potato (*Ipomoea batatas* (L.) Lam) grown under hydroponic culture. **Botanical Bulletin of Academia Sinica**, v.33, p.247-252, 1992.

CHERNELA, J.M. Os cultivares de mandioca na Área do Uaupés. Cap. 9. In: RIBEIRO, B.G. (Ed.). **Suma Etnológica Brasileira.** 1. Etnobiologia. 2.ed. Petrópolis: Editora Vozes; Finep, 1987. p.151-158.

CONTRERAS, J.; AUSTIN, D.F.; PUENTE, F.; DÍAZ, J. Biodiversity of sweetpotato (*Ipomoea batatas*, Convolvulaceae) in Southern Mexico. **Economic Botany**, v.49, p.286-296, 1995.

DAROS, M.; AMARAL JR., A.T.; PEREIRA, T.N.S.; LEAL, N.R.; FREITAS, S.P.; SEDIYAMA, T. Caracterização morfológica de acessos de batata-doce. **Horticultura Brasileira**, v.20, p.43-47, 2002.

FAJARDO, D.S.; LA BONTE, D.R.; JARRET, R.L. Identifying and selecting for genetic diversity in Papua New Guinea sweetpotato *Ipomoea batatas* (L.) Lam. germplasm collected as botanical seed. **Genetic Resources and Crop Evolution**, v.49, p.463-470, 2002.

HOGAN, D.J.; CARMO, R.; ALVES, H.P.F.; RODRIGUES, I.A. Sustentabilidade no Vale do Ribeira (SP): Conservação ambiental e melhoria das condições de vida da população. **Ambiente e Sociedade**, v.3-4, p.151-175, 1999.

HUAMÁN, Z. **Descriptors for sweet potato**. Rome: CIP; AVRDC; IBPGR, 1991. 134p.

HUAMÁN, Z.; AGUILAR, C.; ORTIZ, R. Selecting a Peruvian sweetpotato core collection on the basis of morphological, eco-geographical, and disease and pest reaction data. **Theoretical and Applied Genetics,** v.98, p.840-844, 1999.

JARVIS, D.I.; MYER, L.; KLEMICK, H.; GUARINO, L.; SMALE, M.; BROWN, A.H.D.; SADIKI, M.; STHAPIT, B.; HODGKIN, T. **A training guide for *in situ* conservation on-farm**. Version 1. Rome: IPGRI, 2000. 161p.

LEVINS, R. Some demographic and genetic consequences of environmental heterogeneity for biological control. **Bulletin of the Entomological Society of America**, v.15, p.237-240, 1969.

LOVE, J.E.; HERNANDEZ, P.; MAHMOOD, M. Performance of 'Centennial' sweet potato mutants. **HortScience**, v.13, p.578-579, 1978.

MARTIN, F.W. The system of self-incompatibility in *Ipomoea*. **Journal of Heredity**, v.59, p.263-267, 1968.

MARTIN JR., J.A. Germination of sweet potato seed as affected by different methods of scarification. **Proceeding of the American Society for Horticultural Science,** v.47, p.387-390, 1946.

MARTINS, P.S. Dinâmica evolutiva em roças de caboclos amazônicos. In: VIEIRA, I.C.G.; SILVA, J.M.C.; OREN, D.C.; D'INCAO, M.A. (Org.). **Diversidade biológica e cultural da Amazônia**. Belém: Museu Paraense Emílio Goeldi, 2001. p.369-384.

MOK, I.G.; SCHMIEDICHE, P. Collecting, characterizing, and maintaining sweetpotato germplasm in Indonesia. **Plant Genetic Resources Newsletter**, v.118, p.12-18, 1999.

NASKAR, S.K. Genetic divergence for yield contributing traits in sweet potato (*Ipomoea batatas*). In: KURUP, G.T.; PALANISWAMI, M.S.; POTTY, V.P.; PADMAJA, G.; LABEERATHUMMA, S.; PILLAI, S.V. (Ed.). **Tropical tuber crops**: problems, prospects and future strategies. New Hampshire: Science Publishers, 1996. p.133-136.

NAZAREA, V.D. **Cultural memory and biodiversity.** Tucson: The University of Arizona Press, 1998. 189p.

OLIVEIRA, A.C.B.; SEDIYAMA, M.A.N.; SEDIYAMA, T.; CRUZ, C.D. Avaliação da divergência genética em batata-doce por procedimentos multivariados. **Acta Scientiarum**, v.22, p.895-900, 2000.

PERONI, N. Ecologia e genética da mandioca na agricultura itinerante do litoral sul paulista: uma análise espacial e temporal. Campinas: UNICAMP, 2004. 227p. (Tese - Doutorado).

PERONI, N.; MARTINS, P.S. Influência da dinâmica agrícola itinerante na geração de diversidade de etnovariedades cultivadas vegetativamente. **Interciência,** v.25, p.22-29, 2000.

PERONI, N.; HANAZAKI, N. Current and lost diversity of cultivated varieties, especially cassava, under swidden cultivation systems in the Brazilian Atlantic Forest. **Agriculture, Ecosystems and Environment**, v.92, p.171-183, 2002.

PLARRE, W. Evolution and variability of special cultivated crops in the highlands of West New Guinea (Irian Jaya) under present Neolithic conditions. **Plant Genetic Resources Newsletter**, v.103, p.1-13, 1995.

RAJENDRAN, P.G.; AMMA, C.S.E. Evaluation of sweet potato germplasm. In: KURUP, G.T.; PALANISWAMI, M.S.; POTTY, V.P.; PADMAJA, G.; LABEERATHUMMA, S.; PILLAI, S.V. (Ed.). **Tropical tuber crops**: problems, prospects and future strategies. New Hampshire: Science Publishers, 1996. p.113-119.

RITSCHEL, P.S.; HUAMÁN, Z. Variabilidade morfológica da coleção de germoplasma de batata-doce da Embrapa-Centro Nacional de Pesquisa de Hortaliças. **Pesquisa Agropecuária Brasileira**, v.37, p.485-492, 2002.

RITSCHEL, P.S.; THOMAZELLI, L.F.; HUAMÁN, Z. **Caracterização morfológica do germoplasma de batata-doce mantido pela EPAGRI.** Brasília: EMBRAPA, CNPH, 1998. (Pesquisa em Andamento, 16).

ROHLF, J. **NTSYS-pc**: numerical taxonomy and multivariate analysis system. Version 1.70 (software). New York: Stony Brook, 1992.

SAMBATTI, J.B.M.; MARTINS, P.S.; ANDO, A. Distribuição da diversidade isoenzimática e morfológica da mandioca na agricultura autóctone de Ubatuba. **Scientia Agricola**, v.57, p.75-80, 2000.

SCHNEIDER, S.; ROESSLI, D.; EXCOFFIER, L. **Arlequim ver. 2000**: a software for population data analysis. Geneva: University of Geneva, Genetic and Biometry Laboratory, 2000. Available at: http://anthropologie.unige.ch/arlequin. Accessed at: 14 Oct. 2004.

SOLERI, D.; SMITH, S.E. Morphological and phenological comparisons of two hopi maize varieties conserved *in situ* and *ex situ*. **Economic Botany,** v.49, p.56-77, 1995.

ZHANG, D.; CERVANTES, J.; HUAMÁN, Z.; CAREY, E.; GHISLAIN, M. Assessing genetic diversity of sweet potato (*Ipomoea batatas* (L.) Lam.) cultivars from tropical America using AFLP. **Genetic Resources and Crop Evolution,** v.47, p.659-665, 2000.

Received October 09, 2006
Accepted May 03, 2007