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RESEARCH ARTICLE

MORPHOLOGICAL DIVERSITY AND ENTROPY OF PEPPERS (*CAPSICUM BACCATUM* AND *CAPSICUM CHINENSE*, SOLANACEAE)

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ABSTRACT

The *Capsicum* peppers are consumed worldwide for diverse uses, but mainly as food due pungency of fruits responsible for heat sensation. Peppers were one of the first domesticated species in the western hemisphere. There is a great genetic diversity among species of *Capsicum* genus, even as the genetic variability within each species. The characterization is essential for the maintenance and preservation of genetic resources favoring genotypes availability for immediate or future use. The aim of this work was to perform morphological characterization, genetic divergence evaluation of peppers accessions (*Capsicum baccatum* and *Capsicum chinense*, Solanaceae) and estimate the entropy of descriptors. The evaluation occurred by analysis of 21 accessions from the *Capsicum* Genebank of Embrapa Temperate Agriculture. 47 qualitative descriptors were employed for morphological characterization**.** Qualitative data were statistically analyzed by hierarchical clustering UPGMA and Tocher method. The entropy level of characters (H) was estimated by Renyi entropy coeficiente**.** Morphological descriptors were efficient to characterize the accessions. There is genetic diversity for *C. baccatum* and *C. chinense* accessions evaluated. The UPGMA and Tocher grouping methods partially agree to formation of groups. The descriptors with highest entropy values were flower position, stigma exsertion, colour of fruit at mature stage, pungency, plant height and fruit shape. Stem shape, leaf shape, placenta length and seed colour presented the lowest entropy values.

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INTRODUCTION

The *Capsicum* peppers are consumed worldwide, with diverse uses but mainly as food due to fruits pungency responsible for heat sensation. The fruits are an excellent source of health-related compounds, such as ascorbic acid (vitamin C), carotenoids (provitamin A), tocopherols (vitamin E), flavonoids, and capsaicinoids. Pepper fruits can be consumed fresh or dried, as a condiment. Besides the use as food and as medicinal, peppers are ornamental plants when grown in gardens or pots (Bosland and Votava, 2012; Wahyuni *et al.,* 2013). *Capsicum* peppers are native from the tropical regions of Americas. Chili peppers were one of the first species to be domesticated in the western hemisphere (about 10,000 b.C). In fact, *Capsicum* has an intimate relationship with the Native American peoples. When the European navigators had the first contact with these plants, five different species had been domesticated independently in different regions in Americas: *C. annuum, C. baccatum, C. chinense, C. frutescens* e *C. pubescens* (Bosland and Votava, 2012; Chiou *et al.,* 2014).

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There is a great genetic diversity among and within species of the *Capsicum* genus, for different aspects, which are highlighted morphological characteristics of plants and fruits (Padilha *et al.,* 2016). To facilitate the morphological characterization method of plant species, IPGRI (International Plant Genetic Resources Institute) developed a standardized list of different descriptors for *Capsicum* (IPGRI, 1995). Descriptors are generally highly heritable characters that can be easily observed by visual identification and expressed in diverse environments (Rodrigues *et al.,* 2010). The characterization is essential for the maintenance and preservation of genetic resources, because favors genotypes availability for immediate or future use. Likewise, plant breeding programs are qualified by availability of detailed information of germplasm genetic diversity (Hill *et al.,* 2013). Genebank's activities facilitate the choice of potential accessions for plant breeding because anticipates selection labor since it knows individual characteristics of target accession (Mistura *et al.,* 2015). According to the entropy values and accession frequency for each descriptor was possible to verify the behavior of each character evaluated. The entropy will be higher with increasing of phenotypic class number and how much more balanced is the ratio between

accession frequency in the class. Thus, for a morphological descriptor with two phenotypic classes, the lower entropy occurs when one of the classes provides 100% and another 0% for evaluated accessions (Hill, 1973; Vieira *et al.,* 2008). In Brazil, landraces of *Capsicum* peppers are cultivated by farmers, showing great genetic diversity. Part of these genetic resources are conserved in Genebanks. In 2002, the *Capsicum* Genebank of Embrapa Temperate Agriculture was established in Pelotas – Rio Grande do Sul State, Brazil. Currently, the genebank maintains 403 accessions of the five domesticated species of this genus, originating from collections, donations by farmers (landraces), private peppers collectors and fruit acquisition in popular markets. The aim of this work was therefore to perform morphological characterization, genetic divergence evaluation of peppers accessions (*Capsicum baccatum* and *Capsicum chinense*, Solanaceae) and estimate the entropy of descriptors.

MATERIALS AND METHODS

The evaluation was performed by analysis of 21 accessions (*Capsicum baccatum* and *C. chinense*) from the *Capsicum* Genebank of Embrapa Temperate Agriculture (Table 1). The sowing was carried in September 2014 in polystyrene trays for seedlings, containing 72 filled cells with commercial substrate. In October, when the plants had five to seven true leaves, they were transplanted to the experimental field of Embrapa Temperate Agriculture, spaced 0.5 m between plants and 1.3 m between rows. The rows were covered with black plastic mulching type to make the control of weeds and contribute to the maintenance of soil moisture. The plants were irrigated by drip irrigation system. The field experimental was a completely randomized design composed by 21 treatments (accessions). The experimental unit was composed of a row with ten plants of each accession. In totality, 210 plants were evaluated. For morphological characterization, 47 qualitative descriptors established by the International Plant Genetic Resources Institute - IPGRI (1995) with some changes suggested by Carvalho et al. (2003) were employed. The qualitative descriptors selected and their respective descriptor states are listed below.

- **species**: (1) *Capsicum annuum*; (2) *C. baccatum*; (3) *C. chinense*; (4) *C. frutescens*; (5) *C. pubescens*.
- **stem colour**: (1) green; (2) green with purple stripes; (3) purple.
- **nodal anthocyanin**: (1) green; (3) light purple; (5) purple; (7) dark purple.
- **stem shape**: (1) cylindrical; (2) angled; (3) flattened.
- **stem pubescence**: (3) sparse; (5) intermediate; (7) dense.
- **plant height (cm):** (1) < 25; (2) 25-45; (3) 46-65; (4) 66-85; (5) > 85;
- **plant growth habit**: (3) prostrate; (5) intermediate; (7) erect; (9) other.
- **plant canopy width (cm)**: (1) < 80; (2) 80-120;(3) >120-160; (4) > 160;
- **branching habit**: (3) sparse; (5) intermediate; (7) dense.
- **leaf density**: (3) sparse; (5) intermediate; (7) dense.
- **leaf colour**: (1) yellow; (2) light green; (3) green; (4) dark green; (5) light purple; (6) purple; (7) variegated; (8) green with anthocyanin.
- **leaf shape:** (1) deltoid; (2) ovate; (3) lanceolate.
- **leaf pubescence:** (3) sparse; (5) intermediate; (7) dense.
- **days to flowering:** (1) < 30; (2) 31-60; (3) 61-90; (4) > 90;
- **number of flowers per axil**: (1) one; (2) two; (3) three or more; (4) many with short internode; (5) one and two; (6) one, two and three; (7) two and three; (8) two, three and four.
- **flower position:** (3) pendant; (5) intermediate; (7) erect; (9) all positions; (11) intermediate and erect; (13) pendant and intermediate.
- **corolla colour**: (1) white; (2) light yellow; (3) yellow; (4) yellow-green; (5) purple with white base; (6) white with purple base; (7) white with purple margin; (8) purple; (9) white-green; (10) white with purple spot; (11) white-green with purple spot.
- **corolla spot colour**: (1) white; (2) yellow; (3) green-yellow; (4) green; (5) purple; (6) no spot.

Table 1. Accession, popular name, species and origin of *Capsicum* accessions evaluated from the *Capsicum* Genebank of Embrapa Temperate Agriculture

Accession	Popular name	Species	Origin
P27	pimenta amarela	*Capsicum baccatum*	Renascença, PR
P34	pimenta	*Capsicum baccatum*	Renascença, PR
P41	pimenta	*Capsicum chinense*	Pedro Afonso, TO
P157	pimenta pitanga	*Capsicum chinense*	Rio de Janeiro, RJ
P164	cambuci	*Capsicum baccatum*	Guarujá, SP
P169	estrela do mar	*Capsicum baccatum*	Belo Horizonte, MG
P171	pimenta	*Capsicum chinense*	São Paulo, SP
P175	murupi doce	*Capsicum chinense*	Salvador, BA
P179	pimenta	*Capsicum baccatum*	Rio Grande, RS
P209	pimenta	*Capsicum baccatum*	Pelotas, RS
P223	pimenta café ardida	*Capsicum baccatum*	Rio de Janeiro, RJ
P225	pimenta biquinho suave	*Capsicum chinense*	Rio de Janeiro, RJ
P232	pimenta dedo-de-moça suave	*Capsicum baccatum*	Rio de Janeiro, RJ
P235	pimentinha dedo-de-moça	*Capsicum baccatum*	Belém do Pará, PA
P239	pimenta	*Capsicum baccatum*	Pelotas, RS
P249	pimenta de bico doce	*Capsicum chinense*	Rio de Janeiro, RJ
P273	pimenta	*Capsicum chinense*	Pelotas, RS
P275	pimenta dedo-de-moça	*Capsicum baccatum*	Turuçu, RS
P286	pimenta	*Capsicum baccatum*	Cachoeira do Sul, RS
P299	habanero	*Capsicum chinense*	Pelotas, RS
P319	pimenta acerola	*Capsicum chinense*	Belém, PA

- **anther colour**: (1) white; (2) yellow; (3) pale blue; (4) blue; (5) purple; (6) yellow with light blue spot.
- **filamento clour**: (1) white; (2) yellow; (3) green (4) blue; (5) light purple; (6) purple; (7) blue-purple.
- **stigma exsertion**: (3) inserted; (5) same level; (7) exserted; (9) same level and exserted; (11) inserted and same level; (13) inserted and exserted.
- **calyx pigmentation**: (0) absent; (1) present.
- **calyx margin**: (1) entire; (2) intermediate; (3) dentate.
- **calyx anular constriction**: (0) absent; (1) present.
- **fruit colour at immature stage**: (1) white; (2) yellow; (3) green; (4) orenge; (5) purple; (6) dark purple; (7) yellow-green; (8) green-yellow; (9) white-yellow; (10) brown.
- **fruit position**: (3) pendant; (5) intermediate; (7) erect; (9) all; (11) pendant and intermediate; (13) pendant and erect; (15) intermediate and erect.
- **fruit colour at mature stage**: (1) white; (2) lemon-yellow; (3) pale orange-yellow; (4) orange-yellow; (5) pale orange; (6) orange; (7) light red; (8) red; (9) dark red; (10) purple; (11) brown; (12) black; (13) yellow; (14) pale yellow.
- **fruit shape**: (1) elongate; (2) almost round; (3) triangular; (4) campanulate; (5) blocky.
- **fruit length (cm)**: (1) <1.0; (2) 1.1-2.0; (3) 2.1- 4.0; (4) 4.1-8.0; (5) 8.1-12.0; (6) >12.0.
- **fruit width (cm)**: (1) <1.0; (2) 1.1-2.5; (3) 2.6-5.0; (4) 5.1-8.0; (5) > 8.0.
- **fruit weight (g):** (1) <1.0; (2) 1.1-3.0; (3) 3.1-9.0; (4) 9.1-27.0; (5) 27.1-81.0; (6) >81.
- **fruit pedicel length (cm):** (1) < 2.0; (2) 2.1-4.0; (3) 4.1-6.0; (4) >6.0.
- **fruit wall thickness (mm)**: (1) < 1.0; (2) 1.1-2.0; (3) 2.1-3.0; (4) 3.1-4.0; (5) 4.1-5.0; (6) >5.0.
- **fruit shape at pedicel attachment**: (1) acute; (2) obtuse; (3) truncate; (4) cordate; (5) lobate.
- **neck at base of fruit**: (0) absent; (1) present.
- **fruit shape at blossom end**: (1) pointed; (2) blunt; (3) sunken; (4) sunken and pointed.
- **fruit blossom end appendage**: (0) absent; (1) present.
- **fruit cross-sectional corrugation**: (3) slightly corrugated; (5) intermediate; (7) corrugated.
- **number of locules**: (1) one; (2) two; (3) three; (4) four; (5) five.
- **fruit surface**: (1) smooth; (2) semiwrinkled; (3) wrinkled; (4) smooth with stripes; (5) semiwrinkled with stripes.
- **persistence between pedicel and fruit** (3) slight; (5) intermediate; (7) persistent.
- **placenta length:** (1) < ¼ fruit length; (2) ¼ - ½ fruit length; (3) > ½ fruit length.
- **pungency**: (1) sweet; (2) low; (3) medium; (4) high.
- **fruit aroma**: (1) low; (2) medium; (3) high.
- **seed colour**: (1) yellow; (2) brown; (3) black; (4) other.
- **seed surface**: (1) smooth; (2) rough; (3) wrinkled.
- **number of seeds per fruit:** (1) < 20; (2) 20-50; (3) > 50.

Qualitative data were statistically analyzed by hierarchical clustering method UPGMA (*unweighted pair-group method using arithmetic averages*) based on euclidean distance using R program (v.3.1.2). The cophenetic correlation coefficient (*r*) was applied to check the adjustment between dissimilarity matrix and dendrogram. Number of groups formed was determined according to Mojena's criteria (Mojena, 1977). The cutoff point was based on criteria k = 1.25 (Milligan and Cooper, 1985). Data were also submitted to genetic divergence analysis by multicategoric data procedure using GENES program (Cruz, 2007). The methodology consists in obtain an index that consider several characters simultaneously, and each character display several categories. Dissimilarity matrix was generated based on complement of simple coincidence coefficient. The index considers the occurrence and agreement of values. Distance between i and j genotypes is given by Dij = (1-C) / (C+D), where C is the correlation values, and D is the discordance. Accessions were grouped based on matrix information by Tocher optimization method using GENES program (Cruz, 2007). The entropy level of characters (H) was estimated by Renyi entropy coeficiente, $H = - \sum p_i \ln p_i$, where the entropy is a measure of distribuition frequency of (n) accessions P = (p1, p2 ... ps), and p1 = fi/n e (p1 + p2 + ... + ps = 1) whereas (n = f1 + f2 + ... + fs), and f1, f2, ... fn are the counts of each class per descriptor. Entropy analysis was performed by Multiv program (Pillar, 1997).

RESULTS

Pepper accessions presented genetic diversity according the morphological characterization performed in this study, as shown in Figure 1. Two statistical methods was utilized in order to differentiate the most divergent accessions and cluster those similar according the morphological traits (Figure 2 and Table 2). According to UPGMA grouping considering 0.81 of similarity (Figure 2) were composed four groups (G1, G2, G3 and G4), gathering most similar accessions in each one. Cophenetic correlation (*r*) obtained from dendrogram and genetic distance matrix was 0.78. According to Bussab (1990) values (*r*) higher than 0.80 indicates a good representativity. Group 1 (G1) clustered five accessions (P171, P225, P319, P157 and P249), all belonging to *Capsicum chinense* species. These accessions showed days to flowering over 90 days, calyx anular constriction, ovate leaf shape, same corolla spot colour (no spot) and intermediate calyx margin. G2 grouped four accessions, also belonging to the same species (*C. chinense*). These accessions showed pendant fruit position, intermediate branching habit and intermediate plant growth habit. G3 clustered three *Capsicum baccatum* accessions (P179, P235 and P239). All of them exhibited pendant elongate fruits with red colour at ripe stage, intermediate leaf density, and one flower per axil, intermediate flower position, white corolla and yellow stigma. Finally, the G4 compiled nine accessions, also *C. baccatum.*

Table 2 - Grouping of 21 peppers accessions from the *Capsicum* Genebank of Embrapa Temperate Agriculture according to Tocher method based on 47 morphological descriptors. Pelotas – RS, 2016

GROUPS	ACCESSIONS
1	P179, P286, P275
2	P209, P27, P299
3	P232, P235, P175
4	P223, P273
5	P164, P169
6	P157, P319
7	P249, P34
8	P171
9	P41
10	P239
11	P225

Figure 1. Peppers accessions from the *Capsicum* Genebank of Embrapa Temperate Agriculture at ripening fruit stage

Table 3. Characters, phenotypic classes, accessions frequency (AF) for each class of characters and entropy (H) in *Capsicum* accessions

Descriptor	Phenotypic Classes	AF (%)	H
Flower position	Pendant	9.52	1.48
	Intermediate	28.57	
	Erect	4.76	
	All position	-	
	Intermediate e erect	42.82	
	Pendant and intermediate	14.28	
Stigma exsertion	Inserted	4.76	1.47
	Same level	14.28	
	Exserted	47.61	
	Same level and exserted	9.52	
	Inserted and same level	23.80	
	Inserted and exserted	-	
Fruit colour at mature stage	White	-	1.34
	Lemon-yellow	-	
	Yellow pale Orange	-	
	Yellow-orange	-	
	Pale Orange	4.76	
	Orange	4.76	
	Light red	-	
	Red	76.19	
	Dark red	4.76	
	Purple	-	
	Brown	-	
	Black	-	
	Yellow	4.76	
	Pale yellow	4.76	
Pungency	Sweet	42.86	1.30
	Low	33.33	
	Medium	14.28	
	High	9.52	
Plant height (cm)	< 25	-	1.29
	25-45	28.57	
	46-65	38.09	
	66-85	28.57	
	> 85	4.76	
Nodal anthocyanin	Green	19.05	1.27
	Light Purple	33.33	
	Purple	4.76	
	Dark purple	42.86	
Fruit shape at pedicel attachment	Acute	4.76	1.26
	Obtuse	28.57	
	Truncate	47.62	
	Cordate	19.04	
	Lobate	-	
Persistence between pedicel and fruit	Slight	14.28	1.24
	Intermediate	47.62	
	Persistent	38.09	
Number of flowers per axil	One	19.05	1.23
	Two	-	
	Three or more	-	
	Many with short internode	-	
	One and two	57.14	
	One, two and three	19.05	
	Two and three	-	
	Two, three and four	4.76	
Fruit shape	Elongate	47.62	1.21
	Almost round	-	
	Triangular	38.09	
	Campanulate	9.52	
	Blocky	4.76	
Fruit wall thickness (mm)	< 1	-	1.21
	>1 a 2	38.09	
	>2 a 3	47.61	
	>3 a 4	9.52	
	>4 a 5	4.76	
	> 5	-	
Fruit position	Pendant	57.14	1.19
	Intermediate	-	
	Erect	9.52	
	All	4.76	
	Pendant and intermediate	28.57	
	Pendant e erect	-	
	Intermediate and erect	-	

…… *Continued*

Fruit shape at blossom end	Pointed	57.14	1.19
	Blunt	28.57	
	Sunken	9.52	
	Sunken and pointed	4.76	
Fruit surface	Smooth	19.04	1.15
	Semiwrinkled	66.66	
	Wrinkled	9.52	
	Smooth with stripes	-	
	Semiwrinkled with stripes	4.76	
Fruit colour at immature stage	White	-	1.13
	Yellow	4.76	
	Green	80.95	
	Orange	-	
	Purple	-	
	Dark purple	4.76	
	Yellow-green	4.76	
	Green-yellow	4.76	
	White-yellow	-	
	Brown	-	
Fruit cross-sectional corrugation	Slightly corrugated	28.57	1.09
	Intermediate	38.09	
	Corrugated	33.33	
Aroma	Low	23.81	1.08
	Medium	42.86	
	High	33.33	
Fruit weight (g)	< 1	-	1.03
	>1 a 3	14.28	
	>3 a 9	47.61	
	>9 a 27	38.09	
	>27 a 81	-	
	> 81	-	
Anther colour	White	-	1.03
	Yellow	57.14	
	Pale blue	14.28	
	Blue	28.57	
	Purple	-	
	Yellow with light blue spot	-	
Pedicel length (cm)	< 2	9.52	1.01
	>2 a 4	47.61	
	>4 a 6	42.86	
	> 6	-	
Filament colour	White	61.90	1.01
	Yellow	-	
	Green	-	
	Blue	-	
	Light purple	23.80	
	Purple	14.28	
	Blue-purple	-	
Fruit lenght (cm)	<1	-	0.94
	>1 a 2	4.76	
	>2 a 4	42.86	
	>4 a 8	33.33	
	>8 a 12	19.04	
	>12	-	
Fruit width (cm)	< 1	-	0.94
	>1 a 2.5	52.38	
	>2.5 a 5	42.86	
	>5 a 8	4.76	
	> 8	-	
Calyx margin	Entire	4.76	0.93
	Intermediate	38.09	
	Dentate	57.14	
Corolla colour	White	57.14	0.93
	Light-yellow	-	
	Yellow	-	
	Yellow-green	-	
	Purple with white base	-	
	White with purple base	-	
	White with purple margin	-	
	Purple	-	
	White-green	38.09	
	White with purple spot	-	
	White-green with purple spot	4.76	

…… Continued

Leaf density	Sparse	9.52	0.93
	Intermediate	71.43	
	Dense	19.04	
Leaf colour	Yellow	-	0.90
	Light-green	2.85	
	Green	66.66	
	Dark green	4.76	
	Light purple	-	
	Variegated	-	
	Green with anthocyanin	-	
Plant canopy width (cm)	< 80	71.42	0.88
	>81 até 120	23.8	
	>121 a 160	4.76	
	> 161	-	
Stem colour	Green	19.05	0.85
	Green with purple stripes	76.19	
	Purple	4.76	
Plant growth habit	Prostrate	19.05	0.85
	Intermediate	76.19	
	Erect	4.76	
	Other	-	
Corolla spot colour	White	-	0.69
	Yellow	-	
	Yellow-green	57.14	
	Green	-	
	Purple	-	
	No spot	42.86	
Calyx anular constriction	Absent	57.14	0.69
	Present	42.85	
Calyx pigmentation	Absent	38.09	0.68
	Present	61.90	
Fruit blossom end appendage	Absent	80.95	0.58
	Present	19.04	
Number of seeds per fruit	< 20	-	0.53
	20 – 50	85.71	
	> 50	14.28	
Days to flowering	< 30	-	0.53
	31 a 60	-	
	61 a 90	14.28	
	> 91	85.71	
Leaf pubescence	Sparse	-	0.53
	Intermediate	85.71	
	Flattened	14.28	
Branching habit	Sparse	14.29	0.53
	Intermediate	85.74	
	Dense	-	
Number of locules	One	-	0.46
	Two	-	
	Three	90.47	
	Four	9.52	
	Five	-	
Leaf pubescence	Sparse	-	0.35
	Intermediate	95.23	
	Dense	4.76	
Neck at base of fruit	Absent	95.23	0.35
	Present	4.76	
Seed surface	Smooth	95.23	0.35
	Rough	4.76	
	Wrinkled	-	
Placenta length	< ¼	-	0.00
	¼ - ½	-	
	> ½	100	
Seed colour	Yellow	100	0.00
	Brown	-	
	Black	-	
	Other	-	
Stem shape	Cylindrical	-	0.00
	Angled	100	
	Alada	-	
Leaf shape	Deltoid	-	0.00
	Ovate	100	
	Lanceolate	-	

In this group are present ornamental peppers type (P34, P169, P209 and P223), *cambuci* type (P27 e P164) and *dedo-de-moça* type (P286, P232 and P275). It is worth mentioning that groups 1 and 2 belong to the same *C. baccatum* species and groups 3 and 4 belong to *C. chinense* species. It is possible to observe in Figure 2 the initial formation of two major groups, separating the two species, and this fact was expected since these species share some of the same morphological traits. It was also performed the grouping according to Tocher method (Table 2). As opposed to UPGMA, Tocher composed eleven different groups based on morphological characteristics evaluated. Group 1 clustered accessions with high persistence between fruit and peduncle, three locules fruits, semiwrinkled fruit surface and intermediate stem pubescence. Group 2 clustered P27, P209 and P299, which showed the same canopy diameter (intermediate) and branching habit (intermediate).

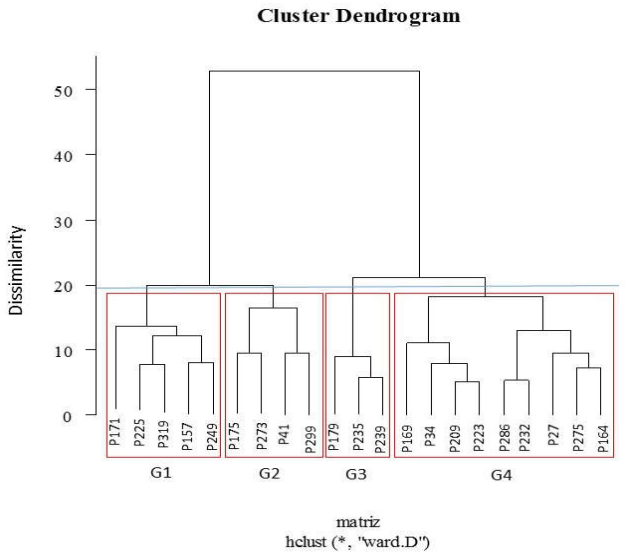

Figure 2. Dendrogram of 21 Capsicum accessions obtained by UPGMA hierarchical method based on 47 morphological descriptors.

Groups 3, 4, 6 and 7 (Table 2) clustered accessions from different species, but still sharing some characteristics in common, for example, in group 3 all accessions exhibited pendant elongated fruit shape and red ripe fruit. Group 5 gathered two *Capsicum baccatum* accessions, both plants showed intermediate growth habit with pendant campanulate fruit shape. The groups 8 (P171), 9 (P41), 10 (P239) e 11 (P225) had only one accession per group. P171 accession (*C. chinense*) showed different characteristics from other accessions, such as, purple stem and leaves, white-green with purple spot corolla and purple unripe fruits. Entropy and accession frequency for each descriptor was performed (Table 3). The descriptors flower position (1.48), stigma exsertion (1.47), fruit colour at mature stage (1.34), pungency (1.30), plant height (1.29), nodal anthocyanin (1.27), fruit shape at pedicel attachment (1.26), persistence between pedicel and fruit (1.24) and fruit shape (1.21) showed high entropy values indicating great diversity and genetic variability for these traits. The descriptors stem shape, leaf shape, placenta length and seed colour had the lower entropy values, whereas all had zero entropy value indicating they were monomorphic for each trait in evaluated accessions. The accessions had only one class for these descriptors (e.g. angulate stem shape). Similarly, the accession frequency for leaf shape was ovate (100%). Otherwise, the accession frequency for flower position was pendant (9.52%), intermediate (28.57%), erect (4.76%), intermediate and erect (42.82%) and pendant and intermediate (14.28%) showing a high entropy coeficient. Thus, there is a great genetic variability for the majority of descriptors evaluated, where only four were monomorphic.

DISCUSSION

There is genetic diversity for *C. baccatum* and *C. chinense* accessions evaluated in this work. Other authors used the UPGMA method to identify similar *Capsicum* accessions according to their morphological characteristics (Büttow *et al.,* 2010; Vasconcelos *et al.,* 2014) and they observed the same great genetic diversity. Similary, the Tocher grouping method was efficient to separating *Capsicum* accessions, as reported by others research team (Faria *et al.,* 2012; Vasconcelos *et al.,* 2014). However, this method formed different number of groups comparing to UPGMA. The UPGMA grouping method gathered some accessions with similar characteristics thus indicates the better usage for those accessions. For example, Group 1 (G1) clustered five accessions (P171, P225, P319, P157 and P249), all belonging to *Capsicum chinense* specie. These accessions showed days to flowering (over 90 days), this is an important aspect to development of new cultivars with shorter or longer cycles, allowing the farmers a largest number of options to choose in field implantation. Further, G2 gathered accessions with intermediate branching habit and intermediate plant growth habit. These aspects are important because it influences directly their indication of use: cultivation in pots, gardens or fields. Besides that, traits such as plant height and canopy diameter guide the planning of tillage structure (distance among plants, number of plants per area). The groups 1 and 2 belong to the same species (*C. baccatum*) and groups 3 and 4 belong to *C. chinense* species. It is possible observe in Figure 2 the initial formation of two major groups, separating the two species. It was expected, since these species share some of the same morphological traits. The morphological traits are used to distinguish different *Capsicum* species. For example, *C. pubescens* is unique that presents black seeds; *C. baccatum* have corolla spot; *C. chinense* presents calyx anular constriction.

The entropy values and accession frequency predicts the behavior of each trait. The entropy will be higher with increasing number of phenotypic class and how much more balanced is the ratio between the accession frequency in the class (Vieira *et al.,* 2008). Thus, for a morphological descriptor with two phenotypic classes, the smallest entropy occurs when one of the classes provide 100% and another 0% for evaluated accessions. Vieira *et al.,* (2008) evaluated morphological traits in cassava (*Manihot esculenta*) accessions from Embrapa Cerrados Cassava Germoplasm Collection by entropy evaluation. They identified characters with higher and lower genetic variability and predicted possible selection methods used by farmers. For example, ancient natives and farmers always selected cassava plants with roots without constrictions, so this trait presented low entropy value. Otherwise the characters with high entropy (e.g stem color external) seems to have not agronomical interest, and probably were bit targeted during the selection process, either conscious or unconscious manner, fact that allowed the maintenance of high variability classes. The term entropy is widely used in ecology mainly to modeling species in geographic distributions, a critical problem in conservation biology. The entropy refers to the degree of randomness in any physical system where can be used to evaluate the diversity and evenness of a specific

population (Hill, 1973). So, the larger the disorder, the larger the change of the system state and therefore the greater entropy degree. This term is eventually used in genetic resources, and we proposed to evaluate the entropy of each descriptor utilized in this work to take a view of genetic variability for each characteristic from pepper accessions.

In case of chili peppers, there is a great genetic variability for the majority of descriptors evaluated in this work, where only four were monomorphic. It represents the current state of genetic diversity of *Capsicum* peppers and reflects the historical selection proccess made by natives and farmers over the years. Chili pepper domestication occured a long time ago. *Capsicum* were widely utilized by the Native American peoples and they selected them for many purposes, even nowadays exists pepper types made by Indian peoples (Bosland and Votava, 2012). Currently, there are different kinds of fruits shapes, plant architecture and pungency and this difference depends directly of targeted trait. For example, fruits pungency trait (H=1.30) is much more interesting for selection, exploring different heat levels when compared to an unattractive feature as stem-shape (H=0). The genetic diversity observed can attribute a kind of selection method utilized by farmers over the years, especially for those landraces accessions. Another relevant fact is the fertilizing system of plants. The exchange process of genetic material is different between autogamous and allogamous species. Domesticated *Capsicum* species perform self-pollination, but can occur cross-pollination depending on the cultivation environment. The cross-pollination rate is practically zero in greenhouse, however, could be quite significant in open field cultivation (Ribeiro and Reifschneider, 2008). Morphological descriptors were efficient to characterize accessions from the *Capsicum* Genebank of Embrapa Temperate Agriculture. There is genetic diversity for *C. baccatum* and *C. chinense* accessions evaluated. The UPGMA and Tocher grouping methods partially agree to the formation of groups. The descriptors with the highest entropy values were flower position, stigma exsertion, colour of fruit at mature stage, pungency, plant height and fruit shape. Stem shape, leaf shape, placenta length and seed colour presented the lowest entropy values.

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