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Phenotypical characterization of *Portulaca umbraticola*: A non-conventional edible ornamental crop

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ABSTRACT. Purslanes are frequently used in Brazil as potted plants and for landscaping because of their beautiful colored flowers. Despite their commercial importance, the genetic diversity within ornamental purslane remains largely unknown. Thus, a complete characterization of ornamental purslane resources is essential for its utilization since genetic variability is indispensable for the efficient development of new cultivars. This study aimed to evaluate genetic variability and recommend accessions to start a genetic breeding program for purslane (*Portulaca umbraticola)*. Twenty purslane accessions were collected in public places in Areia City and Santa Rita City, Paraiba State, Brazil. The experiment was conducted in a greenhouse. An entirely randomized experimental design with 20 accessions and 5 replicates was utilized. Plants were evaluated for quantitative and qualitative traits. Data were submitted to analysis of variance and grouped by Scott–Knott's criteria ($p \leqslant 0.05$). The accessions were grouped using Tocher's method based on the generalized Mahalanobis distance. Principal component analysis was also used to analyze the genetic divergence. There were significant differences ($p \leqslant 0.05$) for all evaluated traits except for internode distance, plant height, and leaf length. The Scott–Knott criteria clustered the accessions into two groups for all traits except days to flowering (five groups). Tocher's grouping based on Mahalanobis distance allowed the accessions to be separated into eight clusters. The genetic diversity observed in this study was supported by the consonance between the Tocher cluster method and the PC analyses. The traits that most contributed to genetic divergence among accessions were days to flowering (70.37%), flower length (6.10%), leaf width (3.89%), branch number (3.57%), and stem length (3.36%). Considering the criteria for use in outdoor spaces, wider plants with several large colored flowers, thicker stems, greener leaves, and earliness were interesting. Accessions 5, 7, 13, 14, 16, 18, and 20 should be selected as parents for further breeding programs. However, if the objective is to produce potted plants, dwarf plants with bigger leaves are desired, and accession 1 should be selected. This will create greater variability in segregating populations, which will increase the overall quality of ornamental use of this species. For those accessions with no reproductive verticils but with other excellent attributes, for example, high chlorophyll content breeding strategies, such as induced mutations or protoplast fusion, can be used.

Keywords: breeding; ornamental plant; neglected plants; underutilized food plants; moss rose purslane; genetic variability; morphological traits.

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Introduction

Portulaca umbraticola Kunth belongs to the Portulacaceae family, which includes 10 genera and 258 species (The Plant List, 2020). They are mainly distributed in the west of North America, South America and Africa, with a smaller number of representatives in Europe and Asia (Coelho, Giulietti, Harley, & Yesilyurt, 2010).

Most *Portulaca* species have no major commercial importance, except *Portulaca oleraceae* (common purslane), *Portulaca grandiflora* (nine o'clock) and *P. umbraticola* (moss rose purslane or large-flowered purslane) (Ocampo & Columbus, 2012). Most literature involving ornamental *Portulaca* is about *P. oleraceae* or *P. grandiflora*; however, some authors have affirmed that *P. umbraticola* is taking the floriculture industry by storm. *Portulaca umbraticola* is planted as a bedding plant or as a container plant for landscaping with morphological characteristics that resemble those of common purslane (*P. oleracea* L.) (Elias, 2018; Jia et al., 2017).

Purslane has flowers with diverse colors, such as yellow, white, red, orange, pink, purple and violet (Coelho et al., 2010; UPOV, 2019). Flower color variation and small plant size potentialize ornamental use for this species (Datta, 2021; Franca & Maia, 2008). Purslane can also be used as a food source because it has essential nutrients, phenolic compounds, flavonoids, carotenoids and antioxidants and has been considered medicinal (Alam et al., 2014a; 2014b; 2014c).

Brazil has eight thousand ornamental plant producers. Most of them are small- and medium-sized producers that produce in an area of more than 15.6 thousand hectares (Ibraflor, 2022). In Brazil, small farmers produce purslane, making it difficult to quantify the commercialized amount. Other species occupy the place in the big chains, such as the roses, orchids, cacti, succulents, ornamental pepper, violets and lisianthus (Ibraflor, 2021).

In Ibraflor's assessment, there is a tendency for home office work and some consumption habits acquired during the pandemic to persist, which makes the sector invest in increased production for the coming years, especially the production of potted plants. This market grew during the pandemic to the detriment of ornamental plants for cutting, such as flowers and foliage (Globo Notícia, 2020; Pereira, Aguiar, & Pires, 2022).

The Ornamental plant's global market is expanding (Ibraflor, 2021), and it is extremely dynamic and demands the constant release of new cultivars. Safdari and Kazemitabar (2009) reported that millions of micropropagated plants of *Portulaca* are being afforded to the commercial ornamental market and the agricultural, clonally propagated crop market large-scale through many mircopropagation laboratories. Thus, to meet this market, ornamental plant breeding programs need to accelerate the production of new cultivars synchronized with the market's demands (Filliettaz, 2007).

Despite its commercial importance, the genetic diversity within ornamental purslane remains largely unknown (Egea-Gilabert, Ruiz-Hernández, Parra, & Fernández, 2014; Jia et al., 2017; Setiawan, Aisyah, & Krisantini, 2016). Thus, a complete characterization of ornamental purslane resources is essential for their utilization (Jia et al., 2017), since genetic variability is indispensable for efficient new cultivar development and for optimizing the choice of parents in a breeding program (Alam et al., 2015).

Thus, this study aimed to evaluate genetic diversity and recommend accessions to start a breeding program for moss rose purslane (*Portulaca umbraticola)*.

Material and methods

The experiment was conducted at *Laboratório de Biotecnologia e Melhoramento Vegetal* of the *Centro de Ciências Agrárias*, *Universidade Federal da Paraíba*, Areia, Paraíba State, Brazil. Twenty accessions of *P. umbraticola* Kunth were used, numbered 1–20 (Figure 1), and collected from public places at Areia and Santa Rita, Paraíba State, Brazil. Accessions were asexually propagated using three cuttings of approximately 15 cm in plastic pots with commercial substrate (Plantmax®). They were submitted to the best agronomic practices, including irrigation, fertilization and pesticide application for pest and plant disease control. Fertilizers were supplied monthly in the dosages recommended for vegetables. The plants received a daily water supply until they reached field capacity in the pots through micro-sprinklers installed on the greenhouse benches. They were also in full sunlight for the location 6°58'18.7" S and 35°43'15.0" W.

The evaluated characteristics were flower number, flower length, stem diameter, internode distance, branch number, canopy width, plant height, stem length, chlorophyll *b*, chlorophyll *a*, leaf length, leaf width and days to flowering. Data measurements were made with a digital caliper (Leetools®) and a graduated rule. Chlorophyll contents were measured with a digital chlorophyll meter (ClorofiLOG -FALKER®). The evaluated traits were recorded 83 days after planting.

The qualitatively evaluated traits were corolla type (pentamerous and multi), presence or absence of reproductive verticils, leaf shape, leaf tip shape and leaf base shape. The accessions were also visually evaluated using the color chart from the Royal Horticultural Society for flower color, corolla base color, anther color, style color, stem color, and leaf color.

The experimental design was completely randomized, with 20 treatments (accessions) and five replicates. The data obtained was submitted to analysis of variance and the means were grouped by Scott–Knott's criteria ($p \leqslant 0.05$). Genetic parameters and their estimators were analyzed for each quantitative trait using the following expressions (Cruz, Carneiro, & Regazzi, 2014):

a) Heritability: $h^2 = \frac{\sigma^2 G}{\sigma^2 F}$

b) Phenotypic variance: $(\sigma^2 F) = \frac{MSt}{k}$

c) Environmental variance: $(\sigma^2_E) = \frac{MSr}{k}$

d) Genotypic variance: $(\sigma^2_G) = \frac{(MSt - MSr)}{k}$

e) Coefficient of genetic variation: $(CVg) = \frac{\sqrt{\sigma^2_G}}{m} \times 100$

f) Coefficient of genetic variation to coefficient of environmental variation ratio: CVg/ CVe $\frac{CVg}{CVe} = \sqrt{\frac{\sigma^2_G}{\sigma^2}}$

where MSt = treatments mean square; k = replicate number; and MSr = residual mean square.

Mahalanobis distance was employed to determine the degree of diversity among accessions, and groups were formed following Tocher's method (Rao, 1952). Divergence analysis was also performed using principal component analysis (PCA). The relative importance of the variables was determined using the method described by Singh (1981). Qualitative data were determined by frequency distribution. All quantitative analyses were performed using GENES software (Cruz, 2018).

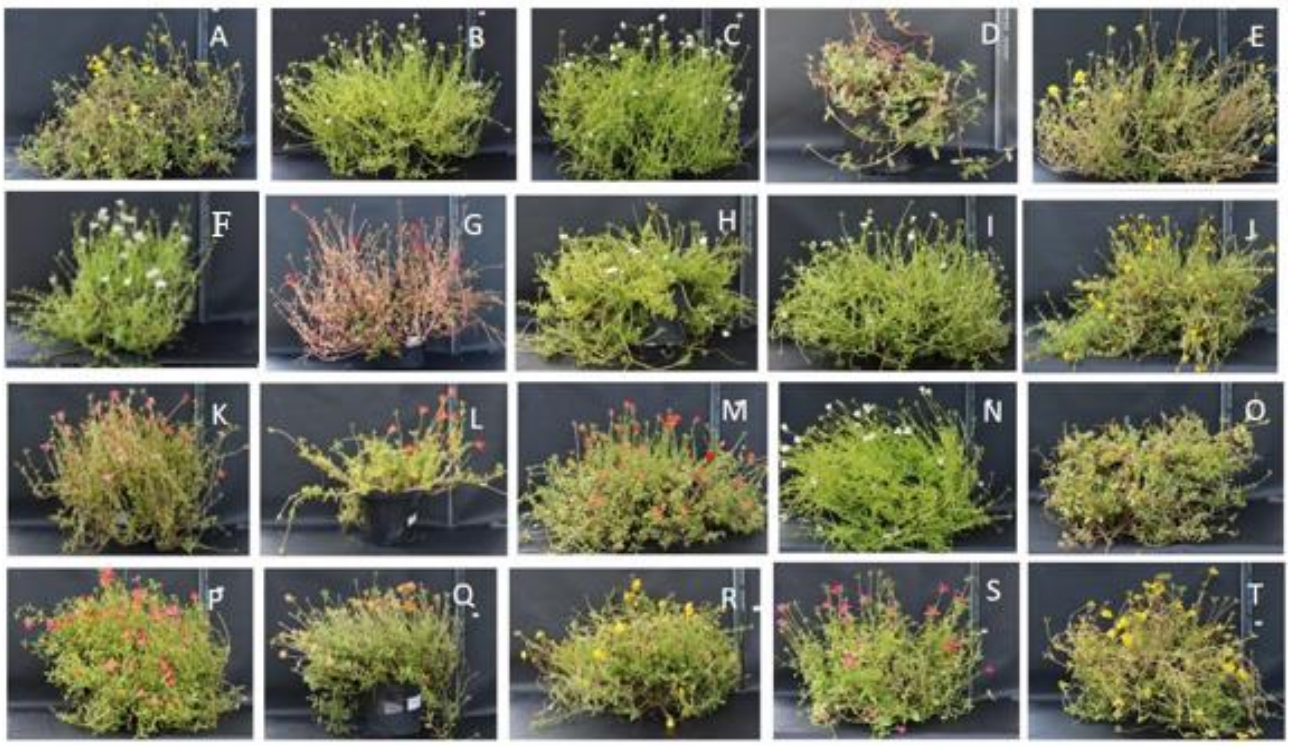

Figure 1. *Portulaca umbraticola* UFPB accessions: 1 (A), 2 (B), 3 (C), 4 (D), 5 (E), 6 (F), 7 (G), 8 (H), 9 (I), 10 (J), 11 (K), 12 (L), 13 (M), 14 (N), 15 (O), 16 (P), 17 (Q), 18 (R), 19 (S), and 20 (T).

Results and discussion

There were significant differences ($p \leq 0.05$) for all evaluated traits except internode distance, plant height, and leaf length (Table 1).

The heritability values were higher than 60% for flower length (72.54%), stem diameter (64.14%), branch number (72.86%), stem length (75.83%), leaf width (66.45), and days to flowering (98.56%). The remaining traits presented values lower than 60% (Table 1). Lower values of heritability were presented for stem diameter, number of branches, plant height, and chlorophyll in a study with *P. oleraceae* (Talei, Labbaf, & Naji, 2020). High values of heritability indicate that differences among accessions were due to genetic variation and not to environmental factors (Cruz et al., 2014).

The coefficient of genetic variation to the coefficient of the environmental variation ratio (CVg/CVe) was lower than 1 for all traits except days to flowering (Table 1). When the values of the CVg/CVe are higher than 1, this indicates a better chance of genetic gain for this trait. According to Cruz et al. (2014), this parameter

should be considered together with the heritability values as an indicator of selection success in breeding programs. Then, it is possible to select for earliness in the evaluated population.

Table 1. Analysis of variance summary: phenotypical variance (σ^2_F), environmental variance (σ^2_E), genotypic variance (σ^2_G), heritability (h^2), coefficient of genetic variation to environmental variation ratio (CVg/CVe), and coefficient of environmental variation (CV%) for 13 morphoagronomic traits with different accessions of *Portulaca umbraticola*.

S.V.	Mean Square													
	D.F	FN	FL	SD	ID	BN	CW	PH	SL	CA	CB	LL	LW	DTF
Treatments	19	104.75*	0.54*	0.01*	0.64ns	17.84*	84.08*	138.84ns	371.04*	43.97*	10.11*	0.30ns	0.11*	60.84*
Residue	80	47.04	0.15	0.004	0.76	4.84	38.11	60.03	89.68	21.17	4.05	0.19	0.04	0.87
σ^2_F	-	20.94	0.11	0.002	0.12	3.57	16.82	27.77	74.20	8.79	2.02	0.06	0.02	12.17
σ^2_E	-	9.40	0.03	0.0008	0.15	0.97	7.62	12.00	17.94	4.23	0.81	0.04	0.01	0.17
σ^2_G	-	11.53	0.08	0.001	0.00	2.60	9.19	15.76	56.27	4.56	1.21	0.02	0.01	11.99
h^2 (%)	-	55.07	72.54	64.14	0.0	72.86	54.67	56.76	75.83	51.85	59.88	38.85	66.47	98.56
CVg (%)	-	23.72	9.79	7.74	0.0	24.66	12.52	8.65	13.43	7.58	13.24	5.73	11.02	18.23
CVg/CVe (%)	-	0.49	0.72	0.52	0.0	0.73	0.49	0.51	0.79	0.46	0.54	0.36	0.62	3.70
C.V. (%)	-	47.91	13.46	12.94	28.95	33.65	25.50	16.88	16.96	16.34	24.23	16.07	17.50	4.92
Mean	-	14.31	2.86	0.52	3.01	6.54	24.21	45.91	55.84	28.16	8.31	2.69	1.12	19.00

Flower number (FN), flower length (FL), stem diameter (SD), internode distance (ID), branches number (BN), canopy width (CW), plant height (PH), stem length (SL), chlorophyll *b* (CB), chlorophyll *a* (CA), leaf length (LL), leaf width (LW), and days to flowering (DTF), ns = non-significant, * = significant at 5% of probability by F test.

The Scott–Knott criteria clustered the accessions into two groups for all traits except days to flowering (five groups) (Table 2). The accessions with a major number of flowers were 13, 15, 10, 18, 12, 9, 20, 14, and 6. Genotypes 14, 12, 20, 19, 1, 6, 11, 4, 18, 15, 5, and 13 showed larger flowers (Table 2). In an ornamental plant breeding program, it is important to select accessions with larger flowers and an increased number of flowers per plant (Datta, 2021). Thus, accessions 6, 12, 13, 14, 15, 18, and 20 can be selected to improve these characteristics (Table 2).

Regarding stem diameter, accessions 8 and 17 presented minor values of 0.41 and 0.40 cm, respectively (Table 2). Despite all the other accessions presenting thicker stems than these, they had thinner stems than the *P. oleraceae* genotypes studied by Talei et al. (2020). A higher stem diameter provides better support for the plant and facilitates asexual propagation by cutting.

Accessions 10, 17, 20, 14, 16, 18, 13, 2, and 5 presented higher branch numbers, with mean values varying from seven to eleven (Table 2). The accessions with major canopy widths were 7, 4, 3, 5, 15, 2, 19, and 6, with values varying from 48.2 to 52.8 cm (Table 2). For the variable stem length, accessions 16, 1, 17, 10, and 8 presented the lowest mean values. All other accessions formed a cluster with major stem length means varying from 53.8 to 65 cm (Table 2). The accessions with major values for these three traits should be used as bedding plants since they presented numerous long and wider branches, allowing empty spots to be filled in the garden or outdoor spaces. Talei et al. (2020) reported no differences among genotypes of *P. oleraceae* for branch number. Despite the lack of significance of plant height, it is important to highlight that the values varying from 15.4 to 36.0 cm (data not shown), showing that the accessions of *P. umbraticola* were smaller than those of *P. oleraceae* studied by Talei et al. (2020).

Considering chlorophyll b, accessions 17, 10, 13, 18, 20, 8, and 9 presented higher mean values (Table 2). All accessions showed higher values of chlorophyll a, except accession 20 (Table 2). However, Talei et al. (2020) reported no significant differences in chlorophyll content among the purslane genotypes of *P. oleraceae*. The accessions with larger leaves were 16, 13, 11, 7, 5, 19, 4, 6, 17, 10, 12, 18, 15, and 20 (Table 2). Traits' mean values are important to help in the decision-making process of plant selection and in choosing accessions with favorable traits in a breeding program. Datta (2021) underlined the importance of pigments as different economic characteristics of ornamental plants. It is important to highlight traits such as canopy width and chlorophyll b leaf width for *P. umbraticola* species since it can be consumed as a traditional orphan crop (Kumar et al., 2021). According to Alam et al. (2014a) and Alam et al. (2014c), purslane can be consumed and can also be used as medicinal plants for bioactive compounds, such as phenolic compounds, flavonoids, carotenoids, essential minerals and antioxidants.

Accessions 16, 3, 7, 2, 17, and 14 presented earliness. They bloomed from 15 to 16 days after transplanting, while other accessions showed values varying from 17 to 25 days to flowering. According to Datta (2021), earliness is a desired trait for ornamental plants. The faster the plants bloom, the less time will be needed until commercialization. Additionally, the breeding program, based on the hybridization method, can be accelerated.

Table 2. Quantitative trait means of 20 purslane accessions (*P. umbraticola*).

Accessions	FN	FL	SD	BN	CW	SL	CB	CA	LW	DTF
1	10.00b	3.14a	0.54a	2.80b	43.20b	46.80b	7.67b	28.35a	0.99b	18.20c
2	11.00b	2.50b	0.54a	7.40a	51.25a	65.00a	7.87b	28.10a	1.01b	15.60e
3	9.60b	2.41b	0.51a	6.00b	52.40a	57.80a	7.97b	30.41a	0.864b	15.80e
4	11.60b	2.97a	0.49a	6.20b	52.80a	61.80a	8.51b	29.14a	1.17a	17.20d
5	9.00b	2.85a	0.57a	7.00a	52.00a	64.80a	12.70a	28.69a	1.22a	19.40b
6	17.40a	3.13a	0.55a	6.00b	48.20a	55.60a	8.09b	27.20b	1.16a	20.20b
7	10.80b	2.66b	0.56a	5.20b	52.80a	60.40a	7.57b	26.89b	1.23a	15.60e
8	7.80b	2.42b	0.41b	3.20b	33.00b	37.80b	8.97a	29.93a	0.87b	16.60d
9	18.40a	2.36b	0.52a	6.00b	45.60b	53.80a	8.77a	30.17a	0.89b	19.00b
10	19.20a	2.55b	0.50a	11.00a	41.60b	39.20b	10.75a	31.35a	1.14a	19.00b
11	12.80b	3.00a	0.54a	6.60b	43.00b	63.80a	7.43b	26.41b	1.30a	25.00a
12	18.80a	3.21a	0.50a	5.20b	45.00b	57.80a	8.37b	28.59a	1.13a	24.60a
13	21.40a	2.83a	0.56a	7.40a	45.60b	63.60a	10.16a	30.38a	1.38a	24.00a
14	17.60a	3.61a	0.62a	8.20a	42.40b	58.00a	6.56b	22.55b	0.96b	15.00e
15	20.87a	2.88a	0.50a	6.00b	51.60a	57.40a	6.46b	22.93b	1.13a	17.20d
16	8.50b	2.67b	0.52a	7.60a	44.50b	48.75b	6.28b	23.61b	1.38a	16.00e
17	14.20b	2.69b	0.40b	8.80a	44.00b	41.00b	11.70a	34.44a	1.16a	15.40e
18	19.00a	2.90a	0.54a	7.40a	40.20b	59.00a	9.07a	31.07a	1.13a	18.00c
19	10.75b	3.17a	0.48a	4.60b	48.40a	61.00a	8.42b	26.37b	1.20a	24.00a
20	17.60a	3.18a	0.50a	8.20a	40.58b	63.25a	9.04a	26.73b	1.12a	24.20a

Flower number (FN), flower length (FL), stem diameter (SD), branch number (BN), canopy width (CW), stem length (SL), chlorophyll *b* (CB), chlorophyll *a* (CA), leaf width (LW), and days to flowering (DTF), Means followed by the same letters in columns do not differ statistically by Scott–Knott criteria ($p \leq 0.05$). ** Means followed by the same letters, in columns, do not differ statistically by Tukey's test ($p \leq 0.05$).

Tocher's grouping based on Mahalanobis distance allowed the accessions to be separated into eight clusters (Table 3). Most of the individuals were included in group I (2, 3, 7, 4, 16, and 15), followed by group II (12, 19, 11, 20, and 13). Accessions 9, 18, 10, and 6 comprised group 3. Accessions 1, 5, 8, 14, and 17 formed clusters IV, V, VI, VII, and VIII, respectively (Table 3). Group I presented the major mean value for branch number and the second major value for canopy width. The second cluster showed the major mean value for internode distance, leaf length, leaf width and days to flowering. Group III exhibited a greater mean flower number. Cluster IV had a major mean leaf width and a minor mean plant height. Group V presented a major mean for canopy width and stem length. Cluster VI showed minor values for canopy width and stem length. Group VII presented bigger flowers, thicker stems and were the most precocious plants. The major means of plant height and chlorophyll a and b were presented by cluster VIII. Alam et al. (2015) grouped 45 purslane accessions into seven clusters using ISSR markers. Thus, we demonstrated that it is possible to discriminate between different accessions based on morphological traits. Several authors opined that the evaluation of genetic diversity within a purslane population is indispensable to germplasm conservation, exploitation and establishment of breeding programs (Alam et al., 2014c; Alam et al., 2015; Talei et al., 2020).

Table 3. Tocher's grouping of 20 Eleven O'clock *P. umbraticola* accessions. Means, minimum and maximum values of 13 evaluated traits.

Groups	Accessions		FN	FL	SD	ID	PH	BN	CW	SL	CA	CB	LL	LW	DTF
	2, 3, 7, 4, 16, and 15	Mean	12.10	2.69	0.52	3.14	6.40	26.53	50.89	58.52	26.84	7.44	2.76	1.13	16.23
I		Minimum	8.50	2.41	0.49	2.72	5.20	20.4	44.5	48.75	22.92	6.28	2.47	0.87	15.60
		Maximum	20.86	2.97	0.56	3.45	7.60	36.00	52.80	65.00	30.47	78.51	3.01	1.38	17.20
	12, 19, 11, 20, and 13	Mean	16.27	3.08	0.52	4.00	6.40	25.06	44.52	61.93	27.70	8.68	2.81	1.22	24.36
II		Minimum	10.75	3.18	0.48	2.56	4.60	23.00	48.40	61.00	26.37	8.42	2.46	1.12	18.00
		Maximum	12.80	3.01	0.54	3.40	6.60	28.60	43.00	63.80	26.41	7.43	3.15	1.37	20.20
	9, 18, 19, and 6	Mean	18.5	2.74	0.53	3.12	7.60	23.50	43.9	51.90	29.95	9.17	2.59	1.08	19.05
III		Minimum	17.40	2.36	0.50	2.90	6.00	21.00	40.20	39.20	27.20	8.09	2.34	0.89	0.69
		Maximum	19.20	3.14	0.55	3.50	11.00	27.40	48.20	59.00	31.35	10.75	2.75	1.16	19.00
IV	1		10.00	3.15	0.54	3.00	2.80	22.00	43.20	46.80	28.35	7.67	2.81	0.99	18.20
V	5		9.00	2.85	0.57	3.30	7.00	23.4	52.00	64.80	28.69	6.56	2.65	1.22	19.40
VI	8		7.80	2.42	0.41	2.00	3.20	15.40	33.00	37.80	29.93	8.97	2.13	0.87	16.60
VII	14		17.60	3.61	0.62	3.30	8.20	21.40	42.40	58.00	22.55	6.57	2.41	0.96	15.00
VIII	17		14.20	2.69	0.40	2.80	8.80	23.60	44.00	41.00	34.44	11.70	2.76	1.16	15.40

Flower number (FN), flower length (FL), stem diameter (SD), internode distance (ID), branch number (BN), plant height (PH), canopy width (CW), stem length (SL), chlorophyll *b* (CB), chlorophyll *a* (CA), leaf length (LL), leaf width (LW), and days to flowering (DTF).

The two first canonical variables explained 81.733% of the total variance (Table 4). The genetic diversity results observed in this study were supported by the consonance between cluster and PC analyses, except for accessions 1 and 14, which were grouped together with the accessions of major group I (Table 3; Figure 2). The data support the variability presented among accessions in this study. The lowest values for the two first principal components were presented by Alam et al. (2015) (57.7%) and Talei et al. (2020) (55.5%) in studies with *P. oleraceae*. Arunachalam (1981) considered joining the distance and principal component analysis a good procedure if the first two components accumulated at least 70% of the total variation.

Table 4. Variance estimates (eigenvalues) associated with principal components of the 13 quantitative traits evaluated in *Portulaca umbraticola* accessions.

Principal component	Eigenvalues	Eigenvalues (%)	% Accumulated
1	18.81	75.46	75.46
2	1.56	6.27	81.73
3	1.36	5.45	87.18
4	0.93	3.73	90.91
5	0.56	2.23	93.15
6	0.50	2.02	95.17
7	0.41	1.65	96.81
8	0.28	1.11	97.93
9	0.23	0.92	98.85
10	0.11	0.45	99.30
11	0.07	0.30	99.60
12	0.06	0.25	99.85
13	0.04	0.14	100.00

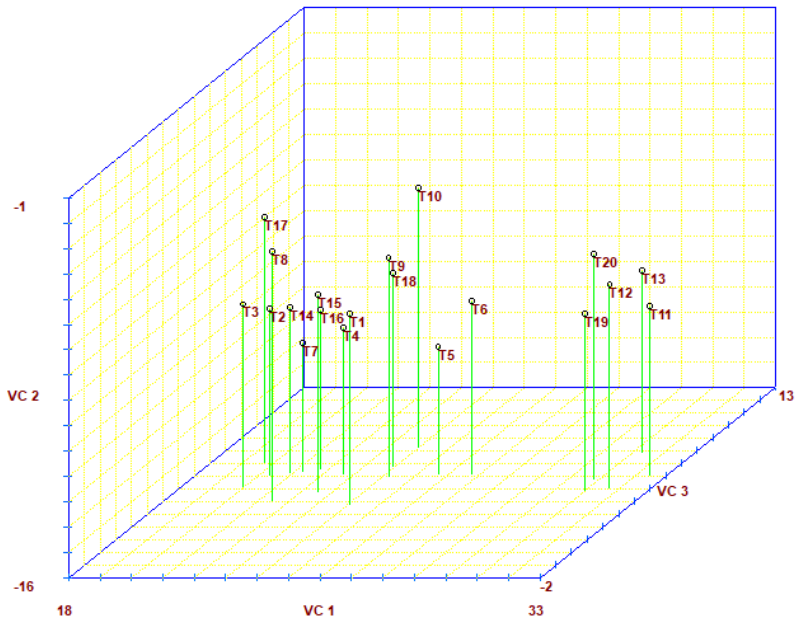

Figure 2. Dispersion of 20 accessions of *Portulaca umbraticola* based on the first three principal components (PCA).

Through Singh's method (1981), it was determined that 5 out of 13 evaluated characteristics contributed to 87.29% of genetic divergence. However, nine traits contributed to only 12.71% of genetic divergence (Table 5). The traits that most contributed to genetic divergence among accessions were days to flowering (70.37%), flower length (6.10%), leaf width (3.89%), branch number (3.57%), and stem length (3.36%) (Table 5). The variables that least contributed to genetic divergence were chlorophyll *a*, canopy width, stem diameter, plant height, flower number, internode distance, leaf length and chlorophyll *b*. According to Arunachalam (1981), the variables that contribute a low percentage of the total variability can be discarded in future studies. However, Rêgo et al. (2003) highlighted the importance of choosing the proper method to avoid discarding important variables.

Table 5. Relative contribution of quantitative characteristics of major importance to the genetic divergence of *Portulaca umbraticola* by the method proposed by Singh (1981) based on the generalized distance of Mahalanobis.

Variables	S.j'*	Contribution (%)
Days to flowering	6,667.51	70.37
Flower length	578.60	6.10
Leaf width	368.33	3.89
Branches number	337.95	3.57
Stem length	318.35	3.36
Chlorophyll a	258.98	2.73
Canopy width	216.43	2.28
Stem diameter	196.80	2.08
Plant height	165.57	1.75
Flower number	156.99	1.66
Internode distance	87.21	0.92
Leaf length	72.82	0.77
Chlorophyll b	49.08	0.52
Total	9,474.62	-

*Contribution to the genetic divergence of each variable (S.j').

Concerning the variable corolla type, 55% of the accessions presented pentamerous flowers and 45% presented multiple petals (Figure 3A). Of the accessions, 55% presented reproductive verticils and 45 did not (Figure 3B). Although accessions 8 and 17 did not present reproductive verticils, they showed minor mean values for canopy width and major mean values for chlorophyll content and belonged to different clusters; they can be selected if the strategy used in the breeding program is induced mutations or protoplast fusion. These strategies can create new variability and increase the attributes of ornamental use of this species.

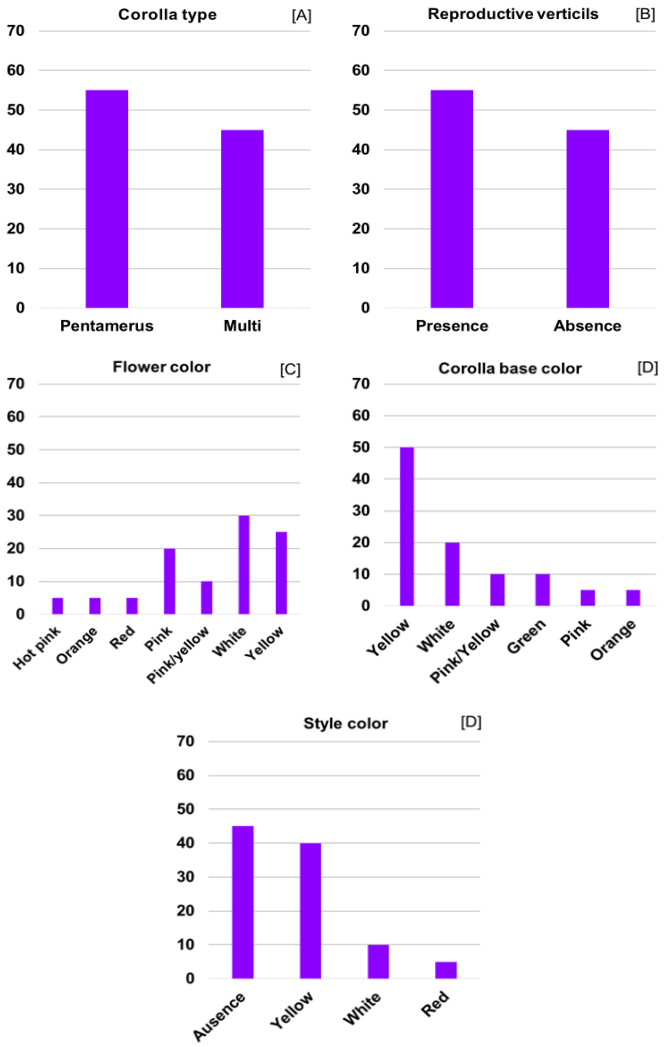

Figure 3. Corolla type (A), reproductive verticils (B), flower color (C), corolla base color (D), and style color (E) of *Portulaca umbraticola*.

Regarding flower colors, 30% were white, 25% yellow, 20% pink, 10% pink/yellow, 5% red, 5% hot pink and 5% orange (Figures 3C and 5). Each of these flowers had differences in their corolla base color, being 50% yellow, 20% white, 10% pink/yellow, 10% green, 5% pink and 5% orange (Figures 3D and 5). These accessions also have different style colors, presenting 40% yellow, 10% white, and 5% red; the others 45% did not present style (Figures 3E and 5). Datta (2021) emphasized flower color as a desired commercial characteristic of ornamental plants.

For stem color, 65% of the accessions were pinkish (Figure 5S), 30% green and 5% pink (Figure 4A). The accessions presented 55% green leaves and 45% green-pink leaves (Figure 4B). However, leaf shape had 55% accessions with cuneiform leaves, 35% with spathulate leaves, and 10% linear leaves (Figure 4C). Leaf tips also presented divergences, being classified 65% as obtuse and 35% as rounded (Figure 4D). According to Souza, Pedrosa, Moreira, Rêgo, and Unêda-Trevisoli (2022), purplish glossy stems in yellow-flower individuals can act as confounders for the processing of images and modeling in analysis toward high-throughput phenotyping. However, this trait can be considered a differential descriptor in new purslane varieties.

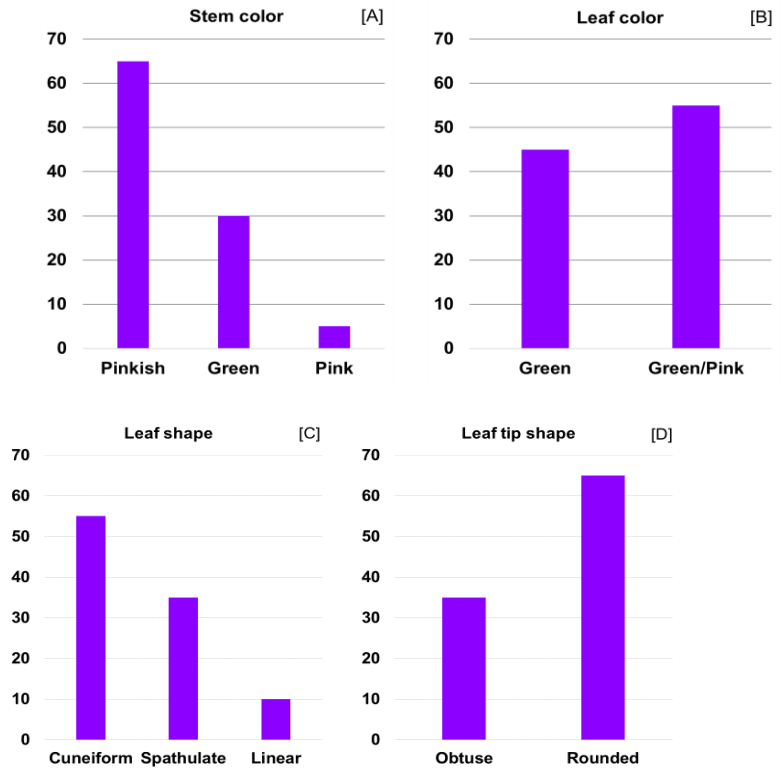

Figure 4. Stem color (A), leaf color (B), leaf shape (C), and leaf tip shape (D) of *Portulaca umbraticola*.

Figure 5. Accessions A-1, B- 2, C-3, D-4, E-5, F-6, G-7, H-8, I-9, J-10, K-11, L-12, M-13, N-14, O-15, P-16, Q-17, R-18, S-19, and T-20 of *Portulaca umbraticola.* Scale: 2.82 cm.

Conclusion

There was a high level of genetic diversity among accessions of *P. umbraticola* in this study, suggesting that morphological traits were effective in the detection of differentiation in this species. Plants belonging to different clusters should be selected as parents and used in the hybridization-breeding program to produce recombinant genotypes of *P. umbraticola*. This species has big, colored flowers, which has made this plant a unique candidate for ornamental breeding programs for both outdoor environments and potted plants. Considering the criteria for use in outdoor spaces, wider plants with several large colored flowers, thicker stems, greener leaves and earliness are interesting. Accessions 5, 7, 13, 14, 16, 18, and 20 should be selected as parents for further breeding programs. However, if the objective is to produce potted plants, dwarf plants with bigger leaves are desired, and accession 1 should be selected. This will create greater variability in segregating populations, which will increase the overall quality of ornamental use of this species. For accessions with no reproductive verticils but with other excellent attributes, for example, high chlorophyll content breeding strategies, such as induced mutations or protoplast fusion, can be used.

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