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ORIGINAL ARTICLE

Parental selection in *Portulaca umbraticola* Kunth for ornamental purposes[1]

Seleção parental de *Portulaca umbraticola* Kunth para fins ornamentais

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HIGHLIGHTS:

The purslane accessions show differences in morphological characteristics that contribute to genetic divergence.
Purslane accessions Ac2, Ac4, Ac6, Ac16, Ac18, and Ac19 are ideal for use as ornamental plants.
The traits crown diameter, plant height and number of flowers per plant contribute to genetic divergence in purslane.

ABSTRACT: Purslane (*Portulaca umbraticola* Kunth) is used as a food, medicinal, and ornamental plant. Its ornamental use is associated with the wide genetic variability in phenotypic traits, which is fundamental in breeding programs. The objective of this study was to select parents of *P. umbraticola* Kunth, based on genetic divergence of ornamental purposes. Twenty-two accessions were collected in the states of Ceará, Rio Grande do Norte, and Paraíba, Brazil. The experiment was conducted in a completely randomized design, with twenty-two treatments and three replicates. Plants were evaluated 40 days after planting, at full bloom. The evaluated traits were: plant height, stem diameter, crown diameter, leaf length, leaf width, flower diameter, petal length, number of flowers per plant, chlorophyll a, and chlorophyll b, and flower color. Data were subjected to analysis of variance and Scott-Knott test ($p \leq 0.05$). Heritability and the ratio between coefficient of genetic variation and coefficient of environmental variation were estimated. The genotypes were grouped by Tocher's method, and the importance of traits by Singh's method. The accessions were grouped into seven clusters, demonstrating genetic variability, with greater importance of the traits crown diameter, plant height, and number of flowers per plant. Eight phenotypic classes were found for flower color, demonstrating the potential of these accessions for use in breeding programs. Based on intergroup distance and considering the key traits for ornamental purposes, the accessions Ac2, Ac4, Ac6, Ac16, Ac18, and Ac19 should be selected as parents. The use of selection index should improve the choice of the parents.

Key words: purslane, germplasm, genetic improvement, ornamental potential, variability

RESUMO: *Portulaca umbraticola* (Purslane) é utilizada como alimento, planta medicinal e planta ornamental. Seu uso ornamental está associado à variabilidade em caracteres fenotípicos que é fundamental em programas de melhoramento. O objetivo deste estudo foi selecionar genitores de *P. umbraticola* Kunth baseado na divergência. Vinte e dois acessos foram coletados nos estados do Ceará, Rio Grande do Norte e Paraíba, Brasil. O experimento foi conduzido em delineamento inteiramente casualizado, com vinte e dois tratamentos e três repetições. As plantas foram avaliadas 40 dias após o plantio, em plena floração. Os caracteres avaliados foram altura da planta, diâmetro do caule, diâmetro da copa, comprimento da folha, largura da folha, diâmetro da flor, comprimento da pétala, número de flores por planta, clorofila a e clorofila b e cor da flor. Os dados foram submetidos à análise de variância e teste de Scott-Knott ($p \leq 0,05$). Foram estimadas a hereditariedade e a razão entre o coeficiente de variação genética e o coeficiente de variação ambiental. Os genótipos foram agrupados pelo método de Tocher e a importância dos caracteres pelo método de Singh. Os acessos formaram sete grupos e diâmetro da coroa, altura da planta e número de flores por planta foram as características com maior peso para a diversidade. Houve oito classes para coloração das flores, demonstrando seu uso potencial em programas de melhoramento. Com base na distância intergrupos e nas caraterísticas-chave para fins ornamentais, os acessos Ac2, Ac4, Ac6, Ac16, Ac18 e Ac19 serão selecionados como parentais. A utilização do índice de seleção melhorará a escolha dos parentais.

Palavras-chave: beldroega, germoplasma, melhoramento genético, potencial ornamental, variabilidade

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Introduction

Floriculture is one of the newest, most dynamic, and promising segments of Brazilian agribusiness, and is a prominent activity in the economy (Reis et al., 2020). This market (flowers and ornamental plants) generated a total of R$17.8 billion in 2023 in Brazil (IBRAFLOR, 2024). This sector has been growing over the last decade, despite being an extremely dynamic chain and constantly demanding innovation, quality, and price (Oliveira et al., 2021). Among the innovations in species for cultivation, purslane is a promising alternative since it shows a myriad of flower colors.

Portulaca umbraticola Kunth. belongs to the Portulacaceae family, to the *Portulaca* genus, and is a succulent, herbaceous, annual, erect species up to 30 cm in height (Srivastava et al., 2023). Popularly known as purslane, it has large, five-petal flowers, variably red, orange, pink, white, and yellow, and is a fast-growing species widely cultivated in several regions for ornamental purposes (González et al., 2024). In addition to ornamental use, it can contribute to the human diet, since it is rich in nutritional compounds (Egua-Gilabert et al., 2014), used in food, being considered a non-conventional food plant (Melo et al., 2023), and in medicinal applications (Zhou et al., 2015).

Purslane has a wide genetic diversity for phenotypic traits among the genotypes present in the germplasm banks, making it possible to identify individuals with superior characteristics (Souza et al., 2024). Knowledge of genetic diversity can effectively assist breeding programs, predicting crosses between genotypes, allowing the production of plants with characteristics of interest (Jia et al., 2017).

Germplasm characterization activities are indispensable in the pre-breeding of any crop. Studying diversity within *Portulaca* species is necessary both for the establishment of breeding programs and for the conservation of germplasm (Talei et al., 2020; Souza et al., 2024). This is possible by identifying variability between plants through morphological characterization, quantifying the genetic similarity between accessions through descriptors and multivariate techniques (Martins et al., 2020).

The genetic diversity studies described for this genus were carried out with the species *P. oleracea* (Alam et al., 2015; Danin et al., 2016) and *P. grandiflora* (Jia et al., 2017). According to Alam et al. (2015), genetic diversity studies are scarce, even for *P. oleracea*. Recently, Souza et al. (2024) conducted a study with 20 accessions of *P. umbraticola* collected in the State of Paraíba and demonstrated that there is genetic variability for this species, both for flower color and for other traits such as chlorophyll content, crown width, number of branches, stature, and earliness.

When choosing *Portulaca* parents for further breeding, aspects related to the flower should be considered, such as the number of flowers per plant, flower size and flower color, as well as characteristics related to plant size, since they are preferably planted in pots (González et al., 2024). Genotype selection is a crucial step in plant breeding programs, as it aims to identify superior genotypes that combine high performance in several traits of interest and is essential to obtain variability in the segregating generations and start a genetic improvement program for the species.

The objective of this study was to evaluate the genetic divergence between *Portulaca umbraticola* accessions and to select contrasting accessions for use as parents in a breeding program of ornamental purposes.

Material and Methods

The experiment was carried out in a greenhouse belonging to the Center for Agrarian Sciences of the Universidade Federal Rural do Semi-Árido (UFERSA), Rio Grande do Norte, Brazil. The climate is classified as BSh, considered dry and very hot, with a dry season and summer rainfall (Alvares et al., 2013). The average temperature in the region is approximately 28 °C, and the annual rainfall is around 695 mm.

The study was conducted with a total of 22 accessions of *P. umbraticola*, from collections carried out in the states of Ceará, Rio Grande do Norte, and Paraíba, divergent for qualitative traits (Table 1; Figure 1), kept in the field in the didactic vegetable garden belonging to the Center for Agrarian Sciences, UFERSA.

The experimental design was completely randomized with 22 treatments (accessions) and three replicates. The genotypes were planted using two cuttings (asexual propagation) of approximately 15 cm collected from the middle part of the parent plant previously established, derived from a single matrix per accession. The cuttings were placed directly into 1 L plastic pots with commercial substrate (Terra Nutri®). The plants were irrigated daily for 40 days, the final period of evaluation of the accessions. There was no need to carry out pest and disease control.

The evaluated characteristics were Plant height [(PH - cm) determined from the base of the stem to the apex of the plant]; Stem diameter [(SD - mm) obtained at the base of the plant, close to the ground]; Crown diameter [(CD - cm) distance between extreme points at the largest part of the plant]; Leaf length [(LL - cm) average length of three leaves]; Leaf width [(LW - cm) average value of the width of three leaves]; Flower diameter [(FD - cm) obtained from the average value of three flowers]; Petal length [(PL - cm) average value of three petals]; Number of flowers per plant [(NFP) obtained by counting the number of flowers per plant]; Chlorophyll a [(Chla) obtained from the average value of three leaves collected randomly from the plant] and Chlorophyll b [(Chlb) obtained from the average value of three leaves collected randomly from the plant]. Data measurements were made with a digital caliper (Leetools®) and a graduated ruler. Chlorophyll content was measured with a digital chlorophyll meter (ClorofiLOG -Falker®).

The experimental design was completely randomized with 22 treatments (accessions) and three replicates. Analysis of variance was performed with subsequent clustering of the means by the Scott-Knott test ($p \leq 0.05$). Heritability (Eq. 1) and the ratio between coefficient of genetic variation (CV_g) (Eq. 2) and coefficient of environmental variation (CV_e) (Eq. 3) were estimated according to Cruz et al. (2012):

Table 1. Identification in the collection, origin, and qualitative traits of *Portulaca umbraticola* Kunth. aiming at parental selection for ornamental purposes

Identification	Origin	Flower color	Anthocyanin in stem	Anthocyanin in leaf
AC01	Mossoró-RN	Yellow	Present	Present
AC02	Mossoró-RN	Pink	Present	Present
AC03	Mossoró-RN	Yellow	Present	Present
AC04	Mossoró-RN	White	Absent	Absent
AC05	Mossoró-RN	Light pink	Present	Present
AC06	Mossoró-RN	Yellow	Present	Present
AC07	Mossoró-RN	Red	Present	Present
AC08	Mossoró-RN	Yellow	Present	Present
AC09	Mossoró-RN	Light pink	Present	Absent
AC10	Mossoró-RN	Pink	Present	Present
AC11	Mossoró-RN	Orange	Present	Present
AC12	Mossoró-RN	White	Absent	Absent
AC13	Mossoró-RN	Lilac	Absent	Absent
AC14	Fortaleza-CE	Orange	Present	Present
AC15	Fortaleza-CE	Pink	Absent	Absent
AC16	Redenção-CE	Light pink	Present	Present
AC17	Redenção-CE	Yellow	Present	Present
AC18	Areia-PB	Light yellow	Absent	Absent
AC19	Areia-PB	Yellow	Present	Present
AC20	Areia-PB	Orange	Present	Present
AC21	Areia-PB	Pink	Present	Absent
AC22	Areia-PB	White	Absent	Absent

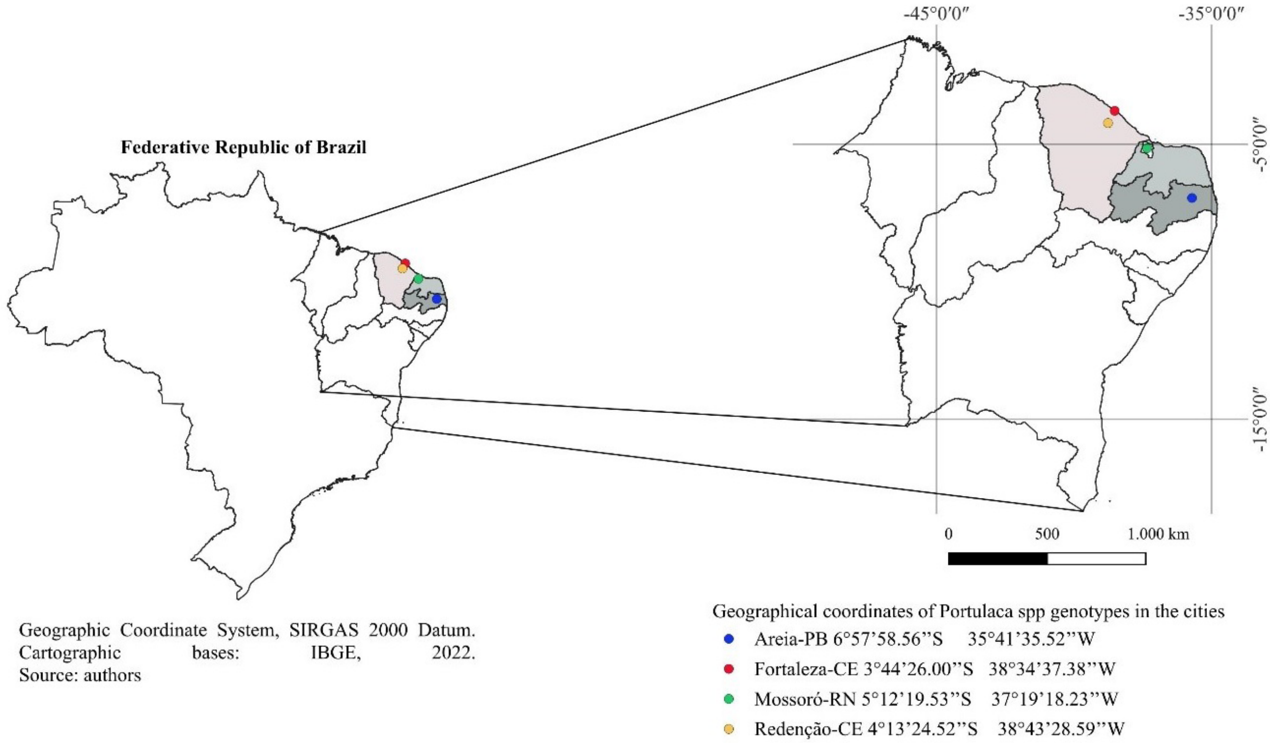

Figure 1. Origin of accessions of *Portulaca umbraticola* Kunth

$$h^2 = \frac{\sigma_g^2}{\sigma^2} \qquad (1)$$

where:

h^2 - heritability;
σ_g^2 - genotypic variance; and,
σ^2 - the environmental variance.

$$CV_g = \left(\frac{\sqrt{\sigma_g^2}}{m}\right) \times 100 \qquad (2)$$

where:

CV_g - coefficient of genetic variation;
σ_g^2 - genotypic variance; and,
m - mean of the trait.

$$CV_e = \left(\frac{\sqrt{\sigma^2}}{m}\right) \times 100 \qquad (3)$$

where:

CV_e - coefficient of environmental variation;
σ^2 - environmental variance; and,
m - mean of the trait.

The genetic divergence among cultivars was calculated using Mahalanobis' generalized distance. The clustering of genotypes was made by Tocher's method (Rao, 1952). The relative importance of the variables was determined using the method described by Singh (1981). All analyses were performed using GENES software (Cruz, 2016). The qualitative variable analyzed (flower color) was systematized using percentages, based on the total number of accessions evaluated.

Results and Discussion

There was a significant difference ($p \leq 0.01$) between the treatments for all the traits evaluated (Table 2), demonstrating that the accessions of *P. umbraticola* Kunth. are phenotypically distinct. Talei et al. (2020) studied 18 populations of common purslane (*P. oleracea* L.) and reported differences between the traits plant height, stem diameter, and fresh matter, which can be used for breeding programs in the selection of superior genotypes. Divergent accessions make it possible to select contrasting parents to be used in crossbreeding.

High heritability values, above 70%, were observed for plant height (70.55%), stem diameter (78.49%), flower diameter (82.98%), petal length (83.99%), number of flowers per plant (77.83%), and chlorophyll a (74.92%), as shown in Table 2. These same traits showed coefficient of genetic variation to coefficient of environmental variation ratios equal to or greater than 1 except PH and LL, confirming that selection based on these traits will lead to genetic gains. Souza et al. (2024) reported high heritability value for flower length when studying 20 accessions of *P. umbraticola*, indicating that the differences between individuals for flower measurements are due to genetic factors.

The means clustering test for the studied traits separated the accessions into distinct classes (Table 3).

Table 2. Summary of the analysis of variance: heritability (h^2%), ratio between coefficient of genetic variation and coefficient of environmental variation (CV_g/CV_e), and coefficient of variation (CV%) for ten phenotypic traits in accessions of *Portulaca umbraticola* Kunth. aiming at parental selection for ornamental purposes

S.V.	D.F.	Traits/Mean squares				
		PH	SD	CD	LL	LW
Treatments	21	54.10**	0.02**	133.24**	0.41**	0.12**
Residual	44	15.92	0.05	44.80	0.15	0.05
Total	65	-	-	-	-	
h² (%)	-	70.55	78.49	66.37	63.74	58.46
CVg/CVe	-	0.89	1.10	0.81	0.76	0.68
CV	-	12.94	14.01	26.41	14.39	18.08
		FD	PL	NFP	Chl a	Chl b
Treatments	21	0.32**	0.13**	22.69**	15.42**	1.61**
Residual	44	0.05	0.02	5.03	3.86	0.51
Total	65	-	-	-	-	-
h²	-	82.93	83.99	77.83	74.92	68.41
CVg/CVe	-	1.27	1.32	1.08	0.99	0.84
CV	-	8.82	10.36	41.46	17.48	24.62

** - Significant at 0.01 probability of error by the F test. SV - Source of variation; DF - Degree of freedom; CV - Coefficient of variation; PH - Plant height; SD - Stem diameter; CD - Crown diameter; LL - Leaf length; LW - Leaf width; FD - Flower diameter; PL - Petal length; NFP - Number of flowers per plant; Chl a - Chlorophyll a; Chl b - Chlorophyll b

Table 3. Clustering of means using the Scott-Knott test for 22 accessions of *Portulaca umbraticola* Kunth. aiming at parental selection for ornamental purposes

Accessions	PH	SD	CD	LL	LW	FD	PL	NFP	Chla	Chlb
1	31.16 a	0.46 b	22.58 b	2.41 c	1.35 a	2.24 c	1.27 b	7.00 b	8.70 c	2.14 c
2	34.66 a	0.47 b	17.41 b	2.43 c	0.98 a	2.63 b	1.58 a	2.33 c	9.72 c	2.44 c
3	33.83 a	0.41 b	17.50 b	2.40 c	1.06 a	2.64 b	1.59 a	2.33 c	12.23 b	3.09 b
4	28.00 b	0.35 b	23.08 b	2.36 c	0.74 b	2.30 c	1.66 a	5.33 c	12.16 b	3.33 b
5	21.00 b	0.46 b	19.50 b	2.31 c	1.22 a	2.70 a	1.66 a	2.33 c	9.73 c	2.64 c
6	34.83 a	0.57 a	29.16 a	2.97 b	1.67 a	2.97 a	1.77 a	4.66 c	9.12 c	2.18 c
7	30.16 b	0.48 b	18.75 b	2.52 c	1.22 a	2.60 b	1.55 a	1.66 c	11.05 c	2.66 c
8	36.00 a	0.55 a	21.83 b	2.23 c	1.09 a	2.54 b	1.37 b	4.33 c	8.03 c	1.83 c
9	34.16 a	0.56 a	18.75 b	3.01 b	1.58 a	1.91 c	1.62 a	4.33 c	12.21 b	3.12 b
10	27.66 b	0.44 b	27.00 b	2.57 c	1.34 a	2.47 b	1.00 c	5.33 c	9.86 c	2.49 c
11	34.50 a	0.37 b	19.16 b	2.41 c	0.98 a	2.54 b	1.06 c	5.66 c	14.12 a	4.08 a
12	32.63 a	0.59 a	24.33 b	3.04 b	1.18 a	2.39 b	1.15 c	6.00 c	8.99 c	2.18 c
13	28.00 b	0.53 a	19.25 b	2.93 b	1.18 a	2.53 b	1.34 b	4.33 c	12.11 b	3.08 b
14	32.00 a	0.62 a	24.58 b	2.54 c	1.22 a	2.91 a	1.12 c	4.00 c	10.29 c	2.50 c
15	40.33 a	0.62 a	21.50 b	2.51 c	1.40 a	2.82 a	1.29 b	7.66 b	8.78 c	2.17 c
16	29.66 b	0.63 a	37.83 a	3.60 a	1.33 a	2.99 a	1.29 b	7.00 b	16.47 a	4.60 a
17	26.50 b	0.67 a	33.16 a	3.56 a	1.40 a	3.24 a	1.38 b	4.33 c	9.96 c	2.42 c
18	32.16 a	0.55 a	37.58 a	2.58 c	1.32 a	2.21 c	1.33 b	14.33 a	15.71 a	2.42 c
19	27.33 b	0.43 b	31.16 a	2.73 c	1.25 a	3.20 a	1.79 a	7.66 b	13.41 b	3.57 b
20	27.16 b	0.55 a	36.50 a	2.94 b	1.41 a	2.94 a	1.57 a	8.66 b	10.47 c	2.64 c
21	30.33 b	0.62 a	30.55 a	2.78 c	1.23 a	2.82 a	1.52 a	6.00 c	12.57 b	3.25 b
22	26.16 b	0.65 a	26.16 b	2.41 c	1.41 a	2.72 a	1.46 a	3.66 c	11.75 b	3.04 c

Means followed by same letters in the column do not differ statistically by the Scott-Knott test ($p \leq 0.05$). PH - Plant height; SD - Stem diameter; CD - Crown diameter; LL - Leaf length; LW - Leaf width; FD - Flower diameter; PL - Petal length; NFP - Number of flowers per plant; Chl a - Chlorophyll a and Chl *b* - Chlorophyll b

The largest number of classes was observed for the traits leaf length, flower diameter, petal length, chlorophyll a, and chlorophyll b (Table 3). Santos et al. (2023) also reported variation among morphological traits in *P. umbraticola* occurring in Brazil. According to Souza et al. (2024) there is variability among and within *Portulaca* species, and this variability can be exploited in breeding programs based on hybridization.

In the selection of *P. umbraticola* for ornamental purposes, the accessions Ac5, Ac6, Ac15, Ac16, Ac18, Ac19, and Ac20 are recommended, since they have at least two traits desired by consumers, such as large flowers, a greater number of flowers per plant, and shorter leaf length, which are ideal for landscaping according to Jia et al. (2017). According to Datta (2021), in an ornamental plant genetic breeding it is important to select cultivars with larger flowers and a higher number of flowers per plant.

The traits plant height, stem diameter, crown diameter, and leaf width grouped the accessions into two classes each (Table 3). This indicates that most genotypes for these traits are similar. For this reason, it may be important to consider other traits studied during hybridization, based on the objectives of interest. Ornamental plants are used for different purposes, for instance in the decoration of indoor environments, parks, and gardens, gaining prominence with their beautiful flowers, leaves (Karagöz et al., 2022), and plant architecture. Thus, the phenotypic variability found in the characterization of the accessions makes it possible to direct the improvement according to the objectives of interest, i.e., to develop cultivars for ornamental use in pots.

It was possible to group the 22 accessions into six clusters (Figure 2). Cluster I (Ac2, Ac7, Ac3, Ac13, Ac5, Ac8, Ac1, Ac10, Ac14, Ac22, Ac12, Ac21, Ac15 and Ac9) was formed by the majority of accessions, 63.63% of the total, with greater genetic similarity between them. Cluster II consisted of three genotypes (Ac6, Ac20 and Ac17) (13.65%) and cluster III consisted of two genotypes (Ac4 and Ac11), totaling 9.10% of the accessions evaluated. Clusters IV, V and VI were composed of only one accession each, representing 4.54% of the total, Ac19, Ac18, and Ac16, respectively. Regarding group distance, in order to select the most distant genotypes we indicate the crosses between genotypes of different groups such as AC6 × AC4 (d23=2.9), AC2 × AC16 (d16 = 2.89), AC2 × AC18 (d15=2.42), AC2 × AC19 (d14=2.38), and AC4 × AC18 (d35=2.18). In order to obtain major variability in recombinant populations it is recommended to select plants belonging to different clusters as parents and use them in the hybridization-breeding program (Souza et al., 2024).

The traits crown diameter, plant height, and number of flowers per plant were more important in discriminating the genetic divergence between accessions (Table 4). Among the advantages of using multivariate analysis techniques is the possibility of evaluating the importance of each trait studied on the total variation (Azevedo et al., 2015). The traits that contributed the least to genetic divergence were stem diameter, leaf length, leaf width, flower diameter, petal length, and chlorophyll b (Table 4). These variables can be disregarded in future studies, thus reducing the labor, time, and costs related to agricultural experimentation (Rêgo et al., 2003; Cruz et al., 2020).

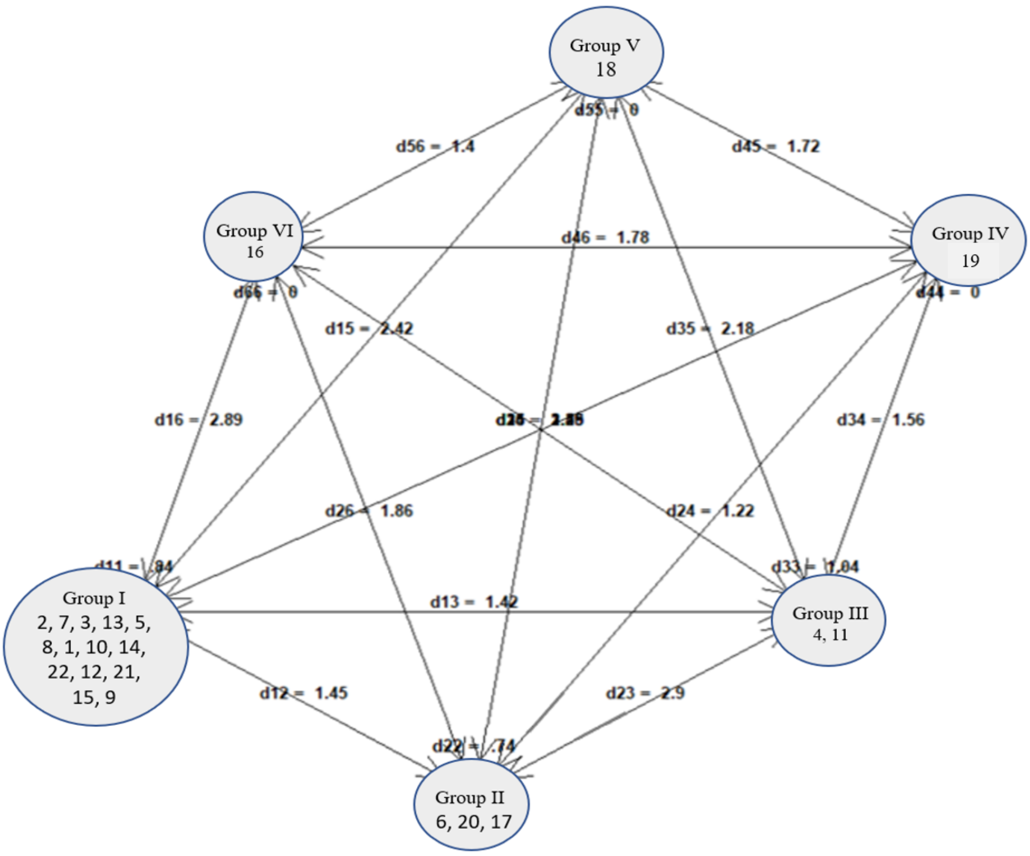

Figure 2. Clustering and interclustering distance of 22 accessions based on ten phenotypic traits in *Portulaca umbraticola* Kunth., according to Tocher's method

Table 4. Relative contribution (%) of phenotypic variables to genetic divergence in *Portulaca umbraticola* Kunth. accessions, estimated by the method proposed by Singh (1981) aiming at parental selection for ornamental purposes

Variable	Relative contribution	
	S.j.	Value in %
Plant height	8332.88	23.72
Stem diameter	3.95	0.11
Crown diameter	20519.08	58.41
Leaf length	64.12	0.18
Leaf width	19.11	0.05
Flower diameter	49.50	0.14
Petal length	21.26	0.06
Number of flowers per plant	3495.22	9.94
Chlorophyll a	2375.01	6.76
Chlorophyll b	248.68	0.70

S.j. - Estimates of the relative contribution of each variable

P. umbraticola flowers draw the attention of consumers due to their attractive color and the number of flowers per plant (Araújo et al., 2022). This study was conducted using accessions with flower color variation, with 27.28% of the accessions having yellow flowers, 18.20% pink, 13.63% light pink, 13.63% orange, 13.63% white, 4.54% light yellow, 4.54% red, and 4.54% lilac (Table 1; Figure 3). The colors in flowers are important traits for the ornamental market (Carrodeguas-González et al., 2022). According to these authors the colors preferred by consumers are warm colors such as yellow, orange, and red, followed by cool colors such as purple and blue, and, finally, neutral and pastel colors. The commercial cultivars of *Portulaca* usually have one flower color. González et al. (2024) observed hybrids with two colors in the same flower, giving it an added value, which highlights the importance of hybridization in *Portulaca*.

Figure 3. Flower color in accessions of *Portulaca umbraticola* Kunth. aiming at parental selection for ornamental purposes

Conclusions

1. There is genetic variability among accessions of *Portulaca umbraticola* Kunth.

2. The traits crown diameter, plant height and number of flowers per plant are more important in discriminating the genetic divergence between accessions.

3. Based on intergroup distance and considering the key traits for ornamental purposes, the accessions Ac2, Ac4, Ac6, Ac16, Ac18, and Ac19 should be selected as parents. The use of selection index should improve the choice of the parents.

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