Morphological Variation of Euphorbia fulgens

Subjects: Horticulture

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Morphological variation is useful in conservation and genetic improvement programs. Euphorbia fulgens, a range-restricted local endemic species of Mexico, is used locally during the altars in the festivities of different saints and is also cultivated as an ornamental plant mainly in Europe. Thus, in the present study, morphological variation was evaluated in wild populations and cultivated populations. Characterization of 90 individuals from three wild populations (the only ones recorded to date) was done by measuring 30 morphological traits both vegetative and reproductive. Thereafter, seeds were collected, and established under greenhouse conditions, and 39 morphometric variables were evaluated in adult plants. An analysis of variance (ANOVA) was done for wild and cultivated groups independently, and when significant differences were found, Tukey's comparison of means was applied ($p < 0.05$). To identify the traits responsible for the differences between wild and cultivated groups, a linear discriminant analysis (LDA) was conducted. Morphological variation was found among wild populations, and this variation decreased in cultivated populations, mainly in reproductive structures. The LDA separated the wild populations from the cultivated groups, according to inflorescence length, petiole length/blade length ratio, and leaf roundness. The variables that determined the separation of individuals between wild and cultivated populations were cyme number, foliar Feret diameter, and inflorescence length, variables that can be important for breeding strategies and artificial selection.

Keywords: cut flower ; Euphorbia ; inflorescence ; Mexican endemic ; morphometry ; ornamental

1. Introduction

Morphological variation refers to the morphometric differences observed as a result of genetic aspects and environmental factors [1][2]. Such variation has been studied in different species that have been subjected to diverse handling methods in situ and ex situ, such as agriculture, harvest, tolerance, induction, and protection [3][4][5][6].

Several authors have proposed that the domestication process of a genetic resource generates phenotypic variation, due to selection of traits that are desirable for humans, and therefore, morphological differences are evaluated between cultivated, semicultivated, and wild-growing plants [7][8][9][10].

Most of the studies in this topic, have been performed in edible plants, while a few have focused on plants used for other purposes. To date, studies in which morphological variation has been evaluated between cultivated ornamental plants and their wild relatives are scarce worldwide [11][12]. Most research has focused on characterizing different genotypes of cultivated plants or with some level of handling [13][14][15][16].

On the other hand, some researchers have studied how diverse environmental factors, such as altitude, precipitation, physicochemical characteristics of soil, light intensity, hillside orientation, among others, contribute to phenotypic variation in different species as a result of the adaptation process in distinct habitats [17][18][19][20]. Most studies have assessed wild species of broad distribution, although some have been done on microendemic species as well because due to their restricted distribution, the morphometric variation associated with edaphoclimatic characteristics can be inferred under different environmental scenarios [21][22][23][24].

Euphobia fulgens Karw. ex Klotzsch is a native species of Mexico, with restricted distribution and local endemic of Sierra Sur in Oaxaca state. To date, only three wild populations have been reported, located in ravines with steep slopes and of difficult access, in acidic (pH ≈ 5) loam soils. In the towns close to the places where the wild populations are found the inhabitants use the flower stems as ornaments in the altars during different saints festivities. In other countries, the common name "scarlet plume" is used to refer to several cultivated varieties of *E. fulgens*, which are produced and commercialized mainly as a cut flower and pot plant in Europe [25][26], whereas in Mexico it is not commercialized.

Due to its ornamental relevance in other countries, *E. fulgens* is a phytogenetic resource that can be exploited sustainably in Mexico, since it has esthetic values (mainly the inflorescences) and it adapts easily to cultivation conditions.

On one hand, variation assessment of wild-growing populations of *E. fulgens* is convenient, due to its local endemism, which could be the start of establishing successful conservation programs. On the other hand, the *E. fulgens* varieties are commercialized are produced abroad. Therefore, the evaluation of variation in populations of *E. fulgens* under controlled conditions could lead to the establishment of genetic improvement programs to produce tolerant varieties for the climatic conditions of Mexico, which would reduce costs, and consequently, would allow local ornamental flower producers to commercialize the plant [27]. Hence, the objective of this study was to quantify the morphological variation of *E. fulgens* in wild and cultivated populations, under the assumption that, due to their restricted distribution, the morphometric variation of wild plants will be lower in plants under cultivation conditions compared to wild-growing ones.

2. Discussions on Morphological Variation of Euphorbia fulgens

2.1. Morphological Variation in Wild Populations

Differences between wild-growing populations were observed in most vegetative and reproductive structures, even though *E. fulgens* has a restricted distribution with only three populations reported so far. Populations 1 and 2 were the most contrasting in leaf shape and size, as well as in inflorescence size and colour. Among the three populations, populations 1 and 2 were the most distant (80 km apart) and belonged to similar vegetation types but in different altitudes and on areas with different edaphoclimatic characteristics (**Table 1**). Moreover, populations 2 and 3 contrasted mostly in reproductive structures, but shared edaphoclimatic characteristics and were located at a similar altitude. However, the three populations did not show outstanding differences. This suggests that phenotypic variation is probably determined by edaphoclimatic factors.

Table 1. Morphometric variables of three wild populations of *Euphorbia fulgens* from Oaxaca, Mexico.

Variable	*p*-Value	Population 1	Population 2	Population 3
Plant height	**0.0696**	**145.53 [a]**	**158.63 [a]**	**180.63 [a]**
Basal diameter	**0.0240**	**0.78 [ab]**	**0.64 [b]**	**1.02 [a]**
Petiole length	**0.0007**	**3.46 [a]**	**2.94 [b]**	**2.95 [b]**
Blade length	**0.0001**	**7.99 [c]**	**9.03 [b]**	**9.73 [a]**
Blade width	**0.0204**	**2.75 [a]**	**2.36 [b]**	**2.45 [ab]**
Blade width/Blade length	**0.0001**	**0.35 [a]**	**0.26 [b]**	**0.25 [b]**
Petiole length/Blade length	**0.0001**	**0.43 [a]**	**0.33 [b]**	**0.30 [b]**
Leaf area	**0.8267**	**14.43 [a]**	**13.77 [a]**	**14.08 [a]**
Leaf perimeter	**0.4161**	**27.88 [a]**	**27.46 [a]**	**28.73 [a]**
Leaf Feret diameter	**0.0504**	**11.12 [b]**	**11.58 [ab]**	**12.01 [a]**
Leaf roundness	**<0.0001**	**0.34 [a]**	**0.26 [b]**	**0.25 [b]**
Number of branches with inflorescences	**0.0037**	**4.20 [a]**	**1.80 [b]**	**4.07 [a]**
Inflorescence length	**0.0080**	**12.07 [b]**	**22.92 [a]**	**18.72 [ab]**
Number of cyathia per axillary cyme	**0.1527**	**3.03 [a]**	**3.37 [a]**	**3.07 [a]**
Longest cyme length	**0.0068**	**2.72 [ab]**	**2.87 [a]**	**2.41 [b]**
Number of axillary cymes	**0.9085**	**14.27 [a]**	**13.40 [a]**	**13.73 [a]**
Number of hermaphrodite cyathia	**0.0001**	**1.53 [b]**	**9.30 [a]**	**0.73 [b]**
Number of male cyathia	**0.0011**	**14.33 [a]**	**7.13 [b]**	**8.17 [b]**
Number of female cyathia	**0.5249**	**1.03 [a]**	**0.60 [a]**	**0.67 [a]**
Peduncle length	**0.0001**	**1.53 [a]**	**1.05 [b]**	**1.51 [a]**
Involucre length	**0.0007**	**0.31 [b]**	**0.30 [b]**	**0.33 [a]**
Petal appendage length	**0.6668**	**0.54 [a]**	**0.54 [a]**	**0.53 [a]**

Variable	*p*-Value	Population 1	Population 2	Population 3
Petal appendage width	**0.0044**	**0.50 [a]**	**0.50 [a]**	**0.44 [b]**
Pedicel length	**0.0033**	**0.98 [a]**	**0.85 [b]**	**1.02 [a]**
Ovary length	**0.0136**	**0.32 [a]**	**0.29 [b]**	**0.31 [ab]**
Style length	**0.0117**	**0.15 [a]**	**0.12 [ab]**	**0.11 [b]**
Stamen length	**<0.0001**	**0.46 [c]**	**0.67 [a]**	**0.53 [b]**
Petal appendages colour	**<0.0001**	**1.57 [b]**	**3.20 [a]**	**1.30 [b]**
Leaf blade colour in the superior third of inflorescence	**0.3721**	**1.00 [a]**	**1.00 [a]**	**1.03 [a]**
Intensity of leaf blade colour in the superior third of inflorescence	**0.3721**	**1.00 [a]**	**1.00 [a]**	**1.13 [a]**

Different letters in the same row indicate statistically significant difference by Tukey's test ($p < 0.05$).

The obtained results agree with those found by other authors. It has been reported that altitude influenced the leaf morphology of *Yucca capensis*, an endemic species of Baja California Sur, Mexico [22], as well as in cone and needle morphology of pines [21]. Likewise, the altitude had an effect on leaf and fruit morphology of shea tree [28]. Furthermore, in a study of soil physicochemical properties, differences were observed in height and leaf size of Iroko trees [18].

Other factors that were not analyzed in this study but have been observed to have an impact on morphometric variation of vegetative and reproductive structures, were ground slope, soil depth, stony soil, temperature, wind speed, rain, and relative humidity [29][30]. In contrast, in other studies conducted in members of the genus *Opuntia*, it was determined that phenotypic differences in cladodes between populations were more related to population density than environmental factors [31]. Therefore, in future studies, it is suggested to increase the number of variables to determine their effects and, consequently, obtain more information for the design of propagation or agronomic management experiments.

The information gathered in this study about the morphological variation between wild-growing populations of *E. fulgens* will contribute to the establishment of in situ conservation programs of a germplasm that is not found in any other part of the world. Endemic species are susceptible to climate change because their restricted distribution is associated with specific environmental conditions. Hence, more studies should be conducted to decipher the adaptations of the local endemic plants in different predicted environmental scenarios in order to establish concrete management plans, as in other endemic species [23][24].

2.2. Morphological Variation in Cultivated Populations

The cultivated populations of *E. fulgens* in greenhouse showed a morphometric variation in vegetative structures, similar to the wild-growing groups, which suggests that these characteristics are highly stable in this species. In most studies of ornamental plants, phenotypic differences in structures with aesthetic or commercial value are evaluated; for instance, stem length, firmness, and flower number, size, colour, and odor in Peruvian lily [15]; branch number and length, flowering duration, height, disc and ligulate flowers, and central head diameter in sunflower [14]; and growth habit, ramification, foliar blade, and fruit shape, size, and colour in ornamental gourds to obtain ideal genotypes for cut flower, bouquets, arrangements, or pots [16]. Cultivation of *E. fulgens* in greenhouse demonstrated that it adapts and develops well under controlled conditions. Thus, a genetic improvement program could be initiated focused on using this plant in a sustainable way since it has only been exploited in other countries. In this first cultivation cycle, individuals with desirable traits were identified; for instance, some with longer panicles, greater cyathium diameters, higher number of cymes, and attractive size and colour of petal appendages that could be used as progenitors of interesting features in breeding strategies. Thus, it is suggested to evaluate the effect of agronomic management variables for the probable cultivation of *E. fulgens* in the greenhouse.

2.3. Morphological Variation between Wild-Growing and Cultivated Populations

The differences between individuals of wild-growing and cultivated populations of *E. fulgens* were determined by number of cymes, petal appendage width, inflorescence length, petiole length, leaf perimeter, and leaf Feret diameter. Cultivated plants presented larger inflorescences and higher number of cymes, which could be the result of applying fertilizer. In contrast, the variables that determined the differences between wild-growing and cultivated individuals of Peruvian lily were flower colour and stem length [11].

In this study, we observed that, from a first cultivation cycle without an artificial selection process, there were morphological differences between wild-growing and cultivated plants of *E. fulgens*. Several authors consider that the morphometric differences and group separation of wild-growing and cultivated individuals is due to the domestication process, which was the case in *Chrysophyllum cainito* L. (star apple), where the differences in fruit and seed characteristics were caused mainly by the artificial selection process of fruits [32]. This was also observed in *Crescentia cujete* L., where due to its use as bowls, a strong selection of larger fruits, rounder forms, and shorter and wider peduncles has been done [9][33]. Differences have also been found between wild-growing and cultivated poinsettia in leaf size, internode distance, stem length and diameter; however, the leaf area/stem volume ratio has remained constant, despite the domestication process [12]. Evaluation of variation in wild-growing populations of a species that is intended to be introduced in cultivation in Mexico, will allow to perform a follow-up of how morphology is modified with handling and selecting desirable traits.

References

1. Schmid, B. Phenotypic variation in plants. Evol. Trends Plants 1992, 6, 45–60.
2. Willmore, K.E.; Young, N.M.; Richtsmeier, J.T. Phenotypic variability: Its components, measurement and underlying dev elopmental processes. Evol. Biol. 2007, 34, 99–120.
3. Casas, A.; Caballero, J.; Mapes, C.; Zárate, S. Manejo de la vegetación, domesticación de plantas y origen de la agricu ltura en Mesoamérica. Bol. Soc. Bot. Méx. 1997, 61, 31–47.
4. Casas, A.; Pickersgill, B.; Caballero, J.; Valiente-Banuet, A. Ethnobotany and domestication in xoconochtli, Stenocereu s stellatus (Cactaceae), in the Tehuacán Valley and La Mixteca Baja, Mexico. Econ. Bot. 1997, 51, 279–292.
5. Blancas-Vásquez, J.; Casas, A.; Pérez-Salicrup, D.; Caballero, J. Ecological and socio-cultural factors influencing plant management in nahuatl communities of the Tehuacán Valley, Mexico. J. Ethnobiol. Ethnomed. 2013, 9, 39.
6. Cruise-Sanders, J.M.; Casas, A. Impactos evolutivos de las actividades humanas sobre las plantas: Manejo, domestica ción y conservación in situ y ex situ. In Domesticación en el Continente Americano Investigación Para el Manejo Suste ntable de Recursos Genéticos en el Nuevo Mundo; Casas, A., Torres-Guevara, J., Parra-Rondinel, F., Eds.; Editorial M orevalladolid: Morelia, Mexico, 2017; Volume 2, pp. 452–473.
7. Casas, A.; Otero-Arnaiz, A.; Pérez-Negrón, E.; Valiente-Banuet, A. In situ management and domestication of plants in Mesoamerica. Ann. Bot. 2007, 100, 1101–1115.
8. De Freitas Lins Neto, E.M.; de Olivieira, I.F.; Britto, F.B.; de Albuquerque, J.P. Traditional knowledge, genetic and morp hological diversity in populations of Spondias tuberosa Arruda (Analcardiaceae). Gen. Res. Crop. Evol. 2013, 60, 1389 –1406.
9. Aguirre-Dugua, X.; Pérez-Negrón, E.; Casas, A. Phenotypic differentiation between wild and domesticated varieties of Crescentia cujete L. and culturally relevant uses of their fruits as bowls in the Yucatan Peninsula, Mexico. J. Ethnobiol. Ethnomed. 2013, 9, 76.
10. Betancourt-Olvera, M.; Nieto-Ángel, R.; Urbano, B.; González-Andrés, F. Analysis of the biodiversity of hawthorn (Crata egus spp.) from the morphological, molecular, and ethnobotanical approaches, and implications for genetic resource co nservation in scenery of increasing cultivation: The case of Mexico. Gen. Res. Crop. Evol. 2018, 65, 897–916.
11. Aros, D.; Meneses, C.; Infante, R. Genetic diversity of wild species and cultivated varieties of alstroemeria estimated th rough morphological descriptors and RAPD marker. Sci. Hortic. 2006, 108, 86–90.
12. Trejo, L.; Rosell, J.A.; Olson, M.E. Nearly 200 years of sustained selection have not overcome the leaf area-stem size r elationship in the poinsettia. Evol. Appl. 2018, 11, 1401–1411.
13. Ferreira de Melo, C.A.; Magalhães-Souza, M.; Viana, A.P.; Azevedo-Santosm, E.; de Oliveira-Souza, V.; Corrêa, R.X. Morphological characterization and genetic parameter estimation in backcrossed progenies of Passiflora, L. for orname ntal use. Sci. Hortic. 2016, 212, 91–103.
14. Mladenović, E.; Cvejić, S.; Jocić, S.; Ĉukanović, J.; Jocković, M.; Malizdža, G. Variability of morphological characters a mong ornamental sunflower collection. Genetika 2017, 49, 573–582.
15. Aros, D.; Suazo, M.; Rivas, C.; Zapata, P.; Úbeda, C.; Bridgen, M. Molecular and mophological characterization of new interspecific hybrids of alstroemeria originated from A. caryophylleae scented lines. Euphytica 2019, 215, 93.
16. Dalda-Şekerci, A.; Karaman, K.; Yetişir, H. Characterization of ornamental pumpkin (Cucurbita pepo L. var. ovifera (L.) Alef.) genotypes: Molecular, morphological and nutritional properties. Gen. Res. Crop. Evol. 2020, 67, 533–547.

17. Bruschi, P.; Vendramin, G.G.; Bussotti, F.; Grossoni, P. Morphological and molecular diversity among Italian population s of Quercus petraea (Fagaceae). Ann. Bot. 2003, 91, 707–716.
18. Ouinsavi, C.; Sokpon, N. Morphological variation and ecological structure of Iroko (Milicia excelsa Welw. C. C. Berg) po pulations across different biogeographical Zonas in Benin. Int. J. For. Res. 2010, 2010, 658396.
19. López-Gómez, V.; Zedillo-Avelleyra, P.; Anaya-Hong, S.; González-Lozada, E.; Cano-Santana, Z. Efecto de la orientaci ón de la ladera sobre la estructura poblacional y ecomorfología de Neobuxbaumia tetetzo (Cactaceae). Bot. Sci. 2012, 90, 453–457.
20. Ouédrago, L.; Fuchs, D.; Schaefer, H.; Kiendrebeogo, M. Morphological and molecular characterization of Zanthoxylum zanthoxyloides (Rutaceae) from Burkina Faso. Plants 2019, 8, 353.
21. Gutiérrez-Vázquez, B.N.; Gómez-Cárdenas, M.; Gutiérrez-Vázquez, M.H.; Mallén-Rivera, C. Variación fenotípica de po blaciones naturales de Pinus oocarpa Schiede ex Schltdl. en Chiapas. Rev. Mex. Cien. 2013, 4, 46–60.
22. Arteaga, M.C.; Bello-Bedoy, R.; León de la Luz, J.L.; Delgadillo, J.; Domínguez, R. Phenotypic variation of flowering an d vegetative morphological traits along the distribution for the endemic species Yucca capensis (Agavaceae). Bot. Sci. 2015, 93, 765–770.
23. Matesanz, S.; Rubio-Teso, M.L.; García-Fernández, A.; Escudero, A. Habitat fragmentation differentially affects genetic variation, phenotypic plasticity and survival in populations of a Gypsum endemic. Front. Plant. Sci. 2017, 8, 843.
24. Winkler, D.E.; Yu-Chan Lin, M.; Delgadillo, J.; Chapin, K.J.; Huxman, T.E. Early life history responses and phenotypic s hifts in a rare endemic plant responding to climate change. Conserv. Physiol. 2019, 7, coz076.
25. Rünger, W.; Albert, G. Influence of temperature, soil moisture and CCC on the flowering of Euphorbia fulgens. Sci. Horti c. 1975, 3, 393–403.
26. Van Leeuwen, P.J. Post-harvest treatment of Euphorbia fulgens. Acta Hortic. 1986, 181, 467–471.
27. Canul-Ku, J.; García-Pérez, F.; Ramírez-Rojas, S.G.; Osuna-Canizalez, F.J. Estrategias para el mejoramiento genético de Nochebuena (Euphorbia pulcherrima Willd. ex Klotzsch). Investigación Agropecuaria 2010, 7, 44–54.
28. Gwali, S.; Nakabonge, G.; Lamoris-Okullo, J.G.; Eilu, G.; Nyeko, P.; Vuzi, P. Morphological variation among sea tree (Vi tellaria paradoxa subsp. nilotica) ‘ethnovarieties’ in Uganda. Gen. Res. Crop. Evol. 2012, 59, 1883–1898.
29. Araiza-Lizarde, N.; Alcaraz-Meléndez, L.; Angulo-Escalante, M.A.; Reynoso-Granados, T.; Cruz-Hernández, P.; Ortega-Nieblas, M.; Valdez-Zamudio, D. Caracterización y distribución de germoplasma silvestre de Jatropha curcas L. (Eupho rbiaceae) en el Noroeste de México. Polibotánica 2016, 42, 137–152.
30. Beltrán-Rodríguez, L.; Romero-Manzanares, A.; Luna-Cavazos, M.; García-Moya, E. Variación arquitectónica y morfoló gica de Hintonia latiflora (Rubiaceae) en relación a la cosecha de corteza y factores ambientales. Rev. Biol. Trop. 201 7, 65, 900–916.
31. Muñoz-Arias, A.; Palomino-Hasbach, G.; Terrazas, T.; García-Velasquez, A.; Pimienta-Barrios, E. Variación anatómica y morfológica en especies y entre poblaciones de Opuntia en la porción sur del desierto Chihuahuense. Bol. Soc. Bot. Mex. 2008, 83, 1–11.
32. Parker, I.M.; López, I.; Petersen, J.J.; Anaya, N.; Cubilla-Rios, L.; Potter, D. Domestication syndrome in Caimito (Chyso phyllum cainito L.): Fruit and seed characteristics. Econ. Bot. 2010, 64, 161–175.
33. Aguirre-Dugua, X.; Eguiarte, L.E.; González-Rodríguez, A.; Casas, A. Round and large: Morphological and genetic con sequences of artificial selection on the gourd tree Crescentia cujete by the Maya of the Yucatan Peninsula, Mexico. An n. Bot. 2012, 109, 1297–1306.