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A BRIEF DESCRIPTION OF CULTIVATED CHILI PEPPERS

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Abstract

Chili peppers is an important vegetable and spice crop grown all over the world for fresh, dried, and processing products. Capsicum spp. is a member of the Solanaceae family and native to the temperate, subtropical and tropical regions of the Americas. This research paper provides a comprehensive overview of the distinctive descriptors of the Capsicum genus, showcasing images sourced from the germplasm collection at the Vegetable Research Development Station (VRDS) Buzau, Romania. The paper focuses on morphological features as the key basis for differentiation among the domesticated Capsicum species: C. annuum L., C. chinense Jacq., C. frutescens L., C. baccatum L. şi C. pubescens Ruiz & Pav. Various descriptors, such as flower and fruit shapes, corolla color, corolla sport color, the presence or absence of calyx annular constriction, and seed colour, are employed to provide a nuanced understanding of the unique characteristics of each species. By elucidating these morphological features, the paper aims to empower readers to easily distinguish between different Capsicum varieties.

Key words*: biodiversity, Capsicum spp., morphological features, Solanaceae.*

INTRODUCTION

The genus *Capsicum* was one of the first genera to be domesticated, around 6000 B.C by Native Americans (Perry et al., 2007), and is now produced at over 35 million tons per year worldwide (FAO, 2021).

Fruits of the genus have good health properties such as fat breakdown and stress relief (Shiragaki et al., 2020). Besides being used fresh and in a broad variety of dishes in international cuisine, hot peppers are a raw material of many industries such as food industry (powder, sauces, pastas), pharmaceutical (creams, patches, sprays, ointments), chemical (protective coatings for electrical wires and as an additive in ship paints), and the military (projectiles, self-defence sprays) (Muñoz-Ramírez et al., 2020).

The genus comprises 43 described species (Barboza et al., 2020), with broad diversity in the colour, shape and size of the fruit, in the sensory attributes such as aroma, taste, and hotness, and levels of pungency (Cardoso et al., 2018). Among these species, five are considered domesticated: *C. annuum* L., *C. baccatum* L. (var. *pendulum), C. chinense* Jacq., *C. frutescens* L., *C. pubescens* Ruiz & Pav. (DeWitt and Bosland, 2009).

The origin of the *Capsicum* genus is presupposed to be along the Andes of western to north-western South America (Carrizo García et al., 2016). According to Pickersgill et al. (1971), three of the domesticated species, *C. annuum*, *C. frutescens*, and *C. chinense* form a closely related group that evolved in the lowlands of the tropics of Latin America and the Caribbean, with *C. annuum* predominating in Mexico, *C. chinense* in the Amazon basin and *C. frutescens* in the Caribbean.

Chili peppers crossed the Atlantic from Mexico to Europe, Christopher Columbus is supposed to have brought to Spain the first samples of chili pepper. Unlike the tomato, often perceived as poisonous, the chili pepper started being cultivated in many areas of Southern Europe soon after its introduction (Katz, 2009).

In Romania, peppers arrived in the XVIII century, and the first varieties of cultivated peppers were mentioned by Alessiu (1894). The common species of pepper predominantly cultivated in Romania is *Capsicum annuum* L. Sweet peppers are the major cultivars released through production and commercialization in Romania, followed by long peppers and hot peppers. Currently, the food industry is actively seeking healthy products, redirecting consumer perception, attitude, and awareness toward a diet

rich in natural and high-quality products (Amicarelli et al., 2021). This shift in consumer interest is why the cultivation of hot peppers has significantly increased among Romanian smallholder and hobby farmers in recent years.

MATERIALS AND METHODS

In this research paper, our primary objective is to present a comprehensive overview of the five domesticated *Capsicum* species housed at the Vegetable Research Development Station (VRDS) Buzau. Our aim is to facilitate the differentiation of these species based on distinct morphological features. Additionally, we seek to provide a user-friendly guide for enthusiasts of *Capsicum* varieties, enabling them to easily distinguish and appreciate the unique characteristics of each species.

The VRDS Buzau holds a pivotal role in the preservation and breeding of peppers in Romania, particularly contributing to the conservation of genetic resources. The extensive germplasm collection at VRDS Buzau encompasses a diverse array of 500 genotypes (refer to Figure 1), further emphasizing the station's significance in maintaining and studying the rich biodiversity of *Capsicum* species.

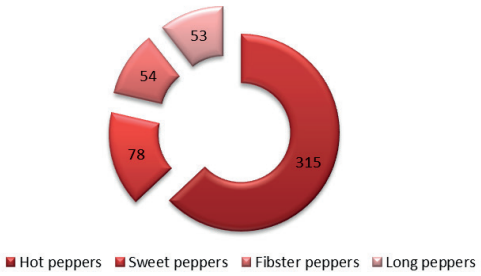

Figure 1. Structure of the *Capsicum* germplasm collection from VRDS Buzau

RESULTS AND DISCUSSIONS

The cross-pollination rate among *Capsicum* spp. is highly variable, ranging from 2 to 90% (Justino et al., 2018). The five cultivated species of *Capsicum* are self-compatible and diploid, with the number of chromosomes in the species being 2n = 24 (Pozzobon et al., 2006). Some wild species have 26 chromosomes (Pickersgill, 1991; Tong and Bosland, 2003). This can be morphologically differentiated based on qualitative characters, such as floral characteristics (Figure 2).

Figure 2. Distinctive inflorescences of the genus *Capsicum:* a), b), c) *C. annuum*, d) *C. chinense*, e) *C. baccatum*, f) *C. frutescens*

C. chinense species presents two or three flowers per leaf node of a whitish-green color, with a constriction at the base of the calyx (Figure 3) at the junction with the pedicel. *C. frutescens* species presents erect white-green flowers without calyx constriction, while *C. annuum* has creamy white or blue flowers (Hernández-Pérez et al., 2020; Paredes Andrade et al., 2020).

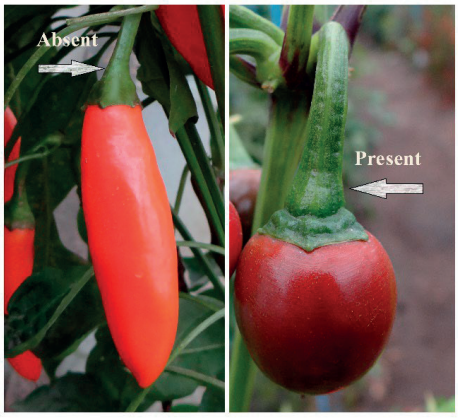

Figure 3. Calyx annular constriction

The other two species are relatively easy to distinguish: *C. pubescens* has black-rough seeds (Figure 4) and either uniformly purple or purple flowers with a white base. *C. baccatum* has yellow or white-yellow flowers with greenish spots towards the basal part of the petals (Paredes Andrade et al., 2020).

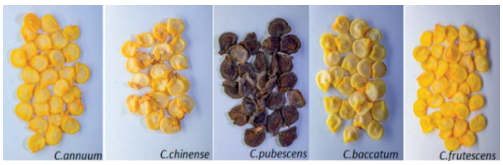

Figure 4. Seeds of *Capsicum* species

Furthermore, the differentiation of the *Capsicum* cultivated species is based on morphological descriptors that define the shape of flowers and fruits (Sudré et al., 2010). For accurate characterization, other descriptors are considered essential, such as those indicated by IPGRI. They can also be identified by the different flavors and pungency of the fruits (Comparini et al., 2021).

However, the classification and recognition of chilies, like that of any multifarious group of cultivars, is confusing. In this paper, we provide an overview of the five domesticated *Capsicum* species to differentiate them based on morphological features.

Capsicum annuum L.

C. annuum L. is the most popular and extensively cultivated pepper worldwide (de Carvalho et al., 2006; Hernández-Pérez et al., 2020). This species is characterized by both non-pungent and pungent accessions (Figure 5) with a sub-shrub or herb growth habit. The fruits exhibit variations in size, shape, and colours at maturity (Tripodi and Kumar, 2019). Some cultivars of *C. annuum* are well-accepted as ornamental plants due to the bright and colourful fruits and leaves (Costa et al., 2019).

C. annuum typically has erect plants that grow 1-1.5 meters tall. The leaves are simple and similar in size and shape. The leaf blade is ovate to elliptic, with a margin that ends in an acuminate or long-acuminate apex. The inflorescences are axillary, with one flower per axil, rarely more. The corolla is usually entirely white, occasionally entirely purple or pale yellow, with white or cream filaments, sometimes purple, and pale blue to purplish anthers.

The berries are highly variable in size, shape (elongated, round, triangular, campanulate, or blocky), and colour (white, yellow, green, orange, purple, and deep purple when immature; lemon-yellow, pale yellow-orange, pale orange, orange, light red, red, dark red, purple, and purple-black at maturity). The seeds are pale yellow, with more than 50 seeds per fruit (Barboza et al., 2022).

Figure 5. *C. annuum* varieties from VRDS Buzau, Romania: Hot peppers: a) Roial; b) Decebal; Sweet peppers: c) Regal; d) Cantemir

Capsicum baccatum L. var. *pendulum*

Capsicum baccatum L. var. *pendulum* is primarily cultivated in South America and is a plant well-adapted to diverse ecological conditions, ranging from 150 to 3,400 meters in elevation (Djian-Caporalino et al., 2007; Cardoso et al., 2018). *C. baccatum* var. *pendulum* is characterized by erect plants that can exceed a height of 2 meters. The leaf pairs are unequal in size but similar in shape, with membranous leaves that are slightly discolorous. The leaf blades are ovate, with entire margins and an acute apex. The inflorescences are axillary, with 2-3 flowers per axil, and occasionally solitary flowers. The flowers are campanulate, with a white corolla featuring greenish-yellow spots. The filaments are white, inserted on the corolla, and the ellipsoid anthers are white or pale yellow, occasionally greyish, and not connivant at anthesis.

The berry (Figure 6) is globose or subglobose, less frequently ellipsoid with a truncate or flattened apex. It is green when immature, turning to greenish-black and then bright red at maturity. The berry is deciduous, pungent, with a thick, opaque pericarp containing giant cells. Seeds are ovoid, subglobose, or C-shaped, pale yellow to yellow, with 12-15 seeds per fruit (Barboza et al., 2022).

Figure 6. *C. baccatum* var. *pendulum* varieties from VRDS germplasm collection: a) L36; b) L135A; c) L135B; d) L135C

Capsicum *chinense* Jacq.

The fruits of the cultivar Pepper X, belonging to *Capsicum chinense* Jacq., have officially earned the title of the world's hottest chili according to the Guinness Book of World Records (2023). *Capsicum chinense* thrives in wet tropical and subtropical forests, typically found at elevations ranging from 100 to 800 meters (Sarwa et al., 2012).

C. chinense is characterized by an erect plant, standing 0.5-2.5 meters tall, with few to many branches originating near the base. The leaf pairs are unequal in size but share a similar shape, with membranous, either concolorous or slightly discolorous leaves - dark green above and pale green below. The leaf blades are ovate to elliptic, featuring entire margins and a short-acuminate, acuminate, or acute apex.

Inflorescences are axillary, typically hosting 2-4 flowers per axil, occasionally with solitary flowers. The corolla is 5 (6)-merous, dull white or greenish-white, occasionally adorned with purple spots both outside and within. The corolla is stellate with an interpetalar membrane, and the filaments come in white, cream, or purple, inserted on the corolla. Anthers are usually blue or bluish-grey, with rare instances of yellow or greenish-white, broadly ellipsoid or ellipsoid, and connivent or not connivent at anthesis.

The berry, measuring less than 10 mm in diameter, is subglobose and orange to red in wild populations. Highly variable in size, shape, and colour, it can be subglobose, triangular, long-triangular, campanulate, or even blocky. The apex may be pointed, blunt, or long-acuminate and upcurved, while the base is obtuse or truncate. When immature, the colour ranges from green, yellow, brown, to purple, transitioning to pale yellow, yellow, dark brown, orange, red, or vermilion-scarlet at maturity (Figure 7). The fruits may be deciduous or persistent and are known for their intense pungency, though occasional non-pungent varieties exist. Seeds are C-shaped or subglobose, pale yellow, or nearly white, numbering from 14 to 35 per fruit. Notably, fruits of *C. chinense* exhibit a robust annular constriction at the junction with the pedicel (Barboza et al., 2022).

a) b) c) d)

Figure 7. *C chinense* varieties from VRDS Buzau germplasm collection: a) L110; b) L137; c) L76; d) L127

***Capsicum frutescens* L.**

Capsicum frutescens L. thrives in low semi-deciduous forests, disturbed areas, and agricultural clearings, with distribution spanning South America and other tropical and subtropical regions such as Asia, Africa, and the Pacific Islands. It is commonly cultivated near homesites and in the chakras of local communities, spanning elevations from 10 to 2,000 meters. The highly pungent fruits are known for their specific aroma and are consumed either fresh or as a spice (Yamamoto and Nawata, 2005).

C. frutescens is characterized by its small, elongate, narrowly triangular, and upright spicy fruits, featuring a thin fruit wall that typically turns red when ripe. Notably, there is no calyx annular constriction between the calyx and the pedicel (Carvalho et al., 2014). The plant's height ranges between 0.3 to 1.5 meters, branching from near the base. The leaf pairs are more or less similar in size and shape, with membranous, concolorous, or slightly discolorous leaves that are glabrescent or glabrous on both surfaces. The blades of the leaves are ovate or narrowly elliptic, with entire margins and an acuminate to long-acuminate apex.

Inflorescences are axillary, typically hosting 2-5 flowers per axil, with solitary flowers being a rare occurrence. The corolla is usually dull white or greenish-white both outside and within, stellate with an interpetalar membrane. Filaments come in cream or purple, and anthers are ellipsoid, bluish-grey, purplish, or, rarely, dark green or yellow, connivent at anthesis. The berry is typically green and yellowish-green when immature, transitioning to yellow, orange-red (Figure 8) as it matures. Seeds are C-shaped to subglobose, pale yellow, numbering from 10 to 52 per fruit (Barboza et al., 2022).

a) b) c) d)

Figure 8. *C. frutescens* L. varieties from VRDS Buzau germplasm collection: a) L33; b) L23; c) L261; d) L91

Capsicum pubescens Ruiz & Pav

C. pubescens Ruiz & Pav is morphologically and genetically distinctive compared to the other four cultivated species of the Capsicum genus (Russo, 2012). *Capsicum pubescens* is more tolerant to low temperatures and is frequently found in the Andean mid-elevations to highlands, ranging from 8000 to 3500 meters and rarely below 500 meters elevation. The phytotoxic activity of *C. pubescens* extracts on weeds of the genera *Amaranthus, Bidens*, and *Ipomoea* is reported. Additionally, its fruits can be considered as nutraceuticals due to their content of phenolic compounds (García-Ruiz et al., 2013).

The plant habit is erect, reaching a height of 1 to 4 meters. The leaf pairs are markedly unequal in size, with similar or dissimilar shapes. The leaves are membranous, concolorous or discolorous, glabrescent to densely pubescent on both surfaces and margins, with trichomes similar to those on stems. The leaf blades are ovate or, more rarely, elliptic, with an asymmetric and attenuate or cuneate base, entire margins, and an acuminate apex.

Inflorescences are axillary, typically hosting 1-2 flowers per axil, rarely up to four flowers. The corolla is dark purple or violet with a white center outside and within (sometimes with a weak yellowish-green center within). It is rotate to stellate, with a thin interpetalar membrane, pubescent adaxially with short glandular trichomes, and glabrous abaxially. Filaments are purple or lilac, inserted on the corolla, and anthers are ellipsoid or ovoid, purple with a wide cream connective, not connivent at anthesis.

The berry is 20-40 mm long, round, blocky, or elongate-curved, with the base obtuse, lobate or truncate, sometimes narrowed forming a neck-like structure, and the apex blunt or sunken, rarely pointed. It is green when immature and brightly colored at maturity, ranging from red to light yellow or blackish (Figure 9). The berry is persistent, very pungent, with a thick pericarp. Seeds are brownish-black to black, C-shaped, subglobose, or irregular, numbering from 15 to 45 per fruit (Barboza et al., 2022).

a) b) c) d)

Figure 9. *C. pubescens* varieties: a) Manzano; b) Brown Rocoto; c) Amarillo; d) Rocoto (Source: Dhamodharan et al., 2022)

CONCLUSIONS

The evaluation of genetic diversity within a *Capsicum* spp. germplasm collection traditionally relies on both qualitative and quantitative morphological descriptors.

The distinction among cultivated *Capsicum* species is achieved through morphological characteristics such as flower and fruit shape, corolla colour, corolla sport colour, the presence or absence of calyx annular constriction, and seed colour.

These morphological descriptors serve as valuable tools for characterizing and differentiating various *Capsicum* species, providing insights into their genetic variations and contributing to the overall understanding of the germplasm collection.

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