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Morphological Diversity of F1 Ornamental Chili Generation from Single Cross Hybridization

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ABSTRACT

Ornamental chilli (*Capsicum annuum* L.) belongs to the Solanaceae family and is highly popular for its aesthetic value. Ornamental chilli plants are edible, with attractive plant architecture and fruit shapes, as well as varying levels of spiciness. The most preferred traits in ornamental chilli plants include compact size (suitable for potted plants), diverse and unique fruit shapes and colors, and upright fruit orientation. This study aims to investigate the morphological diversity in the F1 generation resulting from a single cross-hybridization between two ornamental chilli varieties, namely the Medusa Pepper, known for its compact growth habit, and the Black Pearl Pepper, characterized by purple-coloured fruits and leaves. Analysis of the qualitative data shows that the F1 generation shares a high degree of morphological similarity with the female parent, Black Pearl Pepper, with a similarity value exceeding 75%, while it exhibits no significant resemblance to the male parent, Medusa Pepper, with a similarity value of 0%. The F1 generation from the single cross demonstrates limited morphological variation, with all observed traits being largely influenced by dominant characteristics, including fruit color, plant habit, and leaf color.

1. INTRODUCTION

1.1. Research Background

Capsicum originated from the Western Hemisphere. Before the arrival of the Spanish, plant breeders from the Aztec, Mayan, and Inca civilizations had already developed various types of chili peppers. In Indigenous cultures, chilli peppers played a significant role in religious ceremonies and were considered the second most important staple after corn. The shape of the chilli fruit distinguishes different groups, such as ancho, bell, jalapeño, pasilla, New Mexican, and yellow wax, each with unique characteristics for fresh consumption and processing, in addition to differences in flavor and spiciness. Many of these unique chili varieties have been developed, including those used for ornamental purposes [1].

When chili peppers were introduced to Europe in the 15th century, they were initially valued more as decorative plants than as a food source. Herbalists in the 16th and 17th centuries documented various types of chilli peppers. Today, ornamental chillies remain popular in Europe and are gaining increasing interest in the United States as potted plants, bedding plants, and ornamental plants. Seed catalogs list around a dozen different ornamental chili varieties. When a chili is labeled as ornamental in seed catalogs, it typically means the plant is compact, produces colorful fruits, and is well-suited for container growth. The advantages of ornamental chili include ease of seed propagation, relatively short harvest time, tolerance to heat and drought, and good storage quality [2].

For many years in the floriculture industry, ornamental chilies were known as 'Christmas peppers,' due to their glossy green foliage adorned with bright red fruits, traditionally sold during the holiday season. Christmas peppers, with their vibrant winter colors and edible fruits, were once the most popular holiday gift plants until the 1960s, when the poinsettia industry began promoting and introducing new varieties, making poinsettias the number one holiday gift plant. However, renewed interest in ornamental chilies has sparked new breeding efforts,

and the term 'Christmas pepper' has largely been replaced by 'ornamental pepper' in common usage [2].

In Indonesia, ornamental plant collecting has been substantial, as reflected in the ornamental plant production data from BPS in 2022. However, the ornamental chilli market is still dominated by introduced varieties. The variety of ornamental chilli plants in Indonesia remains limited and has not become a major commodity yet. The development of new ornamental chilli varieties is constrained by the lack of genetic diversity. This study aims to increase the genetic diversity of ornamental chilli plants through single cross-hybridization between the Black Pearl Pepper and the Medusa Pepper.

1.2. Literature Review

Chilli plants belong to the genus *Capsicum*, which exhibits a wide range of phenotypic diversity. This diversity includes variations in plant size, leaf shape, leaf color, fruit shape, and fruit color, making chilli plants highly suitable as ornamental plants [3]. Chilli pepper (*Capsicum annuum* L.) is a perennial shrub belonging to the Solanaceae family, with a height reaching up to 150 cm. The plant's structure consists of roots, stems, leaves, flowers, fruits, and seeds. It has a taproot system, and root development occurs in two stages: the seedling stage with a strong taproot, and the mature plant stage where lateral roots grow from the damaged main root [4].

Chilli plants are classified as woody shrubs with a taproot and lateral branches that form fibrous roots [5]. The primary root of bird's eye chilli typically measures between 35-50 cm in length, while secondary roots can spread to 35-45 cm. The stem is light green and soft when young, but becomes dark green to brown and woody as it matures. Branches begin to form at a height of 30-45 cm [4].

The length and diameter of chilli plant stems can reach 37.5 cm and 3 cm, respectively, depending on the variety [6]. The branches serve as petioles supporting the leaves, with a length of up to 5 cm. The leaves are ovate with pointed tips, and pinnate venation, and are slightly asymmetrical [4].

Chilli plants serve two important roles in horticulture: as a food crop and as ornamental plants. As an ornamental plant, chilli has been developed through selection and hybridization processes to enhance its visual appeal and meet market demands. One of its attractive features is its bushy form, resembling a bouquet. Color also plays a crucial role in influencing consumer perception and product quality. Pigments such as anthocyanin, which is typically associated with colors ranging from blue to red, serve additional functions beyond visual appeal, including protecting the plant from ultraviolet light, attracting pollinators, and offering potential health benefits. The growing demand for chilli as both an ornamental and edible plant necessitates efforts to increase genetic diversity through breeding processes, which can be achieved through methods such as introduction, mutation, hybridization, and polyploidy [7] [8]

1.3. Research Objective

This study aims to investigate the morphological diversity of ornamental chilli plants from a single cross-hybridization between the Black Pearl Pepper line and the Medusa Pepper.

2. MATERIALS AND METHODS

The research was conducted at the Greenhouse of TEFA Celeban Garden, Polbangtan Yogyakarta Magelang Campus, Yogyakarta City, D.I. Yogyakarta. This study utilized several tools, including a ruler, camera, calliper, tweezers, and sprayer. The materials used in this research were Black Pearl Pepper, Medusa Pepper, and F1 plants resulting from the cross between Black Pearl Pepper and Medusa Pepper. Additional materials included potting media in polybags, fungicides, insecticides, NPK fertilizer, micronutrient fertilizer, labelling tags, observation forms, paper, and writing utensils.

The study involved planting Black Pearl Pepper, Medusa Pepper, and F1 plants from the Black Pearl Pepper X Medusa Pepper cross in polybags, followed by qualitative and quantitative observations to determine genetic diversity from the hybridization. The research design used was a single-plant approach, where each F1 chilli plant was individually planted and observed.

1. **Sowing**
   The research began with sowing ornamental chilli seeds. Before sowing, the seeds were soaked overnight. The soaked seeds were then sown in seed trays, with one seed per hole. The seeded trays were covered with mulch plastic for three days before being uncovered. Watering was done daily during the germination period.
2. **Planting**
   Chilli seedlings aged 30 days post-germination were transplanted into polybags. Each plant was labelled with its variety name and individual number.
3. **Maintenance**
   Chilli plant maintenance included fertilization, watering, and pest control. Fertilization was done using NPK 16-16-16 fertilizer. Watering was conducted daily using a drip irrigation system. Pest control was carried out by spraying Pegasus 500SC insecticide once a week, with the frequency increased to twice a week if pest infestation became severe.
4. **Observation**
   Observations were made on each plant based on the "Guideline for The Conduct of Test for Distinctness, Uniformity, and Stability" from the International Union for the Protection of New Varieties of Plants [9]. Both qualitative and quantitative traits were recorded.
5. **Data Analysis**
   The observed traits were analyzed using cluster analysis methods. This analysis aimed to group individuals into clusters based on similarities compared to other groups [10]. The diversity and kinship data were processed using OriginPro 2022 statistical software. This application calculates similarity values and distances between groups to assist in final cluster grouping. Cluster analysis data were based on numeric values following the guidelines from UPOV (2020). The analysis results were presented in the form of a dendrogram, showing the diversity and kinship levels among ornamental chili plants from the single cross-hybridization.

3. RESULT AND DISCUSSION

3.1. Male and Female Parents Morphological Character

The single cross-hybridization used the ornamental chilli varieties Black Pearl Pepper as the female parent and Medusa Pepper as the male parent, both of which are introduced varieties (not developed in Indonesia). This hybridization was carried out to obtain a promising line that combines the characteristics of both varieties. Among all possible genetic recombinations from the two parents, the desired outcome is a promising line with a wide plant habit like Medusa Pepper and fruit shape and color resembling Black Pearl Pepper.

Black Pearl Pepper, a variety of *Capsicum annuum*, has dark purple fruit when immature, which turns deep red when ripe. The fruit is round with a glossy surface, resembling pearls, hence the name "pearl-like pepper." The plant has an upright growth habit, reaching a height of 60-90 cm. Its leaves and flower calyxes are purple. The plant has a lifespan ranging from 80 to 120 days [11].

Figure 1. Black Pearl Pepper variety as the female parent.

Medusa Pepper, a variety of *Capsicum annuum*, derives its name from the mythological character 'Medusa,' as its fruiting pattern resembles Medusa's hair. The plant has a sprawling growth habit with a height of 20-25 cm. Its flower calyxes are white, without anthocyanin pigmentation. The plant produces a heavy fruit set, with 40-50 fruits per plant. The fruit colors vary, ranging from ivory, yellow, orange, to red, and all colors can be observed simultaneously.

Figure 2. Medusa Pepper variety as the male parent.

The single cross involved genetically homogeneous parents, resulting in a relatively uniform F1 population in terms of phenotype. From the cross between Black Pearl Pepper and Medusa Pepper, 39 individual plants were obtained, all with uniform triangular fruit shape, which matches the male parent, Medusa Pepper. The fruit size is a combination of both parents, with the average fruit length of F1 individuals ranging from 2.1 to 3.0 cm. In comparison, the female parent, Black Pearl Pepper, has a fruit length of 0.8 cm, while the male parent, Medusa Pepper, has a fruit length of 4 cm. The immature fruit color of all plants is dark purple, following the trait of the female parent, Black Pearl Pepper, while the mature fruit color is consistently dark red.

The size, flower color, and fruit color changes are important traits in the breeding of ornamental chili peppers [12]. The purple color variation in chili plants is caused by the presence of anthocyanins. Anthocyanins serve several functions, including attracting pollinators, protecting plants from abiotic and biotic stress, enhancing resistance to fungal attacks, and providing camouflage from pests [13].

Chilli fruit is known for its significant variation (Lagiman and Supriyanta, 2021), including variations in orientation, shape, and color. The F1 population resulting from the Black Pearl Pepper and Medusa Pepper cross exhibits an upright fruit orientation. Upright orientation is advantageous for ornamental plants, as it makes the fruits more visible and striking [12].

3.2. F1 Plant Morphological Character

The single cross involved genetically homogeneous parents, resulting in a relatively uniform F1 population in terms of phenotype. From the cross between Black Pearl Pepper and Medusa Pepper, 39 individual plants were obtained, all with uniform triangular fruit shape, which matches the male parent, Medusa Pepper. The fruit size is a combination of both parents, with the average fruit length of F1 individuals ranging from 2.1 to 3.0 cm. In comparison, the female parent, Black Pearl Pepper, has a fruit length of 0.8 cm, while the male parent, Medusa Pepper, has a fruit length of 4 cm. The immature fruit color of all plants is dark purple, following the trait of the female parent, Black Pearl Pepper, while the mature fruit color is consistently dark red.

This is consistent with Ref. [12], who stated that size, flower color, and fruit color changes are important traits in the breeding of ornamental chili peppers. The purple color variation in chili plants is caused by the presence of anthocyanins. Anthocyanins

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serve several functions, including attracting pollinators, protecting plants from abiotic and biotic stress, enhancing resistance to fungal attacks, and providing camouflage from pests [12]. The color diversity of *Capsicum* fruits is associated with pigments such as chlorophyll (green), anthocyanin (purple/dark purple), α-carotene, β-carotene, zeaxanthin, lutein, and β-cryptoxanthin (yellow/orange) [14].

Chilli fruit is known for its significant variation [14], including variations in orientation, shape, and color. The F1 population resulting from the Black Pearl Pepper and Medusa Pepper cross exhibits an upright fruit orientation. Upright orientation is advantageous for ornamental plants, as it makes the fruits more visible and striking [12].

Figure 3. Fruit morphology of the F1 generation resulting from the cross between Black Pearl Pepper and Medusa Pepper.

Uniformity in traits was also observed in the plant habit of the F1 generation, with all 39 plants exhibiting a semi-upright plant habit. The leaf shape of all plants was elongated (lanceolate). The intensity of the green color in the leaves was categorized as moderate, and the presence of anthocyanin on both the upper and lower sides of the leaves was absent (as shown in Figure 4). Smaller plants are more preferred and appealing for pot cultivation [12]. Only cultivars with small plant sizes and harmonious appearance in pots can be grown and marketed as potted plants [16].

Figure 4. Plant habit of the F1 generation resulting from the cross between Black Pearl Pepper and Medusa Pepper.

3.3. Cluster Analysis

Based on the analysis using a dendrogram (with qualitative data), it can be concluded that the 39 individual plants in the F1 generation exhibit very close morphological similarity (similarity value above 75%) to the female parent, Black Pearl Pepper, while morphological similarity to the male parent, Medusa Pepper, is essentially nonexistent (similarity value 0%) (Figure 5).

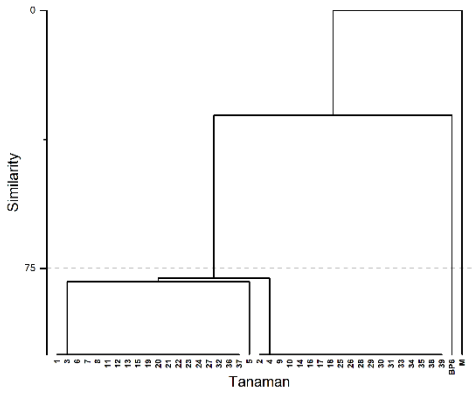

Figure 5. Dendrogram of morphological similarity among individual plants of the F1 generation derived from a cross between Black Pearl Pepper and Medusa Pepper.

The F1 generation from the single cross has not shown a high degree of morphological variation yet; in this generation, all observed morphological traits, such as fruit color, plant habit, and leaf color, are dominated by a few dominant traits. Greater variation is expected in the F2 generation, allowing the selection of desired morphological traits to begin at that stage.

4. CONCLUSION

Analysis of the qualitative data shows that the F1 generation shares a high degree of morphological similarity with the female parent, Black Pearl Pepper, with a similarity value exceeding 75%, while it exhibits no significant resemblance to the male parent, Medusa Pepper, with a similarity value of 0%. The F1 generation from the single cross demonstrates limited morphological variation, with all observed traits being largely influenced by dominant characteristics, including fruit color, plant habit, and leaf color

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