Morphology and phylogenetic relationships of five chili cultivars from Sumatra, Indonesia

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Abstract. Chili is an important horticultural crop which contribute substantially to the national income of Indonesia. As the demand of chili continues to increase, exploration of local superior varieties from various regions in Indonesia become one of priorities in the development of new chili cultivars. This research aimed to study morphology and phylogenetic relationship of chili cultivars from different parts of Sumatra, Indonesia. The study was conducted at the Teaching and Research Farm, Faculty of Agriculture University of Jambi, from May through to November 2021. Five chili cultivars (Loker Telun Berasap and Ahang Adro from Kerinci Regency, Jambi Province, Kopay from West Sumatra Province, and Awe and Udeng from Nanggroe Aceh Darussalam Province) were evaluated for their morphological traits and phylogenetic relationship. The trial was arranged in a randomized block design with 5 replicates, and each replicate consisted of 5 plots. There were 25 plants in each plot, of which 8 plants were taken as samples. Qualitative and quantitative traits were observed on leaves, flowers, fruits, seeds, and stem. Data were analyzed using cluster analysis method using Minitab® (Version 18) application to evaluate phylogenetic relationship among cultivars based on similarity of morphological traits. Results showed that the five chili cultivars showed variations in qualitative and quantitative traits. In addition, there are also variations in their growth and morphology. Based on cluster analysis dendrogram, it was found that Loker Telun Berasap and Ahang Adro showed differences in morphological traits from the other three cultivars. These two cultivars are, therefore, proposed to be listed for cultivar release as part of germplasm conservation program to protect local superior chili cultivar of Jambi Province.

1 Introduction

Plant breeding has a great contribution in developing high-yielding variety of various horticultural crops including chili (Capsicum annuum L.). High-yielding chili varieties have been developed for their high productivity, adaptive to climate change, resistant to major pests and diseases, responsive to various environmental stresses either biotic or abiotic, and meet consumer tastes [1]. The development of high-yielding varieties requires a gene pool of superior traits as a source of diversity. The more variation in morphology and genetics, the greater sources of diversity that can be used to develop high-yielding plant varieties.

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Morphological characterization based on qualitative traits of crops is a very crucial first step in any crop improvement and breeding program [2-4]. Parental purity judgement and varietal identification are important factors for the release of genotypes [4,5]. Cultivars can be identified and differentiated based on differences in morphology of seed, seedling and grown-up plants [6].

Morphological variation is a phenotypic diversity that can be evaluated from the qualitative and quantitative characters of plants. Morphological variation in plants is generally a feedback for the changing climatic conditions and reflects the adaptive evolution [7-10], while the soil factor has apparently shown to be a driving force to determine the morphological traits of plants [10-12].

Many studies of the use of morphological variation for plant breeding purposes have been reported in various species such as Jacaratia mexicana [13], Cicer arietinum [14], Oryza sativa [15], and Musa spp. [16]. Morphological characterization in chili peppers has been found in many reports [6,17-19]. However, there are no reports on the evaluation of morphological variation of chili peppers in different areas in Sumatra, Indonesia.

In addition, the Minister of Agriculture Regulation Number 38/2019 on the Release of Plant Varieties [20] indicated that the release of new crop varieties is possible if it leads to productivity advances that have an impact on increasing farmer welfare, distinct from other varieties, uniform and stable in their quality and agronomic characteristics. Therefore, by the enactment of this regulation farmers and seed growers become assured that they are being supplied with authentic seed material with the known identity of a specific variety and assured quality. Keeping this in view the present investigation was carried out to evaluate five chili cultivars from three provinces (Jambi, West Sumatra, and Nangroe Aceh Darussalam) based on morphological characters for identification of their superior traits.

2 Materials and methods

2.1 Plant preparation

The study was carried out from May through to November 2021 at the Teaching and Research Farm, Faculty of Agriculture University of Jambi, and the Plant Breeding and Tissue Culture Laboratory, Solok Tropical Fruit Research Institute, West Sumatra, Indonesia.

Chili cultivars tested were two from Kerinci Regency (Loker Telun Berasap/TB and Ahang Adro/AA), one from West Sumatra Province (Kopay/KY), and two from Nangroe Aceh Darussalam Province (Awe/AW, and Udeng/UD). Seeds were sown on beds on a media consisted of soil and trichocompost with (2:1), and covered with 50% paranet shade.

Experimental plots were prepared with a size of 2.5m x 2.5m, and 25 tons·ha⁻¹ trichocompost along with 2 tons·ha⁻¹ dolomite lime was applied to improve soil fertility. Plots were then covered with black plastic mulch.

Seedlings were transplanted to experimental plots at 4 weeks after sowing. Plant care such as watering, pests, and diseases control, weeding, and biourine (60%) spray every 2 weeks were routinely carried out. Harvesting was carried out on ripe fruits (75% red) until the end of first flowering period.

2.2 Experimental design

The trial used a Randomized Block Design consisting of 5 variables (chili cultivars) and 5 replicates (blocks). Each block consisted of 5 experimental plots, so there were 25 experimental plots. In each plot there were 25 plants from which 16 individual plants were designated as sample plants.
Following two weeks of transplanting, 8 sample plants were taken out for leaf morphology evaluation, and other 8 samples were taken out for DNA testing to determine their genetic variation.

2.3 Observations

Observations of morphological diversity were carried out on qualitative and quantitative traits based on chili descriptors from the International Plant Genetic Resources Institute [21]. The observation was made on the following descriptors: 1) plant, 2) inflorescences, 3) fruits, and 4) seeds. The Royal Horticultural Society Color Chart Sixth Edition [22] was used for color characters.

2.4 Data analysis

Quantitative and qualitative data were presented in tabular form based on descriptors. Further, data of quantitative and qualitative traits were matched using cluster analysis by using Minitab (Version 18) statistical application, to determine the phylogenetic relationship among cultivars based on similarity of morphological traits.

3 Results and discussion

Morphological variation was evaluated based on qualitative and quantitative traits of plant, stem, leaves, flowers, fruits, and seeds (Table 1). Sinha and Mishra [15] suggested that qualitative characters are considered as the most important characters to identify a particular plant cultivar. Qualitative characters are mostly genetically controlled thus they are less independent to the environmental response.

Table 1. Characterization of qualitative and quantitative traits of five chili cultivars from Sumatra, Indonesia.

<table>
<thead>
<tr>
<th>Characterization</th>
<th>Cultivars</th>
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<tbody>
<tr>
<td></td>
<td>TB</td>
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<tr>
<td>Plant descriptors:</td>
<td></td>
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<tr>
<td>Plant height (cm)</td>
<td>71.6 – 98.7</td>
</tr>
<tr>
<td>Plant growth habit</td>
<td>Erect</td>
</tr>
<tr>
<td>Stem length (cm)</td>
<td>24.3 – 27.7</td>
</tr>
<tr>
<td>Stem diameter (mm)</td>
<td>12.0 – 16.4</td>
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<tr>
<td>Leaf color</td>
<td>Dark green</td>
</tr>
<tr>
<td>Leaf shape</td>
<td>Ovate</td>
</tr>
<tr>
<td>Lamina margin</td>
<td>Undulate</td>
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<tr>
<td>Mature leaf length (cm)</td>
<td>11.0 – 11.6</td>
</tr>
<tr>
<td>Mature leaf width (cm)</td>
<td>4.0 – 4.2</td>
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<tr>
<td>Inflorescence descriptors:</td>
<td></td>
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<tr>
<td>Days to flowering (dat)</td>
<td>29 – 32</td>
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<tr>
<td>Flower position</td>
<td>Pendant</td>
</tr>
<tr>
<td>Flower diameter (mm)</td>
<td>11.1 - 17.3</td>
</tr>
</tbody>
</table>
Data on qualitative traits of leaves, flowers, and fruits indicated that the five cultivars showed fairly the same characters. However, based on the RHS color standard, there is a slight difference in the color serial number for leaf and fruit as well as in leaf shape of UD. While immature and mature fruits of AA showed different colors from other 4 cultivars. Data on the quantitative characters revealed that there were differences in plant, stem height, flower size, fruit size. The ability to grow and produce fruit in the five chili cultivars showed varying results.

In general, the heights of TB, AA, KY, and AW cultivars were relatively uniform, ranging from 68.7 cm to 98.7 cm. While in UD, the plant height reached 105.8 cm. The stem height which was measured from the root neck to the first bifurcation showed that the stem height of the UD reached 30.7 cm, while in TB, AA, KY, and AW the highest stem was only 20.2 cm to 27.7 cm. Meanwhile, the widest stem diameter was shown by the KY which reached 18.2 mm, while in TB, AA, AW, and UD the largest diameter ranged from 12.0 mm to 16.4 mm. The length of mature leaves of TB, AA, KY, and AW cultivars were generally relatively...
the same, i.e., 10.4 cm to 11.8 cm, while in UD it only reached 9.0 cm. Likewise, leaf width in TB, AA, KY, and AW reached 3.3 cm to 4.2 cm, while in UD it was narrower at 1.2 cm.

All cultivars showed an erect growth habit which indicates a high yield potential as erect plant growth and medium and strong branching leads to higher yield [6, 23]. The TB showed a darker leaf color (dark green) than the other four cultivars (green) leaf color. Pachiyappan and Saravannan [24] suggested that the dark green color of leaves indicated a high chlorophyll content which ultimately leads to increased yield. Therefore, it becomes a good criterion for selection of elite cultivars. The leaf shape in TB, AA, KY, and AW is the same, namely ovate, while in UD the leaf shape was lanceolate. The leaf margins on TB and AA were undulate, while those on KY, AW and UD were slightly undulate.

The first flower emergence in TB, AA, KY, and AW cultivars was relatively the same, ranging from 29 days to 33 days after transplanting. Meanwhile, the first flowers emergence in UD appeared earlier, i.e., 26 days after transplanting. The diameter of the flowers in TB and AA cultivars was 11.1 mm to 17.5 mm, while in the KY and AW cultivars it reached 21.3 mm to 23.7 mm. However, the flower diameter of the UD was narrower, reaching only 16.2 mm. Correspondingly, the length of pedicel in UD and AW cultivars was also shorter (2.0 cm) than TB (2.8 cm), AA (2.4 cm) and KY (3.1 cm).

The position of the flowers was pendant with white corolla in all cultivars. The color of the calyx in AA cultivar was darker (dark green) than those petals of the other four cultivars, which was green. While the edges of the calyx on the five cultivars were all dentate. The color of the pedicel was generally green, except for the AA which was dark green. The attractive flower color was a desirable trait as it helped in attracting pollinators during [25] pollination.

In general, the time for fruit formation was the same for TB, AA, KY, and AW cultivars, which was 35 days to 40 days after transplanting, while for UD cultivar, fruit was formed more quickly, at 33 days after transplanting. Meanwhile, fruit length varied between cultivars. The longest fruit shown by KY which was 24.3 cm, followed by UD and AW which were 22.0 cm and 20.3 cm, respectively. In TB and AA, however, the fruit length did not exceed 18.7 cm. Similarly, fruit weight of TB and AA cultivars ranged from 4.48 g to 6.15 g. This weight of fruit was below that of KY, AW and UD cultivars which ranged from 5.29 g to 10.17 g. The diameter of fruit in the five cultivars was generally the same, which was 5 mm to 8 mm. A clear difference was found in the pedicel length, where in TB and AA cultivars the pedicel length reached 6.2 cm to 7.3 cm. Whereas, in KY, AW and UD cultivars the pedicel length did not exceed 5.9 cm.

The color of young fruit was generally green except for AA which was dark green. The ripe fruit was generally red except for AA and AW cultivars which were dark red. Fruits of the five cultivars were elongate in shape. Fruit shape at pedicel attachment was obtuse-shaped, while fruit shape at blossom end was pointed in TB and AA cultivars, and sunken and pointed in the other three cultivars. The five cultivars showed a semi wrinkled fruit surface and a pendant position on the stem. Attractive fruit color and smooth fruit texture were the factors which determine consumer acceptability hence, these traits become a good selection criterion for a breeder [6, 26].

In general, the seed diameter of the five cultivars was relatively the same, ranging from 3 mm to 4 mm, but in UD cultivar it ranged from 2 mm to 3 mm. Seeds in all cultivars were yellow with a rough surface.

Further, to determine the relationship among the five cultivars, a cluster analysis was carried out to group the cultivars based on their characteristic similarity. Data on quantitative and qualitative characters were matched using a cluster analysis (grouping analysis) program with the help of Minitab-18 (MTB-18) software [27] to determine their phylogenetic relationships based on the similarity of morphological traits. The result of the grouping analysis on the five chili cultivars is presented in Figure 1.
The results of the cluster analysis indicated that the five cultivars were distantly related or had less than 50% similarity to each other. Even, AW and UD were in the same group with character similarity of less than 10%. Further, Figure 1 indicates that TB and AA cultivars are in different clusters and show different morphological traits than the other three cultivars. These two cultivars are reported to be able to grow and yield well in different agroclimatic areas [28]. Therefore, they have potential to enrich plant genetic resources for superior chili cultivars from Jambi Province.

4 Conclusions

Based on morphological characterization analysis, it can be concluded that Loker Telun Berasap, Ahang Adro, Kopay, Awe, and Udeng cultivars have diversity in their qualitative and quantitative traits. Based on cluster analysis Loker Telun Berasap and Ahang Adro show a considerable amount of variation in morphological characters from the other three cultivars. It is suggested that Loker Telun Berasap and Ahang Adro cultivars can be proposed to be listed as one of Jambi germplasms for genetic resources of Jambi Elite Chili Varieties and can proceed to the Plant Variety Release stage.

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References