

Study on Several Genus of The Solanaceae Family with Phenetic Approach Methods

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Abstract

This study aimed to determine the morphological diversity of several genera from the Solanaceae family through a morphological approach, and the morphological characters that influence their grouping. The sampling activity is located in Lumajang district. The plant parts studied consisted of 30 characters including stature, stems, leaves and flowers which were then analyzed descriptively and phenetically. Based on the results of the descriptive analysis, it was found that there was a diversity of morphological characteristics between several genera of the Solanaceae family, namely the Solanum, Capsicum, Physalis, Datura, Nicotiana, and Petunia genera. Based on the analysis used the phenetic method in the SPSS program, a dendrogram was produced showing two groups, namely the genus Nicotiana and Petunia and the other groups Solanum, Capsicum, Datura, and Physalis. Then it grouped again and separated and finally got the species. Based on the results of PCA (Principal Component Analysis), the characters that influence the grouping of several genera from the Solanaceae family include phyllotaxis characters, leaf margins, leaf width, leaf length, leaf texture, anther color, and flower type. The result implications a morphological character can be used for plant identification.

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1. INTRODUCTION

Solanaceae is a monophyletic family consists of 100 genera and 2.500 species widely distributed throughout the world, with the highest species diversity in America, Australia, and Africa [1-5]. Species from the Solanaceae family has many benefits for human welfare, such as from an economic perspective, for example, tomatoes (*Solanum lycopersicum*), potatoes (*Solanum tuberosum*), eggplant (*Solanum melongena*), and tobacco (*Nicotiana tabacum*). Although having high economic value, several types of plants from the Solanaceae contain toxins [6].

Solanaceae family species had big importance as food in the world. For example, in 2010, 28 million hectares were cultivated globally and produced an estimated 540 million tons crop for food. However, the data were based on only four main plant species (potatoes, tomatoes, eggplants, and chilies). The data also not including less known cultivated species, or species that are widely cultivated or collected in nature, so that the majority of plants in the Solanaceae family are considered underutilized species [7].

In Java Island there are 18 genus and 65 species of the Solanaceae family, and in East Java there are 13 genera which include 29 species from the Solanaceae family [9]. Husnudin et al. (2015) conducted research in the Greater Malang area, and found 12 genera consisting of 23 species from the Solanaceae family, namely *Capsicum L.*, *Solanum L.*, *Lycopersicon Mill.*, *Physalis L.*, *Cyphomandra Mart. ex Sendtn.*, *Solandra P.S. Green.*, *Datura L.*, *Brugmansia Pers.*, *Jaltomata Schlecht.*, *Nicotiana L.*, *Cestrum L.* and *Nicandra Adanson*. The number of genera and species of Solanaceae plants found in this study was different from the number stated in the Flora of Java. This is presumably due to the presence of new plants imported from abroad and planted in Java so their names have not been published in the Flora of Java [10].

The research that has been conducted on the Solanaceae family mostly contains the active ingredients in certain species or genera in general. Agyare et al. (2013) investigated the anti-inflammatory and analgesic properties of

Nicotiana tabacum and *Schwenkia americana*. According to Irawan (2011), it is stated that a plant that is closely related has the same characteristics or characters, including morphological characters, anatomical characters, the same content of bioactive compounds but different concentrations. In phytochemistry, taxonomically closely related species have the same types of metabolites while taxonomically distant species have very different secondary metabolites [13]. Thus, if there is a shortage of a species in the Annonaceae family, it can be replaced with another species containing the same bioactive and having close relatives/relatives with the species to be used as another alternative as a substitute.

2. MATERIAL AND METHODS

Plants Material

This study used primary data. Primary data obtained from direct observation of the specimen. Observations were made to obtain data in the form of characteristics of the characters of leaves, flowers, fruit, seeds and stems. Data regarding these characteristics was compiled into a table to make it easier for process future data. This research was conducted in Lumajang district for exploration and collection of genus specimens from the Solanaceae family. The materials used in the study were plants representing collect genus specimens from the Solanaceae family: *Solanum*, *Capsicum*, *Physalis*, *Datura*, *Nicotiana* and *Petunia*.

Data Analysis

Data regarding these characteristics was compiled into a table to make it easier for further data processing. The stages of this research included exploration and specimen identification, data collection, morphological characterization, and data analysis. Data analysis was interpreted using two methods, descriptive data analysis and phenetic method (through a morphological approach). Data analysis was conducted descriptively and computerized. Descriptive data analysis was carried out by describing the characteristics of the test specimens in the form of sentences that included analytical descriptions and differential.

3. RESULT AND DISCUSSION

Based on observations in Lumajang district, found plants representing each genus *Solanum*, *Capsicum*, *Physalis*, *Datura*, *Nicotiana*, and *Petunia*, namely *Solanum melongena*, *Capsicum frutescens*, *Physalis minima*, *Datura metel*, *Nicotiana tabacum*, and *Petunia hybrida*. From the six genus specimens, 30 phenotypic characters were obtained, which consisted of 3 stature characters, 5 stem characters, 14 leaf characters, and 8 flower characters [10].

Grouping analysis to determine the similarity of several genera from the Solanaceae family was carried out based on 30 morphological characters used SPSS 25.00 program. The 29 morphological characters used as the basis for grouping consisted of 3 stature characters, 5 stem characters, 14 leaf characters, and 8 flower characters. Descriptive data were assessed numerically by giving a score that describes the difference while quantitative data were obtained from direct measurements. The grouping of several genera from the Solanaceae family was carried out using Classify Hierarchical Cluster analysis and PCA (Principal Component Analysis) analysis as a complement. Classify Hierarchical Cluster analysis was carried out based on the measurement of similarity between operational taxonomic units (OTU) with an agglomerative method based on the average linkage (Table 2) using simple matching coefficients for binary data. The result of calculating the similarity index of the simple matching coefficient (Table 1) were obtained from the data that has been scored and processed with the SPSS 25.00 program. Diagnostic descriptions, Computerized data analysis was performed using SPSS 26 through Hierarchical Cluster Analysis and Principal Components.

TABLE 1. The results the similarity index with simple matching coefficient Coefisien *simple matching*

S1	S2	S3	C1	C2	C3	Ph1	Ph2	Ph3	D1	D2	D3	N1	N2	N3	Pe1	Pe2	Pe3	
S1	1.000	.843	.950	.687	.503	.670	.343	.322	.322	.624	.650	.624	.327	.327	.327	.079	.079	.079
S2	.843	1.000	.885	.748	.707	.753	.224	.215	.215	.456	.542	.456	.505	.505	.505	-.053	-.053	-.053
S3	.950	.885	1.000	.649	.529	.685	.282	.266	.266	.563	.584	.563	.393	.393	.393	.020	.020	.020
C1	.687	.748	.649	1.000	.840	.895	.398	.342	.342	.607	.651	.607	.539	.539	.539	.167	.167	.167
C2	.503	.707	.529	.840	1.000	.938	.373	.333	.333	.477	.510	.477	.431	.431	.431	-.146	-.146	-.146
C3	.670	.753	.685	.895	.938	1.000	.397	.355	.355	.551	.587	.551	.460	.460	.460	-.089	-.089	-.089
Ph1	.343	.224	.282	.398	.373	.397	1.000	.954	.954	.494	.440	.494	.222	.222	.222	.109	.109	.109
Ph2	.322	.215	.266	.342	.333	.355	.954	1.000	1.000	.458	.456	.458	.162	.162	.162	.147	.147	.147
Ph3	.322	.215	.266	.342	.333	.355	.954	1.000	1.000	.458	.456	.458	.162	.162	.162	.147	.147	.147
D1	.624	.456	.563	.607	.477	.551	.494	.458	.458	1.000	.961	1.000	.354	.354	.354	.290	.290	.290
D2	.650	.542	.584	.651	.510	.587	.440	.456	.456	.961	1.000	.961	.394	.394	.394	.317	.317	.317

D3	.624	.456	.563	.607	.477	.551	.494	.458	.458	1.000	.961	1.000	.354	.354	.354	.290	.290	.290
N1	.327	.505	.393	.539	.431	.460	.222	.162	.162	.354	.394	.354	1.000	1.000	1.000	.472	.472	.472
N2	.327	.505	.393	.539	.431	.460	.222	.162	.162	.354	.394	.354	1.000	1.000	1.000	.472	.472	.472
N3	.327	.505	.393	.539	.431	.460	.222	.162	.162	.354	.394	.354	1.000	1.000	1.000	.472	.472	.472
Pe1	.079	-.053	.020	.167	-.146	-.089	.109	.147	.147	.290	.317	.290	.472	.472	.472	1.000	1.000	1.000
Pe2	.079	-.053	.020	.167	-.146	-.089	.109	.147	.147	.290	.317	.290	.472	.472	.472	1.000	1.000	1.000
Pe3	.079	-.053	.020	.167	-.146	-.089	.109	.147	.147	.290	.317	.290	.472	.472	.472	1.000	1.000	1.000

Note: S1 = genus Solanum 1, D1 = genus Datura 1, S2 = genus Solanum 2, D2 = genus Datura 2, S3 = genus Solanum 3, D3 = genus Datura 3, C1 = genus Capsicum 1, N1 = genus Nicotiana 1, C2 = genus Capsicum 2, N2 = genus Nicotiana 2, C3 = genus Capsicum 3, N3 = genus Nicotiana 3, Ph1 = genus Physalis 1, Pe1 = genus Petunia 1, Ph2 = genus Physalis 2, Pe2 = genus Petunia 2, Ph3 = genus Physalis 3, Pe3 = genus Petunia 3.

TABLE 2. Grouping of morphological characteristics based on the average linkage character

Step	Group combination		Coefficient similarity
	Group 1	Group 2	
1	11	12	1.000
2	9	10	1.000
3	7	8	.958

Continued on next page

TABLE 2. Continued Group combination

Step	Group 1	Group 2	Coefficient similarity
4	5	6	.954
5	3	4	.840
6	1	2	.798
7	1	3	.618
8	1	7	.501
9	9	11	.407
10	1	5	.367
11	1	9	.209

Note:

1. Grouped was joined together based on the value of the Coefficient of similarity.
2. The numbers listed in the column for group 1 and group 2 indicate the OUT code being compared.

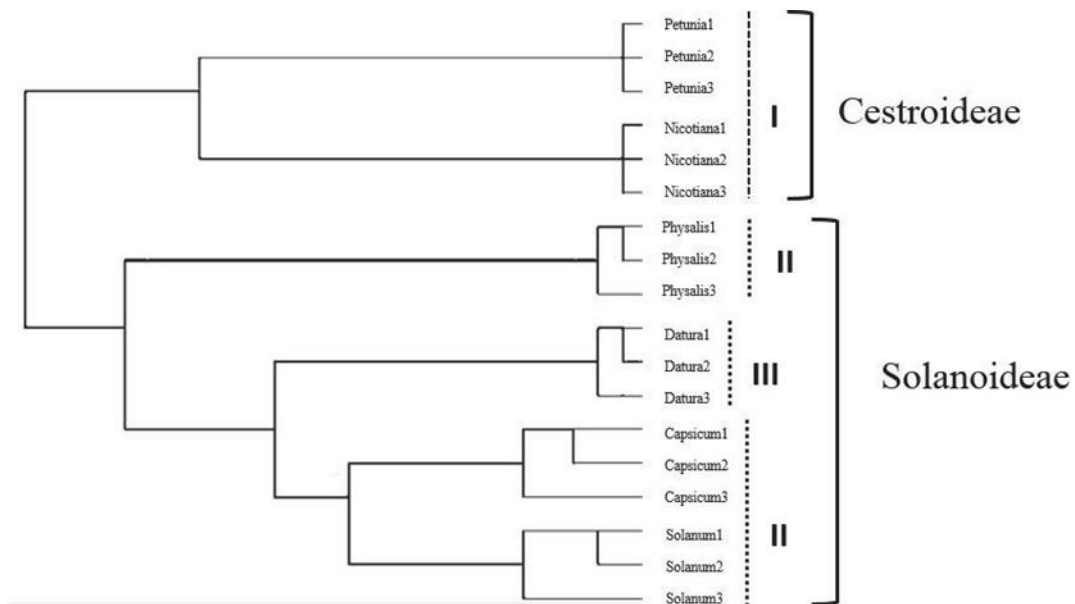


FIGURE 1. Dendrogram of phenetic relationship between 6 genera of the Solanaceae family

The dendrogram in Figure 1 separates several genera based on the similarity of morphological characters possessed by each sample until a group of genera was obtained that completely separates or clumps with other genera groups. The formation of groups between existing genera according to the level of similarity of morphological characters expressed in the similarity coefficient values listed in Table 1. The similarity coefficient showed the ratio between the characters that were shared by the total compared characters [14]. The more common characters that were shared, the greater the value of the similarity scale, the closer the relationship. This relationship was indicated by the many similarities that they have in common [15]. Therefore, it was very clear if the group consisting of various varieties formed first to form two branches (groups A and B) has the smallest similarity value of 18.4%, while the group formed in a group of one genus has the highest similarity value of 100% because it had the highest similarity value of 100%.

TABLE 3. Main Components Values of the character genera Solanum, Capsicum, Physalis, Datura, Nicotiana, and Petunia from the family Solanaceae

Character	1	2	Component 3	4	5
Habitus	.669	.576	.295	.358	.041
Height	.630	.438	.554	.054	.261
Stem color	.749	.617	.048	.201	.119
Stem surface	.131	.729	.310	.535	.242
Stem shape	.626	.333	.250	.324	.555
Stem lenght	.398	.559	.527	.032	.320
Stem diameter	.725	.488	.459	.077	.043
Phylotaxis	.226	.296	.901	.095	.168
Leaf margin	.146	.778	.082	.207	.550
Width of the leaf	.762	.478	.213	.086	.337
Length of the leaf	.757	.406	.117	.325	.182
Surface of the leaf	.131	.729	.310	.535	.242
Leaf texture	.384	.201	.845	.237	.172
Top of the leaf	.740	.500	.006	.402	.292
Bottom of the leaf	.740	.500	.006	.402	.292
Leaf stalk length	.266	.541	.710	.327	.099
Flower bud length	.703	.265	.385	.366	.051
Leaf color	.693	.693	.079	.057	.312
Flower type	.293	.834	.143	.386	.201
Flower shape	.278	.478	.539	.581	.246
Calix color	.411	.322	.636	.556	.062
Corolla color	.431	.342	.743	.378	.009
Pistil color	.669	.242	.554	.427	.033

Notes:

1. The value in red is a character value that had a value more than 0.750 which means that the character had a very strong influence in classifying genera and determining the average character of the Solanaceae family
2. Values in bold was character values that had a value of 0.500 X < 0.750, which means that the character had enough influence in the grouping.

In Table 3 the components of the PCA matrix, there was 5 main components of characters that played a major role in separating 6 groups of genera from the Solanaceae family. Component 1 is the character that played the most important role in separating the varietal groups. While component 2 was the first supporting character component from component 1, component 3 was the second supporting character component from component 1, component 4 was the third supporting character component from component 1, and component 5 is the fourth supporting character component from component 1. The red value in the table is a character value that had a value of 0.750 which means that the character had a very strong influence in the grouping of 6 genera of the Solanaceae family. While the character value of $0.500 < X < 0.750$ means that the character had enough influence in the grouping, and the character value < 0.500 means that the character was less influential in the grouping. In component 1, the most influential characters (had a value of 0.750) include: leaf width, leaf length, and anther color. In the component 2 characters that had a big influence was the edges of the leaves and the type of flowers. Characters that had a big influence on component 3 are leaf structure and leaf texture. While the characters that had a major influence on component 4 and component 5 do not exist.

The results of the analysis described that there were differences and similarities between the six genera of the Solanaceae family. The morphological similarity of an organism had a relative similarity value because the characteristics did not have a significant similarity value, so it was very important to identify an organism. For example, in the genus *Nicotiana* and *Petunia*, which have similarities in the character of the sessile petiole, or in the genus *Datura*, which has black stems.

From analysis using the phenetic method, a dendrogram could describe the close relationship between genera in the Solanaceae family. The results of Figure 1 showed that there are varieties that was grouped or separated based on the similarity index value (table 1) and agglomerative coefficient (table 2). Agglomerative coefficients were used to estimate the level of differences between species or populations [16].

From the dendrogram, it could be seen that the genus *Petunia* and *Nicotiana* form group A with an agglomerative coefficient 0.407. While the genera *Physalis*, *Datura*, *Capsicum*, and *Solanum* form group B with an agglomerative coefficient value 0.367. Group A and group B separated from each other with an agglomerative coefficient 0.209. The grouping of the genus *Petunia* and *Nicotiana* separates from the other 4 genera because it had 1 character that is different from the other four genera, namely the petiole character. It means genus *Petunia* and *Nicotiana* are further related to the other 4 genera.

In the dendrogram, it could be seen that the genus *Physalis* forms a group with the genera *Datura*, *Capsicum*, and *Solanum* with an agglomerative coefficient value 0.367. This means that the genera *Physalis*, *Datura*, *Capsicum*, and *Solanum* have a closer relationship than the genera *Petunia* and *Nicotiana*. However, the dendrogram also shows that the genus *Capsicum* and *Solanum* form another group that is separate from *Datura* and *Physalis*. This is because the genus *Solanum* had more similarities in morphological characters that were shared with *Capsicum* when compared to *Datura* and *Physalis*. In other words, the genus *Solanum* had close taxonomic distance to the genus *Capsicum* when compared to the genera *Datura* and *Physalis*.

From the 30 morphological characters used in this study, 6 characters were common characters, while the other 24 characters are special characters belonging to the genus in the Solanaceae family. The existence of these 24 special characters caused diversity between 6 genera in the Solanaceae family. The 24 special characters were analyzed by PCA. The results of PCA analysis showed that the highest value of character components was found in leaf characters. From table 3, it could be seen that the characters in component 1, namely the characters that play the most major role in separating the group of six genera from the Solanaceae family and which have a value 0.750 are 3 characters, namely 2 leaf characters and 1 flower character. The character of the leaf is leaf width and leaf length, while the flower character is the anther color. Component 2 shows the most important character in separating the genus group from the Solanaceae family and had a value 0.750 2 times, namely 1 leaf character and 1 flower character. The character of the leaf is the edge of the leaf, while the flower included the type of flower. Component 3 showed the characters that had the most role in separating groups of six genera from the Solanaceae family and those with a value 0.750 are 2 leaf characters. The leaf characters included leaf structure and leaf texture.

From the results of PCA analysis on component 1, it showed that the highest component value and has a value 0.750 was found in the flower character that was the anther color character with a value 0.783 (Table 3), but in components 2 and 3 the number of leaf characters which has a value 0.750 more. The highest value and the number of occurrences contained in the leaf character indicated that the leaf character had the greatest influence on the grouping of the six genera of the Solanaceae family. This is supported by the statement of [17] that leaf character is very important in the identification of palms and several other plants of the genus *Azadirachata* with Meia, Sorbus I with Pyrus, and others. In table 3, it could be seen that the value of the first component in the leaf character with a value of 0.750 contains 4 characters. From the PCA results, the most influential leaf characters were leaf structure (0.901), leaf margin (0.778), leaf width (0.762), leaf length (0.751), and leaf texture (0.845) with similarity values > 0.750 . These results are supported by research conducted by [18] that leaf

morphological characters can be used for identification and grouping of Mango (*Mangifera indica* L.) plants.

In addition, table 3 showed that the component value of the flower character with a value 0.750 contains 2 characters. The flower characters that affected the grouping are the anther color character (0.783) and the flower type character (0.834). Based on the results of research using morphological characters (phenotypic characters) in this study, it showed that morphological characters were good for identifying and analyzing plant diversity in the Solanaceae family and could determine the closeness of their relationships. Shape or morphological characters, in general, were the best data to define a taxonomy. According to Stace (1981) and Hardiyanto et al. (20017) a good taxonomic delimitation was conducted by using characters that was easy to see, and not by hidden characters. For that reason, morphological characters could be used as a source of taxonomic evidence. Except for that, the morphological descriptions of several genera from the Solanaceae family that have been obtained can be used as identification keys that are practical and useful for revealing the identity (identity) of a plant [20].

4. CONCLUSION

The relationship between several genera of the Solanaceae family in terms of morphological characters and dendrogram stated that the groups of the genus *Nicotiana* and *Petunia* were separated from the group consisting of the genera *Physalis*, *Datura*, *Capsicum*, and *Solanum*. Characters that can distinguish and influence the grouping between several genera of the Solanaceae family were the anther color, leaf margin, flower type, leaf structure, and leaf texture.

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