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Variation and Non-formal Classification of Indonesian Eggplant (*Solanum melongena* L.) Accessions Based on Macro and Micro-morphological Characters

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ABSTRACT

Indonesia has a variety of eggplant germplasms and is considered as one of the largest producing countries in the world. The study was conducted to assess the variation of 21 accessions and 2 commercial cultivars of eggplant from Indonesia based on 30 macromorphological and 8 leaves micromorphological characters. Cluster analysis was conducted by UPGMA (Unweighted Pair Group Methods with Arithmetic averages) to create a dendrogram and construct eggplants grouping. PCA (Principal Component Analysis) was also performed to define the role of each character in the group by using MVSP (Multivariate Statistical Program) v.3.1 software. Results showed that eggplant accessions have macromorphological variation in fruit curvature, fruit shape, fruit apex, and fruit color, as well as leaves micromorphological characters such as the epidermal wall, trichome shape, and stomata type. Dendrogram based on macromorphological characters divided the accessions into 2 groups: curved and non-curved fruit groups. The non-curved fruit group divided into more spiny and less spiny leaves sub groups. Dendrogram based on leaves micromorphological characters divided the accessions into 2 groups based on the epidermal wall, trichome shape, and stomata type. Eggplant grouping doesn't occur based on the origin of collection areas indicating that its variability isn't affected by the environment.

INTRODUCTION

Eggplant (*Solanum melongena* L.) is a member of genus *Solanum* and becomes the most important vegetable crop in the world after tomato (Knapp, Vorontsova, & Prohens, 2013; Samuels, 2015). The eggplant fruits have become widely used as a food, food supplement, and the vegetative plant parts like peduncles, roots, stalks, and leaves are used for curing diverse ailments such as abscesses, intestinal haemorrhages, and toothache (Daunay & Janick, 2007; Meyer, Bamshad, Fuller, & Litt, 2014; Scorsatto et al., 2019). This plant has been cultivated from wild forms since a long time ago in various continent like Africa, Europe, America and Asia (Weese & Bohs, 2010), with thousands of localized landraces and many commercial cultivars (Samuels, 2015).

In Asia continent, the greatest genetic diversity of eggplant is found in South and Southeast Asia (Samuels, 2015) and India or Indo-China is considered to be the center of eggplant diversity (Behera et al., 2006). Eggplant is warm season crop mostly cultivated in tropical and subtropical regions of the world. The distribution of *S. melongena* is cosmopolitan by abiotic factors such as water flow and biotic factors by human as a vegetable crop and cultivation (Daunay & Janick, 2007). The eggplant was domesticated in India, southern China, and the Malay islands, including Indonesia, Malaysia, the Philippines, and other countries in the Malay

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Peninsula and Malay Archipelago (Meyer, Karol, Little, Nee, & Litt, 2012).

Indonesia is one of the largest eggplants producing countries after China, India, Egypt, Turkey, Iran, and Japan (FAO, 2016). Indonesia has a diversity of eggplant germplasm, the database involves more than 200 accessions collected by The Indonesian Center for Agricultural Biotechnology and Genetic Resources Research and Development (ICABIOGRAD) gene bank and 78 eggplant cultivars have been registered in the information system of plant varieties protection of the Indonesian Ministry of Agriculture (Ditbenih, 2017). Eggplant varieties obtained from domestication, mutation, natural intercrossing, human selection and hybridization have brought an extensive genetic diversity to improve eggplant varieties for sustainable production and adaptation to climate change challenges (Sękara, Cebula, & Kunicki, 2007).

Screening of available accessions for desirable traits and morphological description of the accessions are key issues for the breeding processes (Kaushik, Prohens, Vilanova, Gramazio, & Plazas, 2016). Characterization using conventional morphological descriptors has been proven useful for describing and establishing relationships among local eggplant genetic resources (Plazas et al., 2014). Morphological characters have been the major criteria for classification, although the other characters such as anatomical features, phytochemical contents, embryology, cytology, and molecular features have played important role in plant classification (Singh, 2010). The classification based on morphological feature is also a common reference that contributes specifically to plant groupings.

Morphological characters are divided into macromorphological and micromorphological characters (Stace, 1991). Study of macro-morphological characters of eggplant conducted by Kumar et al. (2008) show the diversity of India accessions of eggplant. Begum, Islam, Rasul, Mian, & Hossain (2013) study also reported groping of Bangladesh eggplant accessions based on macromorphological characters for selecting genotypes as parents for crossing. Micromorphological is characters of plant organs, such as very small seed skin, epidermis on leaves, petals trichomes and papillae (Singh, 2010). Micromorphological characters is important for supporting plant classification. This study used a combination of macromorphological and some micromorphological characters of eggplant leaf epidermis, such as distribution and type of trichomes, the anticlinal walls of epidermal cells, also the type and distribution of stomata. Leaf epidermis characters are useful in distinguishing the *Solanum* species (Nurit-Silva, Costa-Silva, Basílio, & de Fátima Agra, 2012; Sampaio, Araújo, & Agra, 2014).

The classification of cultivated plants is different from the wild ones, it's usually known as an non-formal classification which is set in The International Code of Botanical Nomenclature (ICBN). The categories which are based on the species level are cultivar, group, graft chimaera and hybrid (Hetterscheid & Brandenburg, 1995). Systematic groups in cultivated plants are called culton which consists of categories of cultivars and groups of cultivar (Spooner, Hetterscheid, van den Berg, & Brandenburg, 2003). Regarding the importance of eggplant as a vegetable crop, there are still limited informations on the morphology of the eggplant and moreover there is no study on leaf epidermal of eggplant accessions that has been previously carried out. Therefore, the objective of this research was to determine variations and non-formal intraspesific classification of the Indonesian eggplant accessions based on macro and micro-morphological characters.

MATERIALS AND METHODS

The research was conducted from December 2017 to March 2018. A total of 21 accessions and 2 commercial cultivars of eggplant were used in this study. Eggplant accessions collected from different provinces in Indonesia, were obtained from The Indonesian Center for Agricultural Biotechnology Research and Genetic Resources and Development (ICABIOGRAD), Bogor. The accession number, local name, and origin of samples are listed in Table 1. All of eggplant seeds were soaked in warm water for ± 60 minutes and then planted in the media of soil and compost in a ratio of 1:1 for germination. The newly growing plants were then maintained for 4-5 weeks. The eggplants were transplanted under greenhouse conditions at Pusat Antar Universitas (PAU) Universitas Gadjah Mada for 4-5 months until they produced fruits. *Macro and micro-morphological o*bservations were conducted in the Laboratory of Plant Systematics and Laboratory of Plant Structure & Development, Faculty of Biology, *Universitas* Gadjah Mada.

Table 1. List of Indonesian eggplant accessions used in the study

No.	A.N.	Local name	Code	Origin
1	9	*Terong gelatik*	K14	Pandeglang, Banten, West Java
2	32	*Terong butuh*	K17	Serang, Banten, West Java
3	49	*Terong ungu*	K116	Bogor, West Java
4	68	*Terong gelatik; lalap*	K32	Ciamis, West Java
5	94	*Terong gelatik*	K20	Gunungkidul, Yogyakarta
6	95	*Terong*	K62	Gunungkidul, Yogyakarta
7	156	*Terong gelatik kecil*	K13	Cilacap, Central Java
8	181	*Terong telunjuk*	K88	Deli Serdang, North Sumatera
9	199	*Terong kecap*	K90	Deli Serdang, North Sumatera
10	217	*Terong hijau*	K178	Tanah Karo, North Sumatera
11	240	*Terong manggis*	K110	Padang Pariaman, West Sumatera
12	257	*Terong talang*	K69	Ogan Ilir, South Sumatera
13	267	*Terong apel*	K50	Muara Enim, South Sumatera
14	271	*Terong lalap rebus*	K83	Ogan Komering Ulu, South Sumatera
15	288	*Terong kercil*	K135	Muara Enim, South Sumatera
16	606	*Terong gading*	K118	Kubu Raya, West Kalimantan
17	615	*Terong pinang*	K57	Singkawang, West Kalimantan
18	637	*Terong asam*	K51	Bengkayang, West Kalimantan
19	759	*Faimatak*	K82	Belu, West Nusa Tenggara
20	801	*Poki-poki*	K93	Minahasa, North Sulawesi
21	150	*Terong jawa*	K18	Cilacap, Central Java
22	-	*Terong ungu*	TU	Commercial cultivar
23	-	*Kania* F_1	KF1	Commercial cultivar

Remarks: A.N. = accession number

Data was analyzed descriptively and numerically. The descriptive analysis aimed to illustrate the plant morphology based on each characters. The step for analysis was to put a score for each character that had been observed and measured. All plants were observed using 30 morphological characters based on the descriptor list (Table 2) adopted from the International Board for Plant Genetic Resources (Lester & Niakan, 1988). Macromorphological characters were observed starting from seedling stages (4-5 weeks old plants), vegetative characters (leaf and stem) and reproductive characters (flower, fruit, seed).

The leaf epidermis (micromorphological) observation procedure was carried out based on Sampaio, Araújo, & Agra (2014), paradermal sections of fifth leaf from the terminal shoot were soaked for 2 minutes by commercial sodium hypochlorite, neutralized with 0.2% acetic acid for 30 seconds and the leaves were rinsed with distilled water. The leaves underwent staining process using 1% safranin by add safranin solution, then absorbed by tissue paper and mounted in 50% glycerinated gelatin. The observations and photomicrographs were performed by light microscope connected to the optilab. The observed leaf epidermis characters included the shape of anticlinal epidermal wall, distribution of stomata, type of stomata, leaf trichome (grandullar and non-grandular) at adaxial and abaxial side (Table 3).

All macromorphological and micromorphological characters were scored as binary data (0 for absent or 1 for present) and multistate data based on character coding eg. 0 (green), 1 (white), 2 (purple), etc. Cluster analysis was conducted by UPGMA (Unweighted Pair Group Methods with Arithmetic averages) using Average Distance method analysis to create a dendrogram with MVSP (Multivariate Statistical Program) v.3.1 software (KCS, 2007). PCA (Principal Component Analysis) was also performed to defined the role of each morphological character in grouping of accessions in a scatter plot diagram.

RESULTS AND DISCUSSION

Morphological Variation

The evaluated eggplant accessions show variation in terms of macromorphological characters (Table 2). The variation appears on the characters of seedling, stem, leaf, flower, and fruits. In seedling stage, there are two variations in anthocyanin coloration at hypocotyl i.e. absent and present. Variation on the stem surface was related with the existence of anthocyanin coloration, which are sometimes present or absent.

Table 2. List of macromorphological character of eggplant accessions

No.	Accession	Macromorphological characters							
		Cotyledon colour	Anthocyanin coloration of hypocotyl	Plant growth habit	Anthocyanin coloration of stem	Leaf stem colour	Leaf colour (adaxial)*	Leaf blade lobing	Leaf tip
1	*Terong gelatik* (K14)	Green	Present	Erect	Present	Purplish green	NN137A	Intermediate	Acute
2	*Terong butuh* (K17)	Green	Present	Erect	Present	Purplish green	137B	Intermediate	Acute
3	*Terong ungu* (K116)	Green	Present	Erect	Present	Purplish green	137B	Intermediate	Acute
4	*Terong lalap* (K32)	Green	Absent	Erect	Absent	Green	137A	Intermediate	Acute
5	*Terong gelatik* (K20)	Green	Absent	Erect	Absent	Green	137B	Intermediate	Acute
6	*Terong* (K62)	Green	Absent	Erect	Absent	Green	137B	Intermediate	Acute
7	*Terong gelatik kecil* (K13)	Green	Present	Erect	Present	Purplish green	NN137A	Intermediate	Acute
8	*Terong telunjuk* (K88)	Green	Present	Erect	Present	Purplish green	137B	Intermediate	Acute
9	*Terong kecap* (K90)	Green	Present	Erect	Present	Purplish green	137B	Intermediate	Acute
10	*Terong hijau* (K178)	Green	Present	Erect	Present	Purplish green	NN137A	Intermediate	Acute
11	*Terong manggis* (K110)	Green	Present	Erect	Present	Purplish green	137A	Intermediate	Obtuse
12	*Terong talang* (K69)	Green	Present	Erect	Present	Purplish green	137A	Intermediate	Obtuse
13	*Terong apel* (K50)	Green	Present	Erect	Present	Purplish green	137B	Intermediate	Acute
14	*Terong lalap rebus* (K83)	Green	Absent	Erect	Absent	Green	137A	Intermediate	Acute
15	*Terong kercil* (K135)	Green	Present	Erect	Present	Purplish green	137B	Intermediate	Acute
16	*Terong gading* (K118)	Green	Absent	Erect	Absent	Green	137A	Intermediate	Acute
17	*Terong pinang* (K57)	Green	Present	Erect	Present	Purplish green	137B	Intermediate	Acute
18	*Terong asam* (K51)	Green	Present	Erect	Present	Purplish green	137B	Intermediate	Obtuse
19	*Faimatak* (K82)	Green	Absent	Erect	Absent	Green	137B	Intermediate	Obtuse
20	*Poki-poki* (K93)	Green	Present	Erect	Present	Purplish green	NN137A	Intermediate	Acute
21	*Terong jawa* (K18)	Green	Present	Erect	Present	Purplish green	137A	Intermediate	Acute
22	*Terong ungu* (TU)	Green	Present	Erect	Present	Violet	137C	Intermediate	Acute
23	*Kania* F_1 (KF1)	Green	Absent	Erect	Absent	Green	137A	Intermediate	Acute

Remarks: *using 6th Royal Horticulture Society (RHS) colour chart (2015)

Table 2. *(continued)*

No.	Accession	Macromorphological characters							
		Leaf prickles	Leaf lobe tip	Leaf base	Number of flowers per inflorescence	Corolla colour	Number of corolla	Number of calyx	Leaf calyx prickles
1	*Terong gelatik* (K14)	Very few	Acuminate	Rounded	More than three	Dark violet	More than five	More than five	Absent
2	*Terong butuh* (K17)	Few	Rounded	Rounded	More than three	Light violet	More than five	More than five	Absent
3	*Terong ungu* (K116)	Few	Rounded	Emarginate	One to three	Light violet	More than five	More than five	Present
4	*Terong lalap* (K32)	Very few	Obtuse	Acute	One to three	White	More than five	More than five	Absent
5	*Terong gelatik* (K20)	None	Rounded	Rounded	More than three	White	More than five	More than five	Absent
6	*Terong* (K62)	None	Rounded	Rounded	More than three	Dark violet	Five	Five	Absent
7	*Terong gelatik kecil* (K13)	Very few	Obtuse	Rounded	One to three	Light violet	More than five	More than five	Absent
8	*Terong telunjuk* (K88)	Very few	Rounded	Emarginate	One to three	Dark violet	Five	Five	Absent
9	*Terong kecap* (K90)	Very few	Rounded	Emarginate	More than three	Dark violet	Five	Five	Absent
10	*Terong hijau* (K178)	Very many	Rounded	Rounded	More than three	Light violet	More than five	More than five	Present
11	*Terong manggis* (K110)	Very few	Rounded	Emarginate	More than three	Light violet	More than five	More than five	Absent
12	*Terong talang* (K69)	None	Rounded	Emarginate	One to three	Dark violet	More than five	More than five	Absent
13	*Terong apel* (K50)	Few	Rounded	Rounded	More than three	Dark violet	More than five	More than five	Absent
14	*Terong lalap rebus* (K83)	Few	Obtuse	Emarginate	One to three	Dark violet	More than five	More than five	Absent
15	*Terong kercil* (K135)	Very few	Obtuse	Acute	One to three	Light violet	More than five	More than five	Absent
16	*Terong gading* (K118)	Few	Rounded	Emarginate	More than three	Dark violet	More than five	More than five	Absent
17	*Terong pinang* (K57)	Very few	Rounded	Rounded	More than three	Dark violet	More than five	More than five	Absent
18	*Terong asam* (K51)	Very few	Rounded	Rounded	More than three	Light violet	Five	Five	Absent
19	*Faimatak* (K82)	Few	Rounded	Emarginate	More than three	White	Five	Five	Absent
20	*Poki-poki* (K93)	Few	Rounded	Rounded	More than three	Dark violet	Five	Five	Absent
21	*Terong jawa* (K18)	Very few	Rounded	Emarginate	More than three	Light violet	More than five	More than five	Absent
22	*Terong ungu* (TU)	Very few	Obtuse	Acute	One to three	Light violet	More than five	More than five	Absent
23	*Kania* F_1 (KF1)	Very few	Obtuse	Rounded	More than three	Light violet	More than five	More than five	Absent

Table 2. *(continued)*

No.	Accession	Macromorphological Characters							
		Fruit shape	Fruit length: breadth ratio	Fruit curvature	Fruit position	Fruit apex	Fruit colour at commercial ripeness	Fruit colour at physiological ripeness	Fruit glossiness
1	*Terong gelatik* (K14)	Globular	Broader than long	None	Pendant	Flattened	Green	Orange	Present
2	*Terong butuh* (K17)	Obovate	Slightly longer than broad	None	Pendant	Indented	Violet	Yellowish purple	Present
3	*Terong ungu* (K116)	Ellipsoid	Three times as long as broad	Slightly curved	Pendant	Rounded	Violet	Yellow	Absent
4	*Terong lalap* (K32)	Globular	Broader than long	None	Pendant	Flattened	Green	Orange	Present
5	*Terong gelatik* (K20)	Globular	Broader than long	None	Pendant	Flattened	Green	Orange	Present
6	*Terong* (K62)	Globular	As long as broad	None	Pendant	Flattened	White	Yellow	Present
7	*Terong gelatik kecil* (K13)	Globular	As long as broad	None	Pendant	Flattened	White	Orange	Absent
8	*Terong telunjuk* (K88)	Cilindrical	Several timesas long as broad	Curved	Pendant	Pointed	Green	Orange	Absent
9	*Terong kecap* (K90)	Ovoid	Slightly longer than broad	None	Pendant	Rounded	Green	Orange	Absent
10	*Terong hijau* (K178)	Obovate	Slightly longer than broad	None	Pendant	Indented	Green	Yellow	Absent
11	*Terong manggis* (K110)	Globular	Broader than long	None	Pendant	Flattened	Violet	Orange	Present
12	*Terong talang* (K69)	Obovate	Twice as long as broad	None	Pendant	Indented	Violet	Yellowish purple	Absent
13	*Terong apel* (K50)	Globular	Broader than long	None	Pendant	Rounded	White	Orange	Absent
14	*Terong lalap rebus* (K83)	Globular	As long as broad	None	Pendant	Flattened	Green	Orange	Absent
15	*Terong kercil* (K135)	Globular	Broader than long	None	Pendant	Flattened	Violet	Orange	Present
16	*Terong gading* (K118)	Cilindrical	Several timesas long as broad	None	Pendant	Pointed	White	Orange	Absent
17	*Terong pinang* (K57)	Obovate	Slightly longer than broad	None	Pendant	Rounded	Green	Orange	Absent
18	*Terong asam* (K51)	Globular	As long as broad	None	Pendant	Rounded	White	Yellow	Absent
19	*Faimatak* (K82)	Ovoid	Slightly longer than broad	None	Pendant	Rounded	Green	Orange	Absent
20	*Poki-poki* (K93)	Cilindrical	Three times as long as broad	Curved	Pendant	Rounded	Green	Orange	Present
21	*Terong jawa* (K18)	Obovate	Twice as long as broad	None	Pendant	Indented	Violet	Yellowish purple	Absent
22	*Terong ungu* (TU)	Cilindrical	Several timesas long as broad	Curved	Pendant	Rounded	Violet	Yellowish purple	Present
23	*Kania* F_1 (KF1)	Cilindrical	Several timesas long as broad	Curved	Pendant	Pointed	White	Yellow	Absent

Table 2. *(continued)*

No.	Accession	Macromorphological characters					
		Fruit stripes	**Fruit patches**	**Fruit flesh density**	**Fruit colour of flesh**	**Fruit cross section**	**Seed colour***
1	*Terong gelatik* (K14)	Absent	Present	Dense	Greenish white	Few grooves	164C
2	*Terong butuh* (K17)	Present	Absent	Dense	Greenish white	Many grooves	164B
3	*Terong ungu* (K116)	Present	Absent	Spongy	White	Circular, no grooves	164C
4	*Terong lalap* (K32)	Absent	Present	Dense	Greenish white	Circular, no grooves	164B
5	*Terong gelatik* (K20)	Absent	Present	Dense	White	Circular, no grooves	164B
6	*Terong* (K62)	Absent	Absent	Dense	Greenish white	Circular, no grooves	164B
7	*Terong gelatik kecil* (K13)	Absent	Present	Dense	Greenish white	Circular, no grooves	164B
8	*Terong telunjuk* (K88)	Present	Absent	Spongy	Greenish white	Circular, no grooves	164B
9	*Terong kecap* (K90)	Absent	Present	Dense	Greenish white	Circular, no grooves	161B
10	*Terong hijau* (K178)	Absent	Present	Dense	Greenish white	Circular, no grooves	164B
11	*Terong manggis* (K110)	Absent	Absent	Dense	White	Circular, no grooves	164B
12	*Terong talang* (K69)	Present	Absent	Spongy	Greenish white	Circular, no grooves	161B
13	*Terong apel* (K50)	Absent	Absent	Dense	Greenish white	Circular, no grooves	164B
14	*Terong lalap rebus* (K83)	Absent	Present	Dense	Greenish white	Circular, no grooves	161B
15	*Terong kercil* (K135)	Absent	Absent	Dense	White	Circular, no grooves	164B
16	*Terong gading* (K118)	Absent	Absent	Spongy	White	Circular, no grooves	164C
17	*Terong pinang* (K57)	Absent	Present	Spongy	White	Circular, no grooves	164B
18	*Terong asam* (K51)	Absent	Absent	Dense	Greenish white	Circular, no grooves	164B
19	*Faimatak* (K82)	Absent	Present	Dense	White	Circular, no grooves	164C
20	*Poki-poki* (K93)	Absent	Present	Dense	White	Circular, no grooves	164B
21	*Terong jawa* (K18)	Present	Absent	Spongy	Greenish white	Circular, no grooves	161B
22	*Terong ungu* (TU)	Absent	Absent	Spongy	White	Circular, no grooves	164B
23	*Kania* F_1 (KF1)	Absent	Absent	Spongy	White	Circular, no grooves	164B

Remarks: *using 6th Royal Horticulture Society (RHS) colour chart (2015)

Variations among the evaluated eggplant accessions were also observed on leaf petiole color, leaf color, leaf spines, leaf tip shape, leaf base shape, and leaf lobe tip. Leaf petiole color has three variations, i.e. green, purple-green, and purple. Some accessions have leaves with many spines, yet others have fewer. The spines have a function to protect the plants from herbivors that may damage the plant organ (War et al., 2012). The variation of the flower was observed on corolla color (white, light purple, dark purple) and number of flowers per inflorescence (1-3 or more than 3 flowers per inflorescence). Based on Kaushik, Prohens, Vilanova, Gramazio, & Plazas (2016) in eggplant breeding, the number of large flowers per inflorescences will be reduced in order to increase the uniformity of the fruit. The most distinguished characters among eggplant accessions are fruit appearance. The fruit variation is resulted from a characteristics of fruit shape, fruit length:breadth ratio, curved on fruit, fruit tip, and fruit skin color (Fig. 1). Fruit skin color of eggplant are divided into commercially ripe fruit with varied color (purple, white, green) mostly accumulate purple anthocyanins and physiologycally ripe fruits caused by biosynthesis orange-colored or caretenoid pigments (Liu et al., 2018; Barchi et al., 2019).

The micromorphological data (Table 3) shows variation of leaf surface features (Fig. 2). The shape of the anticlinal walls of epidermal cells in surfaces of adaxial and abaxial were varied from straight to curved. It was clearly observed on *Terong Ungu* (TU)**,** *Terong Apel* (K50) and *Terong Kecap* (K90). The shape of walls on epidermal cells at the adaxial and abaxial surface was straight to curved, curved and sinuous, and they are dominant on the leaf surface. The shape of the curved wall is a common shape found in genus *Solanum* (Nurit-Silva & de Fátima Agra, 2011).

The characteristic of non-glandular trichome are sessile stellate, stalked stellate, unicellular hair and peltate. Stellate trichome is common found in all eggplant accessions and cultivars. The glandular trichome is not varied among the tested accessions. The amphistomatic patterns of stomata distribution were found in the leaves of all tested accessions. These patterns are resulted as an adaptation to increase the rate of photosynthesis in natural environment (Sampaio, Araújo, & Agra, 2014). The two different types of stomata were recognized on leaf epidermis, that is anisocytic and anomocytic. the anomocytic type was predominant at the abaxial surface whereas the anisocytic type was predominant at the adaxial surface ofthe leaf (Nurit-Silva, Costa-Silva, Basílio, & de Fátima Agra, 2012).

Non-formal Classification

The dendrogram (Fig. 3) shows that *S. melongena* is divided into 2 main groups based on 30 macromorphological characters. PCA analysis shows that the grouping was based on the combination of several characters such as the shape of the fruit, the ratio of fruit length:breadth, the curve of the fruit and leaf spines (Fig. 4). Group I consists of all accessions with average distance value of 0.557 that have curved fruit, the fruit length:breadth ratio are three times or more than the broad and the shape of fruit are ellipsoid or cylindrical. This group consisted of 6 accessions, i.e. K39, K116, K88, K118, KF1 and TU. Group II is the accession that has non-curved fruit, fruit length:breadth ratio are longer or the same as the broad and the shape of fruit are globular, ovoid or obovate. This second group composes of 17 accessions that divided into 2 sub-groups; II.A and II.B with average distance value of 0.990. Group II.A was composed of the accession *Terong Hijau* (K178) which has total leaf spines more than 20. While group II.B was composed of 16 accessions i.e. K18, K69, K17, K14, K82, K90, K57, K62, K110, K51, K135, K50, K83, K32, K20, K13 that have lesser leaf spine (total of spine 1-5).

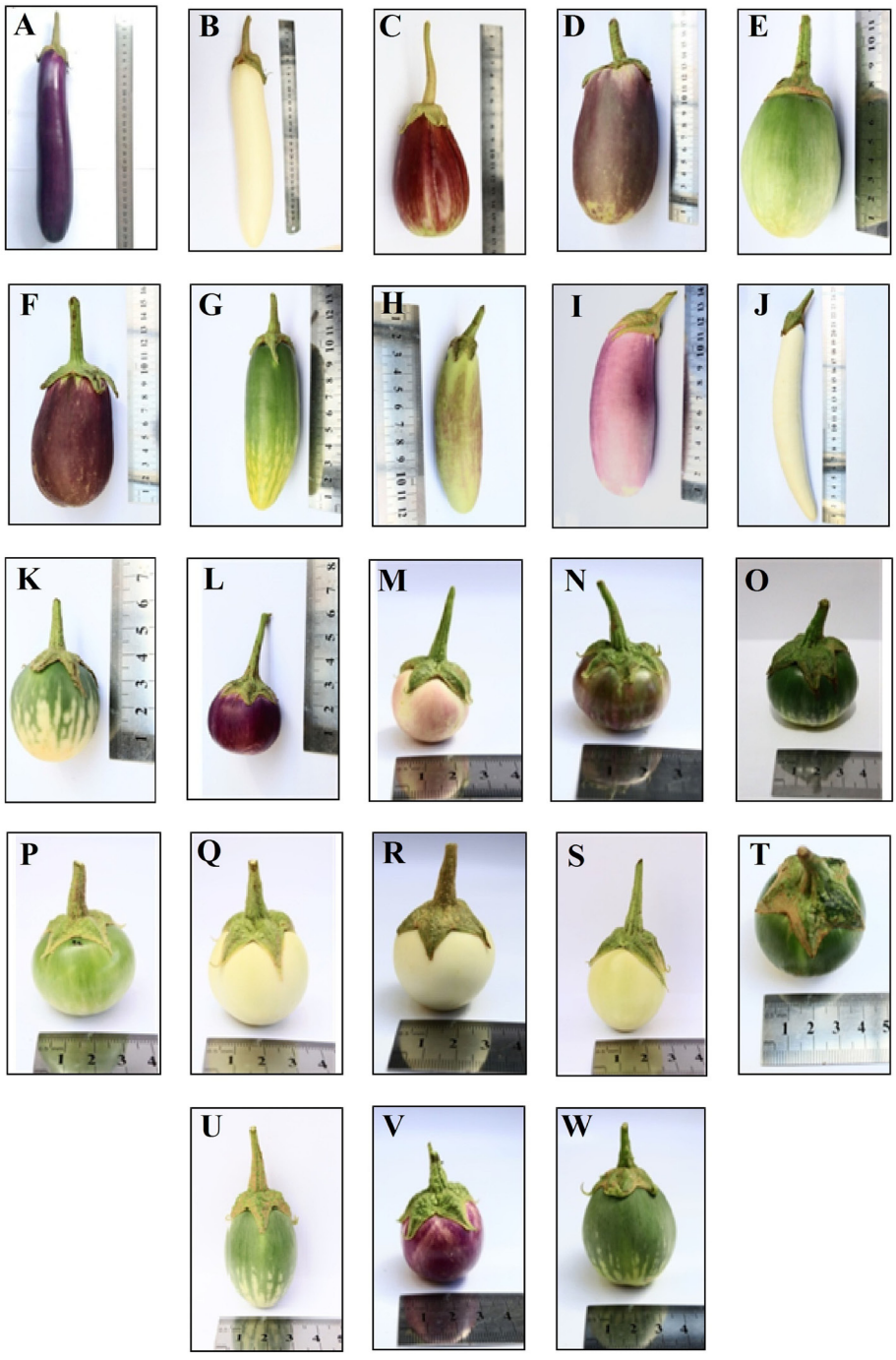
Intraspesific classification in cultivated plant based on morphological characters are considered appropriate for species which has great phenotypic variations. Earlier studies by Begum, Islam, Rasul, Mian, & Hossain (2013) showed that 92 eggplant genotypes from Bangladesh were grouped into ten different groups with the role of days to first harvested-fruit and days to first flowering indicating the important component of genetic divergence, Cakir, Balkaya, Saribas, & Kandemir (2017) was divided 42 Turkish eggpalnts into 9 group based on fruit characters, i.e. fruit shape, fruit curvature, fruit apex shape, fruit length and fruit diameter. Purnomo, Faizah, & Daryono (2017) and Sari, Purnomo, Daryono, Suryadiantina, & Setyowati (2016) also used morphological characters to create some group of cultivated plants. Based on macromorphological characters used in the study, *S.melongena* accessions of Indonesia can be divided into 2 groups.

Table 3. List of micromorphological character of eggplant accessions

No.	Accession	Anticlinal cell walls		Ditribution of stomata	Grandullar trichome		Stellate sessile trichome (non-grandullar)	
		Adaxial	Abaxial		Adaxial	Abaxial	Adaxial	Abaxial
1	*Terong gelatik* (K14)	Curved	Sinous	*Hypostomatic*	Present	Present	Present	Present
2	*Terong butuh* (K17)	Straight to curved	Sinous	*Hypostomatic*	Present	Present	Present	Present
3	*Terong ungu* (K116)	Curved	Sinous	*Hypostomatic*	Present	Present	Present	Present
4	*Terong lalap* (K32)	Curved	Curved	*Hypostomatic*	Present	Present	Present	Present
5	*Terong gelatik* (K20)	Curved	Sinous	*Hypostomatic*	Present	Present	Present	Present
6	*Terong* (K62)	Curved	Sinous	*Hypostomatic*	Present	Present	Present	Present
7	*Terong gelatik kecil* (K13)	Curved	Sinous	*Hypostomatic*	Present	Present	Present	Present
8	*Terong telunjuk* (K88)	Curved	Sinous	*Hypostomatic*	Present	Present	Present	Present
9	*Terong kecap* (K90)	Straight to curved	Sinous	*Hypostomatic*	Present	Present	Present	Present
10	*Terong hijau* (K178)	Curved	Sinous	*Hypostomatic*	Present	Present	Present	Present
11	*Terong manggis* (K110)	Curved	Sinous	*Hypostomatic*	Present	Present	Present	Present
12	*Terong talang* (K69)	Curved	Sinous	*Hypostomatic*	Present	Present	Present	Present
13	*Terong apel* (K50)	Straight to curved	Sinous	*Hypostomatic*	Present	Present	Present	Present
14	*Terong lalap rebus* (K83)	Curved	Sinous	*Hypostomatic*	Present	Present	Present	Present
15	*Terong kercil* (K135)	Curved	Curved	*Hypostomatic*	Present	Present	Present	Present
16	*Terong gading* (K118)	Curved	Curved	*Hypostomatic*	Present	Present	Present	Present
17	*Terong pinang* (K57)	Curved	Sinous	*Hypostomatic*	Present	Present	Present	Present
18	*Terong asam* (K51)	Sinous	Sinous	*Hypostomatic*	Present	Present	Present	Present
19	*Faimatak* (K82)	Curved	Curved	*Hypostomatic*	Present	Present	Present	Present
20	*Poki-poki* (K93)	Curved	Sinous	*Hypostomatic*	Present	Present	Present	Present
21	*Terong jawa* (K18)	Curved	Sinous	*Hypostomatic*	Present	Present	Present	Present
22	*Terong ungu* (TU)	Straight to curved	Straight to curved	*Hypostomatic*	Present	Present	Present	Present
23	*Kania* F_1 (KF1)	Curved	Sinous	*Hypostomatic*	Present	Present	Present	Present

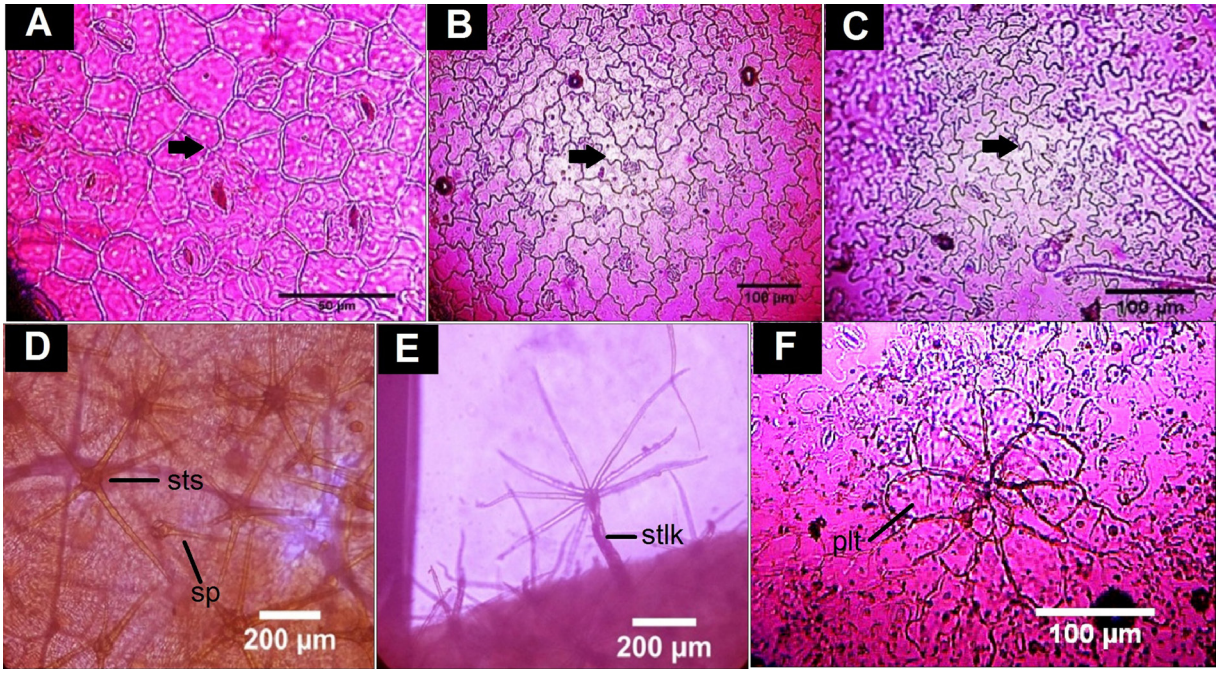
Table 3. *(continued)*

No.	Accession	Stellate stalked trichome (non-grandullar)		Spine trichome (non-grandullar)		Peltate trichome (non-grandullar)		Type of stomata	
		Adaxial	Abaxial	Adaxial	Abaxial	Adaxial	Abaxial	Adaxial	Abaxial
1	*Terong gelatik* (K14)	Absent	Absent	Present	Present	Absent	Absent	*Anisocytic*	*Anomocytic*
2	*Terong butuh* (K17)	Absent	Present	Present	Absent	Absent	Absent	*Anisocytic*	*Anomocytic*
3	*Terong ungu* (K116)	Absent	Absent	Absent	Absent	Present	Absent	*Anisocytic*	*Anomocytic*
4	*Terong lalap* (K32)	Absent	Absent	Present	Present	Absent	Absent	*Anomocytic, Anisocytic*	*Anomocytic*
5	*Terong gelatik* (K20)	Absent	Absent	Present	Absent	Absent	Absent	*Anisocytic*	*Anomocytic*
6	*Terong* (K62)	Present	Present	Present	Absent	Absent	Absent	*Anisocytic*	*Anomocytic*
7	*Terong gelatik kecil* (K13)	Absent	Present	Absent	Absent	Absent	Absent	*Anisocytic*	*Anomocytic*
8	*Terong telunjuk* (K88)	Present	Absent	Present	Absent	Absent	Absent	*Anisocytic*	*Anomocytic*
9	*Terong kecap* (K90)	Present	Present	Absent	Absent	Absent	Absent	*Anisocytic*	*Anomocytic*
10	*Terong hijau* (K178)	Absent	Absent	Present	Present	Absent	Absent	*Anomocytic*	*Anomocytic*
11	*Terong manggis* (K110)	Absent	Absent	Present	Absent	Present	Absent	*Anisocytic*	*Anomocytic*
12	*Terong talang* (K69)	Absent	Absent	Present	Absent	Absent	Absent	*Anisocytic*	*Anomocytic*
13	*Terong apel* (K50)	Present	Absent	Present	Absent	Absent	Absent	*Anisocytic*	*Anomocytic*
14	*Terong lalap rebus* (K83)	Absent	Present	Present	Absent	Absent	Absent	*Anisocytic*	*Anomocytic*
15	*Terong kercil* (K135)	Absent	Present	Present	Absent	Absent	Absent	*Anomocytic*	*Anomocytic*
16	*Terong gading* (K118)	Absent	Present	Present	Absent	Absent	Absent	*Anisocytic*	*Anomocytic*
17	*Terong pinang* (K57)	Present	Absent	Present	Present	Absent	Absent	*Anisocytic*	*Anomocytic*
18	*Terong asam* (K51)	Absent	Absent	Present	Absent	Absent	Absent	*Anomocytic*	*Anomocytic*
19	*Faimatak* (K82)	Present	Present	Present	Absent	Absent	Absent	*Anisocytic*	*Anisocytic*
20	*Poki-poki* (K93)	Present	Present	Present	Absent	Absent	Absent	*Anisocytic*	*Anomocytic*
21	*Terong jawa* (K18)	Absent	Absent	Present	Absent	Absent	Absent	*Anisocytic*	*Anomocytic*
22	*Terong ungu* (TU)	Absent	Absent	Present	Absent	Absent	Absent	*Anomocytic*	*Anomocytic*
23	*Kania* F_1 (KF1)	Absent	Absent	Present	Absent	Absent	Absent	*Anisocytic*	*Anomocytic*



Remarks: A. Terong Ungu (TU); B. Kania F1 (KF1); C.Terong Butuh (K17); D. Terong Jawa (K18); E. Terong Pinang (K57); F. Terong Talang (K69); G. Poki-poki (K93); H.Terong Telunjuk (K88); I. Terong Ungu (K116); J. Terong Gading (K118); K. Faimatak (K82); L.Terong Manggis (K110); M. Terong Gelatik Kecil (K13); N. Terong Gelatik (K14); O. Terong Gelatik (K20); P. Terong Lalap (K32); Q. Terong Apel (K50); R. Terong Asam (K51); S. Terong (K62); T. Terong Lalap Rebus (K83); U.Terong Kecap (K90); V. Terong Kercil (K135); W. Terong Hiijau (K178)

Fig. 1. Variation of shape and skin color of Indonesian eggplant fruits



Remarks: A. Anticlinal walls ofepidermal cells straight to curved; B. Anticlinal walls of epidermal cellscurved; C. Anticlinal walls of epidermal cells sinuous; D. Stellate sessile (sts) and spine (sp) trichome; E. Stellate stalked (stlk) trichome; and F. Peltate (plt) trichome

Fig. 2. Variation of leaf micromorphological of eggplant accessions (at a magnification x100)

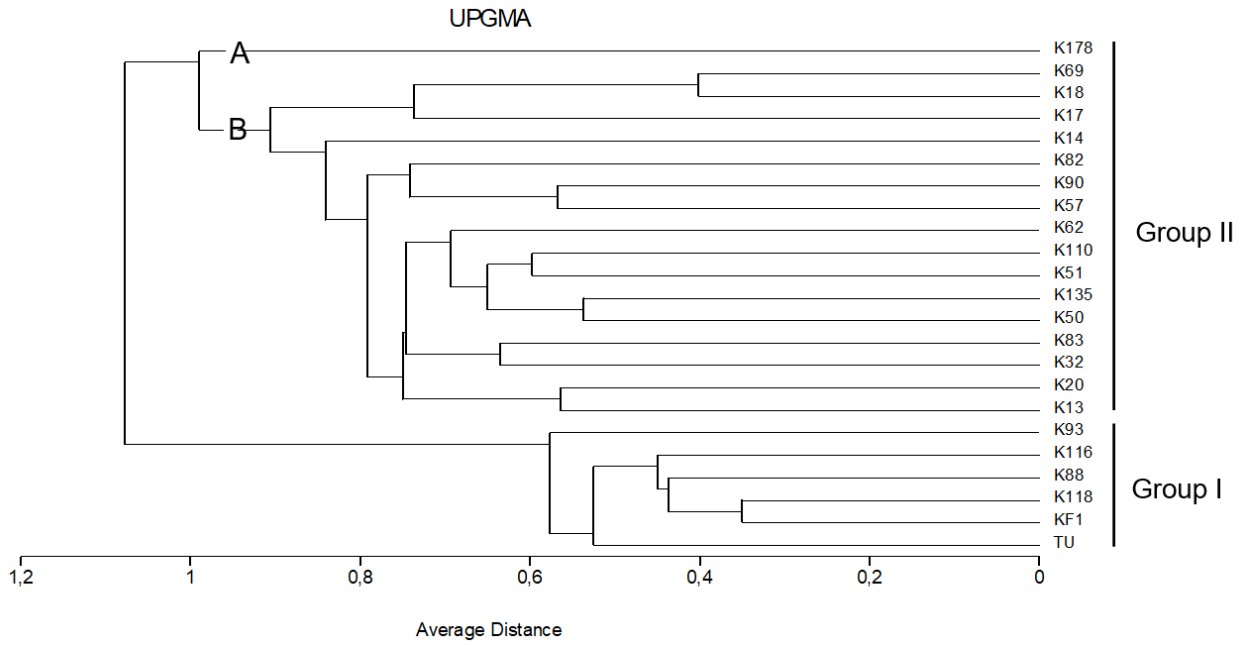


Fig. 3. Dendrogram of 23 eggplant accessions based on macromorphological characters using UPGMA analysis. Name of each accession listed in Table 1

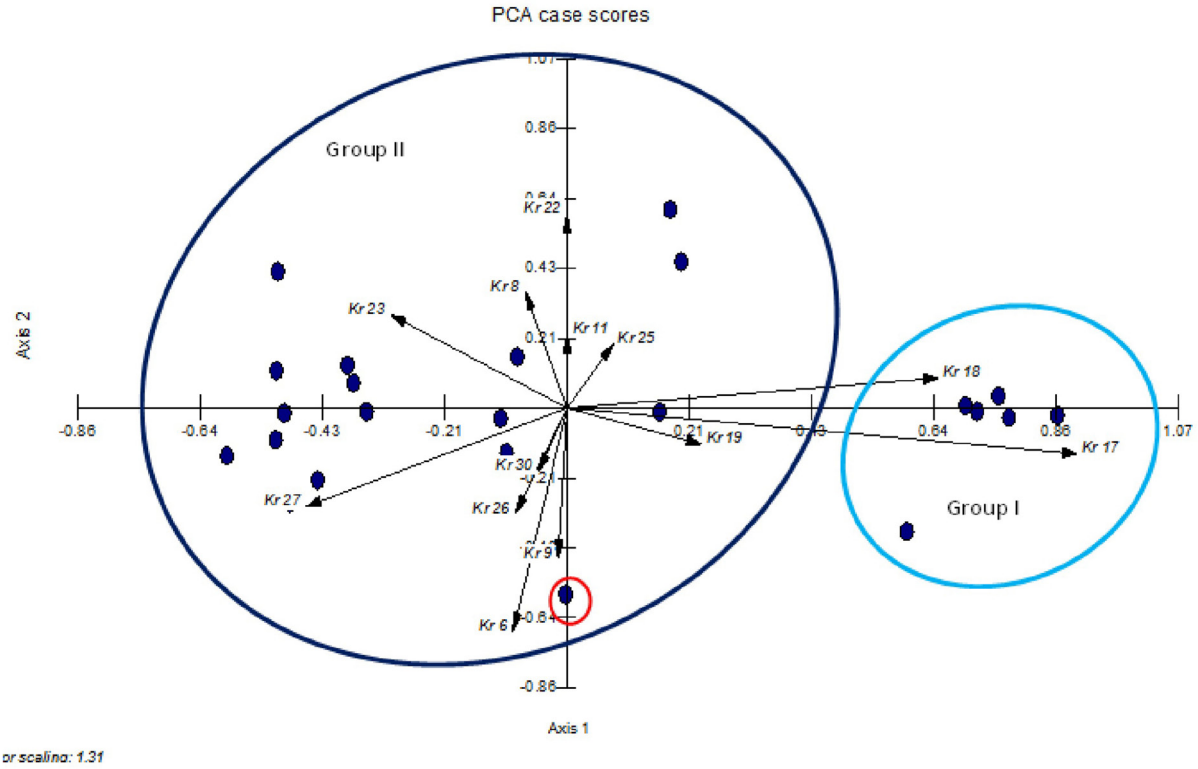


Fig. 4. Scatter plot of 23 eggplant accessions based on macromorphological characters

Table 4. Intraspecific classification (non-formal) of eggplants

Group	Sub-group	Accession*
I "Curved fruit"	-	K93, K116, K88, K118, KF1, TU
II "Non-curved fruit"	IIA more spiny leaves	K178
	IIB less spiny leaves	K18, K69, K17, K14, K82, K90, K57, K62, K110, K51, K135, K50, K83, K32, K20, K13

Remarks: *description of each accession was presented in Table 1

The two groups are curved, non-curved with more spiny leaves and non-curved with less spiny leaves. Both groups can be clearly recognized by some of the markable macromorphological characters. The grouping of 23 eggplant accessions based on macromorphological characters were presented in Table 4.

Group formation based on macromorphology is strongly influenced by a combination of several characters, there are fruit shape, ratio and fruit curvature. Group I consists of eggplant accessions with curved fruit and they have two fruit shapes (cylindrical or ellipsoid). Group II composes of accessions with non-curved fruit and three fruit shapes (globular, ovoid or obovate). The data also confirmed that the eggplant grouping does not occur based on the origin of the collection area. These indicated that the used character is a steady character or its variability is not affected by the environmental factors (Sari, Suryadiantina, Daryono, & Purnomo, 2018). This can be due to the dominating character of grouping as a qualitative character that tends to be more stable towards environmental change (Engels, 1983). Similar findings was also reported by Caguiat & Hautea (2014) that also grouped 32 accession of Philippine eggplant become 4 main groups based on morphological and molecular characters without any correlation of their geographical origin.

Cluster analysis of 23 eggplant accessions based on micromorphological characters resulted in a dendrogram (Fig. 5) that formed 2 groups.

PCA analysis shows that the grouping was based on the combination of several characters such as characters of stomatal type in the adaxial and the abaxial epidermal cell wall (Fig. 6). Group I consists of two accessions with average distance value of 0.818, namely *Terong Lalap* (K32) and *Terong Ungu* (TU). Group II is derived into 2 sub-groups. Sub group II.A consists of *Faimatak* (K82) and separated with average distance value of 0.912 based anisocytic stomatal type on adaxial and abaxial. While, subgroup II.B consists of 20 eggplant cultivar/accessions with variation in adaxial and abaxial stomatal types. Sampaio, Araújo, & Agra (2014) stated that the characters of leaf epidermis and its annexes, mainly themorphology of trichomes, are useful in distinguishing the *Solanum* species (clade *Brevantherum*) from Northeastern Brazil. The result of cluster analysis based on macro and micro-morphological characters formed 2 main groups. However, the member of accessions within each group and number of characters to construct dendrogram based on macro and micro morphological (30 macro and 8 micromorphological characters) were different.

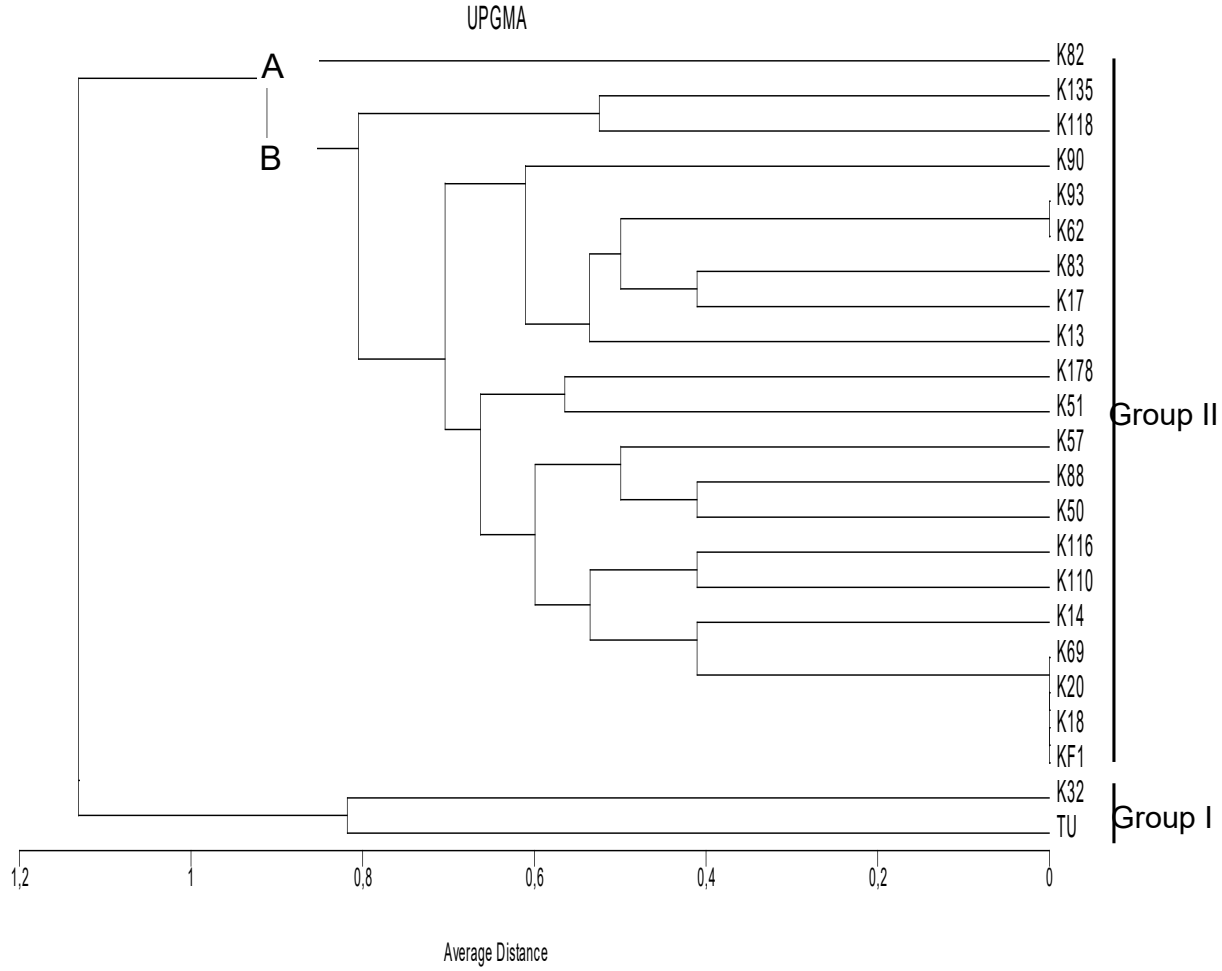


Fig. 5. Dendrogram of 23 eggplant acessions based on micromorphological characters using UPGMA analysis. Name of each accession listed in Table 1

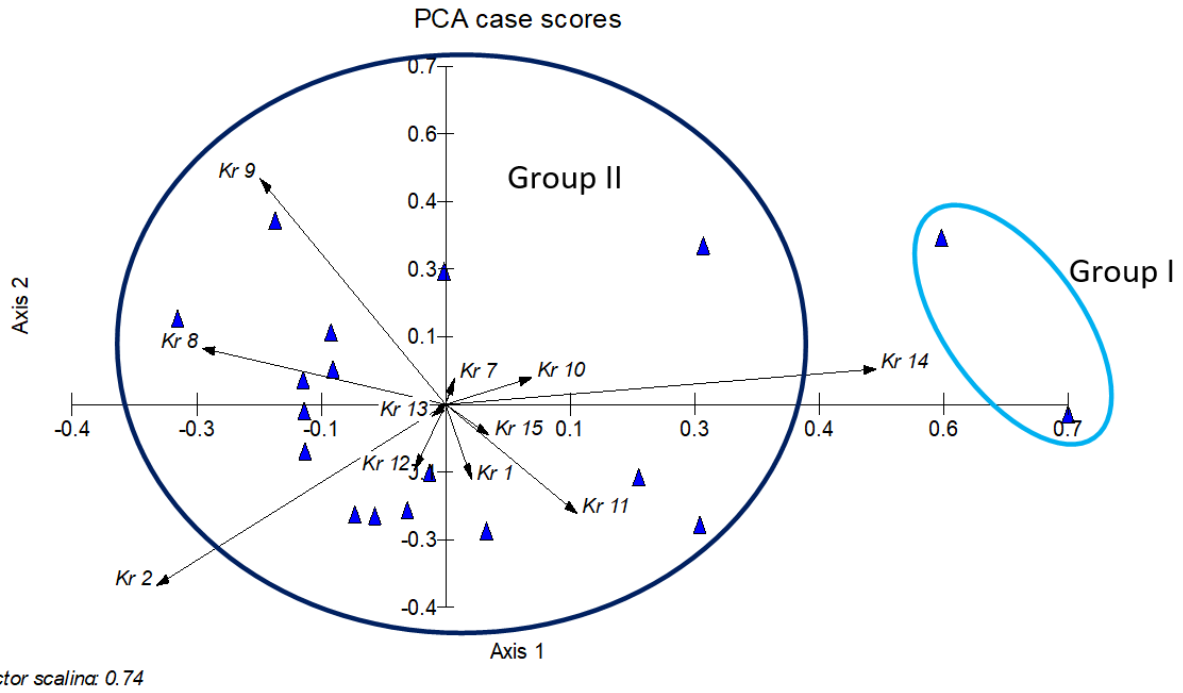


Fig. 6. Scatter plot of 23 eggplant accessions based on micromorphological characters

CONCLUSION

The evaluated eggplant accessions have macromorphological variation especially in fruit characters. The variation of the accessions were also observed on micromorphological characters such as anticlinal walls epidermis, the shape of trichome and the type of stomata. The eggplant accessions are classified into 2 groups, namely "curved fruit group" and "non-curved fruit group" based on macromorphological characters. The phenetic relationship of eggplant accessions based on micromorphological characters was divided into 2 groups based on the epidermal wall, trichome shape, and stomata type characters.

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