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Distribution, variation, and relationship of *Curcuma soloensis* Valeton in Java, Indonesia based on morphological characters

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Abstract. *Jalil M, Purwantoro A, Daryono BS, Purnomo. 2020. Distribution, variation, and relationship of* Curcuma soloensis *Valeton in Java, Indonesia based on morphological characters. Biodiversitas 21: 3867-3877. Curcuma soloensis* Valeton (locally called *temu genyeh*) was a plant originating from Solomon Islands and was synonymous with *Curcuma longa* L. This plant was often considered to be turmeric (*Curcuma longa* Linn.) or temulawak (*Curcuma zanthorrhiza* Roxb.), because the rhizome is almost the same color. The purpose of this study was to determine the distribution, variation, and relationship of *C. soloensis* in Java, Indonesia. Retrieval of data with exploratory roaming methods in 12 districts/cities in Java Island as a center for planting medicinal plants. Morphological character observations were made on habit, rhizome, roots, tubers, leaves, pseudo-stems, and flowers. Morphological data were analyzed by descriptive and numerical methods. Analysis of grouping with Gower Coefficients because it uses 45 binary and multistate data. Principal Component Analysis (PCA) was performed to determine the role of each character in the grouping. Cluster analysis and PCA graphics were assisted with MVSP 3.1 software. The results of the study were obtained from 25 accessions of *C. soloensis* in East Java (Trenggalek, Pacitan, Ponorogo), Central Java (Wonogiri, Karanganyar, Magelang, Semarang), Yogyakarta (Yogyakarta City, Bantul, Gunungkidul), and West Java (Ciamis and Tasikmalaya). The variation of *C. soloensis* lies in habit, stem color, leaf shape, rhizome shape, rhizome flesh color, and tuber shape. The highest abundance percentage is in Pajangan, Tirtomoyo, and Tawangmangu. The dendrogram divides 32 OTUs into two clusters on the phenon line 0.617, namely cluster A (*C. zanthorrhiza*) and cluster B (*C. soloensis* and *C. longa*). PCA results showed that the characters that had the most role in grouping were leaf blade color, leaf blade length, rhizome shape, root color, rhizome taste, outer and inner rhizome flesh color.

Keywords: *Curcuma*, cluster analysis, description, PCA, taxonomy, UPGMA

INTRODUCTION

Curcuma soloensis Valeton originally described from Java, Indonesia (locally called *temu genyeh*) (Heyne 1987; Valeton 1918) as separate species than *Curcuma longa* L. under Section Mesantha of Zingiberaceae (Valeton 1918). However, in the Flora of Java, *Curcuma soloensis* Valeton and *C. longa* L. are included as the members of the collective species *Curcuma viridiflora* Roxb. (Backer and van den Brink 1968). At present, Kew Science (2020) and Theplantlist (2020) considers *C. soloensis* Valeton to be synonymous to *C. longa* L. As South Asia and Southeast Asia belt is home to rich diversity of Zingiberaceae,e morphological and molecular studies are necessary to further enhance our knowledge about the plant family, including members of the genus *Curcuma*. Such studies may help in discovering new subgeneric taxa of *Curcuma* and solving taxonomic uncertainties.

Curcuma soloensis is a native plant of Solomon Islands and is wildly cultivated in Southeast Asia (Zhang et al. 2011). This introduced plant in the Surakarta and surrounding areas (Marliyana et al. 2018) of Java Island, Indonesia and has now been naturalized (Bos et al. 2007) and finds medicinal use through local Hortus Medicus clinic and the Tawangmawu Center for Traditional Medicinal Plants and Medicines (B2P2TOOT Tawangmangu) in Central Java, Indonesia. Though less popular than turmeric (*Curcuma longa* Linn. Syn. *Curcuma domestica* Valeton) in terms of utilization (Subositi and Wahyono 2019), population of *C. soloensis* in Java Island has diminished due to local medicinal extraction and is available mostly under cultivation only (Roemantyo 2000). Rhizomes of *C. soloensis* is rich source of terpenoids, sesquiterpenes, curcuminoids (Bos et al. 2007; Hayakawa et al. 2011; Anuchapreeda et al. 2018) which has antifungal, antioxidant, anti-inflammatory, anticancer activities (Kocaadam and Lieranlier 2017; Mishra et al. 2018; Diastuti et al. 2019). Besides, the presence of beautiful violet-red colored bractea makes *C. soloensis* a potential ornamental and it is cultivated through tissue culture for ornamental use in China (Zhang et al. 2011).

Due to phenotypic similarities between species (Apavatjrut et al. 1999) identity of members of *Curcuma* group and *C. soloensis* are often confused in Javanese

society. As observed in Pasar Imogiri, Bantul, Yogyakarta, Indonesia rhizomes of *C. soloensis* were mixed with temulawak (*C. zanthorrhiza* Roxb.) and turmeric or kunir (*C. longa* Linn.) because of their identical rhizome color. Due to unclear boundaries between members of *Curcuma*, it has been recommended to realign species within genus *Curcuma* (Kress 2002), which in a way minimize misidentification of *C. soloensis*, allow conservation of *C. soloensis* and proper certification and registration of new cultivars. Building strong taxonomic evidence and their assessment through phenetic and phylogenetic approaches are known to clarify taxonomic boundaries (Backer and van den Brink 1968; Silva et al. 2018), which would be helpful in solving identification problems with *C. soloensis*.

In this study distribution of *C. soloensis* in Java was studied, along with variations and patterns between species of *Curcuma* through cluster analysis and principal component analysis based on phenetic characteristics of habit, rhizome, roots, tubers, leaves, pseudo-stems and flowers for compiling the interspecific classification of *C. soloensis* in Java, Indonesia.

MATERIALS AND METHODS

The study was conducted from January 2019 until June 2020. Identification of morphological characters was carried out in the field. Sampling of *C. soloensis* accessions was conducted in twelve (12) districts/cities in Java, Indonesia namely East Java (Trenggalek, Pacitan, Ponorogo), Central Java (Wonogiri, Karanganyar, Magelang, Semarang), Yogyakarta (Yogyakarta City, Bantul, Gunungkidul), and West Java (Ciamis and Tasikmalaya) (Figure 1).

Equipment used to obtain morphological data: descriptor books, GPS, crowbars, hoes, sewing meters, rulers, pencils, shovels, scissors, cutters, and digital cameras. Observed color was compared with the color codes of RHS (Royal Horticultural Society). Photographs of plant and plant parts were arranged in plates using Corel Draw X5. Morphological features like habit, rhizome, roots, tubers, leaves, pseudo-stems, and flowers of *C. soloensis* were compared. Comparison groups in this study are *C. longa* and *C. zanthorrhiza*.

Samples were identified by matching the morphological data with the description and image of the *C. soloensis* specimens (Backer and van den Brink 1968; Delin and Larsen 2000; Sasikumar 2005). Samples were observed for their morphological characters and scoring following the Sasikumar descriptors (Sasikumar 2005), using 45 qualitative and quantitative characters (Table 1), which is more than the characters used in earlier study of Sungkawati et al. (2019). Cluster analysis and PCA graphics were assisted with MVSP 3.1 software. Abundance was analyzed by descriptive percentage.

Figure1. Distribution and sampling locations of *Curcuma soloensis* in Java Island, Indonesia

Table 1. Morphological characters of *Curcuma soloensis* observed (Sasikumar 2005)

Character	Note
Plant type	0 = erect; semi erect = 1
Plant height	0 = 0-0,9 m; 1 = 1-1,9 m; 2 = 2-2,9 m
Habit of leaves	0 = erect; 1 = semi erect; 2 = prostrate
Pseudo-stem color	0 = yellow green group 151-strong greenish yellow a; 1 = green group143-strong yellow green b; 2 = yellow green 144-strong yellow green a; 3 = yellow green group 144-strong yellow green b; 4 = yellow green group n144-strong yellow b; 5 = yellow green group 146-moderate yellow green b; 6 = yellow green group 145-moderate yellow green b; strong yellow green a
Number of pseudo-stems	0 = 1-5 terna; 1 = 6-10 terna; 2 = 11-15 terna; 3 = ≥ 15 terna
Leaf stalk texture	0 = glabrous; 1 = hairy
Leaf blade color	0 = green group 137-moderate olive green a; 1 = green group 137-moderate olive green b; 2 = green group 138- moderate yellowish green a; 3 = green group 143-strong yellow green a; 4 = green group 143-strong yellow green b; 5 = yellow green group 144-strong yellow green a; 6 = yellow green group 144-strong yellow green b
Leaf shape	0 = round (1: 1); 1 = ovate (1.5-2: 1); 2 oblong (2.5-3: 1); 3 = lancet (3-5: 1)
Leaf tip	0 = tapered (acuminate); 1 = sharp (acute);
Leaf base	0 = attenuate; 1 = rounded ; 2 = obtuse; 3 = sharp (acute)
Leaf length (vagina)	0 = 1-50 cm = ; 1 = 51-100 cm = ; 2 = 101-150 cm
Leaf length (lamina)	0 = 15-40 cm; 1 = 41-66 cm; 2 = 67-92 cm; 3 = 93-118 cm
Leaf width	0 = 5-13cm; 1 = 14-22 cm; 2 = 23-31 cm; 3 = 32-40 cm
The number of leaves in a pseudo-stem	0 = 1-5 leaves; 1 = 6-10 leaves
Leaf margin	0 = low wavy (1-7 cm); 1 = medium wavy (8-14 cm); 2 = highly wavy (15-22 cm)
Leaf vein	0 = close (<1 cm); 1 = distant (>1 cm)
Dorsal surface of the leaf	0 = hairy; 1 = glabrous
Ventral surface of the leaf	0 = hairy; 1 = glabrous
Mid-rib leaf color	0 = green; 1 = purple
Mid-rib tinge on dorsal surface	0 = present; 1 = absent
Mid-rib tinge on ventral surface	0 = present;1 = absent
Early Growth	0 = generative; 1 = vegetative
Inflorescence position	0 = lateral; 1 = terminal
Rhizome shape	0 = ovate; 1 = cone; 2 = round; 3 = lengthwise; 4 = ellipse
Nature of rhizome	0 = sessile tubers present; 1 = sessile tubers absent; 2 = stoloniferous
Root shape	0 = oblong; 1 = cylindrical
Root color	0 = yellow; 1 = chocolate; 2 = black; 3 = white
Root length	0 = 1-10 cm; 1 = 11-20 cm; 2 = 21-30 cm; 3 = 31-40 cm
Presence of tubers	0 = absent; 1 = present
Presence of stolon	0 = absent; 1 = present
Aroma of rhizome	0 = mango; 1 = camphoraceous; 2 = turmeric; 3 = non aromatic; 4 = harsh
Taste	0 = bitter; 1 = sweet; 2 = inert; 3 = turmeric flavor; 4 = bitterly spicy
The secondary rhizome	0 = present; 1 = absent
Endodermic ring in the primary rhizome	0 = clear; 1 = unclear
Color of outer rhizome flesh	0 = yellow-orange group-14-vivid yellow a; 1 = greyed-orange group 163-strong orange yellow b; 2 = yellow group 12-vivid yellow a; 3 = greyed-orange group 163-deep orange yellow a; 4 = yellow group 2-vivid greenish yellow a; 5 = yellow group 9-vivid yellow a; 6 = orange group n25-strong orange b
Color of inner rhizome flesh	0 = greyed-orange group 163-deep orange yellow a; 1 = greyed-orange group 163-strong orange yellow b; 2 = greyed-orange group 164-brownish orange a; 3 = orange group n25-stronge orange a; 4 = greyed-orange group n167-brownish orange a; 5 = orange group n25-strong orange b
Rhizome outer skin color	0 = orange; 1 = chocolate; 2 = orange-yellowish
Number of branching rhizomes	0 = 2-5 pieces; 1 = 6-9 pieces; 2 = 10-13 pieces
Number of rhizome segments	0 = 3-6 pieces; 1 = 7-10 pieces; 2 = 11-14 pieces
Rhizome diameter	0 = 1-3 cm; 1 = 4-6 cm; 2 = 7-9 cm; 3 = 10-12 cm
Perimeter the Rhizome	0 = 1-10 cm; 1 = 11-20 cm; 2 = 21-30 cm; 3 = >30 cm
Length of secondary rhizome (entik)	0 = 1-6 cm; 1 = 7-13 cm; 2 = 14-19 cm
Endodermic ring at entik	0 = clear; 1 = unclear
Entik diameter	0 = 1-3 cm; 1 = 4-6 cm
Perimeter of entik	0 = 1-6 cm; 1 = 7-12 cm; 3 = 13-18 cm

RESULTS AND DISCUSSION

Distribution of *Curcuma soloensis* Valeton in Java

Based on the results of exploration explorations that have been carried out, obtained 25 samples (accessions) of *C. soloensis* and 7 comparison groups in 12 districts or cities in Java Island. Accessions of *C. soloensis* found in Java are shown in Table 2. Valeton (1918), divided *Curcuma* in Java and Sumatra into two sections namely Mesantha and Exantha. *C. soloensis* and *C. longa* enter Meshanta, while *C. zanthorrhiza* enters Exantha. Although there were different sections, Javanese people find it difficult to distinguish between *C. soloensis*, *C. longa*, and *C. zanthorrhiza*.

Based on Table 2, the vernacular names of *C. soloensis* covering *temu glenyeh*, *temu blenyeh*, and *kunir kuning* (yellow turmeric). Valeton and Heyne called *temu glenyeh* with the old spelling of *gelenje* and *belenje* (Valeton 1918). The people of Bantul, Yogyakarta, Gunungkidul, Semarang, Magelang, Trenggalek call this plant as *temu blenyeh*. Residents of Karanganyar, Pacitan, and Wonogiri gave the name of a plant similar to turmeric with *temu glenyeh*. However, residents of Sawoo Sub-district (Ponorogo District), *C. soloensis* have another name as *kunir kuning* (yellow turmeric) because the plants are similar to *C. longa* while the color of the rhizome is orange-yellowish. Scientific publications often use the vernacular name *Temu Glenyeh* (Marliyana et al. 2018; Vitasari et al. 2016). *Temu Glenyeh* and *Temu Blenyeh* are two vernacular names that are often used by the Javanese community.

Though *Curcuma* can grow at high altitudes such as above 1000-2500 m above sea level (Sasikumar 2005), *C. soloensis* in Java is found at an altitude of 114 m asl. (Tegalrejo Village, Tegalrejo Sub-district, Yogyakarta City) until 826 m asl. (Tawangmangu Sub-district, Karanganyar District), average altitude of occurrence being 361 m asl. Along with varying altitudinal parameters, *C. soloensis* occurs in varied habitats.

These plants usually cluster to form clumps, which in turn are formed by pseudo-stems with 2-9 leaves. The leaves of *C. soloensis* are 30-100 cm long × 10-24 cm wide. The number of clumps ranges from 2-34 pseudo-stems per clump and the average number of pseudo-stems in a clump is 12.

Curcuma soloensis generally grows in wild habitats such as under teak (*Tectona grandis*), bamboo (*Dendrocalamus asper*), lamtoro (*Leucaena leucocephala*), flamboyant (*Delonix regia*), mahogany (*Swietenia macrophylla*), and cassava (*Manihot utilissima*). As *C. soloensis* occurs naturally, it generally does not need extra care from local communities (Roemantyo 2000). Interestingly, in some areas of Karang-mojo Sub-district (Gunungkidul District) and Ngadirojo Sub-district (Wonogiri District), the spurt of *C. soloensis* growth during the rainy season is considered as weed.

Species abundance refers to the number of individuals per species per site and relative abundance (mostly used as percentage) is one of the factors considered in biodiversity studies. Relative species abundance helps in finding out how common a sampled taxa is relative to the other sampled taxa at a site. In Java Island, the three sites with highest relative abundance index scores for the *C. soloensis* were Pajangan of Bantul District (19.80%), Tirtomoyo of Wonogiri District (15.84), and Tawangmangu of Karanganyar District (11.22) (Table 3).

Variation of *Curcuma soloensis* Valeton in Java

The variation lies in habit, stem color, leaf shape, rhizome shape, rhizome flesh color, and tuber shape. The observations of the variation of *C. soloensis* are shown in Figure 2.

Curcuma soloensis is a herb that forms rhizome at the base. *Curcuma* is composed of a pseudo-stem which is derived from leaf fronds and has broad leaves (Sirirugsa et al. 2007). *C. soloensis* plants are mostly upright, though semi-erect type plants are also found in the Imogiri and Tirtomoyo areas.

Curcuma soloensis propagates vegetatively through rhizomes and its morphology consists of the primary rhizome (empu), secondary rhizome (entik), rhizome roots, and has a tuber. The main rhizomes in *C. soloensis* are generally round (48%), conical (32%), elongated (12%), and ellipsoidal (8%) (Figure 2). Ellipsoidal form can be found in the Nawangan Pacitan and Bendungan Trenggalek. The main rhizome has a large number of entic and clustered. The number of odd branches ranges from 2 to 7. *C. soloensis* generally have primary, secondary and tertiary rhizomes. The secondary rhizome is larger than the primary rhizome. Rhizome also has internode and node. The number of nodes on *C. soloensis* ranges from 5-13 pieces. Each node develops the first branch (secondary rhizome) and they in turn branch off again to form tertiary rhizomes. The main rhizome will experience weathering when the seasons change. The color of the rhizome is one of the important characters for distinguishing between three species of collected *Curcuma* (Backer and van den Brink 1968; Valeton 1918). The color of the *C. soloensis* rhizome in the outer region (cortex) has a brighter color than the color of the rhizome in the region (stele) (Sungkawati et al. 2019). Greyed-orange group 163-strong orange-yellow B rhizome flesh on the inside, while the outside is yellow-orange group-14-vivid yellow A. There is the same color on the outside (cortex) and inside (stele), that is greyed-orange group 163-strong orange-yellow B. Endodermic rings that limit the outer and inner layers are clearly visible or unclear. The pseudo-stem of *C. soloensis* is composed of leaf fronds. Pseudo-stems appear from rhizome nodes. Pseudo-stem functions to support the leaf blade. The number of pseudo-stems in one family is 2-34. The discovery of the most number of pseudostem clumps in Tawangmangu Sub-district. Incidentally in the area adjacent to the location of Tawangmawu Center for Traditional Medicinal Plants and Medicines as a research center for medicinal plants. Pseudo-stem color is dominated by yellow-green 144-strong yellow-green A. Color variations found yellow-green 144-strong yellow-green a (72%), yellow-green group 146-moderate yellow-green b (8%), green group143-strong yellow-green b (8%), 151-strong yellowish yellow a (4%) yellow-green group, 144-strong yellow-green b yellow group (4%), and n144-strong yellow b yellow group (4%).

Tabel 2. Accession of *Curcuma soloensis* found on the Java Island, Indonesia

No. Acc.	Location	Vernacular name	Height (m asl)	Latitude	Longitude	Abundance	Habitat information
CS-01	Imogiri Sub-district, Bantul District, Yogyakarta	Temu Blenyeh	427	7º 55′44 ″S	110º25′58″E	2	Shaded under the Jati tree
CS-02	Sidorejo Village, Tirtomoyo Sub-district, Wonogiri District, Central Java	Temu Glenyeh	382	7º 55′58″S	111º07′31″E	12	Shaded under the Lamtoro tree
C2-03	Sidorejo 2 Village, Tirtomoyo Sub-district, Wonogiri District, Central Java	Temu Glenyeh	393	7º 55′58″S	111º07′30″E	5	Shaded under a Bamboo
CS-04	Tawangmangu Sub-district Karanganyar District, Central Java	Temu Glenyeh	826	7º 38′ 32″S	111º06′15″E	34	Shaded under the Flamboyan tree
CS-05	Tegalrejo Sub-district, Yogyakarta City, Yogyakarta	Temu Blenyeh	114	7º 47′22″S	110º21′ 01″E	2	Open
CS-06	Karangmojo Sub-district, Gunungkidul District, Yogyakarta	Temu Blenyeh	226	7º 53′19″S	110º 41′10″E	30	Shaded under the Jati tree
CS-07	Patuk Sub-district, Gunungkidul District, Yogyakarta	Temu Blenyeh	153	7º 52′47″S	110º 31′33″E	15	Shaded under a Bamboo
CS-08	Godegan RT 003 RW 001 Jembrak Village, Pabelan Sub-district, Semarang District, Central Java	Temu Blenyeh	575	7º 18′50″S	110º 31′39″E	24	Shaded under Bamboo and Jati trees
CS-09	Pakis Sub-district, Magelang District, Central Java	Temu Blenyeh	706	7º 27′30″S	110º 19′05″E	12	Shaded under the Papaya
CS-10	Mangunan Village, Dlingo Sub-district, Bantul District, Yogyakarta	Temu Blenyeh	365	7º 55′42″S	110º 25′19″E	2	Shaded under a Bamboo
CS-11	Gedong Village, Ngadirojo Sub-district, Wonogiri District, Central Java	Temu Glenyeh	195	7º 51′26″S	110º 59′00″E	26	Shaded under the Flower Shoe tree
CS-12	Ngarjosari Village, Tirtomoyo Sub-district, Wonogiri District, Central Java	Temu Glenyeh	168	7º 56′45″S	111º 02′21″E	31	Shaded under the Jati tree
CS-13	Penggung Village, Nawangan Sub-district, Pacitan District, East Java	Temu Glenyeh	809	7º 58′13″S	111º 07′48″E	7	Shaded among bushes
CS-14	Penggung Village, Nawangan Sub-district, Pacitan District, East Java	Temu Glenyeh	815	7º 58′13″S	111º 07′48″E	6	Shaded among bushes
CS-15	Penggung Village, Nawangan Sub-district, Pacitan District, East Java	Temu Glenyeh	816	7º 58′13″S	111º 07′48″E	6	Shaded under the Banana
CS-16	Sawoo Sub-district, Ponorogo District, East Java	Kunir Kuning	239	7º 59′35″S	111º 34′39″E	3	Shaded under the Banana
CS-17	Sumur Village, Bendungan Sub-district, Trenggalek District, East Java	Temu Blenyeh	319	8º 00′17″S	111º 41′54″E	12	Shaded under the Cassava
CS-18	Joho, Pucanganak Village, Tugu Sub-district, Trenggalek District, East Java	Temu Blenyeh	151	8º 01′38″S	111º 36′30″E	2	Shaded under the Flamboyan tree
CS-19	Kucur-Kucur, Nglinggis Village, Tugu Sub-district, Trenggalek District, East Java	Temu Blenyeh	221	8º 02′35″S	111º 35′50″E	6	Shaded under the Jati tree
CS-20	Blumbang Village, Sawoo Sub-district, Ponorogo District, East Java	Temu Blenyeh	394	8º 01′44″S	111º 34′33″E	6	Shaded among bushes
CS-21	Krebet RT 05, Sendangsari Village, Pajangan Sub-district, Bantul District, Yogyakarta	Temu Blenyeh	147	7º 51′19″S	110º 17′51″E	6	Shaded under the Jati tree
CS-22	Krebet RT 05, Sendangsari Village, Pajangan Sub-district, Bantul District, Yogyakarta	Tembu Blenyeh	147	7º 51′17″S	110º 17′51″E	12	Shaded under the Jati tree
CS-23	Krebet RT 05, Sendangsari Village, Pajangan Sub-district, Bantul District, Yogyakarta	Temu Blenyeh	148	7º 51′18″S	110º 17′51″E	14	Shaded under the Jati tree
CS-24	Krebet RT 05, Sendangsari Village, Pajangan Sub-district, Bantul District, Yogyakarta	Temu Blenyeh	145	7º 51′19″S	110º 17′51″E	14	Shaded under the Jati tree
CS-25	Krebet RT 05, Sendangsari Village, Pajangan Sub-district, Bantul District, Yogyakarta	Temu Blenyeh	145	7º 51′20″S	110º 17′51″E	14	Shaded under the Jati tree
CL-01	Demakan Lama RT 25 RW 7, Tegalrejo Sub-district, Yogyakarta City, Yogyakarta	Kunir	114	7 º 47′23″S	110 º21′02″E	34	Open
CX-01	RT 21 RW 6 Tegalrejo, Tegalrejo Sub-district, Yogyakarta City, Yogyakarta	Temulawak	115	7 º 47′20″S	110 º 21′09″E	20	Open
CX-02	Patuk Sub-district, Gunungkidul District, Yogyakarta	Temulawak	148	7 º 52′45″S	110 º31′35″E	20	Shaded under the mahogany tree
CL-02	RT 7 RW 3 Salebu Village, Majenang Sub-district, Cilacap District, Central Java	Kunyit	410	7 º 16′26″S	108 º43′15″E	5	Under the coconut tree
CL-03	Sukamanah Village, Sindangkasih Sub-district, Ciamis District, West Java	Kunyit	517	7 º15′57″	108 º13′04″E	4	Open
CL-04	RT 3 RW 4 Indihiang Village, Indihiang Sub-district, Ciamis District, West Java	Kunyit	407	7 º 17′37″	108 º11′51″E	3	Shaded under the Banana
CX-03	Bendungan Sub-district, Trenggalek District, East Java	Temulawak	529	7 º 57′33″S	111 º42′06″E	10	Shaded under the Jati tree

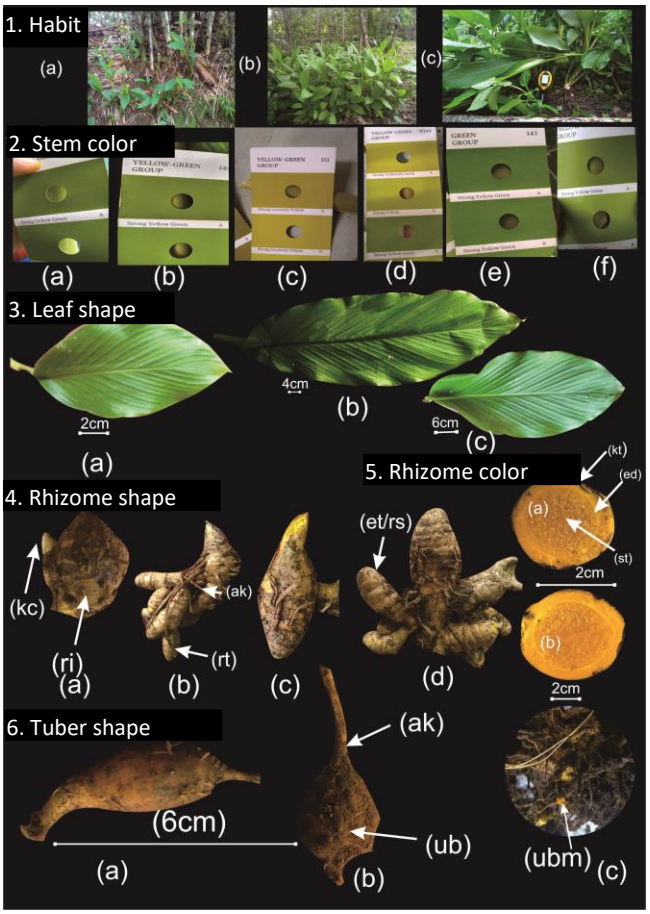

Figure 2. Variation of *Curcuma soloensis*: 1. habit: (a) semi erect under the bamboo tree, (b) erect under the jati tree, erect open; 2. stem color: (a) yellow green 144-strong yellow green a (b) yellow green group 146-moderate yellow green b (c) yellow green group 151-strong greenish yellow a (d) yellow green group n144-strong yellow b (e) green group 143-strong yellow green b (f) yellow green group 144-strong yellow green b; 3.leaf shape: (a) ovoid (ovatus); (b) lancet (c) elongated (oblong); 4. rhizome shape: (a) rounded; (b) cone; (c) ellipse; (d) extends; information: (kc) buds, (ri) primary rhizomes, et/rs/secondary rhizomes, (rt) tertiary rhizomes, (ak) roots, and (ru) segments of rhizomes; 5. rhizome color of flesh: 143 green strong group green yellow a, yellow green group 144 strong yellow green b, 137-moderate olive green group green, 137-moderate olive green group green, yellow 144-strong yellow green group a, green group 138-moderate yellowish green a, and green group 143-strong yellow green b (a) unclear endodermic ring (b) clear endodermic ring; (c) endodermic ring is not clear, information: (kt) cortex, (ed) endodermis, (st) stele; 6. tuber shape: (a) long fusiform; (b) fusiform; (c) fused tubers; description: (ak) roots; (ub) tubers; and (ubm) tubers melt

Leaf characters observed were leaf stalk texture, leaf blade color, leaf blade shape, leaf tip, leaf blade width, number of leaf strands, leaf edges, leaf veins, the presence of dorsal and ventral leaf signs, mid-rib color, mid-rib tinge of leaves. Leaf stalk texture is measured from the ground to the base of the leaf. The texture of *C. soloensis* petiole is generally rough. Some are found refined in the Karangmojo and Tirtomoyo areas. Leaf-blade color is dominated by Green group 143-strong yellow-green A. The

Tabel 3. Abundance of *Curcuma soloensis* in Java Island, Indonesia

Sub-district	Abundance	Relative abundance percentage
Imogiri	2	0.66%
Tirtomoyo	48	15.84%
Tawangmangu	34	11.22%
Tegalrejo	2	0.66%
Karangmojo	30	9.90%
Patuk	15	4.95%
Pabelan	24	7.92%
Pakis	12	3.96%
Dlingo	2	0.66%
Ngadirojo	26	8.58%
Nawangan	19	6.27%
Sawoo	9	2.97%
Bendungan	12	3.96%
Tugu	8	2.64%
Pajangan	60	19.80%
Total	303	100%

color of the leaves of *C. soloensis* varies greatly from green group 143-strong yellow-green a (44%), green group 137-moderate olive green a (28%), yellow-green group 144 - strong yellow-green b (8%), yellow-green group 144-strong yellow-green a (8%), green group 137-moderate olive green b (4%), green group 138-moderate yellowish-green a (4%), and 143-strong yellow-green b (4%) green group. Leaf shape is lancet (68%), elongated (28%), and ovoid (4%). Oblong and lancet strands are also found in Thailand (Chaveerach et al. 2007).

Tubers on *C. soloensis* are at the tip of the root. The roots are linear with two outer and inner layers (Uma and Muthukumar 2014). Root length ranges between 7-34 cm. Exploration results showed that not all main rhizomes were found. Areas found by masters are in the areas of Tirtomoyo, Karangmojo, Pabelan, Pakis, and Display. There are two types of tubers in *C. soloensis*, namely fusiform and long fusiform. This is in accordance with what was conveyed by Sasikumar (2005), that the variations of masters found in the Himalayas are fusiform and long fusion form. Most of the exploration points were not found at the tip of the root tuber. This is because sometimes the tubers come to fuse into the soil during the rainy season. Researchers get evidence that the tubers also fuse into the ground, when conducting exploration activities in the Krebet Pajangan Bantul area. The shape of the tuber has become a yellowish-orange powder attached to the clay. Images of *C. soloensis* tuber variations can be seen in Figure 2.

Curcuma soloensis flowers were found in Karangmojo Sub-district, Gunungkidul District, Yogyakarta in January. *C. soloensis* flowers take place from November to May, while *C. zanthorrhiza* flower in April and May (Škorničková and Sabu 2005). Of the 25 samples obtained, only in Karangmojo and Tirtomoyo were found in flowering conditions. Even the Krebet and Pabelan people said that *C. soloensis* had no flower because it was based on observations during seeing *C. soloensis*'s growth. *C.*

soloensis flowers can be used as ornamental plants in China (Zhang et al. 2011). The arrangement of *C. soloensis* flowers is shown in Figure 3. The striking difference between the flowers of *C. soloensis*, *C. longa* and *C. zanthorrhiza* is in the colors of coma and Bractea. *C. soloensis* is pink, whereas in *C. zanthorrhiza* is dark red (Škorničková and Sabu 2005) and *C. longa* is whitish-green or dark yellow (Sirirugsa 1998). In previous studies also reported that the coma in *C. soloensis* Valeton is white to greenish (Rahman and Yusuf 2012). The equation lies in the shape of the longa type anthera and at the base of the ovary, there are hairs (Chaveerach et al. 2008; Rahman and Yusuf 2012; Sirirugsa et al. 2007).

Description of *Curcuma soloensis* Valeton in Java Island

Morphological characterization and identification were based on *C. soloensis* relationship analysis based on pre-existing identification (Backer and van den Brink 1968; Delin and Larsen 2000; Sasikumar 2005; Sungkawati et al. 2019). Based on the characterization and identification it is known that there are two major groups, namely the first group is the collective species *C. viridiflora* Roxb. (Temu Glenyeh and *C. longa*) and *C. zedoaria* (Berg.) Roscoe represented by *C. zanthorrhiza*. Backer and van den Brink (1968), divided *Curcuma* into three collective species, namely *C. aurantiaca* Roxb., *C. viridiflora* Roxb., and *C. zedoaria* (Berg.) Roscoe. Characterization includes habit, stems, leaves, flowers, rhizomes, tubers, and roots. The following are the morphological characteristics of *C. soloensis* as follows:

Curcuma soloensis *Valeton (temu glenyeh)*

Habit Perennial herb, erect to semi-erect, 73-220 cm in height, pseudo-stem yellow-green 144-strong yellow-green A. *Stem* composed of leaf mid-ribs, number of pseudo-stems 2-34 in one clump, leaf stalk texture mostly rough, leaf blade color dominated by green group 143-strong yellow-green A. *Leaves* lanceolate, longitudinal (oblong), and ovoid on the first leaf, leaf tip tapered (acuminate), acute, leaf base attenuate to acute, length of leaf mid-rib (vaginal) between 36-125 cm, leaf blade 30-100 cm long, 10-24 cm wide, 2-9 leaf blades in one pseudo-stem, leaf margin medium (76%), high (16%) and low (8%), tight leaf veins (68%) and tenuous (32%), dorsal and ventral surface smooth, leaf blade (mid-rib) green, tinge at dorsal and ventral mid-rib absent. *The earliest growths* that appear on the surface of the soil are vegetative organs (leaf buds). *The rhizome* below the surface of the soil, round, elongated, elliptical to conical in shape, the aroma of the rhizome nil to rusty, taste bitter, second side rhizome present, endodermic ring of the primary rhizome clearly visible, the color of the rhizome at outermost (WDRBL) part is greyed-orange group 163-strong orange-yellow B and yellow-orange group-14-vivid yellow A, the color of the inner rhizome (WDRBD) most are Greyed-Orange Group 163-strong orange-yellow B and greyed-Orange Group N167-Brownish Orange A, the outer skin color of the rhizome is mostly brown, the number of branches of the rhizome is 2-7 secondary rhizomes (entik), the number of rhizomes is 5-13 pieces, the diameter of the rhizomes is 3-6 cm, the circumference of the rhizome 10 -18 cm, length of the secondary rhizome 3-12 cm, the endodermic ring present, the diameter of the entik 1-4 inches, the perimeter of entik (secondary rhizome) is 6-10 cm. *Tubers* present, sometimes absent, fusiform to longifusiform in shape, 2-8 cm long, located at the tip of the root. *The roots* are oblong and cylindrical in shape, yellow, brown, black, and whitish in color, root of 7-34 cm length, and mostly stolons are absent. *Inflorescence position* terminal (emerging from the tip of the pseudo-stem), height of the flower stalk (pedunculus) 10-13 cm, coma present, 9-10 steril bractea, coma 2-6 cm long, 0.5-1.5 cm broad, pink in color, lanceolate in shape, coma tip acute to acuminate, sepal white with blunt tip, petal yellow with blunt tip, labellum yellow, bractea ovoid, greenish, 4-6 cm long, 1.5-4.5 cm wide, tip blunt, number of fertile bractea 5-19 pieces, the type of anthera longa.

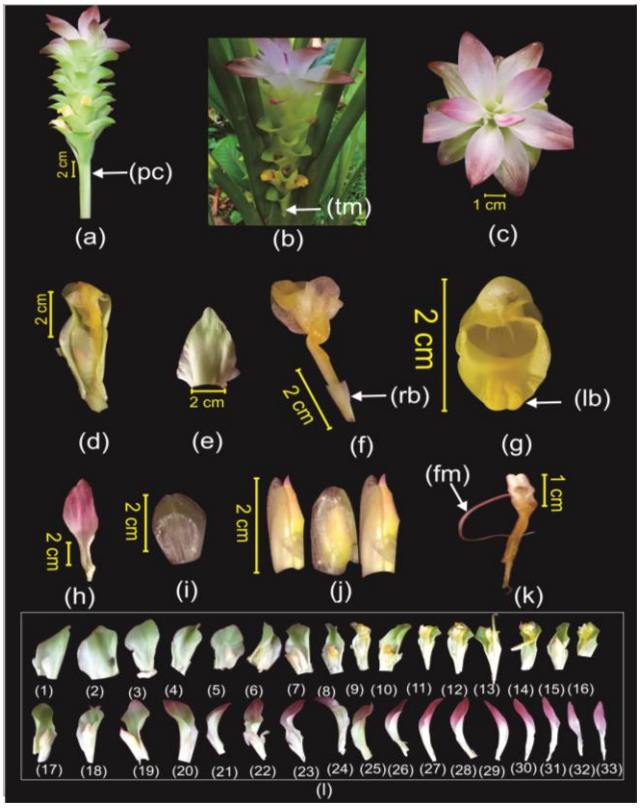

Figure 3. Arrangement of *Curcuma soloensis* flower: (a) Arrangement of compound flower in the form of bunches (b) flower coming out from the tip of pseudo-stem (c) visible on *C. soloensis* flower (d) bractea fertile (e) bractea sterile (f) pistil and *C. soloensis* fruit (ovary) (g) corolla in the form of a tube (h) coma (i) petal leaf (sepals) (j) petal (k) anthers (l) arrangement of bractea with number 33 from bottom to top, information: (pc) pedunculus; (tm) type of terminal flowering; (fm) filament; (rb) hair fur.

Relationship of *Curcuma soloensis* Valeton in Java based on morphological character

Relationship analysis of *C. soloensis* was conducted based on 45 characters consisting of 30 qualitative characters and 15 quantitative characters. The characters consist of 3 habit characters, 2 pseudo-stem characters, 16 leaf characters, 2 flower characters, 18 rhizome characters, 3 root characters, and 1 tuber character. Phenetic analysis used to look at the relationship between morphological characters of the *C. soloensis* in Java, there are two (2) types, namely cluster analysis and principal component analysis (PCA).

Based on the dendrogram (Figure 4) it can be seen that 32 OTUs have the same character so that they are integrated into the Similarity Index (IS) 0.617. These characters are found on the dorsal and ventral surfaces of the leaves. The upper or dorsal surface of *C. soloensis*, *C. zanthorrhiza*, and *C. longa* has a smooth (glabrous) surface. The repetition of *C. soloensis*, *C. zanthorrhiza*, and *C. longa* has a pinnate reinforcement. Maknoi (2006) and Sungkawati et al. (2019), states that most of the genus *Curcuma* has a leaf surface texture that is glabrous and some species have a hairy texture on the lower surface.

The dendrogram above has two large clusters namely cluster A which converges at IS 0.757 and cluster B that integrates at IS 0.665. Cluster A consists of *Curcuma zanthorrhiza*, while Cluster B consists of *C. longa* and *C. soloensis* One may tentatively decide 85 percent similarity as the threshold for the species, 65 for genera and 45 for families (Singh, 2010). Based on similarity (0.665) *C. soloensis* and *C. longa* should be in different species, but this needs to be confirmed through other approaches, for example molecular. Valeton and Backer also separated them into separate species. Other studies report that the *C. viridiflora* group (*C. soloensis* Valeton and *C. longa* L.) separated from the *C. zedoaria* group with taxonomic evidence of anatomy and micromorphology (anther) (Sirirugsa et al 2007; Uma and Muthukamar 2014). This grouping is based on the character equation in the mid-rib color, mid-rib tinge, early growth, and the position of the inflorescence (Figure 5).

Early growth in *C. soloensis* and *C. longa* are generally first vegetative organs, whereas in *C. zanthorrhiza* flowers will appear (generative organs) first and are relatively short (Škorničková and Sabu 2005). According to one of the residents of Sidorejo Village, Tirtomoyo Sub-district, *C. soloensis*, and *C. longa* will grow leaf buds and their mid-ribs, while in *C. zanthorrhiza* the flowers will usually appear first. Recognition differs precisely from residents of Pabelan Sub-district, Semarang and Bantul Pajangan, *C. soloensis* never appears flowers, only grow rhizome, pseudostems, and leaves.

Flowers on *C. zanthorrhiza* appear on the lateral side (arises from the node of the rhizome) then emerge out onto the ground (Škorničková and Sabu 2005; Valeton 1918). *C. soloensis* entered the collective species *C. viridiflora* Roxb. with terminal inflorescence type (Sirirugsa et al. 2007). *C. soloensis* and *C. longa* appear from the terminal side or the tip of the pseudo-stem (Delin and Larsen 2000; Valeton 1918). Pictures of inflorescence patterns in *C. soloensis*, *C. longa*, and *C. zanthorrhiza* can be seen in Figure 5. Valeton (1918), put *C. soloensis* and *C. longa* into the Mesantha section because inflorescent out from the center of the leaf stem, while *C. zanthorrhiza* entered the Exantha section because the inflorescent came out from the lateral side of the rhizome.

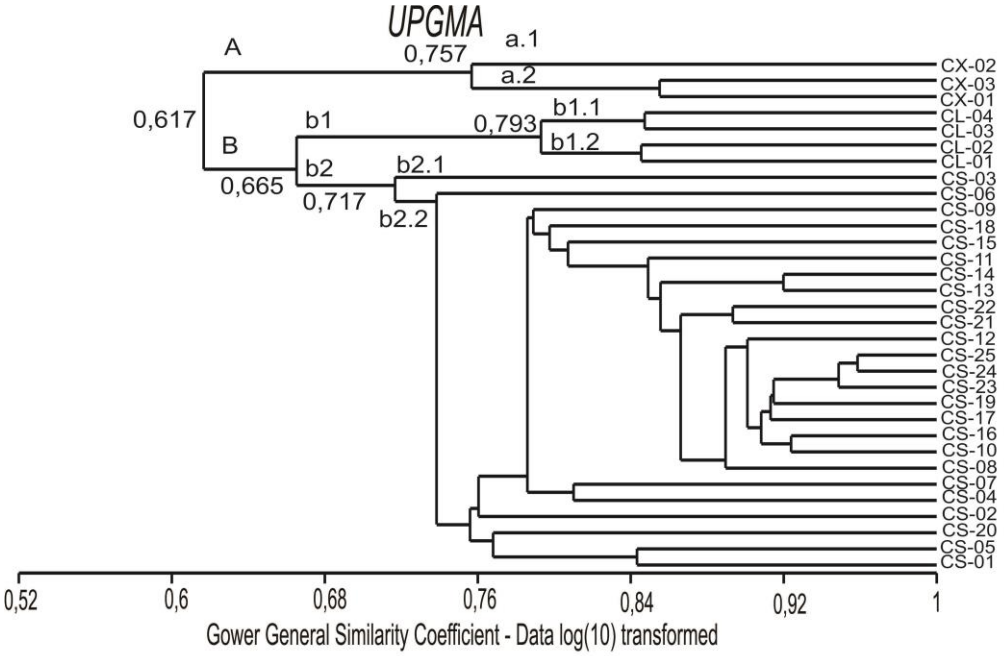

Figure 4. Dendrogram of *Curcuma soloensis* in Java, Indonesia based on morphological characters. Note: Accession code refers to Table 2.

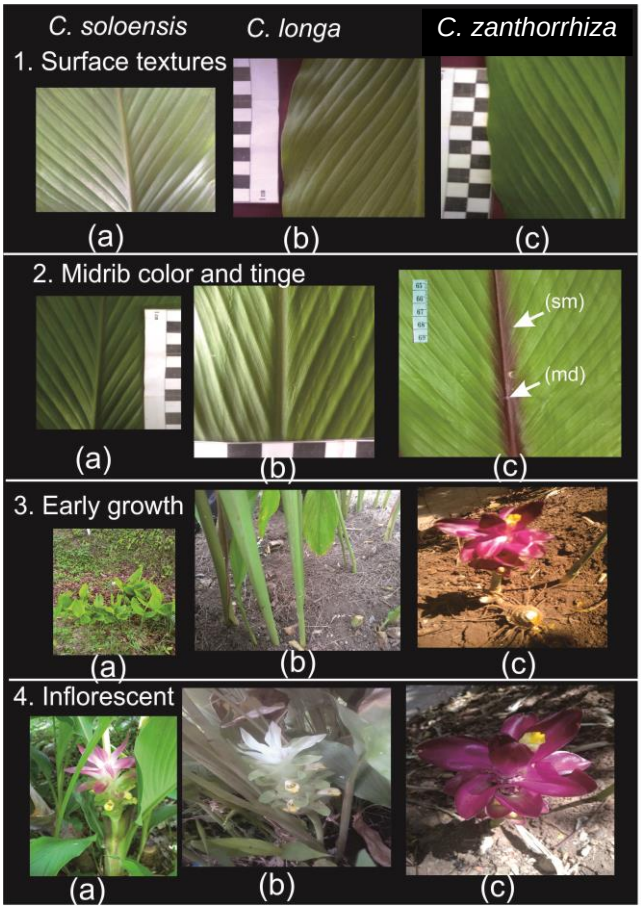

Figure 5. The basis of clustering: 1. Surface textures: (a) reinforcement of pinnate leaves, (b) dorsal: glabrous, (c) ventral: glabrous; 2. Mid-rib color and tinge: (a) *Curcuma soloensis*: green and no purple tinge (b) *C. longa*: green and no purple tinge (c) *C. zanthorrhiza*: purple and purple tinge, description: (MD) mid-rib, (sm) mid-rib tinge; 3. Early growth: (a) *C. soloensis*: leaves and stems appear, (b) *C. longa*: leaves and stems appear (c) *C. zanthorrhiza*: flowers appear; 4. Inflorescence: (a) *C. soloensis*: arises from the tip of the pseudo-stem (terminal), (b) *C. longa*: arises from the tip of the pseudo-stem (terminal) (c) *C. zanthorrhiza*: arises from the node of the rhizome (lateral).

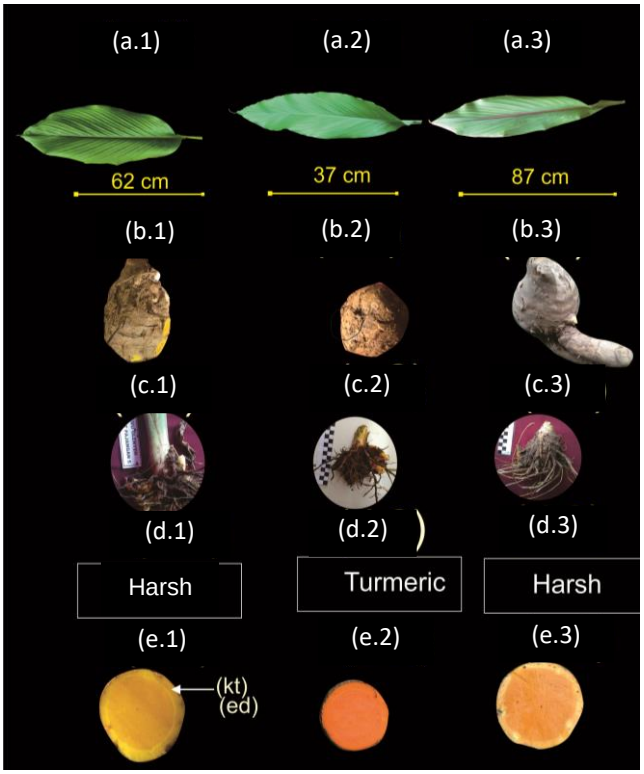

Figure 7. Characters that influence the grouping of *Curcuma soloensis* in Java Island (a) leaves color (WHD), (a1) *C. soloensis*: green group 143-strong yellow green A, (a2) *C. longa*: green group 137-moderate olive green B, (a3) *C. zanthorrhiza*: yellow green group 144-strong yellow green A; (b) leaves length (PHD), (b1) *C. soloensis* an average of 62 cm, (b2) *C. longa* an average of 37 cm (b3) *C. zanthorrhiza* an average of 87 cm; (c) rhizome shape, (c1) *C. soloensis*: ovoid, (c2) *C. longa*: round shape, (c3) *C. zanthorrhiza*: round shape; (d) root color (WA), (d1) *C. soloensis*: brown (d2) *C. longa*: yellow, (d3) *C. zanthorrhiza*: yellow; (e) aroma of rhizome (BR), (e1) *C. soloensis*: harsh; (e2) *C. longa*: turmeric, (e3) *C. zanthorrhiza*: harsh, (f) color of the outer rhizome (WDRBL) and inside (WDRBD), (f1) *C. soloensis*: outer and inner were greyed-orange group 163-strong orange yellow B, (f2) *C. longa*: outer and inner were orange group N25-strong orange B, (f3) *C. zanthorrhiza* outer: yellow group 12-vivid yellow A, inner: orange group N25-stronge orange A.

Cluster A has two small clusters, cluster a1 and a2. Cluster A is integrated into the IS value of 0.757. Cluster a1 consists of one accession CX-02 (*C. zanthorrhiza*, Patuk Sub-district). A2 cluster consists of two accessions CX 0-3 (*C. zanthorrhiza* Bandungan) and accession CX-01 (*C. zanthorrhiza* Tegalrejo). The grouping of these two clusters is based on the length of the leaf mid-rib, leaf blade width, leaf edge, rhizome shape, rhizome circumference, and diameter of the leaf.

Cluster B is divided into two small groups namely b1 and b2. Cluster B merges at IS value 0.665. Cluster B consists of 29 OTUs. Groups are further divided into b1 and b2. group b1 belongs to the species *C. longa* and group b2 has *C. soloensis* Valeton. This grouping is based on the character similarity of rhizome taste. The taste of *C. soloensis* and *C. longa* were both bitter. Cluster b1 consists of two small clusters b1.1 and b1.2. The two groups merge at IS 0.793. (CL-03). Group b1.1 consists of two OTUs, namely Tasikmalaya (CL-04) and Ciamis (CL-03). Cluster b1.2 consists of two small clusters namely *C. longa* Ciamis (CL-03) and Majenang (CL-02), and Tegalrejo (CL-01).

The b2 group is further divided into two small clusters namely, b2.1 and b2.2. Cluster b2 merges at IS value 0.717. Cluster b2.1 consists of one accession of the *C. soloensis* Tirtomoyo (CS-03) accession, and group b2.2 consists of 24 accessions of the *C. soloensis* CS-6, CS-09, CS-18, CS-15, CS-11, CS-14, CS-13, CS-22, CS-21, CS-12, CS-25, CS-24, CS-23, CS-19, CS-17, CS-16, CS-10, CS-08, CS - 07, CS-04, CS-02, CS-20, CS-05, CS-01. The grouping is based on the similarity of the plant type properties of *C. soloensis* and leaf habit found in *C. soloensis* in general is erect, only that the accession of CS-03 is semi-erect.

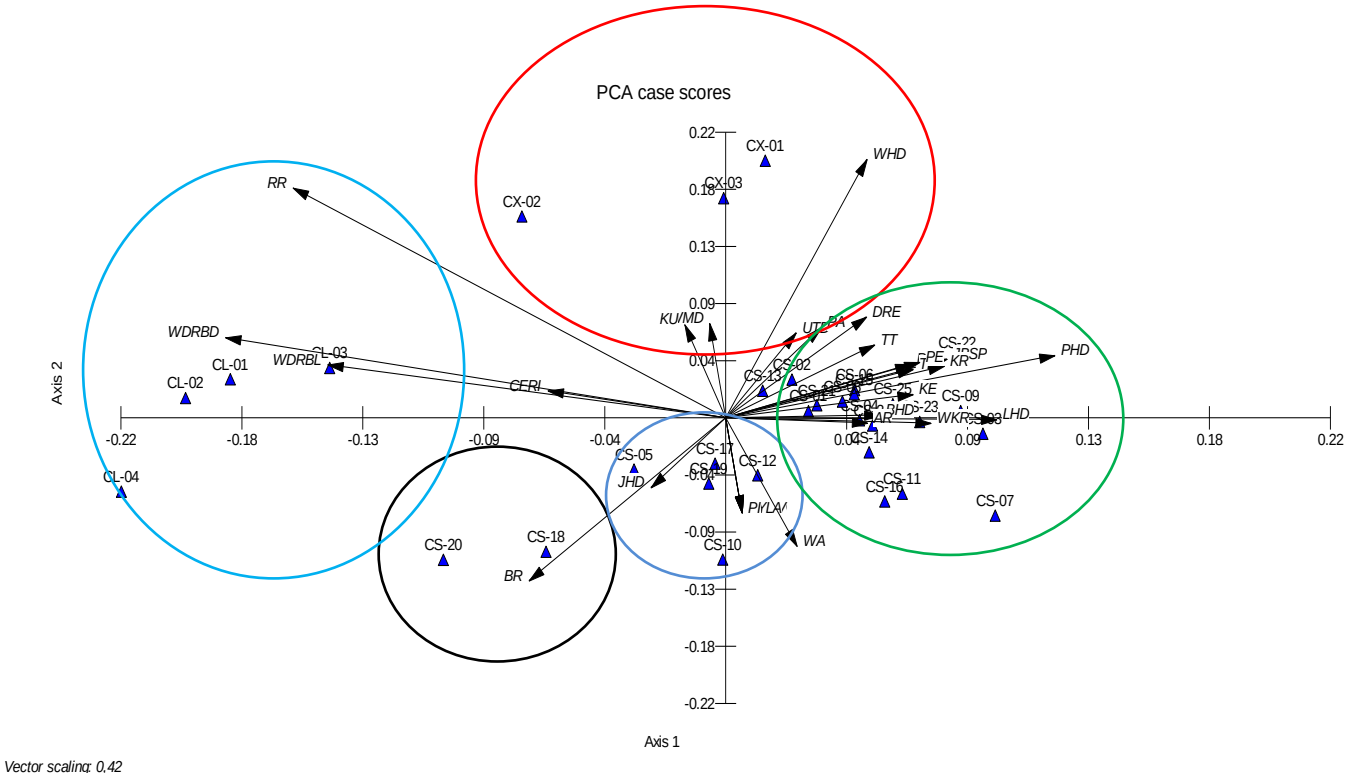

Figure 6. PCA of the *Curcuma soloensis* character's in Java Island, Indonesia

In general, morphological characters that play an important role in the grouping of *C. soloensis* in Java Island are the characters of leaves, roots, and rhizomes. Character that separates members of the *C.viridiflora* Roxb. species group. are leaf and rhizome characters (Backer and van den Brink 1968; Delin and Larsen 2000).

Principal component analysis (PCA) shows the pattern of grouping accessions (PCA arrows) and the role of each character in the grouping process (longer PCA arrows indicating greater role of character in grouping) (Figure 6). Usually, influential characters had an eigen value ≥2.00 (Stevens and Tello 2014). The PCA results showed that the characters most involved in grouping were leaf blade color (WHD), leaf blade length (PHD), rhizome shape (BR), root color (WA), Rhizome flavor (RR), outer rhizome flesh color (WDRBL), and the color of the inner rhizome flesh (WDRBD) (Figure 7). This can be shown in the form of arrows of different lengths.

Based on the results of the PCA (Principal Component Analysis) (Figure 6) the characters that play an important role in grouping are shown by long arrow lines and each individual of the same type is marked with a circle. The accession of *C. longa* CL-01, CL-02, CL-03, and CL-04 is influenced by the color of the outer (WDRBL) and inner rhizomes (WDRBD) and the taste of the rhizome (RR). The color of *C. longa* in orange is influenced by the content of curcuminoids in rhizome meat (Li et al. 2011). Accession of *C. soloensis* CS-18 and CS-20 is affected by aroma of rhizome (BR). Accessions of *C. soloensis* CS-05, CS-09, CS-10, CS-12, CS-17 are influenced by root color (WA). 18 accessions of *C. soloensis* CS-01, CS-02, CS-03, CS-04, CS-06, CS-07, CS-08, CS-11, CS-13, CS-14, CS-15, CS - 16, CS-19, CS-21, CS-22, CS-23, CS-24, and CS-25 are affected by leaf length (PHD) length. Accession of *C. zanthorrhiza* Roxb. CX-01, CX-02, and CX-03 are influenced by the color of leaf blades (WHD). The purple color of the leaf mid-rib is influenced by anthocyanin levels (Sungkawati et al. 2019). During the dry season anthocyanin levels are higher because of the influence of sunlight and temperature.

The results of the study obtained 25 accessions of *C. soloensis* in East Java (Trenggalek, Pacitan, Ponorogo), Central Java (Wonogiri, Karanganyar, Magelang, and Semarang Sub-district), and DI Yogyakarta (Yogyakarta, Bantul, Gunungkidul). *C. soloensis* variation lies in habit, stem color, leaf shape, rhizome shape, rhizome flesh color, and tuber shape. The dendrogram divides 32 OTUs into two clusters on the phenon line 0.617, namely, cluster A (*C. zanthorrhiza*) and cluster B (*C. soloensis* and *C. longa*). PCA results showed that the characters that had the most role in grouping were leaf blade color, leaf blade length, rhizome shape, root color, rhizome taste, outer and inner rhizome flesh color. This study needs to be continued at the molecular level with ISSR and ITS markers to confirm that *C. soloensis* is a separate species from *C. longa*. Although from the current morphological understanding, especially the similarity of flowering types it is possible that *C. soloensis* is a sub-species or variety of *C. longa*.

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