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MORPHOLOGICAL VARIATIONS SPECIES OF *Ziziphus* (RHAMNACEAE) IN JAVA

VARIASI MORFOLOGI JENIS Ziziphus (RHAMNACEAE) DI JAWA

Moh. Ihsan[1*)], Rodiyati Azrianingsih[1)], Rugayah[2)], Muhammad Efendi[3)]

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Authors affiliation:

[1)]Department of Biology, Faculty of Mathematics and Natural Science, Universitas Brawijaya, Indonesia

[2)]Biology Research Center, Indonesian Institute of Sciences (LIPI), Indonesia

[3)]Plant Conservation Research Center and Botanical Gardens, Cibodas Botanical Gardens (KRC), Indonesia

Correspondence email:

*mboteasin@gmail.com

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ABSTRACT

Ziziphus in Indonesia, especially Java, has five species recorded in the book Flora of Java. In 2010, there were two additional species that had not been recorded in the Flora of Java. Some species of unresolved taxon position and nomenclature are valid and precise. Meanwhile, the latest scientific journal publications related to taxonomic studies of Ziziphus species in Java have not been widely carried out and are even almost non-existent. This study aimed to re-examine the Ziziphus species in Java based on variations in morphological characters. Exploration and identification of specimens throughout Java and herbarium study specimens were carried out. The morphological characterizations observed included stature, morphology of stems, leaves, flowers, fruits, and seeds. The identification obtained eight species, Ziziphus mauritiana Lam., Ziziphus spina-christi (L.) Desf., Ziziphus celtidifolia DC., Ziziphus javanensis Blume, Ziziphus horsfieldii Miq., Ziziphus rufula Miq., Ziziphus oenoplia (L.) Mill. and Ziziphus nummularia (Burm. f.) Wight et Arn. Three species of which are new records for the Java region, among others; Ziziphus celtidifolia DC., Ziziphus mauritiana Lam. and Ziziphus spina-christi (L.) Desf. Phenetic analysis based on morphological characteristics showed that Ziziphus in Java had 52% - 81% similarity.

Keywords: *Java, morphological, variations, Ziziphus*

ABSTRAK

Ziziphus di Indonesia terutama Jawa, terdapat lima jenis yang tercatat di buku Flora of Java. Tahun 2010, terdapat tambahan dua jenis yang belum tercatat di Flora of Java. Beberapa jenis belum terselesaikan posisi takson dan tatanama yang falid dan benar. Sementara itu, publikasi jurnal ilmiah terbaru terkait kajian taksonomi terhadap jenis-jenis Ziziphus di Jawa belum banyak dilakukan dan bahkan hampir tidak ada. Tujuan penelitian ini adalah untuk menelaah kembali jenis-jenis Ziziphus di Jawa berdasarkan variasi karakter morfologi. Metode penelitian ini, eksplorasi dan identifikasi spesimen di seluruh wilayah Jawa dan studi spesimen herbarium. Karakterisasi morfologi yang diamati meliputi perawakan, morfologi batang, daun, bunga, buah, dan biji. Dari hasil identifikasi diperoleh delapan jenia yaitu Ziziphus mauritiana Lam., Ziziphus spina-christi (L.) Desf., Ziziphus celtidifolia DC., Ziziphus javanensis Blume, Ziziphus horsfieldii Miq., Ziziphus rufula Miq., Ziziphus oenoplia (L.) Mill. dan Ziziphus nummularia (Burm. f.) Wight et Arn. Tiga jenis merupakan catatan baru untuk wilayah Jawa antara lain; Ziziphus celtidifolia DC., Ziziphus mauritiana Lam. dan Ziziphus spina-christi (L.) Desf. Analisis fenetik berdasarkan karakteristik morfologi menunjukkan bahwa Ziziphus di Jawa memiliki kemiripan 52% - 81%.

Kata kunci: *Jawa, morfologi, variasi, Ziziphus*

INTRODUCTION

Ziziphus (bidara, ber, jujube) belongs to the buckthorn family (Rhamnaceae). This genus consists of 170 species spread in tropical and subtropical regions throughout the world [1]. The *Ziziphus* genus is mostly concentrated in Asia and America, although some of them are widespread in the Pacific Islands and Australia [2]. There are 17 species in India and six species in Pakistan [3, 4] added that there are seven species in Bhutan and eight species in Nepal. In Indonesia, especially Java, there are five species recorded in the book Flora of Java [5] among others; *Ziziphus javanensis* Blume, *Ziziphus horsfieldii* Miq., *Ziziphus rotundifolia* Lam., *Ziziphus oenoplia* (L.) Mill. and *Ziziphus rufula* Miq. [6], added two species of *Ziziphus* in Java that has not been recorded in the Flora of Java book, namely, *Ziziphus jujuba* Lam. and *Ziziphus celtidifolia* DC.

Ziziphus Mill. first published by Phillip Miller in 1768 with the type *Z. jujuba*, based on type specimens from Austria [7]. The name *Ziziphus* has

a complicated history of nomenclature. The species *Z. jujuba* was first described scientifically by Carolus Linnaeus as *Rhamnus zizyphus* in his book Species Plantarum in 1753. Then in 1768, Phillip Miller concluded that the morphological character of *Z. jujuba* was sufficiently different from *Rhamnus* that *Ziziphus* deserved to be separated into a new genus, which was later named *Z. jujuba* Mill.

Several species of *Ziziphus* recorded in the Flora of Java, unresolved taxonomic positions and correct nomenclature such as *Z. jujuba* Lam. which is a synonym for *Z. mauritiana* Lam. [3] reduce the status of *Z. rotundifolia* Lam. as a synonym of *Z. nummularia* (Burm. f.) Wight et Arn.

Meanwhile, the latest scientific journal publications related to taxonomic studies of *Ziziphus* species in Java have not been widely carried out. Because there is confusion and limited scientific information regarding the species diversity of the *Ziziphus* genus in Java. So, it is appropriate that the diversity of *Ziziphus* species in Java is studied again by comprehensively reviewing all taxonomic information, such as taxonomic boundaries, natural classification, naming, similarity analysis, geographic distribution information, as well as ecology and taxonomic records regarding taxon related to its distribution in Java. In addition, field trips in several locations in Java and observations of herbarium specimens stored in Herbarium Bogoriense with a morphological approach have been carried out.

METHODS

Material. The material used was a *Ziziphus* specimen that had been collected by Moh. Ihsan (MI) consisted of 229 collection numbers and 32 herbarium collection numbers. For comparison, using a photo of herbarium specimens from Herbarium Musei Pariensis (P), Royal Botanic Gardens-Kew (K), and National Herbarium Nederland (L), well as specimen types from JSTOR. The collected specimens were then identified at the Taxonomy and Plant Development Laboratory, Department of Biology, FMIPA Universitas Brawijaya, and Herbarium Bogoriense (BO) - LIPI.

Sampling. Exploration activities were carried out on January 11 – October 6, 2020, throughout Java (Banten, West Java, Central Java, and East Java, including Madura and Kangean Islands) (Figure 1). The method of collecting data in the field followed Rugayah et al. [11]. Documentation of samples during exploration was done by taking photos and making dry herbariums, and providing notes on species name information, location name found, coordinate point, date of collection, collector, temperature, and altitude.

Observation and identification. The observed characteristics include stature, morphology of stems, leaves, flowers, fruits, and seeds. The botanical terms used to follow the book guidelines [8], Glossary of Biology by Rifai & Puryadi [9], and Harris & Harris [10]. Furthermore, identification of species using references, including Encyclopedie Methodique Botanique [12],

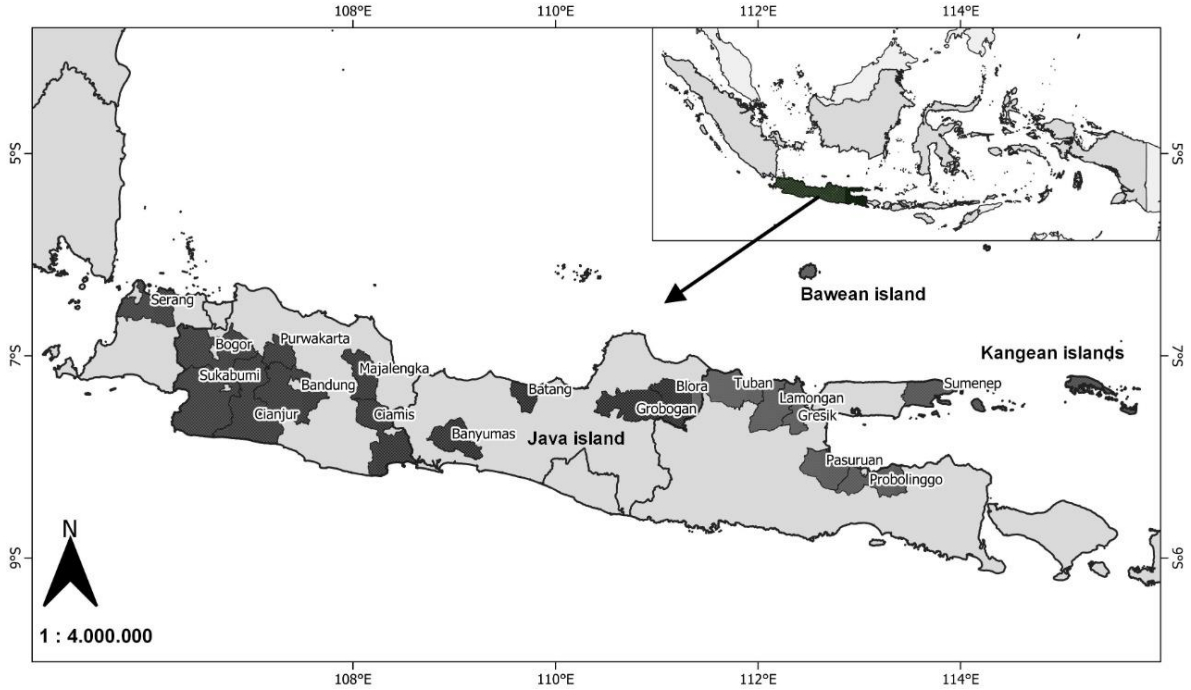

Figure 1. Map of *Ziziphus* sampling locations in Java (dark color)

Flora of Java [5], Flora Atlantica [13], Prodromus Systematis Naturalis Regni Vegetabilis [14], Flora van Nederlandsch Indie [15], Flora of China [16], Flora of Pakistan [17], Flora of Tropical East Africa [18], Taxonomy Study of the *Ziziphus* Mill. (Rhamnaceae) of Bangladesh [7].

RESULTS AND DISCUSSION

Variations of vegetative organs stature. The *Ziziphus* species in Java has the stature of liana, shrubs to trees. In general, the trunk is small to large, and woody. This plant is usually found in low to highlands such as open meadows, open shrubs, cliffs, riverbanks, forest edges, and ride on trees in open canopy areas in the forest in liana stature.

Z. mauritiana, Z. nummularia, and *Z. spina-christi* are species that grow from shrubs to trees. *Z. javanensis* has a stature in the form of a large trunked liana that grows creeping on the ground to hitch a ride on the trees. While *Z. oenoplia, Z. horsfieldii, Z. rufula,* and *Z. celtidifolia* have the stature of small trunked climbers (Figure 2).

Figure 2. Variation stature of *Ziziphus* in Java. Shrubs - trees: A). *Z. numularia;* B). *Z. spina-christi;* C). *Z. mauritiana*; Climb: D. *Z. oenoplia*; E). *Z. javanensis;* and F). *Z. horsfieldii.*

Stem. The stems of *Ziziphus* found in Java were generally slender, except for *Z. mauritiana*, *Z. nummularia,* and *Z. spina-christi*, which had fat stems and reach 55 cm diameter. Based on field observations, the stem diameter of *Ziziphus* with adult lianas can reach 25 cm, for example, in *Z. javanensis*. In climbing or liana stature uses supporting tools in the form of thorns on the twigs and stems. Then the direction of growth of the stem is monopodial. The main stem is always clearly visible compared to the branching, namely twigs.

The stature of *Ziziphus* shrubs to trees, the direction of branching is sympodial, that is, the main trunk is difficult to determine because of the many branches.

The surface texture of *Ziziphus* stems in Java varies widely from rough, irregular cracks to rough or lenticel nodules. The surface of the stem is rough and vertically cracked with gray to blackish color in *Z. mauritiana* and *Z. spina-christi*. For rough stem surfaces and irregular cracks with a reddish-brown color, *Z. nummularia*. Meanwhile, the rough brown surface with black spots is found in *Z. oenoplia*. Furthermore, for the smooth stem surface, gray-black spots were found in *Z. horsfieldii* and *Z. javanensis* (Figure 3). *Z. rufula* and *Z. celtidifolia* have not been found in the field, so that the character and surface color of the stems are not known.

Figure 3. Variations in the texture and surface color of *Ziziphus* stems in Java. Rough and broken: A). *Z. mauritiana* B). *Z. spina-christi*. Lenticels: C). *Z. oenoplia*, D). *Z. horsfieldii* and E). *Z. javanensis.*

Twig. The surface of the twigs in the *Ziziphus* genus found in Java has several variations. Smooth straight-haired twig surfaces were found in *Z. oenoplia*, Z. *horsfieldii*, and *Z. rufula.* Bare to hairy surfaces were found in *Z. javanensis*, Z. *celtidifolia*, and *Z. spina-christi.* Meanwhile, for the surface of the dreadlocks, there are species *Z. mauritiana* and *Z. nummularia.*

The color of the twigs in *Ziziphus* has several variations, including whitish gray to brownish-yellow. The color is thick fine hair-like wool that covers the entire surface of the young twigs. This character is found in *Z. mauritiana* and *Z. nummularia*. Twigs with light brown to dark color are found in *Z. oenoplia* and *Z. rufula*. Meanwhile, the color of the twigs from light to dark green was found in *Z. horsfieldii*, *Z. javanensis*, and *Z. celtidifolia*. *Z. spina-christi* has green to white (Figure 4).

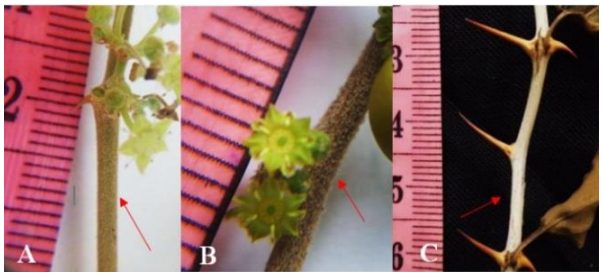

Figure 4. Variation in twig surface of several *Ziziphus* in Java. (A). Dreadlocks (*tomentose*), (B). fine hair (*pubescent*), (C). Hairless (*glabrous*).

Stipule leaves. *Ziziphus* has stipulated leaves that modify into spines that grow at the base of the petiole or stem segment (*nodes*) in the form of single or paired spines. *Ziziphus* spines are generally pointed and woody, paired spines one of which is straight and curved downwards. The number of single spines is found in *Z. javanensis*, *Z. horsfieldii*, and *Z. celtidifolia*. Paired spines are found in *Z. mauritiana*, *Z. spina-christi*, *Z. oenoplia*, and *Z. rufula* (Figure 5).

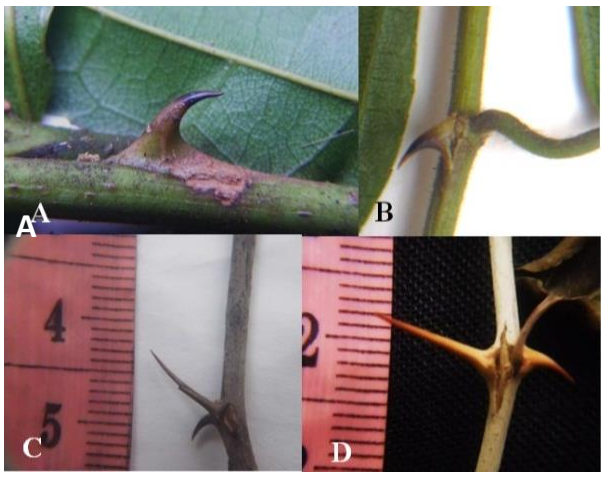

Figure 5. Variations in number and shape of *Ziziphus* stipules in Java. Single thorn, A). *Z. javanensis* B). *Z. horsfieldii*, Couple thorn: C). Z. *nummularia*, D). *Z. spina-christi.*

Leaf stalk. *Ziziphus* leaf stalks found in Java have various variations. The results of sample observations were obtained, including glabrous - pubescent surfaces found in *Z. javanensis*, *Z. horsfieldii*, *Z. celtidifolia*, *Z. spina-christi*, and *Z. rufula*. The pubescent surface is found in the species *Z. oenoplia*. The surface of the gray and brown dreadlocks (tomentose) was found in *Z. mauritiana* and *Z. nummularia* (Figure 6).

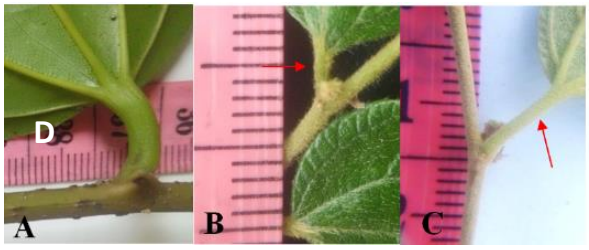

Figure 6. Variation in petiole surface of *Ziziphus* in Java. A). Glabrous, B). Pubescent dan C). Tomentose.

Leaf shape and size. Variations in leaf shape in each species have more than one type of shape. The results of observations obtained several types, including the oval (*ovate*) ratio (2:1 – 3:2), oblong ratio (2:1), and a bit round (*suborbicular*) in one branch found in *Z. mauritiana*. Slightly round (*suborbicular*), oval (*ovate*), and elliptical shapes are found in *Z. nummularia*. Meanwhile, ovate to oval shapes were found in *Z. javanensis* and *Z. horsfieldii*. The oval shape to the elliptic is found in *Z. oenoplia*, *Z. spina-christi*, and *Z. celtidifolia*. Furthermore, the oval shape is only found in *Z. rufula* based on observation of herbarium specimens (Figure 7).

The results of observations and measurements of leaves on *Ziziphus* species in Java obtained several variations in the range of leaf length and width. Among them, the leaf length is less than 4 cm, only found in *Z. nummularia*. Furthermore, the leaf length ranges from 4 to 10 cm were found in *Z. mauritiana, Z. oenoplia, Z. spina-christi, Z. celtidifolia, Z. rufula*, and *Z. horsfieldii*. While the variation in leaf length with a range of 10-30 cm is only found in *Z. javanensis*. Variation of leaf width on *Ziziphus* in Java is 0.5-5 cm except for the species *Z. javanensis*, which has a leaf width range of 5-15 cm, is the species with the largest leaves among *Ziziphus* in Java.

Apex and base leaf. Variations in the apex and base leaf of the *Ziziphus* found in Java have various forms. Generally, it has several forms, including rounded – acute, for example, in *Z. mauritiana* and *Z. nummularia* obtuse – acute form found in *Z. spina-christi*. Acute was found in *Z. oenoplia* and acute – acuminate on *Z. rufula*. Furthermore, for acuminate, there are species of *Z. javanensis, Z. horsfieldii*, and *Z. celtidifolia* (Figure 8).

The characteristic shape of the leaf base in the *Ziziphus* genus found in Java is one of the markers for several species (Figure 9). Among them are rounded leaf bases found *in Z. javanensis, Z. spina-christi*, and *Z. nummularia*. Obtuse – rounded type on *Z. horsfieldii*. Leaf base type obtuse - rounded - slightly oblique found in *Z. mauritiana.* While the oblique type is found in *Z. cetidifolia* and *Z. rufula.* Type rounded - oblique found in *Z. oenoplia.*

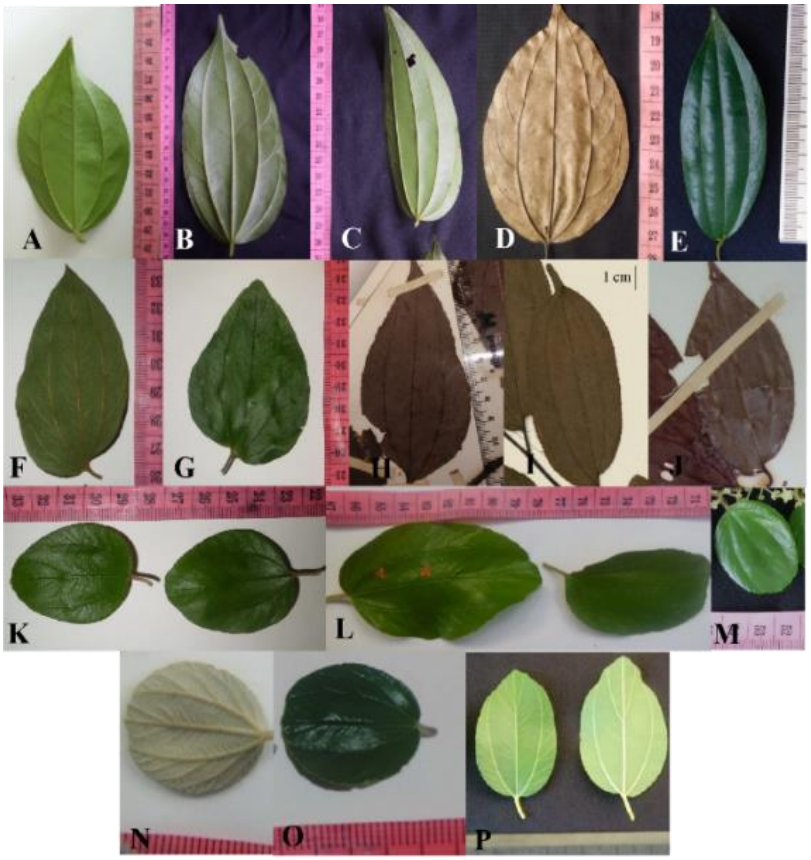

Figure 7. Shape and size variation of *Ziziphus* leaves in Java. Ovate – oblong: A – C). *Z. javanensis*, D – E). *Z. horsfieldii*, Ovate - elliptic: F – G). *Z. oenoplia*, H – I). *Z. celtidifolia*, Ovate: J). *Z. rufula*., (H). Sub rounded – ovate - oblong: K –M). *Z. mauritiana*, N – O). *Z. nummularia*, Ovate: P). *Z. Spina-christi*.

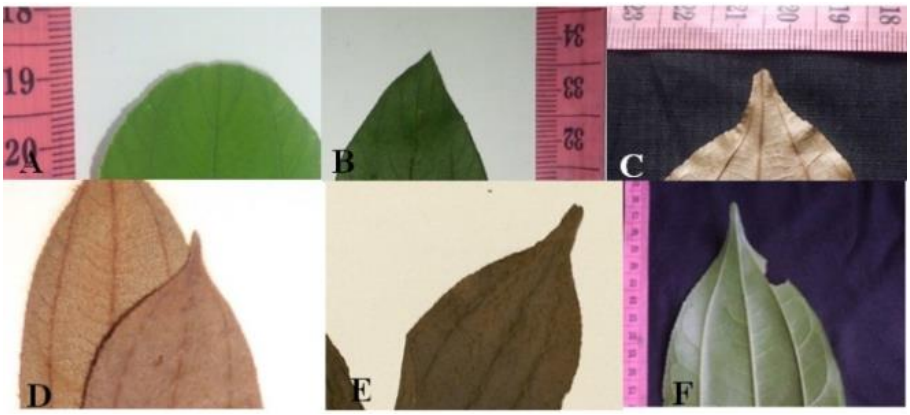

Figure 8. Variations in the shape of *Ziziphus* leaf tips found in Java. A). Rounded, B). Acute and C – F). Acuminate.

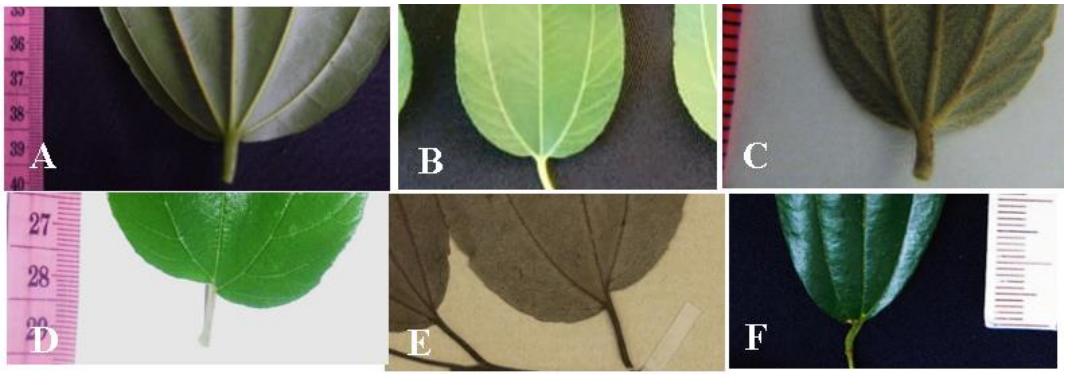

Figure 9. Variations in the shape of the leaf base of several *Ziziphus* species in Java. A – C). Rounded; D – E). Oblique and F). obtuse.

Upper and lower surface variations. Variations on the upper and lower surfaces of *Ziziphus* leaves found in Java have various variations (Figure 10). The results of the observation of the specimen samples obtained include: Glossy green upper surface was found in *Z. javanensis Z. mauritina, Z. horsfieldii, Z. spina-christi,* and *Z. celtidifolia.* Furthermore, the hairy surface was found in *Z. oenoplia, Z. rufula,* and *Z. nummularia.*

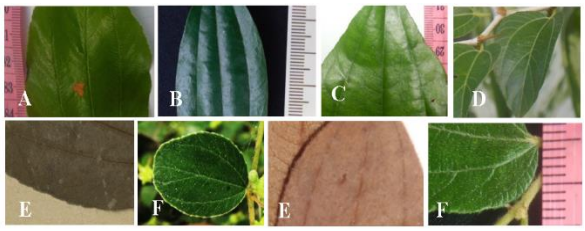

Figure 10. Variation of the upper surface of *Ziziphus* leaves in Java. Glabrous, A). *Z. mauritiana,* B). *Z. horsfieldii,* C). *Z. javanensis,* D). Z. *spina-christi,* E). *Z. celtidifolia.* Pubescent, F). *Z. nummularia,* G). *Z. rufula,* H). *Z. oenoplia*.

The color and texture of the lower surface of the leaves in the *Ziziphus* genus have various variations and are a sign of several species. Among them, the green color type with a glabrous surface, but hair only on the leaf venation surface is found in *Z. javanensis, Z. celtidifolia,* and *Z. horsfieldii*. Then for green to golden yellow color and pubescent, it was found in *Z. oenoplia* and *Z. rufula*. However, in the species *Z. rufula,* when the leaves are old, the hair immediately disappears and is only found on the surface of the leaf venation. While *Z. mauritiana* and *Z. nummularia* are gray to brown with tomentose hair (Figure 11).

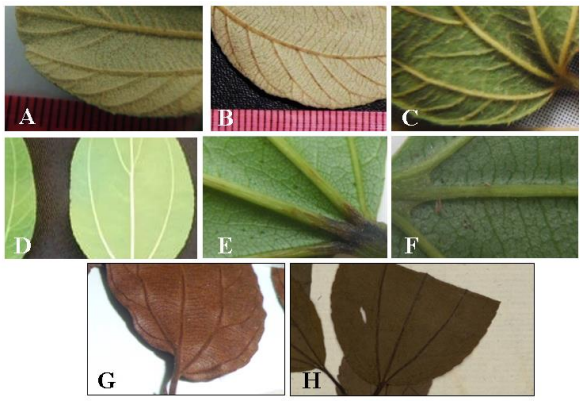

Figure 11. Lower surface variations of *Ziziphus* leaves in Java. Tomentose, A). *Z. nummularia,* B). *Z. mauritiana*. Pubescent. C). *Z. oenoplia* and D). *Z. spina-christi*. Hair only on the surface of the leaf venation, E). *Z. javanensis* F). *Z. horsfieldii,* G). *Z. rufula* and H). *Z. celtidifolia*.

Leaf color. The leaves of the *Ziziphus* found in Java are generally light green to dark green. However, on the day of observation on live specimens in the field, several species had color variations on the leaves when they were young (Figure 12). Among them are red to yellow, for example, in *Z. javanensis* and *Z. horsfieldii.* Meanwhile, *Z. mauritiana, Z. spina-christi,* and *Z. nummularia* have young greenish-yellow leaves. The other species have not been observed because their natural habitus is not found during exploration in the field.

Figure 12. Variations in color of young leaves of several *Ziziphus* genera in Java. Red to yellow color: A). *Z. horsfieldii*, B). *Z. javanensis* and greenish-yellow: D). *Z. oenoplia*, E). *Z. mauritiana.*

Leaf margin. Variations in leaf margins on *Ziziphus* found in Java have several variations, including flat-leaf margins entire - serrate or serrulate found in *Z. mauritiana, Z. oenoplia, Z. rufula, Z. spina-christi,* and *Z. nummularia.* Furthermore, for the crenate–serrate type, there are *Z. javanensis, Z. horsfieldii, and Z. celtidifolia* (Figure 13).

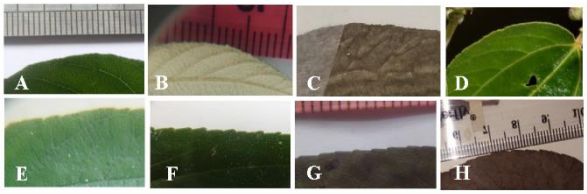

Figure 13. Leaf margin variation of *Ziziphus* in Java. A - C). Entire - serrulate, E). Serrate and F – H). Crenate.

Venations. The characteristics of the leaf veins in *Ziziphus* are generally transverse from the base of the leaf with the main leaf veins numbering from 3 to 5 with clear prominent features. From the observations, the number of leaf veins in *Ziziphus* varies. Among them, three types of leaf bones with

non-fused ends were found in *Z. mauritiana*, *Z. nummularia*, and *Z. spina-christi*. Three leaf veins with fused ends were found in *Z. horsfieldii* and *Z. celtidifolia*. Furthermore, for the type of leaf veins, there are three to four with non-fused ends found in *Z. oenoplia*. Meanwhile, for *Z. rufula* has a number of leaf veins 3-4, the three bones are fused at the end, and the other is sideways. Then for the leaf bone type with a total of five found in *Z. javanensis*. The three main veins are fused at the tip of the leaf, and the others are sideways to the leaf margin (Figure 14).

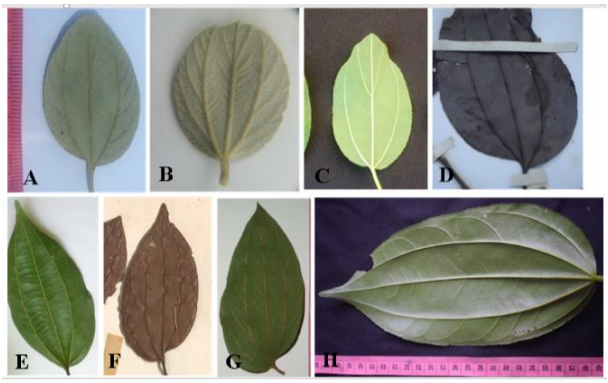

Figure 14. Variation in the number of *Ziziphus* leaf veins in Java.A – E). Tree veins, F-G). Tree –Four Veins, H). Five veins

The results of field observations showed that the leaves of *Ziziphus horsfieldii* were sometimes found to have domatia at the base of the leaf bones. (Figure 15). According to O'dowd & Willson [19], Domatium (plural: domatia, from the Latin "domus" which means "house") is a small room produced by plants that host arthropods insects. This character is not owned by other *Ziziphus* species in Java.

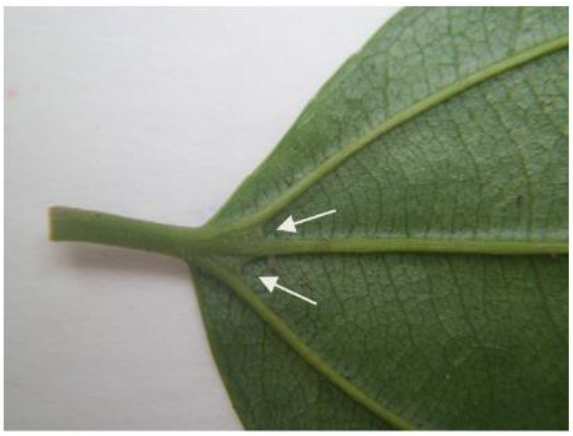

Figure 15. Domatia (arrow) in *Ziziphus horsfieldii*

Variations of generative organs. The morphological characteristics of inflorescences and floral organs in *Ziziphus* are relatively uniform. Some observations of fruit and seed variations can be used as species limits. Variations in morphological characteristics of generative organs in *Ziziphus* are tabulated in Table 1 and described in the following description.

Inflorescence. In Java, the *Ziziphus* clan has a hermaphrodite in one flower, arranged in a series of inflorescent cymes with dichotomous or dichotomous branches. The results of the observations showed that the flower arrangement was axillary, namely a series of compound flowers that grew in each leaf axil. There was no terminal arrangement or growth at the end of the twig (Figure 16).

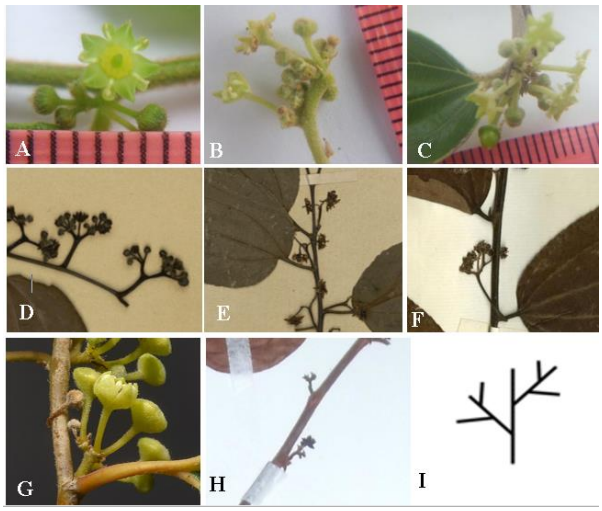

Figure 16. *Ziziphus* inflorescence in Java. A). *Z. oenoplia*, B). *Z. mauritiana*, C). *Z. nummularia*, (D). *Z. horsfieldii*, E). *Z. celtidifolia*, (F). *Z. javanensis* (G). *Z. spina-christi*, H). *Z. rufula*, and I). Illustration of *dichotomous cyme*

Flower. The results of observations of morphological characteristics of flower organs in *Ziziphus* in Java showed that this genus had similar characters, namely the presence of nectar disc-shaped honey glands. The texture of this organ is thin to thick flesh, but what distinguishes this character is its color and shape. *Z. mauritiana* and *Z. nummularia* have disc greenish-white with a hairless surface and ten lobes. Meanwhile for *Z. oenoplia* has a characteristic yellow disc with ten lobes and is concave in each lobe. *Z. javanensis*, *Z. rufula*, *Z. horsfieldii*, *Z. celtidifolia*, and *Z. spina-christi* did not observe because the availability of generative organ material from the field is not found.

Flower ornaments (*perianthium*) on *Ziziphus* in Java, generally in multiples of five. The flower calyx is short tubular with green color, the surface is pubescent to glabrous. The sepals are generally oval triangular in shape with a tapered tip (acute). On the lower surface of the calyx and sepals, the hairy surface is sometimes glabrous. The inner surface of the leaf sepal, always glabrous or

hairless (*glabrous*). Furthermore, the character of the lower surface of the petals has variations, including dreadlocks (*tomentose*) found in *Z. mauritiana* and *Z. nummularia*. The type of fine to pubescent hair is found in *Z. oenoplia* and *Z. spina-christi*. Based on the description, *Z. javanensis and Z. rufula* also have pubescent hair characters [5].

The results of observations and reference information show variations in the shape and color of the crown leaf (*petala*), among others. Spatulate with white is found in *Z. mauritiana* and *Z. spina-christi*. The green spatulate type is found in *Z. oenoplia* and *Z. rufula*. Furthermore, the form of cuneate white color on the species *Z. nummularia*. According to [5], the white oval type was found in *Z. javanensis*, and the white obovate was found in *Z. horsfieldii*. The sex organs in *Ziziphus* flowers in Java are almost uniform. The results showed that the stamens were five, sitting alternately with the sepals, the base of the stamens united with the crown leaf (*petala*), white to greenish in color, and the same length as the crown leaf. Uniformity is also found in the shape of the ovary, which is rounded (*globose*), double bear (*bilocular*).

There are variations in the ovary surface of *Ziziphus*, namely the glabrous surface found in *Z. mauritiana, Z. nummularia, Z. eonoplia, Z. spina-christi,* and *Z. rufula*. Meanwhile, *Z. javanensis* and *Z. horsfieldii*, based on information [5], has a smooth hairy ovary surface. Observations on the pistil organ of the flower were found to be almost uniform with the tip of the pistil (stigma) forked in two with a downward curved type (Figure 17).

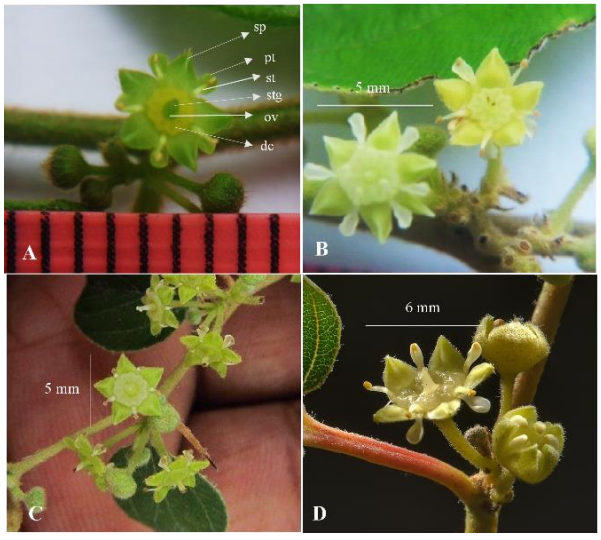

Figure 17. Flowers of several *Ziziphus* species in Java. A). *Z. oenoplia*, B) *Z. mauritiana*, C). *Z. nummularia* and D). Z. *spina-christi*. Informations; sp = sepal, pt = petal, st = stamen, stg = stigma, ov = ovary, ds = nectar disc.

Fruit. The type of fruit in the *Ziziphus* species in Java is a stone or drupe, characterized by having three layers of pericarp on the fruit (Figure 18). Among them, the outer layer (*exocarpium*) is a bearded layer and has a shiny smooth texture, the middle layer (*mesocarpium*) is a thick fleshy layer, and the inner layer (*endocarpium*) is a thick woody layer and has a hard texture [20].

Variations in fruit shape, fruit size, outer skin texture, and fruit skin color when ripe can be used as markers to identify *Ziziphus* species in Java. However, the limitations of fruit organs found in the field, related to the inaccuracy of fruiting and flowering seasons with the time of field visits, caused this feature not to be observed in all *Ziziphus* species in Java.

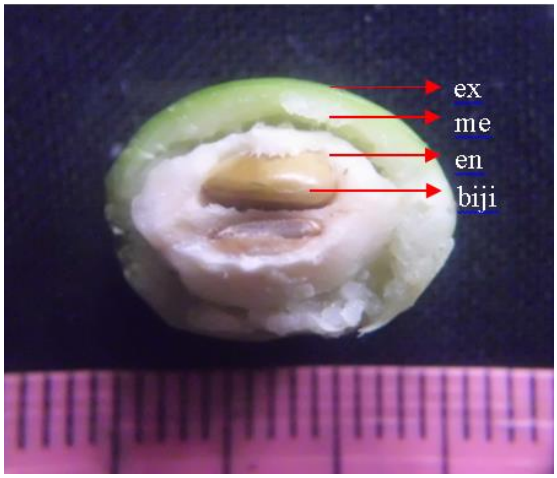

Figure 18. Longitudinal cross-section of the fruit of *Ziziphus mauritiana* Lam. Information; **exo** = Exocarpium, **mes** = Mesocarpium, **end** = Endocarpium

The results of observations on the *Ziziphus* genus obtained variations in fruit shape, namely globose, oblong, and rounded obovate. *Z. mauritiana Z. nummularia, Z. spina-christi,* and *Z. rufula* have a round to oval shape. As for the globose shape, it was found in *Z. oenoplia, Z. javanensis*, and *Z. celtidifolia*. For the globose shape to the oval shape of the obovate found *Z. horsfieldii*.

The color and texture of the fruit skin on *Ziziphus* also showed variations in several species. Among them, yellow, orange, red, brown and black. *Z. mauritiana* and *Z. nummuaria* have an orange to bright red skin color. Yellow-black color with shiny exocarp texture is found in *Z. oenoplia*. According to Backer [5], *Z. rufula* has a shiny black exocarp color and for the species *Z. javanensis* the fruit exocarp is yellow with a thin hairy surface. While *Z. horsfieldii* has a yellow exocarp color with a slightly rough surface and thin hair. Meanwhile, *Z. spina-christi* has a yellow to red-brown exocarp color with a shiny smooth exocarp texture (Figure 19).

Figure 19. Variations in the shape and color of *Ziziphus* fruit skin in Java. A). *Z. Mauritiana* B). Z. *nummularia* C). *Z. oenoplia* (L.) Mill. D – E). *Z. horsfieldii*, F). *Z. javanensis*, G). *Z. celtidifolia*, H). *Z. rufula* Miq. and I). *Z. spina-christi*.

Seed. Seeds in *Ziziphus* fruit are generally 1 to 2 in number, covered by a hard inner fruit shell (*endocarpium*) with a rough outer surface texture and irregularly wrinkled. The results of observations on several species of *Ziziphus* obtained variations in the shape of the *endocarpium* shell, including an ovate shape with a rounded base and a blunt tip to a tapered tip. These characters were found in *Z. oenoplia, Z. mauritiana*, and *Z. nummularia*. Then an oblong shape with both ends tapering to a point was found in *Z. spina-christi* (Figure 20).

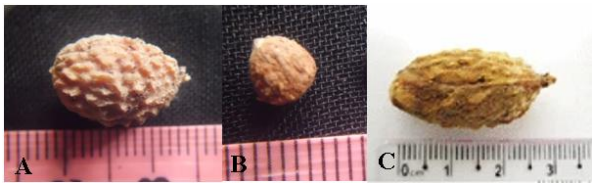

Figure 20. Variations in *Ziziphus* endocarp shell shape in Java. Ovate: A). *Z. mauritiana*, B). *Z. oenoplia*, and C). elliptic: *Z. spina-christi*.

The results of the observations showed that the shape of the seeds in *Ziziphus* in Java was almost uniform. Including the shape of a round (globose) to rounded eggs (ovate) slightly flattened with a blunt tip, has a red-brown seed coat to blackish brown. *Z. mauritiana, Z. nummularia*, and *Z. spina-christi* have a shiny red-brown seed coat. While *Z. oenoplia* has a shiny blackish-brown seed coat color (Figure 21).

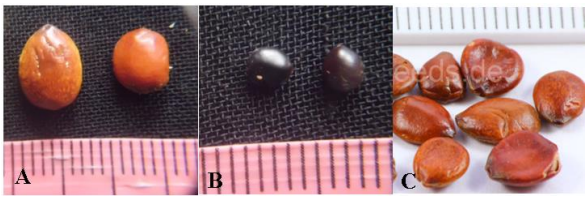

Figure 21. Variations in the shape and color of several seeds *Ziziphus* in Java. A). *Z. mauritiana* Lam., B). *Z. oenoplia* dan C). Z. *spina-christi*.

***Ziziphus* grouping in Java based on morphological characteristics.** The results of the similarity analysis using the Clad'97 program by Rahardi et al. [21], which refers to the algorithm [8] based on morphological characteristics, are presented in the form of a phenogram (Figure 22). The similarity coefficient (Kf) ranges from 52 to 81%.

The analysis is carried out on eight species of *Ziziphus* specimens in Java, including *Z. mauritiana, Z. nummularia, Z. oenoplia, Z. rufula, Z. celtidifolia, Z. horsfieldii, Z. javanensis*, and *Z. spina-christi*. These species grouped and separated based on similarities and differences in characteristics that could be compared.

Eight *Ziziphus* species in Java formed two groups at 52% Kf, namely group I and II. Group I include three species of *Ziziphus* which are combined into one group due to the similarity of habitus characteristics in the form of shrubs - trees. At 64% Kf, group I was divided into two groups, namely group IA which consisted of only one species of *Z. spina-christi* which has the character of the lower surface of the leaves with thin hair (*pubescent*). Meanwhile, group IB includes two species, namely *Z. mauritiana, Z. nummularia.*

CONCLUSION

Morphological characterization of *Ziziphus* vegetative and generative organs against 261 collection numbers found eight species of *Ziziphus* in Java, namely *Z. mauritiana, Z. nummularia, Z. rufula Miq., Z. spina-christi, Z. celtidifolia, Z. oenoplia, Z. javanensis*, and *Z. horsfieldii*. Three are new records for the Java region, namely *Z. mauritiana, Z. celtidifolia*, and *Z. spina-christi*. Phenetic analysis based on morphological characteristics showed that *Ziziphus* in Java had a similarity of 52% - 81%.

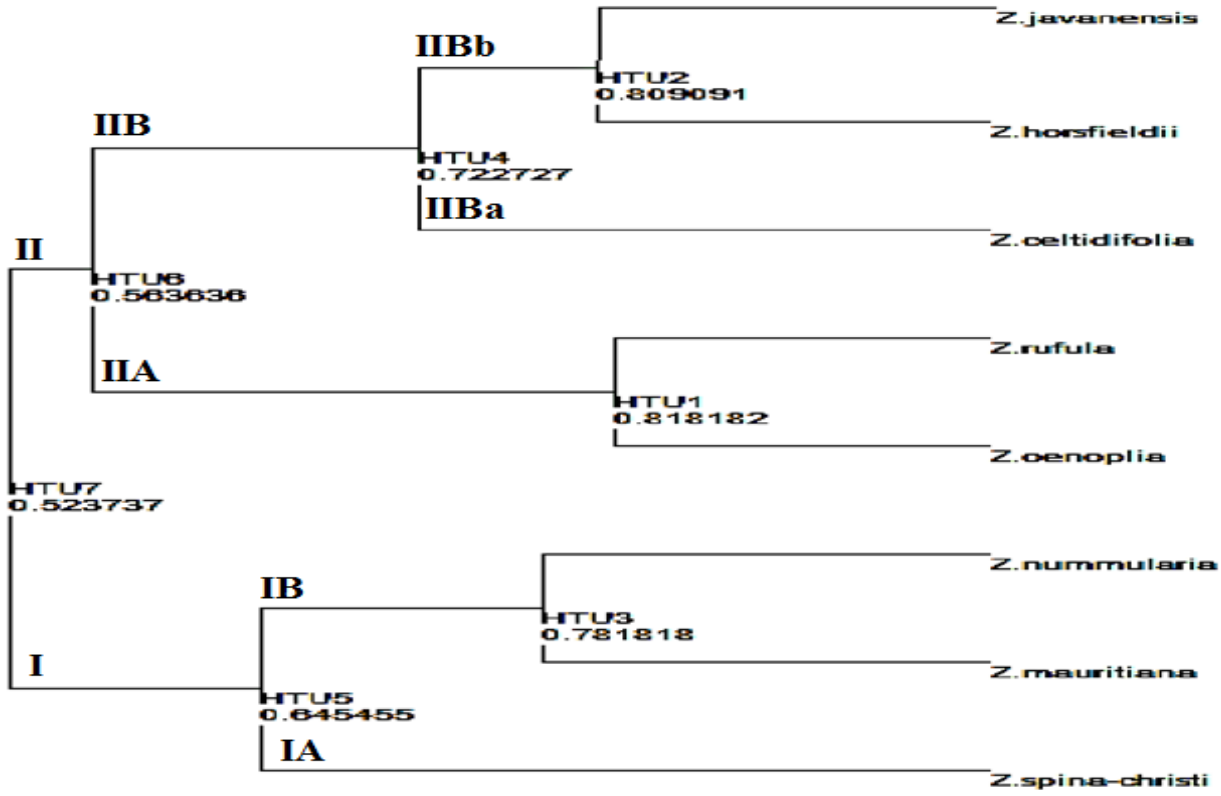

Figure 22. Phenogram analysis results using the Clad'97 program based on 110 morphological characteristics of eight *Ziziphus* species in Java

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Table 1 . Variations morphology of *Ziziphus* in Java

No.	Characteristic	Species							
		***Ziziphus mauritiana* Lam.**	***Ziziphus nummularia* (Burm.)**	***Ziziphus oenoplia* (L.) Mill.**	***Ziziphus rufula* Miq.**	***Ziziphus celtidifolia* DC.**	***Ziziphus horsfieldii* Miq.**	***Ziziphus javanensis* Blume**	***Ziziphus spina chisti* (L.) Defs.**
1	Stature	tree	shrub	liana	liana	liana	liana	liana	tree
2	Stem bark color	gray to black	red-light brown	red-brown	-	-	gray	gray	white to gray
3	Bark texture	rough broken	rough broken	rough with lentils	-	-	rough with lentils	rough with lentils	rough broken
4	Stem branch	symphodial	symphodial	monopodial	monopodial	monopodial	monopodial	monopodial	symphodial
5	Branch internodus	Straight-little zig-zag	zig-zag	straight	straight	straight	straight	straight	zig-zag
6	Branching direction	drooping	drooping	drooping	drooping	drooping	drooping	drooping	drooping
7	Branch surface	tomentose	tomentose	pubescent	pubescent	globrous	glabrous - pubescent	glabrous	glabrous - pubescent
8	Branch color	gray-brown	gray-brown	brown-green	-	-	green	green	white-red
9	Stipule leaf type (thorn)	straight-curved	straight-curved	straight-curved	straight-curved	curved	curved	curved	straight-curved
10	Thorn number	2	2	2	2	1	1	1	2
11	Leaf shape	oblong, ovate, sub orbicular	suborbicular, ovate, elliptic	ovate, elliptic	ovate	ovate, elliptic	ovate, oblong	ovate, oblong	ovate, elliptic
12	Leaf length (cm)	2 – 8	1.3 – 4	2 – 8	5 – 9	2 – 10	2 – 10	7 – 30	3 – 7
13	Leaf width (cm)	1 – 4.5	0.8 – 3	2 – 4	2 – 4	1 - 7	2.5 – 5	4 – 10	1.5 – 4
14	Leaf apex	obtuse, acute, sub rounded	obtuse, acute, sub rounded	acute	acute, acuminate	acuminate	acuminate	acuminate	obtuse, acute
15	Leaf margin	entire-serrulate	entire - serrate	entire-serrulate	entire-serrulate	crenate - serrulate	crenate - serrate	crenate- serrate	entire - serrate
16	Leaf base	obtuse, rounded, oblique	obtuse, rounded	rounded-oblique	oblique	oblique	obtuse-rounded	obtuse-rounded	obtuse
17	Petiole surface	tomentose	tomentose	pubescent	pubescent	globrous	pubescent	pubescent	globrous-pubescent
18	Leaf stalk color	gray-brown	gray-brown	brown-green	-	-	green	green	green- red
19	Young leaf color	light green	light green	light green yellow	-	-	red	red	light green
20	Leaf upper surface (color – texture)	green - glabrous	green- pubescent	green-pubescent	green, glabrous – subpubescent	green glabrous	green glabrous	green glabrous	green glabrous
21	Lower surface (color – texture)	white-brown, tomentose	white-brown, tomentose	brown, pubescent	light brown subpubescens	green, glabrous	green, glabrous	green, glabrous	green, pubescent
22	Venation	cervinervis	cervinervis	cervinervis	cervinervis	cervinervis	cervinervis	cervinervis	cervinervis
23	Venation surface	tomentose	tomentose	pubescent	pubescent	pubescent	pubescent	pubescent	pubescent
24	Venation number	3	3	3-4	3-4	3	3	5	3

No.	Characteristic	Species							
		***Ziziphus mauritiana* Lam.**	***Ziziphus nummularia* (Burm.)**	***Ziziphus oenoplia* (L.) Mill.**	***Ziziphus rufula* Miq.**	***Ziziphus celtidifolia* DC.**	***Ziziphus horsfieldii* Miq.**	***Ziziphus javanensis* Blume**	***Ziziphus spina chisti* (L.) Defs.**
25	Domatia	not available	not available	not available	not available	not available	available	not available	not available
26	Flower type	inflorescence cymes	inflorescence cymes	inflorescence cymes	inflorescence cymes	inflorescence cymes	inflorescence cymes	inflorescence cymes	inflorescence cymes
27	Branch type	dicotomi	dicotomi	dicotomi	dicotomi	dicotomi	dicotomi	dicotomi	dicotomi
28	Cymes layout	axillary	axillary	axillary	axillary	axillary	axillary	axillary	axillary
29	Pedunculus long (mm)	2 – 3	1 – 2	0 – 3	2 – 4	5 – 7	5 – 7	7 – 15	1 – 3
30	Pedunculus surface	tomentose	tomentose	pubencent	pubescent	glabrous	pubescent	pubescent	pubescent
31	Pedunculus color	gray - yellowish	gray - yellowish	green - brown	green - brown	green	green	green	green
32	Pedicellus long (mm)	4 – 7	3 – 4	1.5 – 4	1 – 3	2 – 3	1.5 – 2.5	1.5 – 4	3 – 5
33	Flower diameter (mm)	4 – 6	3 – 4	3	2.5 – 4	4 – 5	3 – 4	5	4
34	Calyx shape	tube	tube	tube	tube	tube	tube	tube	tube
35	Calyx color	gray-brown	gray-brown	green-brown	green	green	green	green	green
36	Sepal number	5	5	5	5	5	5	5	5
37	Sepal shape	ovate-triangular acute	ovate-triangular acute	ovate-triangular acute	ovate-triangular acute	triangular acute	ovate acute	ovate acute	ovate acute
38	Sepal long (mm)	1.5 – 1.7	1.5	1 – 1.2	1 – 1.2	1 – 1.2	1.5	1.5	1.5 – 2
39	Sepal outer surface	tomentose	tomentose	pubescent	pubescent	pubescent	pubescent	pubescent	pubescent
40	Sepal inner surface	glabrous	glabrous	glabrous	glabrous	glabrous	glabrous	glabrous	glabrous
41	Petala number	5	5	5	5	5	5	5	5
42	Petala color	white	white	green	green	white	white	white	white
43	Petala shape	spatulate	cuneate	spatulate	spatulate	oval	obovate	oval	spatulate
44	Petala long (mm)	0.8 – 1.2	1 – 1. 2	0.8 – 1	0.8 – 1	0.8 – 1	0.7 – 0.8	0.8 – 0.9	1.5
45	Stamen color	white-greenish	white	green	green	white	white	white	white
46	Stamen long (mm)	0.8 – 1.2	0.8 – 1	0.7 – 0.9	0.7 – 0.9	0.8 – 1	0.7 – 0.8	0.8 – 0.9	1.2 – 1.5
47	Stamen number	5	5	5	5	5	5	5	5
48	Nectar disc diameter (mm)	3 – 5	2 – 2.5	1.5 – 2	1.5 – 2	3 – 4	3 – 3.5	1.5 – 2	3.5
49	Nectar disc margin	lobed 10	lobed 10	lobed 10	lobed 10	lobed 10	lobed 10	lobed 10	lobed 10
50	Nectar disc shape	pentagon -round	round	round	round	round	round	round	round
51	Nectar disc color	whitish green	green	yellow	-	-	-	-	yellowish green
52	Ovarium shape	round	round	round	round	round	round	round	round
53	Ovarium type	biokular	bilokular	bilokular	Bilokular	Bilokular	bilokular	bilokular	bilokular

No.	Characteristic	Species							
		***Ziziphus mauritiana* Lam.**	***Ziziphus nummularia* (Burm.)**	***Ziziphus oenoplia* (L.) Mill.**	***Ziziphus rufula* Miq.**	***Ziziphus celtidifolia* DC.**	***Ziziphus horsfieldii* Miq.**	***Ziziphus javanensis* Blume**	***Ziziphus spina chisti* (L.) Defs.**
54	Ovarium surface	glabrous	glabrous	glabrous	glabrous	glabrous	pubescent	pubescent	glabrous
55	Fruit type	drupe	drupe	drupe	drupe	drupe	drupe	drupe	drupe
56	Fruit shape	globose-elliptic	globose-elliptic	globose	elliptic	globose	obovate	globose	globose
57	Fruit long (cm)	1.5 – 2	1 – 1. 5	0.5 – 0.7	0.3 – 0.5	0.8 – 1.2	0.5 – 1	1.5 – 2	1 – 2
58	Fruit width (cm)	1 – 1.8	0.8 – 1.2	0.5 – 0.6	0.2 – 0.4	0.7 – 1	0.5 – 0.8	1.5 – 2	0.8 – 1.8
59	Ripe fruit skin color	blackish red	blackish red	black	black	yellow	yellow	yellow	blackish red
60	Fruit skin surface	smooth shiny	smooth shiny	smooth shiny	smooth shiny	smooth	smooth hair	smooth hair	smooth shiny
61	Seed number	1 – 2	1 – 2	1 – 2	1 – 2	1 – 2	1 – 2	1 – 2	1 – 2
62	Seed shape	round - ovate	round - ovate	ovate	-	-	-	-	round - ovate
63	Seed diameter (mm)	5 – 6	5	1 – 2	-	-	-	-	3 – 6
64	Seed skin color	reddish brown	brown	reddish brown	-	-	-	-	brown
65	Seed skin texture	shiny slick	shiny slick	shiny slick	-	-	-	-	shiny slick