BIODIVERSITAS
Volume 20, Number 6, June 2019
Pages: 1617-1623

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d200618

Short Communication: Diversity of duckweed (Araceae-Lemnoideae), morphological characteristics and its potentials as food sources for herbivorous fishes in West Java, Indonesia

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Manuscript received: 2 April 2019. Revision accepted: 16 May 2019.

Abstract. *Andriani Y, Irawan B, Iskandar, Zidni I, Partasasmita R. 2019. Diversity of duckweed* (Araceae-Lemnoideae), *morphological characteristics and its potentials as food sources for herbivorous fishes in West Java, Indonesia. Biodiversitas 20: 1617-1623.* Duckweed is aquatic plant potential as a source of protein to feed herbivorous fish. The purpose of this study was to explore the diversity of duckweed species occurred in several areas in West Java. The exploration was done by collecting duckweed (Araceae) from water bodies such as lakes and ponds located in the fishery center in Garut, Bandung, Sumedang and Tasikmalaya Districts. The sample was identified using stereomicroscope to know the morphological characteristic. Characteristics being observed included root tip and sheath as well as the morphological frond characteristics. The result of study showed there were three species of duckweed recorded at the studied areas in West Java, namely *Spirodela polyrhiza* (L.) Schleid, *Lemna perpusilla* Torr. and *Lemna gibba* L. The three duckweed species can be distinguished based on its morphological characteristics, such as the number of roots, types of root tip, root sheath, symmetric-frond, gibbous-frond, and nerve-frond. In the studied areas, duckweed plants were found in ponds, stagnant water, and rice fields. Duckweeds can be used as a source of protein in fish feed as they have high protein content and complete amino acids.

Keywords: distribution, morphological characteristics, nutrient content, potential feed, taxonomy

INTRODUCTION

Duckweeds are small flowering aquatic plants that belong to the Araceae family (Cabrera et al. 2008; Cusimano et al. 2011; APG IV 2016) and grow free-floating or half submerged on the water surface (van der Plass 1971; Azer 2013). These plants have worldwide distribution and can be found in stagnant fresh waters, such as in ponds and around rice fields (Azer 2013; Paolacci et al. 2015; Ceschin et al. 2016). In the world, there are around 38 duckweed species found in aquatic ecosystems (Azer 2013). Duckweed consist of five genera, namely *Spirodela*, *Landoltia*, *Lemna*, *Wolffiella* and *Wolfia* and is classified into sub-family Lemnoideae of family Araceae (Cabrera et al. 2008; Cusimano et al. 2011; APG IV 2016). Duckweed species can naturally grow in association with various species of aquatic plants, such as *Pistia stratiote*s (water lettuce). Most duckweed species reproduce asexually, and under favorable conditions, it can reproduce very rapidly in which it can double its weight in very few days (Iqbal 1999; Landolt and Kandeler 1987).

Duckweed species are often difficult to identify because of their small size and elusive flowers (Azer 2013), therefore to differentiate species of duckweeds, vegetative morphological characteristics of roots (e.g., root tip, sheath) and fronds (e.g., habit, number, shape, margin, length, branching, papilla, gibbous, symmetry, dimensions) are generally used (Azer 2013; Ceschin et al. 2016). Duckweeds often grow in thick blanket-like mats on still, nutrient-rich, fresh and slightly brackish waters (Leng 1995; Ceschin et al. 2016a, 2018). These duckweeds mats serve as nutrient pumps, reducing eutrophication effects and providing oxygen from their photosynthesizing activity. Even if they are several centimeters thick, they can prevent gas exchange between air and water interface, reducing the amount of oxygen dissolved in the column of water below these mats (Ceschin et al. 2019a).

Duckweed grows on water with relatively high levels of N, P, and K, and they accumulate minerals and synthesize protein (Journey et al. 1993). Lemna is also reported as a pigment source in feeds (Subhan et al. 2018), source of anti-oxidant (Gulcin et al. 2010) and wastewater bioremediation (Mkandawire and Dudel 2007; Ugya 2007; Ceschin et al. 2019b). Duckweeds provide an easily digested protein supplement for poultry, livestock, and fishes. Due to their rapid growth, attractive nutritional properties and relative ease of production, duckweeds have generated a renewed interest among fish nutritionists of their potentials as alternative sources of fish feed. Duckweeds have an important role in aquaculture because

it can be used as a source of quality protein to feed herbivorous fish. Duckweeds have been widely used as a source of feed for several fishes and showed positive effects on growth performance (Bag et al. 2012; Srirangam 2016; Aslam and Zuberi et al. 2017).

West Java has a variety and abundance of duckweed species that can be utilized as a source of biological and potential source of feed for fish farming. Existing studies showed that some duckweeds are potentials as an alternative source of protein in fish feed (Yudhitstira et al. 2015; Kabir et al. 2009; Asimi et al. 2018). More information about different species of duckweed in West Java could expand the database of variety of duckweed, characteristics of each species, strategy of cultivation of the plant and its potential use as fish feeds. The purpose of this study is to explore the diversity of duckweed occurred in West Java and its potentials as animal and fish feed.

MATERIALS AND METHODS

Study area

Duckweeds were collected from several locations in West Java, Indonesia. The exploration was done by collecting duckweeds from lakes and ponds located in the central fishery center in Cikajang Sub-district of Garut District, Lembang Sub-district of West Bandung District, Jatinangor Sub-district of Sumedang District and Padakembang Sub-district of Tasikmalaya District (Figure 1).

The study location in Cikajang was at Mekarjaya Village where community groups carry out cattle farming integrated with agriculture and fisheries activities. At this place, *Lemna* is cultivated in soil ponds covered with tarps with a size of 5 x 7 m and used as fish feed and fertilizer for agricultural crops.

In Lembang, *Lemna* production was located at Sunten Jaya Village and is conducted by a group of cattle farmers who used *Lemna* as their feed. *Lemna* is cultivated in soil ponds, concrete pond, and tarpaulin ponds and fertilized by bio slurry.

The location of study Jatinangor was in Ciparanje Village at Padjadjaran University (Unpad) Campus area. Around the campus there are rice fields and ponds. Duckweeds grow abundantly around the edges of gullies and paddy fields, which are also associated with several aquatic plants such as *kangkung* (water spinach or *Ipomoea aquatica*) and *apu-apu* (water lettuce or *Pistia stratiotes*), or are cultivated in experimental ponds and fiber-based containers.

In Padakembang, the study site was at Rancapaku Village. At this location, there are ponds and paddy fields where *Lemna* flourishes. *Lemna* grows abundantly between rice plants in the paddy fields or in fish ponds.

Procedures

Duckweed samples were collected, labeled according to the date of collection, location, collector, and collection number, and put into bottles. Each sample was identified at the Plant Taxonomy Laboratory of the Department of Biology using stereomicroscope (model) to examine the morphological characteristics of duckweed. The morphological characteristics observed were related to root and fronds. The root morphology of duckweed included tips, the presence of wings on the sheath, the length of the roots and the number of roots. The frond morphology consisted of habit, shape, apex, number of frond, margin, frond-length, branching, scale, surface, gibbous, nerves, and symmetry. Identification of the species was done by identification keys (Backer and Bakhuizen 1968; van der Plass 1971; Azer 2013). A list of description key of each plant was then assigned to determine the species based on the morphological characteristics observed.

RESULTS AND DISCUSSION

Morphological characteristics

The results of identification obtain three species of duckweed found at four study sites in West Java, including *Spirodela polyrrhiza* (L.) Schleid, *Lemna perpusilla* Torr. and *Lemna gibba* L. Morphological characteristics to distinguish each species is shown in Tabel 1.

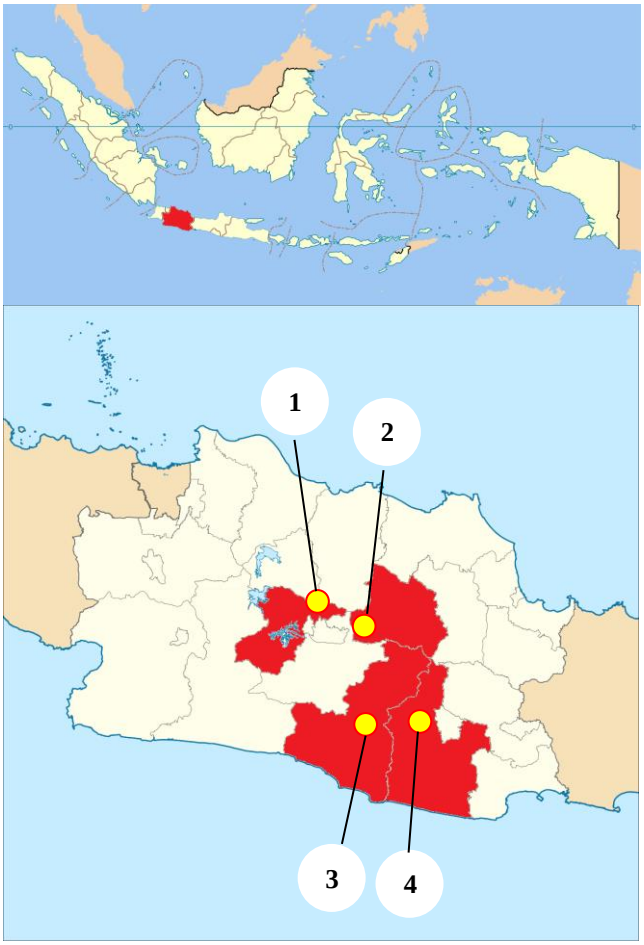


Figure 1. Study locations in West Java Province, Indonesia. 1. Lembang, West Bandung District; 2. Jatinangor, Sumedang District; 3. Cikajang, Garut District; 4. Padakembang, Tasikmalaya District

Species description

Spirodela polyrrhiza (L.) Schleid

Habit floating. Root numerous per frond (9-15 per frond), not winged. Tip pointed, 10-15 mm in length. Frond solitary (2-5 in group), ovate to sub-orbicular, length 8-16 mm. Apex obtuse to rounded, margin entire, unbranching. Scale present in dorsal and ventral. Nerves prominent 7-12 nerve. Surface brown pigment in ventral, green in dorsal, slightly convex. Symmetric frond (Figure 2).

Lemna perpusilla Torr.

Habit floating. **Root** 1 per frond, winged. Tip pointed, 10-20 mm in length. **Frond** solitary (2-5 in group), obovate to oblong, length 10-15 mm. Apex obtuse, margin entire, unbranching. Scale absent. Nerves inarticulate. Surface flat in dorsal and ventral. Symmetric frond (Figure 3).

Lemna gibba L.

Habit floating. **Root** 1 per frond, not winged. Tip rounded, 10-15 mm in length. **Frond** solitary (2-4 in group), obovate, length 7-12 mm. Apex obtuse to rounded, margin entire, unbranching. Scale absent. Gibbous present. Nerves inarticulate. Surface brown pigment in ventral, green shining in dorsal. Asymmetric frond. (Figure 4).

Identification key to the species

1. a. Root numerous (9-15 per frond), nerves prominent ..... *S. polyrrhiza*
   b. Root 1 per frond, nerves inarticulate 2
2. a. Frond symmetric, not gibbous, apex obtuse, green in ventral, root with winged, tip pointed .... *L. perpussila*
   b. Frond asymetric, gibbous, apex obtuse to rounded, brown pigment in ventral, root without winged, tip rounded ..... *L. gibba*

Habitat and distribution of duckweeds in West Java

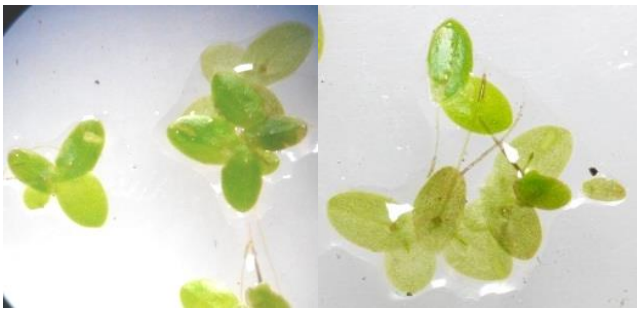
In our study, duckweeds were distributed in ponds and rice paddies. *L. perpusilla* is widely spread in Sumedang, Bandung, Garut and Tasikmalaya Districts, while *L. gibba* was only found in Garut. Similarly, *S.polyrrhiza* was only found in Sumedang. These species of duckweed are likely to grow in other areas in West Java and grow wild in ponds, sewers or paddy fields, and are also cultivated in aquaculture ponds. van der Plass (1971) mentioned that most species of duckweed grow in fresh water, sometimes in brackish water or on wet mud, in stagnant waters of canals, ditches and small ponds, and sometimes in slow-moving streams. Duckweeds are distributed until an altitude of 2100 m asl. *S. polyrhyza* is common in Sumatra, the Malay Peninsula, Java, Flores, North Sulawesi, the Philippines and New Guinea (van der Plass 1971). *L. perpusilla* is commonly found in the Malesia-Australian tropical region, while *L. gibba* is found in temperate regions to tropical regions of the world (van der Plass 1971).

Table 1. Morphological characters of duckweeds at four study sites in West Java, Indonesia

Characters	*S. polyrrhiza*	*L. perpusilla*	*L. gibba*
Root			
Tip	Pointed	Pointed	Rounded
Sheath	Not winged	Winged	Not winged
Length	10-15 mm	10-20 mm	10-15 mm
Number	Numerous (9-15) per frond	1 per frond	1 per frond
Frond			
Habit	Floating	Floating	Floating
Shape	Ovate to sub-orbicular	Obovate to oblong	Obovate
Apex	Obtuse to rounded	Obtuse	Obtuse to rounded
Number	Solitary (2-5 in group)	Solitary (2-5 in group)	Solitary (2-4 in group)
Margin	Entire	Entire	Entire
Length	8-16 mm	10-15 mm	7-12 mm
Branching	Unbranching	Unbranching	Unbranching
Scale	Present in ventral and dorsal	Absent	Absent
Gibbous	Present	Absent	Present
Nerves	Prominent, 7-12 nerve	(3) Indistinct nerve	Indistinct nerve
Symmetry	Symmetric	Symmetric	Asymmetric
Surface	Brown pigment in ventral, green in dorsal and slightly convex	Flat in dorsal and ventral	Gibbous in ventral and dorsal, brown pigment in ventral, shining in dorsal

A B

Figure 2. *Spirodela polyrrhiza* (L.) Schleid. A. Dorsal view, B. Ventral view



A B

Figure 3. *Lemna perpusilla* Torr. A. Dorsal view, B. Ventral view

A B

Figure 4. *Lemna gibba* L. A. Dorsal view, B. Ventral view

Discussion

The useful characteristics to distinguish duckweed species is only its morphological traits of vegetative part. Azer (2013) stated that the morphological characteristics of generative of duckweed which include flowers, fruit, and seeds are rarely found and generally small in size. Duckweed species found in this study in West Java belong to two genera of *Lemna* and *Spirodela*. These two genera can be distinguished based on the number of root and the morphological characteristics of its frond. *Lemna* has one root per frond, whereas *Spirodela* has larger number of roots per frond (9-15 per frond). This is in accordance with the statement of van der Plass (1971) that the number of roots can be used as identification keys to distinguish the genus of *Lemna* and *Spirodela*. In addition, the differences between the two genera can be seen from the size of the frond and nerve. *Lemna* has a smaller frond size than *Spirodela*. Nerve (leaf's vein) in the *Spirodela* is very clear and prominent, whereas the nerve in *Lemna* is inarticulate (van der Plass 1971) (see Figure 2). Other vegetative morphological characteristics to distinguish the species of *Lemna* are the presence or absence of wings in the root sheath (either winged or not winged), tip of the root, symmetry of frond (symmetric or asymmetric), surface of frond (gibbous or not) (van der Plass 1971, Azer 2013). *L. perpusilla* has winged root sheath, whereas *L. gibba* does not have winged root sheath. *L. perpusilla* has a pointed root tip, while *L. gibba* has rounded root tip. The form of frond in *L. perpusilla* is not gibbous, whereas in *L. gibba* has gibbous (bulging) and asymmetric frond. Ceschin et al. (2016) used form, size, symmetry, frond color and number of veins to distinguish *Lemna* species.

The species of duckweed collected in this study are those that grow around rice fields, slow-moving rivers, and also in aquaculture ponds. *L. perpusilla* is the species found at all observation locations. van der Plass (1971) mentioned that this species of duckweed plant spreads from the tropic region to the sub tropic. This species is commonly found in the Malesia region starting from Sumatra, the Malay Peninsula, Java, the Lesser Sunda Islands, North Borneo, the Philippines, Maluku and New Guinea (van der Plass 1971). *L. perpusilla* is found in freshwater, sometimes in still, brackish water, rice fields, gullies or streams which is often in association with *Spirodela* (van der Plass 1971).

A B C D

Figure 5. The occurrence of duckweeds in pools that grow wild and cultivated. A. Lakes; B. Ponds; C. Waterways; D. Aquaculture ponds

Table 2. Proximate composition of duckweed, *Lemna gibba*

Component	Value
Energy	3196 kcal/kg
Ash	20.10 ±0.33%
Crude protein	21.50±0.38%
Lipid	4.45 ±0.65%
Total Dietary Fiber (TDF)	21.55 ±0.49%
Nitrogen Free Extract (NFE)	32.40±0.36%

Source: Aguilera-Morales et al. (2018)

Table 4. Amino acid profiles of duckweed species (g/100 g)

Amino acid	*L. gibba*	*S. polyrrhiza*
Histidine	1.89	2.15
Isoleucine	3.87	3.75
Leucine	7.15	6.85
Lysine	4.13	4.30
Methionine	8.57*)	0.83
Phenylalanine	4.45*)	4.20
Threonine	3.20*)	3.45
Arginine	0.003*)	4.7**)
Valine	2.23*)	4.4**)
Alanine	27.80*)	5.4**)
Aspartic acid	8.77*)	7.8**)
Glutamic acid	23.13*)	9.6**)
Glycine	1.76*)	4.3**)
Proline	0.01*)	3.5**)
Serine	2.03*)	4.1**)
Tyrosine	1.69*)	3.1**)

Sources**:** Rusoff et al. (1980), *) Morales (2018), **) Compeer and de Best (2018)

Aquatic plants are one of the sources of vegetable protein which is widely used in fish farming especially of herbivorous fishes. The use of various aquatic plants such as giant salvinia (*Salvinia molesta*) (Mcintosh et al. 2003; Bosire et al. 2008), water lettuce (*Pistia stratiotes*) (Yudhitstira et al. 2015), duckweed fern (*Azolla pinnata*) (Gangadhar et al. 2015; Das et al. 2018) and water hyacinth (*Eichhornia crassipes*) (Sotolu and Sule 2011; Mohapatra et al. 2015; Hontiveros and Serrano 2015;) as a source of fish feed have been extensively studied. Duckweeds have a great potential to be developed in aquaculture industry. Due to its rapid growth, duckweed has generated great interest among fish nutritionists on its use as an alternative source of fish feed. In term of nutritional values, duckweed has the highest protein content compared to other aquatic plants, so it can be used as a source of vegetable protein (Table 2). Most herbivorous and omnivorous fish require 20-35% protein in their diet, but carnivorous species require higher levels of protein ranging from 40-55% of diet (Lall and Tibbetts 2009).

Protein is an important component in feed that supports the growth of fish. Among various macronutrients, protein is the most expensive and highly used component in fish feed. Protein requirements in fish are higher compared to terrestrial animal because protein is not only used for growth but also used as an energy source.

The potential utilization of duckweed as fish feed has been evaluated through the use of duckweed as a feed for several fishes. Duckweed use as fish feed ingredients, can be provided with fresh duckweed. Giving fresh duckweed can be done especially in the group of Carnivora fish. Few investigations have been carried out to optimize the feeding or consumption rate of duckweed, but most were carried out for grass carp and nilem carp. Grass carp fed duckweed diets in monoculture system showed significantly higher specific growth rate (1.23%) compared to feed by soybean meal (0.96%) (Aslam and Zuberi 2017). Besides, Talukdar et al. (2012) reported that the specific growth rate of grass carp was significantly higher in ponds with supply of fresh duckweed (1.51%), than the ponds without supply of duckweed (0.58%) in polyculture system.

Based on the research results of Yudhitstira et al. (2015) and Asimi et al. (2018), the use of duckweed, which is dried and formulated in artificial feed, results in different growth and feed conversion ratio (FCR) in several types of fish. The addition of duckweed in feed increased the growth of *Oreochromis mossambicus* higher than that of *E. crassipes* and *A. pinnata* (Bag et al. 2012). Duckweed is considered as highly nutritious vegetative food for grass carp because of its high-protein content and softness. It is reported that 225-589 g of grass carp can assimilate an average of 65-67% consumed duckweed, including 61% of available energy and 80% of crude protein. In a study, faster growth rate of grass carp i.e. 1.15 g/day when fed with duckweed than other diets were also observed (Sutton 1977). Similarly, 380 g grass carp showed a significantly higher growth rate (6.1 g/day) when reared using duckweed as compared to 1.9 g/day when fed using pellet (Aslam and Zuberi 2017). Meanwhile, the use of 20% duckweed in grass carp fish feed produced the best growth rate of 0.18% and conversion of feed ratio of 0.6 (Srirangam 2016). A study by Effiong et al. (2009) also indicated that the inclusion of duckweed meal in fish feeds could improve its binding potential and water stability.

One of the most important factors in providing ingredients for fish feed is the amino acid content. Amino acids are important biomolecules that both serve as building blocks of proteins and are intermediates in various metabolic pathways (Mohanty et al. 2014). *Lemna*'s superiority as a feed ingredient is also seen in the amino acid composition of duckweed (Table 4) (Pessione and Cirrincione 2016). Not only in the species found in this study, the amino acid content of *L. minor* also show the same results. The results of Chakrabarti et al. (2018) study indicates that *L. minor* has essential amino acids (39.20%), non-essential (53.64%), and non-proteinogenic (7.13%). All essential amino acids such as histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine are found in adequate quantity. The content of free amino acids is not significantly different among *Spirodela polyrhiza*, *Landoltia punctata*, and *Lemna aequinoctialis* (Zhang et al. 2018).

Amino acid is one component of protein needed for fish growth. Fish requires a quantitatively and qualitatively balanced mix of essential amino acids (EAA), which are influenced by temperature, feeding habit and fish size (Kaushik 1995). The smallest absolute requirement estimated for histidine varies from 1.14 to 1.61% of dietary protein, as opposed to requirements on lysine, which is estimated as much as 5.79, and 6.64% of dietary (Bicudo and Cyrino 2014). Judging from the type and number of amino acids, *Lemna* spp. is sufficient to fulfill fish's need, so it can be used as feed source. The use of protein sources and amino acid composition in feed influences protein retention in certain types of fish (Aslam and Zuberi 2017; Silvão and Nunes 2017).

Based on the results of this study, it can be concluded that the duckweed recorded at the studied areas in West Java are part of the diverse types of duckweed which can be found in several other places. Likewise, when viewed from its potential as a food source, duckweeds found in this study have a good and complete nutrient and amino acid composition so that it can be used as a fish food source.

ACKNOWLEDGEMENTS

The authors are grateful to involve in this research through Gading/Profarm Project. The reported research was funded by Hivos Grant No. 1012621/2016.

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