

## **CABOMBA CAROLINIANA A. GRAY 1837 – A NEW, ALIEN AND POTENTIALLY INVASIVE SPECIES IN SERBIA**

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*Abstract* - During field studies of the vegetation in the canal network of the Hydro-System Danube-Tisa-Danube in Serbia, in 2008, 2011 and 2012, populations of *Cabomba caroliniana* A. Gray 1837 were recorded. *Cabomba caroliniana* was not previously recorded in the aquatic vegetation in Serbia. It is a popular aquarium plant native to South America (Brazil, Uruguay, Paraguay, and northeastern Argentina) and, according to some authors, to southeastern United States. It was introduced into the rest of the USA, Canada, Australia, Asia (China, Malaysia, India, Japan), and in many regions of its new range it is considered an invasive and noxious aquatic weed. In Europe, it was found in the United Kingdom (introduced to England), Belgium, the Netherlands, and Hungary. Newly recorded populations in Serbia are restricted to the canals in Bačka. Populations are established only on two localities (Mali Stapar and Odžaci).

*Kew words*: Neophyte, canal, aquatic vegetation, distribution

### INTRODUCTION

The genus *Cabomba* Aublet, 1775, belongs to the monotypic family Cabombaceae Richard ex A. Richard 1822 of the order Nymphaeales (Takhtajan, 2009). Some authors include the genus *Brassenia* in the Cabombaceae family (Bisby et al., 2012), while others separate it into the Hydropeltidaceae Dumortier 1822 family (Takhtajan, 2009). The genus *Cabomba* is taxonomically problematic due to vegetative similarity among the taxa, and the few morphological characters that are useful in delimiting the species (Ørgaard, 1991). In the monograph study of the genus *Cabomba* published in 1953, Fassett lists seven species: *Cabomba caroliniana* A. Gray 1837; Harper's variety *C. caroliniana* var. *pulcherrima* Harper 1903 he treats as species *C. pulcherrima* n. comb.; *C. australis* Speg. 1880, which is in later studies regarded as a synonym for the typical variety of *C. caroliniana*; *C. aquatica* Aubl. 1775; *C. warmingii* Casp. 1878,

which is in later studies considered conspecific with *C. furcata* Schultes & Schultes f. 1830, as well as *C. piahyensis* Gardn. 1844; and he introduced the new species *C. palaeformis* Fassett 1953 (Fassett, 1953). In the taxonomic study of the genus *Cabomba*, Ørgaard (Ørgaard, 1991) recognized five species and three varieties: *C. aquatica* Aublet 1775, *C. palaeformis* Fassett 1953, *C. furcata* Schultes & Schultes f. 1830, *C. haynesii* Wiersema 1989, and species *C. caroliniana* A. Gray 1837 that includes var. *caroliniana*, var. *pulcherrima* Harper 1903 and var. *flavida* Ørgaard. The same species are recognized by the GRIN database (Germplasm Resources Information Network), although in this case var. *pulcherrima* Harper 1903 is treated as a synonym for the typical variety. However, the ITIS annual checklist (Bisby et al., 2012) lists only three species: *C. caroliniana* A. Gray, *C. furcata* Schultes & Schultes f. 1830 and *C. haynesii* Wiersema 1989. All five generally recognized species are native to subtropical and tropical America, occurring pri-

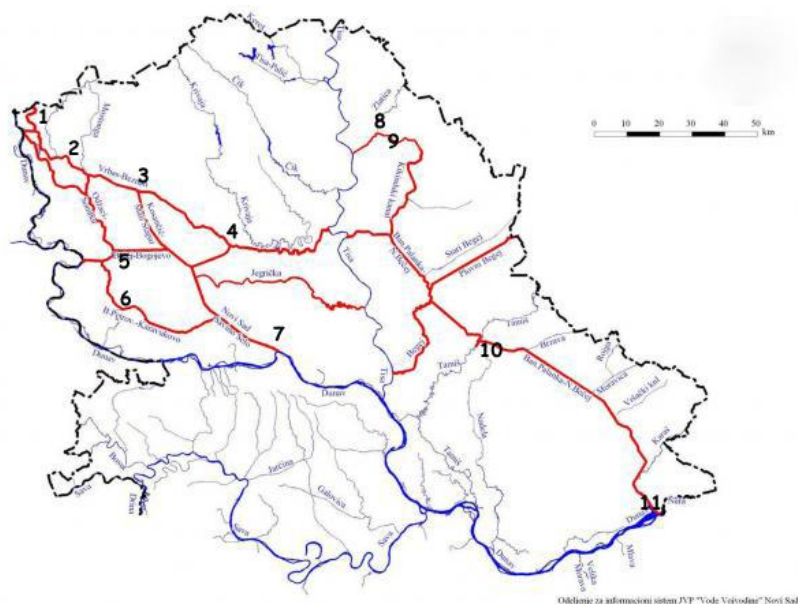


Fig. 1. Studied localities on the canal network HS DTD

marily in South America, from north Argentina to Central America and West Indies (Ørgaard, 1991). *Cabomba caroliniana* has the most northerly distribution, which extends into the United States. It is the only species of the genus *Cabomba* that has been widely introduced outside its native range (Ørgaard, 1991, Wilson et al., 2007). According to the available literature (IASV, 2011), *Cabomba caroliniana* has not been recorded in earlier studies of the aquatic flora and vegetation in the canal network of the Hydro-System Danube-Tisa-Danube, or in the other water bodies in Serbia.

#### MATERIALS AND METHODS

The survey of aquatic vegetation was performed during July and August of 2008, 2011 and 2012 in the canals of the Hydro-System Danube-Tisa-Danube (HS DTD) in Serbia (Fig. 1) at eleven localities (Table 1). Collected plant material was identified using standard keys for plant species identification (Tutin et al., 1968-1993; Jávorka, 1925; Felföldy, 1990; Cook, 1990; Fassett, 1940; Josifović, 1970-1986; Sarić, 1992). Population density was estimated by counting plant stems per square meter, using a plastic frame of

adequate dimensions. Part of the collected *Cabomba caroliniana* plants was conserved in 70% ethanol, part was dried and deposited in the herbarium collection of BUNS, and the rest of the collected material is preserved in the living collection in aquaria for further studies. Distribution of *Cabomba caroliniana* is given in the hydrological map of Vojvodina (scale 1:25000).

#### RESULTS AND DISCUSSION

**Species name and intraspecific variation:** *Cabomba caroliniana* A. Gray Ann. Lyc. New York 4: 47 (1837). **Synonyms** – *Nectris peltata* sensu Pursh, Fl. Am. Sept. 1: 239 (1814), excl. syn. – non *C. peltata* (Pursh) F. Muell., Native Pl. Victoria 15 (1885), quod *Brassenia peltata* Pursh, Fl. Am. Sept. 2: 389 (1814) [= *B. schreberi* J. F. Gmel., Syst. Veg. 1: 853 (1796)]. *Nectris aquatica* sensu Nuttall, Gen. N. Am. 1: 229 (1817) p.p. non Aublet; sensu Elliott, Sketch 1: 416 (1821) non Aublet (Fassett, 1953; Ørgaard, 1991). ***C. caroliniana* A. Gray var. caroliniana.** **Synonyms** – *C. australis* Spegazzini, Anal. Soc. Cient. Argent. 10: 219 (1880); *C. caroliniana* A. Gray var. *paucipartita* Ramsh. et Florsch., Acta Bot., Neerl. 5(4): 342 (1956). ***C. caroliniana* A. Gray var. pulcherrima** Harper Bull. Tor-

**Table 1.** Studied localities on the canal network HS DTD

	Locality	Canal	Length of surveyed section [m]
1	Bajski kanal	Bezdan - Baja	12700
2	Sombor	Vrbas - Bezdan	7600
3	Mali Stapar	Vrbas - Bezdan	740
4	Vrbas	Vrbas - Bezdan	1000
5	Odžaci	Bečej - Bogojevo	1170
6	Bač	Bački Petrovac - Karavukovo	230
7	Novi Sad	Novi Sad - Savino Selo	700
8	Zlatica (Aranka)	Zlatica (Aranka)	200
9	Sajan	Kikindski kanal	800
10	Botoš	Banatska Palanka - Novi Bečej	500
11	Kajtasovo	Banatska Palanka - Novi Bečej	800

rey Club 30: 328 (1903). *C. caroliniana* A. Gray var. *flavida* Ørgaard Nord. J. Bot. 11(2): 201 (1991).

*Description* (Ørgaard, 1991, Wilson et al., 2007) – *Cabomba caroliniana* is a perennial freshwater plant. Rhizome or rootstock is short, carrying numerous, at the base highly branched stems, between 3 and 40, 1-2 (-10) m long. Stems are slender, round or compressed, 2-4 mm in diameter. Young stems are pubescent. Shoots are grass green to olive green, sometimes reddish brown. Slender roots arise from the rhizome, and adventitious roots, which can be up to 24 cm long, are often produced from the stem nodes. In the beginning adventitious roots are not branched, they are slender, white, with yellow tip, and with age they become branched and dark brown, or black. Submerged leaves are opposite, rarely in whorls of three. Leaf lamina is fan-shaped or palmate, divided into (3) 5-7 main segments, each divided dichotomously or trichotomously into many long, narrow linear or spatulate segments 0.3-1.8 mm wide. Basal leaves usually have 3-20 linear segments, while upper leaves may have up to 200. Plants are often coated with thin layer of mucilage. Floating leaves are borne on flowering branches, green to olive green, with thick cuticle on the adaxial surface. Abaxial side and petiole are usually pubescent. Floating leaves are alternate, peltate, with blades liner-elliptic to ovate, with pointed ends. Flowers are solitary, milk white, pale yellow or purplish. Three sepals are elliptic to obovate, 5-12

x 2-5 mm, pale yellow or milk white and purplish on margins and veins. Three petals are alternate with sepals; they are partly fused at the base, with short basal claws or auricles, which are with yellow patches that act as nectaries. The stamens are usually in one whorl of (3-) 6, and are shorter than petals. Pistils are 2-4, usually 3, densely pubescent, reddish, and ripen into a leathery, indehiscent elongate follicle with 1-3 seeds. Chromosome numbers:  $2n=39$ ,  $c.78$ ,  $c.104$ . It is native to subtropical and temperate regions of eastern North and South America.

Within the distribution area of *C. caroliniana*, there are three varieties that are mainly distinguished on the basis of flower color. The flowers of the typical variety (var. *caroliniana*) are creamy white, those of var. *pulcherrima* are purplish, or purplish tinged with darker veins, while flowers of var. *flavida* are relatively larger, and are pale yellow with darker veins (Wilson et al., 2007). Beside flower color, Ørgaard (1991) introduces the color of shoots, as vegetative characteristics of *C. caroliniana* varieties: var. *caroliniana* has reddish to brown, grass green to olive green shoots; var. *pulcherrima* – purple; var. *flavida* green to olive green, sometimes reddish brown. The typical variety is the most widely spread, and its range overlaps with that of the var. *pulcherrima* (restricted to North and South Carolina, Georgia and Florida), and with that of var. *flavida* (restricted to southern Brazil, Paraguay, and northeastern Argentina).

Many authors (Wain et al., 1983; Ørgaard, 1991; Wilson et al., 2007) consider that at least some of the intraspecific variability is the consequence of environmental conditions such as water temperature, nutrient supply, and light.

*Geographical distribution – Cabomba caroliniana* is native to South America: southern Brazil, Uruguay, Paraguay and northeastern Argentina (Ørgaard, 1991). Generally, it is considered native to the southeastern USA, but some authors (Mackey, Swarbrick, 1997) suggest that its disjunctive range indicates its origin in South America, whereas it was introduced and naturalized in the United States some time ago. In the rest of USA, it was recorded in the western states, along the Atlantic, and in the eastern states, along the Pacific, while in the central part of country it was not found. In 1991, it was recorded in Canada, Ontario (Wilson et al., 2007). *Cabomba caroliniana* has been introduced into several Asian (Japan, China, Malaysia), Pacific (New Guinea) and European countries (Netherlands, Belgium, Hungary, UK-England) and Australia, probably due to people discarding or deliberately planting aquarium plants (Ørgaard, 1991).

*Distribution in Serbia –* The first finding of *Cabomba caroliniana* in Serbia was in the canal Vrbas-Bezdan, near Sombor, in August 2008. Later, during surveys of aquatic vegetation in the canal network HS DTD, more populations were recorded in the canal Vrbas-Bezdan, and new ones in the localities Mali Stapar and Vrbas, and in the canal Bečej-Bogojevo at locality Odžaci (Fig. 2). Along the surveyed canal sections in the Sombor locality (canal Vrbas-Bezdan), the species occurred sporadically in small, established populations of average density 42 stems per m<sup>2</sup>. Numerous stem fragments were observed free-floating along the surveyed area. On the locality Mali Stapar (canal Vrbas-Bezdan), in the sections both upstream and downstream of the sluice gate, the species was very abundant, overgrowing the canal bed, even in its deepest, middle part (Fig. 3). Average population density was 151 stems per m<sup>2</sup>. Numerous stem fragments carried by the water were observed. On the localities Vrbas (canal Vrbas-Bezdan, upstream of sluice gate and industrial

zone) and Odžaci (canal Bečej-Bogojevo, upstream of sluice gate), populations of *Cabomba caroliniana* appear not to be established. Only a large number of stem fragments was observed, and many of them had adventitious roots on stem nodes.

Flowering plants, and those with floating leaves, were not found in the surveyed canal sections, so it could be assumed that in Serbia it propagates exclusively by stem fragments. Vegetative reproduction by stem fragmentation is in the case of *Cabomba caroliniana* the primary means of dispersal, where any detached or broken stem section with one node and a pair of expanded leaves can grow into mature plant (Tarver, Sanders, 1977; Ørgaard, 1991; Wilson et al., 2007). While no flowers could be collected, according to the reddish-to-brown stem color it is assumed that specimens found in Serbia belong to the typical variety *Cabomba caroliniana* A. Gray var. *caroliniana*. There are two possible explanations of its occurrence in Serbia. One is that it appeared in the Vrbas-Bezdan canal near Sombor due to people discarding aquarium plants. The other, which is more likely, is that the stem fragments spread from many localities in the canal network in Hungary, where it was recorded since 1995 (Steták, 2004). Since it was not found in the trans-boundary canal (Table 1, Fig. 1 (Locality 1)) that connects Baja (Hungary) and Bezdan (Serbia), it is presumed that it has spread from Hungary through the river Plazović (Fig. 2, black arrow) that flows from Hungary into Serbia and enters the canal Vrbas-Bezdan near Bački Monoštor, upstream of Sombor.

*Invasive potential – Cabomba caroliniana* is a persistent, competitive and invasive plant, which significantly influences aquatic ecosystems in its nonindigenous range (Ørgaard, 1991). When it becomes established in a suitable water body, it rapidly forms large, dense populations that displace the native species, alter the nutrient regimes and affect the ecosystem functioning and stability, using water bodies for industrial, recreational and domestic purposes (Wilson et al., 2007). Its populations that were recorded in Canada grew monocultures in several localities in Ontario, reaching densities of more than 500 stems



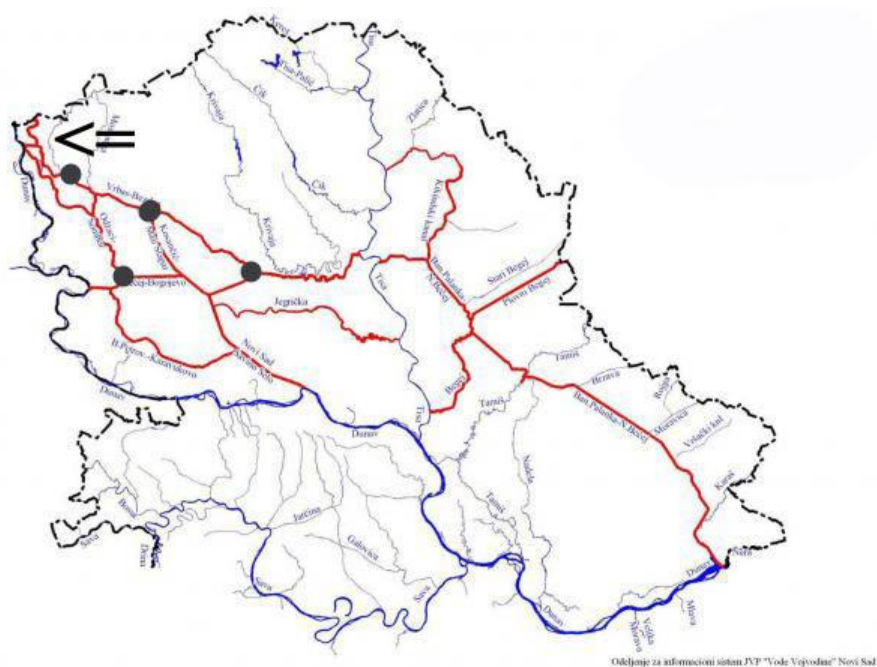


Fig. 2. Distribution of *Cabomba caroliniana* in canal network HS DTD



Fig. 3. *Cabomba caroliniana* A. Gray, specimens from Mali Stapar (photo Vukov, D.)

per m<sup>2</sup>, which reduced the light available through the water column and reduced the diversity of native plant species (Noël, 2004). Similar population characteristics were reported in the United States (Les, Mehrhoff, 1999). In Australia, extensive infestations by *Cabomba caroliniana* in Queensland displaced al-

most all other submerged vegetation (Mackey, Swarbrick, 1997). In two provinces in China, it became the dominant aquatic plant species on all localities where it occurred within ten years of its first introduction (Zhung et al., 2003). Mackey and Swarbrick (1997) suspect that *Cabomba caroliniana* infestations

have impacts on native fish and invertebrate populations, and hence on the rest of the food chain.

Since its invasive potential is proved throughout its introduced range, it is reasonable to assume that it will become invasive in Serbia. Many of its population characteristics observed in other countries have already been recorded on the locality Mali Stapar. Therefore, it is necessary to continue studies on its distribution in Serbia, as well as on its biology and ecology, and especially on its influence on the structure and functionality of the ecosystems it invades, in order to choose the most effective and at the same time, suitable and sustainable measures for its control.

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