

Introduction of a new potential invader into the Mediterranean Sea: the Indo-Pacific *Avrainvillea amadelpha* (Montagne) A. Gepp & E.S. Gepp (Dichotomosiphonaceae, Ulvophyceae)

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Abstract – The Indo-Pacific species *Avrainvillea amadelpha* (Montagne) A. Gepp & E.S. Gepp is reported for the first time from the Mediterranean Sea (Kerkennah Islands, Tunisia). The species is considered as introduced and invasive in the Hawaiian Archipelago. The Mediterranean specimens are studied and the reproductive structures are described and illustrated here for the first time. The possible origins and vectors of this introduction and the risk of propagation of the species in the Mediterranean Sea are discussed.

***Avrainvillea amadelpha* / Ulvophyceae / Tunisia / Mediterranean / Introduced species / Invasive species**

Résumé – L'espèce Indo-Pacifique *Avrainvillea amadelpha* (Montagne) A. Gepp & E.S. Gepp, est signalée pour la première fois en Méditerranée (Îles Kerkennah, Tunisie). L'espèce est considérée comme introduite et invasive dans l'archipel Hawaïien. Les spécimens méditerranéens sont étudiés et les organes reproducteurs sont décrits et illustrés pour la première fois. Les origines et les vecteurs possibles de cette introduction sont discutés, ainsi que les risques de propagation de l'espèce en Méditerranée.

***Avrainvillea amadelpha* / Ulvophyceae / Tunisie / Méditerranée / Espèce introduite / Espèce invasive**

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INTRODUCTION

With nearly 1 000 marine introduced taxa identified, the Mediterranean Sea is one of the regions of the world most severely impacted by the introduction of species (Zenetos *et al.*, 2010, 2012, 2017). In 2017, the number of marine macrophytes introduced into the Mediterranean Sea amounts to around 120-130 taxa (Verlaque *et al.*, 2015; M. Verlaque, unpub. data).

Within the framework of a Program of the RAC/SPA (Regional Activity Centre for Specially Protected Areas) and the University of Corsica, carried out on the coast of Tunisia, a species of *Avrainvillea* Decaisne (Decaisne, 1842), a tropical genus hitherto unknown in the Mediterranean Sea, has been discovered in the region of Kerkennah Islands. The alga was identified as *A. amadelpha* (Montagne) A. Gepp & E.S. Gepp, a tropical species widely distributed in the Indo-Pacific Ocean. The aim of the present study is to report the species for the first time from the Mediterranean Sea and to describe the Mediterranean population and its ecology. The possible origins and pathways of introduction are considered. The risks of further spread of the species in the Mediterranean Sea are discussed.

MATERIAL AND METHODS

Avrainvillea amadelpha was found and sampled during the field monitoring campaigns of the lower limits of *Posidonia oceanica* (L.) Delile beds of the Kerkennah Archipelago in Tunisia (MedPosidonia and CHANGE Programs set up by the RAC/SPA and the FRES 3041 – University of Corsica) (Pergent *et al.*, 2014) (Fig. 1). The seawater temperature was recorded on a continuous basis (24 measures. day⁻¹) at the lower limit of a *P. oceanica* bed of the archipelago from 2008 to 2015.

Sampling and studies of the *A. amadelpha* population were carried out by SCUBA diving in July 2015. Specimens sampled by one of us (H.L.) were transferred

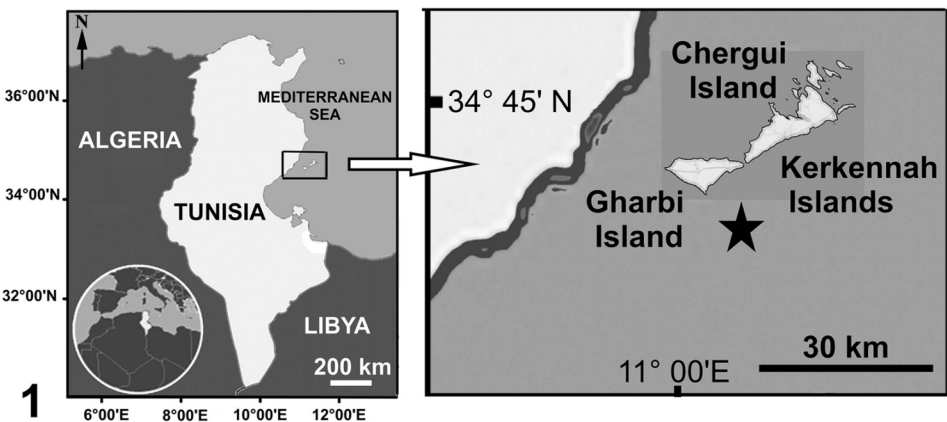


Fig. 1. Study area in Tunisia with detail of the Kerkennah Islands region. Star: location of the first population of *Avrainvillea amadelpha* (Montagne) A. Gepp & E.S. Gepp discovered in the Mediterranean Sea.

to the laboratory in seawater, before being cleaned, pressed and dried. Anatomical studies were carried out under the binocular and light microscopes after re-hydration. Measurements and photomicrographs were made using a Coolpix 995 Nikon® digital camera and an Optiphot-2 Nikon® light microscope. Voucher dried specimens were deposited in the Verlaque Herbarium (HCOM), Marseille, France, with the following references:

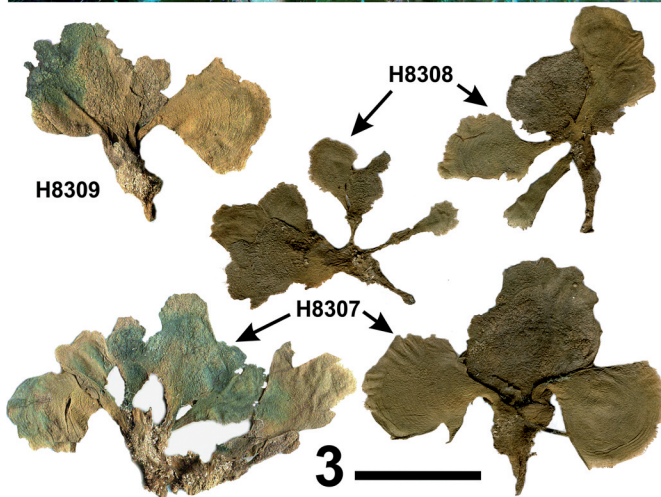
– H8307 to H8309, *Avrainvillea amadelpha* (Montagne) A. Gepp & E.S. Gepp, collection Habib Langar, Tunisia, Kerkennah Archipelago, off Gharbi Island (GPS location: 34° 31' 2.20" N and 11° 07' 1.60" E), 26 July 2015, 22 m depth, at the lower limit of the *Posidonia oceanica* meadow, fertile (Fig. 2).

The Tunisian material was compared with photographs of *A. amadelpha* specimens deposited in the Cryptogamic Herbarium of the Muséum National d'Histoire Naturelle, Paris (PC), especially those from Red Sea, with the following references:

– PC0502136 – *Avrainvillea amadelpha* Gepp, collection Islam Elmanawy, Suez Canal, Egypt, July 1988;



Fig. 2. *Avrainvillea amadelpha* (Montagne) A. Gepp & E.S. Gepp growing on a dead matte of *Posidonia oceanica* (L.) Delile off Gharbi Island (Kerkennah Islands), July 2015, 22 m depth. Figure 3. Pressed habit of fertile Tunisian specimens of *Avrainvillea amadelpha* (specimens H8307 to H8309, Herbarium HCOM, Aix-Marseille University). Bar = 5 cm.



– PC0502137 – *Avrainvillea amadelpha* (Mont.) A & E.S. Gepp, collection J.F. Papenfuss, Israel South Red Sea Expedition, determination J.F. Papenfuss and Y.M. Chiang, Romia Islet, Dhalak Archipelago, Eritrea, Red Sea, 29 March 1962;
 – PC0502138 – *Avrainvillea amadelpha* Gepp, collection Gruvel, Grand Lac Amer (Great Bitter Lake), Egypt, 1932.

Herbarium abbreviations follow Thiers (2014).

DNA extractions from dry material and amplification of the TufA gene were performed as previously (Vieira *et al.* 2016).

RESULTS

Avrainvillea amadelpha (Montagne) A. Gepp & E.S. Gepp

Reference: Gepp & Gepp (1911), pp. 42-44, figs 112-115.

Basionym: *Udotea amadelpha* Montagne (1857), p. 136. Type locality: Agalega Islands, NE of Madagascar, Indian Ocean.

Heterotypic synonyms: *Chloroplegma sordidum* Zanardini (1858), p. 83, figs 1, 1a-c. Type locality: Suez, Tor, Red Sea.

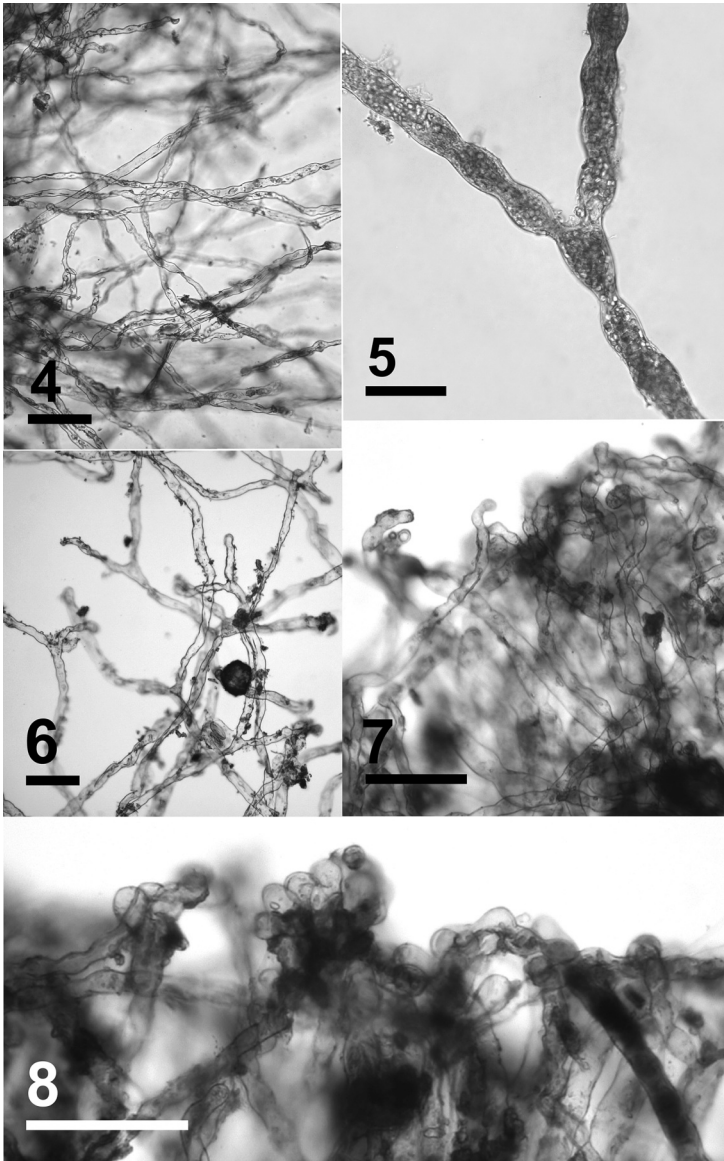
Avrainvillea lacerata Harvey ex J. Agardh f. *robustior* A. Gepp & E.S. Gepp (1911), pp. 38-39, figs 108-109. Type locality: Singapore, Indian Ocean.

Description of the Mediterranean material

Plant forming clusters; thallus non-calcified, 7-12 cm tall, differentiated into holdfast, stipes and blades; holdfast developed into mat from which numerous stipes arise; stipes once to twice-branched; each branch bearing a simple terminal blade; blades spongy, thin, entire, sub-cuneate to flabellate, dark green to olive brown, zonate, 2.5-6.0 cm wide; growing margins smooth or slightly eroded (Figs 2-3); thallus composed of intertwined non-septate filaments (siphons); siphons cylindrical to torulose, tapering upwards, 25-18 μm to 12.0-16.0 (-20) μm in diameter (measurements on segments between two consecutive dichotomies) (Fig. 4); siphons dichotomously branched with dichotomies deeply constricted (Fig. 5); distance between dichotomies decreasing upwards resulting in a highly ramified terminal region, referred to as a pseudocortex, near the surface of the blade; apices of siphons rounded (Figs 6-8); presence of tiny sand grains trapped between the filaments of holdfasts, stipes and lower part of blades; gametangia subspherical to ovoid, 22-36 μm long and 27-32 μm in diameter, shortly pedicellate and laterally inserted on the filament, frequently below a dichotomy (Figs 9-12); basal septum, division of gametangium contain and emission of gametes not observed. The amplification of the TufA gene failed (Line Le Gall, pers. com.).

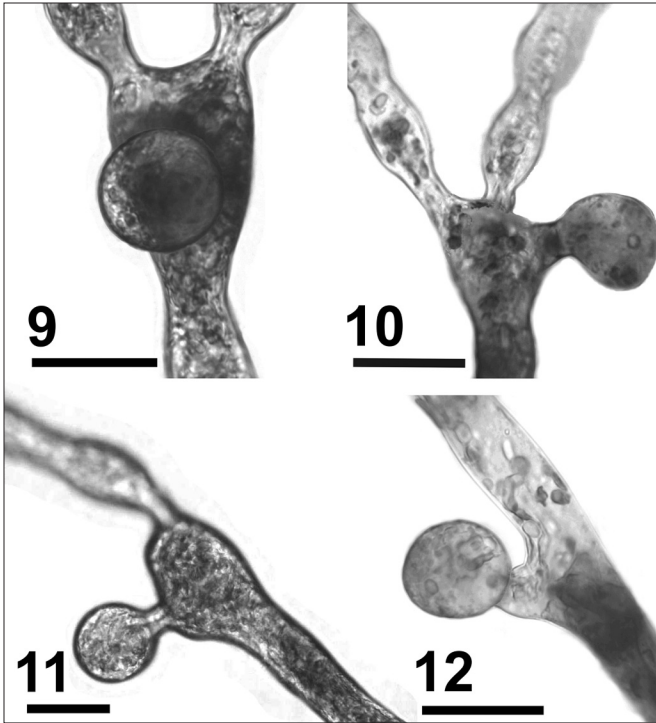
Ecology

The alga was common and was growing gregariously in colonies, between 20-22 m depth, in sunny places (sub-horizontal substrates), in *Cymodocea nodosa* (Ucria) Ascherson meadows, *Posidonia oceanica* beds, on dead mattes of *P. oceanica* meadows and coarse sand bottoms, in association with *Dictyota implexa* (Desfontaines) J.V. Lamouroux, *Flabellia petiolata* (Turra) Nizamuddin, *Jania*



Figs 4-8. Anatomy of Tunisian specimens of *Avrainvillea amadelpha* (Montagne) A. Gepp & E.S. Gepp. 4. Intertwined non-septate filaments (siphons) of the blade. Bar = 100 μ m. 5. Torulose filament with a deeply constricted dichotomy. Bar = 50 μ m. 6. Detail of the upper part of filaments showing the upward decreasing distances between dichotomies. Bar = 100 μ m. 7-8. Detail of the growing margin with filaments organized in pseudocortex. Bars = 100 μ m.

adhaerens J.V. Lamouroux, *Penicillus capitatus* Lamarck, and the invasive exotic species *Caulerpa cylindracea* Sonder and *Pinctada imbricata radiata* (Leach, 1814). At the lower limit of the *Posidonia oceanica* beds, the seawater temperature varied between 12.9-14.8 $^{\circ}$ C in winter and 28.0-29.5 $^{\circ}$ C in summer (2008-2015 data).



Figs 9-12. Reproductive structures of Tunisian specimens of *Avrainvillea amadelpha* (Montagne) A. Gepp & E.S. Gepp. **9-10.** Shortly pedicellate gametangia inserted laterally at the base of a dichotomy. Bars = 30 μ m. **11-12.** Shortly pedicellate gametangia inserted laterally on a filament. Bars = 30 μ m.

DISCUSSION AND CONCLUSION

The Mediterranean specimens of *Avrainvillea* are in good agreement with descriptions and illustrations of *A. amadelpha* (Montagne) A. Gepp & E.S. Gepp (Gepp & Gepp, 1911; Olsen-Stojkovich, 1985; Coppejans & Prud'homme van Reine, 1989; De Clerck & Coppejans, 1996; Littler & Littler, 2003; Abbott & Huisman, 2004; Huisman *et al.*, 2007; Coppejans *et al.*, 2009), especially those from the Red Sea (Zanardini, 1858; Nasr, 1947; Aleem, 1978b, 1980), and with the Red Sea specimens deposited in the PC herbarium.

On the basis of a morphological analysis, Olsen-Stojkovich (1985) distributed the species of *Avrainvillea* in different groups. *Avrainvillea amadelpha* belongs to the '*longicaulis* group', along with *A. asarifolia* Børgesen, *A. calathina* Kraft & Olsen-Stojkovich, *A. carteri* Huisman, *A. lacerata* Harvey ex J. Agardh, *A. levis* M. Howe, *A. longicaulis* (Kützing) G. Murray & Boodle and *A. pacifica* A. Gepp & E.S. Gepp (Agardh, 1887; Murray & Boodle, 1889; Howe, 1905; Børgesen, 1909; Gepp & Gepp, 1911; Kraft & Olsen-Stojkovich, 1985; Olsen-Stojkovich, 1985; Huisman, 2015). Characteristics of the '*longicaulis*' group are (i) stipes simple to branched once to many times near base, each branch bearing a single terminal blade, (ii) siphons cylindrical moniliform, torulose to tortuous, and (iii) siphon dichotomies deeply constricted. *Avrainvillea amadelpha* differs from the other members of the '*longicaulis*' group by the following combination of diagnostic

features: growth in cluster (gregarious carpet); holdfast mat-like; stipe mostly branched; blades spongy and thin; growing margins smooth; siphons 25 μm to 12 μm in diameter; and pseudocortex present (Table I). The two closest species are *A. carteri* and *A. lacerata*, but the first has the stipes mostly unbranched, the blades spongy and firm and the siphons thinner, 30 μm to 5 μm , and the second has the blades without zonation, the growing margins lacerate, the siphons thinner, 28 μm to 6 μm , and does not possess pseudocortex (Table I). In another group, namely the 'nigricans' group *sensu* Olsen-Stojkovich (1985), *A. mazei* G. Murray & Boodle (Murray & Boodle, 1889) shares certain characters with *A. amadelpha* (thallus differentiated into holdfast, stipe and blade; thallus forming gregarious carpets; holdfast mat-like; stipes sometimes branched; blades spongy; growing margins smooth; and siphon dichotomies deeply constricted), but it differs by the greater size, up to 25 cm tall, including stipes up to 16 cm long, the blades never zonate, the siphons predominantly cylindrical and thicker (65 μm to 28 μm), and by the absence of pseudocortex (Olsen-Stojkovich, 1985).

Observations on the reproduction of *Avrainvillea* spp. are very few. Vegetative propagation is more common and constant throughout the year (Olsen-Stojkovich, 1985; Guiry & Guiry, 2017). The life history of the genus has not been experimentally verified. Fragmentary observations strongly suggest holocarp, with a reproductive cycle similar to udoteacean genera, i.e. a dioecious diploid erect thallus in which meiosis precedes gametogenesis (Young, 1977; Olsen-Stojkovich, 1985). Two types of gametangia, terminal or lateral, were described according to the species. The first and the most frequent type, the terminal type, was observed in *A. nigricans* Decaisne (type species of the genus), *A. asarifolia* Borgesen, *A. asarifolia* f. *olivacea* D.S. Littler & Littler, *A. digitata* D.S. Littler & Littler, *A. erecta* (Berkeley) A. Gepp & E.S. Gepp, *A. fulva* (M. Howe) D.S. Littler & Littler, *A. mazei* G. Murray & Boodle, *A. obscura* (C. Agardh) J. Agardh and *A. rawsonii* (Dickie) M. Howe (Howe, 1907; Gepp & Gepp, 1911; Kusel, 1972; Young, 1977; Olsen-Stojkovich, 1985; Littler & Littler, 1992; Cabrera Garcia, 2009–2010; Cabrera *et al.*, 2012). In this group, terminal gametangia result from the transformation of one apical branch of a dichotomy, the other branch undergoing two or three more dichotomies. Gametangia are clavate, i.e. elongated, narrowing toward the base and gradually expanded toward the apex, and large (> 200–250 μm in diameter). The lateral type, which was hitherto only observed in two taxa, *A. elliotii* A. Gepp & E.S. Gepp and *A. longicaulis* f. *laxa* D.S. Littler & Littler (Cabrera *et al.*, 2012), consists in smaller gametangia, usually < 100 μm in diameter, subspherical to ovoid, shortly pedicellate and laterally inserted on the siphon. Gametangia of *A. amadelpha*, which are described here for the first time, belong to the lateral type.

The occurrence of populations of *A. amadelpha* in Tunisia is in good agreement with the hypothesis of a recent introduction because it is consistent with the criteria proposed by Ribera & Boudouresque (1995): (i) the species had never been observed in the Mediterranean Sea; (ii) the first Mediterranean populations occupied a small area; and (iii) they were discovered in a hot-spot of species introductions (Southern Tunisia) where many exotic species native to the Red Sea and the Indo-Pacific Ocean have been reported (Ben Souissi & Zaouali, 2007; Zaouali *et al.*, 2007; Ben Souissi *et al.*, 2010; Oufini Ben Amor *et al.*, 2015; Sghaier *et al.*, 2016). Among the major pathways of introduction, the Suez Canal is ranked as the most important. Since its opening in 1869, the flow of Lessepsian species, i.e. Indo-Pacific species introduced into the Mediterranean Sea via the Suez Canal, has never stopped (Nunes *et al.*, 2014). The introduction of *A. amadelpha* is a new illustration of this phenomenon. In the absence of worldwide molecular data, the

Table 1. Comparison of diagnostic characters of representative *Ahrainvillea* species of the *longicaulis* group *sensu* Olsen-Stojkovich (1985). References: Agardh (1887), Howe (1905), Børgesen (1909), Gepp & Gepp (1911), Kraft & Olsen-Stojkovich (1985), Gepp & E.S. Gepp (1992), Litterer & Litterer (1992, 2003), Abbott & Huisman (2004), Huisman (2015)

	<i>A. amadeipha</i> (Montagne) A. Gepp & E.S. Gepp	<i>A. asarifolia</i> Børgesen	<i>A. calathina</i> Kraft & Olsen-Stojkovich	<i>A. carteri</i> Huisman	<i>A. lacerata</i> Harvey ex J. Agardh	<i>A. levis</i> M. Howe	<i>A. longicaulis</i> (Kützting) G. Murray & Boodie	<i>A. pacifica</i> A. Gepp & E.S. Gepp
Thallus	In clusters, 3-12 (-18) cm tall	Solitary to in clus- ters, 18-24 cm tall	Solitary to in clusters, 4-14 cm tall	In clusters, up to 6 cm tall	In clusters, 3-8 cm tall	Solitary, seldom double, 6 cm tall	Mostly solitary, 12-26 cm tall	Solitary, 4-8 cm tall
Color	Olive to brown olive	Dark olive	Dark olive green	Olive to brownish green	Light green to olive	Grey green to yellow green	Yellow green-yellow brown	Brownish green
Holdfast	Extensive mat-like	Bulbous to mat-like	Bulbous	Mat-like	Bulbous to mat-like	Small conical mass	Rhizomatous, bulbous	Rhizomatous, bulbous
Stipes	Mostly branched	Unbranched	Mostly unbranched	Mostly unbranched	Branched	Unbranched	Mostly unbranched	Unbranched
Blades	Thin, spongy, mostly cuneate, 4-5 cm wide	Thick, velutinous, often perfectly reniform, 5-6 cm wide	Firm, oblong-cune- ate to subpeltate and strongly concave at base (scoop-shaped), 1-6 cm wide	Spongy to firm, subcuneate, reniform or subcircular, up to 4.5 cm wide	Thin, papery, cuneate, occasionally obovate 2-3 cm wide	Thin, velutinous, reniform to obovate, with shallowly cordate base, 6.5 cm wide	Thick, velutinous, spatulate to obovate, with cuneate to truncate base, 3-8 (-10.5) cm wide	Spongy, velutinous, reniform to occasionally cuneate, 5-8 cm wide
Zonation	Present	Present	Present	Faintly zonate near the margins	Absent	Absent to faintly zonate	Absent	Present
Growing margin	Smooth lobed	Smooth lobed to lacerate	Smooth, irregularly lobed to lacerate	Smooth lobed	Distinctly lacerate	Smooth	Smooth lobed	Smooth
Siphons	Cylindrical mon- oform to torulose, tapering towards surface, 25-19 µm to 12-15 µm	Cylindrical, slightly moniliform to torulose, tapering towards surface, 40-30 µm to 8-12 µm	Cylindrical, mon- oform to torulose, tapering towards surface, 30-12 µm to 5-8 (-16) µm	Cylindrical to to- rulose, tapering to- wards surface, 30-12 µm to 5-7 (-10) µm	Cylindrical to torulose-tortuous, tapering towards surface, 28-19 µm to 6-9 (-12 µm)	Cylindrical, slightly moniliform to tortu- ous, tapering towards surface, 25-35 (-40) µm to 8-12 µm	Cylindrical to torulose-tortuous, tapering towards surface, 60-35 µm to 15-25 (-42) µm	Torulose, tapering towards surface, 28-19 µm to 9 µm
Dichotomies	Shallowly to deeply constricted	Deeply constricted	Deeply constricted to shallowly or not constricted	Shallowly constricted	Deeply constricted	Deeply constricted	Deeply constricted	Shallowly constricted
Apices	Rounded	Tapered to threadlike	Rounded	Rounded	Pointed, torn away	Rounded	Rounded or pointed	Twisted and hooked
Pseudocortex	Present	Absent	Present	Present	Absent	Present	Absent	Absent
Distribution	Indo-Pacific	Atlantic	Pacific	Indian Ocean	Indo-Pacific	Atlantic	Pan-tropical	Pacific

identification of the donor region is not possible. New sequencing attempts will be considered with other genes (*rbcL*). However, the Red Sea appears as a good candidate, *A. amadelpha* being native and common in this sea (Zanardini, 1858, as *Chloroplegma sordidum*; Harvey-Gibson, 1908; Harvey-Gibson & Knight, 1913, as *A. lacerata*; Nasr, 1947; Rayss, 1959; Papenfuss, 1968; Aleem, 1978a & b; Lipkin & Silva, 2002). Moreover, it has been growing in the Suez Canal at least since the early 20th century (Lami, 1932, confirmed by the herbarium specimen PC0502138; Lipkin, 1972; Aleem, 1980). Several potential vectors of species introduction have been considered in southern Tunisia: currents, shipping (via fouling and ballast water), pleasure boating and aquaculture (Oufini Ben Amor *et al.*, 2015). In general, psammophytic macroalgae such as *Avrainvillea* spp. do not appear to have the mechanisms for long-distance dispersal such as those shown by hitch-hiking boat foulers, pelagic algae or species with long-lived resistant spores (Littler & Littler, 1992). Only man-made structures that remain for a long time in the same place, such as pontoons, pipelines, drilling and production platforms, seem to be suited to colonisation by *Avrainvillea*. In the case of *A. amadelpha*, the first Mediterranean observation at the Kerkennah Islands, a considerable distance from the Suez Canal, in spite of phycological field studies conducted along the Egyptian and Libyan coasts (Nizamuddin *et al.*, 1979; Shameel, 1983; Nizamuddin, 1991; Godeh *et al.*, 1992; Aleem, 1993; Bazairi *et al.*, 2013) suggests a direct introduction from the Red Sea to Tunisia through human activities. Southern Tunisia and western Libya constitute a major Mediterranean region of oil and gas production, with several petroleum terminals and offshore oil and gas exploitation facilities (Ben Souissi & Zaouali, 2007; Oufini Ben Amor *et al.*, 2015). Consequently, the introduction of *A. amadelpha* and exotic invertebrates directly from oil and gas production sites in the Red Sea via drilling or production platforms, or recycled pipelines, would appear to be a possible scenario.

Every time we are faced with a new introduction, we have to answer to the question: what are the risks of invasion?

In the global distribution of marine species, there are two different types of temperature boundaries, namely the lethal boundaries and the growth and/or reproduction boundaries (Hutchins, 1947; Hoek & Breeman, 1990). Lethal boundaries are set by the species' capacity to survive during the adverse season (i.e. the cold season for a warm-water species). Macroalgal species with tropical to warm temperate distribution patterns have a lower temperature tolerance limit of 10°C to 15°C (Cambridge *et al.*, 1987, 1990a, b; Breeman, 1988; Pakker *et al.*, 1995). In the case of *A. amadelpha*, the 15°C winter isotherm corresponding to the mean sea-surface temperature of the coldest month does correlate well with the limits of its global distribution (Fig. 13). So if we consider the coldest sea-surface temperatures (data from February), a large part of the Mediterranean Sea that never drops below 15°C, is compatible with the temperature requirements of *A. amadelpha* (Fig. 14).

In tropical seas, *A. amadelpha* grows on a wide range of substrates (rocks, reef crests, dead corals, rock crevices, coral rubble, mangroves, sandy reef flats, sand plains, sandy muds and seagrass beds), from the intertidal zone down to 50 m (– 90 m) depth (Gepp & Gepp, 1911; Smith *et al.*, 2002; Littler & Littler, 2003; Abbott & Huisman, 2004; Coppejans *et al.*, 2004, 2009; Godwin *et al.*, 2006; Huisman *et al.*, 2007; Menza *et al.*, 2010; Spalding, 2012). The species has been observed all year round (Abbott & Huisman, 2004; Peyton, 2009). Except for *A. calathina*, which can be heavily grazed, most species of *Avrainvillea* produce toxic secondary metabolites and appear to be grazer-resistant (Sun *et al.*, 1983; Kraft & Olsen-Stojkovich, 1985; Littler & Littler, 1992). Only highly specialised herbivores

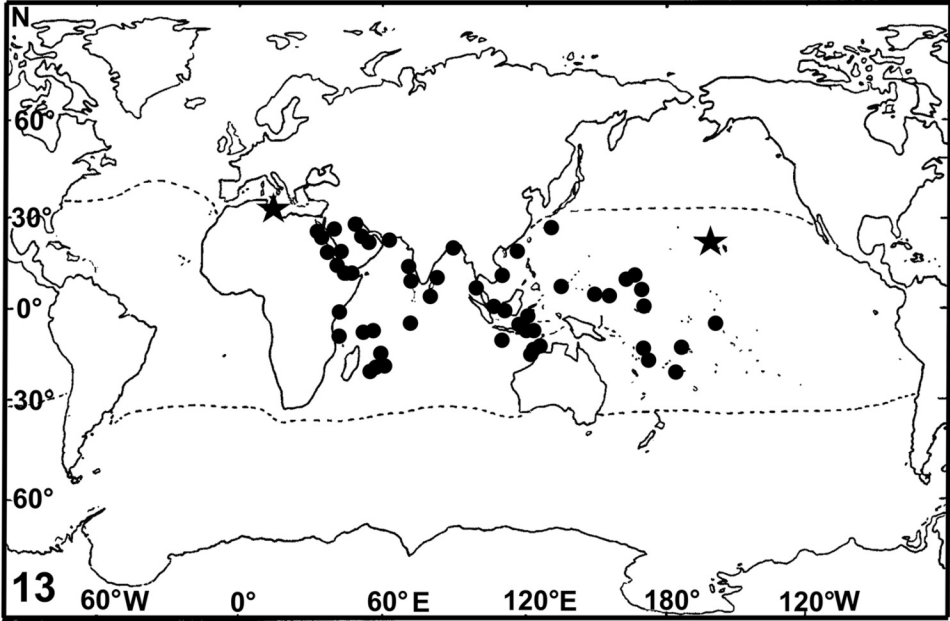


Fig. 13. World distribution of *Avrainvillea amadelpha* (Montagne) A. Gepp & E.S. Gepp according to Aleem (1978a & b, 1980), Coppejans & Prud'homme van Reine (1989), Verheij & Erfteimeijer (1993), De Clerck & Coppejans (1996), N'Yeurt (1996), Saifullah (1996), Coppejans *et al.* (2000), Hodgson & McDermid (2000), Aungtonya & Liao (2002), Tsuda (2002), Tsuda *et al.* (2008), Lee *et al.* (2009), Kaladharan *et al.* (2011), Xia *et al.* (2013), Aziz *et al.* (2015), and references in Guiry & Guiry (2017). Stars: locations of introduced populations. Broken lines: 15°C winter isotherm corresponding to the mean sea-surface temperature of the coldest month according to Gorshkov (1976, 1978, 1980).

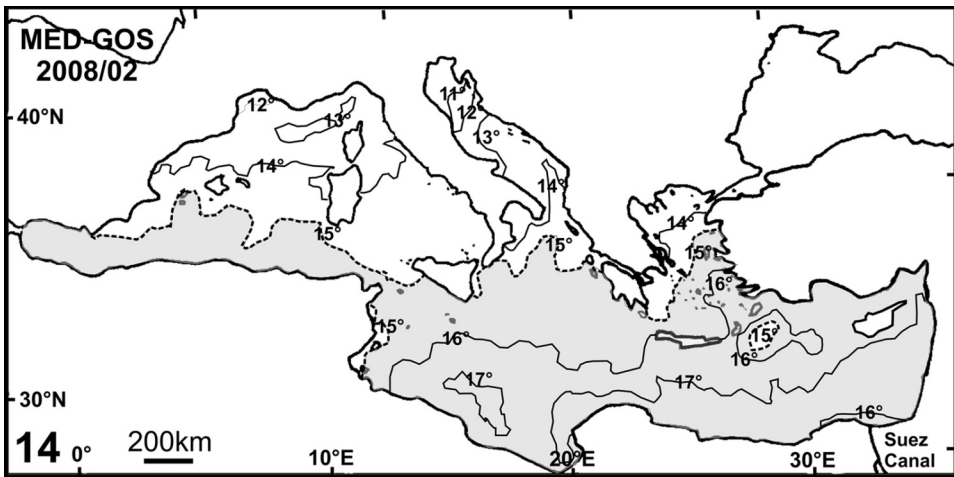


Fig. 14. Mean sea-surface temperature isotherms of the coldest month in the Mediterranean Sea (data from February 2008). Measurements obtained by available satellite infrared sensors developed and distributed by the Gruppo di Oceanografia da Satellite (GOS) (Alhammoud *et al.*, 2012). Shaded area: region with sea-surface temperatures higher than 15°C.

belonging to Sacoglossan gastropods and decapods are capable of ingesting them (Hay *et al.*, 1990).

Avrainvillea amadelpha is considered as introduced and invasive in the Hawaiian Archipelago (Brostoff, 1989; Huisman *et al.*, 2007). The species spread rapidly along the southern shore of the island of its first record (O‘ahu Island), and it extended its range to the neighbouring Kaua‘i Island (Smith *et al.*, 2002; Godwin *et al.*, 2006). *Avrainvillea amadelpha* traps large quantities of sediment between its holdfast and significantly increases the sedimentation rate (Martinez *et al.*, 2009). In some Hawaiian areas, *A. amadelpha* accounted for up to 100% cover, forming extensive mounds with soft sediment more than 30 m in diameter at the margin of *Halophila hawaiiiana* Doty & B.C. meadows, stone beds and on coral patches (Peyton, 2009; Spalding, 2012). In invaded areas, changes in the community composition and overgrowths of *H. hawaiiiana* meadows, *Halimeda* spp. beds and coral patches have been reported (Godwin *et al.*, 2006; Longenecker *et al.*, 2011; Spalding, 2012).

CONCLUSION

Avrainvillea amadelpha is a species possessing a very high development potential: (i) wide ecological niche; (ii) gregarious perennial thallus; (iii) high competition capability; (iv) high resistance to grazing; (v) capability to change the composition of communities and to alter habitats through sedimentation increase; (vi) it reproduces in Tunisia; and (vii) it is invasive in the Hawaiian Archipelago. In the Mediterranean Sea, it seems to be capable of colonizing the southern and the eastern basins, except for the coldest waters of the north-western Aegean Sea. In conclusion *A. amadelpha* must be regarded as a new potential invader in the Mediterranean Sea and therefore calls for special attention.

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