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FIRST RECORD OF *POSIDONIA OCEANICA* FLOWERING AND FRUITING IN THE SOUTHWESTERN MEDITERRANEAN SEA (MOSTAGANEM, ALGERIA)

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POSIDONIA OCEANICA
INFLORESCENCE
SPIKELET
FLOWER
FRUIT
ALGERIAN BASIN

ABSTRACT. – *Posidonia oceanica* (L.) Delile (1813) flowering, and particularly fruiting, is a rarely observed phenomenon in the Algerian coast. During two spaced surveys, inflorescences were observed in wrecks at Stidia (coastal area of Mostaganem, Algeria). Inflorescences from the first prospecting (November 6, 2017) bear only flowers. Each inflorescence carries between one and four spikelets, with an axis length ranging between 24 mm and 27 mm; the majority of the examined spikelets carries two to three flowers. The latter are 56.2 % to 78.6 % hermaphrodite and 21.4 % to 43.8 % are male. The inflorescences of the second prospecting (January 8, 2018) bear aborted fruits and ovaries. Each inflorescence carries between two and four spikelets, with an axis length ranging between 20 mm and 33 mm. The spikelets of the second prospecting carry a single fruit, sometimes two, and some do not carry any. The fruit length is between 7 mm and 15 mm. The aim of this work is to provide the first data collected on *Posidonia oceanica* flowering and fruiting phenomenon on the Algerian west coast (Mostaganem), offering thus the possibility to describe the morphology of the inflorescences and fruits. The collected data show some similarities to those obtained in different regions of the Mediterranean Sea.

INTRODUCTION

Seagrasses comprise less than 0.02 % of the angiosperms flora (Hemminga & Duarte 2000). They are gathered into four families: the Posidoniaceae, the Zosteraceae, the Cymodoceaceae and the Hydrocharitaceae (Kuo & Hartog 2001). According to the Angiosperm Phylogeny Group classification (APG III, 2009), the Posidoniaceae family comprises less than a dozen species belonging to the genus *Posidonia*. *Posidonia oceanica* (L.) Delile, 1813 is one of the most important and the most studied species in the Mediterranean Sea. Endemic to that sea, it constitutes an engineering ecosystem playing a major ecological, geological and economic role in coastal zones (Boudouresque *et al*. 2006, Pergent *et al*. 2014, Campagne *et al*. 2015). *Posidonia oceanica* regression in some areas is mainly related to anthropogenic factors (Telesca *et al*. 2015). The reproductive modality of this marine magnoliophyte, mainly related to climatic and edaphic factors, could also be at the origin of this regression (Caye & Meinesz 1984, Balestri & Cinelli 2003). Indeed, seagrass sexual reproduction could play an important role in the colonization of new areas and the recovery after disturbance (Orth 1999). Adverse environmental conditions and resource limitation are among factors that could act in the pre- or post-fertilization stages and could explain the *Posidonia oceanica* fruit abortion (Balestri & Cinelli 2003). The reproductive cycle of marine magnoliophytes is fully under water; the spreading of pollen to female flowers occurs through water currents (hydrophilic pollination) (Van Tussenbroek *et al*. 2016). The ovaries are adapted to capture the pollen (made of viscous filaments). In fact, they are equipped with denticulations (stigmas) that grip it at their passage (Boudouresque & Meinesz 1982). Three factors are at the origin of the non-visibility of the *Posidonia oceanica* flowers: 1) reproduction does not occur every year and when it takes place, it is only in a much localized areas (Giraud 1977); 2) the green flowers are often hidden by the long leaves and, thus, hard to see; 3) there are no insects underwater to disperse pollen and to ensure fertilization; therefore, advertisement by bright colors of flowers is useless. Unlike flowering that is quite common (Balestri & Cinelli 2003), fruiting is a rarely reported phenomenon (Boudouresque & Thelin 1985).

Several studies have been carried out on *Posidonia oceanica* flowering and fruiting (Balestri & Cinelli (2003) on sexual reproduction, Diaz-Almela *et al*. (2007) on global warming consequences on flowering, and Remizowa *et al*. (2012) on flowers anatomy and development).

No studies have mentioned the flowering, or the fruiting of *Posidonia oceanica* on the Algerian coasts.

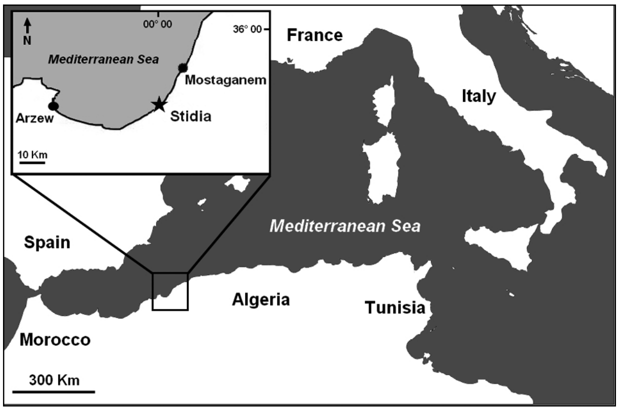

Fig. 1. – Geographical location of the prospected area [Stidia (*), Mostaganem] where the *Posidonia oceanica* inflorescences were observed

MATERIALS AND METHODS

On November 6, 2017, twelve *Posidonia oceanica* inflorescences, with flowers only, were found by chance as drift material within the supralitoral soft substratum zone (biocenosis of beaches with slow-drying wrack) in Stidia seashore (Mostaganem, Algeria) (Fig. 1). Due to the weather conditions during this period (sea particularly agitated and turbid), no underwater observations were made, which hindered the estimate of the flowering intensity of the meadows. Two months later (January 8, 2018), three rhizomes with fruit-bearing inflorescences were also collected in the form of wrecks at the same location. These inflorescences were derived from the adjacent infralittoral area where the *Posidonia oceanica* type III (350.8 shoots/m^2) meadow exists (Belbachir 2012). Each inflorescence was photographed using a digital camera (Fujifilm 10.2 Megapixel); thenceforth, the pictures were processed using Photofiltre software. The terminology proposed by Caye & Meinesz (1984) was used to describe the different parts of the inflorescence. The standardized protocol of Boudouresque & Thelin (1985) was used to measure and describe the *Posidonia oceanica* fruits.

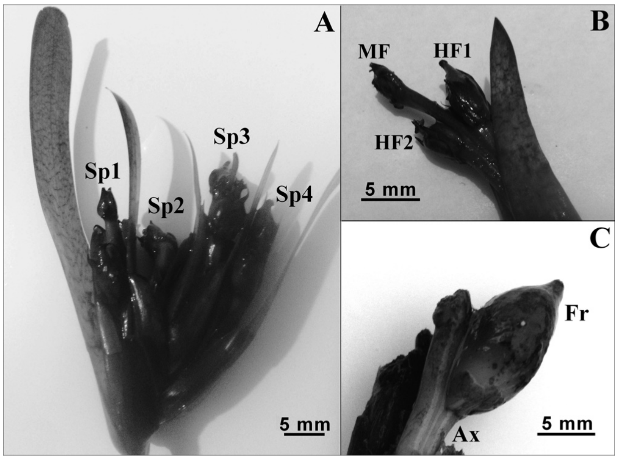

Fig. 2. – Morphological characteristics of *Posidonia oceanica* inflorescences found in wrecks at Stidia area (Mostaganem). **A**: Inflorescence with 4 spikelets (Sp) observed on November 6, 2017. **B**: Spikelet of November 6, 2017 bearing 2 hermaphrodite flowers (HF) and one male flower (MF). **C**: Axis (Ax) bearing a young fruit (Fr) found during the second survey (January 8, 2018).

RESULTS

Inflorescences of the first survey

All inflorescences of the first survey (November 6, 2017) are of green color and are all disconnected from their rhizomes (Fig. 2A). The remaining of the floral scape that was still attached to the inflorescence has an average length of 40.1 mm (maximum: 130 mm and minimum: 8 mm). It should be noted that none of the

Table I. – Characteristics of *Posidonia oceanica* inflorescences sampled on 06/11/2017 at Stidia (Mostaganem). (Sp: Spikelet). [a]: average values and standard deviation.

		Axis length (mm)	Number of flowers	Hermaphrodite flowers			Bract 1 (mm)	Bract 2 (mm)
				Number	Gynoecium (mm)	Androecium (mm)		
Panayotidis & Liapi (1990)	Sp 1	28.9 ± 0.9	4	–	5.6 ± 0.5	5.3 ± 0.5	24.1 ± 0.5	24.2 ± 0.7
	Sp 2	25 ± 0.6	3	–	5.6 ± 0.9	5.1 ± 0.2	20 ± 0.5	17.2 ± 0.8
	Sp 3	26 ± 1	4	–	5.6 ± 0.5	5.1 ± 0.4	25 ± 0.9	21 ± 0.7
	Sp 4	19 ± 5.7	2	–	6.1 ± 0.2	4.8 ± 0.8	12.6 ± 5.1	11.5 ± 5.8
Hamza & Bradai (1994)	Sp 1	21	2	2	6.5 ± 0.7	5 ± 0	–	–
	Sp 2	22	4	2	6.5 ± 0.7	5.5 ± 0.7	–	–
	Sp 3	20	3	2	6.5 ± 0.7	5 ± 0	–	–
Present work (2018)	Sp 1	27[a] ± 8.2	2.0 ± 1.2	1.4 ± 0.7	6.2 ± 2.5	4.8 ± 1.9	26 ± 6.7	23 ± 5.3
	Sp 2	24 ± 4.1	1.4 ± 0.8	0.8 ± 0.8	3.7 ± 3.0	3.0 ± 2.4	22 ± 4.6	17 ± 4.7
	Sp 3	25 ± 6.3	1.7 ± 0.9	1.0 ± 0.7	5.3 ± 3.1	3.7 ± 2.1	21 ± 6.9	18 ± 6.1
	Sp 4	26 ± 5.1	2.3 ± 1.3	1.8 ± 0.9	5.2 ± 1.9	3.9 ± 1.5	25 ± 5.3	22 ± 6.2

Table II. – Percentage of the number and the nature of *Posidonia oceanica* flowers harvested on November 6, 2017 at Stidia (Mostaganem). Male flower (M), hermaphrodite flower (HF).

			No Flower (%)	**1 Flower (%)**		**2 Flowers (%)**		**3 Flowers (%)**		**4 Flowers (%)**	
Panayotidis & Liapi (1990)	**Spikelet 1**		0	0		18		73		9	
				M	**HF**	**M**	**HF**	**M**	**HF**	**M**	**HF**
				0	0	8	92	18	82	8	2
		Total		**M:** 17 %			**HF:** 83 %				
		Percentage of inflorescences bearing the 1st Spikelet					100 %				
	Spikelet 2		**No Flower (%)**	**1 Flower (%)**		**2 Flowers (%)**		**3 Flowers (%)**		**4 Flowers (%)**	
			0	6		76		18		0	
				M	**HF**	**M**	**HF**	**M**	**HF**	**M**	**HF**
				50	50	4	96	28	2	0	0
		Total		**M:** 11 %			**HF:** 89 %				
		Percentage of inflorescences bearing the 2nd Spikelet					100 %				
	Spikelet 3		**No Flower (%)**	**1 Flower (%)**		**2 Flowers (%)**		**3 Flowers (%)**		**4 Flowers (%)**	
			0	0		21		70		9	
				M	**HF**	**M**	**HF**	**M**	**HF**	**M**	**HF**
				0	0	7	93	32	68	17	83
		Total		**M:** 19 %			**HF:** 81 %				
		Percentage of inflorescences bearing the 3rd Spikelet					100 %				
	Spikelet 4		**No Flower (%)**	**1 Flower (%)**		**2 Flowers (%)**		**3 Flowers (%)**		**4 Flowers (%)**	
			0	3		33		33		0	
				M	**HF**	**M**	**HF**	**M**	**HF**	**M**	**HF**
				0	100	0	100	33	67	0	0
		Total		**M:** 21.4 %			**HF:** 78.6 %				
		Percentage of inflorescences bearing the 4th Spikelet					9 %				
Present work (2018)	**Spikelet 1**		**No Flower (%)**	**1 Flower (%)**		**2 Flowers (%)**		**3 Flowers (%)**		**4 Flowers (%)**	
			16.6	16.6		16.8		50		0	
				M	**HF**	**M**	**HF**	**M**	**HF**	**M**	**HF**
				0	100	25	75	33.3	66.6	0	0
		Total		**M:** 37.5 %			**HF:** 62.5 %				
		Percentage of inflorescences bearing the 1st Spikelet					100 %				
	Spikelet 2		**No Flower (%)**	**1 Flower (%)**		**2 Flowers (%)**		**3 Flowers (%)**		**4 Flowers (%)**	
			9.1	45.4		36.3		9.2		0	
				M	**HF**	**M**	**HF**	**M**	**HF**	**M**	**HF**
				60	40	37.5	62.5	33.3	66.6	0	0
		Total		**M:** 43.8 %			**HF:** 56.2 %				
		Percentage of inflorescences bearing the 2nd Spikelet					91.6 %				
	Spikelet 3		**No Flower (%)**	**1 Flower (%)**		**2 Flowers (%)**		**3 Flowers (%)**		**4 Flowers (%)**	
			9.1	27.2		45.4		18.3		0	
				M	**HF**	**M**	**HF**	**M**	**HF**	**M**	**HF**
				66.6	33.3	40	60	33.3	66.6	0	0
		Total		**M:** 42.1 %			**HF:** 57.9 %				
		Percentage of inflorescences bearing the 3rd Spikelet					91.6 %				
	Spikelet 4		**No Flower (%)**	**1 Flower (%)**		**2 Flowers (%)**		**3 Flowers (%)**		**4 Flowers (%)**	
			16.7	0		33.3		33.3		16.7	
				M	**HF**	**M**	**HF**	**M**	**HF**	**M**	**HF**
				0	0	0	100	33.3	66.6	25	75
		Total		**M:** 21.4 %			**HF:** 78.6 %				
		Percentage of inflorescences bearing the 4th Spikelet					50 %				

inflorescences of the first survey bore fruit. These inflorescences range from 1 to 4 spikelets, with an average axis length between 24 mm and 27 mm (Table I). Each spikelet carries between 1 and 2 flowers (Fig. 2B). The average length of the two alternate chlorophylian bracts is between 21 mm (on Spikelet 3) and 26 mm (on Spikelet 1) for the first bract, and between 17 mm (on Spikelet 2) and 23 mm (on Spikelet 1) for the second bract (Table I).

The average number of flowers per spikelet ranges from 1 (minimum value, spikelet 2) to 2.5 (maximum value, spikelets 1 and 4); those of the hermaphrodite flowers range from 1 (minimum value, spikelets 2 and 3) to 2 (spikelets 1 and 4) (Table I). Our results show that the first spikelet is present in 100 % of the inflorescences, the second and the third spikelets are present in 91.6 % of the inflorescences, whereas the fourth spikelet is only present in 50 % of the inflorescences (Table II). The majority of the examined spikelets carries 2 to 3 flowers; a fourth flower was only observed on the fourth spikelet. The hermaphrodite flowers range between 56.2 % and 78.6 % and the male flowers range between 21.4 % and 43.8 %. We noticed that 9.1 % to 16.7 % of the spikelets did not bear any flowers (Table II).

Inflorescences of the second survey

All inflorescences collected on January 8, 2018 were attached to their shoot; they were of brown color and bore a variable number of fruits (Fig. 2C). The position of the flower scape in the *Posidonia oceanica* shoot was central, surrounded by 3 intermediate leaves and 4 adult leaves (Table III).

The analyzed inflorescences ranged between 2 and 4 brown spikelets, with a length of axis ranging from 20 mm to 33 mm (Table IV). The majority of spikelets carries a single aborted ovary, while others carry two and only one was devoid of ovaries (Table IV). When present, one or two fruits were recorded per spikelet (Table IV) of brown, black or green color and size ranging between 7 mm and 15 mm.

DISCUSSION

The inflorescences of November 6, 2017 were all detached from their shoots, therefore preventing us to describe the shoot bearing the flower scape. Comparatively to our results (Table III), Panayotidis & Liapi (1990) have previously recorded lower lengths of the floral scapes (147.2 mm in November 1985 and 156.1 mm in November 1988) from seagrass inflorescences obtained in the Gulf of Saronikos (Greece) at 5 m depth.

The number of spikelets obtained on the inflorescences of November 6, 2017 was similar to those previously described by Panayotidis & Liapi (1990) in the Gulf of Saronikos (Greece), but higher than the one obtained by Hamza & Bradai (1994) in the Gulf of Gabes-Tunisia (3 spikelets per inflorescence) and by Dural (2010) in the Bay of Sigacik-Turkey (between 1 and 3 spikelets per inflorescence). In addition, Dural (2010) reported that the majority of the inflorescences carried two spikelets. The spikelet axis lengths of our inflorescences were almost similar to those obtained by Panayotidis & Liapi (1990) (between 19 mm and 28.9 mm), and larger than those obtained by Hamza & Bradai (1994) (between 18 mm and 24 mm). The average length obtained for the two bracts was close to that obtained by Panayotidis & Liapi (1990) in the Gulf of Saronikos (Greece).

Compared to ours results, while analyzing a single inflorescence at different sites, Hamza & Bradai (1994) recorded higher numbers of flowers per spikelet (up to 4 flowers per spikelet, including 2 hermaphrodite flowers); and Caye & Meinesz (1984) recorded similar distribution of the number of hermaphrodite flowers per spikelet (i.e., 2.2 on the first spikelet, 0.9 on the second, 1.5 on the third and 1.9 on the fourth spikelet). For the same period of the year (November), Panayotidis & Liapi (1990) had obtained in the Gulf of Saronikos (Greece) higher percentages of the presence of the second and third spikelets per inflorescence (100 % each). However, the percentage of the fourth spikelet (9 %) obtained by these authors was significantly less than that obtained in the present study. The number of spikelet per inflorescence and the number of flowers per spikelet were close to those obtained by Den Hartog (1970) (1-4 spikelets per inflorescence, 3 to 5 flowers per spikelet).

The characteristics of the shoots bearing the floral scape harvested on January 8, 2018 were similar to those obtained by Panayotidis & Liapi (1990) in the Gulf of Saronikos (Greece). Referring to Boudouresque & Thelin (1985), the *Posidonia oceanica* fruits are 50 % very young

Table III. – Leaf characteristics of the shoot carrying the floral scape. Sample of January 8, 2018 in the Stidia area (Mostaganem).

	Number	Position	Length (mm)
Floral scape	**1**	Apex Center	201.6 ± 62.9
Intermediate leaf	**1**	Against the floral stem	145 ± 90.2
Intermediate leaf	**2**	Against the floral stem	133.3 ± 69.1
Intermediate leaf	**3**	Towards the periphery of the shoot	309 ± 45.8
Adult leaf	**I**	Towards the periphery of the shoot	356.6 ± 98.2
Adult leaf	**II**	Towards the periphery of the shoot	375.3 ± 85.9
Adult leaf	**III**	Towards the periphery of the shoot	278.6 ± 86.5
Adult leaf	**IV**	Towards the periphery of the shoot	280 ± 87.8

Table IV. – Description of *Posidonia oceanica* fruits collected on Janaury 8, 2018 in Stidia (Mostaganem). Young (Y), very young (VY).

	Number of spikelet	Spikelet axis length (mm)	Number of aborted ovaries	Number of fruit per spikelet	Fruit size (mm)	Fruit age	Fruit color
Inflorescence 1	2	22	1	1	15	Y	Green
		23	2	0	–	–	–
Inflorescence 2	4	24	1	0	–	–	–
		20	1	1	15	Y	Brown
		30	2	0	–	–	–
		28	1	2	14	Y	Brown
					7	VY	Brown
Inflorescence 3	3	25	1	0	–	–	–
		26	1	0	–	–	–
		33	0	2	8	VY	Black
					9	VY	Brown

and 50 % young. The fruit lengths obtained in the present work were smaller than those obtained by Hamza & Bradai (1994) during winter in the Gulf of Gabes (Tunisia); this difference could be due to the sampling period, which is different.

The low temperatures of the north-western Mediterranean waters seem to be at the origin of an irregular flowering of *Posidonia oceanica* (Boudouresque & Meinesz 1982). This is probably not the case for the southwestern Mediterranean, where temperatures are warmer. Mortality inside seedling patches of *Posidonia oceanica* supports the hypothesis that competition for limited nutrients or available space occurred among some seedlings (Balestri *et al*. 2017). For these authors, channels created by the high level of turbulence within the seedling patches during severe storms may play a role in seedling mortality. Ballestri & Cinelli (2003) demonstrated that herbivorous rate significantly reduces the potential of *Posidonia oceanica* seed production. Therefore, the paucity of prospecting during flowering and fruiting seasons could be the major cause of the lack of data. On the other hand, a possible genetic cleavage between *Posidonia oceanica* populations in the eastern and western Mediterranean basins (Arnaud-Haond *et al*. 2007; Serra *et al*. 2010) can also be at the origin of the heterogeneity of the sexual reproduction success (Aires *et al*. 2011). Jahnke *et al*. (2015) suggested that an interaction between genetic factors (relatedness and heterozygosity) and ecological factors (leaf production) causes the heterogeneous flowering patterns in *Posidonia oceanica*. Likewise, seedling substrate preference leads to a more successful sexual recruitment on hard bottoms compared to soft ones; hard substrates have higher potential compared to the soft ones to provide appropriate microsites for *Posidonia oceanica* seedling settlement, leading to a more successful sexual recruitment (Alagna *et al*. 2015).

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