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(RESEARCH ARTICLE)

The growth response of *Galilea mucronata* (L.) Parl. to sea water immersion

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Abstract

Unusual storms along the Bulgarian Black Sea Coast may cause flooding, erosion and therefore destruction of plant communities of psammophytes which dominate sand dunes. In such cases *Galilea mucronata* (L.) Parl. occupies territories from dune pioneers and becomes a major dune stabilizer. This study aims to establish the viability of this species and possible negative consequences during simulated flooding experiments and thereby to investigate its capacity as dune stabilizer. Conducted experiments established that *G. mucronata* was very tolerant to immersion impact and salt stress. Whole plants stay viable longer than the flood with a maximum duration along the Bulgarian Black Sea Coast, and rhizomes were able to regenerate after 30 days in seawater. Statistical analysis of experimental data demonstrates that immersion in sea water increases rhizomes viability, biomass and allocation to root biomass, whereas other factors, such as duration of immersion and temperatures of sea water have no significant effect. *G. mucronata* was less tolerant to water immersion than other psammophytes, but demonstrated a high potential to be a key species for dune stabilization and could contribute to the protection of coastal sands during storms.

Keywords: Immersion tolerance; Viability; *Galilea mucronata* (L.) Parl.; Dune stabilization

1. Introduction

Coastal areas are very fragile ecosystems that are sensitive to global climate changes, sea level rise and frequent storm surges [1]. These areas provide habitats for many rare and endangered species, which will be lost due to the combination of negative consequences of flooding and erosion [2] as well as strengthen anthropogenic impact.

Dune plant species form an extensive system of horizontal and vertical rhizomes that reduced wind speeds across the surface, trapping and holding a great amount of sand [3]. Thus, they support sand stabilization and increase the dune's ability to act as a buffer. Furthermore, they can effectively minimize erosion and reduce storm damages with minimal negative impacts to natural ecosystems [4]. Ecosystem services require searching for well adapted plants with extensive root systems and studying their ability for erosion and flooding control in order to replace the artificial coastal protection and stabilization structures with "soft" transplanting techniques of native, salt-tolerant plant species.

Recorded damages from extreme meteorological events over the Bulgarian Black Sea Coast [5] show the high potential of the root system of native psammophytes to accumulate sands and prevent from washout [6, 7]. Although, the Bulgarian Black Sea Coast is relatively protected from sea floods due to the small amplitude tides [6], some extreme meteorological events, such as unusual storms may cause flooding and erosion of dunes. Storm waves carry away sandy sediments and cause destruction of communities of dominant sand stabilizers *Leymus racemosus* (Lam.) Tzvelev subsp. *sabulosus* (M. Bieb.), *Ammophila arenaria* (L.) Link [7] and *Carex colchica* J. Gay. In such cases *Galilea mucronata* (L.) Parl. become a major dune stabilizer and colonizes territories from the dune pioneers (Fig. 1).

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Figure 1 *Galilea mucronata* communities three months after storm

Data about the impact of storms and flooding to *G. mucronata* are insufficient unlike those about *L. racemosus* subsp. *sabulosus* [7], *A. arenaria* [7-9] and *C. colchica*, which show high viability of psammophytes to the stress of flooding in short-term intervals.

This study aims: 1) to determine the effects of flooding stress caused by storms on whole plants of *G. mucronata* and how long its rhizomes can remain viable in sea water and 2) to investigate post-immersion changes in plant biomass and allocation to above- and belowground biomass in order to determine the capacity of *G. mucronata* as dune stabilizer.

2. Material and methods

2.1. Study species

Galilea mucronata (L.) Parl. (syn. *Cyperus capitatus* Vand.) is a perennial plant from family Cyperaceae with creeping rhizomes, up to 50 cm high, triangular or nearly rounded stem and basal revolute leaves [10]. The species is included in the Red Data Book of the Republic of Bulgaria as endangered [11]. In the investigated area, *G. mucronata* forms fragmented monodominant communities consisting of small number of individuals with high abundance and poor floristic composition [11].

2.2. Simulated flooding experiments

Two simulated flooding experiments were conducted in the Biological Laboratory of the Technical University of Varna. Rhizomes and whole plants of *G. mucronata* were collected at the sandy beach (42º19′48.12′′ N, 27º44′03.73′′ E) in April 2018 for the first experiment and in January 2018 for the second experiment.

In the first experiment, ten whole plants were planted in washed and sterilized sand in plastic pots and immersed in glass tanks (40 l), filled with sea water at a depth of 2–4 cm below the water surface with constant maintained temperatures (4±1 °C, 13±1 °C and 23±1 °C) for 480 hours. The water was changed several times per day. Visible morphological changes of different parts of the specimens (leaves, stems, roots) are recorded and assessed in 12 parameters [7].

In the second experiment, rhizomes were immersed for 720 hours in similar conditions [7]. Ten rhizomes per treatment were removed every fifth day and were planted in washed and sterilized sand in plastic pots in the glasshouse with controlled air temperature [8]. Control rhizomes were planted directly. Rhizomes were watered with fresh water daily and allow growing for one month before harvesting [7]. All plants were cleaned and oven-drying at 60 °C for 24 hours.

2.3. Statistical analysis

Mean bud viability was measured as the percentage of rhizome nodes that produced vegetative shoots and roots [8]. Maximum rhizome bud viability is defined as the bud viability of the rhizome replicate with the highest bud viability for each treatment [8]. Mean bud viability as well as mean dry weight biomass per plant replicate and R:S ratio (Root mass/Shoot mass) were analyzed with one- and two-way analyses of variance (ANOVA). *P*-value less than 0.05 was considered as statistically significant. Where necessary, data were transformed in order to obtain homogeneous variances.

3. Results and discussion

The most important factor in assessments of negative consequences of flooding to natural plant communities is the exposure time to sea water in flooding simulated experiments. In the present study, direct methods were conducted in order to establish the changes and adaptations of *G. mucronata* to the stress of flooding in certain short-term intervals and the period of which whole plants, submerged in sea water still maintain viable buds capable of producing new plants, without taking into consideration the direct mechanical effect of storm waves. Previous study [7] shows that experimental methods based on the direct submergence of psammophytic species are more appropriate than the experiments of studying substrate salinity and salt spray due to their regular exposure to sea water and specific mechanisms of neutralizing sea water salt.

Results from the first simulated flooding experiment showed that submergence in sea water had not lethal effect to the specimens. Twelve visible parameters for morphological changes of different parts of the specimens (leaves, stems, roots) were assessed (Table 1). Beginning of the decomposition of leaves of the submerged plants started at the 140th hours. On the 168th hours, a growth of stems and root sprouts was observed. There were no visible decompositions of newly grown stems, roots and rhizomes till the end of the experiment (480 hours). All investigated parameters were unrelated to water temperature.

Table 1 Results from simulated flooding experiment. Visible morphological changes of different parts of the specimens (leaves, stems, roots) assessed in 12 parameters

Parameter	Hours in seawater		
	4 °C	13 °C	23 °C
Beginning of the decomposition of leaves	140	140	140
Beginning of the decomposition of stems	360	360	360
Beginning of the decomposition of roots	480	480	480
Complete decomposition of leaves	460	460	460
Complete decomposition of stems	n/a	n/a	n/a
Complete decomposition of roots	n/a	n/a	n/a
Growth of stems	168	168	168
Growth of root sprouts	168	168	168
Beginning of the decomposition of newly grown stems	n/a	n/a	n/a
Beginning of the decomposition of newly grown roots	n/a	n/a	n/a
Complete decomposition of newly grown stems	n/a	n/a	n/a
Complete decomposition of newly grown roots	n/a	n/a	n/a

As a result of this test, Critical Decomposition Time (CDT) for *G. mucronata* was obtained. CDT is defined as the time point at which each plant shows signs of irreversible decomposition of vegetative organs [12] and indicates that the plants will not survive and their communities will not be able to recover. This parameter is crucial in models for vulnerability assessments of flooding impacts to coastal plant communities [13]. CDT for *G. mucronata* is 140 hours, which is longer than the flooding with a maximum duration for the Bulgarian Black Sea Coast [7, 12]. This value of the CDT is similar to values of other psammophytes *L. racemosus* subsp. *sabulosus*, *A. arenaria* and *C. colchica* [12].

Results from the second experiment show that *G. mucronata* rhizomes remain viable immersed in sea water for 720 hours, which is the maximum duration of the second simulated flooding experiment. This is in agreement with studies of other psammophytes (e. g. *A. arenaria*) which evaluate their rhizomes viability from 13 to 70 days in sea water [7, 8, 9, 14].

Mean bud viability gradually increased to the maximum of 61.3 % (treatments with 4 °C) on the 480th hours of sea water submergence, followed by slightly decrease at the end of the immersion (Fig. 2). All the treatments had higher values than the mean viability of the untreated control (58.6%) and appeared to be enhanced slightly by sea water (P = 0.037).

Despite different temperatures, all treatments demonstrated identical trends (Fig. 2). The same trend was observed for other psammophytes mean bud viability [7]. The values are similar to the mean viability of *C. colchica* [14], and lower than psammophytes from family Poaceae [7, 14].

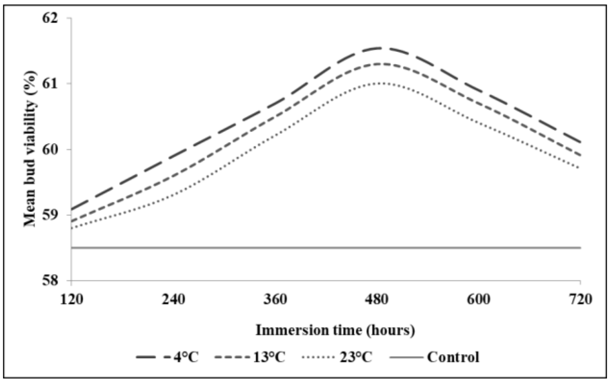

Figure 2 Mean bud viability following sea water immersion

All treatments had a maximum rhizome bud viability of 100%. At the end of each immersion period, 80% of rhizomes still had at least one viable bud and 5% of rhizomes had maximum bud viability.

Storm events on the Black Sea Coast occur during winter and early spring when average surface sea water temperature is about 4 °C [14]. In order to study the relation between temperature and *G. mucronata* viability, two other treatments with temperatures of 13 °C (average surface sea water temperature) and 23 °C (average summer surface sea water temperature) were included in the simulated experiments.

Different temperatures are influenced rhizome viability in similar levels (P = 0.089), and average differences between coolest and warmest temperatures are only 0.44% (Fig. 3). Replicates in all treatments demonstrate higher viability than the untreated replicates (P = 0.038). This is contrary to the results of study of *A. arenaria* rhizomes [9], which retained viability for longer in cooler water. So it can be concluded that the water itself as a defining factor impacts viability more so than the temperature of water.

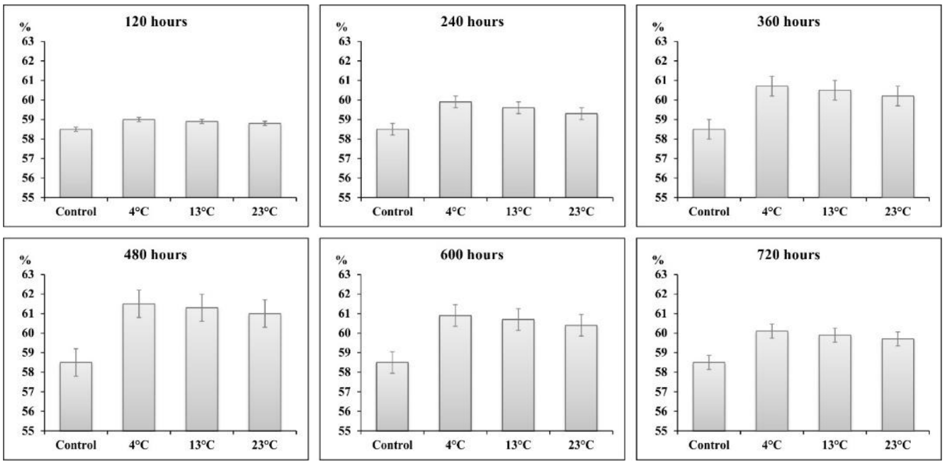

Figure 3 Effects of different temperatures of sea water on mean bud viability

While crucial for rhizomes viability is the cumulative effect on the durability of flooding and sea water temperature, defining factor in ability of psammophytes to fix loose sandy substrates and contribute for dune stabilization is the size of their root systems. In order to measure how immersion affected the root system, the mean dry weight biomass per replicate was taken as well as R:S ratio (Root mass/Shoot mass).

Dry weight biomass was increased by immersion in sea water till 480th hours of the experiment (Fig. 4) and remain unchanged till the end of the experiment. The water temperature had no significant effect (P = 0.077) on the biomass of the treated groups. Replicates in all treatments demonstrate higher biomass than the control replicates (Fig. 4).

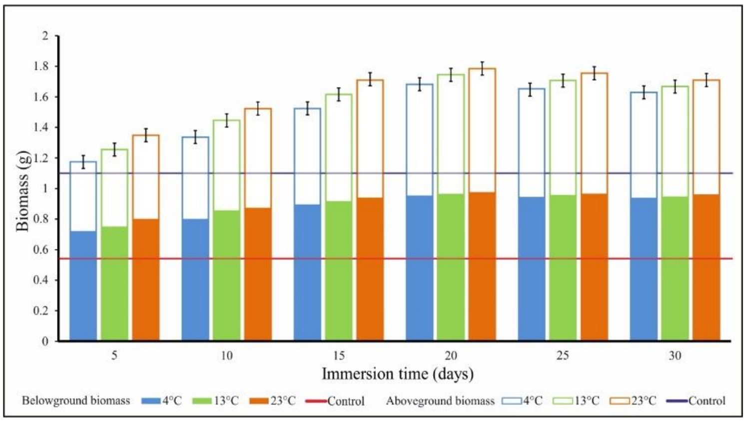

Figure 4 Effects of sea water immersion on dry weight biomass. The shaded portion of the bars represents belowground biomass; blank portion represents aboveground biomass

R:S ratio measures plant allocation to above and belowground biomass [15]. This variable was not affected significantly by immersion duration ($P = 0.072$). Biomass allocation to roots in plants exposed to sea water was slightly increased. Increased water temperatures tended to decrease the R:S ratio, but the effect was insignificant ($P = 0.059$) (Fig. 5). Replicates in all treatments demonstrate higher biomass than the control replicates.

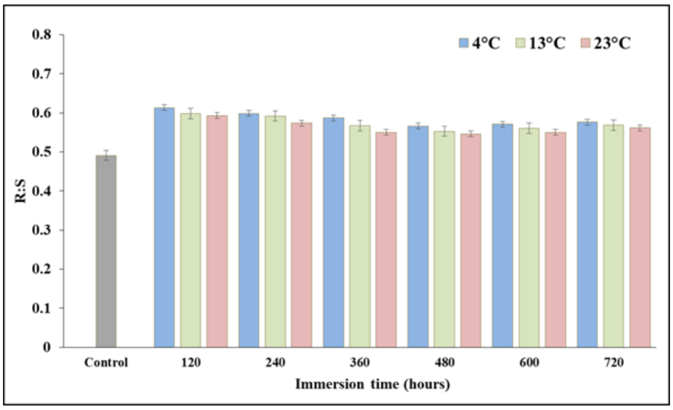

Figure 5 Effects of sea water immersion on R:S ratio

4. Conclusion

G. mucronata shows high tolerance to sea water immersion and high viability during the simulated flooding experiments. Statistical analysis of experimental data shows that the immersion in water increases rhizomes viability, biomass and allocation to root biomass. Other factors, such as duration of immersion and temperatures of sea water have not significant effect. *G. mucronata* are much less tolerant to water immersion than other psammophytes *L. racemosus* subsp. *sabulosus*, *A. arenaria* and *C. colchica*, but demonstrates high potential to be a key species for dune stabilization.

Compliance with ethical standards

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Disclosure of conflict of interest

The author declares the absence of a conflict of interest.

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