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ABOVE- AND BELOWGROUND PRODUCTION OF *ARTHROCNEMUM FRUTICOSUM* IN A VENICE LAGOON SALTMARSH[1]

Riassunto. *Produzione di biomassa epigea ed epigea in* Arthrocnemum fruticosum *in una barena della Laguna di Venezia.*
Nel 1995, in una barena della laguna meridionale di Venezia, sono stati raccolti dati sull'accrescimento e la produzione di biomassa epigea (b.e.) ed ipogea (b.i.) in *A. fruticosum.*
I valori massimi di biomassa viva sono raggiunti in settembre (1007 g p. s./m^2 per b. e. e 3734 per b. i.), mentre la produzione stimata è di 683 per b. e. e 1260 per b. i. Il turnover (P/Biomassa media viva) è di 1.01 per la b. e. e 0.45 per la b. i.; il rapporto produzione epigea/ipogea è di 0.54.
I valori di biomassa e produzione sono confrontabili con quelli riportati per altre aree umide costiere mediterranee; sia la produzione che la biomassa ipogea sono maggiori nel sito lagunare. Questi risultati sono probabilmente da mettere in relazione con le caratteristiche del sito studiato, in cui la vegetazione viene frequentemente ad essere sommersa dalle alte maree.

Summary. In 1995 aboveground biomass (a. g. b.) and belowground biomass (b. g. b.) growth and production were studied for *A.fruticosum* in a intertidal saltmarsh in Venice lagoon. The maximum values of live biomass occurred in September (1007 g d.w./m^2 for a.g.b and 3734 g for b.g.b.) whereas production was 683 g for a.g.b and 1260 for b.g.b. Surface litter was almost absent. Turnover rate (P/Mean live biomass) was 1.01 for a. g. b. and 0.45 for b. g. b; a. g./b. g. production was 0.54. Observed values of biomass and production are comparable with those in other Mediterranean saltmarshes, but higher belowground biomass and production were observed in Venice lagoon. Those findings are possibly linked with the harsh environmental conditions, in a site submerged almost every day. Increasing sea level threaten the productivity and ecological role of these wetlands.

Key words: biomass, production, saltmarshes, *A.fruticosum*, Venice Lagoon.

INTRODUCTION

The northern Adriatic coast of Italy is characterised by a low relief coastline with a number of shallow coastal lagoons and the discharge of several important rivers; the largest Italian lagoon, the Lagoon of Venice (55,000 ha), and the largest delta, the Po Delta (61,0000 ha) are in this area. Coastal marshes make up a significant portion of the area of these coastal ecosystems. Despite the ecological and economic importance of these wetland habitats, no data are available about primary production of salt or freshmarshes plants occurring in these wetlands. There are a number of phytosociological studies in this area (GEHU

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et al., 1984; GERDOL et al., 1984; FERRARI et al., 1985), but growth dynamics have been rarely investigated for the Adriatic saltmarshes (CANIGLIA et al., 1976 and 1978). In the Lagoon of Venice, detailed studies were recently carried out on seagrasses above- and belowground production (RISMONDO et al., 1995 and 1996) whereas no data seem to exist regarding aerial vegetation.

Biomass and production of coastal wetlands are good indicators of vegetation health and of their importance to the functioning of the overall ecosystem (DAY et al., 1989). Factors such as competition, salinity, degree of waterlogging, and nutrient status play important roles in regulating production (PENNINGS & CALLAWAY, 1992; MAHALL & PARK, 1976a and 1976b). Previous literature concerning primary production and decomposition of wetland vegetation is very extensive (e. g., MASON & BRYANT, 1975; HOPKINSON et al., 1978; GROENENDIJK, 1984; LINTHURST & REIMOLD, 1978a; HACKNEY & DE LA CRUZ, 1980; GROENENDIJK & VINK-LIEVAART, 1987); however, none of these papers refer to Mediterranean wetlands. As far as we know, the only comparable studies performed in the Mediterranean on *Arthrocnemum fruticosum* are those of BERGER et al. (1978) and IBAÑEZ et al. (1996) for the Rhône Delta (France) and CURCÒ et al. (1996) for the Ebro Delta (Spain). A study about plant production in the Venice saltmarshes is of interest also because the north-western Adriatic coast has unique environmental conditions when compared to much of the remainder of the Mediterranean, such as low mean temperature, relatively high rainfall distributed over much of the year, and the highest tidal range (about one meter) of the Mediterranean (SESTINI, 1992). This makes the coastal marshes of this region important as a transition between Atlantic and Mediterranean vegetation complexes (DIJKEMA et al., 1984; FERRARI et al., 1985).

This study was carried out as part of a larger European Community project on the impact of climate change on three Mediterranean deltas; the Po, the Rhône and the Ebro. This larger effort involved measurements of vegetation ecology, accretionary dynamics in the deltaic plain, geomorphological change of beach and dune systems along the fringes of the deltas and the physical oceanography of the near shore zone (SANCHEZ-ARCILLA et al., 1996) The primary objectives of the vegetation studies were to determine organic soil formation by the plant community and to quantify the role of this soil formation in contributing to accretion to offset rising sea level. As part of the overall project, we measured the growth, production, and decomposition of *A. fruticosum* in the Venice Lagoon and of *Phragmites australis* in the Po Delta (SCARTON & RISMONDO, 1996); here we report about the results of above and belowground production for the first species. Nomenclature of species follows FERRARI et al. (1985).

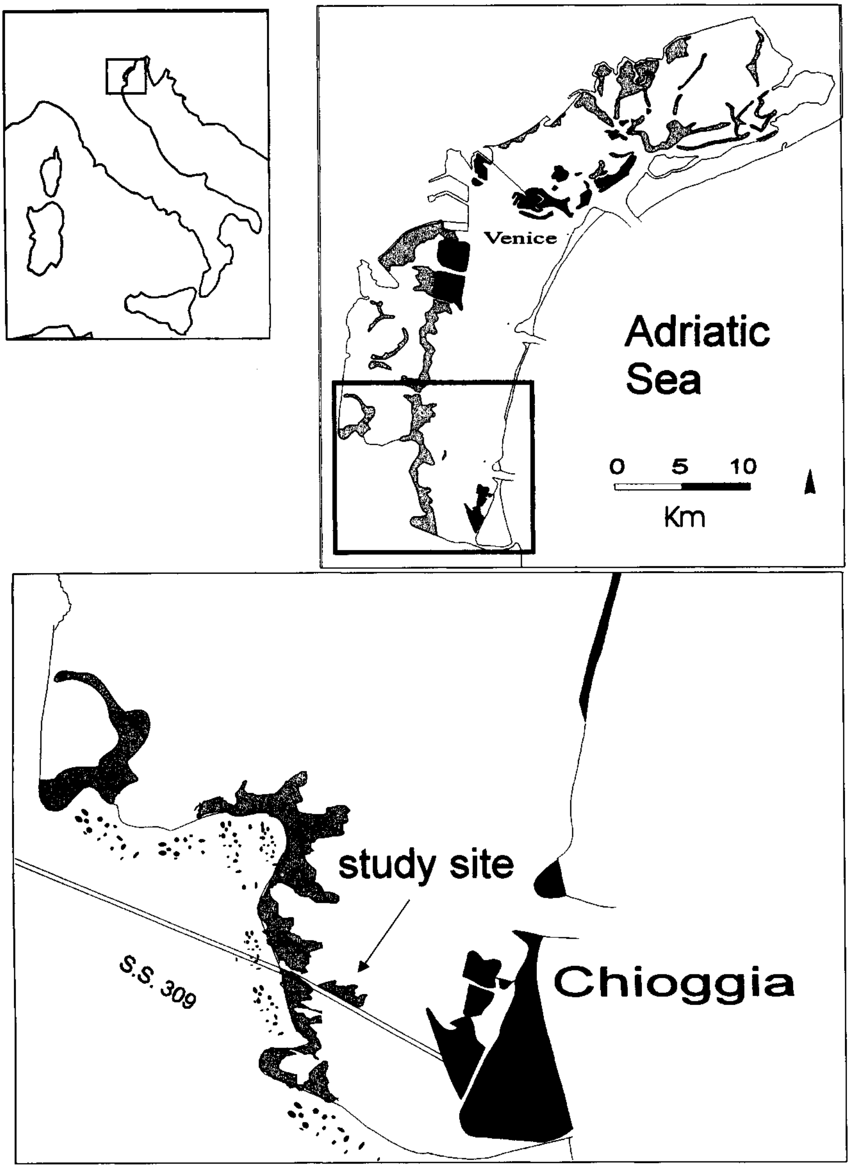

Fig. 1. Study area location; islands are in black and saltmarshes in grey.

STUDY SITE

The study area is located in southern Venice Lagoon (Fig. 1, at approximately 45° 15'N, 12°15'E) in a saltmarsh area bordering the causeway which connects the town of Chioggia and the mainland. The vegetation is mostly composed of *Arthrocnemum fruticosum, Limonium serotinum, Halimione portulacoides* and *Puccinellia palustris*. Patches of *A. fruticosum* are interspersed within the marsh which is dominated by the other species, as is common for the Venetian saltmarshes, where this species rarely covers large, homogeneous areas. The study site, which has an elevation of 0.35 m above sea level, is dissected by a number of shallow creeks. The marsh is regularly inundated during high tide; the mean tide range is 0.6 m while the range of the spring tide is 1.1 m. Salt water is exchanged through the Chioggia inlet located about 5 km from the site. Mean monthly air temperature at Venice ranges from 4.0 to 23.8 °C, with a mean of 13.3 °C and yearly rainfall is 850 mm (A.P.V., 1986); in 1995 temperature ranged between 3.3 °C and 24.3 °C and rainfall was 1045 mm. Groundwater salinity measured in a well located at the study site ranged from 20‰ to 35 ‰

MATERIALS AND METHODS

Measurements were carried out of above and belowground biomass and production. In September and October 1994, preliminary measurements were carried out to determine the number of biomass samples needed and the vertical distribution of root biomass. Estimates of aboveground primary production were calculated from periodic harvest of aboveground biomass (including surface litter). In the study site, a 2500 m^2 plot was randomly established; at each sampling period, sampling locations within the plot were randomly selected. Total aboveground biomass was sampled in March, September and October 1995. In March and October, ten 0.25 m^2 quadrats were chosen and in September, five 0.25 m^2 quadrats were chosen and all live and dead aboveground material was harvested. Each component (leafy stems and woody stems) of the biomass samples was separated into live and dead material. The plant material was taken to the laboratory and dried at 80°C for 48 hours and weighed to a precision of 0.1 g. Ash content was calculated with ignition of dry material at 540 °C for 2 h.

The belowground matter was sampled with a PVC cylinder 9.4 cm in diameter, down to a depth of 40 cm; the material was then sieved in the laboratory through a mesh of 0.1 cm, sorted (in large and small roots, live or dead) and then treated as the aboveground material. Aboveground and belowground production were estimated using the Smalley method (see Groenendijk, 1984 for more details): This method is reported to underestimate production, but it is also more suitable to saltmarshes compared to other methods (see LINTHURST & REIMOLD, 1978b for a comprehensive review).

Results

Maximum total biomass occurred in September for both above (1112 ± 294 g/m^2, all the following values are in g of dry matter ± s.d.) and belowground (4314 g/m^2 ± 806) components; biomass of both components then decreased to October (fig. 1). Surface litter was almost absent in all the campaigns. In September, leafy stems made up the 31.2%, woody stems 59.5%, and dead mate-

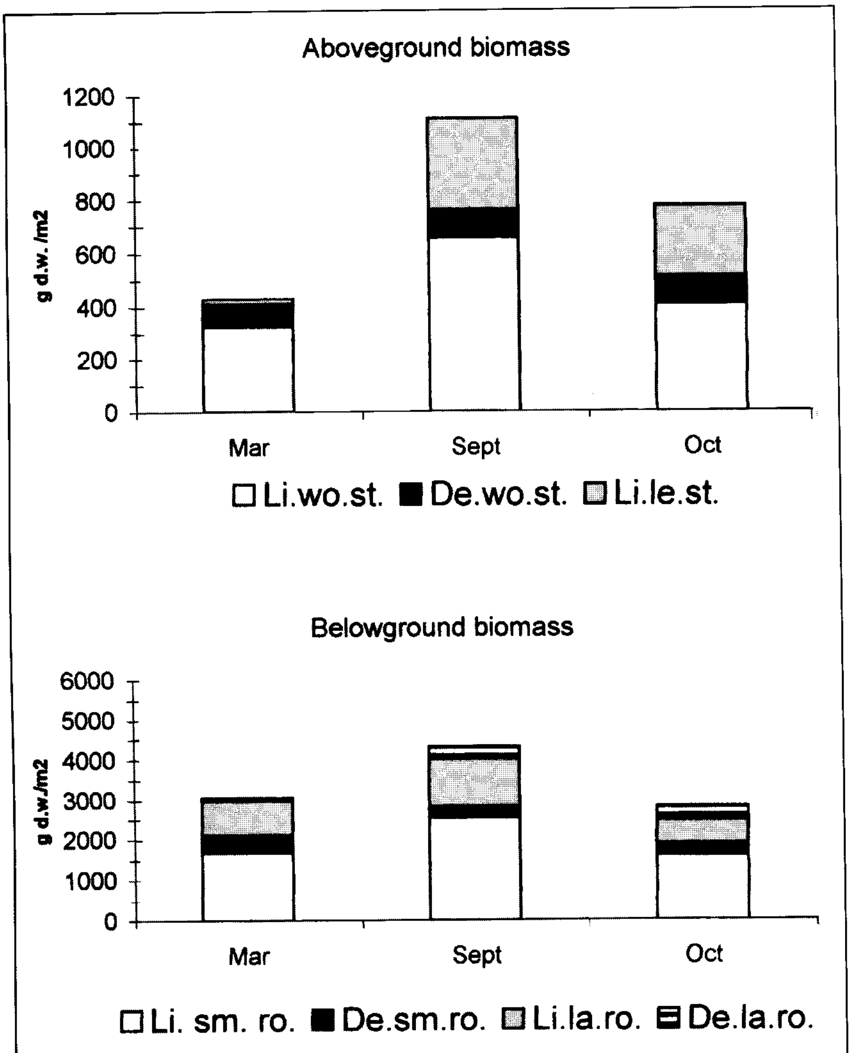

Fig. 2. Above and belowground biomass (note the different scales in the graphs) of *A. fruticosum*. De=dead, Le=leafy, Li=live, Ro=roots, Sm=small, St=stems, Wo=woody.

rial (only dead woody stems) 9.3% of the total aboveground biomass. Total live biomass went from 345 g/m^2± 178.4 in March to 1007 ± 165.3 g/m^2 in September, with increase in both the leafy and the woody stems.

For belowground material, in September large roots comprised 34.7% and small roots 65.3% of total biomass; dead material was about 13.4% of the total belowground material. Whereas for large roots, it was simple to discriminate between live and dead; among small roots this was more difficult and a certain degree of uncertainty was inherent. Overall, roots were abundant in the first 25-30 cm and absent below this level. Due to the occurrence of other species nearby (in particular *L. serotinum* and *P. palustris*) the values for belowground material likely included a non-measured, but possibly small part of their roots. The ratio of above to belowground live biomass ranged between 0.13 (March) and 0.30 (October).

From March to September, the estimated aboveground production was 683 g/m^2, with a turnover rate of 1.01 (table 1). The estimated mean daily production over the whole period was 3.8 g/m^2. Belowground production for the same period was 1260 g/m^2, with a turnover rate of 0.45; a mean daily production rate of 6.9 g/m^2 was estimated. Based on the ash content of live material (table 1), 113 g/m^2 of the aboveground production was inorganic (18 g from woody stems and 95 g from leafy stems), while 315 g/m^2 of the belowground production was inorganic.

Discussion and conclusions

There are few other studies which deal with *A. fruticosum* growth and production in the Mediterranean. Two of them were carried out in the Rhône delta (Berger et al., 1978; Ibañez et al., 1996) and one in the Ebro delta (Curcò et

Table 1. Biomass, primary production and ash content for *A. fruticosum*.

	Aboveground	Belowground
Mean live biomass (g/m^2)	678	2829
Peak live biomass (g/m^2)	1008	3735
Production (g/m^2)	683	1260
Turnover rate (P/Mlb)	1.01	0.45
Ash content (% on d.w.)		
woody stems	5.3	
leafy stems	29.2	
large roots		25.1

al., 1996). By comparison with the results of these other studies, the *A. fruticosum* marshes in southern Venice Lagoon have lower aboveground biomass but higher belowground biomass. Mean live aboveground biomass for the Venice site (678 g/m^2) is in the lower part of the range found in the Ebro delta (438-1658 g/m^2) and much lower than the Rhône delta (1560-2310 g/m^2 and 2000-3500 g/m^2). For mean live belowground biomass, the value (2829 g/m^2) is much higher than those reported either for the Ebro (168-793 g/m^2) or the Rhône (around 1150 g/m^2) deltas. CANIGLIA et al. (1978) studied the biomass growth in a site very close to ours; if we calculate our peak total above and belowground biomass as they did, the resulting values agree well (3966 g/m^2 against 4205 g/m^2). Nevertheless they found maximum biomass values in July, with a decrease from the following campaign (November) onwards; logistical constraints did not allow us to perform more sampling campaigns, as it would have been more appropriate. For aboveground primary production, our values are intermediate between than those observed in the Camargue (1200 g/m^2; Ibañez, pers. comm.) and in the Ebro delta (581 g/m^2); for belowground production, our values are higher than those of the Spanish site (950 g/m^2).

The ratio of belowground/aboveground mean live biomass was 4.2 in Venice Lagoon, 0.5 in the French site and 0.3 in the Spanish one; the ratio of belowground/aboveground production was 1.8 in our study and 0.9 in the Ebro Delta. Our site is the only one among these three sites which is regularly flooded by high tides, often for several hours per day. Low production and a high belowground/aboveground ratio are both indicators of stressful environmental conditions (Schubauer and Hopkinson, 1984), where stressful conditions lead to the investment in belowground tissues by plants. MAHALL & PARK (1976a) reported that increasing salinity led to lower production in *Salicornia virginica* in California. In the Rhône delta, the growth of *Arthrocnemum* species was affected primarily by salinity and waterlogging and the lowest production in the Rhône delta occurred in a site with high ground water level and interstitial salinity (IBAÑEZ et al, 1996). From these data, we conclude that vegetation growth at the Venice lagoon site is affected by the tidal flooding and this results in high belowground biomass and comparatively low aboveground production.

According to our data (unpubl. obs.), the aboveground production for several halophytes in the Lagoon of Venice ranges between 200 and 800 g/m^2, values which are very close to those recorded in other European saltmarshes (HUSSEY & LONG, 1982; GROENENDIJK, 1984; BENITO & ONAINDIA, 1991) but much lower than those reported for the east coast of the United States (see LINTHURST & REIMOLD, 1978a) where the saltmarsh vegetation has been extensively studied for many decades.

In the lagoon of Venice there are still about 4000 ha of saltmarshes (FAVERO, 1992); if we assume that 10-15% (400-600 ha) of this area is covered with *A.fruticosum*, it is possible to roughly estimate the total yearly production for this species at 2730-4100 t (dry weight) for the aboveground biomass and 11300-17000 t for the belowground biomass. The belowground production accumulates *in situ*, where it decomposes very slowly (SCARTON & RISMONDO, 1996). Aboveground production is probably mostly exported outside, as it appears from the virtual absence of surface litter, entering the detritus chain. Our recent studies (DAY et al., 1998) have shown that most of the saltmarshes in the Lagoon of Venice are not able to cope with the future expected sea level rise (about 50 cm in the next 100 years; IPCC, 1995). As a result, prolonged flooding time of the saltmarshes will probably severely affect the vegetation, with a progressive reduction in the aboveground production and a consequent decrease in the organic and inorganic material available to the whole ecosystem.

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