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Propagation and Mechanical Control of *Potamogeton illinoensis* Morong in Irrigation Canals in Argentina

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ABSTRACT

Aquatic weeds development and mechanical control were evaluated in irrigation canals in Viedma (Argentina). Biomass allocation strategy of *Potamogeton illinoensis* Morong was studied in a simple destructive experiment under outdoor tank conditions and a chain cutting experiment of weed control was done in natural situations from September 1993 to April 1994. There were no discernible effects of the spring clearance operations because of the fast regrowth from the rhizomatous system which is formed from the beginning of the season. Plant biomass shows important growth rates from ±10th November reaching almost 17 ton.ha^{-1} in April. Control of vegetative propagation by mean of rhizomes is the key point to manage the population of this weed. Chain cutting plus some other method (e.g. grass carp, herbicides) may be useful tools to solve the aquatic weed problems in the area.

Key words: biomass allocation, growth rate, weed control, chain cutting.

INTRODUCTION

In arid and semi-arid regions irrigation is essential for agriculture. The water for irrigation systems flows through supply and drainage canals which are often seriously affected by excessive aquatic plant growth causing blockage of water flow (Murphy 1988a).

In the semi-arid lower valley of the Rio Negro, Argentina, management costs in irrigation systems are increased by the need for weed control measures. Aquatic weed growth in both irrigation and drainage canals increases the risks of crop production loss, salinization of soils, and flooding, because of the reduced efficacy of water movement through canals and irrigated soils. The risk is so great that the costs of canal weed control must be included, as an integral part of the crop management regime, and a range of physical weed control measures is available for this purpose (Murphy 1988b; Fernandez et al. 1978).

Study areas are located in Viedma, Rio Negro province in the south of Argentina (40°48'S; 63°05'W). The climate here is arid to semi-arid. Water from the Rio Negro supplies the IDEVI (Lower Valley Development Institute) irrigation system, comprising in total 235 km of irrigation canals, with an

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associated 550 km of drainage canals. The length of the main supply canal is 95 km, of which 12 km are concrete-lined, the remainder being unlined. Unlined sectors of the main canal were used for the work reported here. The width of the main canal reduces from 18 m at the river, down to 12 m at the far end; with water depth fluctuating in the range 1.8 - 3.2 m.

The mean flow taken from the river during the 1993/94 growing season was between 9.5 $m^3.s^{-1}$ in August, when the irrigation period started, and 20 $m^3.s^{-1}$ in January when the irrigation demand was greatest.

Among all the species that growth in this canal, *Potamogeton illinoensis* develops the highest biomass levels. Little is known about this weed in Argentina (Tur 1982). Although listed by Pieterse & Murphy (1990) as an aquatic weed, Steward (1990) categorized the species as one which does not cause major weed problems in North America. It is a common lake species in areas such as Florida (e.g. Ewel and Fontaine 1983). However the species is named in the Applied Biochemists Inc. (1976) listing of aquatic weeds.

Locally, it is known by the common name of "lama" but until this study it had not even been properly identified in the area.

Plants of *Potamogeton illinoensis* begin growing from the first days of September, when the canals are refilled (Dall'Armellina et al. 1993). Then a main shoot develops and at the same time two new rhizomes are produced belowground, from de third and forth nodes of the main shoot. These rhizomes have buds on alternate nodes over which they produce both, a shoot and a new rhizome (branch). Each new rhizome develops as the previous one (Bezic 1994).

Seasonal sampling on natural populations of *Potamogeton illinoensis* shows different kinds of rhizomes (Dall'Armellina et al. 1993). Bezic (1993) recognize two different types of rhizomes in this species, a) Rhizomes I, produced from initial stages in the annual cycle and died in the next winter, which are structures of colonization, and b) Rhizomes II, that appears at the beginning of the summer as an enlargement of the Rhizome I extremes, probably by accumulation of carbohydrate reserves, are whiter and bigger than the previous type and develops one short belowground overwintering sprout per node in alternate nodes.

Only Rhizomes II survives the dry season and initiates the next season sprouting (Bezic 1994).

Aboveground parts are 92-93% represented by stems and submerged leaves (Bezic 1994). Floating leaves have never been observed on *P. illinoensis* plants in the study area. Inflorescences are terminal spikes as in other *Potamogeton* species (Sculthorpe 1967).

The objectives of this study were: (I) to determine the seasonal pattern of biomass production for each species growing in the main canal with emphasis in *P. illinoensis*; and (II) to examine the impacts of physical weed control on these species.

MATERIALS AND METHODS

Two study lines were conducted under different environmental situations, a) outdoor tank studies on seasonal pattern of biomass production of *Potamogeton illinoensis*, and b) main canal studies on biomass production of several macrophytes and effects of mechanical control measures.

a) Outdoor tank studies

The studies were performed in an outdoor concrete-lined 2 m deep circular tank, 50 m in diameter, between September 1993 to May 1994 at the IDEVI-INTA Experimental Station 2; near Viedma. The tank was topped up weekly with water piped from the irrigation supply (derived from the Río Negro).

Dissolved oxygen concentration ranged between 8.6 - 14.6 $mg.l^{-1}$, mean electrical conductivity was 0.18 $mS.cm^{-1}$ and midday water temperature ranged between 10.3 - 25.4C during the study period.

Plants were grown in laboratory glass aquaria from pieces of rhizomes (mean ± standard error: 0.8 ± 0.01 g fresh weight) with an overwintering sprout, collected from the bottom of the main irrigation canal in July 1993 and maintained in a refrigerator until 6 August. After 17 days growth in the laboratory (water mean temperature 18C; light intensity 100 $uE.m^{-2}.s^{-1}$; 16 h illumination per day) the plants were transferred to 54 wooden boxes (0.37 × 0.51 × 0.19 m) internally lined with a black plastic sheet and filled with soil free from propagules of other aquatic macrophytes.

Each box contained 3 plants. Plant development was followed for a further 265 days. On each sampling occasion, 3 boxes were selected at random and the 9 plants which they contained were harvested. In the laboratory the plants were washed with clean water and separated into their main constituent parts (leaves, stems, rhizomes I and II), stem and rhizome length was measured, and then dried for 24 hours at 105C. Dry weight (DW) was taken with a 0.0001 g precision balance at the first stages and with a 0.01 g precision during the middle and at the end of the growing season. Biomass measurement and analysis followed the recommendations of Madsen (1993).

Relative growth rate (RGR) was calculated for total plant biomass over the main period of growth (measured at t1, 105 days after start and t2, 282 days after start). Although data were collected for other organs, we present here the results for leaves, stems, and rhizomes: these accounted for >90% of total plant weight in all specimens.

b) Main canal studies

One station in the main canal was used (km80) taking 15 samples at random from treated and untreated sectors every month during the growth period, from September to April. Samples of above and belowground biomass (Madsen 1993) were collected from a tethered raft using a 0.028 m^2 core sampler, and taken to the laboratory for processing.

Above and belowground parts of the plant samples were separated in the laboratory. Aboveground biomass was separated into different species, and dried in an electric oven at 105C for 24 hours.

Environmental parameters measured at each site were water temperature (C); dissolved oxygen concentration ($mg.l^{-1}$), light intensity ($\mu E.s^{-1}.m^{-2}$), pH and electrical conductivity ($\mu S.cm^{-1}$).

At the sites where biomass was recorded a simple submerged aquatic weed control experiment was undertaken, using the chain cutting method, with treatments applied on 15 November when *Potamogeton illinoensis* was approximately

50 cm long on average, the second treatment on 3 January, and the third treatment on 22 February.

RESULTS AND DISCUSSION

Outdoor Tank Studies

Visible plant development from an overwintering sprout began when this was submerged in water. Then a main shoot developed which had alternate submerged leaves with a ligule. Within the below-ground system the only components present were roots and rhizomes.

Rhizome production began at the first developmental stages with the production of two initial rhizomes at the 3rd and 4th main shoot nodes. From January (150 days) new rhizomes increase their size, turning more white and normally with a nodal scale. These rhizomes (Rhizomes II) do not produce new rhizomes but only an overwintering sprout at every node.

Although the growing season began during the last days of winter, the main period of growth commenced 105 days after the start, in the middle of November (Figures 1 and 2). Thereafter, growth was linear until 239 days, with the exception of rhizomes II that continuous growing until the end of the season, in May 1994. The calculated value of RGR for mean total plant biomass over the main growth period was 0.33 g g^{-1} d^{-1}.

Leaves and stems average growth rates are presented in Table 1. The main growth period for Rhizomes I was the same as for leaves and stems, commencing in mid-November, and reaching maximum biomass at the end of April. Rhizomes II production did not begin until the first week of January (150 days from start), with the maximum reached in May after 282 days.

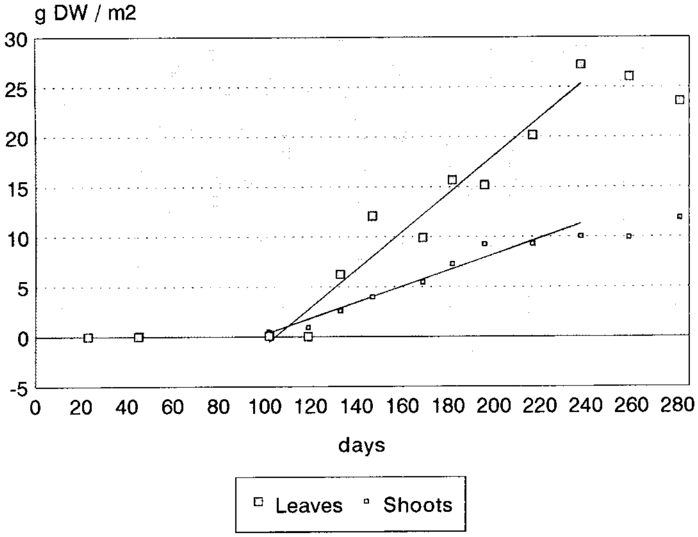

Figure 1. Development of main above-ground structures of *Potamogeton illinoensis* from overwintering sprouts in an outdoor tank during the 1993/94 season. Time axis is days after 6 August 1993. Data are mean dry weight per plant ± standard error (n=9). Linear regression comprises the active growing period between t1=105 and t2=239 days.
______ = fitted linear regression for leaves (y = 0.199x - 21.40; r = 0.98, P<0.001). - - - - = fitted linear regression for stems (y = 0.078x - 7.83; r = 0.99, P<0.001).

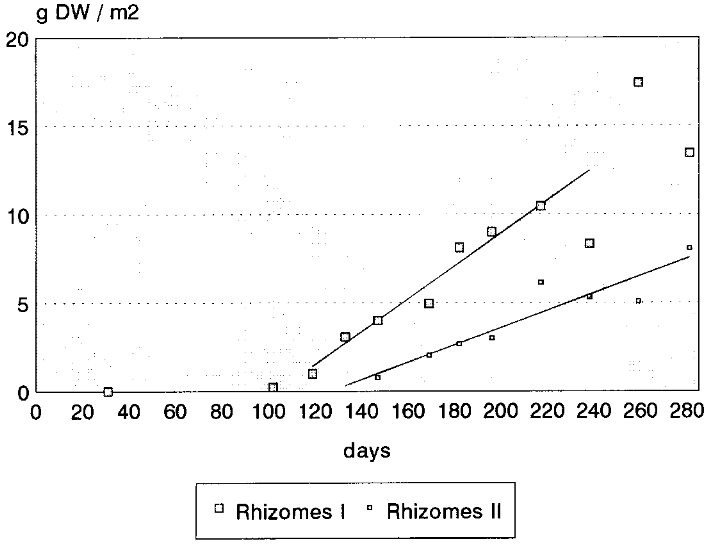

Figure 2. Development of main below-ground structures of *Potamogeton illinoensis* from overwintering sprouts in an outdoor tank during the 1993/94 season. Time axis is days after 6 August 1993. Data are mean dry weight per plant ± standard error (n=9). Linear regression comprises the active growing period between t1=105 and t2=239 days for rhizomes I and between t1=150 to t2=282 days for rhizomes II.
______ = fitted linear regression for rhizomes I (y = 0.087x -9.05; r = 0.99; P<0.001). - - - - = fitted linear regression for rhizomes II (y = 0.046x - 5.70; r = 0.96, P=0.003).

These organs show varying growth rates, with the main period of growth being between November and May. Leaf biomass showed the fastest rate of increase, and rhizomes II the slowest, but these latter organs appear to play a key role in the regenerative strategy of *P. illinoensis*, permitting survival of annual periods of drought produced by dewatering of the channel habitat. Dependence on vegetative propagules is a common regenerative strategy in *Potamogeton* and many other submerged macrophytes (e.g. Kautsky 1988; Yeo 1965), but in *P. illinoensis* appears to be of particular importance.

As rhizomes II do not develop until the mid-late phase of the growing season, control measures which prevented or reduced their formation would probably be a highly effective approach to managing this species. For example, the use of mechanical control, such as dredging, to destroy a high proportion of rhizomes I, before rhizomes II had a chance to form, could be very effective in reducing population survival

TABLE 1. PLANT PRODUCTION IN POTAMOGETON ILLINOENSIS OUTDOOR TANK STUDIES SHOWING THE AVERAGE GROWTH RATE (AGR) PER PLANT PART DURING THE MAIN GROWTH PERIOD AND BOTH THE MAXIMUM BIOMASS AND LENGTH REACHED AT THE END OF THE 1993/94 SEASON.

Plant part	AGR (g DW.day^{-1}.pl^{-1})	Max. Biomass (g DW.pl^{-1})	Max. Length (m.pl^{-1})
Leaves	0.130	27.21 ± 1.33	—
Shoots	0.060	11.87 ± 0.38	40
Rhizomes I	0.085	17.40 ± 3.22	10
Rhizomes II	0.060	8.09 ± 0.68	1.8

into the next season. Alternatively, the introduction of control measures which severely depleted photosynthate supply for rhizome formation (by destroying foliage) during the period before production of rhizomes II might have the same effect. Possibilities here might include appropriate herbicide treatments (e.g. Fernandez et al. 1987), or the use of grass carp. It is, however clear that the current management methods, based on repeated use of a weed-clearing chain (Dall'Armellina et al. 1994) are very ineffective in reducing formation of rhizomes II, probably because the method has no little direct effect on rhizomes and regrowth of foliage after treatment is too fast to permit much depletion of rhizome carbohydrate resources.

Main Canal Studies

Potamogeton illinoensis was present in 100% of samples taken from the two stations, with other species present in different percentages. Development of aboveground biomass of all macrophytes growing in the main canal is shown in Figure 3. The growing period started in September, with substantial growth increase from the last week of October to a peak at the end of December.

Potamogeton pectinatus was found in a high percentage of the samples taken in the main irrigation canal but its biomass production was always lower than *Potamogeton illinoensis*, which represented more than 93% of the total biomass produced in the canal. Belowground data for *Potamogeton illinoensis* at treated and untreated sites are shown in Table 2. Minor species like *Elodea callitrichoides* and *Myriophyllum aquaticum* reached maximum development in February. Growth of *Cladophora sp.* and *Chara sp.*, began late in the season, and produced only very low biomass (Figure 4).

Biomass changes after cutting showed that the first treatment had little effect on macrophyte growth. The second treatment was more effective, decreasing total biomass substantially compared with the untreated control data. The third treatment maintained this low biomass.

There were no discernible differences in any water quality data between treated and untreated sites.

Table 2. Belowground biomass (g DW.m^{-2}) of *Potamogeton illinoensis* in the main irrigation canal during the 1993/94 growing period in both treated (chain) and untreated (check) sectors.

Date	Treated	Untreated
September	25.75 ± 2.57	32.30 ± 2.85
October	21.20 ± 4.25	12.62 ± 2.18
January	16.88 ± 2.34	47.31 ± 4.08
February	29.22 ± 2.34	40.38 ± 3.67
March	13.29 ± 1.63	50.89 ± 2.60
April	23.10 ± 2.56	77.19 ± 4.86

Note: the growing period mean values of belowground biomass in treated and untreated sectors were 21.57 ± 2.37 and 43.45 ± 8.74 g DW.m^{-2} respectively.

Thus, it is clear that the irrigation canals of the IDEVI area are a very favorable habitat for submerged plant growth, and production is high (approximating to some 18-20 t ha^{-1} yr^{-1}). This may be compared with productivity values of 25 t ha^{-1} yr^{-1} recorded by Howard-Williams (1978) for *Potamogeton pectinatus* at similar latitudes in New Zealand; and up to 40 t ha^{-1} yr^{-1} for *Potamogeton schweinfurthii* in tropical Africa (Wade 1990).

The physical weed control regime used in the IDEVI irrigation canals appears to produce results very comparable to those seen with mechanical clearance elsewhere in the world. Early-season clearance produces a brief check to growth, postponing the spring increase, but producing virtually no effect on rate of increase (as is clearly visible after the first cut in Figure 3). Later season clearances are more effective in actually reducing biomass. Very similar results have been reported from navigable canals in Britain (Eaton et al 1981). Timing of weed control operations is clearly an important factor in managing this system effectively. Timing is also crucial with regard to reducing vegetative propagule formation for the main *Potamogeton* species present: rhizomes in the case of *Potamogeton illinoensis* and tubers in the case of *Potamogeton pectinatus* (Yeo 1965). There is plenty of evidence to suggest that control is most effective against aquatic weeds

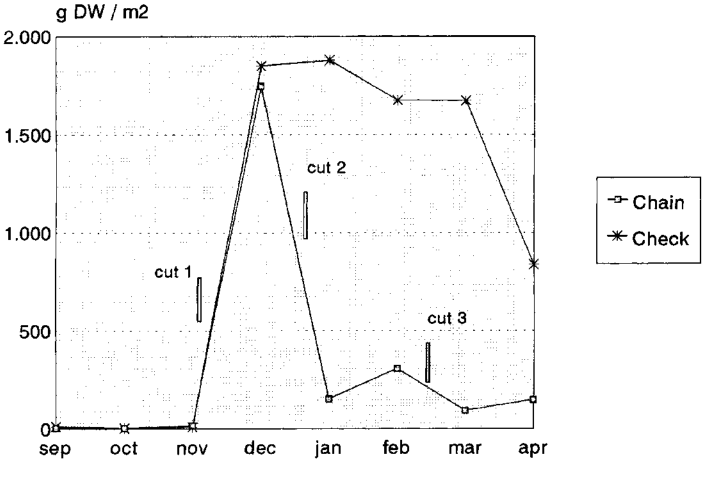

Figure 3. Development of aboveground biomass of macrophytes growing in the main canal (km 80) in both treated and untreated areas.

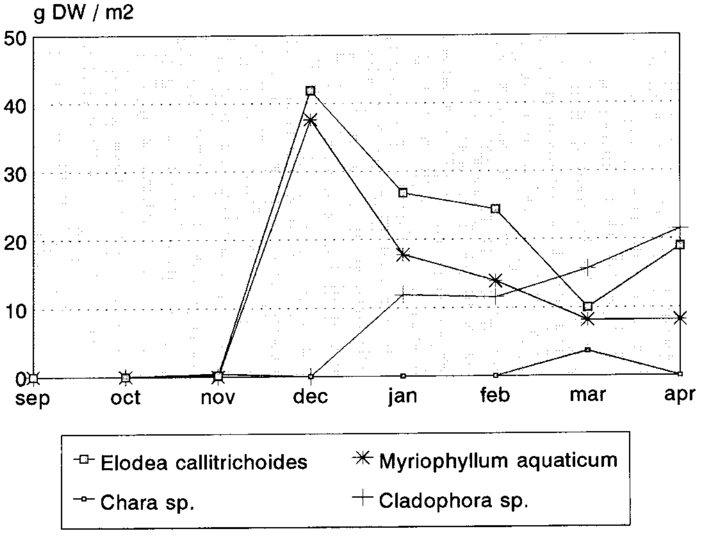

Figure 4. Development of aboveground biomass of several macrophytes growing in the main canal (km 80) during the last 93/94 season.

dependent on vegetative propagules, when used before the formation of these structures (Wade 1990). For rhizomatous species, regular defoliation of the plants can be an effective mean of depleting carbohydrate reserves in the belowground structures, producing longer-lasting control (e.g. Wallsten 1983).

Although it does decrease belowground biomass, the control method (chaining) currently favored in the IDEVI area probably produces insufficient destruction of submerged foliage, for long enough, to produce significant effects on rhizomes. Indeed, the method probably favors the spread of species like *P. illinoensis*, by breaking up the plants, and allowing viable rhizome and stem fragments to move downstream. It is probable that a control regime which produced longer-term suppression of aboveground biomass would give better control of the main weeds present in the system. Possibilities might include drip-feed herbicide control, for example using acrolein (e.g. Bowmer and Sainty 1977), or the use of biological measures such as grass carp. An integrated control regime utilizing grass carp and physical control may well be the optimal solution to the problem in the IDEVI system, and in similar irrigation systems elsewhere in Argentina.

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