Rev. FCA UNCUYO. 2019. 51(2): 201-216. ISSN (en línea) 1853-8665.

Growth of *Stuckenia pectinata* under greenhouse and irrigation canal conditions in the lower valley of the Colorado River (Argentina)

Crecimiento de *Stuckenia pectinata* en condiciones de invernáculo y canales de riego del valle inferior del río Colorado (Argentina)

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Originales: *Recepción:* 22/06/2018 - *Aceptación:* 06/07/2019

ABSTRACT

Stuckenia pectinata is an invasive submerged weed in the irrigation district in the lower valley of the Colorado River, Argentina. The objective of this study was to analyze the initial growth of *S. pectinata* from tubers, and its annual growth cycle in irrigation canals, in order to be efficient in adapting future control techniques. Tubers were planted in aquaria in order to evaluate the effect of their size, depth of burial and below zero temperatures on the initial growth. Under field conditions, samples of plants were collected from two irrigation canals, from October to March, in two complete growth cycles. Plant height and biomass of the leaves, stems and spikes were measured. The largest tubers were able to emerge from deep burial and generated larger plants than the smallest tubers. Frozen tubers did not germinate at any burial depths. Maximum biomass in the irrigation canal reached 1660 g DM m^{-2} with a peak at the beginning of summer. The elimination of biomass at the end of the irrigation season would result in small tubers that would die in the winter time. The information generated could lead to more appropriate and sustainable control.

Keywords

sago pondweed • tubers • freezing • burial depth • growth cycle • lower valley of Colorado River

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RESUMEN

Stuckenia pectinata es una maleza invasora sumergida de canales de riego del valle inferior del río Colorado, Argentina. El objetivo de este estudio fue analizar el crecimiento inicial desde tubérculos de *S. pectinata* y de su ciclo de crecimiento anual, para incrementar la eficiencia en la adaptación de futuras técnica de control. Los tubérculos se plantaron en acuarios, para evaluar el efecto de su tamaño, la profundidad de entierro y temperatura de congelación en el crecimiento inicial. En condiciones de campo, se recogieron muestras de plantas y biomasa de dos canales de riego desde octubre a marzo en dos ciclos completos de crecimiento. Se midieron la altura y el peso de las hojas, tallos y espigas de las plantas. Los tubérculos más grandes pudieron emerger de un entierro profundo y generar plantas más grandes que los tubérculos más pequeños. Los tubérculos congelados no germinaron a ninguna profundidad. La biomasa máxima en canales de riego alcanzó 1660 g de MS m^{-2} con un pico al comienzo de verano. La eliminación de la biomasa al final de la temporada de riego producirá pequeños tubérculos que morirán en el invierno. La información generada podría conducir a un manejo más apropiado y sostenible.

Palabras clave
lama • tubérculos • congelación • profundidad de entierro • ciclo de crecimiento • valle inferior del río Colorado

INTRODUCTION

The construction of the "Casa de Piedra" dam 700 km upstream from the irrigation network changed the ecological features of the water. The high load of suspended sediments that was carried down by the river, resulting in a very turbid-reddish water (giving the name "Colorado" to the river), was deposited in the dam (6). Therefore, increased light penetration in the irrigation canals facilitated the rapid development of aquatic weeds (8). One of the most important weeds is *Stuckenia pectinata* (Sago Pondweed), which significantly impedes the water flow due to the development of a large amount of biomass. Previous studies showed that in severe *S. pectinata* infestations the normal water flow can be reduced up to 60% in the irrigation canals, consequently, the water available for irrigated crops is critically reduced (2).

Stuckenia pectinata is a morphologically variable species due to its great phenotypic plasticity (19). It is a cosmopolitan, perennial, monocotyledon plant, with some branches on the stem (19). Plants are rooted in the sediment by a robust subterranean system containing roots, rhizomes and tubers (12). The stems, extending to 3 or 4 m in length, are branched with small alternate leaves (from 22 to 125 cm). Sexual reproduction is by drupelets which provide long-term dormancy and a broad dispersal, and by tubers for overwintering and short-distance dispersal (13). The irrigation canals of CORFO can have 260 tubers per m^{-2} with 54% of emergence (1). *Stuckenia pectinata* plants allocate up to 41.5% of dry biomass in the production of tubers which is considered as the most important strategy for the re-establishment of a population (19). The threshold for controlling the submerged weed is 200 g of dry biomass per square meter to avoid blockage and the stopping of water flow in irrigation canals (4).

Unfortunately, the current weed management is carried out by hydraulic excavators with a cutting basket, which only operate efficiently with large sized plants during the irrigation season. The delay in the application of the hydraulic excavators promotes large tubers compared with other types of management (2). In fact, no weed management is undertaken in the last three months of the irrigation season which leads to the development of a large number of large tubers. This species survives the winter in the form of tubers. The principal infestation strategy is through tubers and seed is virtually not important according to Kantrud (1990). As the *S. pectinata* plant biomass increases in relation to the initial tuber size (18), the CORFO irrigation canals quickly become blocked, meaning that the current management practices may result in an increasing annual infestation.

Moreover, the dry irrigation canals are restructured and cleaned in winter time. Mechanical restructuring modifies the environment of the irrigation canals, burying the tubers to different depths. Tuber size and burial depth are significant factors in regulating *S. pectinata* growth (17). For this reason, knowledge of the effect of low temperatures, the size and burial depth of the tubers are essential for understanding the population dynamics.

In spite of the importance of the *S. pectinata* problem in irrigation canals, there is no useful information about its growth in the aquatic environment in the lower valley of the Colorado River. Determination of the growth cycle in the irrigation system would lead to treatment at the most feasible moment for obtaining the highest negative impact on the *S. pectinata* infestation. Considering that most of the irrigation canals (5,440 km) are infested in a short period of time, it is difficult to operate weed management techniques simultaneously. Hence, it is essential to have accurate information for scheduling the different control tasks as efficiently as possible. We hypothesized that by decreasing the tuber size, it is possible to delay biomass production and therefore, a lower effort is needed to control it during the irrigation season. Therefore, the objectives of the present research were to generate essential information on the effect of tuber biomass, as well as the interaction between the burial depth of tubers and freezing on the initial growth of *S. pectinata*, and to analyze the annual growth cycle in the irrigation canals of CORFO.

MATERIAL AND METHODS

Site description

The irrigation district of CORFO (Development Corporation of the lower valley of the Colorado River) 39°30'9.77" S, 62°41'13.01" W located in the semiarid zone in the south of Buenos Aires province, which covers 140,000 ha of horticulture, pastures and cereal production including 5,441 km of canals (2). The landscape is characterized by a slight slope (0.002%) with Mollisol, Entisol and Aridisol soils (5). Rain decreases from north to south and the hydric deficiency is 400 mm year^{-1} so, irrigation is vital for crop production in the area. There are 42 days per year on average with temperatures below zero degrees Celsius (6). The field study was carried out in 1995/96 and 1997/98 and the study under greenhouse conditions was conducted in 2000 and 2001.

The present research involved the evaluation of some factors of the initial growth of *S. pectinata* from tubers conducted under greenhouse conditions and the study of the annual growth cycle of the species under irrigation canal conditions.

Initial growth of *S. pectinata*

Effect of tuber biomass on initial growth

In the irrigation canals, sediment was passed through a mesh of 1 mm to separate tubers of diverse sizes. Different sized tubers were planted in black plastic 333 cm^3 pots filled with sandy loam soil in glass tanks under greenhouse conditions. Five categories of tubers were selected according to their biomass: 0-30 mg, 30-60 mg, 60-90 mg, 90-120 mg and higher than 120 mg. Four tubers of each category were planted at a depth of 2.5 ± 0.5 cm in each black plastic pot which was the optimal burial level according to our preliminary research (3) and similar to the research of Spencer (1986). These five treatments were replicated inside eight glass tanks filled with water up to the 40 cm level. The experiment was a complete randomized block designed with 8 replicates (tanks). Each block involved one fixed tank filled with water. In this way, the potential variation due to the aquarium position can be isolated from the natural variation of the principal parameter evaluated. The average temperature and turbidity of water were 20°C ± 2 and 9 NTU (Nephelometric Turbidity Unit), respectively. An air pump was incorporated in each tank. After 21 days from the beginning of the experiment (initial growth), all the plants were collected and the height, dry biomass of foliage, aboveground and belowground biomass were measured. Samples were placed in an oven at 60°C for 3 days.

Effect of freezing and burial depth of tubers on the initial growth

The tubers were categorized into three categories according to biomass: 0-60 mg, 60-120 mg, and higher than 120 mg. To analyze the reduction in the initial growth of *S. pectinata* caused by the effect of tuber biomass and the interaction between freezing temperatures and burial depth, four tubers without freezing and four tubers with 12 h of freezing at -3°C were sown at 7, 10, 15, 20, 25 cm in depth. The tubers were planted in silty clay loam soil in black plastic pots under greenhouse conditions. All 30 treatments were replicated four times in each of the five glass tanks filled with water up to the 40 cm level. The average temperature and turbidity of the water were 20°C ± 2 and 9 NTU, respectively. Air was incorporated with a pump. The percentage of emergence and aboveground plant biomass were recorded 32 days after the beginning of the treatments. A plant was considered as emerged when the first green part was seen on the sediment surface.

Annual growth cycle of *S. pectinata*

Research was conducted in two stretches of irrigation canals at CORFO which were identified as Canal 55.6 (hereafter Villalonga canal-39°51'55" S, 62°34'42" W) and 58 Sur (hereafter Buratovich canal-39°22'45" S, 62°26'56" W). The depth and water flow were 95 cm and 0.6 $m^3 s^{-1}$ in the Villalonga canal and 120 cm and 1 $m^3 s^{-1}$ in the Buratovich canal, respectively. Both canals were representative of the irrigation system and had a typical infestation of *S. pectinata*. The growth dynamic was evaluated with randomized samples collected from October to May of the following year, during two growth cycles (1995/96 and 1997/98). Irrigation canals remain dry during winter time.

Data of the photoperiod (hours) were measured at the weather station located in Hilario Ascasubi (39°23'32" S, 62° 37'43" W). Specific conductance (water electrical conductivity) was recorded by a Hach conductivity meter CO150. Range of temperature was measured with a digital thermometer. The temperature of the water was 9 -12°C at the beginning of the observations and it increased to 25°C in the summer. Turbidity was measured using a turbidimeter Hach 2100P. The average water electrical conductivity was 1.03 ± 0.03 mS cm^{-1} and the pH ranged from 6.84 to 8.33. The average turbidity in the canal sections was 27.36 ± 17.72 UTN.

Biomass production

Ten biomass samples were collected by sampling date using an iron quadrat of 30 cm sides which was randomly placed in the sediment during the growth cycle. The non-subterranean biomass inside each quadrat was cut with scissors, put into a plastic bag, and taken to the Weed Ecophysiology Laboratory of CERZOS. Each sample date was carried out in different sections of the canal, thus, samples were independent of each other. Plant samples were washed and dried to a constant weight in an oven at 70°C.

Individual plant size

An individual plant was defined as a primary stem emerging from the sediment and all the parts included on it, such as secondary stems, leaves, and spikes. At each site, five individual plants were collected at random in the first growth cycle and 15 plants in the second cycle. All samples were washed and dried to constant weight in an oven at 70°C. The parameters measured included the plant height and dry biomass of stems, leaves and spikes.

Statistical analysis

The experiment was a complete randomized block designed with 8 replicates (aquarium), and its results were analyzed by ANOVA. Freezing and burial depth of tuber data on the initial growth were subjected to a 3-way ANOVA (fixed factors: tuber size, burial depth and freezing) with 5 replicates. With regard to the field research (2.2), plant height was transformed by natural logarithmic to assess variance homogeneity prior to statistical analysis (15). This parameter together with the total biomass and individual plant biomass, and spike biomass were analyzed by ANOVA. All the means were separated by a Fisher Least Significant Differences test (LSD. P<0.05). Analyses were conducted with INFOSTAT software (7).

RESULTS AND DISCUSSION

Initial growth of *S. pectinata*

Effect of tuber biomass on initial growth

The height and biomass of the plants were affected by the biomass of the original tuber. Even though there were no differences in plant height between tubers of 60-90 mg and 90-120 mg (figure 1a, page 206), these plants presented differences in biomass (figure 1b, page 206).

Analysis of the above and belowground biomass showed differences between the different categories of tubers (table 1, page 206).

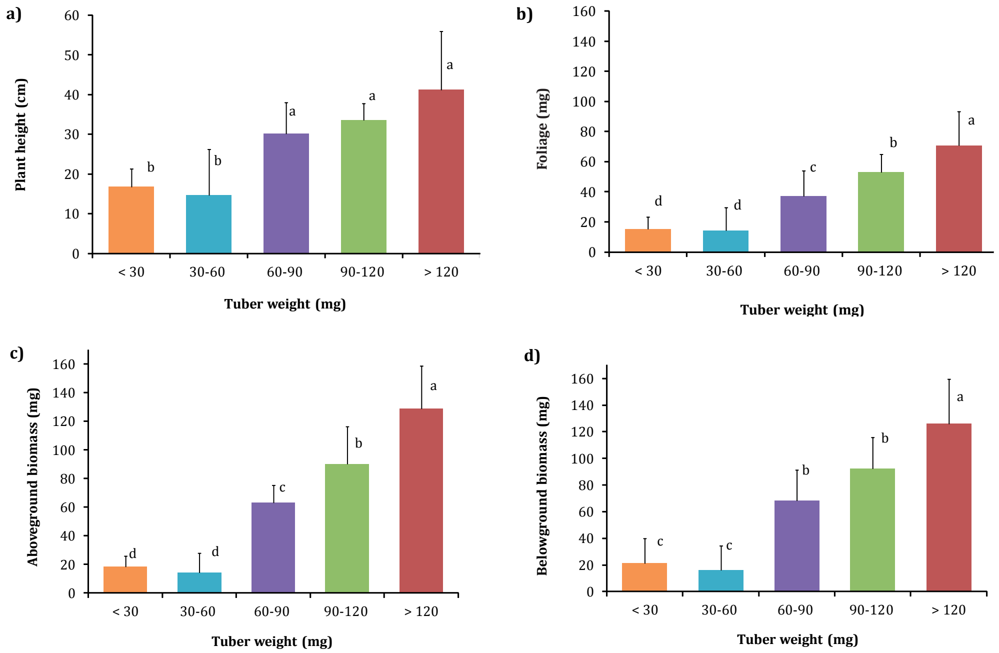

Figure 1. Effect of the tuber biomass (mg) on the initial growth (21 days) of *Stuckenia pectinata* growing in aquaria under lab conditions, a) plant height (cm), b) foliage (mg dry mass), c) aboveground biomass (mg dry mass), and d) belowground biomass (mg dry mass).

Figura 1. Efecto del peso de los tubérculos (mg) sobre el crecimiento inicial (21 días) de *Stuckenia pectinata* creciendo en peceras bajo condiciones de laboratorio, a) altura de plantas (cm), b) follaje (mg peso seco), c) biomasa no subterránea (mg peso seco), y d) biomasa subterránea (mg peso seco).

Table 1. Results of ANOVA for plant height, plant biomass, above and belowground biomass for different sizes of *Stuckenia pectinata* tubers under aquarium conditions.

Tabla 1. Resultados del análisis de varianza para la altura y peso de plantas, biomasa subterránea y no subterránea para diferentes tamaños de tubérculos de *Stuckenia pectinata* en ensayos de peceras

Source	Numerator DF	F	Pr > F
Plant height			
Treatment tuber size	4	13.2	<0.0001
Aquaria	7	1.8	0.1206
Plant biomass			
Treatment tuber size	4	35.2	<0.0001
Aquaria	7	5.1	0.0008
Aboveground biomass			
Treatment tuber size	4	62.8	<0.0001
Aquaria	7	2.5	0.0411
Belowground biomass			
Treatment tuber size	4	46.9	<0.0001
Aquaria	7	5.2	0.0007

Increments in the latter three categories of tuber biomass resulted in increases in the aboveground and belowground biomass (figure 1c and 1d, page 206).

The initial growth of plant biomass and height increased with the biomass of the tuber. The tubers heavier than 120 mg produced greater plant height and plant biomass than the other tuber categories. The same tendency was recorded for the above and belowground biomass (table 2). Spencer and Ksander (1995) determined that increasing tuber biomass resulted in increasing plant biomass, using a category of large tubers between 100-150 mg of biomass. Another experiment was conducted with four categories of tubers, the highest category being 91-100 mg which resulted in the highest plant biomass after 30 days of the trial (17).

Effect of freezing and depth of burial of tubers on the initial growth

Tubers exposed to freezing temperatures were not capable of sprouting. The smallest tubers (<60 mg) did not produce any plants at any of the burial depths. Moreover, there were no differences in plant biomass between the medium and large tubers at the same burial depth. Large tubers planted at 7 and 10 cm in depth generated more biomass than those buried at 20 and 25 cm; however, the biomass produced by large tubers planted at 15 cm showed no differences to those buried at 20 and 25 cm. Maximum emergence in large tubers was reduced by 80 % when planted at 25 cm.

The plant biomass of *S. pectinata* decreased with the burial depth of the tuber in agreement with Spencer and Ksander (1995). Similarly, Spencer (1987) also found that plant biomass increased with the initial tuber biomass and declined as the planting depth increased.

All the tubers that had been exposed to freezing temperatures for only 12 hours died. Similarly, overwintering tubers localized 2.54 cm under the snow that were exposed to 0°C or lower also died (21).

Table 2. Effect of the size and burial depth of tubers on percentage of germination (%) and the production of biomass (mg) of *Stuckenia pectinata* after 32 days under aquarium conditions*.

Tabla 2. Efecto del tamaño y profundidad de entierro de los tubérculos sobre el porcentaje de germinación (%) y la producción de biomasa de *Stuckenia pectinata* después de 32 días de crecimiento en peceras*.

Burial Depth	**Percentage of germination (%)**			**Biomass (mg)**		
	Tubers size			**Tubers Size**		
	Small (< 60 mg)	Medium (60-120 mg)	Large (>120 mg)	Small (< 60 mg)	Medium (60-120 mg)	Large (>120 mg)
7 cm	0	80	80	---	151.5 A	200.3 A
10 cm	0	0	100	---	---	254.7 A
15 cm	0	20	40	---	76.7 AB	77.8 AB
20 cm	0	0	40	---	---	63.95 B
25 cm	0	0	20	---	---	53.3 B

* Means with the same letter in the same column do not show differences according to the LSD Fisher test ($p < 0.05$).

* Medias con la misma letra en la misma columna no difieren estadísticamente acorde al test de diferencia mínima significativa de Fisher con una probabilidad < 0,05%.

In addition, year old tubers, or the oldest exposed to wet chilling, were not able to germinate (9). It would be advisable to perform mechanical tillage on the bottom of the canal to expose tubers to the normal freezing temperatures in winter, which would affect their subsequent infestation ability.

Annual growth cycle of *S. pectinata*

Biomass production

Stuckenia pectinata grows in the CORFO area as a spring-summer plant from October to February, when maximum radiation and water temperature facilitate the growth.

There were differences during the growing season in the biomass collected in different harvests (table 3).

Whereas in the first growth cycle the biomass showed two peaks, in the second growth cycle it only reached one peak at the end of the cycle (figure 2, page 209).

In the second growth cycle in the Villalonga canal, the maximum biomass accumulation was 1120 and 410 g DM m^{-2} in the first and second growth cycles, respectively (figure 2, page 209). In the Buratovich canal, the total biomass was significantly lower compared with the first cycle. Inverse behaviour was recorded in the Buratovich canal, where maximum biomass reached 800 g DM m^{-2} in the first growth cycle, and it was 1660 g DM m^{-2} in the second growth cycle (figure 2, page 209). The accumulation of biomass reached a maximum value of 1660 g DM m^{-2} at the end of February. In a monospecific stand of *S. pectinata* in The Netherlands, values of 1070 g DM m^{-2} were reported by Van Wijk (1988) without reaching the maximum levels. An infestation of 1900 g DM m^{-2} was reported in an estuary of South Africa, reaching the highest biomass level (10). Madsen and Adams (1988) cited biomass accumulation of 712 g DM m^{-2} in a Wisconsin stream.

Table 3. Results of ANOVA for biomass production, plant height and plant biomass, for *Stuckenia pectinata* during two growth cycles in Villalonga and Buratovich irrigation canals.

Tabla 3. Resultados del análisis de varianza para la producción de biomasa, altura y peso de plantas de *Stuckenia pectinata* durante dos ciclos de crecimiento en los canales de riego Villalonga y Buratovich.

Source	Canal	Cycle	Numerator DF	F	Pr > F
Biomass	Buratovich	First	10	31.09	<0.0001
		Second	8	49.2	<0.0001
	Villalonga	First	10	48.35	<0.0001
		Second	8	33.4	<0.0001
Plant height	Buratovich	First	12	19.8	<0.0001
		Second	8	114.8	<0.0001
	Villalonga	First	10	10.6	<0.0001
		Second	8	100.01	<0.0001
Plant biomass	Buratovich	First	12	29.4	<0.0001
		Second	8	21.8	<0.0001
	Villalonga	First	10	12.6	<0.0001
		Second	8	59.8	<0.0001

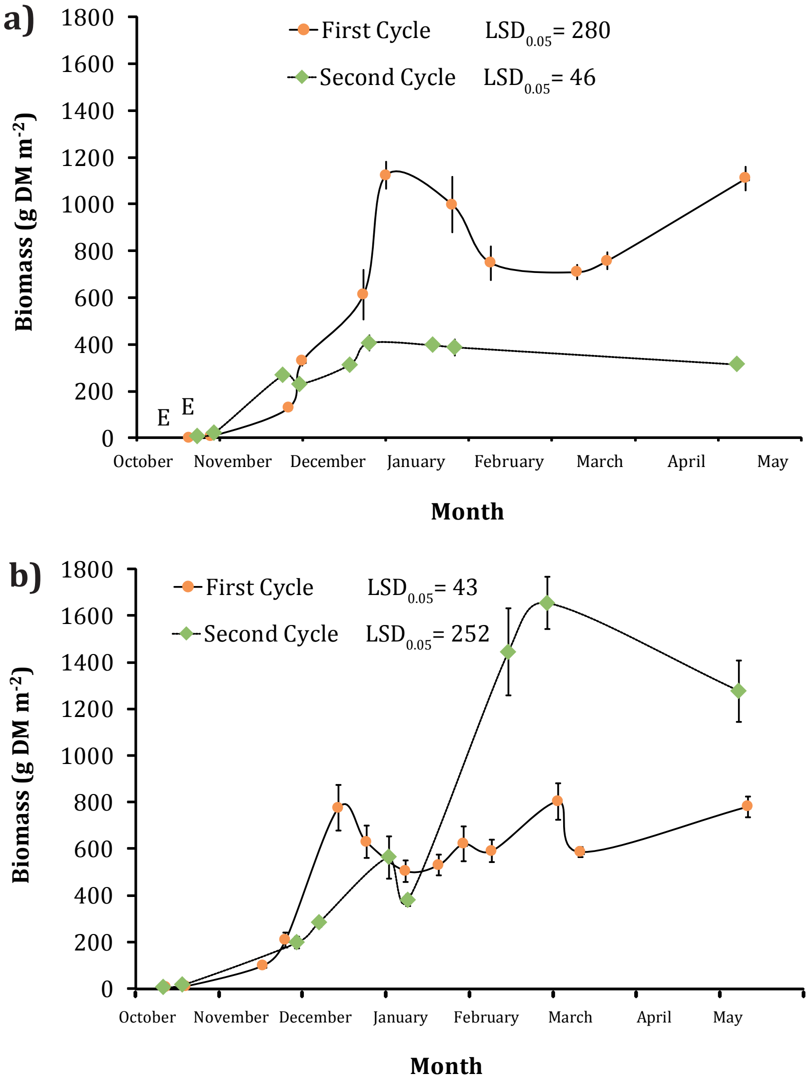

Figure 2. Dynamic of the aboveground biomass (g DW m^{-2}) of *Stuckenia pectinata* during two growth cycles in Villalonga (A) and Buratovich (B) irrigation canals.

Figura 2. Dinámica del crecimiento no subterráneo (g MS m^{-2}) de *Stuckenia pectinata* durante dos ciclos de crecimiento en los canales de riego de Villalonga (a) y Buratovich (b).

Individual plant size

Differences in plant height were recorded during the growing season (table 3, page 208). The maximum plant height recorded was 267 cm (figure 3). This value was greater than the value found in the North Baltic (208 cm) by Idestam-Almquisty and Kautsky (1995).

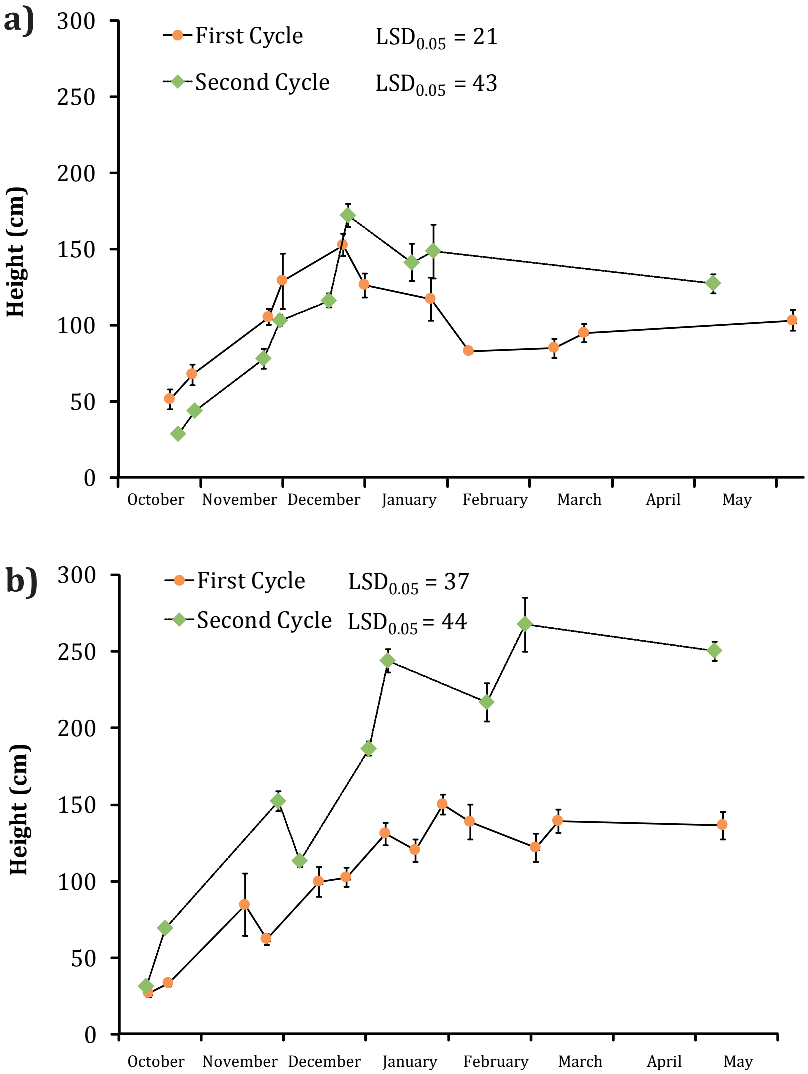

Figure 3. Plant height (cm) of *Stuckenia pectinata* during two growth cycles in Villalonga (A) and Buratovich (B) irrigation canals.

Figura 3. Altura de plantas (cm) de *Stuckenia pectinata* durante dos ciclos de crecimiento en el canal de riego Villanoga (a) y Buratovich (b).

The superior height of the plants that was recorded in plants harvested in the Buratovich canal compared with plants from the Villalonga canal can be attributed to the greater water depth in the first canal as it is known that plant height is associated with water depth (14). Moreover, the maximum plant height at the beginning of summer (late December/ early January) produced a blockage in the water flow and an urgent reduction in *S. pectinata* plants is needed.

There were differences in plant biomass. The maximum plant biomass in the Villalonga canal was 852 and 625 mg for the first and second growth cycles, respectively. In the Buratovich canal, maximum plant biomass was 1.263 and 2.230 mg for the same cycles (figure 4, page 212).

The maximum biomass of leaves and stems in each canal was recorded on the last sampling date in late autumn, whereas the maximum biomass of the spikes was recorded in late summer. In all cases, the highest values occurred in the first cycle in the Villalonga canal and in the second cycle in the Buratovich canal (figure 5, page 213-214). The maximum biomass of the leaves, stems and spikes in the Villalonga canal was 733.4, 317.9 and 30.0 mg, respectively. Whereas the maximum biomass of leaves, stems and spikes in the Buratovich canal was 1506.0, 785.4 and 87.1 mg, respectively (figure 5, page 213-214).Water flow, depth and canal orientation were variable in the irrigation system; consequently plant growth was different between the canals. Due to the fact that the rate of increasing biomass was different in each canal and year of study, the management should be adapted to each particular case. As the plant biomass reached the damage threshold of 200 g dry weight m^{-2} very quickly (4), the contact herbicide or mechanical control would have to be conducted early in the irrigation season (begining of October).

At the beginning of the growth period, plants of *S. pectinata* were only a few centimeters in height, and the aboveground biomass was comprised of 80 % of leaves and 20% of stem. Then, plants reached the water surface, by elongating the principal stem and without secondary stems, as cited by Vermaat and Hootsmans (1994). By late December, the dry matter of the leaves and stems tended to be similar. This is the moment when plants allocated a lower proportion of resources to the production of leaves. From that point onwards, the plants increased the proportion of leaves, reaching the end of the cycle with approximately double the dry biomass in leaves compared to the stems.

Fructification and seed production started in the middle of spring and continued throughout the rest of the growing season (figure 5, page 213-214). The same period of fructification was determined in Montana, USA by Yeo (1965). Spike production reached a high value of 187.6 mg of biomass in the second cycle at Buratovich. In running water, Gannie *et al.* (2016) only found 30 mg of spike biomass; however, no drupelets were produced because moving water inhibits pollination.

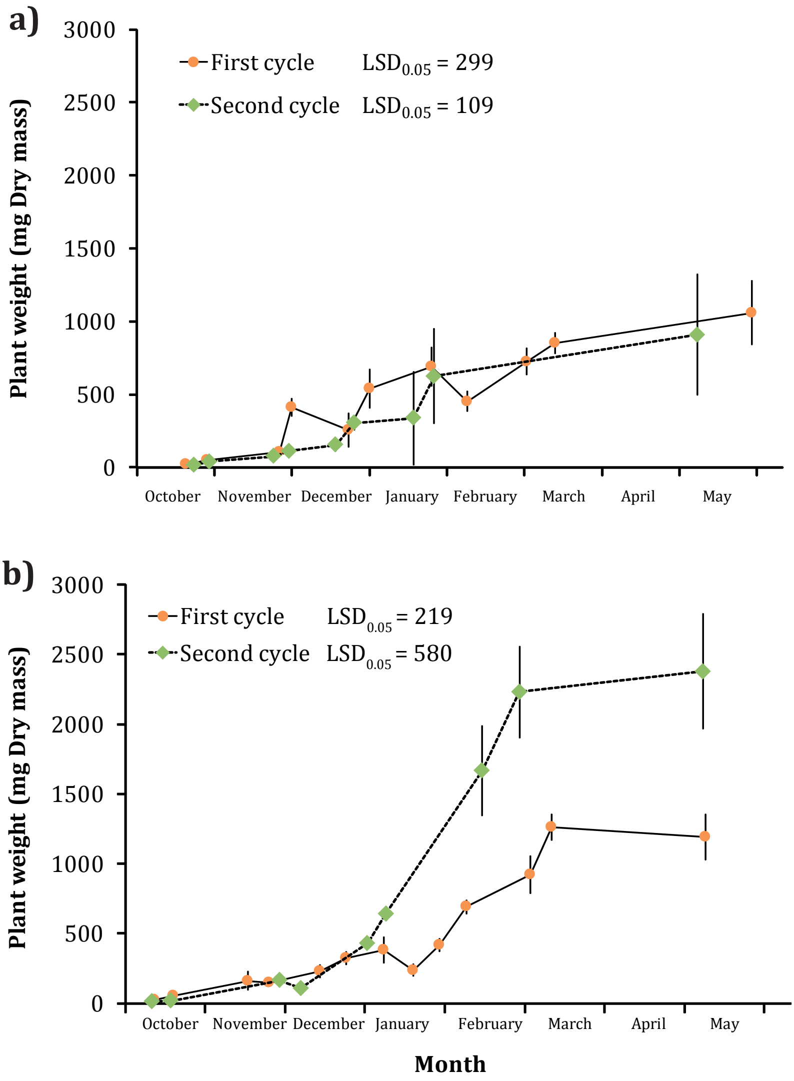

Figure 4. Plant biomass (mg) of *Stuckenia pectinata* during two growth cycles in Villalonga (A) and Buratovich (B) irrigation canals.

Figura 4. Biomasa de plantas (mg) de *Stuckenia pectinata* durante dos ciclos de crecimiento en el canal de riego Villanoga (a) y Buratovich (b).

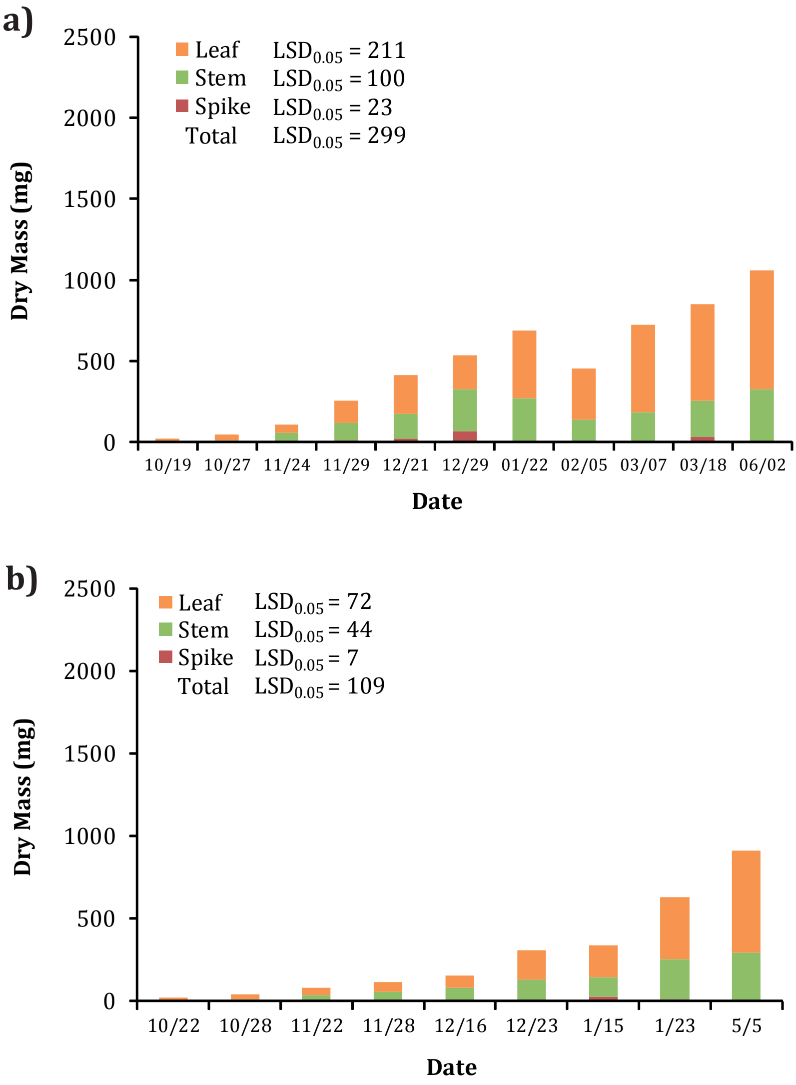

Figure 5. Leaf, stem and spike biomass of an individual plant of *Stuckenia pectinata* during two growth cycles (First A and C, Second B and D) in Villalonga (A, B) and Buratovich (C, D) irrigation canals.

Figura 5. Peso de hojas, tallos, y espigas de plantas individuales de *Stuckenia pectinata* durante dos ciclos de crecimiento (Primero A y C, Segundo B y D) en el canal del riego Villalonga (A,B) y Buratovich (C,D).

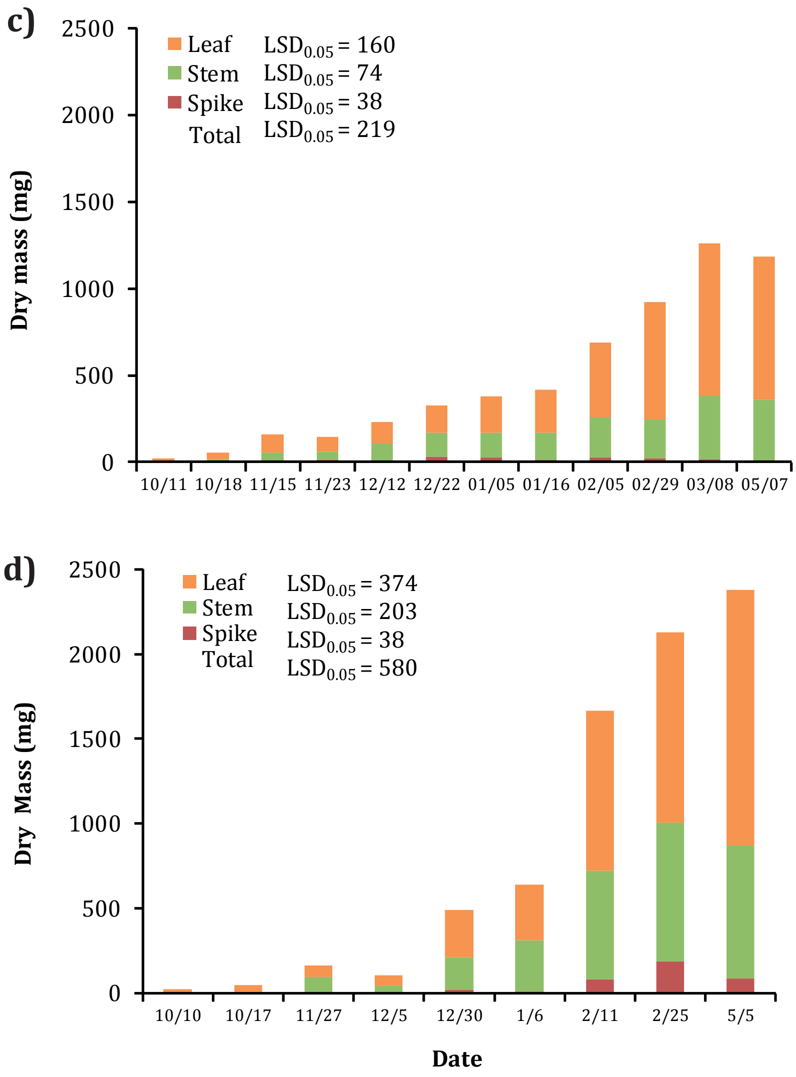

Figure 5. (cont.). Leaf, stem and spike biomass of an individual plant of *Stuckenia pectinata* during two growth cycles (First A and C, Second B and D) in Villalonga (A, B) and Buratovich (C, D) irrigation canals.

Figura 5 (cont.). Peso de hojas, tallos, y espigas de plantas individuales de *Stuckenia pectinata* durante dos ciclos de crecimiento (Primero A y C, Segundo B y D) en el canal del riego Villalonga (A,B) y Buratovich (C,D).

CONCLUSIONS

Freezing temperatures damaged tuber tissue and killed the tubers. Large tubers are capable of generating the largest plants and they emerge from up to 25 cm in depth; however, at the deepest sites they generate smaller plants than the superficial tubers. In order to reduce the number of future plants or to result in smallest size of plants, tubers have to be exposed to freezing temperature or be incorporated deep in the soil.

Changes in dry biomass of leaves, stems, spikes are produced during the growth season. At first, more leaves than stems are recorded. Finally, leaves increase until the end of the cycle. Spike weight is negligible in relation to the other plant constituents.

Contact herbicide, such as Acrolein, should be applied at the beginning of the growth season when plants have more leaves. When the stems increase on the plant, the amount of herbicide needed to control them should also be increased. Mechanical control is only effective with large plants, as most of the below ground biomass develops and new growth takes place rapidly.

Stuckenia pectinata reaches one of the highest values of biomass (1660 g DM m^{-2}) in the world. Also, the plant height reaches a high value of 2.67 m. High values of biomass and plant height lead to unavoidable canal blockage very quickly in the season.

According to the threshold of 200 g dry weight m^{-2} of Caffrey (1990) and the plant and biomass data of this research, several management procedures should be undertaken during the growing season to eliminate or reduce biomass to acceptable levels. Furthermore, many years of studies are needed to determine the real impact of these management techniques on biomass production and propagule depletion.

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ACKNOWLEDGEMENTS

This research was supported by CORFO Río Colorado Organization.
The authors want to thank the technicians Ricardo Haag and Ismael Verón for their assistance with the field work.