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INTRASPECIFIC NEIGHBOUR EFFECTS ON THE GROWTH AND MORPHOLOGICAL PLASTICITY OF *SALVINIA MOLESTA*

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Abstract: The tropical fresh water fern salvinia (*Salvinia molesta* D.S. Mitchell) is a problematic weed and is being controlled biologically by the introduction of a weevil, *Cyrtobagous salviniae*. The plant consists of three morphologically different growth forms; primary, secondary and tertiary, during its growth. The present paper describes how the initial density of primary stage plants affected its morphological plasticity. Primary stage apical cuttings consisting of three ramets (uniform in size) were selected and were grown at densities of 16, 400 and 800 ramets per square metre. The growth and morphological changes were observed for a period of 100 d. Plants remained at their primary stage under the lowest density and they transformed from primary to secondary and then to tertiary growth stages at higher densities. There were significant differences between the growth forms and their growth.

Key words: Intraspecific neighbour effect, *Salvinia.*

INTRODUCTION

A plant may show a change in its development pattern, during its life cycle, which may start with the germination of a seed, continuation with a juvenile phase which grows exponentially and transformation into maturity phase during which the plant is capable of changing from vegetative to reproductive phase producing flowers, fruits and the production of a new generation of seeds. This may be followed by a state of senescence.

As early as in 1889 Goebel[1] concluded that some plants show heteromorphism between the juvenile and mature phases. During this transition plants show distinctive morphology of leaves, stems and other structures, and also change in growth rate. In different plant species the duration of each growth form differs. In *Xanthium* sp. juvenile leaf forms may occur only on the first or first several nodes of the germinating seedling. Juvenile types of stem growth, leaf form and thorniness persist for four to ten years in *Citrus* spp..

A plant may regulate these changes as adaptations to different environmental conditions. The timing of the onset and emergence from dormancy of plants in temperate and arctic climates can also be considered as such adaptations.

The fern salvinia (*Salvinia molesta* D.S. Mitchell) which is an aquatic weed in tropical fresh waters also shows some morphological plasticity during its growth. The plant is sterile[2] and the entire species can be considered as a single genet without any genetic variations. Therefore the population dynamics depend on branching, growth and fragmentation. The plant consists of pairs of floating leaves, submerged root-like structures at each node along the stolon.

Room[3] has reported that there are three lateral buds in each alternate leaf axil, and the sequence of their development is from apical to first, to second and then to third rank. Under natural conditions, it is always the first rank bud that develops into a branch whereas the second and third rank buds develop in high nutrient conditions such as in sewage treatment lagoons. Reproductive structures consisting of an axis bearing sporocarps are produced among the root-like structures. The upper surface of the floating leaf is covered with multicellular papillae, on the apex of which there is an arrangement of four hairs that are united at their tips to form a bird - cage like structure. The rest of the surface of the plant is covered by uniseriate, multi-cellular, pointed hairs.

It has been observed by Mitchell[4] that there are three morphologically distinctive growth forms and they are produced in response to environmental conditions. When the plant is growing in deep shade or in rich nutrient conditions or is in the first stage of invasion of an area, it produces small leaves upto 1.5 cm in width. These leaves float flat on the water surface. Internodes are long and leaves do not overlap one another. Growth rate is very high and it is termed as the "primary-invading form". The leaves of the secondary growth form or "open-water-colonizing form" which is transitional between the first and third forms, are more than 2.0 cm in width, and become deeply keeled and boat-shaped and leaf undersurface still lying in contact with the water surface, and leaves do not overlap. The tertiary stage which is characteristic "mat form" bears sporocarps. Internodes are relatively shorter and the floating leaves are larger (upto 6.0 cm in width). The leaves are bilobed and conduplicately folded along the midrib and the leaves remain above the water surface.

The effect of immediate neighbours on plant growth has been observed by Darwin in 1859.[5] These neighbours may be intraspecific and interspecific.[6] Majority of the intraspecific neighbour effects (density effects) have been exercised with plants of single upright stems and the mortality and reduced size of surviving genets have been reported.[7-9]

But in clonally spreading plants density stress may affect more at the modular level than at the genet level. Reduced tiller numbers in grass, *Lolium perenne* L.,[10] and reduced node number and number of branches in *Trifolium repens* L.[11-13] under high densities have been reported.

The present paper describes the results of an experiment designed to study the effect of the initial density of plants of *Salvinia* on their growth with special reference to their morphological plasticity. Knowledge on the above aspects could be of great importance in controlling of *Salvinia*.

METHODS AND MATERIALS

Cement pond of 5x3x1m in the Botanical Garden of the Department of Botany, University of Kelaniya was filled upto 25 cm with mud brought from a water body where *Salvinia* was growing. It was then filled with water upto 90 cm in height and this level was maintained throughout the experiment by adding pond water whenever necessary. Therefore it was assumed that the nutrient levels in this pond maintained more close to natural pond water. Wooden frames (quadrats) of 25 x 25 cm were placed afloat.

Uniform (size) apical cuttings consisting of three nodes were selected from a healthy clone of *S. molesta* at its primary form. Each quadrat was allocated to one of the following three density treatments.

Treatment 1 (D_1 - Control) - 1 plant per quadrat (density = 16 plants/m^2), Treatment 2 (D_2) - 25 plants per quadrat (density = 400 plants/m^2), Treatment 3 (D_3) - 50 plants per quadrat (density = 800 plants/m^2).

The layout of the experiment was according to a completely randomized design. Three replicates from each treatment were harvested every five days upto 100 days. Number of leaves, number of nodes, number of branched nodes, mean internode length and the length of the main stolon, mean leaf length, mean leaf width, mean leaf area, total leaf area, and mean length of roots were measured for each plant in each frame. In treatments D_2 and D_3, ten plants were randomly selected for measurements. Plants were then washed carefully and shoots and roots were separated in each plant and were oven dried at 80^{0}C until a constant weight was recorded. The shoot/ root ratio was then calculated. The percentage of branching was also calculated.

The analysis of variance was done using MINITAB data analysis software package. Multiple comparison tests were carried out for the comparison between three treatments using Sheffe's method.[14] This experiment has been carried out thrice and the results were more or less similar and the present paper describes the results of the third experiment.

RESULTS

The single plants in treatment 1 (D_1 - Control) remained at their primary stage throughout the experimental study. Plants in the other two treatments (D_2 and D_3) remained at primary stage upto 25 days in all treatments and became secondary and finally after 45 days tertiary. However, there was no significant difference between D_2 and D_3 treatments . During primary stage, leaves were small and oval shaped and did not overlap one another. Boat shaped leaves were found during the secondary stage. During tertiary stage the leaves became large bilobed and folded along the midrib. Internode length became relatively short and the leaves overlapped one another. Sporocarps could be seen only in plants at tertiary stage.

Table 1 shows the overall means of number of leaves, nodes, branched nodes, branching percentage, mean internode length, length of the main stolon, mean leaf length, mean leaf width, mean leaf area, total leaf area, mean length of roots, dry weights of shoots, roots and whole plants, and shoot/root ratio per individual plant in each treatment.

Table 1: Comparison of the effect of initial density of ramets on morphological changes of *Salvinia molesta*.

Variable	D_1	D_2	D_3
Number of leaves	68.87±2.14[a]	30.73±1.43[b]	30.80±1.43[b]
Number of nodes	39.00±1.61[a]	17.60±1.08[b]	17.93±1.09b[b]
Number of branched nodes	4.52±0.55[a]	1.61±0.33[b]	1.53±0.32[b]
Percentage branching	12.94±0.93[a]	8.10±0.73[b]	6.83±0.67[c]
Mean internode length (cm)	1.19±0.28[a]	0.77±0.23[b]	0.77±0.23[b]
Length of the main stolon (cm)	11.97±0.89[a]	9.94±0.81[b]	9.70±0.80[b]
Mean leaf length (cm)	1.40±0.31[a]	1.47±0.31[a]	1.46±0.31[a]
Mean leaf width (cm)	1.25±0.30[a]	1.57±0.32[a]	1.67±0.33[a]
Mean leaf area (cm^2)	2.11±0.20[a]	3.15±0.53[b]	3.50±0.58[b]
Total leaf area (cm^2)	185.40±3.51[a]	136.22±3.01[a]	152.68±3.1[a]
Mean length of roots (cm)	4.10±0.52[a]	4.62±0.55[a]	5.24±0.60[a]
Dry weight of shoots (g)	0.19±0.11[a]	0.11±0.08[a]	0.14±0.10[a]
Dry weight of roots (g)	0.13±0.10[a]	0.06±0.06[a]	0.07±0.06[a]
Dry weight of whole plants (g)	0.31±0.14[a]	0.16±0.10[a]	0.21±0.12[a]
Shoot/root ratio	1.48±0.37[a]	1.91±0.35[a]	1.84±0.33[a]

Each value is an overall mean of all replicates at all harvests of each treatment. (D_1 = 16 plants / m^2 Control, D_2 = 400 plants / m^2, D_3 = 800 plants / m^2). Means ± SE sharing the same letter within each row do not differ significantly ($p<0.05$).

Control plants bore significantly highest number of leaves ($p<0.05$). In the other two treatments (D_2 and D_3), it has reduced by 55% (Table 1). However, number of leaves were more or less similar in all three treatments upto 40 days (Fig. 1a). During this period the leaf number has increased at the rate of 0.625 per day in the control plants. Thereafter, it has increased at the rate of 2.5 leaves per day. Plants at higher densities have increased their leaves at the rate of 0.6 per day upto 25 days (i.e. during their primary stage). Thereafter leaf number increased at the rate of 0.8 per day.

The number of nodes and branched nodes also showed a similar trend as with the number of leaves. The greatest number of branched nodes were found in control plants and it has significantly ($p<0.05$) decreased by 64% in the two density treatments (Table 1 & Fig. 1b). Branching percentage was also greatest in the control plants and it has reduced by 37% and 47% in the low density and high density treatments respectively.

Mean internode length was greatest in control plants whilst it has significantly ($p<0.05$) reduced by 35% in the two density treatments. Length of the main stolon also has reduced at higher densities. The reduction was 18% of the control.

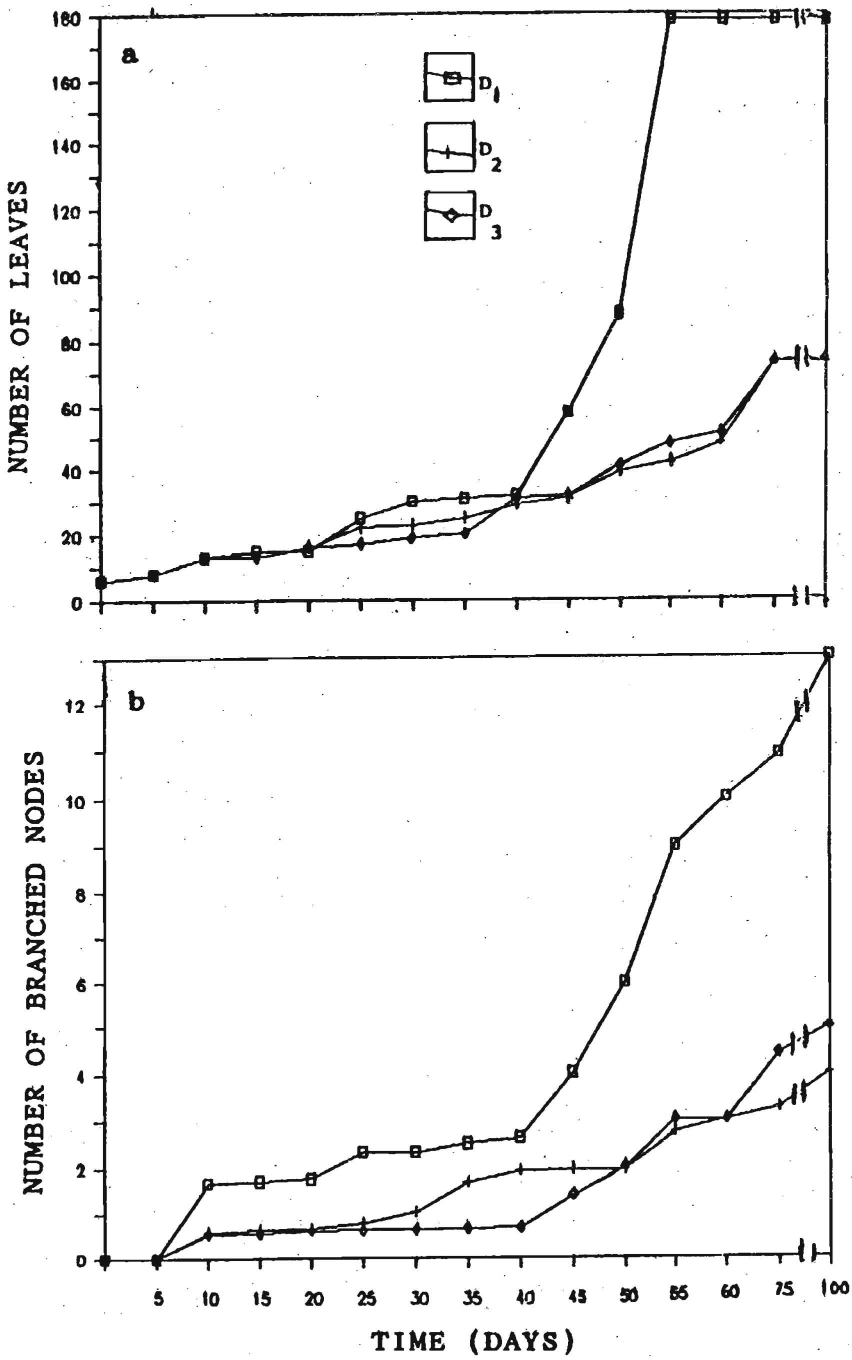

Figure 1: Comparison of number of leaves and number of branched nodes in each *Salvinia* plant grown under three different densities (D_1 = 16, D_2 = 400 and D_3 = 800 plants per square metre). a. Number of leaves, b. Number of branched nodes.

Mean leaf length and mean leaf width did not show any significant difference between treatments (Table 1). But the mean leaf area was significantly ($p<0.05$) smaller in control plants (i.e. plants of primary stage). However, the total leaf area per plant did not show any significant difference between treatments (Table 1). Mean length of roots, dry weights of shoots, roots and whole plants and shoot/root ratio also did not show any significant difference between treatments.

DISCUSSION

The results showed significant morphological and growth difference between the control and higher density treatments during the growth period. At lower densities plants remained at primary stage and at higher densities they transformed into secondary and then to tertiary stages. Eventhough there were no significant differences between the effects of the two selected densities (D_2 & D_3), if intermediate density treatments were also included in the present study, significant differences would have been observed between treatments.

The effect of density was to reduce the growth and branching of single plants and hence they are smaller in size. Branching adds new nodes which bear buds. Reduced growth could be attributed to reduced branching. Similar results have also been shown with other clonally spreading species.[10-13] Reduced branching was due to the inhibition of the development of axillary meristems. At primary stage Leaf Area Index (LAI) as estimated was 3.0 and they were 5.45 and 12.21 in D_2 and D_3 treatments respectively.

Thus, at higher densities bud sites may be naturally shaded by leaves of individuals,[15] whereas at lower densities, as the individual plants are spaced apart, the natural shading may have occurred to a lesser extent.[16,17] When there is natural shading, not only the quantity but also the quality of light may change. e.g. Red/Far red ratio is reduced as the red light is selectively absorbed by chlorophyll pigments present in leaf canopies. Reduced Red/Far red ratio also has shown to be inhibitory on the further development of axillary buds and hence reduced branching.[17]

Within water bodies, *Salvinia* plants are dispersed mainly by wind and water currents. It may provide a chance for plants to grow at low densities which again may increase their growth rate and branching percentage. Therefore, it would be economical if the Salvinia population can be prevented from dispersing during control efforts.

The influences exerted by *Salvinia* to the water bodies vary according to their growth stages. Plants remained at the primary stage at lower densities and at higher densities they became tertiary. Thus the primary stage, plants have fewer nodes, smaller leaves (hence smaller LAI) and roots per unit area of the water surface allowing more light penetration into the water. Smaller number of nodes implies smaller number of bud sites and hence less regeneration potential. On the other hand, the tertiary plants, form a very thick layer (about

1 m in depth) consisting of greater number of nodes, leaves and roots. Larger leaves and a higher number of roots reduce the amount of light penetration into the water, and this affects both flora and fauna in the medium. The potential regeneration is greater as they have a greater number of bud sites. The chance of regeneration of these buds may also be greater due to its greater initial capital than that in the primary stage. Thus the primary stage plants influence the water body at a minimum level in comparison to tertiary stage (The effects of secondary stage may lie intermediate between the primary and tertiary stages, but as it is a transitional stage only the two extreme stages are considered in the present discussion).

Therefore, it could be suggested that if this weed could be controlled during its primary stage, mechanically, at least in manageable water bodies, the result would be quicker, less problematic and less expensive than its control during its tertiary stage. If this form is allowed to grow longer, then they become tertiary which affects the waterbody more harmfully.

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