

Effects of *Neochetina eichhorniae* on the Growth of Waterhyacinth

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ABSTRACT

The effects of attack by the weevil *Neochetina eichhorniae* Warner on floating, anchored and rooted plant forms of waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) were studied in a glasshouse where conditions approximated field values as closely as possible. Insect attack reduced petiole diameter and leaf density of floating plants, and petiole length and standing crop of those which were rooted. Although there was a reduction in the standing crop of anchored plants during autumn and winter, this plant form showed greater overall tolerance to insect damage. This could have resulted from growth during spring and summer compensating for damage during other seasons. It was concluded that *N. eichhorniae* might contribute to the biological control of waterhyacinth in Australia by limiting the dispersal of floating plants and by suppressing growth in established infestations.

INTRODUCTION

Waterhyacinth was introduced into Australia about 1895 (1). Since then it has become a very serious weed of static and slow moving waters along the east coast south to latitude 34°, in the north near Darwin, in the west at Perth and inland at Moree (4, 8, 11). A number of chemical and mechanical control programs were initiated and while some have been measurably successful (8, 10, 11), the cost has often been high. As an alternative, a program of biological control was undertaken by the Division of Entomology, Commonwealth Scientific Industrial Research Organization of Australia in 1975. The weevil, *Neochetina eichhorniae*, which had previously been imported and established on waterhyacinth in the United States of America, was the first biological control organism to be introduced into Australia for this weed. *N. eichhorniae* lays most of its eggs in the tender central leaf just below the epidermis of the pseudolamina, and others are deposited in the fleshy sheath at the base of each petiole, in the petiole itself, or frequently in the feeding scars of the adults (7). The larvae enter the petioles and tunnel towards the crown of the plant where the late instar larvae feed before pupating amongst the submerged roots. Adults feed soon after emergence and make block-like feeding scars on the leaves (7). Three generations of *N. eichhorniae* per year have been observed in the field in Argentina (6) and in Australia.

Following extensive host-specificity studies, *N. eich-*

horniae was approved for release in Australia.¹ Although several authors (2, 3, 5, 12, 13) had concluded that this insect had the potential to control waterhyacinth, little was known of its relative effectiveness against the different forms of the weed. For these studies three forms were chosen: 1. short-leaved free-floating plants with bulbous, spongy petioles which usually occur at the open-water margin of infestations, 2. plants with taller, more slender petioles which occur in the densely packed mat and have only some of their roots firmly anchored in the mud, and 3. taller plants which grow near the shore-lines and have almost all their roots embedded in the mud. Although the relative abundance of these forms varies seasonally, damage to each would be desirable. Suppression of free-floating edge plants is particularly important as these can readily break away from mats and be carried by wind and water currents to infest new areas. During 1976 and 1977 a series of glasshouse experiments was carried out to examine the effects of a single insect generation, at different seasons of the year, on each of these plant forms.

MATERIALS AND METHODS

The following procedure was applied in each of four experiments. Standard-size insect-free plants of the forms described above were collected from the field. In the first form, which was designated 'floating,' each plant had five leaves with bulbous petioles 5 to 10 cm long. Plants of the second form, designated 'anchored,' were taller and had six leaves and straight petioles 10 to 15 cm long. The third form, 'rooted' plants, had six leaves and straight petioles of 15 to 20 cm long.

It was essential that plants maintained the same form throughout the experiments. This was achieved by growing large groups of each form separately in black, fibre-glass tubs 88.5 cm long, 65.6 cm wide and 35.0 cm deep (surface area 0.58 m²). Fifty floating plants were placed in each tub in water (30 cm deep) taken from the domestic supply and supplemented with micro-nutrients, iron and a mud filtrate. Forty anchored plants were planted in 15 cm of mud covered by 15 cm of water and forty rooted plants were planted in 15 cm of mud covered by 5 cm of water. The mud used as the source for the mud filtrate for the floating plants was taken from the lagoon where the plants originated. Water

¹Harley, K.L.S., 1975. Unpublished report, Division of Entomology, CSIRO, Long Pocket Laboratories, Indooroopilly, Brisbane, Australia.

levels were maintained by the addition of softened water. Mud and water were analysed at the start and the water at weekly intervals throughout each experiment.

An insect-proof cage 62.0 cm high was bolted on to each tub and the junctions sealed. These tubs were placed in a glasshouse where mean daily maximum and minimum temperatures were within $\pm 3\text{C}$ of those in a meteorological screen outside the building.

Weevils were reared in the same glasshouse in units similar to those used in the experiments and were considered to be acclimatised at the commencement of each experiment. Sexually mature adults were used for each study.

Plant number, total leaf number, number of leaves damaged by adults and the number of leaf petioles damaged by larvae were recorded at the commencement of each experiment and at 14 day intervals for three experiments and weekly for a fourth. In addition, immediately after one sampling occasion each month, four plants were harvested without bias. The leaves of these plants were categorised by the length of the petiole into four groups, 0 to 10 cm, 10 to 20 cm, 20 to 40 cm, 40 to 60 cm and from these, the mean petiole length calculated. For the floating plants, the maximum petiole diameter of each leaf was also measured and the leaves further assigned to sub-groups 0 to 1 cm, 1 to 2 cm, 2 to 3 cm, 3 to 4 cm, on the basis of these diameters. After recording these data the leaves and rhizomes of the harvested plants were dried to constant weight at 70 C. In this paper, standing crop is defined as the dry weight of leaf material 0.58 m².

Three experiments were designed to study the effects of *N. eichhorniae* on waterhyacinth. In a fourth experiment the potential of this weevil to damage floating plants during summer was further investigated. Experiments are designated by the season in which each commenced.

The 'Late Summer' terminated with emergence of the F₁ generation in early winter. Ten pairs of adult weevils were distributed over the plants in each of 3 replicates of each plant form. A fourth tub of each form was kept as insect-free control.

The 'Mid-Spring' experiment terminated with the F₁ emerging in late summer and the 'Mid-Autumn' with the F₁ emerging in late spring. Two tubs of each plant type were set up in each of these experiments. Ten pairs of adults were added to one tub of each type while the other was an insect-free control. Treatments were not replicated.

The fourth experiment, 'Mid-Summer,' terminated in mid-autumn when the F₁ generation emerged. Three tubs of floating plants were used, one was kept free of insects, four pairs of insects were added to the second and eight pairs to the third. Treatments were not replicated.

To obtain monthly means fortnightly recordings were averaged in the Late Summer, Mid-Spring and Mid-Autumn experiments and weekly recordings in the Mid-Summer.

RESULTS

The chemical composition of the water within or between treatments remained constant for the duration of any experiment.

The temperatures during the Late Summer (mean

maximum 32.6 C; mean minimum 19.0 C), Mid-Spring (mean maximum 33.6 C; mean minimum 17.2 C) and Mid-Summer experiments (mean maximum 33.0 C; mean minimum 19.1 C) were close to those most favourable for oviposition and larval development (7). By contrast in the Mid-Autumn experiment temperatures (mean maximum 29.4 C; minimum 15.6 C) were below optimum for oviposition and subsequent larval development was also slower.

Late Summer

The percentage of leaves attacked by adults increased rapidly during early autumn with significantly higher attack on floating and anchored plants than on rooted plants during the first two weeks (Figure 1a). By mid-autumn almost all leaves were damaged but the percentage damaged declined slightly as winter approached. Plant form had no significant effect on larval feeding and damage to the leaf petioles was similar for floating, anchored and rooted plants (Fig. 1b).

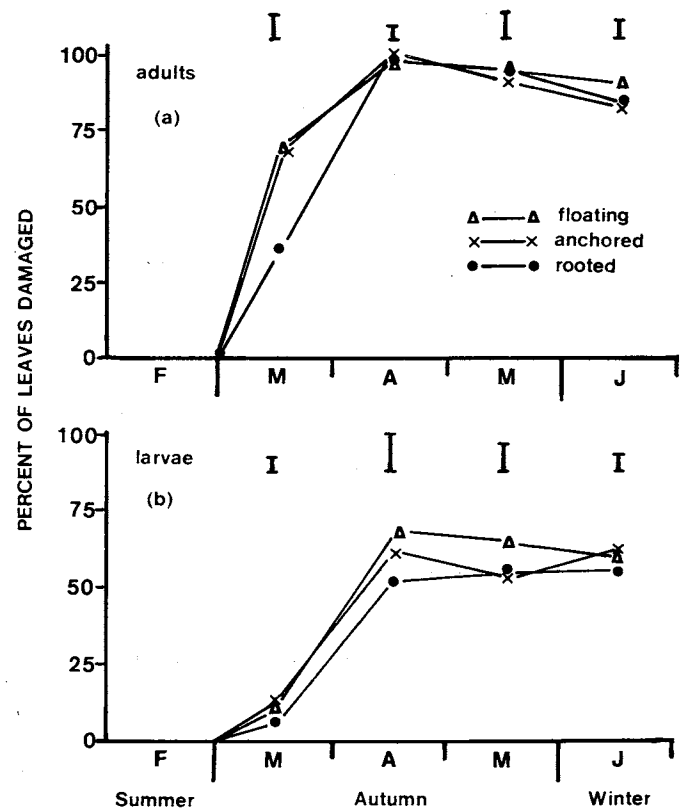


Figure 1. Percentage of waterhyacinth leaves damaged by adult *N. eichhorniae* during the Late Summer experiment. Vertical bars indicate LSD, $P < 0.05$.

The standing crop of floating control plants increased initially, whereas the standing crop of these being attacked by insects remained almost unchanged and was always less than the insect-free plants (Figure 2a). This difference appeared to be due to insect attack reducing the average petiole diameter (Figure 3a) which by June was less than half that of the insect-free plants. Also under insect attack, leaves had slightly longer petioles and there were fewer leaves per plant (Table 1). Rhizome dry weights increased

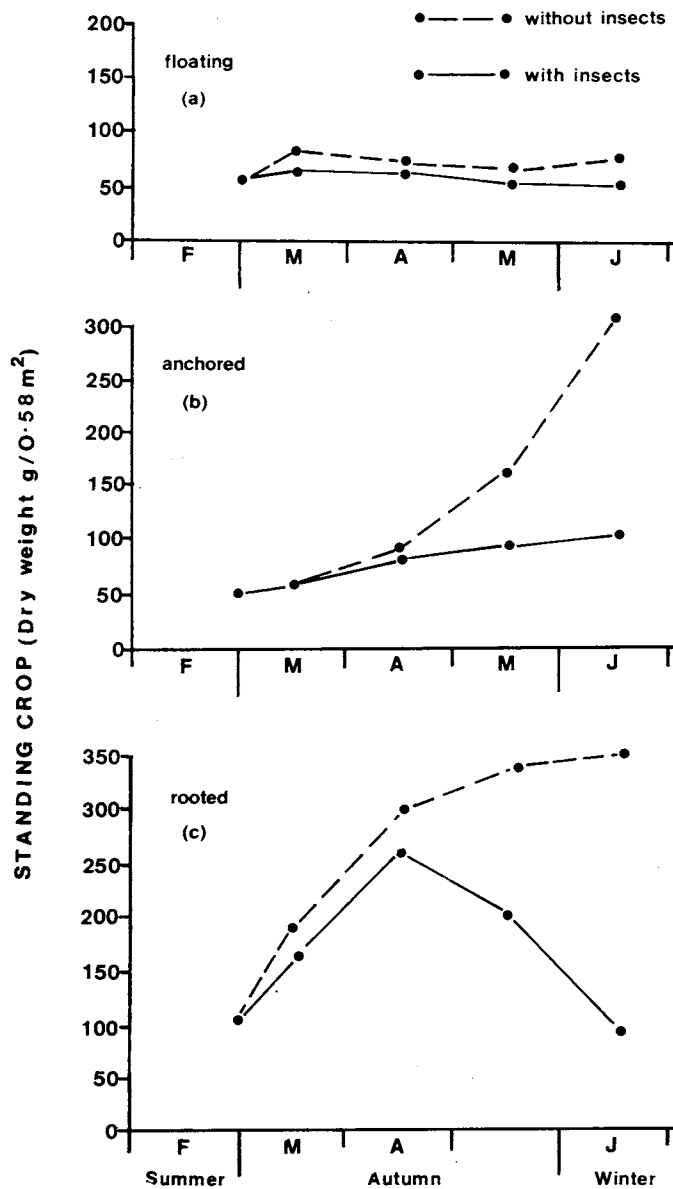


Figure 2. A comparison of changes in the standing crop of water hyacinth/0.58 m² in the Late Summer experiment when damaged by 10 pairs of *N. eichhorniae* and their larval progeny (replicated three times) and when not damaged by insects (replicated once).

in both treatments and were slightly higher in those with insects (Table 1).

Insect attack on anchored plants caused reductions in number of leaves/plant and the length of the petioles (Table 1). Rhizome dry weight again increased in both treatments but at the final harvest, plants free of insects had a rhizome weight more than twice that of the insect damaged plants (Table 1). The standing crop of control plants was still increasing rapidly when the experiment was terminated but plants under insect attack showed little increase following the decline in the relative growth rate, i.e. after mid-autumn (Figure 2b).

Whether insects were present or not, rooted plants grew rapidly during early autumn and the standing crop of those without insects approached in asymptote in winter (Figure 2c). However, under insect attack the standing crop declined

after mid-autumn, due to a reduction in the number of leaves/plant and petiole length (Table 1). Rhizome dry weights were considerably less in plants under insect attack (Table 1).

Mid-Spring and Mid-Autumn

When insects were introduced in mid-spring (October), the pattern of insect attack was similar to that of the Late Summer experiment for each of the three plant forms. Adults damaged all leaves throughout summer and the larvae damaged an average of 50 to 60% of the leaves.

With a mid-autumn start (April), the increase in attack by adults and larvae was much slower and though trends were similar to those in the Late Summer experiment, it was almost four months before all leaves were damaged by adult feeding. Levels of larval damage were generally much lower during this experiment than in those which commenced in late summer and spring. Only at the termination of this experiment, in spring, were damage levels on the floating and anchored plants comparable to those of the other experiments.

During spring and summer of the Mid-Spring experiment the pattern of change in the standing crop of floating plants was similar to that of the Late Summer experiment with the standing crop of insect-damaged plants always less than that of the insect-free plants. Petioles diameters (Figure 2b) and petiole lengths were not reduced by the weevil but there was a reduction in plant number and the number of leaves/plant which resulted in a reduction in the standing crop (Table 1).

In the Mid-Autumn experiment, insects did not reduce the standing crop of the floating plants during autumn and winter. However in spring, the standing crop of the insect-damaged plants declined because of reductions in plant number, petiole length (Table 1) and petiole diameter (Figure 3b). Rhizome weights increased in both treatments but whereas the increase was four-fold in undamaged plants, it was only 2.9 times in plants damaged by the weevil (Table 1).

During the period of active plant growth in spring and summer, the weevil caused little change in the standing crop of anchored plants. Petiole lengths and rhizome dry weights of the anchored plants were greater in treatments with insects and the average number of leaves/plant was less than that of insect-free plants (Table 1).

In the Mid-Autumn experiment the standing crop of anchored insect-damaged plants was initially higher than the standing crop of undamaged plants but by spring, plant number, petiole length, number of leaves/plant and the standing crop were all less than that of the insect-free plants (Table 1). A lower rhizome dry weight was recorded for the insect-damaged plants.

Standing crop of rooted plants in the Mid-Spring experiment initially increased but in treatments with insects this increase did not continue and there was a drastic decline at the beginning of summer. This decrease was due to the lesser number of leaves/plant, fewer plants and a reduction in petiole length (Table 1).

In the Mid-Autumn experiment the standing crop of

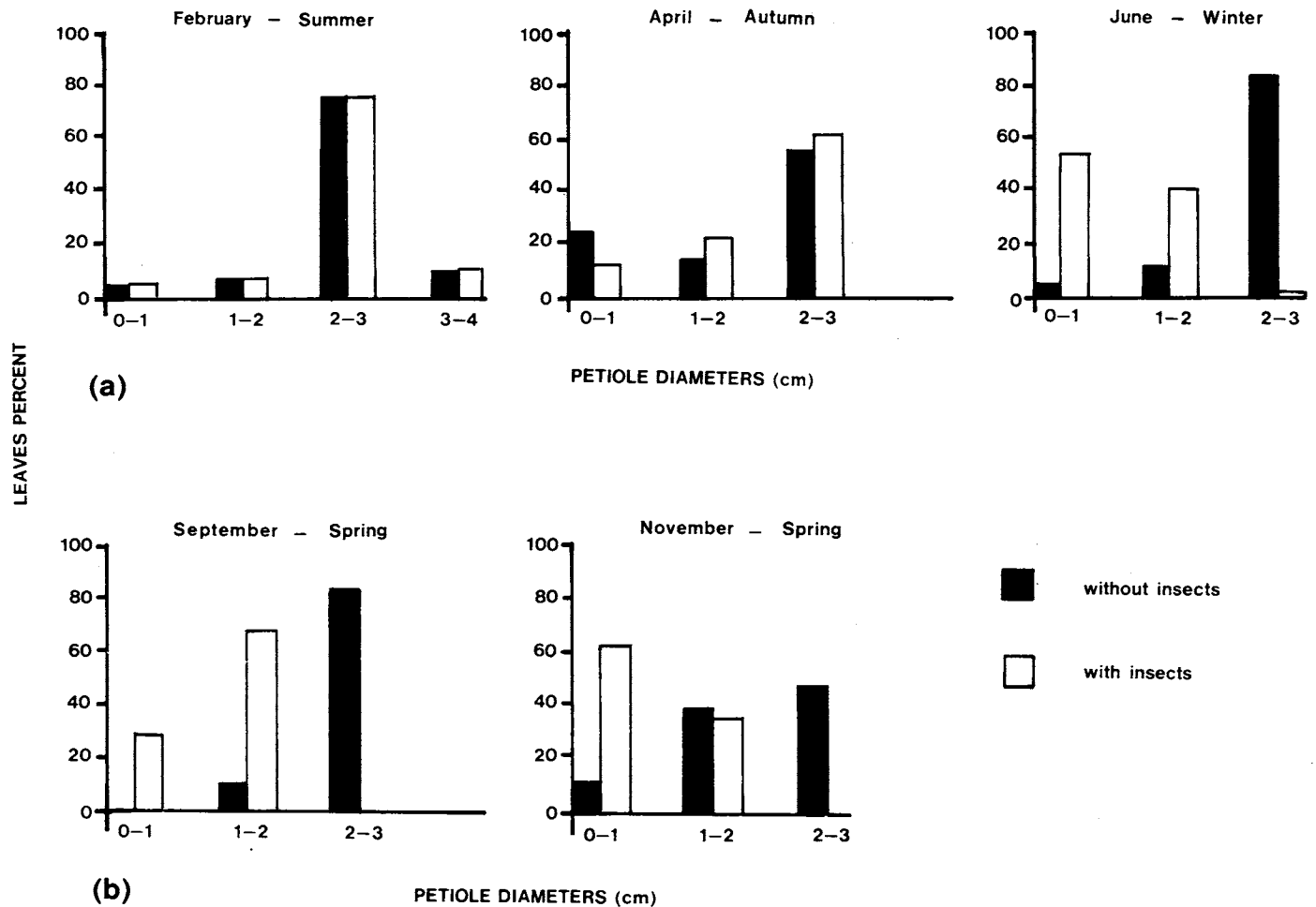


Figure 3. Changes in distribution, by petiole diameter, of leaves of floating waterhyacinth plants with and without insect attack. (a) Late Summer experiment, (b) Mid-Autumn experiment.

rooted plants increased in both treatments throughout autumn and winter but in the spring, only the standing crop of control plants increased. Petiole length and leaves/plant were reduced in the insect damaged plants (Table 1). The increase in the dry weight of the rhizome in the Mid-Spring experiment was less on the damaged plants. When insects were introduced in mid-autumn the final rhizome dry weight was only 23% that of the unfested plants and 63% of the initial weight (Table 1).

Mid-Summer

The trends in adult and larval damage for both insect densities were similar to those of the previous experiment with always fewer leaves being attacked at the lower density. Reductions in the petiole diameters caused by *N. eichhorniae* were also similar illustrating that small populations of adults and larvae can cause the loss of the bulbous float-leaf. When this experiment was terminated, the leaves and petioles of insect damaged plants were tough, the petioles spindly and they were longer than those of plants in the insect-free treatment (Table 1). Although there were fewer leaves/plant in both insect treatments, there were no reductions in the standing crops following insect attack.

Rhizome dry weights were similar in all treatments (Table 1).

DISCUSSION AND CONCLUSION

In these experiments, 10 pairs of adults and their larval progeny/ 0.58 m² reduced plant growth of floating, anchored and rooted plant forms within one insect generation. The level of damage varied with season and the duration of insect attack. This variation supported observations on the effects of season on plant tolerance to insect attack, which have been previously reported for other weeds (9).

Daily temperatures apparently influenced the rate of oviposition and larval development, particularly in the Mid-Autumn experiment where the mean maximum and minimum temperatures were less than those most favourable for oviposition (7). Adult and larval feeding in this experiment were less during autumn and winter and, although there was a delay before effects were apparent, plant growth was reduced by the following spring to levels similar to that in the other experiments. Usually if 15 to 20% of the leaves were damaged by larvae during winter and at least 50% in spring and summer, reductions in plant growth occurred.

TABLE 1. INITIAL AND FINAL VALUES FOR PLANT NUMBER, MEAN PETIOLE LENGTH, MEAN NUMBER LEAVES/PLANT, STANDING CROP AND RHIZOME DRY WEIGHT FOR FLOATING, ANCHORED AND ROOTED PLANTS IN EACH EXPERIMENT. TREATMENT NUMBERS REPRESENT THE NUMBER OF ADULT PAIRS OF *N. eichhorniae* PRESENT AT THE COMMENCEMENT OF EACH EXPERIMENT.

Season Initiated	Period of Experiment	Treatment	No./0.58m ²			Petiole length (cm)			Leaves/plant			Standing crop/0.58m ² (g)			Rhizome dry wt./0.58m ² (g)		
			float	anchor	root	float	anchor	root	float	anchor	root	float	anchor	root	float	anchor	root
Late Summer	Feb	0	50	40	40	5.5	10.0	20.0	5.0	6.0	6.0	50.3	55.0	106.6	12.0	16.0	50.0
		10	50	40	40	5.5	10.0	20.0	5.0	6.0	6.0	50.3	55.0	106.6	12.0	16.0	50.0
	June	0	39	42	49	5.1	11.7	24.5	8.3	7.4	7.0	77.9	304.6	353.4	21.5	103.4	182.2
		10	38	41	46	6.6	8.7	16.0	6.1	4.7	6.4	49.4	100.9	97.7	25.7	41.4	108.9
Mid-Spring	Oct	0	50	40	40	5.5	10.0	20.1	5.0	6.0	6.0	70.0	92.0	176.0	15.0	20.0	55.5
		10	50	40	40	5.5	10.0	20.1	5.0	6.0	6.0	70.0	92.0	176.0	15.0	20.0	55.5
	Feb	0	37	30	30	5.2	30.8	39.4	9.9	10.0	10.2	55.1	201.0	337.5	18.3	64.8	90.0
		10	28	32	25	5.5	32.1	24.4	7.2	7.4	5.5	24.6	263.0	118.0	13.4	67.6	69.1
Mid-Autumn	Mar	0	50	40	40	5.0	15.0	17.5	5.0	6.0	6.0	50.0	75.0	160.0	10.0	15.0	40.0
		10	50	40	40	5.0	15.0	17.5	5.0	6.0	6.0	50.0	75.0	160.0	10.0	15.0	40.0
	Nov	0	80	98	86	6.7	8.0	10.5	8.8	8.1	7.7	94.8	176.4	298.8	40.0	60.5	109.2
		10	64	71	100	3.0	6.0	7.8	7.0	7.3	5.0	52.2	58.8	200.0	29.4	44.7	25.0
Mid-Summer	Jan	0	50			5.0			5.0			68.8			13.7		
		4	50			5.0			5.0			68.8			13.7		
		8	50			5.0			5.0			68.8			13.7		
	Mar	0	42			5.0			9.5			46.8			35.7		
		4	41			9.7			8.1			60.9			37.0		
		8	42			6.3			7.8			50.9			36.0		

Of the 3 plant forms, anchored plants compensated most effectively for insect damage, particularly in summer when the rhizome dry weight and the standing crop were similar to those of control plants. In other seasons growth of anchored plants was suppressed and leaf density and length reduced.

The growth of rooted plants was reduced by insect attack during all seasons. In addition, insect attack may have reduced growth in winter by depleting rhizome reserves at a time when the plant apparently draws upon these to compensate for environmental stress due to low temperatures. Therefore this weevil could complement the effect of the environment during winter. Subsequent field observations in Australia support this view (Wright, pers. comm.).

When floating plants were attacked by the weevil, the number of leaves/plant and the petiole diameter were reduced in almost all seasons. Plants attacked by insects did not show the normal vigorous growth typical of floating plants during summer, and reduction in the amount of spongy mesophyll associated with the smaller diameter of the petioles caused several plants to sink. The reduction in the buoyancy and vigor of the plants could reduce the dispersal of bulbous floating plants by wind or water currents.

These studies indicated, and subsequent field studies have confirmed (14), that *N. eichhorniae* will assist the control of waterhyacinth in Australia by reducing plant growth.

ACKNOWLEDGMENT

I gratefully acknowledge the assistance of Drs. R. D. Hughes and P. R. Room, in the preparation of the manuscript and Mr. A. D. Wright for technical assistance.

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