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Integrated Control of Waterhyacinth with *Neochetina* and Paclobutrazol[1]

THAI K. VAN[2]

ABSTRACT

A study was conducted in outdoor pools to determine the potential of *Neochetina eichhorniae* Warner, an introduced weevil species from Argentina, in combination with the growth retardant paclobutrazol [1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl)pentan-3-ol] for control of waterhyacinth, *Eichhornia crassipes* (Mart.) Solms. A single application of 1.1 kg ai/ha paclobutrazol alone was sufficient to sustain growth retarding effects (52% decline in standing crop) over the 8-month study period from December 1983 to August 1984. Weevils alone caused a 24% decline in plant growth; however the pools were still fully covered with waterhyacinths after the 8 months. The combination of weevils and growth retardant was most effective, providing 95% reduction in standing crop within the study period. The results indicated a synergistic effect of integrating the two control agents. The retardant paclobutrazol reduced considerably plant size and standing crop causing proportionally greater weevil effects.

Key words: Biological control, weevils, growth retardant, *Eichhornia crassipes.*

INTRODUCTION

Waterhyacinth [*Eichhornia crassipes* (Mart.) Solms] is a serious aquatic weed in the southeastern United States, and many other areas. Two weevils, *Neochetina eichhorniae* Warner and *N. bruchi* Hustache, were imported in the early 1970's from Argentina for release as biological control agents of waterhyacinth. The weevils are now well established throughout the range of waterhyacinth infestations (Center, 1982), and may already have contributed to the gradual decline of this weed problem in the U.S. over the past decade (Theriot, 1982). However, the effects of weevil damage are often not rapid enough for practical control purposes, and most waterhyacinth infestations still require constant management using herbicide applications. The problem is that weevil populations increase at a much slower rate compared to plant growth rate (Center *et al.*, 1982). As a consequence, population densities of waterhyacinth weevils at many field sites remain too low to provide effective control (Haag, 1986). Recently, attempts have been made, with some success, to increase the insect-to-plant ratio by reducing the plant population through limited herbicide application (Haag, 1986). Alternatively, Center *et al.* (1982) investigated the use of a growth retardant (EL-509) to reduce plant growth, thereby allowing time for populations of waterhyacinth weevils to build up and sustain control. These authors reported that the weevils were more effective when used in combination with the growth retardant treatment; however, the interaction between the two control agent was unclear, probably due to the lack of long-term growth regulation by the retardant used.

Paclobutrazol[3] is a new plant growth retardant that appears to interfere with the biosynthesis of gibberellins (Shanks, 1980). The compound inhibits internode elongation, reduces leaf enlargement, and suppresses vegetative growth of a number of plant species (Davis *et al.*, 1986). Paclobutrazol activity has been shown to be persistent, and effective growth retardation usually continues beyond the year of treatment (Williams, 1984). Preliminary results from a greenhouse experiment also indicated that treatments of waterhyacinth with paclobutrazol resulted in long-term growth suppression which lasted more than 6 months (Van, unpublished data). This study was undertaken to evaluate the potential synergistic effects from combination treatments of waterhyacinth weevils and paclobutrazol.

MATERIAL AND METHODS

During August of 1983, waterhyacinth plants were collected locally and established in outdoor pools located on the grounds of the Fort Lauderdale Research and Education Center, University of Florida, Institute of Food and Agricultural Sciences, in Fort Lauderdale. Plants were grown in 12 circular pools (3.0 m diam and 0.6 m deep) with a surface area of 7.3×10^{-4} ha and filled with pondwater. A commercial water-soluble fertilizer (N:P:K, 20:20:20) and a chelated iron powder (10% Fe) were added to the water to yield 5 mg/l N and 1 mg/l Fe. Fertilization was repeated once every month, and pondwater was added to replace that which was lost through evapotranspiration. Plants were allowed to grow for 2 months before being used in the study, forming a dense canopy completely covering the pools.

Individual weevil-by-retardant combination treatment levels were applied in a completely randomized design as a 2 X 2 factorial. Each treatment was replicated three times. The high density weevil treatment represented nat-

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[2]Plant physiologist, ARS, U.S. Department of Agriculture, Ft. Lauderdale, FL 33314.

[3]Mention of a trademark name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the U.S. Department of Agriculture or the University of Florida, and does not imply its approval to the exclusion of other products that also may be suitable.

ural infestation by the well established weevil population in and around the Fort Lauderdale area (Center and Durden, 1986). Weevil feeding damage was evident in the high weevil treatment throughout the study period. Furthermore, we observed that most of the weevils (99%) were *N. eichhorniae,* so species was not an important variable. The low density weevil treatment was accomplished by spraying the plants once every week with an insecticide mixture (0.4% v/v malathion in water). The weekly insecticide spray was begun in October and continued throughout the study. Previous experiments indicated that this procedure resulted in waterhyacinth plants with a minimal weevil infestation within 2 to 3 months following the first malathion spray.

On December 19, the growth retardant paclobutrazol was applied over the plant foliage in half of the culture containers at a rate equivalent to 1.1 kg ai/ha. The retardant formulation was made in pondwater, and applied in a spray volume equivalent to 935 l/ha using a compressed gas sprayer equipped with a single-nozzle handgun. A nonionic surfactant [X-77 (alkylarylpolyoxyethylene glycol, fatty acids, and isopropanol)] was added to the spray mixture at a concentration of 0.25% v/v.

The experiment was discontinued on August 15, 1984. A square frame measuring 50 cm by 50 cm (0.25 m^2) was randomly placed into the plant mat of each pool. Ten shoots within the frame were randomly selected for measurement of plant height, root length, and leaf parameters. Leaf measurements were made using third nodal position leaves (usually the youngest mature leaf). The total number of shoots per sample was then counted, and the plant material was dried at 70 C to constant weight to estimate plant density and standing crop for each pool.

Weevil damage to the ten shoots subsampled from each square frame was also assessed. The number of adult weevils per plant was counted, and the proportional lamina area eaten was estimated from the third nodal position leaves. Similarly, the number of larvae per plant was counted, and the proportional tissue damage due to larval feeding was determined.

Data were analyzed as two-way analyses of variance with interaction (SAS Institute Inc., 1985). The crossed-factor interaction term was tested for possible synergism of weevils and retardant on various plant growth responses.

Table 1. Insect population densities and feeding damage on waterhyacinth 8 months after treatment with different combinations of weevils (W) and paclobutrazol (R) from 19 Dec 1983 to Aug 1984.[1]

Weevil density[2]	Paclobutrazol (Kg/ha)	Adults (No./plant)	Adult feeding damage (%)	Larvae (No./plant)	Larval feeding damage (%)
Low	0	0.5 bc	3.2 b	0.03 c	1.4 c
	1.1	0.1 c	4.1 b	0 c	1.3 c
High	0	1.7 ab	29.5 a	1.4 b	20.3 b
	1.1	2.5 a	42.7 a	3.0 a	33.3 a
Analysis of Variance		Calculated F values (Prob. > F)			
W		14.3 (.0003)	185.7 (.0001)	47.5 (.0001)	314.5 (.0001)
R		1.6 (.2024)	0.6 (.4607)	6.3 (.0134)	20.2 (.0001)
W*R		0.2 (.6699)	0.2 (.6807)	6.9 (.0101)	20.8 (.0001)

[1]Mean values followed by the same letter within each column do not differ significantly at P = 0.05 as determined by the Waller-Duncan Test.
[2]The high weevil density treatment represented natural population of *Neochetina* spp. in Ft. Lauderdale, Florida. The low weevil density treatment was maintained with weekly applications of insecticide.

RESULTS AND DISCUSSION

The weekly insecticide sprays effectively excluded weevils from the waterhyacinth plants (Table 1). These plants were large, robust, and healthy with little apparent weevil damage when the insecticide was used. The population of larvae was barely detectable and feeding damage by both adults and larvae was typically less than 5%. In the absence of insecticide, however, natural occurrences of *N. eichhorniae* caused feeding damage ranging from 20 to 30%. Paclobutrazol appeared to have no negative impact on the adult weevil populations, while significantly higher larval densities and feeding were observed in the retardant treatment (Table 1).

The effect of different combination treatments of weevils and retardant on growth of waterhyacinth is presented in Table 2. The retardant alone, at 1.1 kg ai/ha paclobutrazol, was effective in limiting vegetative growth of waterhyacinth over the entire 8-month study period. The observed growth effects were generally similar to those reported for a number of other plant species (Davis *et al.,* 1986). Treatment of waterhyacinth with paclobutrazol caused 72% reduction in plant height compared to controls. In addition, root length and leaf area were reduced by 41% and 50%, respectively; however, leaf petiole was doubled in diameter. As a result, plants treated with the retardant had a bulbous growth form even in a dense plant canopy. Internodal elongation also was severely inhibited, resulting in very short stolons between the newly formed ramets. This resulted in several small and crowded ramets tightly packed around the parent rosette. Standing crop of the retardant treatment was reduced 52% after 8 months, despite an almost three-fold increase in plant density due to much smaller individual plant size (Table 2). The pools remained fully covered with smaller but much more densely packed waterhyacinth plants.

Weevils alone caused a slight decrease in the plant growth rate. Insect damage was evident on most leaves, imposing a constant stress on the plant, and causing an overall reduction in plant height, leaf area, and petiole diameter. After 8 months, the standing crop in the weevil treatment declined by 24% mainly because of a reduction of the size of the plant (Table 2). Plant density and coverage remained unchanged, however, and control of waterhyacinth was not achieved after the 8 months. Center (1982) observed that biological control of waterhyacinth using weevils could be very effective but required an extended period of time.

Plants treated with a combination of weevils and retardant were much more severely affected than plants treated with either weevils or retardant alone (Table 2). They were

TABLE 2. EFFECTS OF COMBINATIONS OF WEEVILS (W) AND PACLOBUTRAZOL (R) ON GROWTH OF WATERHYACINTH 8 MONTHS AFTER THE RETARDANT TREATMENT.[1]

Weevil density	Paclobutrazol (Kg/ha)	Plant height (cm)	Root length (cm)	Petiole diameter (cm)	Lamina area (cm^2)	Plant density (No. plant/m^2)	Standing crop (Kg/m^2)	Individual plant wt (g/plant)
Low	0	37.5 a	52.9 a	1.2 c	39.6 a	129.3 b	2.84 a	21.9 a
	1.1	10.5 c	31.9 b	2.4 a	20.5 b	320.0 a	1.36 c	4.4 c
High	0	30.6 b	56.0 a	0.8 d	24.8 b	148.0 b	2.17 b	14.6 b
	1.1	3.7 d	7.7 c	1.6 b	6.4 c	36.0 c	0.13 d	3.5 c
Analysis of Variance		Calculated F values (Prob. > F)						
W		36.7 (.0001)	24.0 (.0001)	58.3 (.0001)	62.3 (.0001)	21.6 (.0036)	8.3 (.0278)	1.6 (.2558)
R		576.4 (.0001)	258.0 (.0001)	117.8 (.0001)	104.2 (.0001)	47.4 (.0005)	193.3 (.0001)	630.0 (.0001)
W*R		0.1 (.9824)	40.1 (.0001)	4.2 (.0438)	0.1 (.8338)	19.4 (.0045)	38.4 (.0008)	78.8 (.0001)

[1]Mean values followed by the same letter within each column do not differ significantly at P=0.05 as determined by the Waller-Duncan Test.

extremely small and showed extensive damage from heavy weevil feeding. Adult weevils destroyed almost half of the lamina area. Petiole bases became necrotic and waterlogged due to larval tunneling, and were severed from the stem. Plants treated with both weevils and retardant died, decayed, and sank, leading to open water in the treated pools 8 months after the retardant was applied. Data analysis showed that the crossed-factor interaction was significant for many of the observed growth responses, indicating a weevil-retardant synergism from integrating these two control agents (Table 2). Weevils were significantly more effective when used in combination with the retardant. The retardant suppressed vegetative growth, reduced plant biomass, and thus improved the insect-to-plant ratio. Furthermore, this reduction in biomass by paclobutrazol was achieved with no apparent decline in food quality and palatability of the waterhyacinth tissue. There were no signs of phytotoxicity following paclobutrazol treatment. In fact, the retardant-treated plants became characteristically darker green than controls. Increased leaf chlorophyll contents and delayed leaf senescence (chlorophyll loss) were observed in waterhyacinth following paclobutrazol treatment (data not presented). Also, other studies with several different plant species have indicated that leaf carbohydrates and mineral contents were unchanged or slightly increased after paclobutrazol treatment (Davis *et al.*, 1986).

Plant size is related to ability to withstand herbivore attack (Krischick and Denno, 1983). Reduction in plant size or prevention of growth to larger size thus appears to enhance efficacy of herbivores as biocontrol agents. In this regard, paclobutrazol reduced individual plant weight by 80% while increasing plant density about three fold (Table 2). The number of insects per plant was relatively unaffected, however (Table 1). This resulted in a considerable increase in the ratio of insect mass to plant mass, thus causing proportionally greater weevil effects. Furthermore, because the retardant-treated plants were smaller in size and tightly packed, it was conceivable that one larva could have moved around and damaged several plants before completing its life cycle.

In summary, results from this study indicated that weevils were more effective when used in combination with the growth retardant paclobutrazol. A combination of these two control agents provided 95% reduction in biomass of waterhyacinth after 8 months in outdoor pools. A larger scale study is required to evaluate this integrated control approach in the field.

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