PROC. V INT. SYMP. BIOL. CONTR. WEEDS, BRISBANE, AUSTRALIA, 1980: 367–73

RELEASE OF *TUCUMANIA TAPIACOLA* (LEPIDOPTERA:PYRALIDAE) IN SOUTH AFRICA AGAINST *OPUNTIA AURANTIACA*: THE VALUE OF DETAILED MONITORING

J.H. Hoffmann[1]

ABSTRACT

Two aspects of this release have been monitored in detail: (i) egg mortality in the field and the role of predators; (ii) the efficiency of larvae in penetrating and colonizing jointed cactus plants in different habitats. Also, the fate of pupae has been determined for the construction of life-tables. These results are being used to plan future releases and to evaluate the potential of this moth as a biological control agent.

INTRODUCTION

The success of most biological weed control projects is measured by the amount of weed destroyed after release of a biological control agent. Seldom has any quantitative study been made, in the case of weeds, to determine factors affecting the establishment and progress of newly introduced natural enemies. This is especially true for species that fail to establish or that remain at low population levels after release (Goeden and Louda 1976).

The pyralid moth, *Tucumania tapiacola* Dyar, was first released in South Africa on 10 May 1976 for the biological control of jointed cactus, *Opuntia aurantiaca* Lindley (Moran and Annecke 1979). The moth has been established for at least two years but has not yet had a noticeable impact on the weed. This paper summarizes the results of a study designed to identify and quantify the various mortality factors affecting *T. tapiacola* in South Africa. A partial life table has been constructed that has been used to plan releases of the moth and to predict its potential as a control agent.

LIFE HISTORY OF *T. TAPIACOLA*

Each *T. tapiacola* female lays an average of 309 eggs which are attached singly to thorns on *O. aurantiaca* plants. The eggs hatch after five to twenty days and most newly hatched larvae move down the plant to a point near the soil at the base of the stem. The larva spins a loose silk structure which it uses as a brace to force its mouthparts into the epidermis and penetrate the plant (Hoffmann and Moran 1977). The solitary larva feeds internally but is able to move from one plant or cladode to another should the host become unsuitable for development. Pupation may occur within the dry husk of a destroyed cladode, but most larvae excavate and pupate in tunnels up to five centimetres below the soil. In summer, adults emerge two to three months after egg hatch with a sex ratio of 1:1. Development is much slower in overwintering larvae (Mann 1969).

METHODS

Laboratory reared *T. tapiacola* eggs on thorns, newly hatched larvae, and mature larvae in joints were placed onto different size *O. aurantiaca* plants at

[1] Plant Protection Research Institute, c/o Department of Zoology and Entomology, Rhodes University, Grahamstown, 6140, South Africa.

various localities in the field, or in a greenhouse. Usually, jointed cactus grows in direct sunlight in the open veld and in this habitat three size categories were recognized: small plants with one to four joints, medium plants with five to ten joints and large plants with more than ten joints. Etiolated plants growing in the shade were grouped together in a fourth category.

For some experiments, ant and mite predators were excluded by surrounding plants with a ring of Gamma BHC powder. Alternatively, potted plants standing on trays covered with Gamma BHC were placed in the field. Some of the experimental plants were sheltered from rain with glass sheets. The effect of predators and rain on all the immature stages was measured by comparing mortality on experimental and on control plants.

RESULTS

Egg mortality (Table 1)

In the laboratory, 13 per cent of *T. tapiacola* eggs were infertile or failed to hatch. In the field, even when the eggs were protected from rain and predators, mortality was higher (20.3 per cent) than in the laboratory. Rain, and especially heavy storms, increased field mortality of eggs by dislodging them from the thorns and no larval penetrations were recorded from these dislodged eggs.

Table 1. Percentage mortality of *Tucumania tapiacola* eggs on thorns of *Opuntia aurantiaca* plants in the field and in the laboratory.

Field conditions	Per cent mortality	*n*
Protected from predators in sun		
No rain	20.3	360
Light rain (< 6mm/hour)	33.0	300
Heavy rain (> 20mm/hour)	61.7	60
Exposed to predators in sun		
No rain	88.9	90
Light rain	82.3	2577
Heavy rain	?	–
Exposed to predators in shade		
No rain	71.1	90
Light rain	76.8	750
Heavy rain	?	–
In Laboratory	13.0	200

Nine species of ants, *Monomorium albopilosum, Monomorium delagoensis, Tetramorium laevithorax, Tetramorium quadrispinosum, Technomyrmex albipes, Pheidole megacephala, Camponotus rufoglaucus, Acantholepis capensis* and *Acantholepis* sp. removed most eggs from the thorns and an undetermined mite species pierced eggs leaving the shrivelled shells on the thorns. These predators killed a greater percentage of eggs on plants growing in the sun compared to eggs on etiolated plants growing in the shade.

Larval penetration (Table 2)

Plant size influenced the success of penetration by first instar larvae of *T. tapiacola* on *O. aurantiaca*. Percentage penetration was highest on the small plants and on etiolated plants. Fewest larvae penetrated the tough stems of plants with more than ten joints. Predators reduced the percentage larval penetration on all categories of plants.

Table 2. Percentage penetration by first instar larvae of *Tucumania tapiacola*, into plants of *Opuntia aurantiaca* of different size categories, with and without predators.

	Percentage larval penetration into plants with			
	1 to 4 joints	5 to 10 joints	>10 joints	Etiolated joints
Predators excluded	70.0	40.0	20.0	57.5
(*n*)	(40)	(40)	(40)	(40)
Exposed to predators	39.7	34.8	11.3	42.5
(*n*)	(131)	(66)	(79)	(120)

Larval mortality (Table 3)

Once inside the cactus, developing larvae are protected from predators. However, gum secretions from large plants caused high mortality of larvae (up to 53.4 per cent). Most larvae starved in small and etiolated plants and many larvae died or disappeared for unknown reasons in all plant categories. Total larval mortality during development ranged from 64.5 per cent in small plants to 82.4 per cent in large plants.

Table 3. Percentage mortality of *Tucumania tapiacola* larvae during development in *Opuntia aurantiaca* plants of different size categories.

	Percentage larval penetration into plants with			
Cause of mortality	1 to 4 joints	5 to 10 joints	>10 joints	Etiolated joints
Gum	6.6	53.4	41.2	0.0
Starvation	35.5	1.7	5.9	57.9
Other	22.4	13.8	35.3	17.5
Total	64.5	69.0	82.4	75.4
(*n*)	(76)	(58)	(17)	(57)

Pupal mortality (Table 4)

Two indigenous parasitoids, *Invreia* sp. and *Hockeria* sp. (both Chalcididae), and an ant predator, *Oligomyrmex* sp., occasionally attack *T. tapiacola* pupae in the field. A small proportion of pupae failed to produce adults for other undetermined reasons. Overall pupal mortality, even in exposed situations was low (<20 per cent), and the pupae seem to be well protected in the soil.

Table 4. Percentage mortality of *Tucumania tapiacola* pupae in exposed (sun) and sheltered (shade) situations.

Cause of mortality	Percentage pupal mortality in Sun	Shade
Parasitoids	4.6	0.0
Predators	6.6	5.7
Other	8.6	2.9
Total	19.8	8.6
(*n*)	(151)	(35)

A partial life-table (Table 5)

The partial life table for *T. tapiacola* summarizes mortality from egg to adult emergence on the four categories of *O. aurantiaca* plants. Adult mortality is not included. Mortality was greatest (99.7 per cent) on large plants, indicating that these plants are least suitable for colonization by *T. tapiacola*. The average mortality on the other three plant categories was 98 per cent and ranged from 97.7 per cent on small and etiolated plants to 98.4 per cent on medium sized plants.

Table 5. A partial life table for *Tucumania tapiacola* on different size categories of *Opuntia aurantiaca* plants based on average fecundity of 309 eggs per female moth.

Stage	Numbers entering each stage on plants with 1 to 4 joints	5 to 10 joints	>10 joints	Etiolated joints
Eggs	309	309	309	309
Larvae	55	55	55	72
Penetration	22	19	6	31
Pupae	8	6	1	8
Emergent adults	7	5	1	7
Total mortality (egg to emergent adult)	97.7%	98.4%	99.7%	97.7%

DISCUSSION

Population changes of *T. tapiacola* after releases on *O. aurantiaca* in the field can be predicted using a simple model (May *et al.* 1974)

$$N_{t+1} = \lambda N_t$$

where N_{t+1} and N_t are population numbers in successive generations and λ is the net rate of increase from generation to generation. In this case

$$\lambda = \frac{AFJ}{2 \times 10^4}$$

where A is the percentage survival of adults (half of which are females), F is the average female fecundity (309 for *T. tapiacola*) and J is the average percentage survival of all the immature stages (2 per cent, calculated from Table 5). The percentage adult survival (A) has not been measured during this study and must therefore be given an assumed value in the model. Also, survival of both adults and immature stages has been assumed to be density independent because *T. tapiacola* has been recently introduced, is still dispersing at low population levels, and is not yet limited by resources or competition.

Based on the data in Table 5, a typical release of 10 000 *T. tapiacola* larvae (R in Figure 1) would result in 1044 adults (522 females) in the first field generation. If adult survival in the first and each subsequent generation is above 32 per cent, λ will be greater than one and the population will increase from generation to generation (Figure 1). When adult survival equals 32 per cent per generation λ will equal one and there will be zero population change (Z.P.C.). If adult survival drops below 32 per cent, λ will be less than one and the popullation will decrease from generation to generation.

The model indicates that, even with a mortality of 98 per cent in the immature stages, compounded by a survival of only 45 per cent for the adults, *T. tapiacola* populations could increase rapidly within ten generations (about five years). *T. tapiacola* was first released in South Africa about four years ago and there is no indication yet of any population increase. This suggests that an adult survival rate of 45 per cent is probably unrealistically high. Figure 1 shows that with a 35 per cent adult mortality, there may be a delay of thirty-five to forty generations before there are noticeable increases in numbers of *T. tapiacola* in the field. Taking a more pessimistic view of Figure 1, and assuming an adult survival of only 25 per cent, the *T. tapiacola* population could well be on the decline towards extinction.

T. tapiacola was released in Australia in 1935 (Mann 1969) and the moth remained at low population levels for forty-four years until 1979, when numerous larvae were found attacking *O. aurantiaca* near Ravensworth, New South Wales (J.R.Hosking pers. comm. to H.G. Zimmermann). This may suggest that an adult survival of between 32 and 35 per cent could be expected from *T. tapiacola* in South Africa.

This model is clearly an oversimplification of complexities in the field. However, it does stress that in spite of very high mortalities in all stages of the life cycle, *T. tapiacola* can survive and eventually increase, and that biological control agents should not be rejected and hope abandoned on the basis of what may appear to be, at first sight, unacceptably high mortalities in the field.

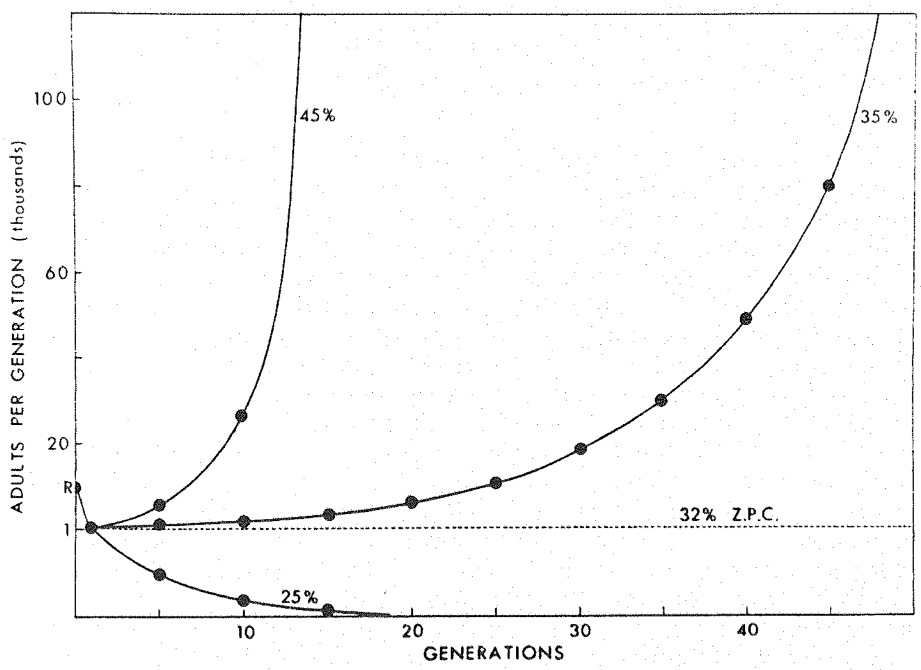

Figure 1. Population change of *Tucamania tapiacola* during successive generations when female fecundity equals 309 eggs per moth, survival of immature stages is 2.0% and adult survival is assumed at either 25%, 35% or 45%. Z.P.C. = zero population change.

ACKNOWLEDGEMENTS

My sincere thanks to Professor V.C. Moran for his invaluable help with the manuscript. His comments and suggestions during the study, as well as those of Dr. D.P. Annecke, Mr. H.G. Zimmermann, Dr. M.P. Hassell, Dr. S. McNeill, Professor T.R.E. Southwood and many other colleagues, are greatly appreciated. My thanks to the Cape Province Department of Nature and Environmental Conservation, Mr. G.J.H.C. Willetts and Mr. M.N. Moss on whose properties most of the work was conducted. Financial support from the Department of Agricultural Technical Services is gratefully acknowledged. Last, but not least, I thank Mr. M.P. Ngeju for his untiring technical assistance.

REFERENCES

Goeden, R.D. and Louda, S.M. (1976). Biotic interference with insects imported for weed control. *Ann. Rev. Ent.* **21**:325–42.

Hoffmann, J.H. and Moran, V.C. (1977). Pre-release studies on *Tucumania tapiacola* Dyar (Lepidoptera:Pyralidae), a potential biocontrol agent against jointed cactus. *J. Ent. Soc. S. Af.* **40**:205–9.

Mann, J. (1969). Cactus-feeding insects and mites. *U. S. Nat. Mus. Bull.* **256**:1–158.

May, R.M., Conway, G.R., Hassell, M.P., and Southwood, T.R.E. (1974). Time delays, density-dependence and single-species oscillations. *J. An. Ecol.* **43**:747–70.

Moran, V.C. and Annecke, D.P. (1979). Critical reviews of biological pest control in South Africa. 3. The jointed cactus, *Opuntia aurantiaca* Lindley. *J. Ent. Soc. S. Af.* **42**:299–329.