Dispersal of *Dactylopius opuntiae* Cockerell (Homoptera: Dactylopiidae), a biological control agent of *Opuntia stricta* (Haworth.) Haworth. (Cactaceae) in the Kruger National Park

L.C. Foxcroft and J.H. Hoffmann

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Chemical control efforts, the introduction of *Cactoblastis cactorum* and attempted releases of *Dactylopius opuntiae* Cockerell into the expanding infestation of *Opuntia stricta* in the Skukuza region of the Kruger National Park (KNP) have had limited success in preventing the spread and densification of *O. stricta*. To boost the biological control component, a new strain of *D. opuntiae* was introduced into KNP during 1997. The new strain established readily and has destroyed large clumps of plants in the vicinity of the release site. A large-scale redistribution programme with *D. opuntiae* is now needed to exploit this biological control agent to the full. In order to match the frequency of manual releases with the natural rates of spread of the insects, surveys were conducted under field conditions to determine the dispersal abilities of *D. opuntiae*, with regard to rate and direction of movement. Dispersal of *D. opuntiae* was found to be slow and restricted and that the insects need to be redistributed by placing them onto plants at approximately 10 m intervals to ensure that they become quickly and evenly distributed on the weed. This information will be crucial in the revision of the integrated management plan for *O. stricta* in the KNP, in integrating the cochineal and other control mechanisms.

Key Words: *Dactylopius opuntiae*, dispersal, biological control agent, *Opuntia stricta*, Cactaceae.

L.C. Foxcroft, South African National Parks, Kruger National Park. Private Bag X 402, Skukuza, 1350 Republic of South Africa; J.H. Hoffmann, Zoology Department, University of Cape Town, Rondebosch, 7701 Republic of South Africa.

Introduction

Opuntia stricta (Haworth) Haworth, a noxious alien cactus weed has invaded approximately 30 000 ha, to varying extents, in the Skukuza region of the Kruger National Park (KNP) which is one of the worst affected areas in South Africa (Hoffmann *et al.* 1998a, 1998b; Hoffmann *et al.* 1999; Lotter & Hoffmann 1998; Lotter *et al.* 1999).

Prolific seed dispersal by elephants (*Loxodonta africana* Blumenbach) and baboons (*Papio ursinus* Kerr) (Hoffmann *et al.* 1998a, 1998b; Lotter *et al.* 1999) and a high rate of germination make mechanical and chemical control of the weed difficult (Lotter *et al.* 1999). This, together with a shortage of resources (Lotter & Hoffmann 1998), led to the initiation of a biological control programme against the weed. The main objective of the programme has been to curb long-range dispersal of the weed by preventing the plants from fruiting (Hoffmann *et al.* 1998b).

The first biological control agent to be introduced against *O. stricta* in KNP was a phycitid moth, *Cactoblastis cactorum* Bergroth, which was released in 1998. Populations of the moth established readily, but long-term population studies showed that *C. cactorum* alone failed to provide adequate control of *O. stricta* (Hoffmann *et al.* 1998a, 1998b; Lotter & Hoffmann 1998; Hoffmann *et al.* 1999).

A second agent, the cochineal insect *Dactylopius opuntiae* Cockerell, that had played a predominant role in the control of *Opuntia ficus-indica* and *Opuntia lindheimeri* Engelmann in South Africa, was released in KNP on three separate occasions between 1990 and 1995, but this species never established on the weed (Lotter & Hoffmann 1998; Hoffmann *et al.* 1999). Host specificity studies showed that *D. opuntiae* consists of at least two discrete host-specific biotypes and that the one from *O. ficus-indica* failed to survive in KNP because *O. stricta* is an unsuitable host (Volchansky *et al.* 1999). As a result, a different biotype of *D. opuntiae* was obtained from *O. stricta* in Australia and was released in KNP during May 1997 (Hoffmann & Lotter 1998; Hoffmann *et al.* 1999). This biotype immediately established and started to destroy stands of *O. stricta* in the vicinity of the release sites. The prospects for successful biological control were substantially enhanced and redistribution of the insects became a priority.

One of the main limitations in using cochineal insects for biological control of cactus weeds is that the insects are susceptible to rain (Moran *et al.* 1987) and populations of the insects decline substantially during wet periods, allowing the host plants to recover (Moran & Hoffmann 1987; Moran *et al.* 1987). Therefore, in order to exploit cochineal insects more effectively, it is essential to deploy colonies onto as many plants as possible during periods of low rainfall so that the insects can proliferate and destroy their hosts before the insects are dislodged from the plants by rain.

The problem is compounded because the dispersal abilities of cochineal insects are rather limited (Moran *et al.* 1982: Sullivan & Hosking 1995). Adult female cochineal insects are sessile (i.e., once they settle and start feeding they lose mobility). Thus, dispersal of cochineal insects is limited to the first-instar nymphal stages which are known as 'crawlers'. Some nymphs settle and develop on the plants on which they hatch but others utilise the long wax filaments which they develop to make them buoyant and easily lifted into air streams. The crawlers are deposited at random and brought into contact with surrounding objects. Encounters with suitable hosts are therefore largely a matter of chance (Moran *et al.* 1982; Sullivan & Hosking 1995).

In order to optimise the redistribution programme and establish the insects economically over as wide an area as possible, the dispersal abilities of the insects needed to be determined on *O. stricta* under the specific environmental conditions of the Kruger National Park. This paper presents results of surveys that were conducted over 70 weeks to measure the dispersal of *D. opuntiae* and provide further assessment of the contribution that *D. opuntiae* may make to the overall management strategy. The study forms part of a broader investigation into the impact of *D. opuntiae* on *O. stricta*, with the immediate objective to distribute the cochineal as widely and quickly as possible in order to derive maxim benefit from the damage they cause.

Table 1

Characteristics of eight plots at which dispersal of D. opuntiae *was recorded in KNP. For each plot the mean (± se) distances between the plants and each sample point on the transects is given to show the relative density of the* O. stricta *plants in each plot. Mean (± se) plant sizes are recorded as the numbers of cladodes per plant*

Co-ordinates	Distance (m)	Plant size
25.034 S 31.569 E	1.4 ± 0.2	17.4 ± 2.7
25.010 S 31.598 E	1.8 ± 0.1	10.8 ± 1.4
25.011 S 31.590 E	2.0 ± 0.1	13.1 ± 0.7
25.011 S 31.599 E	2.1 ± 0.1	9.6 ± 0.5
25.012 S 31.593 E	2.3 ± 0.1	9.1 ± 0.6
25.013 S 31.600 E	2.4 ± 0.1	10.7 ± 0.9
25.012 S 31.597 E	2.6 ± 0.2	11.8 ± 0.7
24.994 S 31.613 E	3.9 ± 0.4	16.2 ± 2.3

Material and methods

Eight plots of 3 600 m² were demarcated at various localities (Table 1), surrounding the original release site of *D. opuntiae*, in the Skukuza region of KNP.

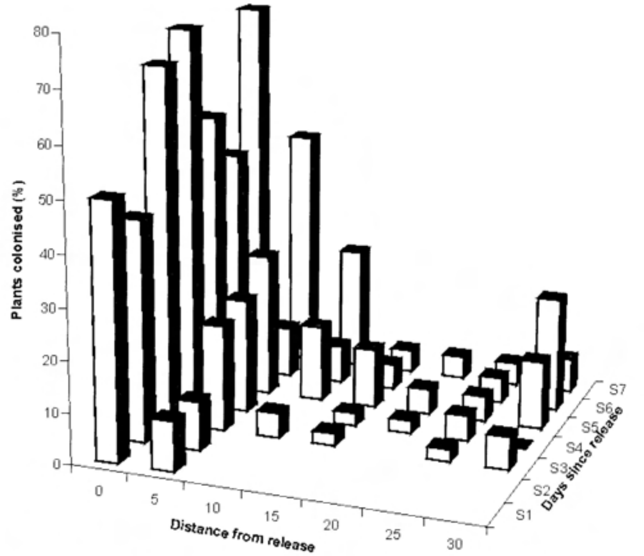

Fig. 1: The percentage of *Opuntia stricta* plants colonised by *Dactylopius opuntiae* at different distances from release points and on different sampling occasions (i.e. S1 - S7).

In each of the plots four permanent transects, 30 m in length, radiated out from a central plant in each of the four cardinal compass directions. On 8 February 1998, one cladode infested with colonies of females of *D. opuntiae* was placed on each of the central plants. The *D. opuntiae* colonies used for these releases were collected from the original release site of the insects near Skukuza. In four of the plots, *D. opuntiae* failed to establish successfully from the initial releases and two further cladodes with *D. opuntiae* were placed on each of the original release plants. All the plots were surveyed on seven occasions between February 1998 and the end of May 1999.

On each sampling occasion, measuring tapes were laid along the transects. At 5-m intervals the distance to the five nearest *O. stricta* plants was measured to record the relative density of the plants in the plots. The density of cactus in each of the plots varied but was representative of the range of densities that existed throughout most of the infested portion of the KNP at the time. To compare the effect of host plant density on the dispersal of the insects, the plots were divided into two categories and rated as either 'low' or 'high', depending on whether the average distances in the plots were above or below the overall mean for all the plots (Table 1).

The number of cladodes on each of the sample plants (= plant size) and the number of cladodes colonised by *D. opuntiae* were recorded. On small plants (< 150 cladodes), direct counts were made, while on larger plants (> 150 cladodes) the number of cladodes was estimated from a regression of $\text{LogN} = \text{logV}^{0.515} + 2.575$, as described by Hoffmann *et al.* (1998a), where N is the number of cladodes on a plant and V is the volume of the plant measured from its height and basal circumference and assumed to approximate the shape of a 'cap' (Hoffmann *et al.* 1998a). The range of plant sizes encountered varied between 9.1 and 17.4 cladodes per plant (Table 1) but the overall average size of the plants in the two density categories was almost identical.

Results and discussion

During the 70-week survey period, *D. opuntiae* seldom became abundant on plants that were more than 10 m beyond the plants on which they were originally released (Figs. 1 & 2). There was some long-range dispersal onto plants up to 30 m away from the release plants but the insects were relatively scarce on these plants by the end of the survey period.

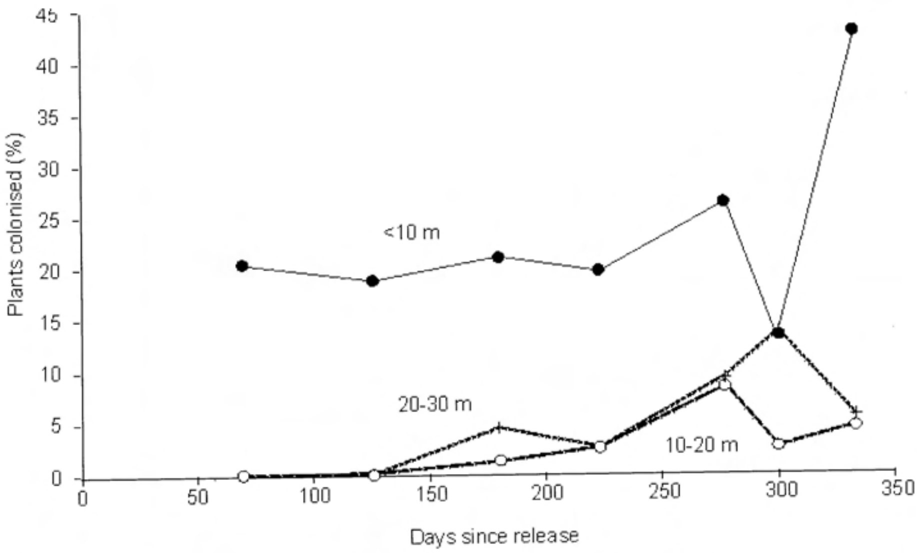

Fig. 2. Percentage of plants colonised by *D. opuntiae* in three different distance categories (< 10 m, 10–20 m and 20–30 m) from the release plant over time.

At least theoretically, dispersal of *D. opuntiae* should be most rapid in areas where its host plants are most dense because the chances of passively, wind-dispersed crawlers landing on a suitable host will be directly proportional to the area occupied by *O. stricta*. Chemical control efforts, together with damage caused by *C. cactorum* (Lotter & Hoffmann 1998), have ensured that there are no very dense stands of *O. stricta* left in the KNP and the density of the weed is moderate and fairly uniform throughout the park. There was no correlation between the rate of spread of *D. opuntiae* and the range of cactus plant density that was monitored during the trials and that were representative of those in existence in KNP at the time and the density was therefore not taken into account.

This study showed that in order to maximise the effectiveness of *D. opuntiae* as a biocontrol agent of *O. stricta* in KNP, colonies of the insects should be deployed at intervals of no more than 10 m. This knowledge will allow for the integration of the biological and chemical control methods when the management plan is revised, with areas containing few *O. stricta* plants being chemically treated, while high density stands being controlled by *D. opuntiae*. Every effort should be made to deploy colonies after prolonged rainy periods, to replenish and boost the abundance of existing stocks in the field and to ensure that the insects are abundant enough to exploit the weed during drought periods.

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