WHY NODDING THISTLE RECEPTACLE WEEVIL DESTROYS SO LITTLE NODDING THISTLE SEED IN CANTERBURY

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SUMMARY

Nodding thistle receptacle weevil (*Rhinocyllus conicus*) is widespread throughout New Zealand where nodding thistle grows. Previous work in Hawkes Bay showed seed predation increased to 49% over 4 years after the release of the insect, while in Canterbury in 1988-89 only 2.8% of seed was destroyed 12 years after the insects release. In the 1990-91 season, damage by *Rhinocyllus* in Hawkes Bay (38.6% of all seed) did not increase beyond the levels seen before 1986, while at three sites in Canterbury less than 9% of seed was lost. The later timing of flowering (by 3 weeks) and the lower densities of larvae per inflorescence in Canterbury are jointly responsible for the limited effectiveness of *Rhinocyllus* there.

Keywords: nodding thistle, *Rhinocyllus conicus*, seed predation, biological control

INTRODUCTION

Nodding thistle (*Carduus nutans*) is a serious pasture weed in eastern New Zealand. A biological control programme led to release of nodding thistle receptacle weevil, *Rhinocyllus conicus*, from 1972 onwards. *Rhinocyllus* has been credited with successful control of nodding thistle in Canada and the USA (Harris 1984; Popay and Medd 1990), with levels of seed destruction as high as 78% (McCarty and Lamp 1982). In New Zealand the insect has established throughout the range of nodding thistle but thistle densities seem not to have declined. Popay *et al* (1984) and Kelly *et al* (1990) studied the effect of *Rhinocyllus* in nodding thistle at a site in Argyll Road, Hawkes Bay, and showed that the percentage of seeds lost had increased following the release of *Rhinocyllus* in the area in 1981, to peak at 48.9% in 1985-86. It was not clear whether *Rhinocyllus* had yet reached maximum densities in New Zealand (Jessep 1989), so seed losses at Argyll since 1985-86 might have increased further.

Kelly *et al* (1990) also showed that at a Canterbury site in 1988-89 only 2.8% of seeds were destroyed by *Rhinocyllus*. They attributed the low figure to poor synchrony between weevil and plant caused by later flowering in Canterbury. It was not clear whether this was unusual, as a response by thistles to a drought affecting the region in 1987-89. In this study we set out to answer the following questions:

- (1) Has the level of seed loss to *Rhinocyllus* at Argyll continued to increase between 1985-86 and 1990-91?
- (2) Was the low seed loss in Canterbury in 1988-89 typical for the area, or a result of that year's drought?
- (3) How important is synchrony between insect and plant in determining levels of seed loss to *Rhinocyllus* in New Zealand?

METHODS

Data were collected at four sites. Two were the same as used by Kelly *et al* (1990): Argyll Road, near Waipawa in Hawkes Bay, and Fereday Island by the Rakaia River in Canterbury. Two new Canterbury sites were added: a second paddock on Fereday Island (Fereday 2), 1 km south of the first; and Lagmhor, 9 km west of Ashburton. All four sites had many thistles present. Fereday was grazed by cattle, while Lagmhor was grazed by sheep, and Argyll by sheep, cattle and goats (excluded from the plots).

Proc. 44th N.Z. Weed and Pest Control Conf. 1991: 280-283

Rhinocyllus was released at Argyll in 1981, at Fereday in 1976, and at Winchmore, 8 km northeast of Lagmhor, in 1973 (Kelly *et al* 1990; Jessep 1975). Sites were followed from November 1990 until the end of flowering (April/May 1991).

Methods followed those used by Kelly *et al* (1990). At 3 week intervals (4 weeks for Argyll), nodding thistle inflorescences were collected and the receptacle inside diameter and number of *Rhinocyllus* larvae were recorded. The potential number of seeds and seeds destroyed by *Rhinocyllus* were then calculated using the equations in Kelly *et al* (1990). The timing of seed production was determined by recording inflorescences ripened between visits in permanent quadrats totalling 100 m² at Fereday 2 and Argyll, and 5 m² at Lagmhor.

To investigate the relative effects of timing and weevil density on seed losses, the data for Fereday 1 were manipulated to calculate the theoretical seed losses given different timings of seed production relative to weevil activity, and different overall levels of weevil attack. To measure weevil densities over the whole season, larvae-days/m² were summed over all sample intervals; this was then divided by the number of inflorescences/m² to give larvae-days per inflorescence.

RESULTS

The seasonal pattern of seed loss to *Rhinocyllus* (Fig. 1a) showed high losses early in the season, with a dip in January, followed at some sites (particularly Argyll) by another increase late in the season. The density of *Rhinocyllus* larvae/m² peaked in December at all sites (Fig. 1b).

Fig. 1.: Effect of *Rhinocyllus conicus* on nodding thistle in 1990-91 at Argyll (Hawkes Bay) and three sites in Canterbury. (a) Percentage of seeds destroyed. (b) Density of *Rhinocyllus* larvae/m².

Overall levels of seed production (Table 1) were very high in 1990-91, especially at Lagmhor where thistles were extremely dense. The overall losses to *Rhinocyllus* were higher at Argyll than in Canterbury, where at all sites losses were less than 9%. The time to 50% seed production was later in Canterbury than at Argyll by 16-25 days. Weevil densities (both peak densities and whole season) were much lower in Canterbury (Fig. 1b, Table 1). There was a highly significant relationship between larvae-days per inflorescence and the overall level of seed lost over the season, both for the four cases in the 1990-91 season ($R^2=0.995$, $P<0.001$) and when including the data for Fereday 1 in 1988-89 and Argyll in 1983-86 ($R^2=0.819$, $n=8$, $P<0.01$).

TABLE 1: Density of *Rhinocyllus conicus* larvae, and nodding thistle seed production, at Argyll (Hawkes Bay) and three Canterbury sites in 1990-91. Potential and actual seed outputs are before and after losses to *Rhinocyllus*, respectively.

Site	% seed destroyed	Infl/m ² over season	Potential seeds/m ²	Actual seeds/m ²	Day to 50% seed set	Peak larvae/m ²	Larvae-days/m ²	Larvae-days/infl
Argyll	38.6	50.7	11086	6812	2 Jan	103	5985	118.0
Fereday 1	6.1	49.1	13474	12658	19 Jan	23.5	722	14.7
Fereday 2	7.2	65.7	17240	16005	27 Jan	42.8	1343	20.4
Lagmhor	8.8	114.5	36304	33112	18 Jan	81.6	3079	26.9

At Fereday 1, the overall loss of seed for the season was 6.1%. If peak seed production had been 3 weeks earlier (as at Argyll), with no change in weevil densities, then 20.2% of seeds would have been destroyed. If *Rhinocyllus* densities had recovered from February onwards as seen at Argyll, with the timing of seed production unchanged, 16.1% losses would be predicted. If weevil densities had been higher throughout the entire season (i.e. using the percentage seed lost at each date observed at Argyll), then 35.9% losses would be expected. If these higher weevil densities had been combined with a three week shift in seed production, then 49.9% of seeds would have been lost at Fereday 1.

DISCUSSION

The general increase in the levels of seed destruction by *Rhinocyllus* at Argyll between 1982 and 1986 (Kelly *et al* 1990) seems to have levelled out, with the 1990-91 data similar to that for 1983-84. *Rhinocyllus* apparently expanded to near its natural maximum density within 2 years of its release in the area in 1981-82. On this evidence, future seed losses to *Rhinocyllus* at Argyll are not likely to exceed 50% with any regularity. The effect of repeated losses of 30-50% of seeds is unknown, but many seeds still survive to germinate (see also Kelly *et al* 1990; Popay *et al* 1984).

The seasonal pattern of *Rhinocyllus* losses seems very predictable. Early in the season, beetles are ready to oviposit before flowering begins (Jessep 1989). The first inflorescences are heavily attacked, with many more larvae than are necessary to destroy all the seeds. Essentially all early season seeds are destroyed. By late December, weevil numbers have peaked, but inflorescence maximum densities occur in January or early February. The level of seed loss falls rapidly over this time, because weevil density is dropping while inflorescence density is increasing. Later in the season the insect numbers increase at some sites, but by this time there are only a few small axillary inflorescences being set.

Therefore, the relative timing of *Rhinocyllus* attack and nodding thistle seed production is crucial in determining the levels of seed loss. The earlier that flowering is completed, the larger the proportion of seeds which are produced while weevil densities are high and seed losses are almost 100%, and hence the higher the overall levels of seed loss. This effect is most pronounced in Canterbury, where flowering was 3 weeks later than at Argyll in both 1988-89 and 1990-91. The weevils' timing seems similar between the two areas. Therefore in Canterbury very few seeds are set early, so most escape predation. If flowering had been 3 weeks earlier at Fereday 1 in 1990-91, 20.2% of seeds could have been destroyed, rather than the actual 6.1%.

However, the Argyll site has higher densities of weevils per inflorescence, as well as earlier flowering. Had similar densities occurred at Fereday 1, the corresponding higher percentages of seed destroyed at each date would have resulted in a 35.9% seed loss; hence the effect of weevil density is greater than the effect of flower timing, though both are important. In contrast, the late season recovery in weevil densities is of less importance (few seeds are set after January, and losses then never approach 100%). If both higher weevil densities and earlier flowering had occurred, seed losses at Fereday 1 might have been as high as 49.9%. However, the lower densities in Canterbury presumably mean that the environment is less favourable for *Rhinocyllus*. This could be due to factors like higher mortality over winter, or lower numbers of offspring due to more competition for the few early flowers.

Overall, there was a very good relationship between whole-season weevil densities per inflorescence and losses of seeds. This is of little practical use as the weevil densities are no easier to estimate than seed losses themselves; however it does show the importance of overall weevil densities. As a general indicator in the field, if flowering peaks later than mid-January, and seed losses at the time are below 20%, the overall losses to *Rhinocyllus* are likely to be very low.

The consistency of the data for 1988-89 and 1990-91 suggest that Canterbury typically has very low levels of seed loss to *Rhinocyllus*. Perhaps the particular strain of *Rhinocyllus* found in New Zealand is not well matched to the flowering of nodding thistle in Canterbury; importation of a different strain of *Rhinocyllus* might improve the prospects of thistle control. Conversely, we predict that north of Hawkes Bay (e.g. in the Bay of Plenty), thistle flowering might be even earlier than at Argyll, and seed losses to *Rhinocyllus* correspondingly greater.

ACKNOWLEDGEMENTS

We express our thanks to the landowners involved, Mr T. Hobson (Argyll), Mr Dave Turner (Fereday), and Mr W. Keen (Lagmhor), without whose cooperation this work could not have been undertaken.

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