Survival of dock moth larvae, *Pyropteron doryliformis* (Lepidoptera: Sesiidae), in tubers of fiddle dock (*Rumex pulcher*)

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Summary Docks (*Rumex* spp. (Polygonaceae)) are significant weeds of pasture in Australia. In 1989 a biological control agent, *Pyropteron doryliformis* (Ochsenheimer, 1808) (Lepidoptera: Sesiidae) was released for the management of docks in Australia. It is known that female moths lay a large number of eggs, many on a single plant, but usually only one or two larvae survive to adulthood from a single tuber. We suggest that tuber size may be limiting the survival of larvae. We collected tubers of *Rumex pulcher* from five sites in southwestern Australia at three different times (early, mid, late summer) to explore the relationship between tuber size and number of larvae within a single season. There is clearly a positive relationship between tuber size and number of larvae. However, there are fewer of *P. doryliformis* larvae surviving in tubers of *R. pulcher* at the end of summer relative to the number present early in summer and that appears to be independent of the size of the tubers.

Keywords Weed biological control, resource limitation, *Pyropteron doryliformis*, Sesiidae.

INTRODUCTION

Docks (*Rumex* spp.; Polygonaceae) are considered some of the worst perennial weeds in the world (Zaller 2004). There are several dock species found in Western Australia that are of economic concern primarily in pastures; fiddle dock (*R. pulcher* L.), curled dock (*R. crispus* L.), broadleaf dock (*R. obtusifolius* L.), clustered dock (*R. conglomeratus* Murray) and swamp dock (*R. brownii* Campd.) (Allen 1975, Parsons and Cuthbertson 1992). Fiddle dock is the most common and dominant weedy *Rumex* found in Western Australia (Allen 1975).

Docks became the target of a biological control program in Australia in 1982. A species of clearwing moth, *Pyropteron doryliformis* (Ochsenheimer, 1808) (Lepidoptera: Sesiidae), from Morocco, was released in 1989 (Fogliani and Strickland 2000). The releases have proved to be successful with 69% of the release sites having populations established but spread of the moth has been slower than expected (Fogliani and Strickland 2000). Female moths in the biocontrol mass rearing program laid a lifetime, of which 71.9% hatched In the mass rearing program *P. doryliformis* females were observed to lay many eggs (an average of 291.6 eggs) in their lifetime and in many cases laid many on a single plant (Fogliani and Strickland 2000). These had a high hatching rate (71.9%) and under these conditions multiple individuals completed development in a single tuber (Fogliani and Strickland 2000). However, in the pre-release host specificity testing only one *P. doryliformis* larva per plant was found in dead, mature plants (Scott and Sagliocco 1991). We sought to evaluate the relationship between tuber size and larval survival. We suspect that larger tubers will have more larvae than smaller tubers and that the larval numbers will decrease over time but more so in smaller tubers.

METHODS

Five sites in Western Australia were used for collecting fiddle dock samples: one site near Northam (Allandale farm 34°46.747'S, 116°22.118'E), one near Pinjarra (Burkett farm 32°41'10.52"S, 115°56'29.40"E) and three near Mount Barker (the Western Australia Department of Agriculture and Food Mt Barker Research Station (RS) 34°38'14.96"S, 117°32'44.63"E), Coffey farm (34°41.887'S, 117°30.893'E) and Clothier farm (34°40.029'S, 117°32.012'E)). There are approximately 440 km between the northern sites (Allandale and Burkett) and the southern sites (Mt Barker RS, Coffey and Clothier). These sites were selected to provide an assessment of dock moth infestations across the State and because they had already well established populations of the dock moth. Previously documented levels of infestation for all sites were over 20% (Fogliani and Strickland 2000).

Once the presence of moths at the site was confirmed, tubers were dug up. Plants were selected randomly from each collection site. No plants had any green above-ground tissue. Once removed from the soil the tubers were rinsed of dirt. The number of stems on each tuber was counted and the stem diameter for each stem was measured at about 3 cm from the top of the tuber. The stems were then cut from the tuber and the tubers were scrubbed in a bucket of water and air-dried overnight. The tubers were then dissected and

all larvae found in each tuber were removed, weighed and the number of larvae in each tuber was recorded. The larvae were preserved in 70% ethanol.

A minimum of 20 tubers was collected from each site at three times (early, mid and late) during the summer season (December 2002-March 2003).

The relationship between the number of stems and tuber mass and the relationship between the average stem diameter per tuber and tuber mass were analysed using regression analysis. The effect of time (early, mid and late) and site of collection on the relationship between the number of larvae per tuber and tuber mass was evaluated using a generalised linear model. A backwards elimination model fitting procedure was used to generate the model of best fit. The final model included only the main effects and the two-way interactions between tuber mass and the site, and tuber mass and date of collection ($r^2 = 0.33$). A significant relationship between tuber mass and number of larvae per tuber was found but this interacted with site of collection. Therefore, a subsequent analysis of the relationship was conducted for each collection site separately. All analyses were conducted using GenStat 9th edition. Where appropriate the data were transformed (stem number, tuber mass, larval number) using the natural logarithm. Data were reverse transformed for graphical presentation.

For each sampling date at each site, the distribution of the number of larvae per tuber was tested against the Poisson distribution using an index of dispersion test (Krebs 1999). The null hypothesis for this test is that the observed number of larvae per tuber is randomly distributed. Rejecting this null hypothesis assumes that the number of larvae per tuber are not distributed randomly but approach either a uniform or an aggregated distribution.

RESULTS

There were 2.3 ± 0.1 stems per dock plant on average. Only seven plants (1.6%) sampled did not have stems. As the mass of the tuber increased the number of stems present on the plant increased ($y = 0.06x - 1.03$; $r^2 = 0.44$; $F_{1,426} = 296.57$, $P < 0.001$). Average stem diameter was 0.44 ± 0.01 cm and as tuber mass increased so did the average stem diameter ($y = 0.002x + 0.38$; $r^2 = 0.08$; $F_{1,426} = 59.54$, $P < 0.001$).

Across all sites, 30–100% of tubers were attacked. Of the 428 plants sampled, 257 (60%) had at least one larva present. If a plant had larvae present there were, on average, 2.5 larvae in the tuber. One tuber had 32 larvae present. The number of larvae per tuber was influenced by the collection time ($F_{2,414} = 13.0$, $P < 0.001$). There were more larvae per tuber in the second sample (2.1 ± 0.2 larvae per tuber) than the first sample (1.6 ± 0.3) but the number of larvae decreased in the third sample below that of the first sample (0.9 ± 0.1). As tuber mass increased the number of larvae increased (Figure 1; $F_{1,414} = 70.58$, $P < 0.001$). This relationship changed with the collection site ($F_{4,414} = 2.64$, $P = 0.03$) but not with the date of collection ($F_{2,414} = 2.83$, $P = 0.06$). At each site there was a significantly positive relationship ($P < 0.05$) between the tuber mass and the number of larvae per tuber. But the strength of this relationship was not as strong at two of the sites (Pinjarra and Mt Barker) as at the other three.

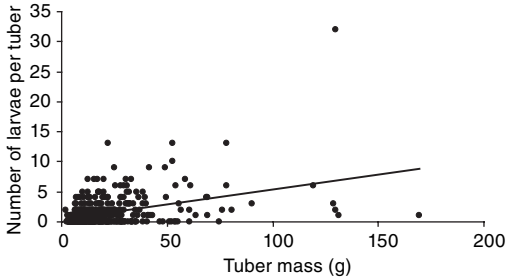

Figure 1. The relationship between *R. pulcher* tuber mass and the number of *P. doryliformis* larvae per tuber in Western Australia ($y = 0.048x + 0.5066$; $r^2 = 0.15$).

Based on the results of the index of dispersion test, the pattern of larval distribution at all sites was either random or aggregated and this changed through time (early: 60% were random; mid: 20% were random; late: 60% were random).

DISCUSSION

Larger tubers produced more and larger stems than plants with smaller tubers. This relationship suggests that the above ground tissue may be a reliable indicator of host plant tuber size for ovipositing *P. doryliformis.* Once a host plant is encountered, a female may assess host plant quality based on her perception of above ground biomass and then decide how many eggs to lay on the plant, laying more eggs on those plants with greater above ground biomass. Alternatively multiple females may lay a single egg each on one plant and the larger plants attract more females resulting in greater numbers of larvae. As a greater number of larvae were found in larger tubers there does appear to be a relationship between plant size and number of eggs laid but we did not directly assess the egg laying behaviour of the moths. What is unclear is why ovipositing females would lay multiple eggs (either from a single female

or multiple females) on a single host plant, potentially jeopardising the survival of their offspring, especially when there are abundant host plants available. Thus further studies are needed to explore this.

Larger tubers appear to have more larvae, as we expected. We also expected a decreasing number of larvae in each tuber over time. The lower number of larvae in the first collection than the second collection does not appear to support our expectations. However, it may be that some of the larvae in the first collection were too small to be accurately counted. The decrease in the number of larvae per tuber from the second collection time by the third collection time supports the hypothesis that the number of larvae per tuber does decrease over time but this appeared to be independent of the tuber mass, given there was no significant interaction between tuber mass and the collection time on the number of larvae. This suggests that there is a discrepancy between potential reproductive output (as measured by the large number of eggs produced and laid) and realised reproductive output of *P. doryliformis* that is due to some other cause besides resource limitation. As the larvae get bigger over time it is likely that the encounter rate increases and some of the larvae die or are eaten by conspecifics. Furthermore, later in larval development mature larvae move to the top of the tuber prior to pupation and are likely to encounter each other at that time. This encounter may lead to the singular survival noted by Scott and Sagliacco (1991). Serrano *et al.* (2001) found that as the number of larvae increased, survival decreased in a fruit infesting Lepidopteran and mortality increased when the larvae encountered each other more frequently.

There was considerable variation in the distribution pattern of *P. doryliformis* larvae within tubers both between sites and within the season. Similar within season variation between aggregation and random distribution patterns was observed in two other Lepidopteran species that infest blueberries and the variable distribution was influenced by proximity to wooded habitats (Mallampalli and Isaacs 2002). At each of the sites in our study there was some wooded area near the dock infestation however, we did not evaluate whether this might influence the distribution. We sampled over one summer only, and while we sampled at five sites and had variable distributions at all sites, repeating this work over time either at the same sites or others is necessary to determine if the distribution varies within a season.

The number of individuals produced over time declines so that not all emergent larvae survive to pupation and become adults. In the case of a biological control agent for a significant weed, this strategy may reduce the overall population size of the agent and thus the resultant impact on the weed population.

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