LATE-SEASON SPRAYING FOR LUCERNE FLEA, *SMINTHURUS VIRIDIS* (LINNAEUS) (COLLEMBOLA: SMINTHURIDAE), CONTROL IN THE NEXT SEASON

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Summary

The potential of late-season spraying with insecticide to break the seasonal cycle of the lucerne flea, or to reduce damage in the next season, was evaluated in 1999–2000. Significant reductions in numbers of individuals capable of producing over-summering eggs were achieved with one and three sprays in 1999. This effect was carried over as lower numbers of all stages during the 2000 establishment and damaging phases. However, although the single spray reduced lucerne flea density by 40 to 50% at the next-season peak, it did not prevent or delay numbers exceeding damaging levels relative to an unsprayed treatment. The three late-season sprays followed by an early spray in the next season prevented lucerne flea damage. Further study to optimise the effect of spraying late in the season is warranted.

Keywords: Lucerne flea, *Sminthurus viridis*, insecticides, control strategies

INTRODUCTION

The lucerne flea, *Sminthurus viridis* (Linnaeus) (Collembola: Sminthuridae) is an important pest of legume-based pastures in the Mediterranean-type climates of southern Australia (Ireson 1993) and is increasing in importance in the summer-rainfall, temperate-type climates of New South Wales (Bishop *et al*. 2001a). It commonly aestivates, hatches in autumn and remains active into spring (Wallace 1967). Some eggs also hatch throughout summer in New South Wales although viable populations never develop until autumn (Bishop *et al*. 2001b). Damage is primarily to leaves and ranges from minor windowing to total defoliation.

Predators and cultural methods sometimes negate the need for insecticidal control of lucerne flea in southern Australia (Grimm *et al*. 1995; Ireson and Webb 1995; Michael *et al*. 1995). There are no effective predators in temperate New South Wales and pasture protection from lucerne flea damage is almost totally reliant on chemical control (Bishop *et al*. 2001a). Numerous compounds are registered and effective against lucerne flea (Bishop *et al*. 1998). Their application is proposed soon after the autumn break in aestivation to prevent early generation females from laying next generation eggs (Wallace 1954; Johnston 1960), at any time when damage can no longer be tolerated, and late season to prevent last generation females from producing over-summering eggs (Johnston 1960). Early spraying can be effective but may be unnecessary in many New South Wales pastures where populations are still establishing (Bishop *et al*. 2001b). Treatments based on damage are effective but are difficult to time accurately. Both of these strategies can leave populations capable of producing over-summering eggs that perpetuate seasonal damage. Late spraying to break the seasonal cycle or to reduce damage in the next season appears feasible but has not been confirmed as a control strategy. This study was designed to evaluate the potential of late spraying for control of the lucerne flea.

MATERIALS AND METHODS

An experimental area was located at Scott's Flat near Singleton (32°36'S, 151°13'E) in the Hunter Valley of New South Wales. An incomplete latin square (Cochran and Cox 1957) with seven replicates was used to test three treatments. The trial started in August 1999 and finished in September 2000. Plots were 12 m x 12 m with 2 m buffers on each side. Although movements of lucerne flea between plots is minor (Wallace 1957), a 0.5 m insecticide barrier was established between plots. Chlorpyrifos was applied by knapsack sprayer at a rate of 200 mL ha^{-1} for all insecticide treatments, with a spray-drift barrier between plots. Insecticide applications were timed by monitoring stages and activity of lucerne flea at fortnightly intervals.

Treatments were:
T1 (Untreated) - No protection in 1999 and treated only when at damaging levels [lucerne flea numbers > 1300 m^{-2} (Bishop 1991)] in 2000.
T2 (Late-season spray strategy) - A single insecticide treatment timed to have predicted maximum effect on females producing aestivating eggs at the end of 1999 and other treatments if lucerne flea reached damaging levels in 2000.
T3 (Protected) - Three sprays at two weekly intervals to ensure maximum effect on females producing

aestivating eggs in 1999 by targeting the last two generations of lucerne flea. This was to be followed by a single early season spray in 2000 to continue protection and further sprays if numbers started to increase.

Two 0.25 m^2 samples were taken with a vacuum sampler (Holtkamp and Thompson 1985) in each plot each fortnight while lucerne flea was active and monthly in T1 over the summer period. Summer sampling was used to confirm the break in aestivation. Collections were placed in plastic bags and returned to the laboratory where arthropods were killed with ethyl acetate, separated from plant material by sieving and lucerne flea numbers counted under a binocular microscope. As instars could not be separated accurately, lucerne fleas were divided into the following size categories (stages): small nymphs (< 0.82 ± 0.15 mm); medium-sized nymphs (0.82 ± 0.15 mm to 1.94 ± 0.13 mm); large nymphs (>1.94 ± 0.13 mm) and adults.

Due to the complexity of treatment application and measurement time, experimental data were grouped into five time periods for analysis [i.e. excluding the period of aestivation (Time Period 3)] (Figure 1) to simplify the covariance structure when a repeated measurement analysis was used. Small + medium nymphs (small) and large nymphs + adults (adults) were analysed separately. Small and medium sized nymphs represented actual reproduction. Large nymphs and adults represented the reproductive [and major generational damage (Bishop *et al*. 2001a)] potential in each of the treatments. Pre-treatment data (Time 0 = 31 August 1999) were analysed using an ANOVA to test whether lucerne flea counts varied between plots associated with assigned treatments. Data were log transformed to normalise the error distribution when fitted to the following model:

Y = treatment + time + treatment x time + *row* + *column* + *row.time* + *column.time* + *error*,

where italicised terms are fitted as random effects. Error was assumed to be normally distributed with mean zero and variance σ^2 R where R = correlation matrix of first order auto-regressive coefficients. An F-test was used to test the fixed term effects and means separated using the LSD procedure.

RESULTS

Figure 1 shows the changes in total numbers of lucerne flea in the three treatments in response to insecticide application, rainfall and season over six time periods from August 1999 to September 2000. Rainfall data were representative of the region's

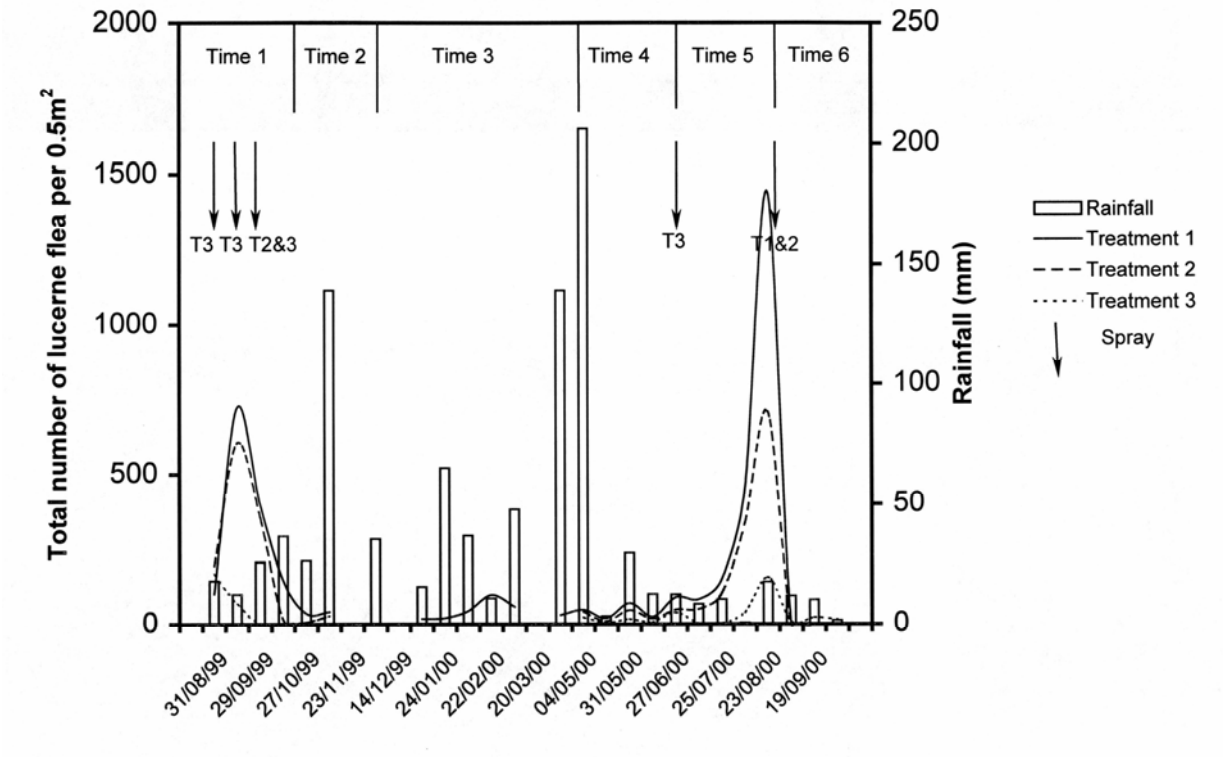

Figure 1. Seasonal changes in lucerne flea numbers following three late-season spray strategies in 1999 and 2000.

summer-rainfall, temperate climate. Damage was restricted to single peaks (> 650 lucerne flea 0.5 m^{-2}) in August-September in each season.

Adult numbers were significantly lower in T2 and T3 (Table 1) in periods when females were expected to be laying over-summering eggs in 1999 (Time Periods 1 and 2). Small nymph numbers were similarly reduced although there were no differences between treatments at the last October sampling (Table 2). These and subsequent hatchings failed to reach higher instars throughout summer.

Lucerne flea recommenced development following heavy rainfall in March-April 2000 (Figure 1). Significant differences between T1 and T3 were recorded as it re-established in the fourth time period. At the same time, numbers of all stages in T2 were intermediate although rarely different from either T1 or T3 during re-establishment. Damaging levels were exceeded in T1 and T2 at the end of the fifth time period (Figure 1) even though T2 numbers were significantly lower than those in T1 (Tables 1 and 2). Spraying of T1 and T2 was followed within 2 weeks by the natural cessation of lucerne flea activity in spring (Time Period 6). The protection given T3 at the end of Time Period 4 maintained numbers below the other two treatments until T1 and T2 were

Table 1. Counts (back-transformed means) of large nymphs + adult lucerne flea per 0.5 m^2 in three treatments over five time periods. T1 (sprayed 15/08/00); T2 (sprayed 15/09/99 and 15/08/00); T3 (sprayed 19/08/99, 2/09/99, 15/09/99 and 22/6/00). Means in rows with the same letter are not significantly different (P > 0.05) .

	TREATMENT NUMBER		
DATE	**T1**	**T2**	**T3**
		TIME PERIOD 1	
31 August 1999	64.3 a	59.7 a	2.1 b
14 September 1999	131.4 a	171.7 a	1.7 b
		TIME PERIOD 2	
29 September 1999	62.7 a	0.2 b	0.6 b
12 October 1999	22.3 a	5.5 b	3.2 b
27 October 1999	3.9 a	0 b	0.3 ab
		TIME PERIOD 4	
10 April 2000	8.5 a	6.3 a	2.0 a
04 May 2000	4.4 a	3.1 a	1.2 a
16 May2000	28.9 a	23.2 a	5.1 b
31 May 2000	18.6 a	12.6 ab	4.5 b
13 June 2000	33.7 a	13.9 a	14.3 a
		TIME PERIOD 5	
27 June 2000	26.9 a	13.3 a	1.7 b
11 July 2000	42.1 a	28.7 a	1.8 b
25 July 2000	62.4 a	33.5 a	1.8 b
08 August 2000	292.8 a	143.0 b	24.5 c
		TIME PERIOD 6	
23 August 2000	0.08 b	0 b	8.4 a
02 September 2000	0.02 b	0.06 b	1.7 a
19 September 2000	0.6 b	0.7 b	11.0 a

sprayed after which time adult and nymph numbers in T3 were significantly higher but still well below damaging levels.

DISCUSSION

Lucerne flea is capable of producing one (this study) and often two (Bishop *et al*. 2001a) damaging generations each season in temperate regions of New South Wales. Any method of delaying or preventing this damage reduces spray costs and helps maximise yield in the critical winter production period. Johnston (1960) proposed that late-season spraying would negatively impact on the next season's populations. We considered that this should be achieved with a minimum number of sprays to make the strategy economically viable. Treatments were therefore designed primarily to allow a single, timed treatment to be compared with protected and unprotected treatments.

Significant reductions of the stages leading to production of over-summering eggs (large nymphs and adults) were achieved in both T2 and T3 at the end of the first season. Correspondingly, reproduction (small and medium sized nymphs) was also lower towards the end of the 1999 season. This

Table 2. Counts (back-transformed means) of small + medium sized lucerne flea nymphs per 0.5 m^2 in three treatments over five time periods. T1 (sprayed 15/08/00); T2 (sprayed 15/09/99 and 15/08/00); T3 (sprayed 19/08/99, 2/09/99, 15/09/99 and 22/6/00). Means in rows with the same letter are not significantly different (P > 0.05) .

	TREATMENT NUMBER		
DATE	**T1**	**T2**	**T3**
		TIME PERIOD 1	
31 August 1999	182.6 a	267.3 a	48.4 b
14 September 1999	52.4 a	66.2 a	0.5 b
		TIME PERIOD 2	
29 September 1999	59.9 a	10.2 b	0.4 c
12 October 1999	11.1 a	0.2 b	0.4 b
27 October 1999	35.4 a	26.1 a	26.7 a
		TIME PERIOD 4	
10 April 2000	39.4 a	32.8 a	15.5 b
04 May 2000	10.0 a	5.8 ab	1.6 b
16 May2000	30.4 a	12.9 b	4.5 b
31 May 2000	1.1 a	0.3 a	0.1 a
13 June 2000	31.1 a	22.9 ab	15.9 b
		TIME PERIOD 5	
27 June 2000	10.5 a	12.4 a	0 b
11 July 2000	57.9 a	40.9 a	0 b
25 July 2000	282.4 a	193.0 a	21.3 b
08 August 2000	734.1 a	294.9 b	71.5 c
		TIME PERIOD 6	
23 August 2000	0	0	0
02 September 2000	0.6 b	0.4 b	12.7 a
19 September 2000	0.4 b	0 b	2.6 a

latter trend was confounded by the final count in October when it appeared that sizeable and perhaps equal numbers of eggs were still present and capable of hatching once direct effects of insecticide applications had ceased.

The negative impact of late spraying of lucerne flea carried over into 2000 and negated the possibility that similar egg reservoirs were present in each treatment. Recovery still appeared possible as the populations re-established (13 June 2000), however, a single spray (22 June 2000) reduced and maintained low numbers in T3 for the rest of the season. This spray may or may not have been necessary in a commercial sense but could be considered further in a combined late/early season spray strategy. T2 never recovered fully, but this was only confirmed statistically when lucerne flea numbers peaked in August. Importantly, T2 did not prevent or delay the need for "next-season" control relative to T1. T1 and T2 were sprayed at a time when another late-season spray treatment was being considered. The aim was to not spray T3 and to compare this with the now sprayed T1 and T2 in 2001. Unfortunately, further study was prevented by *Spodoptera litura* (Fabricius) damage in summer, necessitating spraying and eventually crop replacement.

Late-season spraying significantly reduced numbers of lucerne flea in the next season but even three closely-applied sprays to the last two generations did not completely break the life cycle. The production of over-summering eggs in spring therefore appeared to be more complex and far less predictable than the relatively clearly defined breaking of aestivation in autumn. Late oviposition may be even more complex as some nymphs continue to hatch throughout summer. A single-spray strategy may therefore be difficult to implement effectively and multiple sprays may not be cost effective or environmentally sound. Further consideration should be given to late spraying: as a stand-alone strategy; in combination with early season sprays; and perhaps as a way of giving predators in southern Australia a competitive advantage in the next season. It may also be interesting to test if repeated early- and late-season disruptions to the life cycle over several seasons could eventually lead to the species' eradication in localised areas.

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