GIANT BUTTERCUP (*RANUNCULUS ACRIS* L.) SEEDLING EMERGENCE AND SURVIVAL IN GOLDEN BAY DAIRY PASTURES

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ABSTRACT

Giant buttercup (*Ranunculus acris* L.) is an unpalatable weed in New Zealand dairy pastures and is estimated to cost the dairy industry over $150 million annually in lost milk solids revenue. In this study, the survival of giant buttercup seedlings was determined by following their fates in permanent plots on eight randomly selected dairy farms in the Takaka Valley from November 2004 to August 2008. Seedling emergence occurred year-round but tended to be higher in winter and spring than in summer and autumn. Seedling survival was very low with less than 5% of seedlings surviving beyond 12 months. Seedlings that germinated in autumn had significantly higher survival at 6 and 12 months (22% and 12% respectively) than seedlings germinating in spring, summer and winter (3-7% and 2-3% respectively). Good pasture management, that prevents over-grazing and pugging in autumn and winter, should reduce the autumn flush of seedlings and minimise their survival.
Keywords: *Ranunculus acris* L., emergence, seedling survival, pasture management.

INTRODUCTION

Giant buttercup (*Ranunculus acris* L.), a perennial herb of European origin, has become a serious weed in dairy pastures in the Taranaki and Golden Bay regions of New Zealand. At its peak seasonal cover in October-November each year, it reduces utilisable pasture by up to 50%, causing significant losses in milk solids production (estimated national value of NZ $156 million p.a. in 2001-02) (Bourdôt et al. 2003). Control of giant buttercup in dairy pastures has become increasingly difficult because it has become resistant on many farms to the ‘phenoxy’ herbicides MCPA and MCPB (Bourdôt et al. 1996) and newer herbicides do not give complete control. In addition, progress towards finding a biocontrol solution has been slow.

It has been recognised for a long time that understanding the mechanisms behind giant buttercup establishment and persistence in pastures will help to design strategies to control this weed more effectively (Harper & Sagar 1953). By identifying the lifecycle stages that contribute most to population growth, effort can be directed towards those stages for improved management (Lamoureaux & Bourdôt 2007).

Giant buttercup reproduces both by seed (sexual) and by vegetative shoot production (asexual) but the shortness of the rhizome restricts its vegetative spread (Sarukhán 1974). According to a population model developed for the species in Wales (Sarukhán & Gadgil 1974) asexual and sexual reproduction contribute equally to a population. However, in some populations in other parts of Europe reproduction occurs almost exclusively by seed (Harper 1957; Rabotnov 1958; Rabotnov & Saurina 1971; Sarukhán & Harper 1973; Harper 1977). The experiment reported here was aimed at determining the importance of the seedlings in New Zealand dairy pastures by monitoring their emergence and survival over 4 years in established populations of the weed. The factors potentially limiting seedling recruitment and their implications for managing giant buttercup in dairy pastures are considered.

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METHODS

The experiment was established in November 2004 in populations of giant buttercup on 12 dairy farms in the Takaka Valley, New Zealand, which were randomly selected from a pool of 52 farm contacts provided by the local milk processing company, Golden Bay Dairies Ltd. It was designed to quantify the population dynamics of the buttercup and its response to a mycoherbicide (based on *Sclerotinia sclerotiorum*) using five treatments, plus an untreated control with one replication on each of the 12 farms. Only the untreated control plots are considered in this paper. The mycelium of the fungus was applied only once per year to plots adjacent to the control plots and while it is possible that some may have been transferred by stock to the control plots, this is unlikely because farmers withheld grazing after the applications were made and there was also a 1.0 m buffer between the plots. Furthermore, transfer of the fungus by spores is minimal in a dairy pasture (de Jong et al. 2002). Four of the 12 farms were withdrawn for various reasons so the data used here are from measurements taken on the remaining eight farms.

The study plots measured 2 × 2 m and were located at sites chosen for a uniform high density of giant buttercup. *Ranunculus repens* occurred on some plots at very low density so there was the possibility of misidentification of seedlings but the likelihood of this was low. The plots were marked using small wooden pegs on the corners, which were also used to attach temporary string lines dividing the plot into 0.5 x 0.5 m grid cells and metal pegs to locate a removable measuring bar at one edge of each plot. Within the first row of grid cells in each of the plots, two 0.25 x 0.25 m quadrats were established at 0.5 and 1.5 m along the measuring bar for the purpose of recording the emergence and death of seedlings. These quadrats were located at each time of census using a portable frame divided into 25 5 cm x 5 cm grid squares. The frame was designed to attach onto the measuring bar to ensure accuracy of placement at each census. The plots were unfenced, the normal grazing regime continued throughout the experiment, and no buttercup control measures were undertaken.

Censuses were carried out every 6 weeks from November 2004 to October 2005 and then every 3 months at the end of spring, summer, autumn and winter (November, February, May and August, respectively) until August 2008. Various measurements were carried out on giant buttercup in the main part of the plots and in the quadrats. However in this paper, only data from the quadrats are described. At the first census all seedlings within the quadrats were mapped using X-Y co-ordinates defining their location within the grid. Each seedling was allocated a unique ID number. The seedlings of giant buttercup were distinguished from clonally produced small plants by the presence of cotyledons. At each of the subsequent censuses the 25 x 25 cm quadrat was searched to locate both new recruits and to record the fates ('present' or 'gone') of those seedlings present at the previous census. In addition, the number of leaves (including cotyledons), and leaf area (measured in two directions, at right angles parallel to the grid, using a digital calliper) were recorded. Surviving seedlings that had lost their cotyledons and had replaced their initial small leaves with larger leaves were considered 'established' and their measurement as a seedling ceased; instead, these became part of the shoot and clump (comprising of a group of shoots) measurements carried out in the main plots. Occasionally areas within the quadrats were covered by dung, possibly obscuring seedlings; these areas were ignored for that census.

For the purpose of the analysis, the data for the 2007/8 year were omitted because seedlings emerging during the final year were not tracked for a full 12 months. Additionally, for the first year, when censuses were 6-weekly, and there were two measurements per season, these data were combined so that there was one data point per season. Each seedling that emerged had its 'birth' date and its 'gone' date recorded and its survival duration was then calculated in Julian days. The percent survival of seedlings for each season and year was analysed using a generalised linear model analysis with a binomial error term, a logit-link function, and allowing for over-dispersion (using the actual variability rather than the theoretical variability of 1). The emergence data were square-root transformed and analysed using an analysis of variance with factors year and season, using GenStat (v10).

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RESULTS

Emergence of seedlings occurred in every season for each of the 3 years of the study but it varied both between years and between seasons (Table 1). Seedling emergence was significantly higher in 2004/5 than in 2006/7, but not different from 2005/6. It was also significantly higher in winter than in summer but not between any other seasons (Table 1). Seasonal emergence was lowest in summer in three out of four years.

TABLE 1: Square root of the mean number of giant buttercup seedlings/m^2 emerged over the 3 years from 2004 to 2007, and by season on eight farms in Golden Bay. Back-transformed means are given in parentheses.

Year	No. emerged/m^2		Season	No. emerged/m^2	
2004/5	10.83	(117)	Spring	9.04	(81)
2005/6	8.04	(65)	Summer	5.22	(29)
2006/7	4.39	(19)	Autumn	6.72	(45)
			Winter	10.04	(101)
LSD (P=0.05)	3.45			3.98	

The percent survival of seedlings is given in Table 2. Autumn-germinating seedlings survived better than seedlings germinating in winter, spring and summer to 3, 6 and 12 months, although the difference was not statistically significant for the 3 month data.

DISCUSSION

The number of seedlings arising within the giant buttercup populations in this study varied considerably between both years and seasons (Tables 1 & 2). Very few seedlings arose during the third year of the study, especially compared to the first year. It is possible, however, that more seedlings were recorded in the first growing season (2004/05) because there were seven sample times, but only four sample times in 2006/07. Counting more often may result in a higher total number simply because there is more chance of sampling during the seedling flush, or observing seedlings that germinated and died between the 3-monthly sample times. However, even averaging the two data points per season for the first year still gives a higher value for the 2004/5 year than for the other years. The difference between years may also be because climatic conditions were more favourable for seedling germination during the 2004/5 and 2005/6 growing seasons. According to meteorological records both rainfall and temperature were similar, on a seasonal basis, over the 4 years of the study, although summer rainfall over the first 2 years was slightly higher. Variation in the numbers of seedlings emerging between years may also be due to the proportion of plants flowering and this has been reported in Europe to range from 3–80% (Rabotnov 1958; Sarukhán 1974), and furthermore, may be influenced by timing of flowering in the previous season (Totland & Eide 1999) and the density of plants (Bourdôt et al. 1996).

In summer and autumn, recruitment was considerably lower than spring or winter (Table 1). This is most likely due to a lack of soil moisture during these months. During the summer period particularly, it was not uncommon to observe the drying off of mature buttercup leaves and in some extreme cases a browning off of the entire pasture sward in the plots. Soil moisture is an important factor for seedling germination, which is known to be reduced in both well drained and waterlogged conditions (Harper & Sagar 1953; Harper 1957).

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TABLE 2: Total numbers of giant buttercup seedlings per m^2 emerged by season, and percent surviving to 3, 6 and 12 months, at eight farms in Golden Bay from 2004 to 2007.

Year	Season	Total emergence	% surviving to:		
			3 months	6 months	12 months
2004/5	Spring	145	12.4	7.6	2.8
	Summer	32	28.1	18.8	9.4
	Autumn	121	36.4	23.1	9.1
	Winter	214	22.9	4.7	1.9
2005/6	Spring	108	5.6	2.8	1.9
	Summer	57	5.3	3.5	0.0
	Autumn	38	73.7	39.5	21.1
	Winter	65	18.5	6.2	3.1
2006/7	Spring	22	72.7	4.6	0.0
	Summer	6	0	0	0
	Autumn	9	22.2	22.2	22.2
	Winter	55	3.6	0	0
Adjusted means[1]					
	Spring		14.94	4.33	1.97
	Summer		13.23	6.66	2.70
	Autumn		44.52	21.76	11.84
	Winter		18.91	3.44	1.75
Contrasts[2,3]					
	Sp vs S		ns	ns	ns
	Sp vs A		ns	**	*
	Sp vs W		ns	ns	ns
	S vs A		ns	**	*
	S vs W		ns	ns	ns
	A vs W		ns	**	*

[1]Adjusted means were calculated using a generalised linear model analysis with a binomial error term, a logit-link function, and allowing for over-dispersion.
[2]ns=not significant at P=0.05; * and **=significant at P=0.05 and P=0.01 respectively.
[3]Sp = spring, S = summer, A = autumn and W = winter.

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The data from this study show that the probability of a seedling surviving to 1 year is very low, about 0.046 (average of adjusted means for spring, summer, autumn and winter at 12 months; Table 2). The reason for survival being greater in autumn-emerging seedlings than in those emerging at other times of the year is probably related to climate. Seedlings that emerge in the late spring must survive through summer hot/dry periods, whilst those emerging in late autumn would not be subjected to the same conditions until they were older and more established. In this study seedlings were measured either 6-weekly or 3-monthly, therefore this is the minimum survival age. Tracking the fates of individual seedlings for up to 1 year was relatively easy, but once these seedlings became shoots they would often merge with other nearby plants. Moreover, because shoots within clumps often move position and come and go over time it was not possible to track individual shoots' survival beyond one year. However, it was assumed that if a seedling survived for a year or more it would probably survive to become part of a clump.

The contribution of the seedlings to the population growth of the giant buttercup populations studied here cannot be determined from this experiment because the turnover of shoots arising from the rhizomes was not measured. In other studies, seedling recruitment was of little importance to population growth (Sarukhán & Harper 1973). Seed may be important only in colonising new sites and retaining genetic diversity (Barrett & Silander 1992).

The present finding of low seedling survival in giant buttercup is not unusual (Saurina 1972; Sarukhán & Harper 1973), and this phenomenon is also common on other long-lived vegetatively spreading perennials (Weppler et al. 2006). Sarukhán & Harper (1973) found that the probability that a giant buttercup seedling would survive to 1 year was 0.12 and that high mortality occurs soon after germination, becoming gradually less with increasing age. However, seedling survival has been found to vary between years and has been recorded to be as high as 0.7–0.97 (Rabotnov 1958; Rabotnov & Saurina 1971). In addition, environmental heterogeneity, emergence time, seedling density, seed production, natural field conditions (e.g. temperature, predation, competition) and the availability of suitable micro-sites can all have an effect on seedling survival (Harper 1977; Barrett & Silander 1992). Seedling survival was also found to be reduced in both waterlogged and well drained conditions (Harper & Sagar 1953; Harper 1957) and increased where vegetation had been disturbed (Kiviniemi & Eriksson 1999) or covered by dung pats (Parish & Turkington 1990).

Disturbance to the pasture cover can contribute to both the recruitment and demise of seedlings. Dung pats are a primary source of disturbance in dairy pasture causing smothering of existing seedlings and later creating bare raised sites suitable for recruitment. Moreover, Takaka valley pastures typically become trampled and pugged by stock in winter, a process that also creates bare raised sites. In the case of recruitment, disturbance and raised sites where seedlings can become established may account for the increase in seedling emergence in late winter.

In considering pasture management to reduce seedling establishment, dairy farmers should aim to reduce the risk of seedling flushes by improving the pasture condition during the late autumn and winter. This could be done by minimising pugging and maintaining a good cover of grass to reduce the number of raised and bare micro-sites where germination can occur.

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