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Emergence and seedling survival of *Lotus tenuis* in *Festuca arundinacea* pastures

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Abstract

Emergence and survival of seedlings of lotus or narrowleaf trefoil (*Lotus tenuis* Waldst.) were monitored in 4 grazed pastures dominated by tall fescue (*Festuca arundinacea* Schreb.) for 2 successive years. The objective was to detect patterns and environmental conditions promoting successful seedling establishment of lotus. Emergence followed a seasonal pattern each year, with most emergence occurring towards the end of winter. Seedling emergence occurred mainly in heavily grazed sites which occupied 45 to 90% of each pasture. Seedling emergence was greatest, but seedling survival was poorest in the wettest year. Competition resulting from climatic conditions favoring growth of established pasture plants was detrimental to establishment of lotus seedlings. In contrast, heavily grazed areas provided microsites that enhanced survival of new recruits during the spring growing season. Dense seedling stands emerging on feces were overcrowded and suffered the highest mortality, thus, they contributed little to recruitment of lotus. However, dispersal of lotus was enhanced by the presence of seeds in livestock feces.

Key Words: *Lotus tenuis*, population dynamic, emergence, seedling survival.

Flooding grasslands of the Salado River Basin occupy about 5,800,000 ha, in the province of Buenos Aires, between latitudes 35° 30'N and 37° 40'S and longitudes 56° 50'E and 60° 30'W (Vervoorst 1967, Tricart 1973). The climate is subhumid-mesothermal (Thornthwaite 1948). Average annual rainfall is 840 mm with a moderate hydric deficit from December to March, and droughts are frequent. Soils are characterized by high alkalinity, high salt concentration, phosphorus deficiency, and poor drainage. Native grasslands are continuously grazed during cattle-breeding seasons. Low levels of beef production, averaging 70 kg ha^{-1} $year^{-1}$ (Boccheto 1981), are due to livestock management and low primary herbage production in winter and summer.

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Legumes such as the short-lived perennial lotus (*Lotus tenuis* Waldst.) with highly nutritious herbage may be useful for increasing beef production. Lotus is naturalized to the area (Miñón et al. 1990), but little information is known about population dynamics of this species and requirements for annual regeneration from seed in this area.

The objective of this study was to determine temporal and spatial dynamics of natural seedling emergence and establishment of lotus in tall fescue (*Festuca arundinacea* Schreb.) pastures subjected to different levels of cattle grazing pressure.

Materials and Methods

This study was conducted at the INTA (National Institute of Agricultural Technology) Experimental Station in Balcarce (37° 47'S 58° 17'W and 130 masl) on a Typic Natraquol soil (USDA Soil Survey Staff 1975) which represents low lands of the Flooding Pampas. Meteorological data (Fig. 1) were provided by the Agromeotorological Station at Balcarce located about 5 km from the experimental field.

The study was conducted on four 1-ha pastures each sown in April 1984 with a mixture of lotus and tall fescue. Lotus was sown at 3 kg ha^{-1} with 1 of 2 tall fescue cultivars sown at 10 kg ha^{-1}. The 2 cultivars differed in growing season with Maris Kasba a Mediterranean selection and El Palenque a temperate selection. Beginning in August 1984, 2 grazing pressures with Aberdeen Angus steers were imposed which resulted in about constant herbage masses of 1,200 kg ha^{-1} dry matter at the high pressure and 2,400 kg ha^{-1} at the low. Steer numbers were adjusted every 14 days based on harvest of herbage biomass. Herbage in fifteen 0.25 m^2 circular quadrats was cut at ground level on each pasture.

Patterns of annual seedling emergence were estimated from December 1986 to November 1988 by monthly counting seedlings which attained the cotyledon stage, within ten 10x200-cm quadrats positioned at random in each 1-ha pasture. Each frame was subdivided into 20 microquadrats, and the sampled microsites were visually characterized as bovine feces, heavily grazed areas (< 2 cm tall) lightly grazed areas (>2 cm tall), and their combinations. Data were analyzed by analysis of variance and means separated by Tukey's ($P<0.05$).

Density of viable seeds was determined in the upper 5-cm of soil after seed production each autumn. Four bulked soil samples were taken per pasture, each consisted of forty 25-mm diameter soil cores. Seeds were recovered and seeds germinated under laboratory conditions were counted with a binocular magnifier (×15).

Seedling survival was assessed by counts beginning with the following dates: August 1987 on pasture, August 1987 on bovine feces, October 1987 on pasture, and October 1988 on pasture. Beginning dates corresponded to the period when the greatest seedling emergence occurred. These emergence fluxes are hereafter referred as cohorts. Counts were conducted every 2 months through April each year after the lotus flowering period. Surviving seedlings up to that time were considered established. These plants bore secondary or higher order branching.

Establishment was measured in forty 30 × 45-cm fixed quadrats located at random on heavily grazed areas and twenty 10 × 10-cm quadrats on bovine feces. No samples were monitored on lightly grazed areas, because of the low emergence that occurred in that situation.

Emerged individual seedlings were marked with telephone wire of different colors, except for those growing in dense groups on feces. In this case, all seedlings were counted and the number of surviving seedlings subsequently overestimates accumulated emergence as it includes seedlings emerged after the initial counting.

Seedling survival data were transformed with $y=(x+0.5)^{0.5}$ when normal distribution of y (Lilliefors 1969) was not achieved. Analysis of variance in a split-plot design with repeated measures was used for data analysis. Simple log-linear regression analysis between survival probability (y = density at sample date/initial density) and month from emergence to sampling (x) was used.

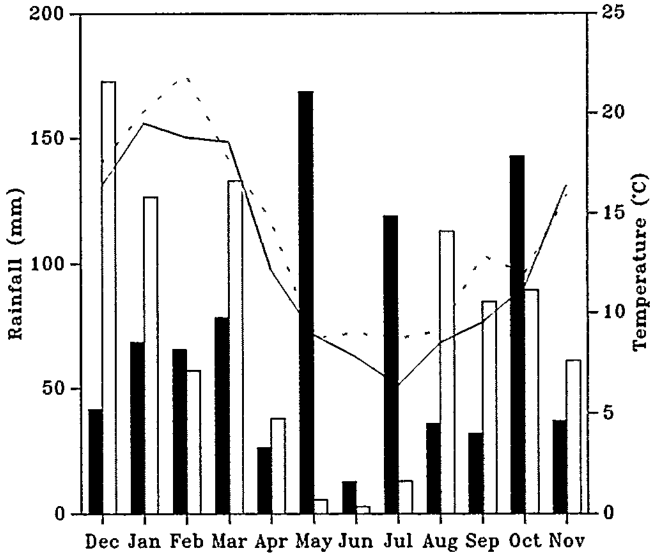

Fig. 1. Rainfall (■ 1986-87; □ 1987-88) and mean daily air temperature (- - - - 1986-87; —— 1987-88) at the Agrometeorological Station of Balcarce, Buenos Aires province (37° 47′ S; 58° 17′ W).

Results and Discussion

Temporal Variation: Seasonality

Accumulated seedling emergence was greater during the December 1986 to November 1987 period (52 seedlings m^{-2} $month^{-1}$) than the December 1987 to November 1988 period (8 seedlings m^{-2} $month^{-1}$). Differences between periods were mainly due to differences in emerging seedlings to seed ratios which were greater during the first (0.158) than the second period (0.042). While the overall mean density of available seeds decreased by 41% (3,968 to 2,355 m^{-2}) from 1987 to 1988, the mean emergence rate decreased by 74%.

Values of monthly emergence were calculated to describe and compare seasonal variation of emergence (Fig. 2). Although more than 6 times as many seedlings emerged during 1986–87 than during 1987-88, the proportion of seedlings emerging from July through September was similar during both periods, 81% and 88% of annual emergence.

Even though climatic conditions differed between years (Fig. 1) the greatest emergence occurred in August ($P<0.05$). The second year was drier and cooler than the first one during the period preceding maximum seedling emergence from May to July (1987: 301 mm and 3.5°C; 1988: 22 mm and 2.3°C mean low temperature). Thus fewer seedlings emerged in 1988 than in 1987. However, some seedling emergence was recorded in all months except November.

Weather affects seed germination, either directly on the seed or indirectly through effects on surrounding vegetation. Seed germination and seedling emergence are integrated responses of seeds to the totality of physical and biotic environmental factors (Karssen 1982). Seed rain of lotus normally contains more than 90% hard seeds (Milano et al. 1975) that have an impermeable seed coat. These coats could prevent germination of most seeds until the next spring (Midgley and Stone 1958 cited by Seaney and Henson 1970). The small proportion of soft seeds can germinate as quickly as favorable environmental conditions occur. Hard ones germinate only after seed coats are scarified and may require cold stratification similar to that required by several other species (Baskin and Baskin 1985, Come and Thevenot 1982, Grime 1979, Karssen 1982, Mujica and Rumi 1991a, 1991b).

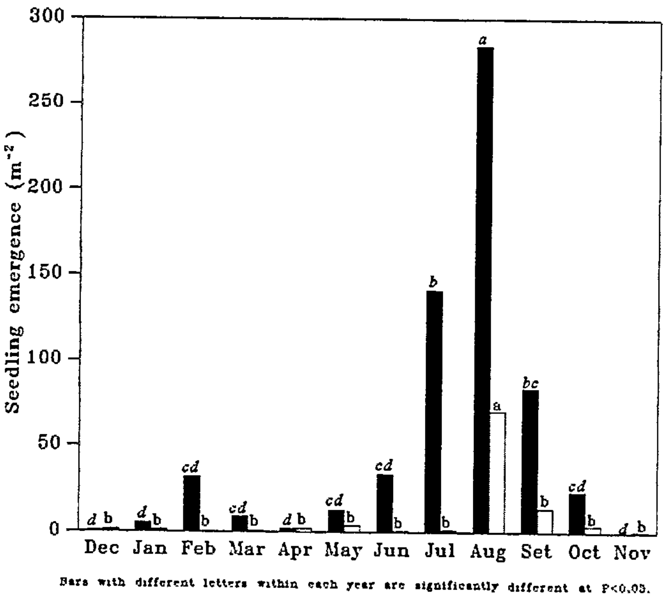

Fig. 2. Monthly emergence during 1986-87 (n) and 1987-88 (r).

Table 1. Variation of seedling densities for 4 monitored cohorts of *Lotus tenuis*.

Cohort	August	October	December	February	April
	(m^{-2})				
August 87 in pasture	131 a[1]	107 a	27 b	11 b	6 b
August 87 in feces	6929 a	7265 a	710 b	310 b	140 b
October 87 in pasture		104 a	13 b	4 b	2 b
October 88 in pasture		49 a	16 b	11 b	10 b

[1]Dates with different letters within each cohort are significantly different at P<0.05.

Emergence and Regenerative Niche

Heavily grazed areas, lightly grazed areas, and feces occupied an average of 71%, 26%, and 3% in the 4 pastures. Emergence was greater ($P<0.05$) in heavily grazed areas (39 seedlings m^{-2} $month^{-1}$) than in lightly grazed areas (19 seedlings m^{-2} $month^{-1}$) or on feces (11 seedlings m^{-2} $month^{-1}$). Similar results were reported for other plant species (Fenner 1978, Gross 1980, Goldberg and Werner 1983), and the importance of soil disturbance for the regeneration of opportunistic species such as lotus is well known.

Mean annual emergence was similar between feces and lightly grazed areas. Dense emergence was concentrated only in feces from cattle that ingested lotus during seed production. Consequently, the proportion of months without emergence was greater in feces (50%) than in lightly grazed (33%) or heavily grazed (13%) areas. Thus, the area of feces contributes little to the realized recruitment of lotus on a per area basis, since feces occupies very little surface area of grassland. However, the long-distance spread of lotus may be facilitated by ingestion of seed and its subsequent excretion in feces.

Table 2. Linear regression of $\log_e$ surviving seedlings (m^{-2}) on time (in month) from 4 cohorts on pastures and on feces (see materials and methods).

Cohort	Equation
August 87 in pasture	$y = 14.33 - 1.01 \times, r = 0.61$
August 87 in feces	$y = 14.33 - 1.04 \times, r = 0.68$
October 87 in pasture	$y = 12.56 - 1.55 \times, r = 0.65$
October 88 in pasture	$y = 13.39 - 0.72 \times, r = 0.40$

Differences in initial seedling density for each cohort (Table 1) diminished with time due to an increase in the mean monthly mortality rate (d) among cohorts, calculated from the fitted linear regression for survivorship (Table 2) as $d= 1 - e^{-b}$ (August 1987 in pasture= 0.64, August 1987 in feces= 0.65, October 1987 in pasture= 0.79 and October 1988 in pasture= 0.47).

The only cohort in which seedling mortality rate was significantly different ($P<0.05$) from the others was October 1987. Differences in the initial density and mortality rates were finally translated to the mean density of established plants.

Survival of seedlings was described adequately by log-linear models indicating a constant death rate throughout the analyzed period, but early emerging seedlings in the August cohorts survived until October. However, from October on all seedling density decreased exponentially in all cohorts.

Conclusions

Persistence of lotus in pastures appears to be highly dependent upon maintenance of a viable soil-seed bank from which a few seedlings emerge (4 to 16%) and fewer survive through the main growing season. Recruitment of lotus could be increased by controlling grazing pressure to reduce the competition or interference of grasses on lotus seedlings.

Moreover, it is also evident that even though feces can concentrate high densities of seeds and seedlings of lotus, these seedlings have little influence on the overall recruitment but can play a significant roll in long distance dispersal of lotus.

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