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# EMERGENCE AND SURVIVAL OF *BROMUS SETIFOLIUS* SEEDLINGS IN DIFFERENT MICROSITES OF A PATAGONIAN ARID STEPPE

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## ABSTRACT

In a plant community of the arid steppe, structurally characterized by shrubs encircled by grasses and scattered tussocks with bare soil patches interspersed, the hypothesis of differential seedling survival in differentially protected microsites was tested. Seeds of *Bromus setifolius* were placed in the soil at two different depths and in two different microhabitats: leeward of a shrub and bare soil patch. No changes were recorded in the germination rate treatments. However, seadling survival under shrub protection was lower than in bare soil patches. Higher soil water potential in bare soil patches - probably due to smaller root biomass of established grasses – appeared to be the major determinant of the higher survival rate observed. A model based on seed density and seedling survival is proposed for seedling recruitment in relation to distance from the mother plant. The promotion of seedling establishment in the best suited microhabitats is visualized as a possible means of enhancing recovery of vegetation.

## INTRODUCTION

Extent of sustenance of vegetation cover in arid environments is largely determined by the rates of germination and of seedling survival (Went, 1979; Goodall, 1979). Plant cover is also modulated by factors which influence growth and plant mortality of both seedlings and adult plants, such as grazing and water availability.

Germination and seedling survival are key processes for the Patagonian arid steppe, where bare soil patches account for 36% of the total area (Soriano et al., 1986), and species with long rhizomes or stolons are rare. Thus, sexual reproduction does not represent a mere alternative reproduction pathway, becoming relevant only under extreme conditions, but it is the major pathway for recruitment of new individuals in the existing plant community.

Most of Patagonia is covered by arid steppes (Soriano, 1956), according to the interpretations of Singh et al. (1983). The most conspicuous plant community of this huge steppe – as determined in SW Chubut (45°30′S, 70°10′W) – is characterized by *Stipa speciosa* Trin. et Rupr., *Stipa humilis* Vahl and *Adesmia campestris* (Rendle)

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Skottsberg (Golluscio et al., 1982). *Mulinum spinosum* (Cav.) Pers. is an abundant shrub species in this community. *Bromus setifolius* Presl. (*Bromus macranthus* Mey. var. *setifolius* Desv.) is the only grass species with tender, nonlinear leaves in the community and it is one on which sheep commonly graze. Mean annual precipitation in the area is 168 mm. The coldest month is July, with a mean temperature of 1.9°C, and the warmest month is January, with a mean temperature of 13.6°C. Strong west winds prevail during most of the year. Soils are sandy with abundant pebbles and stones, commonly cemented by calcium carbonate at a depth of 50 cm or more. Sheep grazing has been practised since the beginning of this century all over the region (Soriano, 1983).

Plant community structure is characterized by two components:(a) shrubs encircled by a ring of grasses and other herbaceous plants; and (b) scattered tussock grasses interspersed with bare soil patches (Soriano, 1981). It is suggested here that these different structural components form a variety of microsites, dissimilar in ecological conditions. The central hypothesis also states that microsites with maximal protection from dessicating winds provide the best conditions for germination and survival.

Plant cover increase, after exclusion of large herbivores, has proved to be extremely slow (Soriano et al., 1980). It is assumed that a better understanding of the processes involved in microhabitats within the arid steppe might lead to an improvement in our knowledge of the causes for such slow response. It will also assist us in developing effective procedures for the acceleration of plant cover increase.

## MATERIALS AND METHODS

Propagules of *Bromus setifolius* (caryopses enveloped by lemma and palea) were harvested in the experiment area during the month of January. (For simplicity, propagules will be denominated as seeds.) Batches of 10 seeds were placed in nylon mesh bags 5 x 5 cm in size. A mesh size of 17 threads per centimeter was used and each thread was 0.25 mm in diameter. Bags were buried in May (autumn) either with a very thin sand cover above them ("s" treatment) or 4 cm deep in the soil ("d" treatment). A plastic covered wire attached to each bag and in view above the soil surface indicated the bag's position. In accordance with the structure of vegetation already described and the hypothesis proposed, seed were located in two different sites: (a) leeward (to the east) of *Mulinum spinosum* shrubs; and (b) in the center of bare soil patches, each of which was about 30 cm in diameter. Twenty bare patches and twenty microsites leeward of shrubs were used for statistical replications. The number of seedlings which emerged from each buried bag in September and November was recorded. The number of plants surviving during the following January and June was also recorded.

Two bags of each treatment were recovered in November, after digging carefully to a depth sufficient to recover the young plants with their entire system. The following characteristics of each plant were determined: (1) number of leaves and maximum length of exposed parts, in order to assess possible responses and adjustment to soil water conditions. Length of the "aboveground" exposed portion was calculated by subtracting the length of the etiolated part from the maximum length of the leaves. Maximum length of the seedling roots was added to the length of the etiolated part in order to estimate the actual depth attained by the roots in each case. The length of the etiolated part at the base of the plant was an indicator of the actual depth from which the seedlings emerged.

Various environmental factors were determined for the two microhabitats selected for seed location. Soil water potential was measured by means of thermocouple hygrometers (Spanner, 1951) located 10 cm deep in places similar to those where seed bags were buried: bare soil patches and grass rings encircling a shrub. Three replications were used for each case.

Wind velocity behind a typical *Mulinum spinosum* shrub (70 cm high) and at the center of a bare soil patch was determined, during January (summer), by means of integrating cup anemometers installed so as to locate the center of the cups 30 cm above the soil surface. A third anemometer registered wind velocity above canopy level at a height of 100 cm. Evaporation was also determined during January by means of Piche evaporimeters (Walter, 1951), located on the same sites as the anemometers, but with evaporating discs at 10 cm and 45 cm above the soil surface.

Root densities of established grasses for the two microsites were estimated during January, from soil samples obtained – using cylinders 5 cm in diameter and 10 cm high – at locations representative of each microsite. Ten replications were used in each case. Roots were separated from soil after carefully washing the samples on a sieve, drying at 70°C and weighing.

Analysis of variance was performed on the data, which included: number of emerged seedlings, plant survival determinations and measurements of seedling characteristics. Angular transformations were performed when appropriate. Differences among means were tested for significance by Duncan's or Sheffé's tests (Snedecor and Cochran, 1967).

## RESULTS

In the course of the year of the experiment (May 1980–April 1981), total precipitation was 114.7 mm. During the period September–December, which is presumed to be a critical time for the establishment of seedlings, rainfall totaled 10.3 mm. Soil water potential was high at the time seeds were buried (May) and remained so during September, by which time the bulk of seedling emergence had occurred. Germination rates during early spring (September) was high and quite similar to the values obtained under best conditions in laboratory trials (Soriano, 1960). The mean maximum and the mean minimum temperatures during September were 11.7 and −0.6°C, respectively. Results for soil potential (Fig. 1) and the average number of plants per treatment did not significantly change during November (Table I). Between September and November some new seedlings appeared and some died. New seedlings were easily distinguishable from older plants, and standing dead seedlings remained clearly detectable. Comparison of number of seedlings for the counts of September and November indicated no significant differences ($p \leqslant 0.05$) resulted during either treatment at either of the two sites. During the November–January period, deaths occurred at different rates in different microsites. We assumed that no new germination ocurred after November because water potential in the upper soil layer was very low during this period. Based on this assumption, "survival", in Table II, was represented by the percentage of the number of seedlings which had been registered in November. Survival of young plants in open soil patches was significantly higher ($P \leqslant 0.01$) than leeward of a shrub, regardless of seed depth. Similar trends were observed both in January – when there were severe stress conditions – and in June – when the water deficit period had ended (Table II).

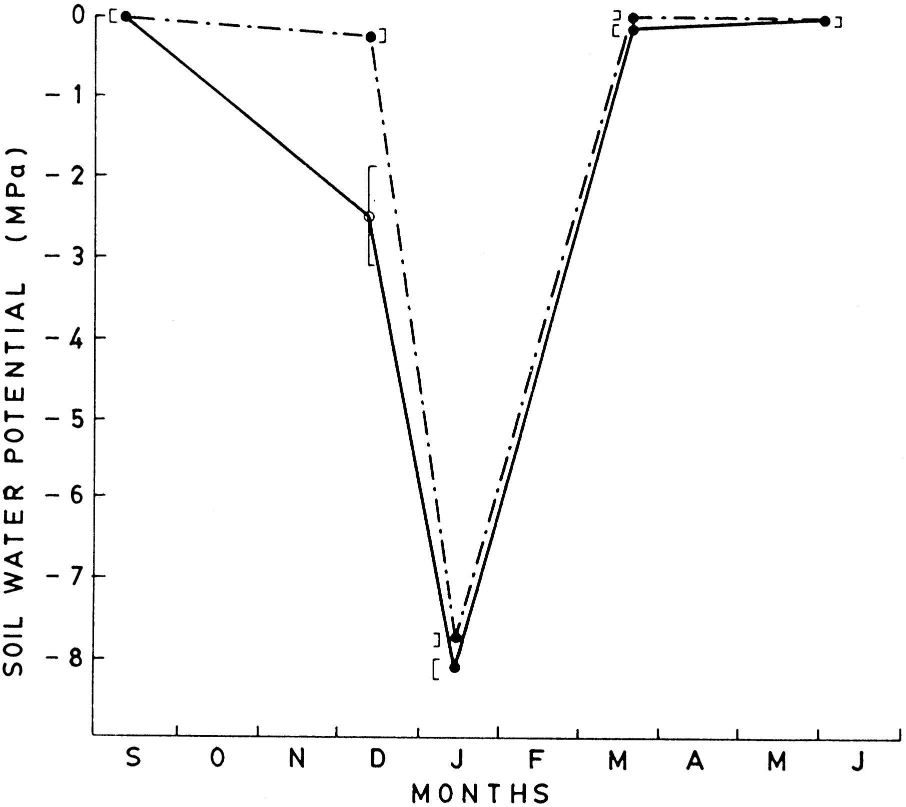

Fig. 1. Soil water potential throughout the year (± standard error; number of replications, N = 3) in bare soil patches (— · — · —) and in the grass rings surrounding shrubs (————).

TABLE I
Percentage number of seedlings in September and November: percentage of the number of seeds buried in May at each microsite. Values are means ± SE.

| *Microsite:* | *Leeward of a shrub* | | *Bare soil patch* | |
|---|---|---|---|---|
| *Month* | *Depth: Soil surface* | *4 cm* | *Soil surface* | *4 cm* |
| September | 58.5 ± 0.53 | 72.3 ± 1.20 | 66.0 ± 2.07 | 67.6 ± 1.30 |
| November | 58.1 ± 0.76 | 69.0 ± 2.13 | 60.0± 2.60 | 64.3 ± 1.25 |

TABLE II
Survival of plants in January and June expressed as percentage of seedling countings in November. Vaues are means ± SE

| | *Microsite* | |
|---|---|---|
| *Month* | *Leeward of a shrub* | *Bare soil patch* |
| January | 15.2 ± 4.6 | 45.3 ± 5.7 |
| June | 7.5 ± 3.7 | 24.8 ± 4.7 |

Length of etiolated portion was 1.8 cm (SE = 0.2) for shallow buried seeds and 2.9 cm (SE = 0.01) for deep buried seeds, indicating that seeds remained within the range of depths at which they were located. This does not mean that deflation or sand accumulation had not occurred, but that original differences in depth were not nullified.

Number of primary roots and of leaves at the end of the experiment did not differ among treatments. On the other hand, length of the exposed "aboveground" part was significantly ($p \leqslant 0.05$) smaller in bare patches than in microsites behind shrubs, while seedlings from shallow planted seeds were significantly ($p \leqslant 0.05$) smaller than those from deep planted seeds (Table III).

Length of the "belowground" portion presented an opposite pattern to that of the "aboveground" portion. The "belowground" part was longer in bare patches and for shallow planted seedlings. Consequently, seedlings in bare patches had a smaller ratio of shoot length to root length. Shallow buried seeds produced a longer root system, which apparently compensated for original differences in location (Table III).

TABLE III
Length (cm) of "aboveground" and "belowground" portions of plants recovered in different microsites at the end of the experiment. Values are means ± SE.

| *Plant portion* | *Planting depth* | *Microsite* *Leeward of a shrub* | *Bare patch* | *Mean* |
|---|---|---|---|---|
| Aboveground | Shallow | 3.7 ± 0.2 | 3.0 ± 0.3 | 3.4 ± 0.2 |
| | Deep | 5.8 ± 0.4 | 4.1 ± 0.3 | 5.2 ± 0.3 |
| | Mean | 4.7 ± 0.3 | 3.4 ± 0.3 | |
| Belowground | Shallow | 16.8 ± 0.9 | 20.0 ± 0.6 | 18.2 ± 0.7 |
| | Deep | 14.9 ± 0.9 | 13.5 ± 1.5 | 14.4 ± 0.8 |
| | Mean | 15.9 ± 0.7 | 17.4 ± 1.1 | |

There were large differences in microhabitat conditions, as indicated by data on wind velocity, evaporation rate (Table IV), and soil water potential (Fig. 1). As expected, wind velocity and evaporation rate were higher in open sites than in protected sites behind shrubs. Soil water potential presented a different pattern. No differences were observed during fall and winter, but soil in bare soil patches dried out at a slower rate. Soil water potential was higher in bare soil patches than in the surroundings of shrubs during the dry period (Fig. 1).

TABLE IV
Relative evaporation rate and relative wind velocity in open sites and leeward of shrubs. Both measurements were carried out in January and indicate atmospheric water vapor demand in the two microsites

| *Site* | *Height above soil (cm)* | *Relative evaporation rate (%)* | *Relative wind velocity (%)* |
|---|---|---|---|
| Open site | 5 | 80.0 | – |
| | 30 | – | 76.0 |
| | 45 | 100.0 (1.56 mm h $^{1}$) | – |
| | 100 | – | 100.0 (6 m s $^{1}$) |
| Leeward of a shrub | 5 | 36.5 | – |
| | 30 | – | 15.0 |
| | 45 | 57.5 | – |
| | 100 | – | |

TABLE V

Root mass of established grasses for the two different microsites at which seeds were buried. The measurements were carried out in January and the values are means of 10 replications ± SE. Different superscripts indicate significant differences of the means of 10 ($p \leqslant 0.01$)

| *Microsite* | *Root mass (g. dm$^{-2}$)* |
|---|---|
| Leeward of a shrub | $1.87^{a} \pm 0.30$ |
| Bare soil patch | $0.62^{b} \pm 0.05$ |

Root biomass of established grasses was significantly smaller in bare soil patches than behind shrubs (Table V). The large difference in root biomass between microsites could account for the differences in soil water potential.

## DISCUSSION

Results indicated that there were no differences in germination of *Bromus setifolius* between microsites. Survival of plants after the first year and through the stress period of summer drought differed between microsites within the arid steppe. However our proposed "central hypothesis" was rejected, since young plants living behind shrubs showed lower survival rate than fully exposed plants in bare soil patches. Higher soil water potential as well as smaller ratios of shoot length to root length for seedlings in bare soil patches appear to be the major determinants of the lower mortality rate. Higher water availability was, seemingly, the result of smaller root biomass in these microsites. Grasses in the arid steppe are concentrated around shrubs and scattered in between them (Soriano, 1981). Root biomass and water availability apparently follow a similar spatial pattern. The smaller plants which grow in exposed microsites indicated that shrubs must have provided initially some kind of shelter and that this effect was later offset by the differences in water availability. During winter, when water was usually available, the shelter effect probably gave an advantage to seedlings close to shrubs, which resulted in longer leaves. During the dry period in spring and summer, young plants in bare soil patches with higher water availability and a smaller ratio of shoot length: root length had a definite advantage, which resulted in a higher survival rate. Probably, in wet years differences between microsites are smaller than in dry years. Average precipitation, according to a 39 year record, is 168 mm, and the proportion of years for which the precipitation is below 150 mm is 49%. Moreover, in 55% of the years with annual precipitation above 150 mm, rainfall in spring (September–December) is below 45 mm. Thus, the probability of having responses like those described here seems to be rather high.

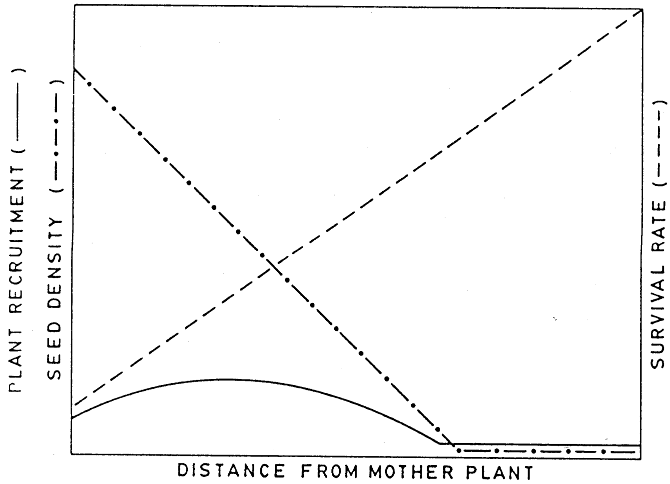

Fig. 2. A hypothetical model of plant recruitment as a function of distance from the mother plant. Seedling recruitment is the result of the product of seed density and survival rates. The shape of the seed density and survival curves was suggested by observations and experimental results.

Studies of the pattern of water absorption by shrubs and grasses (Soriano and Sala, 1983) suggest that the differences in soil water potential between the two microsites were more likely due to the higher grass density in the rings that surround shrubs than to the effects of the shrubs themselves.

The hypothesis of a lack of competition among plants in desert environments has been proposed previously (Noy-Meir, 1979/80). The results presented here point out that a high degree of competition existed among adults and seedlings. Moreover, conditions determining competition were no evenly distributed among the microhabitats of this plant community.

Deep planted seeds seemed to enjoy growing conditions, as indicated by the length of their exposed portions, although this was not enough to significantly modify the survival rate. The observed differences could have been the result of greater translocation of soluble substances out of the seed because of a longer duration of high water potential in its tissues. Differences in growth could not be accounted for by differences in water supply to the plant, since both root systems explored approximately the same portion of the soil profile.

The propagules of *Bromus setifolius* are relatively large (approximately 15 mm long and 4 mm wide) and flat; they have sharp points at both ends. By the end of January it is common to see them stuck in the sand around the mother plant. Ellner and Shmida (1981) pointed out that the absence of telechory is a characteristic of most desert plants. Taking into account the atelechory of *Bromus setifolius* and the effect of distance from the mother plant upon seedling survivability, a hypothetical model of the pattern of seedling recruitment was developed (Fig. 2). The experiment described here indicates that as the distance from a mother plant located in a ring around a shrub increases, the probability that seedling will survive through the first year also increases. Seed density, we assume, rapidly decreases with distance from the mother plant (Alippe and Soriano, 1978). The product of seed density and survival rate yields a recruitment curve with a peak at a distance from the parent plant where a new individual is most likely to appear. This is a simplification of the pattern which occurs in nature, because it assumes that there is no influence of neighbouring plants. The model used is similar to Janzen's model for plant recruitment in a forest ecosystem. In the latter case seed availability and predation are considered the determinants of the recruitment pattern (Janzen, 1970).

Young shrubs, which have not developed a complete and dense peripheral ring of grasses, would produce a different pattern of recruitment. Seeds located very close to these young shrubs would not suffer as much from competition for soil water with established grasses. Consequently, recruitment would be maximum very close to the protecting plant and would decrease with distance.

The hypothetical model for recruitment suggests an explanation of the extremely low recovery for vegetation rate referred to previously. Most seeds are concentrated in microhabitats where their seedlings have a very low probability of surviving through the first year. Therefore, it is possible to envisage techniques for accelerating recovery by increasing the number of available seeds at optimum microsites or increasing the density of these microhabitats.

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## REFERENCES

Alippe, H.A. and A. Soriano. 1978. La problación de diseminulos en el suelo de un pastizal de Stipa en el oeste de Chubut. Ecología 3: 133–138.

Ellner, S. and A. Shmida. 1981. Why are adaptation for long-range seed dispersal rare in desert plants? Oecologia (Berl.) 51: 133–144.

Golluscio, R.A., R.J.C. León and S. Perelman. 1982. Caracterización fitosociológica de la estepa del oeste del Chubut; su relación con el gradiente ambiental. Bol. Soc. Argent. Bot. 21: 299–324.

Goodall, D.W. 1979. The autoecology of desert plants. Cairo Univ. Agric. Studies, Special Publication 1: 53–65.

Janzen, D.H. 1970. Herbivores and the number of tree species in tropical forests. Am. Nat. 104: 501–528.

Noy-Meir, I. 1973. Desert ecosystems: Enviroment and producers. Annu. Rev. Ecol. Sys. 4: 25–51.

Noy-Meir, I. 1979/80. Structure and function of desert ecosystems. Isr. J. Bot. 28: 1–19.

Singh, J.S., W.K. Laurenroth and D.G. Milcunas. 1983. Geography of grassland ecosystems. Prog. in Phys. Geogr. 7: 46–80.

Snedecor, E.W. and W.G. Cochran. 1967. Statistical Methods. 6th ed. The Iowa State University Press, Ames, Iowa USA. 593p.

Soriano, A. 1956. Los distritos florísticos de la Provincia Patagónica. Rev. de Invest. Agrícolas. 10: 323–347.

Soriano, A. 1960. Germination of twenty dominant plants in Patagonia in relation to regeneration of the vegetation. Proc. 8th Int. Grassland Congr. pp. 154–158.

Soriano, A. 1981. Ecología del patizal de coirón amargo en el sudoeste de Chubut. Producción Animal 8: 38–43.

Soriano, A. 1983. Deserts and semi-deserts of Patagonia. In : N.E. West, ed. Temperate deserts and semi-deserts. Elsevier Scientific Publishing Co., Amsterdam. pp. 423–460.

Soriano, A., O.E. Sala and R.J.C. Léon. 1980. Vegetación actual y vegetación potencial en el pastizal de coirón amargo (*Stipa* spp.) del SW de Chubut. Bol. Soc. Argent. Bot. 19: 309–314.

Soriano, A. and O.E. Sala. 1983. Ecological strategies in a Patagonian arid steppe. Vegetation 56: 9–15.

Soriano, A., A.H. Nuñez and C.M. Ghersa. 1986. The two module structure of a Patagonian arid steppe. J. Ecol. (Submitted.)

Spanner, D.C. 1951. The Peltier effect and its use in the measure- ment of suction pressure. J. of Exp. Bot. 2: 168–195.

Walter, H. 1951. Einführung in die Phytologie. III. Grundlagen der Pflanzenverbreitung I. Teil. Standortslehre. Eugen Ulmer, Stuttgart, 525 p.

Went, F.W. 1979. Germination and seedling behaviour of desert plants. In : D.W. Goodall and R.A. Perry, eds. Arid-land Ecosystems, Vol. 1. pp. 477–489.