THE SOIL SEED BANK OF A LONG-GRAZED *THEMEDA TRIANDRA* GRASSLAND IN VICTORIA

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The soil seed bank of a remnant *Themeda triandra* grassland was described using the seedling emergence technique. The grassland had been grazed by stock for over 70 years until managed for nature conservation in 1985. Seventeen native species and 24 exotics were recorded in the seed bank, which was dominated by exotics. *Vulpia bromoides* accounted for 61% of germinants and *V. bromoides, Romulea rosea* and *Aira cupaniana* together accounted for 81%. The seed bank contained one native species, *Crassula decumbens*, that was not otherwise known from the reserve and three additional exotics, *Cerastium glomeratum, Sagina procumbens* and a *Vicia* species. Species-poor and species-rich *T. triandra* grasslands within the reserve had very similar seed banks, and few of the extra species in the vegetation of the former were present in the soil seed bank. It is suggested that the soil seed banks of long-grazed remnants of *T. triandra* grasslands may contain few native species that are not present in the standing vegetation. In long-grazed *T. triandra* grassland, disturbances that are necessary to maintain the diversity of native species, such as burning, are likely to promote exotic species as much as, if not more than, natives.

TEMPERATE grasslands dominated by *Themeda triandra* are poorly represented in conservation reserves in Australia (Specht 1981) and the best remnants in Victoria are typically small and fragmented on rail and road easements (Stuwe & Parsons 1977, Stuwe 1986). Effective conservation of grassland ecosystems requires the reservation of large areas. However, suitable sites invariably have been grazed by stock for considerable periods of time and, consequently, have relatively low diversities of native species, and many exotics (Stuwe 1986). Many sites from which grazing has recently been removed support dense *T. triandra* (over 90% cover) with few individuals of other species (Stuwe 1986, McDougall 1987).

Typically, the standing vegetation at a particular site is only part of the total flora, and propagules of additional species are stored in the soil, often for periods far longer than the lifespan of established plants. Species present in the soil seed bank may often be promoted by soil or vegetation disturbances such as ploughing or burning (Major & Pyott 1966, Roberts 1981, Fenner 1985, Chancellor 1986). Soil seed banks thus provide the potential for vegetation change.

The 154 ha Derrimut Grassland Reserve, the largest grassland reserve on the basalt plains of western Victoria, was grazed by sheep and cattle for over 70 years until managed for nature conservation in 1985. It was studied in order to: (a) provide a general description of the soil seed bank of a previously grazed *T. triandra* grassland now managed for nature conservation; and (b) determine whether native species in the standing vegetation of small patches of species-rich grassland within the reserve were represented in the seed bank of larger areas of species-poor grassland.

METHODS

The Derrimut Grassland Reserve (37°48′30″S, 144°47′40″E) is 14 km west of Melbourne, Victoria. Site characteristics, land use history and a floristic classification of the vegetation are given by Lunt (1990a). Although the reserve contains a number of native grassland and wetland vegetation types, the seed bank study included only grasslands dominated by *T. triandra*. One species-rich site, floristically related to *T. triandra* grassland but classified as *Vulpia bromoides* grassland due to a low cover of *T. triandra* (Lunt 1990a), is referred to *T. triandra* grassland throughout this paper.

In January 1987, soil samples 40 mm deep and 0.25 m^2 in area were taken next to four of the richest and four of the poorest vegetation quadrats. The mean species richness of the former was 35 species per 15 m^2 quadrat and of the latter 11 species per quadrat. Except for one soil sample which could not easily be sieved, samples were passed through a 4 mm^2 sieve to remove coarse material and recognizable vegetative propagules, particularly corms of *Romulea rosea*. A 10 mm deep layer of each soil sample was spread over potting mix in five seedling trays, each 8.96×10^{-2} m^2 in area, except for two quadrats for which sieved soil was sufficient for only four trays. Five control trays were filled only with potting mix. Trays were randomly arranged in an unheated glasshouse for 151 days, from 13 January to 24 May 1987. They were regularly watered and seedlings were removed as identified. Densities of viable seeds were compared statistically by Students t-test (Sokal & Rohlf 1981).

Danthonia and *Isolepis* seedlings were identified only to genus, and in three cases pairs of species were not distinguished (Table 1). *Cyperus tenellus* and *Schoenus apogon* were noted in the field but not as glasshouse germi-

Species	Density (viable seeds per m^2)					
	Species-poor			Species-rich		
	mean	range		mean	range	
*Vulpia bromoides	3199	268	10848	15087	8796	23950
*Romulea rosea	1483	455	3103	2711	170	9497
*Aira cupaniana	128	56	170	1759	45	3509
Juncus bufonius/capitatus	805	112	1786	319	27	786
Themeda triandra	769	447	1375	139	98	241
*Briza maxima/minor	81	0	313	430	9	1149
Wahlenbergia sp.	232	152	304	208	45	304
*Centaurium tenuiflorum	221	71	536	186	45	509
Isolepis spp.	142	22	277	199	0	777
*Sagina procumbens	152	0	591	186	54	509
Danthonia spp.	26	9	54	253	100	643
*Cicendia quadrangularis	47	0	170	147	36	420
Calocephalus citreus	9	0	27	172	0	500
Crassula decumbens	46	22	89	103	0	313
*Gnaphalium purpureum	39	9	67	110	0	402
*Hypochoeris radicata	73	45	125	53	0	107
Oxalis sp.	73	9	212	36	0	98
Juncus subsecundus	9	0	27	70	0	201
*Trifolium campestre/dubium	32	9	71	7	0	11
*Cerastium glomeratum	16	0	54	16	0	36
*Leontodon taraxacoides	14	0	36	10	0	27
Deyeuxia quadriseta	3	0	11	24	0	67
*Lolium rigidum	12	0	22	11	0	44
*Vicia sp.	2	0	9	7	0	18
Helichrysum apiculatum	2	0	9	3	0	11
*Trifolium subterraneum	131	0	473			
*Bromus hordeaceus	84	0	170			
*Trifolium angustifolium	7	0	27			
*Sonchus oleraceus	15	0	22			
Lythrum hyssopifolium	2	0	9			
Leptorhynchos squamatus				14	0	54
Eryngium ovinum				5	0	18
*Hainardia cylindrica				3	0	11
Convolvulus erubescens				3	0	11
*Plantago coronopus				3	0	11
Solenogyne dominii				2	0	9
*Erodium sp.				2	0	9
Hypericum gramineum				2	0	9

Table 1. Mean and range of number of viable seeds per m^2 recorded from species-poor and species-rich *T. triandra* grassland. Species nomenclature follows Forbes & Ross (1988); asterisks denote exotic species.

nants and may have been mistaken for *Isolepis* species. Specimens referred to *Vulpia bromoides* may have included some *Vulpia myuros* forma *megalura*, but most appeared to be of the former species. The *Juncus bufonius/capitatus* group included the native *J. bufonius* and the exotic *J. capitatus*, and equal numbers of both were assumed in native/exotic comparisons.

RESULTS

Excluding glasshouse contaminants, 41 herbaceous species including 17 natives and 24 exotics germinated from the soil seed bank (Table 1). No ferns or woody plants were recorded. Exotics comprised 59% of species but 91% of individuals (Table 2). A small number of species dominated the soil seed bank: *Vulpia bromoides* accounted for 61% of individuals, and the three exotics *V. bromoides, Romulea rosea* and *Aira cupaniana* together accounted for 81%. In contrast, 24% of species were represented by only one or two individuals. Four species identified from the seed bank had not previously been recorded from the reserve: one native, *Crassula decumbens*, and three exotics, *Cerastium glomeratum, Sagina procumbens* and a *Vicia* species.

For all but three species, the number of viable seeds in species-poor and species-rich *Themeda* grassland was not significantly different ($p > 0.05$). Viable seeds (and established plants) of *V. bromoides* and *Aira cupaniana* were significantly more abundant in species-rich than in species-poor grassland, and viable seeds (and flowering culms) of *T. triandra* were more abundant in species-poor than in species-rich grassland ($p < 0.05$). Thirty species were recorded from the seed bank of species-poor grassland and 33 from that of species-rich grassland (Table 1). Both seed banks were similar in composition, with 25 species (66% of seed bank species) occurring in both. Of the 22 native species recorded from the vegetation of species-rich but not species-poor grassland, only four appeared in the seed bank of species-poor grassland: *Calocephalus citreus, Helichrysum apiculatum, Isolepis* species and *Juncus bufonius.*

Group	Individuals Number	%	Species Number	%
Annuals	10113	80	24	59
Perennials	2496	20	17	41
Exotics	11506	91	24	59
Natives	1103	9	17	41
Monocotyledons	11608	92	15	37
Dicotyledons	1001	8	26	63
Total	12609	—	41	—

Table 2. General characteristics of soil seed bank of a long-grazed *Themeda triandra* grassland.

DISCUSSION

The seed bank of *Themeda triandra* grassland in the Derrimut Grassland Reserve possessed characteristics typical of most seed banks, including high spatial variability, poor correspondence with the standing vegetation, domination by one or two species of annual monocotyledons, and a relatively low representation by perennials (see e.g. Roberts 1970, Donelan & Thompson 1980, Rabinowitz 1981, Reichman 1984, Schenkeveld & Verkaar 1984, Thompson 1986). Its composition was very similar to that of seed banks of annual grasslands in inland California (Heady 1956, 1977, Major & Pyott 1966, Bartolome 1979), due to the abundance of exotic annual grasses, including *Aira, Briza* and *Vulpia.* Before these species were introduced, Victorian and inland Californian grasslands were dominated by perennials, *T. triandra* and *Stipa pulchra* respectively (Willis 1964, Heady 1977, Bartolome et al. 1986). Seed densities could not be compared accurately, due to different sampling and germination procedures, but those obtained here (from 4,601 to 28,337 viable seeds per m^2) were of the same order of magnitude as those recorded from California (Major & Pyott 1966). Up to 670,000 seeds of *Vulpia bromoides* per m^2 occurred in dense stands of *Vulpia* in California (Bartolome 1979), and comparable densities might be expected in dense stands of *V. bromoides* at Derrimut.

It has been suggested that the demise of *T. triandra* under grazing may have been caused by an inherently low rate of seed production (Groves et al. 1973, Groves & Williams 1981) but this appears unlikely since, in this study, *T. triandra* was the fifth most abundant species in the seed bank, producing up to 1,375 viable seeds per m^2.

Species that did not germinate in the glasshouse cannot be presumed absent from the seed bank, since sampling and germination procedures may not have been appropriate for all species. Although sampling intensity was sufficient to indicate general characteristics of the seed bank, particularly in relation to the life-form and origin of component species, the limited number of samples has undoubtedly under-estimated the total number of species. The abundant germination of two species with contrasting optimal germination temperatures (*Romulea rosea* at 9.5–13°C and *T. triandra* at 20–30°C; Eddy & Smith 1975, Groves et al. 1982) suggests that the variable temperature regime encompasses the requirements of most species. However, species requiring extremely low or high soil temperatures (e.g. hard-seeded Fabaceae) or those with obligate after-ripening requirements were probably undetected or under-represented. Despite these qualifications, the results presented here are supported by a study of post-fire regeneration in the reserve (Lunt 1990b). Following a 21 ha fire in autumn 1987, only 16 of 58 native species in the burnt area regenerated from seed. All but four, *Acaena echinata, Agrostis avenacea, Spergularia rubra* and a *Stipa* species, were recorded from the soil seed bank.

Despite limited sampling, the soil seed bank appeared to contain few native species that were not known from the standing vegetation. The seed banks of many natives were probably grossly depleted by stock grazing or associated management (e.g. an absence of burning). Given the paucity of additional natives and the preponderance of exotics, Donelan & Thompson's (1980) conclusion that "no help can be expected from the seed bank in any attempt to restore species-rich [English] grassland" may prove to be equally relevant to the management of long-grazed, *T. triandra* grassland.

T. triandra grasslands need to be disturbed frequently, by burning or macropod grazing, to maintain the diversity of native species (Stuwe & Parsons 1977, Robertson 1985, Kirkpatrick 1986, Stuwe 1986). However, the composition of the soil seed bank suggests that disturbances in long-grazed grasslands may promote exotics as much as, if not more than, natives. Grassland ecologists face the formidable task of devising disturbance regimes to promote natives at the expense of exotics. Unfortunately, as in Californian grasslands (Heady 1977, Foin & Hektner 1986), many exotics now appear to be permanent residents of *T. triandra* grasslands.

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REFERENCES

Bartolome, J. W., 1979. Germination and seedling establishment in California annual grassland. *Journal of Ecology* 67: 273–281.

Bartolome, J. W., Klukkert, S. E. & Barry, W. J., 1986. Opal phytoliths as evidence for displacement of native Californian grassland. *Madrono* 33: 217–222.

Chancellor, R.J., 1986. Decline of arable weed seeds during 20 years in soil under grass and the periodicity of seedling emergence after cultivation. *Journal of Applied Ecology* 23: 631–637.

Donelan, M. & Thompson, K., 1980. Distribution of buried viable seeds along a successional series. *Biological Conservation* 17: 297–311.

Eddy, J. L. & Smith, D. F., 1975. Seed dispersal and germination in *Romulea rosea* (onion grass). *Australian Journal of Experimental Agriculture and Animal Husbandry* 15: 508–512.

Fenner, M., 1985. *Seed Ecology*. Chapman & Hall, London.

Foin, T. C. & Hektner, M. M., 1986. Secondary succession and the fate of native species in a California coastal prairie community. *Madrono* 33: 189–206.

Forbes, S. J. & Ross, J. H., 1988. *A Census of the Vascular Plants of Victoria*, 2nd edn, National Herbarium of Victoria, Melbourne.

Groves, R. H., Hagon, M. W. & Ramakrishnan, P. S., 1982. Dormancy and germination of seed of eight populations of *Themeda australis. Australian Journal of Botany* 30: 373–380.

Groves, R. H., Keraitis, K. & Moore, C. W. E., 1973. Relative growth of *Themeda australis* and *Poa labillardieri* in pots in response to phosphorus and nitrogen. *Australian Journal of Botany* 21: 1–11. (With appendix by H. J. Langer.)

Groves, R. H. & Williams, O. B., 1981. Natural grasslands. In *Australian Vegetation*, R. H. Groves, ed., Cambridge University Press, Cambridge, 293–316.

Heady, H. F., 1956. Evaluation and measurement of the California annual type. *Journal of Range Management* 9: 25–27.

Heady, H. F., 1977. Valley Grassland. In *Terrestrial Vegetation of California*, M. G. Barbour & J. Major, eds, Wiley & Sons, New York, 491–514.

Kirkpatrick, J. B., 1986. The viability of bush in cities - ten years of change in an urban grassy woodland. *Australian Journal of Botany* 34: 691–708.

Lunt, I. D., 1990a. A floristic survey of the Derrimut Grassland Reserve, Melbourne, Victoria. *Pro-*

ceedings of the Royal Society of Victoria 102: 41–52.

LUNT, I. D., 1990b. Impact of an autumn fire on a long-grazed *Themeda Triandra* grassland: implications for management of invaded, remnant vegetations. *Victorian Naturalist* 107 (in press).

MAJOR, J. & PYOTT, W. T., 1966. Buried, viable seeds in two California bunchgrass sites and their bearing on the definition of a flora. *Vegetatio* 13: 253–282.

MCDOUGALL, K., 1987. *Sites of Botanical Significance in the Western Region of Melbourne*. Melbourne Western Region Commission Inc. & Department of Conservation, Forests and Lands, Melbourne.

RABINOWITZ, D., 1981. Buried viable seeds in a North American tall-grass prairie: the resemblance of their abundance and composition to dispersing seeds. *Oikos* 36: 191–195.

REICHMAN, O. J., 1984. Spatial and temporal variation of seed distributions in Sonoran Desert soils. *Journal of Biogeography* 11: 1–11.

ROBERTS, H. A., 1970. Viable weed seeds in cultivated soils. *Report of the National Vegetation Research Station*, 1969, 25–38.

ROBERTS, H. A., 1981. Seed banks in soils. *Advances in Applied Biology* 6: 1–55.

ROBERTSON, D., 1985. Interrelationships between kangaroos, fire and vegetation dynamics at Gellibrand Hill Park, Victoria. PhD thesis, University of Melbourne.

SCHENKEVELD, A. J. & VERKAAR, H. J., 1984. The ecology of short-lived forbs in chalk grasslands: distribution of germinative seeds and its significance for seedling emergence. *Journal of Biogeography* 11: 251–260.

SOKAL, R. R. & ROHLF, F. J., 1981. *Biometry*, 2nd edn, W. H. Freeman & Co., New York.

SPECHT, R. L., 1981. Conservation of vegetation types. In *Australian Vegetation*, R. H. Groves, ed., Cambridge University Press, Cambridge, 393–410.

STUWE, J., 1986. *An Assessment of the Conservation Status of Native Grasslands on the Western Plains, Victoria and Sites of Botanical Significance*. Technical Report Series No. 48, Department of Conservation, Forests and Lands, Melbourne.

STUWE, J. & PARSONS, R. F., 1977. *Themeda australis* grasslands on the basalt plains, Victoria: floristics and management effects. *Australian Journal of Ecology* 2: 467–476.

THOMPSON, K., 1986. Small-scale heterogeneity in the seed bank of an acidic grassland. *Journal of Ecology* 74: 733–738.

WILLIS, J. H., 1964. Vegetation of the basalt plains in western Victoria. *Proceedings of the Royal Society of Victoria* 77: 397–418.