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Recurrent selection for grazing tolerance in winter-active populations of the perennial grass, *Phalaris aquatica* L.

Richard Culvenor[1], *Suzanne Boschma*[2] *and Kevin Reed*[3]
[1]CSIRO Plant Industry, GPO Box 1600, Canberra ACT 2601, Australia
[2]NSW Department of Primary Industries, Tamworth Agricultural Institute, 4 Marsden Park Rd, Calala NSW 2340, Australia
[3]Department of Primary Industries, Private Bag 105, Hamilton, Victoria 3300, Australia

Abstract. Phalaris (*Phalaris aquatica* L.) is a perennial grass of Mediterranean origin used widely by the sheep and cattle industries of south-eastern Australia. Winter-active cultivars released since the 1970's have the potential for higher herbage productivity than the earlier, semi-winter dormant cultivars but have been reported to be less persistent under sub-optimal grazing management and soil conditions. To improve genetic potential for persistence in winter-active phalaris, a program of recurrent selection was conducted by subjecting three populations of half-sib families to two cycles of selection for persistence under heavy, largely continuous grazing pressure. Cycle 2 progeny families and bulked seedlots of each generation were grown in separate grazed plot trials in Western Victoria and the Southern Tablelands and North-West Slopes of New South Wales from 1999-2003 to assess response to selection. Positive linear response to selection was observed in all populations at the Western Victorian and Southern Tablelands sites. Response to selection was absent and persistence was very low under higher temperature and drought stress on the North-West Slopes. This high level of genotype × environment interaction for persistence was also observed among final generation families. Families with better persistence than current winter-active cultivars at the two southern sites were identified in each population and a new cultivar is being formed from the parents.

Introduction

Phalaris (*Phalaris aquatica* L.) is a long-lived Mediterranean grass used widely by the sheep and beef industries of south-eastern Australia. The interaction of soil conditions and drought with grazing management influences phalaris survival in this environment (Oram and Culvenor 1994).

The CSIRO phalaris breeding program has released several 'winter-active' cultivars with higher seedling vigour and productivity in the cooler months compared with 'semi-winter dormant' cultivars (Oram and Culvenor 1994). However, present winter-active cultivars are perceived as being less persistent under heavy grazing pressure (Kemp and Dowling 2000) particularly when associated with soil acidity (Ridley *et al.* 2002). The breeding program currently aims to improve phalaris persistence through projects on grazing tolerance, soil acidity and tolerance of hotter, more drought-prone environments.

Brummer and Moore (2000) demonstrated variation among grass and legume cultivars in their tolerance of continuous grazing and the grazing tolerance of lucerne has been improved by selection under continuous grazing (Smith and Bouton 1993). Culvenor *et al.* (2002) described a program to develop a winter-active phalaris cultivar with improved persistence by subjecting winter-active populations to two cycles of recurrent half-sib family selection for persistence under heavy grazing pressure by sheep on soils differing in suitability for productive phalaris growth. Grazing was largely continuous and conducted for 2-3 years in each cycle. This paper reports selected results from a study in which bulked seed of half-sib families in each generation from three populations was grown in grazed small plots from 1999-2003 to assess response at three sites to selection for persistence in widely-separated regions of south-eastern Australia. Small plots of half-sib progeny families of cycle 2 selections were also assessed as a progeny test of potential parent plants for a new cultivar.

Materials and methods

Sites were located in western Victoria (Bulart), the Southern Tablelands of NSW (Rye Park) and the North-West Slopes of NSW (Tamworth). Rainfall distribution was winter-dominant at Bulart (annual average rainfall [AAR] 640 mm), uniform at Rye Park (AAR 670 mm) and summer-dominant at Tamworth (AAR 670 mm). The soil at Bulart was moderately acidic (pH_{Ca} 4.4, 0-10 cm) with high P status due to prior fertilizer applications. Rye Park soil was strongly acidic (pH_{Ca} 4.1, 0-10 cm) with low-moderate P levels. The cracking clay soil at Tamworth site was pH_{Ca} 5.8 (0-10 cm) and of moderate P status.

Three winter-active populations, a Broadly-based Population (BBP), the cv. Holdfast pre-basic population (Hf) and a more summer-dormant population, Perla Retainer (PR), were subjected to two cycles of selection for improved grazing tolerance from 1990-98 by subjecting half-sib families to grazing by sheep at sites near Canberra on the Southern Tablelands of NSW (Culvenor *et al.* 2002). The two resulting cycle 1 (C_1) and cycle 2 (C_2) generations, each with two seedlots differing in age (C_2 seedlots also differed slightly in parentage) plus the unselected or base generation of each population (C_0), were grown as small swards in a split plot design with populations as main plots and generations and seedlots as split plots. A fourth main plot consisting of five commercial cultivars was also included in each of three replicates at each site. These were the winter-active cultivars, Sirosa and Sirolan, and the semi-winter-dormant cultivars, Australian and Australian II. Small swards of the 143 half-sib families that collectively made up the final generation of the three populations were grown alongside the response to selection experiment in a three-replicate row-column design.

Small swards were sown at the three sites in May-June of 1999 at a sowing rate of 3 kg viable seed/ha. Plot size was 6 m^2 at Bulart and 5 m^2 at Rye Park and Tamworth. Grazing commenced in early 2000. Bulart was grazed for long periods at 10-40 sheep/ha with occasional short breaks. Rye Park was managed initially with bursts of high grazing intensity followed by long periods of continuous grazing at 11-13 sheep/ha. Tamworth received less grazing overall and at lower rates, particularly during severe drought in 2002 and 2003. Mean stocking rates from 1 January 2000 to 1 June 2003 were 17, 12 and 4 sheep/ha at Bulart, Rye Park and Tamworth, respectively.

Density of phalaris was measured as the frequency (presence) of live plant base during winter/early spring in three weldmesh grids per plot. Grid dimensions were 1.0 × 0.75 m at Rye Park and Tamworth divided into 0.15 × 0.10 rectangles, and 0.5 m × 0.5 m divided into 0.1 m × 0.1 m squares at Bulart.

Data from the response to selection experiment were subjected to analysis of variance with linear contrasts used to test the linear component of the generation effect. The main plot of control cultivars was omitted from this analysis but was included in a second split plot analysis to compare cultivars with breeding populations. C_2 half-sib progeny data were subjected to spatial analysis to model site variation (Cullis and Gleeson 1991).

Results

Establishment was even and differences in second year frequency were small across sites (88-94%) and breeding populations (90-92%). Seedlots in the C_1 generation differed in their frequency at emergence but plants spread so that no differences were observed between seedlots of either the C_1 or C_2 generations by the second year (data not shown).

Severe drought conditions occurred from 2001 at Tamworth and 2002 at Rye Park until the end of the experiment, and rainfall was also below average at Bulart in 2002. Under these conditions, frequency of all populations declined markedly by 2003. Persistence as a fraction of final frequency over maximum frequency was lowest at Tamworth (0.09), down from 0.75 in the previous year because of the drought. Final persistence was similar at Bulart (0.60) and Rye Park (0.54) but declined markedly only in the final year at Bulart whereas it declined each year from 2000 to 2003 at Rye Park. The Rye Park response to selection experiment declined more than the final generation half-sib families (see Fig. 1 for 2003 frequencies) because the response experiment was located on shallower soil.

Highly significant (P<0.001) positive linear response to selection was observed for persistence at Rye Park and Bulart in both 2002 and 2003 (see Table 1 for 2003 data). In contrast (site × generation P<0.001), response to selection was absent at Tamworth up to 2002 and slightly negative (P=0.06) in 2003. The population × generation effect was non-significant (P>0.05) at all sites indicating that all populations responded similarly.

The final generation of each population showed promising levels of persistence at Bulart and Rye Park compared with the current winter-active cultivars, Sirosa, Sirolan and Holdfast (base generation of Hf population), although in a number of cases the differences were not significant at the P≤0.05 level (Table 1). With similar qualification, the final generations performed well at Rye Park compared with the grazing-tolerant cultivars, Australian and Australian II, due to better survival of the 2002 drought year. Results at Tamworth indicate that drought was an overwhelming factor there, only the base generation of the more summer-dormant PR population showing some ability to survive under the severe drought.

On the assumption that a cultivar selected from these breeding populations would be more persistent than current winter-active cultivars in the Rye Park and Bulart environments but not at Tamworth, the persistence of final generation families at Bulart and Rye Park is shown in Fig. 1. Families from all three populations were among the more persistent and it was decided to base the cultivar on selections from all three populations. Slightly more emphasis was given to persistence at Bulart than at Rye Park because persistence was generally lower in the half-sib experiment at this site. Other criteria for selection included seed retention and winter yield potential assessed in the second year.

Discussion

Clear evidence of response to selection in all three winter-active populations at the Southern Tablelands and western Victorian sites confirmed that, as in lucerne (Smith and Bouton 1993), the method of selecting under heavy grazing pressure is an effective means of improving persistence in winter-active phalaris. The strikingly different response at Tamworth, however, indicates that grazing tolerance was only one of several factors affecting persistence. G × E interaction was also high among the final generation half-sib families. However, there was significant family variance common between the two southern sites, probably because their climates were similarly suitable for phalaris survival. The North-West Slopes experience much higher heat and moisture stress than the southern sites. We believe there is a limited but viable market for temperate grasses in this environment to provide high quality feed in the cooler months and are conducting a breeding program aimed at this region based on more summer-dormant types of phalaris from North Africa.

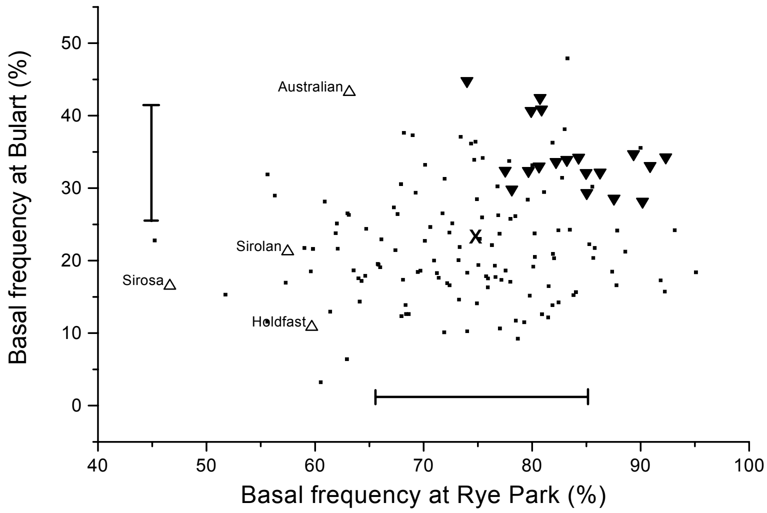
Effect of selection on winter productivity potential was not reported here. Briefly, there does appear to be a negative correlated response in second year winter yield in the order of 12% on a per plant basis but this should be more than compensated on an area basis over time as expected persistence differences appear.

Pre-basic seed of a new cultivar is being produced from the parents of the families selected for better survival at both Bulart and Rye Park. There is a need to further improve persistence in the western Victorian environment as shown by rather low persistence in the final generation half-sib families (Fig. 1). It would be desirable in future selection work to place emphasis on yield potential as well as persistence.

Table 1. Phalaris persistence in 2003 for the base generation (C_0) and the mean of three seedlots in the cycle 1 (C_1) and cycle 2 (C_2) generations in three breeding populations selected for persistence plus control cultivars at three sites. Lsd's are shown at *P*=0.05.

Population/Cultivar	Cycle	Bulart	Rye Park	Tamworth
BBP	C_0	0.42	0.43	0.16
	C_1	0.70	0.60	0.07
	C_2	0.79	0.78	0.09
Hf	C_0	0.47	0.48	0.11
	C_1	0.68	0.57	0.04
	C_2	0.64	0.67	0.05
PR	C_0	0.39	0.35	0.26
	C_1	0.56	0.52	0.12
	C_2	0.69	0.72	0.14
lsd C_0 vs C_1 or C_2 within populations	0.18	0.16	0.12	
C_1 vs C_2 within populations		0.15	0.13	0.10
Sirosa		0.58	0.41	0.09
Sirolan		0.40	0.17	0.05
Australian		0.72	0.51	0.04
Australian II		0.73	0.37	0.01
lsd among cultivars and between cultivars and generations		0.26	0.28	0.16

Fig. 1. Plot of phalaris frequency for C_2 half-sib families (■) and control cultivars (Δ) at Bulart and Rye Park in 2003 showing the families selected to form a new cultivar (▼). × indicates the overall mean of the 143 families. The bar indicates lsd (P=0.05).



References

Brummer EC, Moore KJ (2000) Persistence of perennial cool-season grass and legume cultivars under continuous grazing by beef cattle. *Agronomy Journal* 92, 466-471.

Cullis BR, Gleeson AC (1991) Spatial analysis of field experiments – an extension to two dimensions. *Biometrics* 47, 1449-1460.

Culvenor RA, Dobbie MJ, Wood JT, Forrester RI (2002) Selection for persistence under grazing in winter-active populations of the perennial grass, *Phalaris aquatica* L. (phalaris). *Australian Journal of Agricultural Research* 53, 1059-1068.

Kemp DR, Dowling PM (2000) Towards sustainable temperate perennial pastures. *Australian Journal of Experimental Agriculture* 40, 125-132.

Oram RN, Culvenor RA (1994) Phalaris improvement in Australia. *New Zealand Journal of Agricultural Research* 37, 329-339.

Ridley AM, Avery AL, Oram RN, Hunter J, Shovelton JB, Mahoney GP, Müller WJ (2002) Long-term persistence of aluminium tolerant and sensitive *Phalaris* lines on acidic soils and associated changes in soil acidity. *Australian Journal of Experimental Agriculture* 42, 1033-1042.

Smith SR, Bouton JH (1993) Selection within alfalfa cultivars for persistence under continuous stocking. *Crop Science* 33, 1321-1328.