Evaluating new phalaris populations for lower rainfall margins in SE Australia

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Abstract
Phalaris (*Phalaris aquatica* L.) options suitable for growers in the lower rainfall margins for the species are currently restricted to one cultivar (Atlas PG) with higher summer dormancy and a low summer dormancy cultivar (Sirolan) which is difficult to obtain. Five new populations developed in environments with long periods of low effective rainfall on the NW Slopes of NSW are being evaluated against commercial cultivars in an on-going genotype × environment study sown in 2009 at sites in west central Victoria, southern NSW and northern NSW (sown 2010) with long-term average annual rainfall ranging 460-760 mm. The populations were also evaluated in southern NSW at Yanco (430 mm) from 2008 in a separate study. Rainfall well above average in Years 2 and 3 of the genotype × environment experiment compromised the aim of observing persistence under low rainfall and clear differences in persistence are yet to develop. This period of high rainfall, particularly over summer, has slightly favoured basal frequency of lines with lower summer dormancy whereas four of the five new populations are known to be of a more summer-dormant type. Sirolan was the highest yielding entry overall, although two of the new populations were relatively high yielding in most or all environments. In contrast, following severe drought early in the Yanco experiment, four of the new populations were superior in basal frequency to Sirolan and in some instances Atlas PG, while three of the populations had higher dry matter yield than both Sirolan and Atlas PG.

Key Words
Perennial grasses

Introduction
Increased use of perennial species in regions of southern Australia dominated by annual pastures has potential to improve productivity, increase ground cover and reduce leakage of water from the upper soil profile. Lucerne (*Medicago sativa* L.) is currently the dominant perennial for medium to lower rainfall areas of south-eastern Australia (<450-500 mm average annual rainfall) but has limitations due to low ground cover and sensitivity to over-grazing, soil acidity and waterlogging. Winter-active perennial grasses adapted to summers with low effective rainfall can help fill the winter feed gap and address some of the limitations of lucerne. The major commercial species are phalaris, cocksfoot (*Dactylis glomerata* L.) and tall fescue (*Festuca arundinacea* Schreb. *Lolium arundinaceum* Schreb. S.J. Darbyshire) but the number of well-adapted cultivars is limited.

Current phalaris cultivars are broadly restricted to areas with average rainfall of at least 400-450 mm in winter-rainfall dominant areas (Victoria and South Australia), 450-550 mm in uniform rainfall areas in southern-central NSW and 650-700 mm in summer rainfall-dominant northern NSW. Improved adaptation in phalaris to lower rainfall environments is correlated with a sufficiently high level of summer dormancy, high seedling vigour and early flowering (Oram and Freebairn 1984; Culvenor and Boschma 2005). A cultivar with relatively high summer dormancy, Sirocco, was released in 1967 but is no longer available. Seed of Sirolan is scarce although it is a highly productive cultivar for the cropping zone, interestingly with low summer dormancy. The more summer-dormant cultivar, Atlas PG, is currently recommended for drier environments. However, Boschma and Culvenor (2008) demonstrated that several new populations based on other relatively summer-dormant germplasm, and a population selected at Tamworth, survived drought better than Atlas PG at two sites on the North West Slopes of NSW. This paper reports progress in evaluating these populations in a broader range of environments to select one for cultivar release.

Methods

Genotype × Environment Experiment

Five new seed-retaining populations (Northern Retainer, Sirocco Retainer, 19305 Retainer, P × C, Tam PWA) and commercial cultivars of phalaris (Atlas PG, Sirolan, Landmaster at all sites, Australian, Australian II at three sites) were evaluated. Two sites were in the winter-dominant rainfall zone of west central Victoria (Bealiba and Eversley), two in the uniform rainfall zone of southern NSW (Beckom and Trungley Hall) and one in the summer-dominant zone of northern NSW (Inverell). Northern Retainer, Sirocco Retainer, 19305 Retainer, P × C and Atlas PG are higher in summer dormancy than the remaining entries (5.5-6.7 *vs*. 2.5-3.4 on a 0-10 scale with 10 completely dormant; Norton 2011). New and commercial lines of cocksfoot and tall fescue were also evaluated in the same experiments but are reported elsewhere (Clark et al. 2012; Harris et al. 2012). Soils at Victorian sites were the most acidic (pH_{CaCl2} 4.0 at Eversley, 4.6 at Bealiba in 0-10 cm layer). In NSW, soil pH_{CaCl2} was 4.8 at Beckom, 5.1 Trungley Hall and 5.4 at Inverell. Annual and long-term average rainfall is shown in Table 1. Rainfall was well below average at most sites in 2009 with a hot, dry spring. Rainfall was well above average in 2010 and 2011 particularly during both summers (Table 1). All sites were sown in autumn-winter 2009, but the Inverell experiment failed due to drought and was resown in spring 2010. Sowing rate was 2.25 kg/ha of viable seed at all sites except Inverell where the sowing rate was 3 kg/ha. Plot size was 5 × 1.5 m at Bealiba and Eversley, 6 × 2 m at Beckom and Trungley Hall, and 6 × 2.5 m at Inverell. There were four replicates at all sites in a randomised block design. Subterranean clover (*Trifolium subterraneum*) was sown as a companion legume at all sites. Measurements included: seedling density at establishment; basal frequency each autumn/winter in two fixed 1 m^2 quadrats per plot; sward composition by Botanal and herbage mass by calibrated visual assessment seasonally. Sites were grazed or mown after herbage assessment. Data were subjected to analysis of variance and least significant differences calculated at the 5% level. Analyses of phalaris entries common to all sites, across sites and years, were also performed.

Yanco Experiment

Thirty phalaris cultivars, breeding populations including the new populations, and wild accessions were evaluated at Yanco Agricultural Institute, southern NSW, from 2008-11 to search for attributes that promote survival in lower rainfall environments. The experiment was sown in July 2008 at 2.2 kg/ha of viable seed without a companion legume. Plot size was 4 × 1.2 m and there were four replicates in a row-column design. Plots were irrigated in early November 2008 due to severe moisture stress. Rainfall was very low throughout 2009 (167 mm April to October) but was much above average in 2010 and 2011 (Table 1). Spatial analyses were performed on basal frequency measured each winter and the annual total of seasonal DM production assessments for each year.

Table 1. Location of sites and long-term average (LTA) and annual rainfall (mm).

Site	Latitude (S)	Longitude (E)	LTA	2008	2009	2010	2011
Bealiba	36°49’22”	143°35’7”	470	-	428	754	700
Eversley	37°12’54”	143°8’45”	590	-	599	829	661
Beckom	34°16’00”	146°59’44”	460	-	330	594	632
Trungley Hall	34°15’21”	147°39’26”	520	-	447	749	702
Inverell	29°46’31”	151°4’55”	700	-	539	889	1088
Yanco	34°36’50”	146°25’16”	430	343	289	548	591

Results

Genotype × Environment Experiment

Sites varied widely in phalaris seedling density with 52 plants/m^2 on average at Bealiba, 59 at Trungley Hall, 74 at Beckom, 104 at Eversely in 2009, and 126 at Inverell in 2010. Among entries, Atlas PG emerged at lower density at all sites sown in 2009 due to unexpectedly low viability of its seed despite germination tests, and this difference was still reflected in Year 3 basal frequency (Table 2). Average basal frequency increased in the second year and remained steady in the third year at Victorian sites (42%, 57%, 55% for years 1, 2 and 3 respectively) whereas average basal frequency at southern NSW sites was lower in the second year following the dry spring in 2009, but partially recovered in the third year under high rainfall in 2010 and 2011 (47%, 30%, 38% for years 1, 2 and 3 respectively).

Ranking of entries for basal frequency in 2011 was complicated by a significant site × entry interaction (P<0.05). Averaged across the four sites sown in 2009, TamPWA was significantly higher in frequency than 19305 Retainer (P<0.05) although this difference was pre-existing to some extent in 2009. TamPWA was highly ranked at Bealiba, Eversley and Beckom in 2011 and 19305 Retainer lower ranked compared with the top entries at Bealiba (with Northern Retainer), Eversley and Trungley Hall (Table 2). Under higher rainfall, entries responded differently in basal frequency between years 2 and 3 based on their expected level of summer activity (entry × year, P<0.01). At Victorian sites, the five entries of the more summer dormant type declined by 6% units of basal frequency on average whereas the more summer active entries did not decline. At southern NSW sites, the five entries of the more summer dormant type increased by 9% units whereas the more summer active entries increased by 15% units. Basal frequencies were high for most entries at Inverell in Year 2 with the lower value for Sirocco Retainer caused by a decline from the previous year, while the lower value for Australian II remained from establishment (Table 2).

Table 2. Basal frequency (%) in 2011 at sites in the genotype × environment experiment.

Entry	Bealiba	Eversley	Beckom	Trungley Hall	Inverell
Northern Retainer	32	73	40	54	91
Sirocco Retainer	40	67	40	51	86
19305 Retainer	38	64	38	35	95
P × C	51	68	34	46	95
Tam PWA	56	75	45	47	93
Atlas PG	21	39	33	28	93
Sirolan	48	72	33	54	94
Landmaster	47	71	31	53	91
Australian	46	79	-	-	93
Australian II	35	71	-	-	74
LSD (P=0.05)	16	14	11	13	6

Sirolan had the highest annual DM production averaged across all sites in both post-establishment years but was not significantly higher (P<0.05) than P × C in either year or Tam PWA in Year 3 (Table 3). In the third year at Bealiba, Tam PWA was higher yielding (P<0.05) than 3 of the other new populations (Northern Retainer, Sirocco Retainer, 19305 Retainer). At Eversley, only Sirocco Retainer yielded less than the top-ranked entry, P ×C, in Year 3 (Table 3). Landmaster was similar in DM production (P<0.05) to the top-ranked entry at Victorian sites but its yield was lower (P<0.05) than the top-ranked entry at southern NSW sites. Three entries, Sirolan, P × C and Northern Retainer, stood out for annual DM production at Trungley Hall in Year 2 and to a lesser extent in Year 3 (Table 3).

Yanco experiment

In response to the severe drought in 2009, clear differences in frequency had emerged by 2010 with four new populations of the more summer-dormant type (Northern Retainer, Sirocco Retainer, 19305 Retainer, P × C) higher in frequency than all other entries (Fig. 1a). This difference remained in 2011 under higher rainfall. TamPWA did not survive as well as the other new populations. As expected, Australian and Australian II were adversely affected by the low rainfall in 2009. Both Atlas PG and Sirolan had lower DM production in 2010 and 2011 than three of the four new populations. Of the four more persistent populations, Sirocco Retainer yielded less than the other three which did not differ significantly from each other (Fig. 1b).

Conclusion

The high rainfall experienced during 2010 and 2011 in the genotype × environment experiment was unsuitable for fulfilling the aims of ranking entries for persistence and productivity under low rainfall conditions. This was amply demonstrated by the excellent survival of the summer active and later flowering cultivar Australian at three sites contrary to its performance at Yanco where both Australian and the closely related Australian II declined rapidly after one very dry year. The low summer dormancy cultivar Sirolan was highest yielding on average of all phalaris entries in the genotype × environment experiment. Landmaster and TamPWA, also of the lower summer dormancy type, performed relatively well at Bealiba and Eversley but it is possible that they may also be expressing better tolerance of the more acidic, lower fertility soils. Relative performance of entries of the more summer dormant type may have been disadvantaged by the high rainfall particularly in the 2010/11 summer. Among this group, P × C appeared to have a yield potential nearest to that of Sirolan. Results of the Yanco experiment indicate that several of the new populations may well be more persistent than present cultivars under lower rainfall conditions and supports continuation of the genotype × environment experiment to confirm this finding.

Table 3. Annual total DM (t/ha) of phalaris entries in post-establishment years of the genotype × environment experiment.

Entry	Bealiba		Eversley		Beckom		Trungley Hall		Inverell
	Yr2	Yr3	Yr2	Yr3	Yr2	Yr3	Yr2	Yr3	Yr2
Northern Ret.	3.1	2.0	6.5	5.2	6.3	4.9	10.0	2.6	8.8
Sirocco Ret.	3.8	1.7	5.6	4.2	6.7	4.9	8.0	2.3	8.2
19305 Ret.	3.2	2.0	6.8	5.7	6.5	5.1	7.3	2.1	7.9
P × C	4.6	2.4	7.2	5.8	6.5	4.8	10.1	2.8	8.4
TamPWA	4.6	3.0	6.6	5.2	6.1	5.3	8.5	2.1	8.0
Atlas PG	2.1	1.2	4.1	3.6	5.6	4.4	6.5	2.1	8.3
Sirolan	4.9	2.8	7.0	5.8	6.3	5.6	11.8	3.2	8.9
Landmaster	4.3	2.9	6.4	5.2	5.2	4.5	8.0	2.3	7.8
Australian	3.2	1.9	5.5	4.2	-	-	-	-	7.9
Australian II	2.8	2.1	5.0	4.6	-	-	-	-	5.2
LSD (P=0.05)	1.5	0.8	1.7	1.5	1.1	1.0	2.4	0.8	1.1

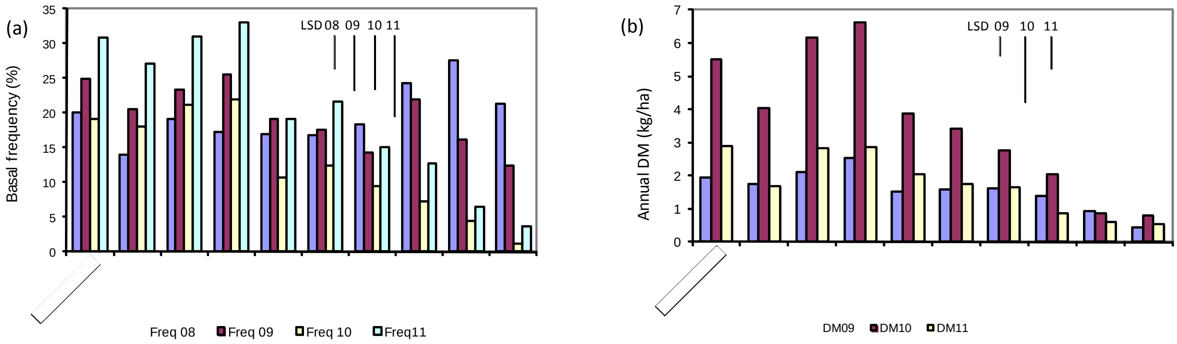

Figure 1. (a) Basal frequency from 2008-11 and (b) annual total DM from 2009-11 in the Yanco experiment.

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