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Improvement of seed yield potential in tall fescue

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Abstract. Modest and unreliable seed yield limits the usefulness of some forage tall fescue cultivars. In preliminary experiments, significant correlations for seed weight per panicle but not panicle number were established between spaced plants and sown rows of half-sib progeny derived from them. However, seed yield of the sown rows in the second year was not correlated with first year values. Half-sibling families of an elite breeding pool were sown in rows at three contrasting sites in autumn 1999. The following spring, panicle numbers were counted and in summer seed was harvested and weight per panicle calculated. Families varied significantly for seed yield and yield components, and family values were correlated between sites. Seedlings were raised from remnant seed of the best performing families (based on first year data at the 3 sites) and assessed pre-anthesis for panicle number. Selected plants were isolated and seed harvested. After progeny tests, three sub-sets of elite plants were isolated to produce improved selections. Plot trials sown at Lincoln (New Zealand) and at Pergamino (Argentina), showed significant seed yield improvements from the selections compared with "Grasslands Advance," a standard cultivar derived from the same breeding pool.

Introduction

Tall fescue (*Schedonorus phoenix* (Scop.) Holub syn *Festuca arundinacea* Schreb) is increasingly used in New Zealand as a pasture providing leafy summer herbage in districts where ryegrass performance is limited by water stress (Easton *et al.* 1994). The cultivar 'Grasslands Advance' is excellent for palatability and ease of management, but seed supply has not met demand. In comparative trials, seed production potential of Advance has proved to be inferior to that of some other cultivars (M.P. Rolston, unpublished data).

Seed yield can be analysed as the product of several components (panicle number, spikelets per panicle, florets per spikelet, mature seeds per floret and seed size). Of particular interest is the inter-relationship between the number of potential seeds and the number of mature seeds harvested. This is affected by efficiency of fertilisation, rate of embryo abortion, seed filling and seed loss right up to pre-harvest shattering. Seed yield in open-pollinated temperate grasses is reported to show significant genotype-environment interaction (Casler *et al.* 2003), and in particular poor correlation between spaced plant and seed stand performance (Elgersma 1990a, Elgersma 1990b).

This paper describes experiments assessing variation for seed yield potential, and response to multi-site selection.

Materials and methods

A common strategy used to generate and maintain elite breeding populations is to polycross 100 or more elite plants per generation, selected for traits such as, seedling vigour, herbage yield, rust and leaf softness, and harvest seed from individual plants resulting in the generation of half-sibling families (Easton and Pennell 1993).

The series of experiments described in this paper were managed according to best practice for seed production, with fungicide and nitrogen application and defoliation as appropriate. Straw shortening plant growth regulators which have subsequently become common practice in New Zealand, were not used.

Experiment 1

Two clonal replicates of 240 elite tall fescue plants were grown as spaced plants in a randomised complete block experimental design at Lincoln, and the traits panicle number and seed yield were recorded. The resulting data, and estimates of seed weight per panicle were analysed using the analysis of variance (ANOVA) option in GenStat v8, with one factor being the half-sib families in which the elite plants were nested.

Experiment 2

A small set of families (representing plants of high, medium and low seed yield) harvested from 38 of the 240 plants was sown in autumn in 2 m rows 60 cm apart, at Lincoln in a randomised complete block (RCB) trial. The following spring/summer panicles were counted on a 1m section of each row, and yield of clean mature seed was measured on the same section. Seed weight per panicle was derived from these data. One year later, a second harvest was taken from the same rows, and the weight of clean mature seed recorded.

Experiment 3

RCB trials of 1 m rows of a set of 205 half-sibling families, harvested from the 240 elite parental plants, and control cultivars were established in autumn 1999 at three sites, Lincoln and Palmerston North in New Zealand, and Pergamino in Argentina. Climate details for the sites are shown in Table 1. Number of panicles per row was assessed on two occasions before anthesis. This assessment at the three sites and seed yield per panicle from the parents in Experiment 1 were used to identify families to be harvested. These included the expected 40 best families. In addition, another 25 were based on traits such as performance at a particular site, good head number but poor seed weight per head, and 15 representing the remainder of the experiment, plus six control cultivars. Yield of clean mature seed was obtained for this sub-set at all sites, at Lincoln and Palmerston North panicles were counted and seed weight per panicle was derived. Data were processed by ANOVA for each site, and across sites.

Experiment 4

Seedlings were raised from remnant seed of the best performing families (based on first year data at the three sites) and assessed pre-anthesis for panicle number. Selected plants were isolated and seed harvested. After progeny tests, three sub-sets of elite plants were isolated to produce improved selections and the resulting experimental lines (GT85, GT86 and GT104) were compared with control cultivars in seed production plot trials at Lincoln and Pergamino. Plots 8 m x 4 m were sown at 5 kg.ha^{-1} in autumn 2002. The following spring/summer, yield of mature seed was measured by harvesting quadrats within plots.

Results and discussion

Pergamino represents a low latitude environment with hot summers, but similar summer rainfall to Palmerston North. Lincoln was the most southern of sites with lower rainfall which was supplemented with irrigation (Table 1).

Table 1. Annual and spring-summer monthly rainfall, maximum and minimum mean temperatures for the trial sites.

	Aug	Sept	Oct	Nov	Dec	Jan	Year
Pergamino lat 33° 44’ S							
Mean max °C	17	19	22	26	29	30	22.6
Mean min °C	5	7	10	13	15	17	10.2
Rainfall (mm)	41	58	119	97	94	114	974
Palmerston North 40°23’ S							
Mean max °C	13	15	17	19	21	22	17.1
Mean min °C	5	6	8	10	12	13	8.5
Rainfall (mm)	84	69	89	79	104	84	1000
Lincoln 43°38’ S							
Mean max °C	12	14	17	19	21	22	16.2
Mean min °C	3	4	6	8	10	11	6.2
Rainfall (mm)	68	40	55	56	61	50	640

The spaced plants in Experiment 1 and rows in Experiments 2 and 3, all showed significant family effects for seed yield, numbers of panicles and yield per panicle (Table 2). Further, data for families in Experiment 2 were correlated with data for respective parent plants in Experiment 1 for total seed yield and for seed per panicle, but not for number of panicles (Table 3). Early heading plants in Experiment 1 tended to produce higher yielding families in Experiment 2. The poor correlation between spaced plants and seed stand conditions (better represented by the sown rows 50 cm apart) for panicle number has been described for perennial ryegrass (*Lolium perenne* L.) (Elgersma 1990b). The correlations between parent and progeny for yield per panicle confirm the indications of heritable variation provided by the inter-family comparisons.

Table 2. The ANOVA mean squares (MS) for seed yield, yield/panicle and panicle number showing significant family effects in different experiments.

Experiment	Trait	Family MS	Error MS	Prob F
Experiment 1	Seed yield	155	36	<0.001
	Yield/panicle	609	113	<0.001
	Panicle number	2305	499	<0.001
Experiment 2	Seed yield*	146	40	<0.001
	Yield/panicle	230	70	<0.001
	Panicle number	2015	495	<0.001
Experiment 3 PN	Seed yield	173	106	0.004
	Yield/panicle	271	114	<0.001
	Panicle number	1250	467	<0.001
Experiment 3 Lcn	Seed yield	313	84	<0.001
	Yield/panicle	188	30	<0.001
	Panicle number	9706	6938	0.028
Experiment 3 Perg	Seed yield	189	54	<0.001
Experiment 3 All	Seed yield	384	101	<0.001
	Yield line*site	107	99	0.233

*Year 1 data

Table 3. Correlation coefficients of parent spaced plant seed component data (Experiment 1) with data of sown progeny rows (Experiment 2). Cells in bold designate significance at P<0.05.

		Progeny row			
Parent plant		panicle emergence	panicle number	yield/ panicle	seed yield
	panicle emergence	**0.322**		**0.477**	**0.374**
	panicle number	0.296	0.016	0.234	0.180
	yield/panicle			**0.541**	**0.328**
	seed yield				**0.346**

Conversely, there was no significant correlation (r = 0.25, P=0.13) between yields in successive years in the same plots in Experiment 2 (Fig 1). Yield differences between families were significant in each year, but this was much clearer in Year 1 than in Year 2. Combined analysis across years showed a significant (P<0.05) family effect, but this was much less clear than in either year considered alone (data not presented). We do not have seed yield component data for Year 2. However, it will be important to determine which components vary most between years. Tall fescue varies greatly for seedling vigour, both genetically and as a function of seed lot history (Easton and Pennell 1993), and early vigour reflects on herbage productivity and eventual seed yield in the first year .

Tall fescue seed crops are commonly harvested for four or more harvest seasons and the data suggests that selection for seed yield should include second year data.

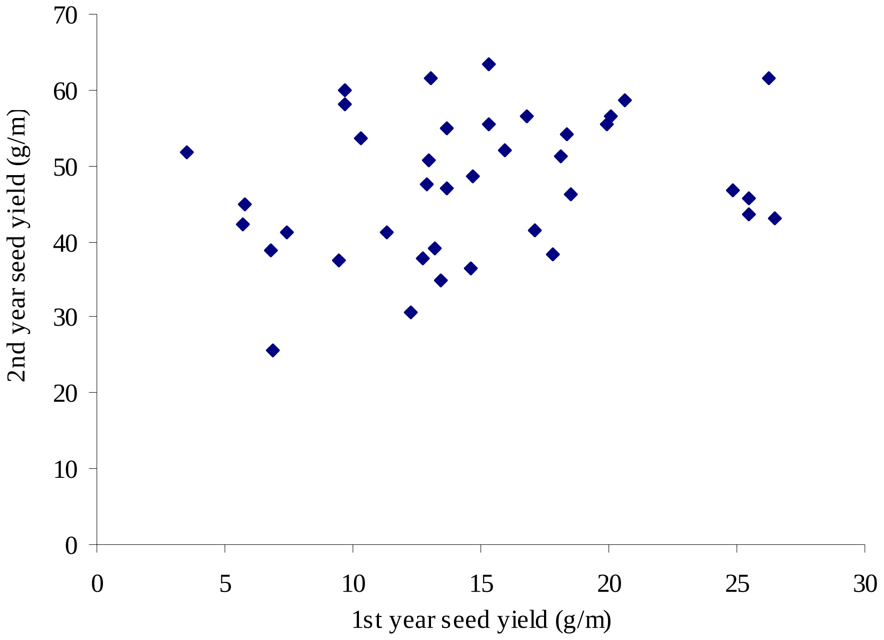

Figure 1: Half-sib family seed yields (g/m row) in years 1 and 2, in Experiment 2.

For Experiment 3, there was no family x site interaction for yield, indicating that the families had consistent performance across the three sites. However, examination of an illustrative subset of lines in Fig 2 indicates that family 17 would have been discarded if only assessed at Palmerston North, as would have family 18 if only assessed at Pergamino. The good yield of family 43 at Palmerston North was not repeated at the other sites.

Consistent genetic effects over sites are not always observed in seed production experiments (Casler *et al.* 2003), and their presence in this data set is encouraging, particularly in view of the poor correlation between successive years in Experiment 2 (also observed in another experiment not reported here, MP Rolston unpublished, in which 2nd and 4th year yields did not correlate).

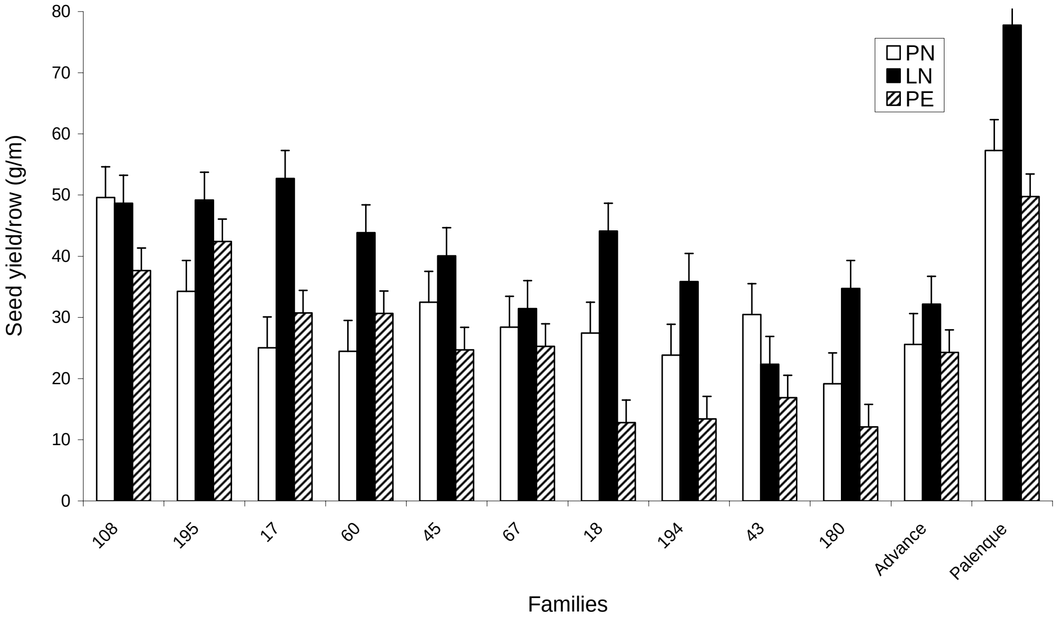

Figure 2: Seed yield per row (g/m) of a subset of lines from the Palmerston North (PN), Lincoln (LN) and Pergamino (PE) sites in experiment 3.

The high genotype-environment interaction regularly observed for seed production has led to the conclusion (Casler *et al.* 2003) that multi-site selection should be practised for this trait. The value of this is evidenced by results from Experiment 4 (Table 4) showing yields of the selected lines to be better than those of ‘Grasslands Advance,’ the reference cultivar based on the same breeding pool. At Pergamino, panicle numbers were significantly higher for all three selections but did not differ for yield per panicle.

Table 4. Seed yield, panicles/m^2 and yield/panicle of experimental selections and cultivars at Lincoln and Pergamino in 2003.

	Lincoln	Pergamino		
Selection	Seed yield (kg/ha)	Seed yield (kg/ha)	Panicles/ m^2	Yield/ panicle (mg)
Advance	700	230	155	140
GT85	1125	520	260	210

GT86	960	470	370	130
GT104	705	600	275	230
Palenque	900			
Taita		1100	315	340
LSD (P=0.05)	295	365	110	110

Conclusion

Our results show that breeding for seed yield in tall fescue is possible, but requires a strategy that addresses genotype-environment interaction. Further, it may prove essential to take data from more than one year. The cost of this, both directly and in extending the length of a breeding cycle, would need to be considered. Certainly, it would imply that seed yield potential should be considered in early stages of a breeding programme, rather than as a truncation exercise immediately prior to constitution of cultivars. This approach has been previously recommended in the breeding of white clover (Jahufer and Gawler 2000). While there may be a penalty to genetic advance in herbage production if selection for seed yield is introduced early in the breeding programme this must be balanced against the risk of seed production failures.

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