Breeding tall fescue for establishment vigour

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Abstract

Tall fescue (*Festuca arundinacea* Schreb.) has been shown to have great potential to supply quality forage through the summer in environments where the water regime limits performance of perennial ryegrass (*Lolium perenne* L.). The use of tall fescue seed in NZ has risen from almost none 15 years ago to about 200 tonnes today. However the further use of tall fescue is limited by the difficulty some farmers have in establishing it, particularly when performance is compared with perennial ryegrass. Experience is generally that the widely used imported cultivar AU Triumph establishes more vigorously than the NZ cultivar Grasslands Roa. Tall fescue breeding at AgResearch Grasslands has in the past 10 years concentrated on improving the vigour at establishment, while maintaining the excellent standard of forage quality achieved with Roa. Data are presented indicating substantial progress, with breeding line families outperforming all control cultivars. However, further data suggest a strong effect of conditions of seed ripening and harvest on the vigour of seed when sown. Data comparing different field multiplications and comparing breeding families harvested in the field and in the glasshouse confirm this. Field sowings and more controlled nursery box experiments are described. The paper discusses implications for plant breeding method and for seed production.

Introduction

The use of tall fescue (*Festuca arundinacea* Schreb.) in New Zealand, almost nil before the release of Grasslands Roa (Anderson 1982; Brock 1983), has now grown to represent a significant contribution to our pastures, particularly in regions with hot dry summers (MacFarlane 1990; Milne & Fraser 1990). Tall fescue is valued for its ability, once established, to tolerate hot dry conditions and pasture pest attack (Kain *et al.* 1979; East *et al.* 1982; Prestidge *et al.* 1986) and to produce leafy green herbage over the summer. Recorded animal performance has varied, with some excellent results being obtained (Wright *et al.* 1985).

A recognised shortcoming of tall fescue is slow establishment (Brock *et al.* 1982). The breeding of Roa concentrated on forage quality and on seasonal regrowth (Anderson 1982). It is generally observed that the imported cultivar AU Triumph establishes more readily than Roa, but it too is slow compared to some other pasture grass species.

Tall fescue breeding at AgResearch Grasslands (formerly DSIR Grasslands) through the 1980s sought to improve vigour of establishment, while maintaining the forage quality of Roa and enhancing its seasonal regrowth.

Breeding programme

Methods

Plant material from the Roa programme, from wild New Zealand populations and from overseas, was subjected to the following selection methods:

1. Seed was germinated in Petri dishes and the most rapidly germinating seeds were grown on. When plants were mature they were isolated in a glasshouse and seed was harvested from them. The seed from one plant in such an isolation and harvest is a family of half siblings. A second generation of selection was practised within each half sibling family.
2. For the second of the above generations, seed was also counted out and sown in rows in river sand, which was watered daily. It was found that the mean emergence of families from the sand correlated closely with their mean performance in Petri dishes.
3. After the above two generations, seed was sown into the field in rows of half sibling families. Families were assessed for their establishment, and for later traits such as seasonal regrowth, palatability and resistance to leaf diseases. After 3-4 years, individual plants of the best families were grown out and compared. The best plants of the best families became the parents of the next generation of families.

Results

After two generations of field sowings (following the Petri dish and sand sowings) the families of the breeding pool showed outstanding performance relative to the commercial control cultivars (Table 1). From the best families, elite plants were selected to be the parents of an experimental cultivar designated G48.

However, early experiments showed that although the original glasshouse nucleus isolation of the experimental cultivar proved to be outstanding, the subsequent field increases, while performing well, fell short of the original promise (T.J. Fraser, T.B. Lyons, J. Miller, unpublished data). Whereas the breeding families and the glasshouse nucleus were clearly superior to all controls, the field increases are an improvement on Roa but no better in establishment than Triumph.

Possible explanations

The genetic structure of G48 is such that inbreeding depression cannot be an explanation of this result.

The conditions of seed harvest are known to affect the germinability and vigour of seed of many grasses, including tall fescue (Simpson 1990). In particular, seed which matures on the plant in warm temperatures (25°C rather than 15°C) will generally germinate and establish better than seed which matures under cooler conditions.

For convenience and efficiency, grass breeding programmes use seed produced in a glasshouse. This seed matures in an environment which is warmer and less variable than field conditions.

Effect of seed harvest conditions on seedling vigour

Material and Methods

One hundred and fifty elite tall fescue plants were isolated in a glasshouse in November 1991 and seed was harvested from them to form a set of half sibling families. The following autumn the same plants were split in two. Part of each plant was placed in an isolation block on the Aorangi Research Farm, 15 km west of Palmerston North. The other part was held at Palmerston North and placed in an isolation glasshouse in November 1992. Those plants which were too small to split in two were planted at Aorangi. Seed was harvested from the isolations at Aorangi and in the glasshouse to form two more sets of half sibling families.

Box experiment:
Forty-eight families with sufficient seed in all 3 sets (i.e., glasshouse 91, 92 and Aorangi 92 harvests) were compared with 6 control seed lots, forming an experiment with 150 entries. Seeds were individually sown approximately 4 cm apart, into nursery boxes, in a peat-based potting mix and covered with approximately 5 mm of sand. Entries were sown in plots of 8 seeds. Two randomised complete block designs with 4 replicates were sown on 18 and 19 February 1993, with one grown in a glasshouse and the other outside.

Table 1 Comparison of breeding pool with controls

	Establishment note[1]	Regrowth index[2]	Dry weight (g)[3]
Roa	2.07	3.30	23
S170	2.51	3.43	25
AU Triumph			23
Breeding pool[4]	3.42	3.46-5.43	33
l.s.d. (5%)	0.76		6

[1] mean of 16 notes in 4 trials (1 = poor, 5 = excellent)
[2] mean of 23 notes in 4 trials, inversely weighted by standard error
[3] harvest of 0.5 m of row in 1 trial
[4] mean of 166 half sibling families

Seedling emergence was noted at weekly intervals. All tillers and the leaves on the primary tiller were counted, 32 and 39 days after sowing for the glasshouse and outdoor trials respectively. For the outside experiment alone, plant number, tiller number on two plants and total plot dry weight were recorded 75 days after sowing. Tiller number and dry weight were converted to logarithms for analysis of variance.

Germination percentagein an incubator at 25°C after 3 days imbibing at 4°C, and the weight of 100 seeds were also determined.

Field trial:
A replicated complete block trial was sown in the field at Lincoln in mid March 1993. There were 280 entries, 104 families of the 1991 glasshouse isolation, 139 of the Aorangi isolation, 30 of the 1992 glasshouse isolation and 7 controls. Each plot consisted of approximately 100 seeds sown in a 1 m row. Emergence was first observed after 18 days and establishment was noted 6 times over the next month. The sum of these notes represents both the numbers of seedlings established and their size.

Results

The seed from Aorangi was lighter (25% lighter than the 1992 glasshouse isolation) and had a lower germination % than that of the other groups (Table 2.). The higher seed weight of the 1992 glasshouse isolation than the 1991 was not reflected in better germination.

Of seeds germinated after 19 days, the proportion germinated after 7 days was lower for the Aorangi harvest than for the glasshouse harvests. Speed of germination is affected as well as total seeds germinating.

Box trial:
Group, family and their interaction were almost always significant for the seedling characters (Table 3). The seed harvested at Aorangi established less well than

Table 2 Seed weight and germination % of progenies harvested in different conditions.

	1000 seed weight (g)[2]	Germination %[1] I	II	Germination rate[4]
Seed origin				
Glasshouse '91[3]	2.780	95.2	96.8	0.87
Aorangi '92[3]	2.455	51.6	66.2	0.53
Glasshouse '92[3]	3.235	91.2		0.69
l.s.d. (5%)	0.051	2.9	3.5	0.09
G48, Aorangi	2.525	67		
G48, Hawkes Bay	2.525	53		
G48, Lincoln	2.790	61		
G48, Glasshouse	2.430	93		
Roa, Aorangi	2.630	89		
AU Triumph	2.775	97		

[1] Two experiments, each of 100 seeds per entry
[2] Calculated from two lots of 100 seeds per entry
[3] Mean of 48 entries.
[4] Germlnation % at 7 days 1% at 19 days (arcsin transformation for analysis)
One experiment with 100 seeds

Table 3 Seedling growth of progenies harvested in different conditions.

	leaf number[1]	tiller number'	plant number[2]	tiller number[2,3]	dry weight[2,4]
Seed origin					
Glasshouse '91	4.31	2.59	6.7'7	3.70	134
Aorangi '92	4.07	2.39	4.60	3.85	135
Glasshouse'	4.57	2.94	7.09	4.54	187
l.s.d. (5%)	0.07	0.08	0.26	0.31	13
G48, Aorangi	3.73	1.94	5.25	3.00	55
G48, Hawkes Bay	3.74	1.81	5.25	2.13	58
G48, Lincoln	3.77	2.02	6.50	2.75	87
G48, Glasshouse	4.62	3.15	7.50	3.63	217
Roa, Aorangi	3.70	1.88	4.25	2.38	37
AU Triumph	4.29	2.88	5.75	5.00	135
l.s.d. (5%)	0.48	0.54	1.80	2.12	108

[1] 32-39 days after sowing, mean of seedlings outside and in glasshouse.
[2] 75 days after sowing, seedlings outside.
[3] mean of two seedlings per plot.
[4] total dry weight per plot/seedlings present.

either set of glasshouse seed for the first examination, but except for plant number was as good as the 1991 glasshouse isolation for the later measurements. The seed of the 1992 glasshouse isolation was better for all traits. Note that the low plant number of the Aorangi harvest is fully accounted for by the lower germination from the germination experiment. However, for other traits such as leaves and tillers per plant and unit weight, only those plants actually emerging enter into the statistics. Poor germination does not account for differences between groups. Those seeds harvested in the field which germinate do not establish viable seedlings as quickly as seeds harvested in a glasshouse.

The progeny variance was generally higher for the progenies harvested at Aorangi than for the other two groups (Table 4). Some family seed lots in the field-harvested group germinated as well as those from the glasshouses (>90%), and for the growth traits recorded also, some field-harvested progenies showed very promising performance.

Within the Aorangi harvested group, the correlations between germination percentage and other traits measured in the box experiment were generally significant but modest (5-25% of the variability accounted for).

Of the control lines, 4 were seed lines of G48 (Tables 2 and 3). The glasshouse nucleus isolation was clearly the best of the controls. Of the 3 G48 field increases, the line harvested at Lincoln was superior to those from Manawatu (the Aorangi Research Farm) and Hawkes Bay. The G48 field harvests were generally superior to Roa but did not establish as well as Triumph.

Table 4 Family standardised variances for seed of different origin - groups of 48 families.

	leaf[1] number	tiller[1,3] number	plant[2] number	tiller[2,3] number	dry[2,3,4] weight
Seed origin					
Glasshouse '91	0.58	0.95	0	0.14	0.69
Aorangi '92	0.86	1.13	1.77	1.29	0.94
Glasshouse '92	0.71	1.29	0.22	0	0.43

[1] 32-39 days after sowing, mean of seedlings outside and In glasshouse.
[2] 75 days after sowing, seedlings outside.
[3] analysis of logarithms
[4] total dry weight per plot/seedlings present.

Field trial:

As for the box trial, the families harvested at Aorangi established poorly in the Lincoln trial compared with the other groups (Table 5). The field increases of G48 were not different from the G48 glasshouse harvest.

The between-family variance was highest for the group harvested in the field, and several progenies in this group had higher means than the controls.

Discussion

Several authors have discussed the possibility of breeding tall fescue for better seedling vigour (e.g. Badoux 1977; Lewis & Garcia 1979; Brock et al. 1982; Faulkner *et* al. 1982). Faulkner et *al.* (1982) noted the effects on establishment of seed lots and conditions of seed production.

The data of both the breeding families and the control lines indicate that seed matured in a warm glasshouse germinates and establishes more readily than seed harvested in the field in early New Zealand summer. The 1992 spring and early summer in Manawatu were cooler and moister than the long-term mean. However, some families harvested in the field did show good germination and establishment.

For tall fescue breeding the implications are clear. In the Lincoln trial, like those of earlier breeding experiments, the glasshouse-harvested families appeared outstanding relative to the controls. This was not true, however, of the breeding families harvested in the field, although they were genetically identical to those from the glasshouse. Breeding material needs to be harvested in conditions similar to those of commercial seed production. In these conditions, useful variation will be revealed which will allow selection for good seedling vigour. If seed is harvested in a glasshouse, this variation is partly hidden, as indicated by the consistently lower family variances of the glasshouse-harvested groups, and response to selection will be limited.

For the seed industry, our results suggest that tall fescue seed would be better grown in districts with a reliable warm spring and early summer. The results also pose the question of whether the acknowledged superior establishment of 'AU Triumph' relative to Roa may be related to conditions of seed harvest.

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Table 5 Mesas and variances from Lincoln field trial[1]

	number of entries	mean	family variance*
Glasshouse '91	103	19.69	1.26
Aorangi '92	139	9.32	1.96
Glasshouse '92	30	10.66	1.35
l.s.d. (5%)[3]		0.76	
G48, Aorangi		12.9	
G46, Hawkes Bay		13.3	
G48, Lincoln		14.4	
G48, Glasshouse		14.1	
Roa, Aorangi		13.1	
AU Triumph		16.4	
l.s.d.(5%)		4.6	

1 Sum of 5 growth notes within 6 weeks of sowing
2 Standardised family variances
3 l.s.d. for comparing Aorangi against mean of other groups

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