finalreport

Project code: **DAV.095**

Prepared by: **Z.Jahufer, K.Reed, F.Gawler, H.Armstrong, D.Pickett, G.Kearney, J.Ayres, C.Harris**
Agriculture Victoria Hamilton

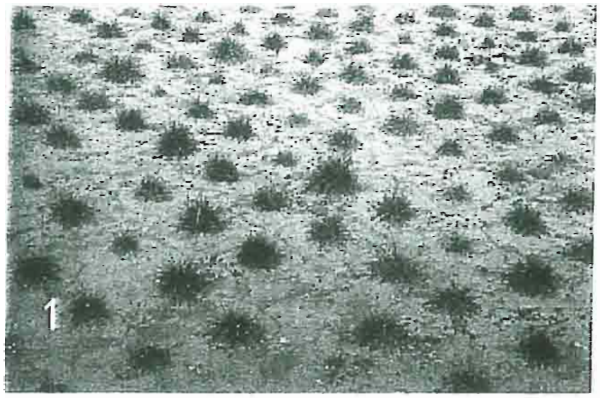
NSW Agriculture

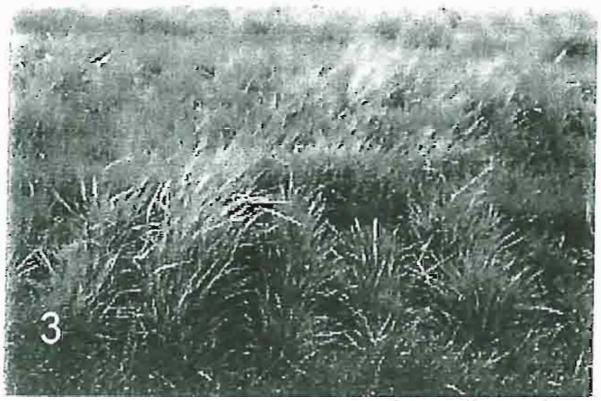
Date published: **October 1999**

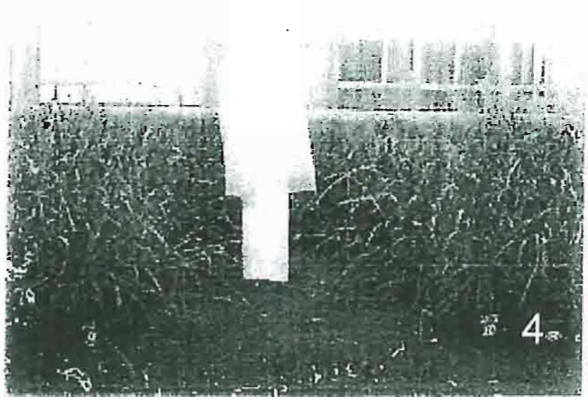
ISBN: **9781741912425**

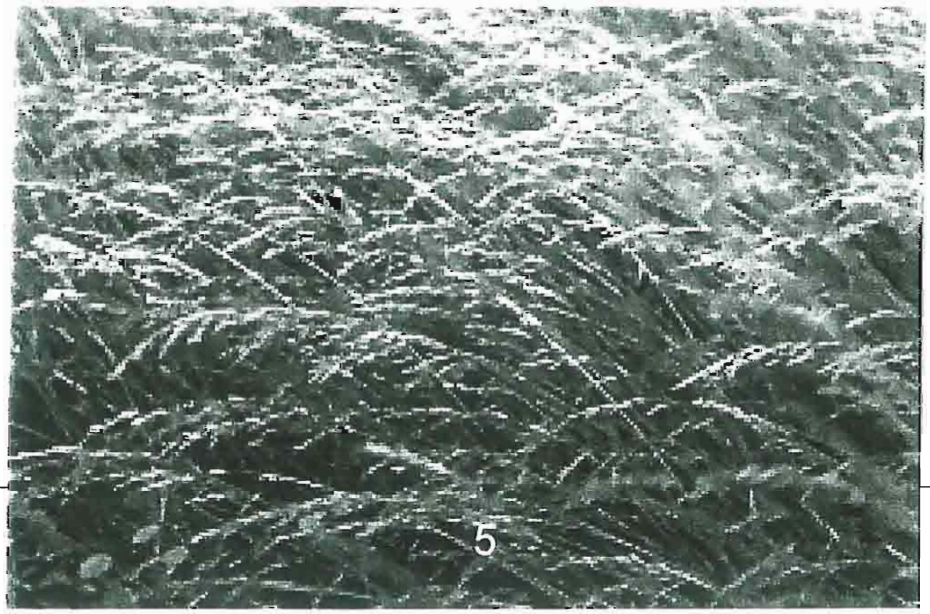
PUBLISHED BY
Meat & Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Tall fescue improvement for winter growth, seedling vigour, and productivity 1996 - 1999









1. Spaced plant nursery.
2. Early evaluation drill rows.
3. Late evaluation drill rows.
4. Seed multiplication in crossitron.
5. Seed multiplication under field conditions.

Project Staff

Agriculture Victoria – Hamilton

Pastoral and Veterinary Institute

Dr. Zulfi Jahufer *(Principal Investigator)*

Dr. Kevin Reed *(Project Supervisor)*

Ms. Felicity Gawler *(Assistant Plant Breeder)*

Mr. Harry Armstrong *(Senior Technical Assistant)*

Mr. Darren Pickett *(Technical Assistant)*

Mr. Gavin Kearney *(Consulting Biometrician)*

NSW Agriculture

Agricultural Research and Advisory Station, Glen Innes

Dr. John Ayres

Ms. Carol Harris

Contents

Summary

Limitations such as poor seedling vigour, poor winter production, and low palatability impede the use of tall fescue in Australia. Demeter and AU Triumph are presently the only two generally approved tall fescue cultivars in Australia. These two cultivars are both summer active and grow in areas where the rainfall exceeds 600 mm. Although there are a number of other cultivars commercially available, they lack adaptation to Australian environments.

Australia's National Tall Fescue Breeding Program was initiated in 1989 and based at the Agriculture Victoria, Pastoral and Veterinary Institute (PVI), Hamilton. This final report documents the successful achievement of the key milestones of the project "Tall Fescue improvement for winter growth, seedling vigour, and productivity (DAV 095)" for the period, July 1996 to June 1999.

The key objectives for this three year period were (i) multiplication of seed of the winter active/summer dormant selection from cv. Melik, (ii) selection and seed production of summer active germplasm accessions with superior cool season vigour, for the northern temperate summer rainfall environment of Australia, and the southern winter/spring rainfall environment of Australia.

A winter active/summer dormant experimental variety named "Fraydo" has been developed from the cultivar Melik for the low rainfall (500 mm to 600 mm), short grazing season temperate environments such as Balmoral in south-western Victoria. This experimental variety is based on 10 parents selected on half-sib families that had a mean performance across the sites Balmoral and Hamilton, of at least 40%, 50% and 40% higher than the cvs. Demeter and AU Triumph for the attributes: seedling vigour, winter production and plant density, respectively.

A total of 20 kg of synthetic II generation seed of Fraydo was produced at PVI, Hamilton, during the summer 1997/98 and summer1998/99 seasons. A seed production program has been initiated by Seed Grain and Biotechnology (SGB), the commercial partner to the program, to have the experimental variety commercially available by the year 2001. The provisional protection of PBR of Fraydo was granted in 1999. DUS trials of Fraydo were successfully initiated at Rutherglen, Victoria, in June 1999. Fraydo was submitted for Australian Pasture Plant Evaluation Committee (APPEC) trials in early 1999. The evaluation sites for the APPEC trials are at Balmoral and Rutherglen in Victoria, and Jericho in Tasmania. In addition to these

sites, Fraydo is currently being tested by SGB at a number of sites around Australia. An in-house merit testing trial was initiated by Agriculture Victoria in 1998 to evaluate the performance of Fraydo relative to a range of commercially available grass cultivars, under a rotational grazing management, at Balmoral. Preliminary results indicate that Fraydo has high seedling establishment, and good autumn dry matter production relative to the other treatments. This experiment will end July 2001.

Three years of evaluation (1993-1996) of 371 tall fescue germplasm accessions (from the United States Department of Agriculture) at Glen Innes, NSW, and Hamilton, Victoria, enabled identification of three superior summer active accessions with cool season vigour. They were, accession 358 for the northern NSW summer rainfall environment, accession 70 for the winter/spring rainfall environments of south-west Victoria, and accession 363 for broad adaptation. The final choice of cultivars to be marketed was made by SGB, indicating the preference for the development of accession 358 into a cultivar for northern NSW.

The experimental variety from accession 358 was developed from seed harvested from plants with superior seed yield from within a population of this accession in 1996. The first crop of the second generation seed (5.5 kg) of accession 358 was harvested in December 1998. An APPEC trial of accession 358 was established in June 1999 at Glen Innes, NSW.

In the future, trials to define optimum agronomic and management strategies for the two cultivars developed during the first 10 years (1989-1999) of the program will be carried out at Balmoral, Vic., and Glen Innes, NSW. Information from these trials will benefit farmers by providing them with appropriate management guidelines to exploit the potential of the new cultivars for animal production.

The potential of tall fescue for meat production will only be realised if the breeding effort initiated by Agriculture Victoria ten years ago is continued with the objectives of improving seedling vigour, seasonal dry matter production, leaf texture, and nutritive value. Considerable benefits of the current investment by DNRE, MLA, and NSW Agriculture, into the National Tall Fescue Breeding Program will be achieved if the genetic advance gained during the past ten years is supplemented with management information and genetic value adding (eg. development of new recombinant genotypes for persistence and palatability attributes using morphologically diverse intra specific crosses).

1. Introduction

Important attributes such as tolerance to drought, heat, insects, salinity, water logging, and response to irrigation, make tall fescue (*Festuca arundinacea*) a significant pasture species (Sleper and Charles 1996). In the United States, tall fescue is planted over an estimated area of approximately 14 million ha (Buckner *et al.* 1979). About 10 million ha of this area forms the feed base for over 8.5 million cattle for meat production (Hoveland 1993). Tall fescue is also used in Japan, southern Canada, Australia, New Zealand, Mexico, Columbia, Argentina, in certain parts of the African continent, and in most parts of Europe.

The potential of tall fescue has not been fully utilised in Australia (Reed 1996; Hill and Donald 1997; Milne and Johnson 1997). Tall fescue is currently grown over an estimated area of 1.3 million ha, of which 0.51 million ha are in NSW (Archer 1995), and the potential area of adaptation is estimated as 19.6 million ha (Hill and Donald 1997). Limitations such as poor seedling vigour, poor winter production, and low palatability impede the use of tall fescue in Australia (Easton *et al.* 1993; Milne and Johnson 1997). Demeter and AU Triumph are presently the only two generally approved tall fescue cultivars in Australia. These two cultivars are similar in their growth patterns. They are both summer active and grow in areas where the rainfall exceeds 600 mm. Although there are a number of other cultivars commercially available, they lack adaptation to Australian environments.

Australia's National Tall Fescue Breeding Program was initiated in 1989 and based at the Agriculture Victoria Pastoral and Veterinary Institute, Hamilton. Since 1993, the program has been a joint program between Agriculture Victoria and NSW Agriculture, supported by Meat and Livestock Australia. The commercial partner to the program is Seed Grain and Biotechnology (SGB).

This final report documents the successful achievement of the key milestones of the project "Tall Fescue improvement for winter growth, seedling vigour, and productivity (DAV 095)" for the period, July 1996 to June 1999.

The key objectives for this three year period were: (i) multiplication of seed of the winter active/summer dormant selection from cv. Melik, (ii) selection and seed production of summer active germplasm accessions with superior cool season vigour for the northern temperate summer rainfall environment of Australia, and the southern winter/spring rainfall environment of Australia.

2. Development of the winter active/summer dormant experimental variety "Fraydo"

The experimental variety (*in this report, the term experimental variety refers to a genetically improved population of tall fescue that is at present not officially registered as a commercial cultivar*) Fraydo was developed from cultivar Melik to improve winter production for the low rainfall (500-600 mm), short grazing season, and temperate environments such as Balmoral in south west Victoria. In 1995, ten superior parents were selected based on progeny testing trials at Hamilton and Balmoral, Victoria (Venkatanagappa 1996). Selection was based on herbage production (winter, spring, and summer), seedling vigour, and leaf texture. The means of the superior half sib families, were at least 40%, 50% and 40% higher than the cvs. Demeter and AU Triumph for the attributes: seedling vigour, winter production, and plant density, respectively. The 10 parents of these superior half sib families were polycrossed in 1996 under strict isolation to produce the first generation of seed.

In June 1997, a random sample of 4,500 plants taken from the synthetic I generation was planted in a spaced plant nursery (an area of 25 m x 25 m, 25 cm between plants within rows and 50 cm between rows). The seed multiplication block was surrounded by an isolation crop of Triticale. The seed multiplication block was maintained using strict weed and pest/disease control.

Earlier evaluation of a prototype variety of Fraydo ("Melik selection") indicated outstanding cool season vigour and persistence relative to cvs Demeter and AU Triumph in a four year trial at Balmoral (Anderson *et al.* 1999).

2.1 Seed production

The first seed crop of the synthetic I generation was harvested in December 1997. A total of 14 kg of clean synthetic II seed was obtained from harvest 1. This seed was used for the production of synthetic III generation seed by SGB.

Following the harvest of the first seed crop, the plants in the seed production block were rotationally grazed by sheep until the beginning of autumn 1998. The high density of seed heads produced during the spring/early summer period of 1998 indicated a high potential seed yield. However, the occurrence of a frost in early summer 1998 resulted in a severe decrease of seed yield down to 6 kg. This seed will

be maintained as breeders seed in the working collection of germplasm at the Agriculture Victoria,Hamilton.

A seed production program has been initiated by SGB to have the experimental variety commercially available by the year 2001.

2.2 Endophyte status - Endophyte tests conducted on a random sample of the synthetic II generation seed indicated a negative status for the presence of the fungus.

2.3 Naming and merit testing

The experimental variety was named "Fraydo" by SGB in 1998. In early 1999, 900 g of synthetic II seed was submitted for Australian Pasture Plant Evaluation Committee (APPEC) trials. The evaluation sites for the APPEC trials are at Balmoral (Vic.), Jericho (Tas.), and Rutherglen (Vic.). In addition to these sites, Fraydo is currently being tested by SGB at a number of sites around Australia (refer to attached Table 1). The provisional protection of plant breeders rights of cv. Fraydo was granted in early 1999. DUS trials of Fraydo were successfully initiated at Rutherglen in June 1999.

Table 1. Evaluation sites of Fraydo

Site	Type of experiment
Gympie, Qld.	Demonstration plot
Braidwood, NSW	Replicated small plots
Cooma, NSW	Demonstration plot
Marangarell, NSW	Replicated small plots (slightly saline soil)
Marinna, NSW	Demonstration plot
Wagga Wagga, NSW	Replicated small plots
Yass, NSW	Replicated small plots
Balmoral, Vic.	In house merit testing site
Balmoral, Vic	APPEC trial
Coprryong, Vic.	Replicated small plots
Rutherglen, Vic	APPEC trial
Mt Compass, SA	Replicated small plots
Naracoorte, SA	Replicated small plots
Jericho, TAS	APPEC trial

2.3.1 The current in house merit testing trial at Balmoral, Victoria

The objective of this trial is to evaluate the performance of the new tall fescue experimental variety Fraydo relative to a range of commercially available grass cultivars, under a rotational grazing management, in a low rainfall (500-600 mm) environment. The experiment started in June 1998.

2.3.1.1 Experimental site

The experimental site at Balmoral represents the climatic and pastoral management conditions typical to the low rainfall target environment for which Fraydo was developed. The experimental plots are located in a paddock that enables grazing by sheep.

2.3.1.2 Treatments

The treatments included commonly used cultivars of tall fescue, ryegrass, phalaris, cocksfoot, and two blends of Fraydo and cv. Demeter. The treatments were: Fraydo, Blend 1 (70% Fraydo + 30% Demeter), Blend 2 (50% Fraydo + 50% Demeter), Demeter, AU Triumph, Victorian (perennial ryegrass), Fitzroy (perennial ryegrass), Australian (phalaris), Holdfast (phalaris), and Porto (cocksfoot).

Sub clover cv. Trikala has been used as the companion species in all the grass treatments. The planting rates were tall fescue - 10 kg/ha, perennial ryegrass - 7 kg/ha, phalaris - 3 kg/ha, cocksfoot - 3 kg/ha, and sub clover - 10 kg/ha.

2.3.1.3 Experimental design

A row column experimental design was used. This design will enable the variation due to row, column and row-by-column interaction effects to be estimated in the final data analysis. The plot size is 3 m x 5 m. There is a 0.5 m path way between columns and a 2 m path way between rows. Planting was carried out using a direct drill.

2.3.1.4 Grazing management

During the first 12 months (June 1998 – July 1999) the experiment was grazed lightly by sheep at the end of every season. Starting from July 1999, the experiment was rotationally grazed.

2.3.1.5 Measurements

Seedling establishment: The density of seedlings was determined by measuring the length of a row occupied by 10 seedlings at a randomly chosen position along a row. Three samples were taken from each plot.

Seasonal dry matter production: The first seasonal dry matter production measurement was taken at the end of summer 1998/99. The summer 1998/99 and autumn 1999 dry matter measurements were carried out using a 50 cm x 50 cm quadrate. Two random samples were taken from each plot using a reciprocating clipper at a height of 1cm above ground level.

2.3.1.6 Statistical analysis

The Residual Maximum Likelihood (REML) method (Harville 1977; Patterson and Thompson 1971, 1975) was used to estimate variance components and Best Linear Unbiased Predictor (BLUP) values (White and Hodge 1989) for seedling establishment, and summer 1998/99 and autumn 1999 dry matter production. The BLUP values were used to construct bar charts.

2.3.1.7 Results and discussion

The analysis of variance indicated significant ($P<0.05$) variation among the treatments for plant establishment, summer dry matter production and autumn dry matter production (Figs 1, 2, and 3). The perennial ryegrass cvs Fitzroy and Victorian were similar in establishment to the tall fescue cvs AU Triumph, Fraydo, and Blend 1 (Fig. 1). The establishment scores of these cultivars were high. The summer dry matter production of the ryegrass cultivar Victorian was significantly ($P<0.05$) higher than all the other cultivars (Fig. 2). The summer dry matter production of cvs AU Triumph and Demeter were similar but significantly higher than Fraydo and the Blends 1, and 2. The cv. Fitzroy perennial ryegrass, the experimental variety Fraydo and Blend 1 of tall fescue, and cv. Porto cocksfoot, had similar autumn dry matter production (Fig. 3).

The experimental variety Fraydo showed a significantly ($P<0.05$) better performance in terms of establishment, and summer and autumn dry matter production in comparison to the cultivars Australian, and Holdfast, of phalaris (Figs 1, 2 and 3).

These preliminary results indicate that the experimental variety Fraydo had a good seedling establishment, and a relatively low summer dry matter production, in comparison to cvs AU Triumph and Demeter, as expected. In autumn, Fraydo was among the highest yielding cultivars.

This trial will be terminated at the end of winter 2001. The final analysis of the experimental results should provide a good indication of the performance of Fraydo and the two blends in comparison to the other treatments.

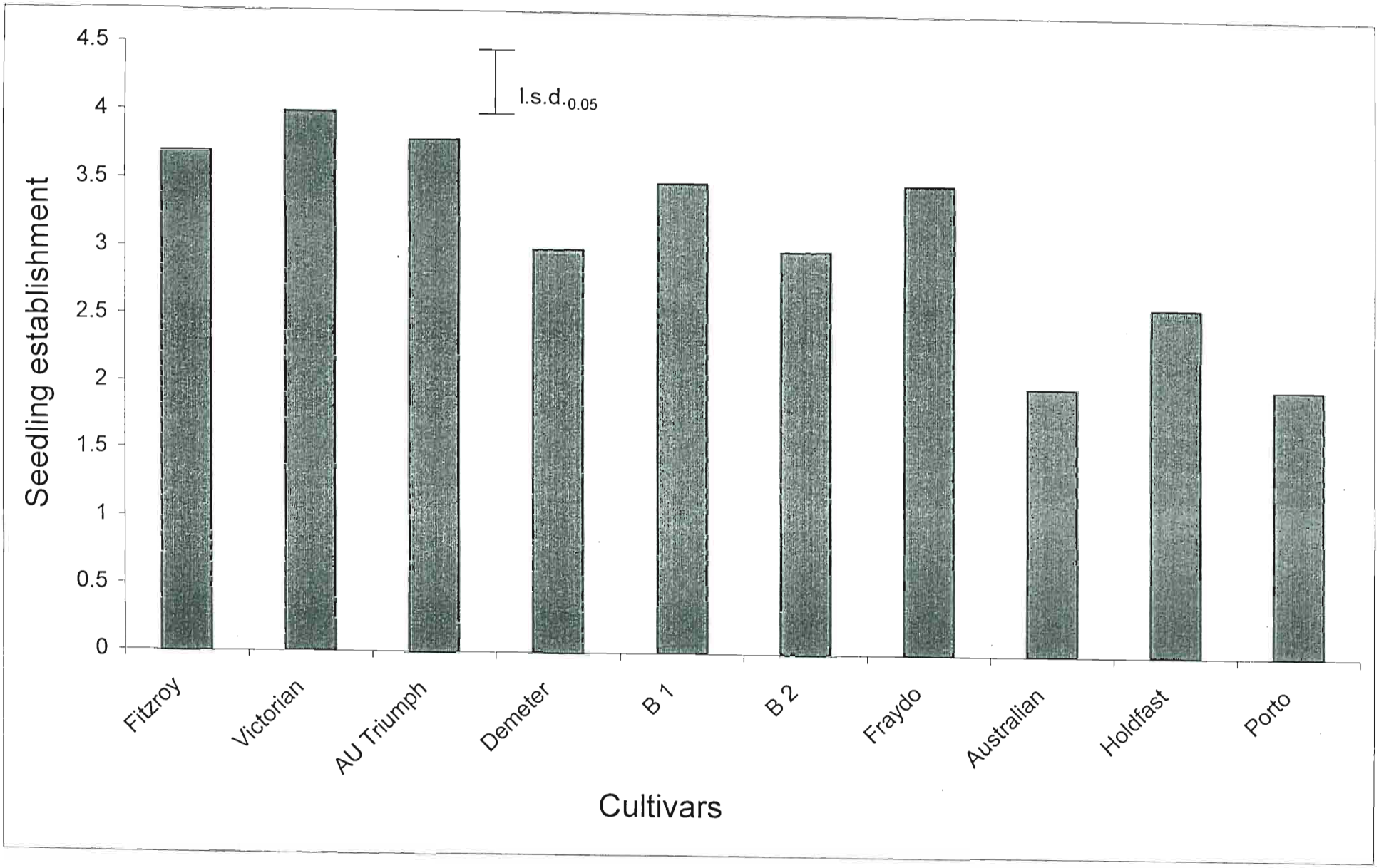


Figure 1. Seedling establishment (1-4). Ryegrass/Fitzroy, Victorian; Tall fescue/AU Triumph, Demeter, Fraydo, B 1 (70% Fraydo, 30% Demeter), B 2 (50% Fraydo, 50% Demeter), Phalaris/Australian, Holdfast; Cocksfoot/Porto.

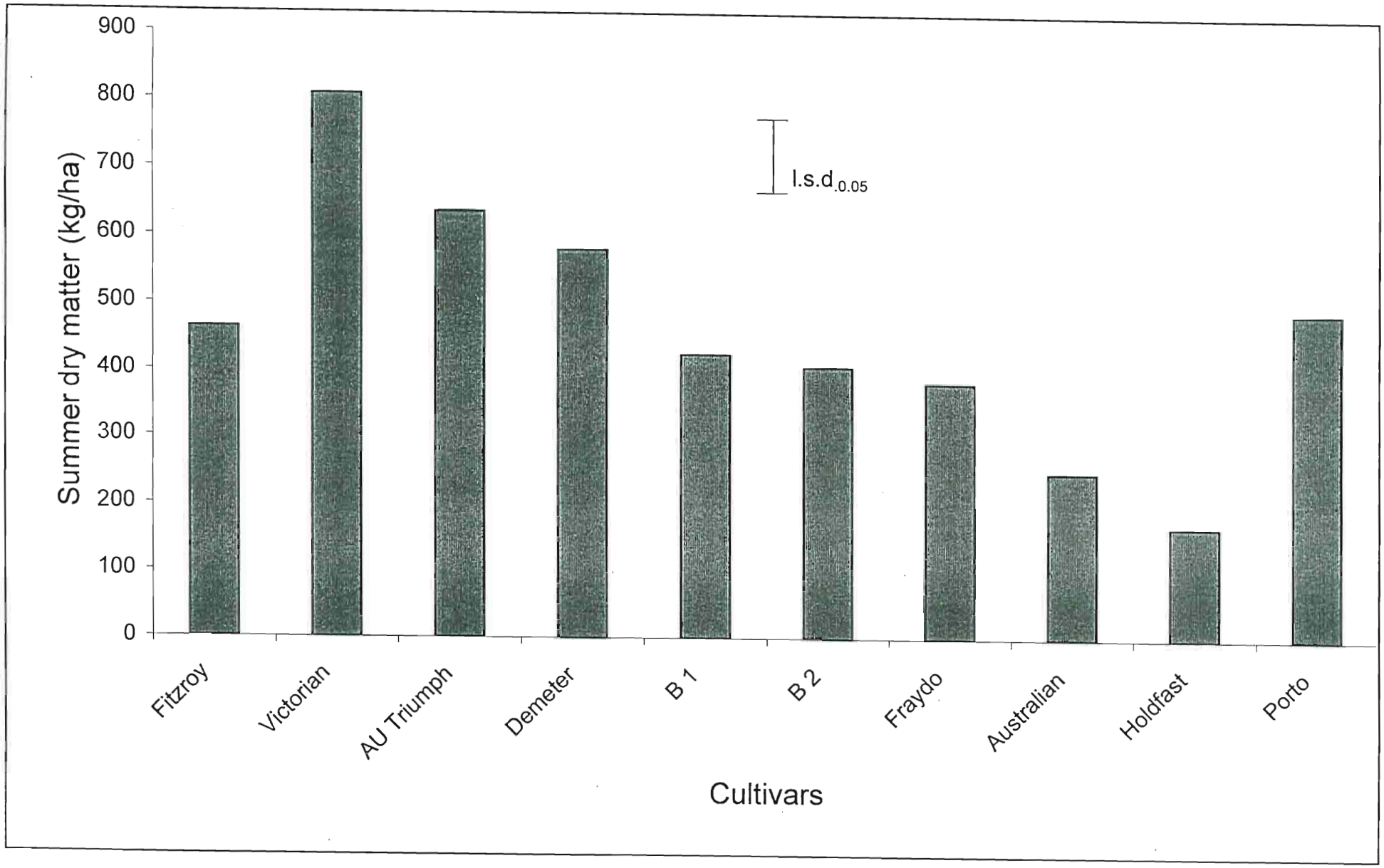


Figure 2. Summer 98/99 dry matter. Ryegrass/Fitzroy, Victorian; Tall fescue/AU Triumph, Demeter, Fraydo, B 1 (70% Fraydo, 30% Demeter), B 2 (50% Fraydo, 50% Demeter), Phalaris/Australian, Holdfast; Cocksfoot/Porto.

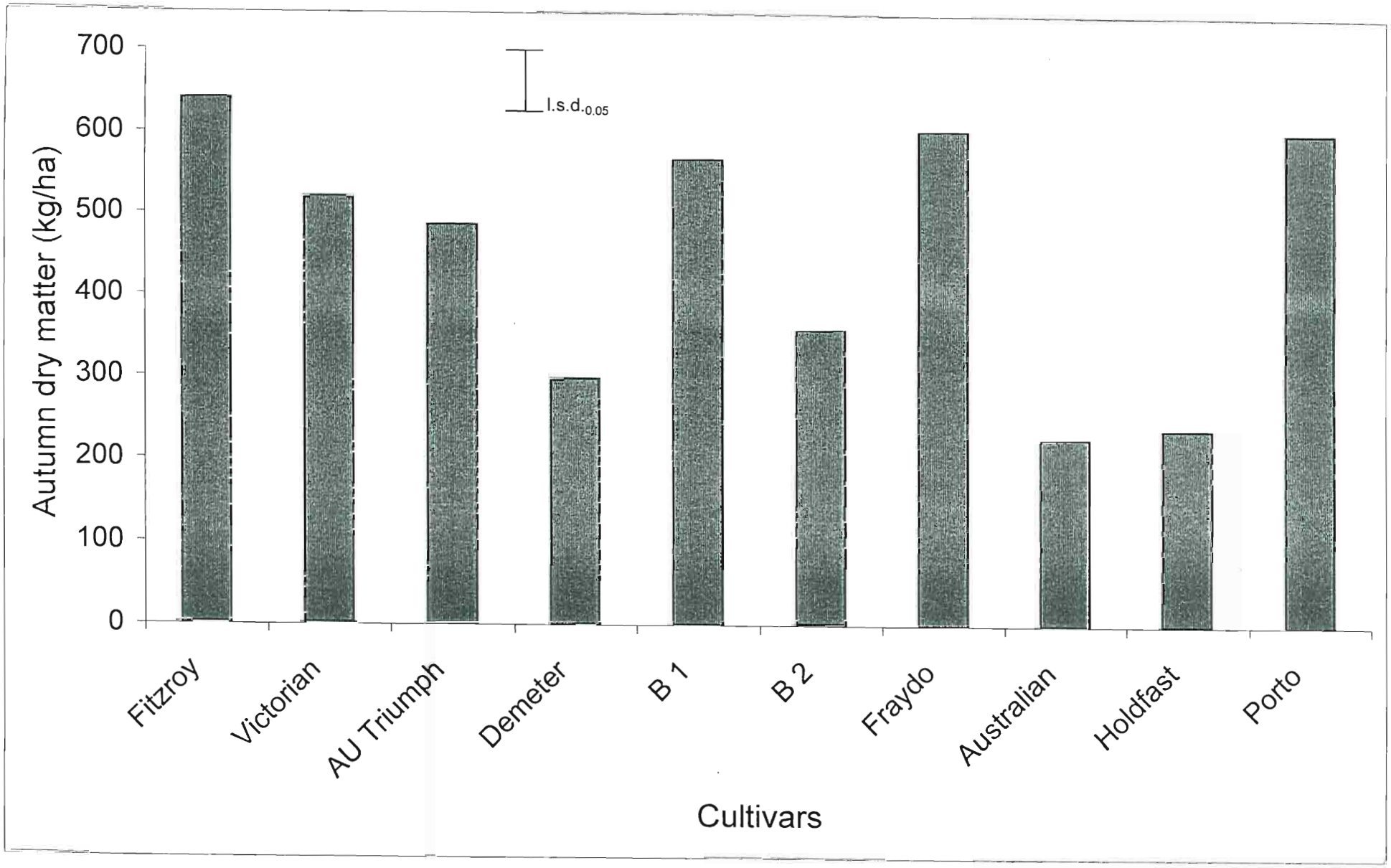


Figure 3. Autumn 99 dry matter. Ryegrass/Fitzroy, Victorian; Tall fescue/AU Triumph, Demeter, Fraydo, B 1 (70% Fraydo, 30% Demeter), B 2 (50% Fraydo, 50% Demeter), Phalaris/Australian, Holdfast; Cocksfoot/Porto.

3. Development of summer active tall fescue cultivars with superior cool season vigour for (a) the northern temperate summer rainfall environment of Australia, and (b) the southern winter/spring rainfall environment of Australia

3.1 Selection of superior accessions

In autumn 1993, 371 tall fescue germplasm accessions obtained from the USDA (United States Department of Agriculture) were planted for evaluation at Glen Innes, NSW, and Hamilton, Victoria (Venkatanagappa 1996). The accessions were evaluated for seedling vigour, rust resistance, flowering, growth habit, nutritive value, and seasonal herbage yield. Cultivars AU Triumph, Demeter, and Advance were used as standards.

A detailed description of the experimental layout, and the statistical analysis conducted is given in the final report "Tall Fescue improvement for winter growth, seedling vigour, and productivity" (DAV 095) for the period, July 1996 to June 1999, by Dr. Shoba Venkatanagappa.

3.1.1 Summary of data analysis

The selection of the superior accessions among the 371 germplasm accessions and check cultivars AU Triumph, Demeter, and Advance, was based on, a) the use of selection indices, and b) independent culling.

a) Selection index - The first culling of the 371 accessions was based on a selection index. The selection index was based on seasonal herbage yield. Weightings for winter (1994/95), spring (1994/95), and summer (1994/95) herbage yields were used. For the southern zone of Australia (mainly winter/spring growth), the weightings used were: 1.0 (winter), 0.9 (spring), and 0.6 (summer). A weighting of 0.75 was given for mean yield across all seasons. For the northern zone of Australia (mainly spring/summer growth) the weightings used were: 0.8 (winter), 0.9 (spring), and 0.9 (summer). A weighting of 0.75 was given for mean yield across all seasons.

b) Independent culling - The accessions identified using selection indices were subjected to further selection based on individual attributes: seedling vigour, plant habit, tiller type, leaf texture, recovery after summer, and nutritive value.

The use of the two methods of selection enabled identification of superior accessions that had a combination of better seasonal herbage yield and expression of

other selection attributes in comparison to the standards AU Triumph, Demeter, and Advance.

3.1.2 Results

Based on the selection indices developed, accession 358 was identified as the best suited for the northern zone, and accession 70 the best for the southern zone (Table 2). The accession 363 was ranked second in both zones.

Table 2. Selection indices of the selected tall fescue germplasm accessions from the USDA collection evaluated at Glen Innes, NSW, and Hamilton, Victoria

Northern zone of Australia		Southern zone of Australia	
Accessions/cultivar	Index*	Accession/cultivar	Index*
358	44.33	70	24.69
363	44.10	363	22.99
70	41.36	358	21.36
343	40.92	343	22.44
AU Triumph	42.09	AU Triumph	22.19
Demeter	40.95	Demeter	21.15
Advance	33.12	Advance	17.65

*the selection indices were developed by Dr. Shoba Venkatanagappa

The recommendations by Dr. Shoba Venkatanagappa indicated the suitability of accession 358 for the northern NSW environments (summer rainfall), accession 70 for the winter/spring rainfall environments of south-west Victoria, and accession 363 for broad adaptation. The accession 343 was not considered further as it was endophyte positive.

However, the final choice of cultivars to be marketed was made by SGB, indicating their preference of a single cultivar for northern NSW.

3.2 Seed production of the selected accessions

In early November 1997, over 100 plants of each 70, 358, and 363 were established in pots. The seed used to establish accession 358 was harvested from plants with superior seed yield from within a population of this accession in 1996.

When the first seed heads appeared, each population of 100 plants were isolated in a crossitron. The three accessions were harvested for seed in March 1998 (clean seed: 150 g accession 70, 50 g of accession 358, and 42 g of accession 363).

3.3 Seed multiplication of generation II of accession 358

In autumn 1998, a random sample of 5,500 plants taken from the first generation was planted in a spaced plant nursery (25 cm between plants within rows and 50 cm between rows). This seed multiplication block was surrounded by an isolation crop of Triticale.

The first seed crop of generation II seed (5.5 kg) was harvested in December 1998. Following the harvest of the first seed crop, the plants in the seed production block were rotationally grazed by sheep until the beginning of autumn 1998. The second crop of seed will be harvested in December 1999. This seed will be maintained at the Agriculture Victoria, Hamilton, as Breeders seed.

3.4 Endophyte status

Endophyte tests conducted on a random sample of the synthetic II generation seed of 358 indicated a negative status for the presence of the fungus.

3.5 Merit testing of 358

Seed of accession 358 was submitted for an APPEC trial sown in June 1999 to be evaluated at Glen Innes, NSW.

4. Conclusion

i) A winter active/summer dormant experimental variety has been successfully developed for the short grazing, low rainfall (500-600 mm) zone of south-west Victoria. This experimental variety "Fraydo" is currently under going merit testing by APPEC, and at a number of sites across Australia. The cultivar Fraydo should be available commercially by the year 2001.

ii) Four summer active accessions with relatively good winter growth, 70, 343, 358, and 363, were identified from within the USDA germplasm evaluated at Glen Innes, and Hamilton Victoria, as potential cultivars. It was decided by the National Tall Fescue Management Committee to proceed with the development of accession 358 as a cultivar for the summer rainfall environment of northern NSW. The development of accession 70, recommended as a potential cultivar for the winter/spring rainfall environments of south-western Victoria, is currently withheld as requested by SGB.

5. Future directions

i) Progressive development – The development of support management packages for efficient use of the genetic improvements made in the new cultivars for animal production

Trials to define optimum agronomic and management strategies for the two cultivars developed in phase 1 (1989-1999) of the program will be carried out at Balmoral, Vic., and Glen Innes, NSW. Strategies such as the use of blends between winter active and spring/summer active material will be investigated. Information from these trials will benefit farmers by providing them with appropriate management guidelines to exploit the potential of the new cultivars for animal production.

ii) Value adding for animal performance

The potential of tall fescue for meat production will only be realised if the breeding effort initiated by Agriculture Victoria ten years ago is continued with the objectives of improving seedling vigour, seasonal herbage production, leaf texture, and nutritive value. Considerable benefits of the current investment by DNRE, MLA, and NSW Agriculture, into the National Tall Fescue Breeding Program will be achieved if the genetic advance gained during the past ten years is supplemented with management information and genetic value adding (eg. development of new recombinant genotypes for persistence and palatability attributes using morphologically diverse intra specific crosses).

Key publications

Easton, H. S., Lee, C. K., and FitzGerald, R. D. (1994). Tall fescue in Australia and New Zealand. *New Zealand Journal of Agricultural Research*, **37**:405-17.

FitzGerald, R. D., Venkatanagappa, S., and Lane, L. A. (1995). Tall fescue improvement for Australian perennial pastures. *Proceedings NSW Grasslands Society Conference*, June 28-30, 1995.

FitzGerald, R. D., Venkatanagappa, S., and Lane, L. A. (1995). Tall fescue Agronomy research. *Proceedings NSW Grasslands Society Conference*, June 28-30, 1995.

Venkatanagappa, S., FitzGerald, R. D. Raleigh, R., Rowe, J. and Arulthilakan, J. (1996). Tall fescue breeding and improvement. *8th Australian Agronomy Conference*, January 29- February 2, 1996.

Venkatanagappa, Shoba. (1996). Final Report-DAV 095, Tall Fescue improvement for winter growth, seedling vigour and productivity. Final report to the Meat Research Corporation.

Venkatanagappa, Shoba, and Jahufer, Zulfi. (1998). A new summer dormant/winter active Australian tall fescue cultivar. *Proceedings of the 39th Annual Grassland Society of Victoria Conference*. pp. 131.

References

Anderson, M. W., Cunningham, P. J., Reed, K. F. M., and Byron, A. (1999). Perennial grasses of Mediterranean origin offer advantages for central western Victorian sheep pasture. *Australian Journal of Experimental Agriculture,* **39**:275-84.

Archer, Ken. (1995). The New South Wales pasture base. *Proceedings of the Tenth Annual Conference of the Grassland Society of NSW.* pp. 10-13.

Buckner, R. C., Powell, J. B., and Frakes, R. V. (1979). Historical development. In "Tall fescue" (eds R. C. Buckner, and L. P. Bush). pp. 1-8. Agronomy Monograph, 20. (American Society of Agronomy, Inc., Madison, Wisconsin USA).

Easton, H. S., Lee, C. K., and Fitzgerald, R. D. (1993). Tall fescue in Australia and New Zealand. (Eds K. Archer, R. A. Oram, and D. L. Michalk). pp.112-121. *Proceedings Perennial Grass Workshop, Pastoral and Veterinary Institute, Hamilton, Vic., Oct. 27-29, 1993.*

Harville, D. H. (1977). Maximum likelihood approaches to variance component estimation and related problems. *Journal of the American Statistical Association* **72,** 320-40.

Hill, M. J., and Donald, G. E. (1997). Determination of benefits from pasture improvement. *Final report for Australian Meat Research Corporation, March 26,1997.* (CSIRO, Australia).

Hoveland, C. S. (1993). Importance and economic significance of the *Acremonium* endophytes to performance of animals and grass plant. *Agricultural Ecosystems and Environments*, **44**:3-12.

Milne, G. D., and Johnson, F. (1997). Tall fescue guide for meat produces. (Pacific Seeds, NSW, Australia).

Patterson, H. D. and Thompson, R. (1971). Recovery of inter-block information when block sizes are unequal. *Biometrika* **58**, 445-554.

Patterson, H. D. and Thompson, R. (1975). Maximum likelihood estimation of components of variance. *In* ' Proceedings of the 8th International Biometrical Conference'. (Eds L. C. A. Corsten, and T. Postelnicu). pp. 197-207. (International Biometrics Society: Bucuresti, Romania).

Reed, K. F. M. (1996). Improving the adaptation of perennial ryegrass, tall fescue,

phalaris, and cocksfoot for Australia. *N. Z. Journal of Agricultural Research*, **39**:457-464.

Sleper, D. A., and Charles, P. W. (1996). Tall Fescue. In "Cool season and forage grasses" (eds L. E. Moser, D. R. Buxton, and D. Casler). pp. 471-502. (American Society of Agronomy, Inc., Madison, Wisconsin USA).

Venkatanagappa, Shoba. (1996). Final Report-DAV 095, Tall Fescue improvement for winter growth, seedling vigour and productivity. Final report to the Meat Research Corporation.

White, T. L., and Hodge, G. R. (1989). Predicting breeding values with applications in forest tree improvement. *In* 'Forestry Sciences', **33**, (Kuwer Academic Publishers, Boston).

Acknowledgments

The Department of Natural Resources and Environment Meat Program, and Meat and Livestock Australia, are acknowledged for their financial support to the National Tall Fescue Breeding Program.

The important scientific contribution made to the tall fescue breeding program by Dr. S. Venkatanagappa, as the Geneticist/Plant Breeder (1994-1997), is acknowledged. The contribution of Dr. R. Nair to the program as acting plant breeder in 1997 (March/August) is also acknowledged.