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Evaluation of bred populations and cultivars of *Setaria sphacelata*

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Abstract

Setaria sphacelata (setaria) is a widely sown pasture grass in wetter regions of the sub-tropics and tropics of Australia and elsewhere. The species is extremely variable, and it was considered that there were opportunities for improving yield in the cool season, winter-greenness, digestibility and seed production by breeding. Sward trials are described in which 13 populations of setaria were grown with nitrogen fertilizer or with a legume at two sites, in south-east Queensland, for three years. The setarias included nine advanced breeding populations, one accession and the cultivars Nandi, Narok and Kazungula. Plots were harvested at c. 6-weekly intervals. Dry matter yield and inflorescence numbers were recorded, as well as winter-greenness following frosting. For several harvests, *in vitro* digestibility and percentage stem were also measured.

Yields from N-fertilized swards differed significantly for all but three of the 12 site-season (2 sites, 3 years, winter and summer) combinations. At Lawes, Narok was consistently higher yielding than other setaria cultivars, especially in winter. At Beerwah, Narok was markedly superior to Kazungula in winter but otherwise differed little from other entries. None of the breeding populations was significantly higher yielding than Narok.

Total yield from legume-based swards differed for only three of the six sites-years and legume yield only once. The setarias showed large differences in flowering and winter-greenness and significant differences in digestibility.

It is concluded that the bred populations of setaria studied showed little advantage over Narok under the management systems imposed, but that phenological differences could be associated with improved seed production as compared with Narok, which is commercially regarded as a poor seed-producer. Two of the breeding populations were later combined and released as the cultivar Splenda and another as cv. Solander.

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Resumen

Setaria sphacelata *(setaria) es una gramínea ampliamente utilizada en las pasturas de las regiones más húmedas de los trópicos y subtrópicos de Australia y de otras partes del mundo. La especie es extremadamente variable y se consideró que hay oportunidades para mejorar el rendimiento en la estación fría, el verdor en el invierno, la digestibilidad y la producción de semilla mediante el cruzamiento. Se describen experimentos en pasturas de 13 poblaciones de setaria, ya sea fertilizadas con nitrógeno o asociadas con leguminosas; conducidos en dos localidades al sur-este de Queensland durante tres años. El grupo de setarias incluyó nueve poblaciones de cruzamiento avanzado, una accesión y los cultivares Nandi, Narok y Kazungula. Las parcelas fueron cosechadas a intervalos de aproximadamente seis semanas.*

Los rendimientos obtenidos en las parcelas fertilizadas con N difirieron significativamente en 9 de las 12 combinaciones de localidades, años y estaciones (2 localidades, 3 años, invierno y verano). En Lawes, Narok fue consistentemente más rendidor que los otros cultivares de setaria, particularmente en el invierno. En Beerwah, Narok fue marcadamente superior a Kazungula en el invierno pero varió poco con respecto a las otras gramíneas. Ninguna de las poblaciones cruzadas fue significativamente mayor que Narok.

El rendimiento total de las parcelas asociadas difirió únicamente en tres de las seis combinaciones de localidades y años y únicamente se obtuvo una cosecha de la leguminosa. Las setarias tuvieron grandes diferencias en floración y en el verdor de invierno y las diferencias en la digestibilidad fueron significativas.

Se concluyó que las poblaciones de setaria estudiadas mostraron poca ventaja sobre Narok bajo el sistema de manejo impuesto, pero las diferencias fenológicas pudieran estar asociadas con un mejoramiento en la producción de semilla en relación a Narok, el cual es considerado comercialmente como pobre productor de semilla. Dos de las poblaciones cruzadas fueron posteriormente combinadas y liberadas como los cultivares Splenda y Solander.

Introduction

Setaria sphacelata[1] is a cross-pollinating perennial pasture grass of African origin which is widely grown in subtropical and montane tropical regions with rainfall exceeding c. 800 mm in Australia and overseas (Hacker and Jones 1969). The cultivar Nandi, developed in Kenya (Bogdan 1965), was introduced to Queensland in 1961; Kazungula, of southern African origin, was released as a cultivar in Australia in 1962 (Oram 1990). Both these cultivars are susceptible to light frosts which result in total leaf kill. With increasing interest in the species, a collection of introductions was assembled in Brisbane and it was noted that ecotypes from the Aberdares region of Kenya retained green leaf following light frosts (Williams 1964). Further collections were made by R.J. Jones and many of these proved to remain green when lightly frosted, the level of frost tolerance increasing with altitude of provenance (Hacker 1972, Hacker *et al.* 1974).

The first winter-green cultivar to be released was cv. Narok, in 1969 (Oram 1990). It is now grown widely from northern NSW to the Atherton Tableland in north Queensland. However, results from small-plot trials suggested that a range of frost-sensitive accessions had potential for growth both in winter and in summer which much exceeded that of CPI 33452, the introduction from which Narok was selected (Hacker 1972). It was considered that opportunities existed for combining the yield attributes of some lowland accessions with the winter-greenness of montane accessions by hybridization and selection. The possibility was restricted, however, because most of the winter-green accessions (from the highest altitudes) are hexaploids ($2n = 6x = 54$) whereas the commercial cultivars, including Narok, and higher-yielding lowland accessions, are mostly tetraploids and diploids (Hacker 1966). Although there is the possibility of moving genes from one level of polyploidy to another by hybridization (Hacker 1968) the disruption to meiotic stability would be likely to result in seed production problems and genetic instability.

A deficiency in Narok, which only became apparent after its release, is its relatively poor seed production, especially after the first year. The acceptance of Narok by the grazing industry was limited by the high cost of seed. Improvement in seed production thus became a goal of the selection program.

A quite separate goal of the setaria breeding program related to the near-total sterility of the botanical variety *splendida*. This variety is high-yielding (Hacker 1972, Rodriguez and Rebelo 1983) and supports high levels of animal production when clonally planted in a nitrogen-fertilized pasture (T.R. Evans and J.B. Hacker, unpublished data). It is now grown in Malaysia (T.R. Evans, personal communication) and Indonesia (Siregar *et al.* 1985), where it is vegetatively planted (T.R. Evans, personal communication). Development of a seed-producing cultivar with the yield attributes of *splendida* became a breeding objective.

The present paper discusses the breeding programs in setaria and the agronomic evaluation of the resultant bred populations which subsequently gave rise to the cultivars Solander and Splenda. The objectives of the work were to determine whether any of the bred experimental populations were sufficiently superior to the existing cultivars, in terms of total and seasonal productivity, compatability with pasture legumes, quality and/or winter-greenness to warrant release as new cultivars. A secondary objective was to compare the agronomic performance of Nandi, Narok and Kazungula, as no comparative data had been published on these cultivars.

Materials and methods

The breeding program which gave rise to the nine experimental populations is summarized in an

[1] The currently accepted binomial *S. sphacelata* (Schumach.) Moss includes taxa which are reported in the literature referred to in this paper as *S. splendida*, *S. anceps* and *S. trinervia*.

appendix to this paper. The populations are in three groups, coded LH and EH (tetraploids) and D (hexaploids). Within groups, the three populations have a common parental origin.

Two trials were established at each of the two sites, Lawes (27° 34 'S, 152° 20 'E) and Beerwah, (26° 50 'S, 153° 02 'E). The Lawes site was on a fertile prairie soil developed on alluvium, the Beerwah site on a sandy, infertile, yellow podzolic grading to a gleyed podzolic soil. All four trials were randomized block experiments with 13 populations and three replicates. The populations consisted of the cultivars Nandi, Narok and Kazungula, the nine bred populations and CPI 33453 (Table 1). Plot size was 8 x 2 m with intervening 1 m alleyways. All plots at Lawes were sown into cultivated seedbeds in October 1974, except for the experimental variety EHA, of which very limited quantities of seed were available, which was planted vegetatively. Sowing rate was 1 kg pure live seed per ha. The experiments at Lawes were irrigated to promote germination and early establishment. The Beerwah trials were sown in December 1974 in a similar manner to the Lawes trials.

One experiment at each site included a legume, the other was nitrogen fertilized. At Beerwah, *Desmodium intortum* cv. Greenleaf was sown at 3 kg/ha; at Lawes glycine (*Neonotonia wightii* cv. Cooper) was sown at the same rate.

Before sowing, a general fertilizer which included trace elements (Bryan 1968) was applied to the Beerwah site together with 50 kg/ha NH_4NO_3. No pre-sowing fertilizer was applied to the more fertile Lawes site. Both experiments were fertilized with 200 kg/ha superphosphate and 100 kg/ha KCl in split dressings in October and March throughout the experimental period. The nitrogen-fertilized experiments were fertilized with 25 kg/ha N as urea after each harvest.

Establishment counts were carried out at Beerwah on January 31, 1975 and at Lawes on December 6, 1974.

Experimental harvests were initiated at Lawes on November 25, 1975 after a clearing cut on October 14, 1975 and fertilizer application on October 23, 1975. At Beerwah, a clearing cut was made on November 4, 1975, fertilizer was applied on November 7, and the first experimental harvest was taken on December 16, 1975.

Thereafter, plots were harvested at c. 6-weekly intervals. Before each harvest, the number of flower heads was counted within two 1 m^2 quadrats. A 2.8 m strip was harvested to a height of 75 mm with a forage harvester with a 0.71 m cutting width, giving a harvested area of 2 m^2 per plot. Harvested fresh material was weighed, subsampled and the subsamples oven-dried and weighed. In the legume experiments, further subsamples were taken for separation into grass and legume fractions.

Harvests taken from the nitrogen-fertilized experiments at Lawes on February 17 and March 30, 1976 and at Beerwah on January 29 and March 12, 1976 were analyzed for *in vitro*

Table 1. Dry matter yield from N-fertilized plots at Lawes

	Summer				Winter			
	23.10.75-29.3.76	14.9.76-13.4.77	20.9.77-18.4.78	Mean	29.3.76-14.9.76	13.4.77-20.9.77	18.4.78-23.8.78	Mean
				(t/ha)				
Nandi	3.94	6.70	8.69	6.44	0.69	0.42	0.38	0.50
Narok	5.69	8.86	10.73	8.43	1.18	0.67	0.84	0.90
Kazungula	4.10	7.10	9.18	6.79	0.18	0.21	0.15	0.18
LHA	4.05	8.22	9.45	7.24	0.57	0.41	0.43	0.47
LHB	4.42	7.97	10.02	7.47	0.76	0.47	0.60	0.61
LHC	4.74	8.14	10.85	7.91	0.68	0.50	0.64	0.61
EHA	7.51	9.58	10.87	9.32	1.44	0.91	0.89	1.08
EHB	6.80	9.38	10.08	8.75	1.20	0.70	0.97	0.96
EHC	5.33	8.15	9.40	7.63	1.03	0.59	0.88	0.83
DA	5.18	8.51	10.74	8.15	1.25	0.83	0.63	0.90
DB	5.20	8.96	10.50	8.22	0.95	0.69	0.52	0.72
DC	5.25	8.94	11.40	8.53	1.26	0.72	0.70	0.90
33453	5.68	8.02	9.46	7.72	1.04	0.74	0.59	0.79
Mean	5.22	8.35	10.10	7.89	0.94	0.60	0.63	0.73
CV (%)	24.6	8.3	12.5	9.5	27.2	25.2	20.6	17.8
LSD 5%	—	1.17	—	1.26	0.43	0.26	0.22	0.22
	N.S.	**	N.S.	**	***	***	***	***

digestibility following the method of Minson and McLeod (1972).

Four harvests from the nitrogen-fertilized experiment at Lawes were subsampled and separated into leaf lamina and stem + leaf sheath. These were harvests of March 1 and April 13, 1977 and January 24 and March 7, 1978.

During winters a minimum thermometer was located within the Lawes nitrogen-fertilized experiment at a height of c. 0.2 m above the soil surface and examined as necessary for measurement of frost severity. (The Beerwah site was only infrequently subject to frost.)

Data were compared by analysis of variance. Percentage green leaf after frosting and inflorescence numbers were subjected to angular transformation, in the latter case after first dividing by 10.

Results

Establishment

At Beerwah, mean desmodium establishment was 18 plants/m^2 (range 8-32). One replicate only had a strong germination of *Macroptilium atropurpureum* seedlings (19-38 plants/m^2), a carry-over from an earlier trial. This species was included in legume yield for the duration of the experiment. *Stylosanthes* spp. seedlings were also evident in some plots; these tended to increase over the three years of the experiment but were not included in the legume totals. Grass seedlings were not counted at this site but a good establishment was obtained in all plots.

At Lawes, there was an average of 6.8 glycine seedlings/m^2 (range 4.8-11.5). Numbers of grass seedlings ranged from 23.7 to 76.5 seedlings/m^2.

Summer and winter dry matter production

Populations at Lawes differed in dry matter yield for mean summers ($P<0.01$) and mean winters ($P<0.001$), also for all seasons ($P<0.01$) excluding summer 1975-76 and 1977-78 (Table 1). The setaria cultivars in summer ranked Narok > Kazungula > Nandi. In winter, the poor growth potential of Kazungula was clearly evident, with Narok having 3-6 times the dry matter yield of Kazungula. Considering the bred populations, there was an overall tendency for the EH series to be higher yielding than D or LH series but in no instance did dry matter yield significantly exceed that of Narok. Similarly, the D series populations did not significantly outyield their parental accession 33453.

At Beerwah (Table 2), results were broadly in agreement with those at Lawes. Significant differences were obtained for mean summers and winters ($P<0.001$), summer, 1977-78 and all three winters ($P<0.001$). The setaria cultivars did not rank consistently in summer, but in winter Narok produced 4-5 times the yield of Kazungula. None of the bred populations was significantly and consistently higher yielding than Narok either in

Table 2. Dry matter yield from N-fertilized plots at Beerwah

	Summer				Winter			
	4.11.75-20.4.76	5.10.76-26.4.77	11.10.77-9.5.78	Mean	20.4.76-5.10.76	26.4.77-11.10.77	9.5.78-12.9.78	Mean
	(t/ha)							
Nandi	5.16	6.75	4.18	5.36	0.71	0.63	1.36	0.90
Narok	4.88	6.47	4.67	5.34	0.89	0.69	1.73	1.10
Kazungula	5.63	6.97	4.71	5.77	0.18	0.17	0.30	0.22
LHA	5.24	6.71	5.13	5.69	0.55	0.51	0.46	0.51
LHB	5.13	6.28	4.53	5.31	0.68	0.54	0.65	0.62
LHC	5.38	7.33	4.96	5.89	0.61	0.48	0.59	0.56
EHA	5.71	6.26	4.54	5.51	0.80	0.43	1.19	0.81
EHB	6.34	6.91	4.42	5.89	0.68	0.66	1.17	0.84
EHC	5.68	7.05	4.54	5.76	0.79	0.71	1.15	0.89
DA	5.03	6.79	4.96	5.59	0.82	0.59	1.06	0.82
DB	6.51	7.54	5.36	6.47	0.95	0.73	1.37	1.02
DC	5.62	7.12	5.01	5.92	0.93	0.74	1.22	0.96
33453	4.68	6.15	3.93	4.92	0.74	0.64	1.54	0.97
Mean	5.46	6.79	4.69	5.65	0.72	0.58	1.06	0.79
CV (%)	11.7	10.0	6.9	6.9	14.9	18.5	18.9	11.9
LSD 5%	—	—	0.55	0.66	0.18	0.18	0.34	0.16
	N.S	N.S.	***	***	***	***	***	***

summer or winter; however, the LH series were lower yielding than the D or EH series in all three winters.

Productivity in grass-legume experiments

Total yield in summer at Lawes decreased from year to year but populations did not differ significantly in yield in any year (data not presented). Mean legume yield decreased from 50% of total yield in year 1 to 33% in year 3. Legume yield had a markedly higher coefficient of variation than did total yield; differences were not statistically significant in any of the three years.

At Beerwah, as at Lawes, total summer yield fell from year to year (data not presented). Differences were statistically significant in year 1, when only one population (EHC) was significantly higher yielding than Narok. In years 1 and 2, Narok was highest yielding of the cultivars although differences were not significant. Legume yield averaged 23%, 49% and 21% of total yield for the three successive years of the experiment. Coefficients of variation were extremely high (48-73%) for legume yields, which did not differ significantly between grass populations.

Frost sensitivity

Damaging frosts occurred at Lawes on July 31, 1977 (−3.5 °C) and July 11, 1978 (−2.0 °C).

Estimates of percentage green leaf following frosting (Table 3) in 1977 and 1978 exhibited a high order of inter-population variation ($P<0.001$) and closely comparable results for the two estimates. The only commercial cultivar exhibiting winter-greenness was cv. Narok. EH series populations exhibited equivalent levels of winter-greenness to Narok, with progressively lower levels in D series and LH series populations. However, even LH series exhibited a higher level of winter-greenness than the frost-sensitive Nandi and Kazungula. Within groups LH, EH and D winter-greenness of the three populations was closely comparable.

Table 3. Percentage green leaf after frost at Lawes

	1977[1]	1978[2]
33453	91 (72.4)[3]	92 (73.6)
EHB	90 (71.7)	86 (68.8)
Narok	87 (69.4)	86 (68.2)
EHC	86 (68.2)	83 (65.6)
EHA	78 (62.3)	83 (65.8)
DB	77 (61.7)	70 (56.6)
DC	76 (61.0)	78 (62.2)
DA	72 (58.9)	75 (60.3)
LHC	67 (55.3)	53 (46.9)
LHB	67 (55.1)	42 (40.7)
LHA	60 (50.8)	50 (45.0)
Kazungula	44 (41.6)	33 (35.0)
Nandi	27 (31.1)	35 (36.4)
LSD (5%)	(9.0)	(7.8)

[1] August 2, 1977; 3 days after −3.5 °C grass temperature
[2] July 17, 1978; 6 days after −2.0 °C grass temperature
[3] Angular transformed data in parentheses

Digestibility

Mean digestibility data are given in Table 4. Narok and CPI 33453 had high values and Nandi the lowest.

Table 4. Digestibility of total herbage of setaria populations averaged over N-fertilized experiments at Lawes (harvests of 18.2.76 and 29.3.76) and Beerwah (harvests of 20.1.76 and 9.3.76)

Population/genotype	Digestibility
33453	62.5
Narok	61.9
DA	61.4
EHA	61.1
LHC	61.1
DB	61.0
Kazungula	60.9
LHA	60.8
LHB	60.7
EHC	60.0
DC	59.7
EHB	59.2
Nandi	58.7
LSD (5%)	1.5

Stemminess

Averaged over the four summer harvests from Lawes, which were separated into leaf and stem, Kazungula had the highest percentage stem (50%) and EHB the lowest (34%). Narok and Nandi had 36 and 45% stem, respectively.

Percentage stem differed at Lawes on March 2 ($P<0.01$) and April 13 ($P<0.001$) 1977 but there was no correlation ($r = 0.06$; $P>0.10$) between data from the two dates. On March 2, the range was from 22% (EHB) to 46% (Kazungula) and on April 13 from 36% (DB) to 62% (LHA). In 1978, the range for the January 24 harvest was 33-40% ($P>0.05$) and for the March 7 harvest, 40-50% ($P<0.05$).

Inflorescence numbers

Total inflorescence numbers varied widely between populations but were relatively constant from year to year (Table 5). D series populations and 33453 had markedly more inflorescences than did the EH populations, which in turn had more than the LH populations. Amongst the cultivars, Nandi had the highest number of inflorescences. Inflorescence number was not significantly correlated with leafiness, either in 1976-77 summer (March, $r = 0.34$; April, $r = -0.26$) or in 1977-78 summer (January, $r = 0.43$; March $r = -0.05$).

Discussion

The objectives of this study were to compare the setaria cultivars available in the 1970s in terms of agronomic attributes and to determine whether any of the experimental setaria varieties, bred primarily for winter yield, frost tolerance and digestibility, exhibited any superiority to existing cultivars.

In the N-fertilized experiments, summer yields of the cultivars were inconsistent, with a tendency for Narok to be higher yielding at Lawes, the more fertile site. In contrast there were consistent and marked differences in winter, when yield of Narok exceeded that of Kazungula by a factor of 3-6. This was associated with leaf-survival of Narok following frosting, but was not dependent on frost tolerance, as yield superiority was evident in the absence of frost. Narok was also the most digestible of the cultivars in summer, had the highest leaf percentage and produced fewer inflorescences during the year than did the other cultivars.

Amongst the nine experimental setaria varieties none showed superiority to Narok in any characteristic other than flower head number. The initial goal, to improve winter growth through hybridization between winter-green and lowland frost-sensitive accessions, was not achieved. The superior winter growth of the *splendida* and lowland frost-sensitive accessions, classed as Groups A and B in an earlier study (Hacker 1972), is likely to be due to the small plots in that experiment and to the contiguous arrangement which allowed some inter-plot competition.

It is clear that the EH populations have levels of frost tolerance and winter growth closely similar to that of Narok. The D populations had lower levels of tolerance than their frost tolerant parent CPI 33453 and also differed in having many more flower heads, a characteristic presumably inherited from CPI 32714.

The 6-weekly cutting schedule prevented any assessment of inflorescence number which might relate directly to commercial seed production as it clearly favoured early-flowering populations. Thus Kazungula, which gave low numbers of seed heads in this study, produces relatively heavy commercial seed crops and has a high tiller fertility (J.B. Hacker, unpublished data). Nevertheless, it is clear from this study that there is large variation between populations in floristic development. Consequently, a study of seed production characteristics of the setarias in the Lawes trials was carried out and is the subject of another paper (Hacker 1991).

Table 5. The total number of inflorescences per m² at Lawes (L) and Beerwah (B) over the growing seasons — October-May 1975-76, August-May 1976-77 and August-May 1977-78, and length of inflorescence at Lawes in May 1978

	1975-76		1976-77		1977-78		Inforescence length (cm)	
	L	B	L	B	L	B	Mean	s
Nandi	73 (15.6)[1]	31 (10.1)	389 (38.6)	64 (14.6)	210 (27.1)	31 (10.2)	13.1	4.8
Narok	11 (6.1)	10 (5.6)	76 (15.8)	19 (8.0)	54 (13.2)	20 (8.2)	15.1	4.4
Kazungula	42 (11.9)	46 (12.4)	43 (11.9)	48 (12.7)	46 (12.4)	31 (10.1)	13.4	4.3
LHA	11 (6.1)	4 (3.6)	30 (9.4)	2 (2.7)	2 (2.4)	1 (1.5)	—	—
LHB	12 (6.2)	12 (6.3)	18 (7.7)	6 (4.3)	5 (3.8)	2 (2.4)	—	—
LHC	4 (3.3)	4 (3.6)	10 (5.6)	0 (0.6)	7 (3.9)	1 (0.7)	—	—
EHA	72 (15.5)	37 (11.1)	106 (18.8)	44 (11.9)	61 (14.2)	34 (10.5)	17.3	4.8
EHB	38 (10.9)	25 (9.1)	91 (17.1)	34 (10.5)	45 (12.1)	18 (7.5)	17.5	4.0
EHC	29 (9.6)	28 (9.6)	69 (15.2)	49 (12.7)	45 (12.1)	37 (11.0)	15.0	5.1
DA	87 (17.1)	179 (25.0)	527 (46.6)	384 (38.3)	597 (50.6)	312 (33.9)	7.0	2.5
DB	105 (18.8)	190 (25.8)	499 (45.0)	403 (39.4)	676 (55.4)	291 (32.6)	6.4	2.4
DC	210 (26.2)	177 (24.9)	512 (45.7)	462 (42.8)	834 (67.1)	298 (33.0)	6.8	2.9
33453	139 (21.1)	54 (13.4)	419 (40.3)	308 (33.7)	435 (41.1)	148 (22.6)	6.7	2.4
LSD (5%)[1]	(6.1)	(2.4)	(5.0)	(3.8)	(9.1)	(3.2)		

[1] Angular transformed data

Legume yield in the legume-grass experiments exhibited significant differences only at Lawes in 1975-76. There are no indications from this experiment that the grasses studied vary in their ability to combine satisfactorily with these legumes. However, the removal of cut forage from the plots would have prevented the return of a high proportion of legume-N to the soil and hence swung the competitive balance to the detriment of the grass.

It was concluded that there is little justification based on improved herbage yield, either *in toto* or during the cool season, for considering any of the bred varieties of *Setaria* for release as commercial cultivars. However, subsequent studies on seed production of the setarias at Lawes, backed up by the yield and frost-response data discussed in this paper, contributed to the release of the cultivars Solander and Splenda. In the case of Solander, the data provided in this paper indicate that the experimental variety from which it was derived, EHB, has comparable summer and winter yield and winter-greenness to that of Narok, and the subsequent study showed that it had double the seed production. Solander was released as a cultivar in 1985. The experimental varieties LHA and LHB, which gave rise to Splenda, were not exceptional for any of the attributes measured in this study. The cultivar was registered in 1982 and a decision to market the cultivar for export and to release it in 1989 was based on good performance in a number of trials in South-East Asia and Oceania (T.R. Evans, personal communication).

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Appendix

Derivation of experimental varieties

Accessions used in the program are listed in Appendix Table 1, together with provenance details. Hybrids between accessions were made within ploidy levels by bagging heads of the two parental plants together prior to anthesis in a glasshouse. Crosses which contributed to populations EH and D were all between winter-green and frost-sensitive accessions. Putative hybrids were grown in the field at Samford (27°22'S, 152°53'E) and hybrids were distinguished from selfs on gross morphological appearance. The tetraploid hybrids flowered in two groups, early and late, which gave rise to EH (Early Hybrid) and LH (Late Hybrid) populations, respectively. The contribution of the accessions to these two populations is shown in Appendix Table 1. The hybrids between the hexaploids CPI 33453 and 32714 flowered synchronously and gave rise to the D series populations. (D is an abbreviation

Appendix Table 1. Origin and provenance details of parents and their proportional contribution to breeding populations

	Country	Region	Altitude	Proportional contribution to EH	LH	D
			(m)			
Tetraploids (winter-green)						
32930[1]	Kenya	Aberdares Range	2150	.16	0	0
33452	Kenya	Aberdares Range	2200	.34	0	0
Tetraploids (frost-sensitive)						
15899	Tanzania	—	—	.08	.39	0
16067	Zaire	—	—	0	.22	0
16413 (off-type)	—	—	—	.24	0	0
19915	S. Africa	—	—	.18	.39	0
Hexaploid (winter-green)						
33453	Kenya	Aberdares Range	2400	0	0	.5
Hexaploid (frost-sensitive)						
32714	Tanzania	Arusha-Moshi	1100	0	0	.5

[1] Commonwealth Plant Introduction (CPI) number

of Drought, as one of the parental accessions, CPI 32714, came from a comparatively lower rainfall provenance and had the morphological appearance of a plant which could be adapted to moisture stress).

The winter of 1968 at Samford provided frosting conditions suitable for screening hybrids for frost tolerance. In general leaf kill of hybrids was intermediate between that of the parents.

Nineteen EH, nine LH and 14 D F_1 plants, selected primarily for winter yield and (excluding LH) for winter-greenness were cloned and polycrossed in isolation during 1968-69. The F_2 progeny of 220 LH, 750 EH and 1880 D plants was planted at Lawes, south-east Queensland (27°34 'S, 152°20 'E) in January 1970 and similar populations were planted at Samford. Frosting at Samford in 1970 resulted in almost complete foliage kill but at Lawes there was marked segregation for winter-greenness and winter vigour. At Lawes two replicates of 20 families in the D series (three plants in each replicate) were analysed for *in vitro* digestibility in January and May 1971; on neither occasion were there significant among-family differences. Plants were also collected from the EH series and intercrossed for diallel analysis. Although there was significant genetic variation for a number of chemical characteristics, genetic variance for *in vitro* digestibility was detected for only two of 14 harvests (Bray and Hacker 1981).

Four EH and five D series genotypes were selected with high winter-greenness and winter vigour and high digestibility. Similarly, six LH series plants were selected for high fertility, vigour and digestibility and conformity with the *splendida* morphotype, based on 1970-71 data. Seed was produced from the three groups of plants in isolation and the resulting progenies, 32 plants in each family, were planted out in replicated rows in October 1972 at Lawes. From the D and EH populations three groups of eight plants were selected with good winter vigour; DB and EHB were further selected as being of high digestibility. No frosts occurred during the winter of 1973 so no screening for winter-greenness was possible. Within the LH population selection was primarily for yield; the population was further assessed for fertility, digestibility of young leaf (top 2-leaf fraction of vegetative tillers) and flowering date; the three sets of eight genotypes selected (LHA, LHB and LHC) were for high fertility, high digestibility and late flowering, respectively (Appendix Table 2).

Appendix Table 2. Characteristics of parents of synthetics LHA, LHB, LHC. Primary selection was for vigour and conformity to the *splendida* morphotype

	Seeds/cm inflorescence	Days to flower after Feb 28	Leaf digestibility
			(%)
LHA	12.2	4.6	63.8
LHB	5.0	5.1	67.0
LHC	1.1	29.4	63.1

The nine sets of selections were cloned to ten ramets per plant and polycrossed in isolation at Lawes; seed was harvested in summer, 1974.

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