Grasslands Tribute: a multi-purpose white clover for Australasia

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Abstract
Grasslands Tribute is a medium-large leaved white clover released in 2003. It was initially bred for drought tolerance and winter activity in Victoria, Australia from crosses among elite New Zealand germplasm. Tribute was then screened for agronomic performance in New Zealand and reselected for medium-large leaf size, uniform flowering pattern, absence of foliar disease and high seed yield potential. Almost half of the 11 parental lines of Tribute came from half-sib families based on a Syrian accession with the remaining half-sibs based on Sustain, Southern Europe II and Crau in approximately equal proportions. The decision to release Tribute was based on its consistent performance and persistence under grazing in a series of seven New Zealand trials. Tribute was the best medium-large leaved variety under both sheep and dairy grazing, with only the large-leaved Kopu II having better performance under dairying. It shows strong growth in all seasons but has very good cool-season growth, and good drought tolerance in Canterbury.

Keywords: breeding, cultivars, dairy, sheep, *Trifolium repens*, white clover

Introduction
Soil moisture deficits reduce white clover (*Trifolium repens* L.) productivity, nitrogen fixation and persistence, and result in lower animal performance in many regions of Australia and New Zealand (Williams *et al.* 1990; Ayres *et al.* 1996). White clover has a shallow root system and is particularly vulnerable to drought during spring when individual plant size is at its smallest (Brock 1988), while the more common summer and autumn droughts can result in collapse of stolon populations due to a combination of high soil surface temperatures and soil moisture deficits (Archer & Robinson 1989). Uneven distribution of seasonal rainfall, slope, aspect and low soil water holding capacity can all contribute to soil moisture deficits. Improving the drought tolerance and persistence of white clover cultivars available to Australasian farmers has been a long-term breeding objective (Woodfield & Caradus 1987; van den Bosch *et al.* 1993; Ayres *et al.* 1996). A collaborative programme was initiated in 1991 between AgResearch and Darratech, Victoria to provide better selection pressure for drought stress. Exposure to prolonged drought stress frequently experienced in Victoria was used to identify white clover lines and genotypes with better persistence and productivity. This paper outlines the breeding history, morphology and agronomic performance of *Grasslands Tribute*, the first cultivar to be released from this programme.

Origin and breeding
Grasslands Tribute, formerly known as GC75, was developed from an original collection of 20 white clover lines that included several Australian ecotypes, a range of New Zealand cultivars and breeding lines, and three ecotypes collected from Southern Europe and Syria. The ecotypes from Southern Europe were collected in 1988 (Caradus *et al.* 1990), while the Syrian line had exhibited drought tolerance, rust resistance and high DM yield (Caradus *et al.* 1991; Barker *et al.* 1993). This gene pool was screened at Hamilton, Victoria, from 1989 to 1992, and 45 genotypes were selected in 1992 from four lines (Crau, Southern Europe II, Syrian and Sustain) on the basis of their persistence and overall herbage yield. These genotypes were polycrossed at Hamilton, Victoria, in summer 1992/1993 and the resulting 45 half-sib families were sown at Hamilton in autumn 1993 with four control cultivars Kopu, Tamar, Irrigation and Tahora. Based on performance after 2 years, 25 half-sib families were selected for improved autumn/winter growth and drought tolerance. These 25 half-sib families were subsequently screened and reselected for medium-large leaf size, uniformity of flowering pattern, absence of foliar disease and high seed yield potential at Lincoln, New Zealand in 1995/1996. Elite plants from eleven half-sib families originating from Sustain (2 half-sib families), Crau (2), Syrian (5) and Southern Europe II (2) were recombined to produce the pre-nucleus generation in 1996/1997. Plant Variety Rights were granted for Grasslands Tribute in March 2002 (MAF 2002).

Materials and methods

Morphological measurements: Detailed morphological data were collected in space-planted Plant Variety Rights trials at Palmerston North in 2000/2001 and 2001/2002. These measurements were made on at least 50 genotypes per cultivar and included cyanogenesis (%), leaf size (cm^2), growth habit (1=prostrate to 9=erect), petiole length (mm), stolon internode length (mm), stolon diameter (mm), peduncle length (mm), the number of florets per inflorescence, and days from first flower to 50% flowering.

Agronomic performance: Tribute has been evaluated in seven trials (four in the North Island and three in the South Island), with each trial running for at least 2 years and in most cases for 3 years. Six of these trials have been managed using rotational grazing by sheep while the seventh trial was managed using rotational grazing by dairy cows.

Individual plots in all trials contained 10 plants in a 1-m long row with 1-m intervals between plots in each direction. Each trial contained between 19 and 90 white clover lines with at least four replicates and most commonly six replicates of each line. The performance of 12 cultivars that were present in all North Island sheep- and dairy grazed trials (12 cultivars) are reported here. The white clover cultivar Apex referred to in this paper is also known as Crusader (Woodfield *et al.* 2001). It is marketed as Apex in New Zealand and as Crusader in Australia and Europe to avoid confusion with Crusader ryegrass. Only three cultivars (Huia, Demand and Tribute) were present in all three South Island trials; therefore we have summarized the results from these trials into one 3-year trial with seven cultivars and two 2-year trials with five cultivars.

Clover performance was assessed visually on a scale of 1=low yield to 10=high yield prior to each grazing. Seasonal DM harvests were also collected but as the ranking of cultivars was similar from visual and DM cuts in all trials we have presented the more extensive visual data. Stolon density was measured annually on all trials, with the exception of the 3-year sheep grazed trial in Canterbury for which only a visual assessment of stolon density is available.

Data were analysed from each trial separately, and then reanalysed for the combined North Island and South Island trial data sets. To allow comparison among cultivars and trials, data were summarised by year and season and are presented relative to Grasslands Huia.

Data on clover root weevil tolerance is adapted from Eerens *et al.* (2001) and includes 20 white clover cultivars that were bred in New Zealand or were bred overseas but are commercially available in New Zealand.

Results and discussion

Morphological measurements

Tribute is a medium to medium-large-leaved cultivar with a high frequency of cyanogenic plants (Table 1) and good stolon growing point density (Table 3). Larger leaf size and upright growth habit are associated with increased yield potential of white clover, however, stolon growing point density, which is an important factor in improved persistence, can be negatively correlated with leaf size (Caradus *et al.* 1997). Tribute has larger leaf area than Apex, Huia and Demand but is smaller than Sustain and Challenge. Tribute had the highest frequency of cyanogenic genotypes (95%) among the white clover cultivars evaluated in the PVR trials (Table 1). Improved persistence and productivity in New Zealand are strongly associated with a higher frequency of cyanogenic plants (Caradus & Williams 1989; Crush & Caradus 1995). Tribute has comparable growth habit and stolon diameter to other medium- to medium-large leaved cultivars such as Apex, NuSiral and Sustain. Tribute is an early-season variety, flowering about 10 days earlier than main-season varieties such as Huia, Demand, Kopu and Kopu II. The peduncle length of Tribute is similar to Apex, Huia, NuSiral and Demand but only Kopu and Kopu II have significantly more florets per inflorescence (Table 1).

Agronomic performance

Tribute has performed well in a series of seven trials, conducted in Canterbury and Manawatu (Tables 2-5). In the Manawatu dairy trial, the larger-leaved cultivars (Kopu II, Kopu, Pitau and Sustain) and two medium-leaved varieties (Tribute and Apex) performed best (Table 2). Tribute performed well in all years and its overall performance was second only to Kopu II, a cultivar developed specifically for dairy grazed farm systems (Table 2; Woodfield *et al.* 2001). Tribute had lower perfomance than Apex in the establishment year but was better than Apex in third year performance, which indicates good persistence. Kopu II, Apex, Tribute and Pitau performed best in the second year when white clover plants shift from depending on the seedling taproot to depending on nodal roots (Table 2).

In the three sheep-grazed trials in the North Island, Tribute and Apex had the best overall performance (Table 2). Tribute and Apex had significantly better establishment year performance than the other

Table 1 Cyanogenesis (HCN), morphology and flowering of 12 white clover cultivars in Plant Variety Rights trials at Palmerston North.

Cultivar	HCN (%)	Leaf area (cm^2)	Growth habit† (1 – 9)	Petiole length (mm)	Internode length (mm)	Stolon diameter (mm)	Peduncle length (mm)	Flowering (days)	Florets (no./inflorescence)
Grasslands Huia	68	2.9	5.8	81.9	25.4	2.4	158	45	85
Aran	65	6.4	3.9	99.0	28.0	3.4	188	40	99
Grasslands Kopu	70	5.6	4.2	93.7	30.2	3.1	190	41	104
Grasslands Tahora	48	1.9	6.9	60.7	23.7	1.9	129	39	74
Grasslands Demand	83	2.8	5.7	77.2	23.1	2.3	161	43	82
Grasslands Prestige	70	2.7	6.2	67.5	24.3	2.2	140	40	79
Grasslands Sustain	67	4.9	4.5	101.1	28.4	2.8	189	38	85
Grasslands Challenge	78	5.0	4.6	93.1	26.6	2.9	179	43	93
NuSiral	87	3.7	4.9	75.9	26.1	2.6	153	30	103
Grasslands Kopu II	63	5.3	4.0	106.0	35.6	3.4	203	43	108
Apex	93	3.0	4.9	77.0	27.2	2.8	162	33	94
GrasslandsTribute	95	3.5	5.0	68.8	30.8	2.6	157	34	92
LSD (0.05)	-	0.4	0.3	8.2	2.3	0.2	11	4	11

† Growth habit score (1=erect to 9=prostrate).

Table 2 Annual and seasonal performance of 12 white clover cultivars relative to Huia in three trials under rotational grazing by sheep and in one trial rotationally grazed by dairy cows in the Manawatu.

	Annual performance under sheep grazing (Huia = 100) (%)				Annual performance under dairy grazing (Huia=100) (%)			
Cultivar	Year 1	Year 2	Year 3	Overall	Year 1	Year 2	Year 3	Overall
Grasslands Huia	100	100	100	100	100	100	100	100
Grasslands Pitau	106	93	96	97	184	117	105	137
Grasslands Kopu	85	81	101	87	148	106	145	130
Grasslands Tahora	108	110	122	109	141	83	80	102
Grasslands Demand	109	119	124	113	131	92	114	111
Grasslands Prestige	102	115	111	105	132	99	91	108
Grasslands Sustain	98	104	110	99	154	112	98	123
Grasslands Challenge	93	88	113	99	134	96	125	117
NuSiral	81	58	77	73	143	99	96	114
Apex	126	120	125	123	199	136	112	152
Grasslands Kopu II	107	108	110	105	193	155	172	172
Grasslands Tribute	132	127	111	123	173	120	141	143
LSD (0.05)	14	12	13	12	18	17	15	16

cultivars, while Demand and Prestige had comparable second year performance to these two varieties. The persistence of the smaller-leaved cultivars (Demand, Tahora and Apex), based on year 3 performance, was slightly better than Tribute, Sustain, Challenge and Kopu II (Table 2).

Three cultivars, Tribute, Apex and Kopu II, exhibited superior cool-season growth in the North Island (Table 3). Good winter activity was expected for Tribute because winter activity is very important in Victoria where the initial screening was done. Tribute also had strong warm-season growth, with its summer and autumn performance being top equal with Apex and superior to all other cultivars except Demand and Kopu II in summer and autumn (Table 3). These differences in seasonal growth were also reflected in the South Island sheep-grazed trial with Tribute and Apex showing better winter growth than the other cultivars. Huia, Prop and Kopu II had significantly worse spring growth than the top three

cultivars (Demand, Prestige and Tribute) (Table 4). The summer and autumn performance of Tribute in the South Island was also amongst the top group of cultivars that included Demand and Prestige.

In the three sheep-grazed South Island trials, Tribute had strong performance and persistence (Tables 4 and 5). The overall performance of Tribute was equivalent to Demand, Prestige and Apex, but the third year performance of Tribute was significantly better than all other cultivars (Table 4).

Table 3 Mean seasonal performance and stolon density of 12 white clover cultivars relative to Huia in four trials rotational grazing by either dairy cattle or sheep in the Manawatu.

Cultivar	Seasonal Performance (Huia = 100)				Stolon density
	Spring	Summer	Autumn	Winter	
	(%)				(no./m²)
Grasslands Huia	100	100	100	100	1645
Grasslands Pitau	115	98	106	122	1376
Grasslands Kopu	105	90	95	114	1187
Grasslands Tahora	120	97	106	117	1967
Grasslands Demand	118	109	114	113	2025
Grasslands Prestige	114	105	101	102	2205
Grasslands Sustain	113	98	101	122	1752
Grasslands Challenge	109	88	102	121	1424
NuSiral	94	75	79	91	1507
Apex	144	116	125	149	1906
Grasslands Kopu II	131	107	122	150	1805
Grasslands Tribute	135	118	123	153	1837
LSD (0.05)	17	12	13	16	365

The newer cultivars (Tribute, Apex, Colt, Demand, Prestige and Kopu II) all had better persistence than Huia and Prop under rotational grazing (Table 4). Similarly in the two-year trials, Tribute had significantly better yield than Demand and Huia (Table 5).

Persistence

High stolon density is an important characteristic for production and persistence in intensively grazed pastures. The stolon growing point density of Tribute is slightly higher than Huia based on both visual assessment and *in situ* counts (Tables 3, 4 and 5). In the North Island trials only Prestige had significantly higher stolon density than Tribute, while Pitau, Challenge and Kopu had significantly lower stolon density (Table 3). In the South Island trials, Tribute had lower stolon density than the smaller leaved Demand (Tables 4 and 5), but similar stolon density to Apex and Prop (Table 4).

The strong performance of Tribute under summer moisture stress at Lincoln particularly in the third year (Table 5) suggests that further improvements in drought tolerance

Table 4 Annual and seasonal performance of seven white clover cultivars relative to Huia under rotational sheep grazing in Canterbury.

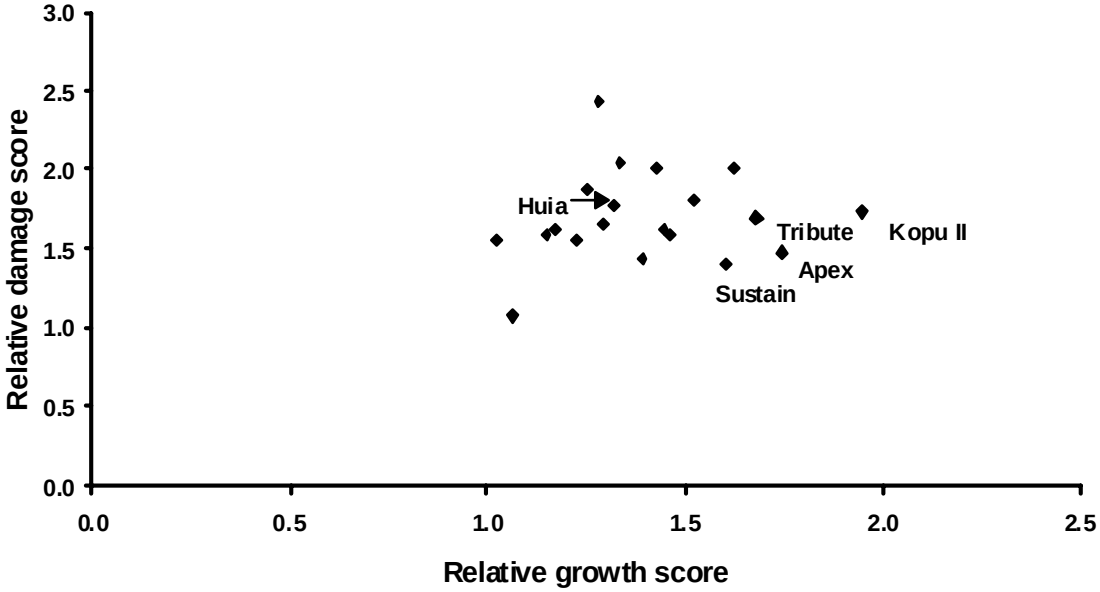
Cultivar	Annual performance (Huia =100)				Seasonal performance (Huia =100)				Stolon density[§]
	Year 1	Year 2	Year 3	Overall	Spring	Summer	Autumn	Winter	
	(%)				(%)				(1-5)
Grasslands Huia	100	100	100	100	100	100	100	100	2.2
Grasslands Demand	128	135	148	132	144	134	123	135	3.4
Grasslands Prestige	115	137	146	126	140	127	124	123	3.6
Prop	92	104	100	98	116	88	97	88	2.4
Apex	121	127	136	122	128	117	112	155	2.6
Grasslands Kopu II	127	106	120	117	122	116	105	128	2.0
Grasslands Tribute	119	135	171	129	138	129	120	153	2.6
LSD (0.05)	10	11	14	13	11	13	11	14	0.3

[§] Stolon density scored visually on a 1=sparse to 5=very dense basis.

Table 5 Annual and stolon density of five white clover cultivars relative to Huia in two trials under rotational sheep grazing in Canterbury.

Cultivar	Annual performance (Huia=100)			Stolon density
	Year 1	Year 2	Overall	
	(%)			(no./m²)
Grasslands Huia	100	100	100	1600
Grasslands Kopu	108	64	87	1075
Grasslands Demand	149	123	136	2850
NuSiral	104	69	81	962
Grasslands Tribute	168	137	150	1825
LSD (0.05)	12	11	12	564

Figure 1 The relationship between Clover root weevil damage and clover productivity under dairy grazing in the Waikato for 20 white clover cultivars. (Adapted from Eerens *et al.* 2001).



should be possible from continued selection for drought tolerance in Australia.

Tolerance to pests and diseases is an important component in ensuring adequate persistence of new cultivars. Tribute was selected for tolerance to the common foliar diseases that affect white clover performance in New Zealand including viruses, pepper spot and sclerotinia. It has also exhibited a level of tolerance to clover root weevil that is similar to Apex based on trials under dairy grazing in the Waikato (Figure 1).

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