

Elite selection of tagasaste (*Chamaecytisus palmensis*) for drought-prone sites

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Abstract

Tagasaste (tree lucerne) is a drought-tolerant, shrub/tree legume which is naturalised in many parts of New Zealand. It is a potentially useful supplementary forage for sheep and cattle, particularly in summer and early autumn. Tagasaste is highly variable for a range of attributes and in the 1980s, 16 lines were identified which had improved production, habit, and frost and disease tolerance. From 1993 to 1996, this germplasm was evaluated for morphological and chemical attributes at two sites in the lower North Island – Onga Onga, central Hawke's Bay (Trial 1) and Bulls, Rangitikei (Trial 2) – to select material for release. Differences in survival and growth of the lines between sites were the major finding. Average plant survival of lines in Trial 1 was higher than in Trial 2 (89 vs 58%), whereas growth of lines in Trial 2 exceeded that in Trial 1, for example for plant height (274 vs 168 cm), plant width (325 vs 168 cm), root collar diameter (91 vs 58 mm) and total plant dry matter (15.6 vs 6.7 kg/plant). The total N content of lines in Trial 2 was 25% higher than in Trial 1 (33 vs 26 g N/kg DM) whilst *in vitro* digestibility of herbage from all lines at each site was 75%. Two lines, AL2244 and AL2432, which had high survival at both sites, and means for other attributes which were similar to or exceeded the site mean for all lines, were selected to comprise the final release. Seed of these lines is being increased.

Keywords: browse shrubs, *Chamaecytisus palmensis*, drought fodder, dryland legumes, revegetation, selection

Introduction

Tagasaste (*Chamaecytisus palmensis* (Christ) Hutch.), formerly known as tree lucerne, is a fast-growing, perennial, evergreen, leguminous tree, 5–6 m tall when mature, which is widely distributed throughout New Zealand (Woodfield & Forde 1987). It originates from the island of La Palma in the Canary Islands, and probably arrived in New Zealand from seeds distributed late last century or early this century.

For almost two decades, there has been interest in tagasaste as a potential source of supplementary feed in drought-prone environments. Tagasaste produces good dry matter (DM) yields and is acceptable to sheep, cattle and goats. Its leaves have a nitrogen (N) content of 25–40 g N/kg DM and *in vitro/in vivo* DM digestibility levels normally exceed 70% (Lambert *et al.* 1989b; Douglas *et al.* 1996). An advantage during drought is the ability of the species to retain green leaf for 3–5 months, much longer than for temperate grasses and legumes (Borens & Poppi 1990). Tagasaste is susceptible to frost damage (Sheppard & Bulloch 1986), particularly when young, which restricts its potential widespread usefulness to drought-prone areas, probably in Canterbury and northwards in the South Island, and most places in the North Island, except for the Central Plateau.

There is considerable genetic variation within and between populations of tagasaste for a range of morphological attributes, including production and growth habit. Accordingly, in the early to mid 1980s, a breeding programme was initiated at Palmerston North to develop lines of tagasaste with improved production, habit, and frost and disease tolerance (Woodfield & Forde 1987). This resulted in 16 elite lines which were established in 1993 at two lower North Island sites, to determine their suitability for release. This paper summarises the results of these evaluations and identifies the final selection.

Materials and methods

Sites

Both trials were conducted on commercial farms. Trial 1 was on cultivated flat land at Onga Onga, central Hawke's Bay on a stony silt loam (pH = 6.9, Olsen P = 53 mg/kg soil, S(SO₄) = 6 mg/kg soil), which is subject to moderate to severe wind erosion, when vegetation cover is sparse. Trial 2 was on a <10° north-westerly face at Bulls in Rangitikei on former erodible coastal sand dune country (pH = 7.4, Olsen P = 41 mg/kg soil, S(SO₄) = 3 mg/kg soil), approximately 140 km from Trial 1 and 12 km from the sea. Resident pasture was dominated by assorted grasses and flatweeds, which were sprayed with glyphosate (1.1 kg/ha) and dicamba (0.4 kg/ha) 4 weeks before planting. Both sites are

prone to significant summer soil moisture deficits, and have free-draining soils.

Lines, plant preparation and experimental design

Seedlings of the 16 lines (Table 1) were prepared in the glasshouse in autumn/winter 1993, including inoculation with an effective *Rhizobium* strain (Douglas *et al.* 1996), and transplanted into the trial sites in September/October 1993. Trials comprised 3 (Trial 2) or 4 (Trial 1) randomised complete blocks, and each plot (experimental unit) consisted of a single row of 6 plants. Plant spacing was 1.5 × 4.0 m within and between rows, respectively, equivalent to 1670 plants/ha. Both trials were fenced to exclude rabbits. In late April 1994, all plants were cut to 50 cm height above ground, to encourage branching. Surrounding pasture was mown and sprayed (glyphosate at 1.1 kg/ha + simazine at 1.0 kg/ha) periodically throughout the evaluations to minimise competition with the trees.

Table 1 Lines of *Chamaecytisus palmensis* evaluated in two trials in the lower North Island from 1993–96.

Line/Plant ¹	Description ²
AL1943/220	Umere ³
AL2168/561	Totaranui, Abel Tasman National Park introduction
AL2244/179	'Auchenflower', Darfield ex T5 elite plant (AL1941/910)
AL2258/555	Ormand, Gisborne introduction
AL2286/427	Rewa, ex T5 elite plant (AL1993/130)
AL2301/364	Umere, ex T5 elite plant (AL1943/220)
AL2370/228	Southern Hawke's Bay, ex T5 elite plant (AL1980/806) ⁴
AL2432/233	Napier, ex T5 elite plant (AL1917/1123)
AL2528/164	Greymouth root rot resistant introduction
AL2541/357	Kaikohe introduction
AL2701/227	Brandy Creek, Wakefield introduction
AL2723/059(a)	Te Uri, ex T4 clonal block
AL2723/456(b)	Te Uri, ex T4 clonal block
AL2724/269	Pukekohe, ex T4 clonal block
AL2725/144	'Auchenflower', Darfield ex T4 clonal block
AL2726/329	Margot's Green, ex T4 clonal block

¹Line numbers are those allocated in the Margot Forde Forage Germplasm Centre, Palmerston North; ²Place names refer to the original collection sites, T numbers refer to blocks at AgResearch, Palmerston North; ³Trial 1 only; ⁴Trial 2 only

Assessments

Plants were assessed from 1993 to 1996 for numerous attributes including survival (%), maximum height (mm) and width (mm), extent of branching (score 1 (low) to 3), vigour (score 1 (low) to 5), canopy density (score 1 (low) to 5), root collar diameter (mm), edible and total dry matter (DM) yield (kg DM/plant), leaf content (%), and growth stage (vegetative, flowering, pods). On 20–21 April 1994, edible foliage (leaf + stem < 3 mm diameter) of lines at each site was sampled, freeze-dried, and ground to pass through a 1 mm aperture sieve for laboratory analyses. Samples were analysed for total

nitrogen (N) content (g N/kg DM) by combustion, reduction to elemental N and detection by thermal conductivity in a Carlo Erba (Milan, Italy) auto analyser, and *in vitro* DM digestibility (g DM/kg DM) by a two-stage pepsin/cellulase technique (McLeod & Minson 1976) using Onozuka 3 S cellulase (McLeod & Minson 1980). The nutritional data and selected assessment results from 1995/96 are presented.

Statistical analyses

Data for each attribute were analysed by analysis of variance for a randomised complete block design (Steel & Torrie 1980), using the PROC GLM procedure in SAS (1988). For the 14 lines evaluated at both sites (Table 1), analyses of variance pooled over sites were also conducted to test the significance of differences between sites and between lines, and their interaction. Probabilities (P) of significance tests were classified as NS (P>0.05), * (P<0.05), and ** (P<0.01).

Results

Morphology and forage yield

Trial 1: There were significant differences between lines for three of the ten attributes assessed quantitatively, namely plant vigour in December 1995 and February 1996, and canopy density (Table 2). Plant survival after approximately 2 years exceeded 80% for all lines, except for AL2723, which was 60%. Maximum average height and width were similar for all lines and average plant vigour score in February was slightly higher than in December. However the lines at both times exhibited only occasional leaf chlorosis and wilting/rolling, except for AL1943 which had leaf tip necrosis on some plants, suggesting slight drought stress. Lines AL2244 and AL2432 had "near perfect" vigour in February. All lines were predominantly vegetative in December, apart from AL2244 which had pods on most plants. Across the 15 lines, edible DM/plant in March 1996 was similar, ranging from 19.6 to 22.4% of total plant DM.

Trial 2: Plant survival and growth were not significantly different (P>0.05) between lines (Table 3) although across lines there was over a two-fold variation in survival (40–93%) (Table 3). Maximum plant width exceeded height by 50 cm and most lines had similar vigour in December 1995 and February 1996. For all lines, plants with pods were most prevalent in December. In March 1996, edible DM/plant ranged from 10.1 to 12.4% of total plant DM for the 15 lines.

Between-trial comparisons: Lines in Trial 1 had higher plant survival (89 vs 58%; P<0.05) and their canopies were more highly branched (2.7 vs 2.2; P<0.01) than

Table 2 Survival and growth of 15 lines of *Chamaecytisus palmensis* in Trial 1 at Onga Onga, central Hawke's Bay in 1995/96.

Line	Survival (%)	Height (cm)	Width (cm)	¹ Vigour	² Canopy Density	³ RCD (mm)	⁴ Reproductive development	Vigour	⁵ Branching	Total dry weight (kg/plant)	Total edible dry weight (kg/plant)
	14/12/95	14/12/95	14/12/95	14/12/95	14/12/95	14/12/95	14/12/95	22/02/96	22/02/96	20/03/96	20/03/96
AL1943	85	151	139	3.3	3.1	46	V,F,P	4.5	2.4	5.6	1.1
AL2168	95	175	171	3.9	4.2	64	V,F,P	4.5	2.8	8.4	1.7
AL2244	95	178	174	4.2	4.1	67	P,V,F	4.9	2.9	7.2	1.5
AL2258	95	184	178	4.2	3.8	63	V,F,P	4.6	2.8	8.0	1.6
AL2286	85	156	163	3.9	3.8	49	V,F,P	4.3	2.4	6.2	1.3
AL2301	100	166	187	3.6	4.1	57	V,F,P	4.5	2.9	6.3	1.3
AL2432	95	180	185	4.2	4.2	60	V,F,P	4.8	2.8	7.6	1.6
AL2528	85	159	155	3.8	3.7	55	V,F,P	4.1	2.3	6.0	1.2
AL2541	90	164	169	3.9	4.1	65	V,F,P	4.6	2.4	6.5	1.4
AL2701	80	168	160	4	3.5	56	V,P	4.4	2.6	6.4	1.3
AL2723a	60	184	182	3.7	4.2	61	V,F,P	4.7	2.8	7.1	1.4
AL2723b	85	153	151	3.7	3.8	54	V,F,P	4.2	2.8	6.9	1.4
AL2724	95	155	160	3.8	3.8	58	V,P	4.3	2.7	5.8	1.3
AL2725	90	171	169	3.8	3.7	59	V,P	4.7	2.6	6.3	1.3
AL2726	95	169	173	3.9	3.9	60	V,F,P	4.5	2.7	6.7	1.4
mean	89	168	168	3.9	3.9	58		4.5	2.7	6.7	1.4
Signif	NS	NS	NS	**	*	NS		*	NS	NS	NS

¹scored 1 (poor) to 5 (near perfect); ²scored 1 (low) to 5 (high); ³root collar diameter; ⁴V=vegetative, F=flower, P=pods (most frequent occurrence in bold); ⁵scored 1 (low) to 3 (high); final selections indicated by shading

Table 3 Survival and growth of 15 lines of *Chamaecytisus palmensis* in Trial 2 at Bulls, Rangitikei in 1995/96.

Line	Survival (%)	Height (cm)	Width (cm)	¹ Vigour	² Canopy Density	³ RCD (mm)	⁴ Reproductive development	Vigour	⁵ Branching	Total dry weight (kg/plant)	Total edible dry weight (kg/plant)
	13/12/95	13/12/95	13/12/95	13/12/95	13/12/95	13/12/95	13/12/95	28/02/96	28/02/96	06/03/96	06/03/96
AL2168	73	254	289	4.1	3.3	87	P	4.3	2.5	10.9	1.1
AL2244	80	280	297	4.2	3.3	81	P,V	4.3	1.8	15.4	1.8
AL2258	53	290	312	4.1	3	81	P	4.4	2.1	18.4	2.2
AL2286	47	245	316	3.9	3.3	87	P	4.1	2.3	11.9	1.2
AL2301	53	220	312	4.4	4	108	P	4.5	2	15.5	1.8
AL2370	53	265	322	4.5	3.6	97	P	4.8	2.8	14.3	1.6
AL2432	93	264	330	4.4	3.4	86	P	4.6	2.1	14.7	1.7
AL2528	60	311	407	4.8	3.7	108	P	4.7	2	21.7	2.7
AL2541	60	264	325	4.2	3.3	80	P, V	4.4	1.7	15.9	1.9
AL2701	47	285	249	4.1	3.3	85	P	4.4	2	17.8	2.2
AL2723a	40	320	342	3.8	3.2	92	P	4.8	2.5	16.2	1.9
AL2723b	53	240	316	4.1	4	86	P	4.6	2	12.2	1.3
AL2724	47	297	362	4.4	3.7	96	P	4.9	2.3	15.3	1.7
AL2725	47	285	309	3.8	2.1	95	P	4.7	2.4	17.3	2.1
AL2726	60	285	394	4.3	3	101	P	4.7	2.3	15.6	1.8
mean	58	274	325	4.2	3.4	91		4.5	2.2	15.6	1.8
Signif	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS

¹scored 1 (poor) to 5 (near perfect); ²scored 1 (low) to 5 (high); ³root collar diameter; ⁴V=vegetative, P=pods (most frequent occurrence in bold); ⁵scored 1 (low) to 3 (high); final selections indicated by shading

those in Trial 2. Conversely, growth of lines in Trial 2 exceeded that of lines in Trial 1 for plant height (274 vs 168 cm; $P < 0.01$), plant width (325 vs 168 cm; $P < 0.01$), root collar diameter (91 vs 58 mm; $P < 0.01$), and total plant DM (15.6 vs 6.7 kg/plant; $P < 0.05$). There were no overall differences between trials in plant vigour in December and February, and mass of edible DM/plant.

Pods occurred on all plants of most lines in Trial 2 but on fewer plants of each line in Trial 1.

Nitrogen content and digestibility

Total N content of lines in Trial 2 was 25% higher than in Trial 1 (33 vs 26 g N/kg DM; $P < 0.01$) but there was no significant variation between lines in each trial. In

contrast, *in vitro* digestibility was similar ($P>0.05$) in both trials and for all lines, averaging 750 g DM/kg DM, with a range of 730–800 g DM/kg DM.

Discussion

Establishment and survival

Rooted seedlings were used to establish the trials, which is an effective method to ensure relatively high productivity in the first 1–2 years (Frame *et al.* 1998). An alternative and cheaper option is direct seeding, particularly when hard seed content is reduced by appropriate scarification, seed is drilled rather than broadcast, and resident vegetation is reduced by strategic use of appropriate herbicides (Townsend & Radcliffe 1987).

The major finding in this evaluation was the significant difference between plant survival and growth of lines at the two trial sites. Lower plant survival in Trial 2 than Trial 1 may have been owing to the occurrence of unseasonally severe frosts shortly after transplanting and at various times during the trial. Trial 2 was located on gently sloping land and it was found that after one year, plant survival at the lower end of the slope was less than at slightly higher elevation, again suggesting the influence of frost. Tagasaste is moderately susceptible to frost damage (Sheppard & Bulloch 1986; Frame *et al.* 1998), particularly when young, and therefore needs to be planted at relatively frost-free sites for best results. The use of larger and more developed plants than used in this study, for example 50–80 cm high and multi-branched, coupled with extended periods of frost-hardening before transplanting, may confer increased plant tolerance to frosting in the field. Also, plants aged 1–2 years should not be defoliated in autumn, to avoid soft new regrowth being killed by frost.

Despite low to moderate plant survival of most tagasaste lines in Trial 2, similar levels have been recorded for the species in other studies, but probably for different reasons. For example Lambert *et al.* (1989a) found that after 3.5 years, 53% of plants of one line had survived at a summer-moist hill site in the lower North Island. The main factors influencing survival at that site were probably moderately acid soils (pH 5.3), low plant-available soil phosphate levels (Olsen P = 4–8 mg/kg soil) and fungal collar rot disease arising from excessive soil moisture levels. None of these factors were regarded as important determinants of survival in the present evaluation because at both sites, Olsen P levels were very high, soil pH was approximately neutral, and soils were free-draining.

The relatively poor plant survival of most lines in Trial 2 was more than compensated for by surviving

plants of each line producing more than twice the total DM yield of plants of those same lines in Trial 1. Hence there was a slight net advantage from growing tagasaste at the sandier Rangitikei site compared with the other site. However, within lines at each site, plant loss was not compensated for by increased yield of surviving plants. Despite the relatively large plants in Trial 2, they produced similar ($P>0.05$) total edible DM to those in Trial 1. Plants were not grazed in this evaluation but those in Trial 1 were less than 180 cm tall, and it is therefore likely that most edible foliage would have been accessible to sheep and particularly cattle. In contrast, all lines in Trial 2 exceeded 240 cm height which would have resulted in a relatively high proportion of edible foliage being above the height which could be reached by livestock. In this situation, particularly, harvesting by mechanical equipment or hand saw/loppers, would be required to fully utilise the available edible foliage.

Dry matter yield and quality

The total plant yields achieved in this study, equivalent to 9–14 t DM/ha in Trial 1 and 18–36 t DM/ha in Trial 2, were slightly higher than those reported elsewhere (Radcliffe 1985; Douglas *et al.* 1996). Although this may in part be owing to the evaluation of more productive material than previously, the most likely reason was that yield estimates were based on almost 2 years of growth, compared with earlier results which were obtained from about one year's regrowth following cutting. The lower proportion of edible foliage in the present study compared with the 40% found by Douglas *et al.* (1996) was also probably owing to age differences in the foliage harvested, since less frequently cut (older) foliage of tagasaste and numerous other shrub/tree species has significantly higher stem content (Lambert *et al.* 1989a).

The similar *in vitro* dry matter digestibility (DMD) for edible foliage of all lines across both trial sites (average 750 g/kg DM) suggested that this attribute may be approximately constant over a range of environments where tagasaste might be grown. This was supported further by estimates obtained for different lines of tagasaste in other environments. For example 710–780 g/kg DM in Canterbury (Borens & Poppi 1990) and 710 g/kg DM on lower North Island hill country (Lambert *et al.* 1989b). Although N content of the lines varied between the two sites, it always exceeded 17 g/kg DM which is the recommended level for an adequate diet for a lactating ewe with a single lamb (NRC 1975; Grace 1983).

Plants in Trial 2 had a significantly higher non-edible component of dry matter, including thicker trunks, than in Trial 1. Inedible stems of tagasaste burn with an

intense heat when dry (Snook 1986) and the present results showed the potential of the species to produce potentially useful quantities of firewood in certain environments. The use of tagasaste for firewood is unlikely to be a major reason for its planting in New Zealand, but it is one of several uses for the species in addition to providing supplementary forage. Tagasaste is an important source of firewood internationally, especially in Africa.

Selection for release

On the basis of the results presented here, as well as other data from the evaluations at both sites, lines AL2244 and 2432 have been selected to form the final release. The dominant criterion used to select the two lines was high survival at both sites. However, numerous other morphological attributes were also considered and in every instance, AL2244 and AL2432 exceeded the average values for them. In earlier evaluations (Woodfield, unpubl.), line AL2244 ('Auchenflower') always had impressive growth habit and lack of foliar diseases, and its selection here supported the earlier findings. There was no evidence of collar or root rot disease of material in either trial, perhaps owing to the free-draining characteristics of both trial sites.

Seed is being collected from plants of each of the two lines at the original evaluation sites, following the cutting of all plants of the other lines to prevent flowering, and hence possible contamination of the selected material. There is uncertainty about tagasaste being predominantly self- or cross-pollinated. However, the consistency in growth and morphological development between plants within lines suggests that selfing was dominant in these trials. This will ensure relative genetic stability of the selection in successive cycles of seed multiplication.

Availability of the selection will provide pastoral farmers in drought-prone and frost-free environments with another source of supplementary forage for their livestock. Possible planting options for tagasaste are 1) the establishment of a feedbank and 2) widely spaced rows of the species with pasture in between.

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