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# GENETIC VARIABILITY WITHIN TAGASASTE

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Abstract

**A collection of 65 accessions of tagasaste was grown in Palmerston North for description and analysis of potentially useful variation within the species.**

**Variability within populations of tagasaste was high (74—90% of the phenotypic variation) but differences between populations were also evident. In particular there is a large amount of potentially useful variation both within and between populations for production and growth habit. Initial evidence suggests that much of this variation is heritable, with broad-sense heritabilities ranging from 35—84%, and that the potential for breeding Improved varieties is good.**

**Keywords: Browse shrubs, plant breeding, growth habit, heritability *Chamaecytisus palmensis.***

## INTRODUCTION

Tagasaste or tree lucerne *(Chamaecytisus palmensis),* a leguminous shrub native to La Palma, in the Canary Islands, was introduced during the late 19th or early 20th century, and has become widely distributed throughout NZ. Tagasaste has received considerable research attention over the past decade as a potential browse shrub for drought-prone areas. The production of large quantities of high quality dry matter (Davies and MacFarlane 1979; Radcliffe 1982, 1983, 1985; Poppi 1982), and the value of tagasaste as a forage for bees (Davies and MacFarlane 1979; MacFarlane and Beresford 1982) have been emphasised.

Tagasaste is both self- and cross-pollinated (Webb and Shand 1985), and because of its restricted natural range it might be expected to have a narrow genetic base. It is not known whether the tagasaste in NZ originated from a single introduction or from several introductions, or whether all seed came directly from the Canary Islands, but variation has been observed within the species (Radcliffe 1982; Wright and Menzies 1985). Since it has been naturalised in NZ it is possible that natural selection has led to local differentiation of populations.

The present study was undertaken to determine the amount and nature of variability within tagasaste, and the potential for selecting plants with improved production, habit, frost and disease tolerance (Trial one); and to establish the heritability of important characteristics (Trial two).

## MATERIALS AND METHODS

### Trial one

Sixty-five lines of tagasaste (including 3 from the Canary Islands and 1 from Australia) were evaluated. The trial was designed to have 3 replicates with 4 genotypes per plot, but uneven germination and later plant losses resulted in plant numbers varying from 2 to 14 (averaging 6) per population.

Two-month-old seedlings which had been inoculated with lotus rhizobium were transplanted into cultivated ground at DSIR, Palmerston North in February 1984. A late-summer drought meant that initial irrigation was required for adequate establishment. The soil was a well-drained recent alluvium mapped as Manawatu fine sandy soil (Cowie 1972). Plants were 1 m apart within rows and rows were 2 m apart.

Plants were not cut or grazed during the first 12 months to allow full expression of their phenotypic variation. In February 1985 all plants were cut to a height of 1 m, and the yield of ten plants representing a range of plant types was measured and dissected into edible and non-edible fractions. This cut was immediately followed by an intensive grazing by sheep so that all plants were a fairly uniform size at the beginning of the second year.

Plants were not grazed or cut throughout the remainder of 1985 so that regrowth could be measured, and open-pollinated seed collected from each plant. In February 1986 all plants were cut to 0.75 m; again ten plants were cut for yield measurement and dissection into edible and non-edible fractions.

Theproduction of each plant was scored on a 1-9 scale in winter/spring 1984 and summer, winter and spring 1985. A mean figure for each year was used to characterise each plant for 1984 and 1985 production, as the correlation between individual scores was high ($r = 0.70\text{-}0.91^{**}$). Height was measured in February, April, August, November 1984, January and June 1985. Branch density was scored on a 1 = sparse to 5 = dense scale in April and September 1984. Branch angle was scored on a 1 = horizontal to 3 = vertical scale in August 1984.

The distance between five branch nodes on the main stem (internode length) was measured in April 1984, and the average branch length was measured in April 1984 and July 1985. The height at which plants lost apical dominance (i.e. the height at which the main leader was equalled by secondary leaders) was measured in August 1984 and prior to cutting in February 1985. Plants that had not lost apical dominance in February were scored as 300 cm, but many plants were actually taller than this. Leaf density was scored on a 1 = sparse to 5 = dense scale in August 1984, and the length of 5 central leaflets per plant was measured in July 1985.

The results were analysed both as a two-way ANOVA of plot means with substitution of missing plots, and as an unbalanced one-way ANOVA with replicates pooled. In both cases highly significant population variation ($P < 0.001$) was found for all characters measured. Correlations between population means were calculated to determine which characters were linked or developmentally correlated.

### Trial two

Thirty cuttings were taken in January 1985 from six genotypes ranging in habit from short, densely branched to tall, open branching types. All plants were inoculated with lotus rhizobium and planted in June 1985 as three replicates of 10 plants, with 1 m between plants and 2 m between rows.

Plants were not cut or grazed during the first nine months, and in February 1986 plant height, height at which apical dominance was lost, internode length, average branch length, number of leaders per plant, leaflet length and leaflet width were measured.

## RESULTS AND DISCUSSION

### Plant height

Initial growth to September 1984 was almost linear, with a slight decrease in growth rate during winter. The average growth rate during this period was 0.47 cm/tree/day, doubling in the spring to 1.0 cm/tree/day (Fig. 1). Although height was not measured again prior to cutting, plant height increased rapidly throughout summer. Recovery from cutting was rapid, and in the period from mid February-mid June there was an average growth rate of 0.90 cm/tree/day, reaching 2.05 m (Fig. 1).

Mean plant height varied between populations, but most of this variation was masked by the within-population variation, with only 15% (1984) and 11% (1985) of the phenotypic variation being attributable to population (Table 1).

The differences in plant height shown in Fig. 1 suggests that there are differences in growth rate, particularly during winter, which may be linked with frost tolerance. Plant height in itself is a poor indicator of production ($r = 0.40^{**}$)

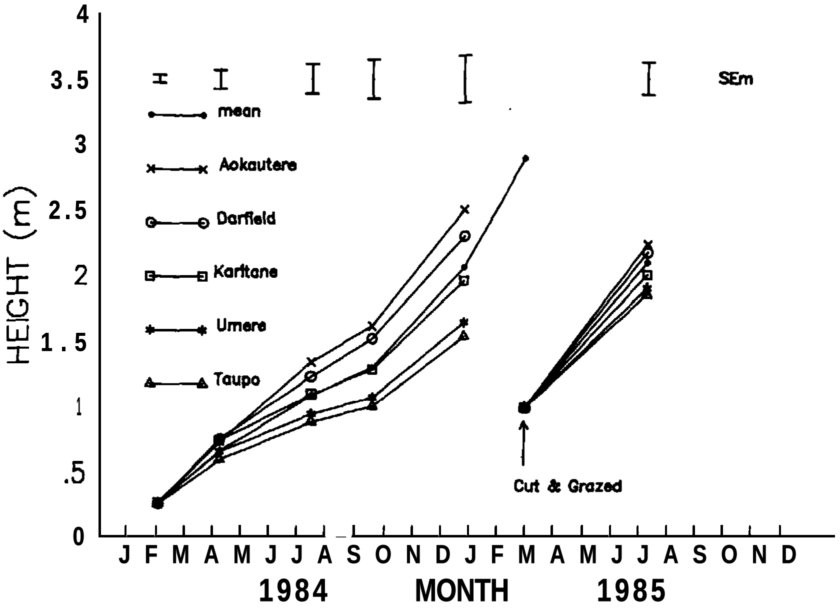

Figure 1: The height of several populations of tagasaste compared with the species mean during 1984 and 1985.

Table 1: Overall mean and range of means for growth characteristics of all tagasaste populations in trial one.

| Character | Overall mean | Range of population means | c v % | Variation due to line (%) |
|---|---|---|---|---|
| Production 1984 | 3.6 ± 1.0 | 1.7 - 7.3 | 29 | 23 |
| Production 1985 | 3.8 ± 1.2 | 1.8 - 6.7 | 32 | 26 |
| Plant height Nov 1984 (m) | 2.07 ± 0.36 | 1.55 - 2.65 | 17 | 15 |
| Plant height June 1985 (m) | 2.10 ± 0.23 | 1.75 - 2.45 | 22 | 11 |
| Branch density 1984 | 2.4 ± 1.0 | 1.0 - 5.0 | 42 | 22 |
| Internode length 1984 (cm) | 11.4 ± 3.0 | 6.2 - 15.5 | 26 | 10 |
| Branch length 1984 (cm) | 13.3 ± 4.9 | 7.5 - 29.0 | 37 | 13 |
| Branch length 1985 (cm) | 50.6 ± 13.2 | 26.5 - 83.0 | 26 | 13 |
| Leaf density 1984 | 3.3 ± 0.9 | 1.7 - 5.0 | 26 | 24 |
| Leaflet length 1985 (mm) | 43.2 ± 5.2 | 35.3 - 50.5 | 12 | 18 |
| Height at which apical dominance lost 1984 (cm) | 157 ± 102 | 10 - 300 | 65 | 11 |
| Regrowth 1985 | 3.3 ± 1.2 | 1.6 - 6.3 | 38 | 23 |
| Edible DM yield 1984 (kg/plant) | - | 0.10 - 1.70§ | - | |
| Edible DM yield 1985 (kg/plant) | - | 1.30 - 5.45§ | | |
| % edible DM 1984 | - | 38 71§ | | |
| % edible DM 1985 | - | 29 - 355 | | |

§*range of individual plants not populations means

(Rutherford, 1979), for example, the Karitane population was of average height but was one of the lowest producing lines in the trial, while Umere was among the shortest yet most productive lines.

Production

The correlation between production in 1984 and 1985 was strong (r = 0.73**). Several populations from Umere, Darfield, Aokautere, Banks Peninsula and Southern Hawke's Bay showed particularly good basal regrowth after cutting and grazing of all plants in February 1985, and there was a strong correlation (r = 0.75") between regrowth in June 1985 and production throughout 1984 and 1985.

The amount of edible dry matter (EDM) produced in 1984 ranged from 0.10-1.70 kg DM/plant, and in 1985 from 1.30-5.45 kg DM/plant (Table 1). The proportion of the total DM which was edible (% EDM) ranged from 38-71% in 1984, with high % EDM being associated with particularly poor producing plants (i.e. low total DM). In 1985 % EDM (29-35%) decreased while total EDM increased (Table 1). No statistical analysis was possible due to the small number of plants measured. At the trial density of 5000 plant/hectare, a maximum potential yield of 7500 kg/ha (Year 1) and 725,000 kg/ha (Year 2) is indicated. This is based on individual plant yields however and real production would be less, particularly in dryland areas. Grass and clover growth was strong throughout the first year but was shaded out in the second year and contributed little to overall production. In a grazing system the trees would be restricted in size, thus allowing continued sward growth.

### Growth habit

Differences in growth habit were noticeable from an early age and became more evident as plants matured. Within-population variation was initially large, possibly because of early damage to some plants, but populations later exhibited a greater degree of uniformity.

Growth habit ranged from prostrate and densely branched to tall and open branched types. The strength of apical dominance appeared to be the single most important feature governing plant form.

Growth habit can be broken down into several contributing characteristics which are weakly correlated with one another (Table 2) and contribute to overall plant productivity. Because growth during 1984 and 1985 is correlated with branch density (r = 0.61* ● ), branch length (r = 0.55' • and r = 0.69' *) and leaf density (r = 0.40* ● ) plant habit can probably be improved while maintaining or even increasing production. Schuster (1965) showed that twig length was strongly correlated with yield ($r^2$ = 0.85-0.93") but also that a combination of twig number and length was an even better predictor of yield ($r^2$ = 0.94-0.96**). Branch length has a high heritability (Table 4) and should be used as a major selection parameter.

Table 2: Significant correlations between tagasaste population means for growth, internode length, branch density, leaf density, branch length (1984 and 1985), regrowth score and plant height (r = 0.32, P = 0.01).

| | Production 1984.85 | Internode length | Branch density | Leaf density | Branch/length 1984 | Branch/length 1985 | Regrowth 1985 |
|---|---|---|---|---|---|---|---|
| Internode length 1984 | | | | | | | |
| Branch density 1984 | 0.61 | | | | | | |
| Leaf density 1984 | 0.40 | | 0.55 | | | | |
| Branch length 1984 | 0.55 | 0.62 | 0.33 | | | | |
| Branch length 1985 | 0.69 | | 0.32 | 0.31 | 0.38 | | |
| Regrowth 1985 | 0.75 | | 0.52 | 0.30 | 0.46 | 0.47 | |
| Height Nov 1984 | 0.40 | | | | 0.31 | | 0.37 |

There was a very strong correlation (r = 6.86") between leaflet length and leaflet width, indicating that only one dimension needs to be measured to give a good measure of leaflet size.

Trial two showed that the growth habits of the selected genotypes were genetically rather than environmentally derived, with most clones bearing a strong resemblance to their original parent plant. The early dwarf or shrubby characteristics of two parent plants from Pukekohe and Umere were not as strong in their clonal offspring, but these clones still had significantly shorter internodes, shorter branches and smaller leaves than the other lines (Table 3).

Table 3: Characteristics and heritabilities of clonally replicated plants in trial two.

| Clonal lines | Height (m) | Apical dominance (m) | Branch length (cm) | Internode length (cm) | Leaflet length (cm) |
|---|---|---|---|---|---|
| Holbrook, NSW. Aust | 2.9 | 139 | 68 | 17.4 | 45 |
| Pukekohe | 2.1 | 26 | 45 | 11.5 | 25 |
| Darfield | 2.4 | 15 | 65 | 14.6 | 42 |
| Umere | 1.2 | 24 | 35 | 11.4 | 34 |
| Te Uri | 2.4 | 17 | 69 | 12.6 | 36 |
| Stormy Pt. | 1.6 | 13 | 46 | 13.9 | 41 |
| LSD .05 | 0.6 | 110 | 22 | 3.5 | 6 |
| c v (%) | 14 | 132 | 20 | 12 | 8 |
| Heritability (%) | 76 | 35 | 61 | 52 | 64 |

## Distribution of variation

The most notable feature of the first trial was the large within-population variation, which accounted for 74—90% of the total phenotypic variance of the characters studied (Table 1). In some lines this may represent the variation in the progeny of an individual tree, either selfed or outcrossed, and in others the variation in a local population sample. No further interpretation is possible except to conclude that the species is probably significantly outcrossing, as suggested by Webb and Shand (1985).

Differentiation between populations, by comparison, was relatively weak for most measured and observed characters. The variation in population means was continuous, but populations at the extremes were significantly different from the overall mean. For the most part there was no obvious pattern in the geographical origin of populations which were extreme for various characteristics. This suggests that natural selection has so far had only a limited effect in establishing a pattern of ecogeographic variation within NZ since the species was introduced, though it might have been expected that the capacity to self-pollinate could lead to rapid divergence of isolated local populations, and “founder” effects. Such differences as do occur may sometimes represent historical accidents in the stock originally planted. Lines from the Canary Islands and Australia which were included in the trial did not appear to greatly extend the range of variation already present in N.Z.

There is a large amount of potentially useful variation both within and between populations for production and habit characteristics (Table 1). The initial evidence from trial 2 shows that much of this variation is heritable, with broad-sense heritabilities ranging from 35-84% (Table 3), plant height and leaflet length having the highest heritabilities. Broad-sense heritabilify estimates are in general larger than narrow-sense heritabilities (Falconer, 1960) but do indicate which characters may respond best to selection pressure.

By selecting elite plants and utilising inbred lines it should be possible to achieve major increases in the production of tagasaste, and improvements in its growth habit. It will however be necessary to establish:

(i) the level of inbreeding depression or hybrid vigour.
(ii) the general and specific combining ability of selected elite plants and
(iii) the variability present within self-pollinated lines.

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