Identifying Persistent Lucernes For Dryland Pastures

R.W. Williams[1] and S.P. Boschma[2]

[1]NSW Agriculture, PMB, Yanco Agricultural Institute, Yanco, NSW 2703
[2]CSIRO, PMB Pastoral Research Laboratory, Armidale, NSW 2350

Summary. The breeding of lucernes for dryland pastures can be improved by identifying simple traits associated with plant survival or persistence. Twenty lines were assessed for their morphology, response to water deficit, patterns of carbohydrate utilisation, and resistance to pests and diseases. Multiple regression analysis of the data suggested that persistent lucernes in old dryland trials at Yanco and Tamworth were those with long stems in summer and short stems in winter. Lines with long stems in winter were generally less efficient in water use and exploited root carbohydrate reserves more during early regrowth than other varieties. Near infared spectroscopy was used to describe the average pattern of carbohydrate utilisation after cutting. This will help to determine the grazing intervals required to maintain energy reserves. These results should provide better varieties and improved management options for lucerne in the pastoral zone.

INTRODUCTION

Lucerne can provide a reliable, high-yielding, and nutritious source of feed in dryland pastures. However, most varieties have been bred for irrigated haymaking and do not survive more than a few years. Poor survival or persistence reduces pasture quality and productivity and increases costs due to the need for frequent re-sowing. Breeding for persistence currently requires lines to be tested over many years and sites. Persistence is also a *complex* character that involves numerous traits, processes, and genes. Uncertainties regarding the cause/s of poor survival in pastures also limit progress in the breeding of persistent lines. This study sought to develop our knowledge of lucerne morphology and physiology in relation to pasture performance and to use this to identify key traits that were associated with lucerne persistence. Directed breeding for these traits should quickly and efficiently lead to superior new lucernes for dryland pastures.

MATERIALS AND METHODS

Dryland trials were established in NSW at Yanco and Tamworth during 1988. Persistence was measured over time using counts of relative plant frequency in two 1 m^2 fixed quadrats. A subset of twenty lines were examined in a further series of experiments to identify traits which may be associated with variation in persistence. For example, morphological traits were measured using four replicates of 24 spaced plants per line in an irrigated trial at Leeton, NSW. These traits included the length of longest stems 7, 21, and 35 days after cutting in each season of the first year, forage yields for each regrowth period, leaf:stem weight ratios in autumn and spring, and the areas, erectness, and growth rates of plant crowns. Root weight, crown weight, crown depth, root branching, and cross sectional areas of crown and root were measured by digging up six plants per plot. In a separate field trial, five young plants from each line were removed at 0, 13, 20, 27, 33, and 42 days after cutting. Roots were trimmed to 10 cm long, then washed, microwaved to prevent enzymatic degradation of carbohydrate, then oven dried. Finely-ground samples were weighed, then analysed for percentage starch content using the near infared reflectance spectrophotometer (NIRS).

In an experiment in the greenhouse, individual seedlings of all twenty lines were grown for three months in one litre cups filled with three parts course sand and one part peat. Plants were then cut back and watered to field capacity. Water was thereafter added at 40% of the volume needed to return the cups to field capacity when one of a subset of 40 cups fell to 30% plant available water content. Total dry weights, leaf:stem weight ratios, root:shoot weight ratios, specific leaf weights, and relative water use efficiencies (mg total dry wt. per ml H_2O added) were recorded after flowering. Other tests in the greenhouse were used to measure the resistance of lines to phytophthora root rot, colletotrichum crown rot, spotted alfalfa aphid, and blue-green alfalfa aphid.

Simple phenotypic correlations were calculated between persistence measures and the means for each trait. Multivariate regressions were used to identify combinations of traits associated with differences in persistence and to develop models of ideal plant type/s for dryland pastures.

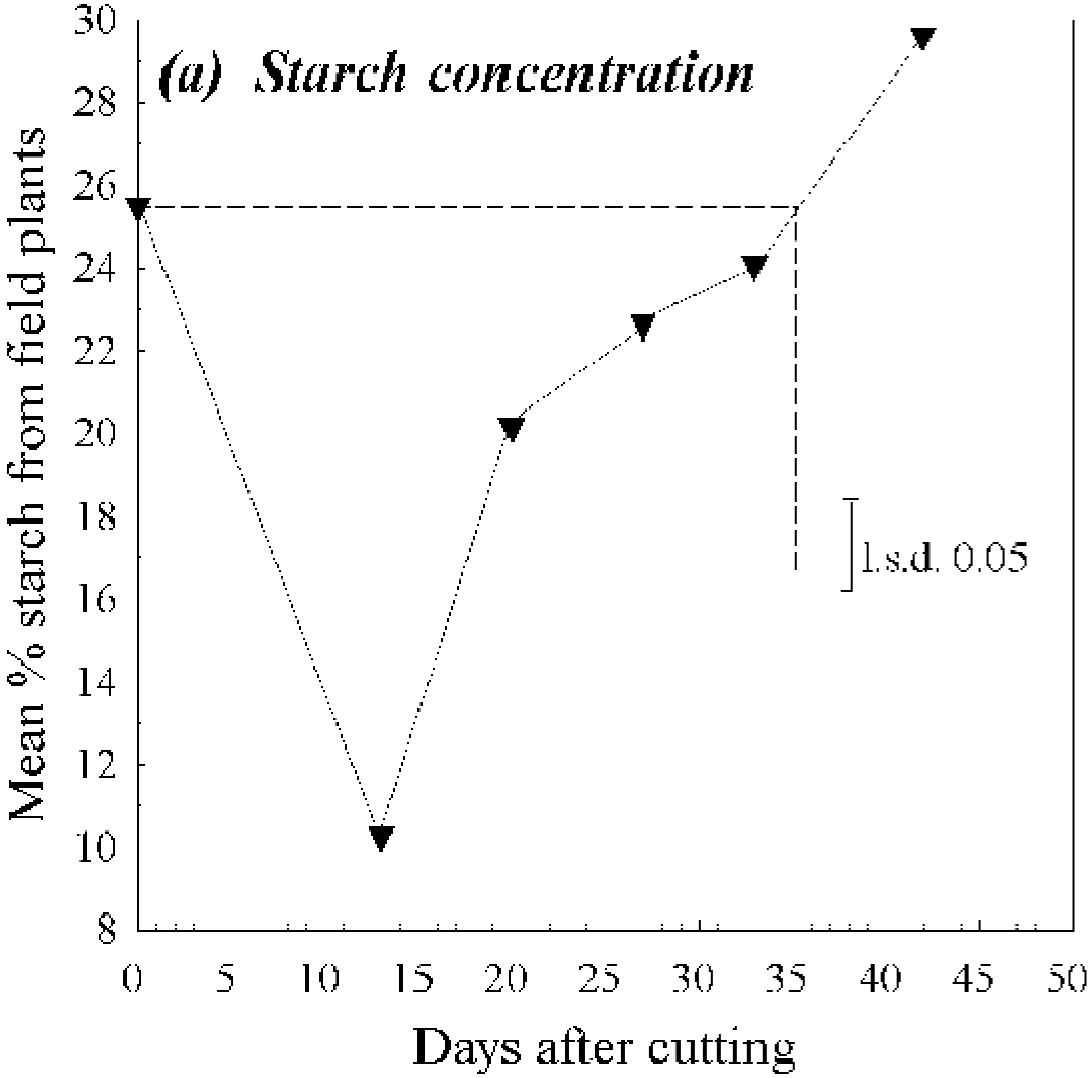
RESULTS AND DISCUSSION

Plant morphology

Lines differed in winter dormancy as expressed by the length of longest stems during late autumn. This trait aids survival in extreme winters (1). Unlike overseas reports (2), winter-dormant lucernes had slower rates of regrowth in summer, autumn, and spring at Leeton than winter-active types. They also produced lower yields in summer and autumn, had greater leaf:stem weight ratios, and produced larger, less erect crowns with faster cross-sectional growth rates. Forage yield in spring was one of the few traits unaffected by winter dormancy. Lines also varied in crown weight ($P<0.03$) and in the ratio of crown weight to root weight ($P<0.001$). The weight of the top 15cm of tap root was similar across lines ($P>0.12$), but significant differences among lines were recorded for the extent of root branching ($P<0.002$) and in the cross-sectional areas of crowns ($P<0.001$) and tap roots ($P<0.03$).

Use of carbohydrate during regrowth

Starch accounts for over 90 percent of the carbohydrate reserves in lucerne roots and is the primary source of energy for regrowth after herbage removal (3). Starch concentrations in roots generally declined following regrowth for 13 days after cutting (Fig. 1a) and did not fully recover until after 35 days regrowth. However, root growth continued and only 23 days were required for the initial weight of root starch to be renewed (Fig. 1b). There were generally no significant differences among lines in starch concentrations. However, lines did differ in the magnitude of the decline in starch concentration during early (0-14 days) stages of regrowth. Generally, highly winter-active lines (*e.g.* CUF101 and WL605) showed greater reductions in starch reserves during early regrowth than more dormant lines such as Y609 and Hunter River ($P<0.01$).


(a) Starch concentration
Mean % starch from field plants
30
28
26
24
22
20
18
16
14
12
10
8
0
5
10
15
20
25
30
35
40
45
50
Days after cutting
l.s.d. 0.05

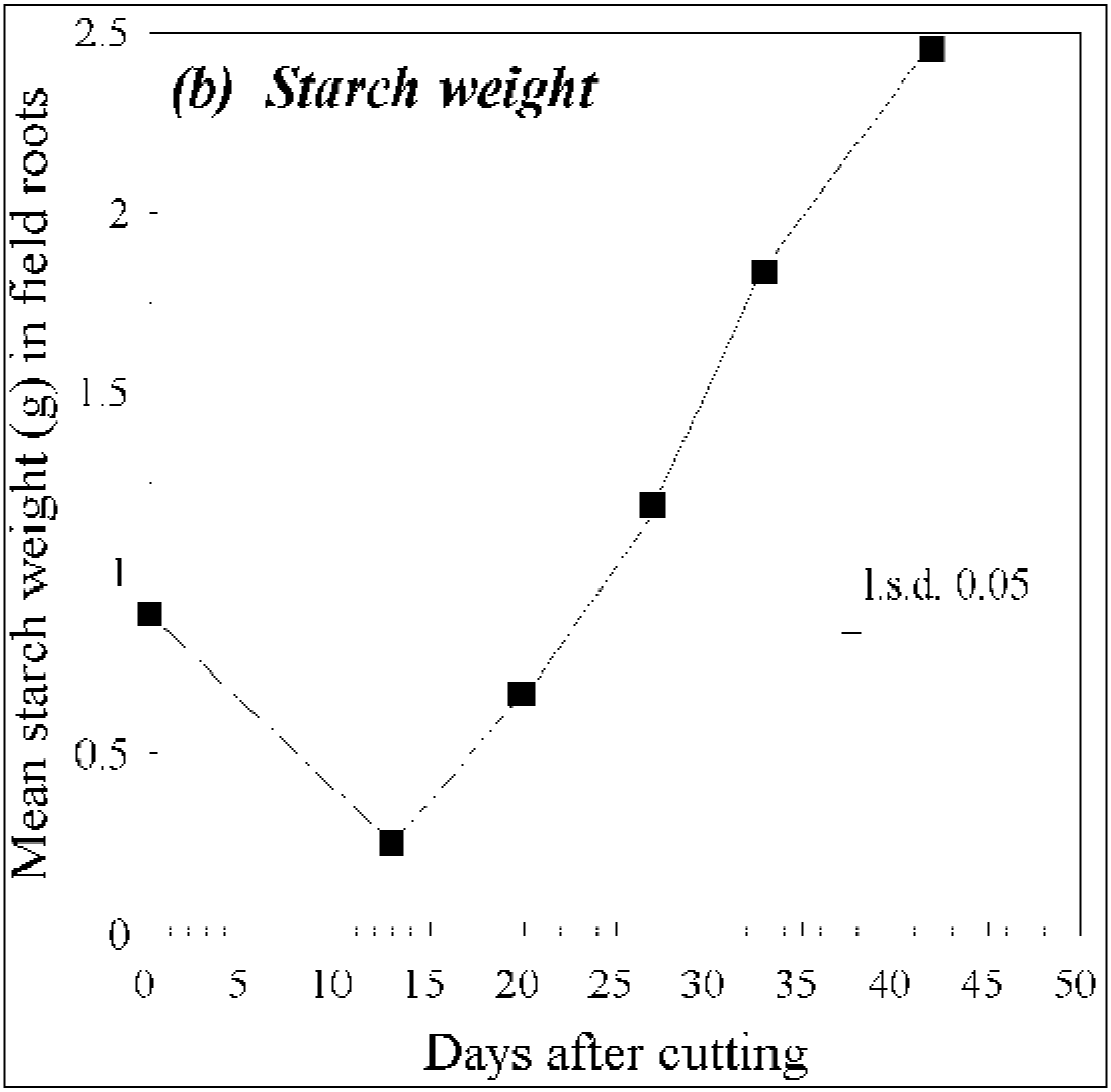


Figure 1. Mean effect of the duration of regrowth on (a) the concentration of starch and (b) the weight of starch in roots of twenty different varieties of lucerne.

Response to water deficit

Lines varied in relative water use efficiency (RWUE) when stressed. Highly winter-active lines generally had low RWUE's, whereas the highest RWUE's were produced by winter dormant lines such as P545 and Y8401. Similar results have been reported elsewhere (4). Variation among lines for RWUE were due to differences in dry mater accumulation and not in total water use. There was no association between RWUE and leaf area, specific leaf weights, root weight, root:shoot weight ratio, nor the carbohydrate concentrations in roots and crowns of the material following water deficit.

Identifying traits associated with lucerne persistence

No single trait reliably predicted the persistence (%P) of lines in dryland trials at Yanco or Tamworth. However, variation in persistence could be explained by multiple regressions which combined measures of the longest stems in February after 33 days regrowth (LSS) with those in August after 46 days regrowth (LSW) for young plants in their seedling year at Leeton. Persistent varieties in dryland trials at Yanco and Tamworth were consistently those that were relatively dormant in winter but that also had relatively long stems during the summer under irrigation at Leeton. Less persistent varieties grew actively in winter or were relatively short in summer.

Regression equations based on stem lengths (cm) in summer (LSS) and winter (LSW) included:

%P (Yanco, 52 months) = 2.07 (?0.31)*LSS - 1.75 (?0.21)*LSW - 67.39 (?17.95) (r^2 adj. = 0.79**)

%P (Tamworth, 46 months)= 1.89 (?0.37)*LSS - 1.82 (?0.26)*LSW - 49.55 (?20.94) (r^2 adj. = 0.74**)

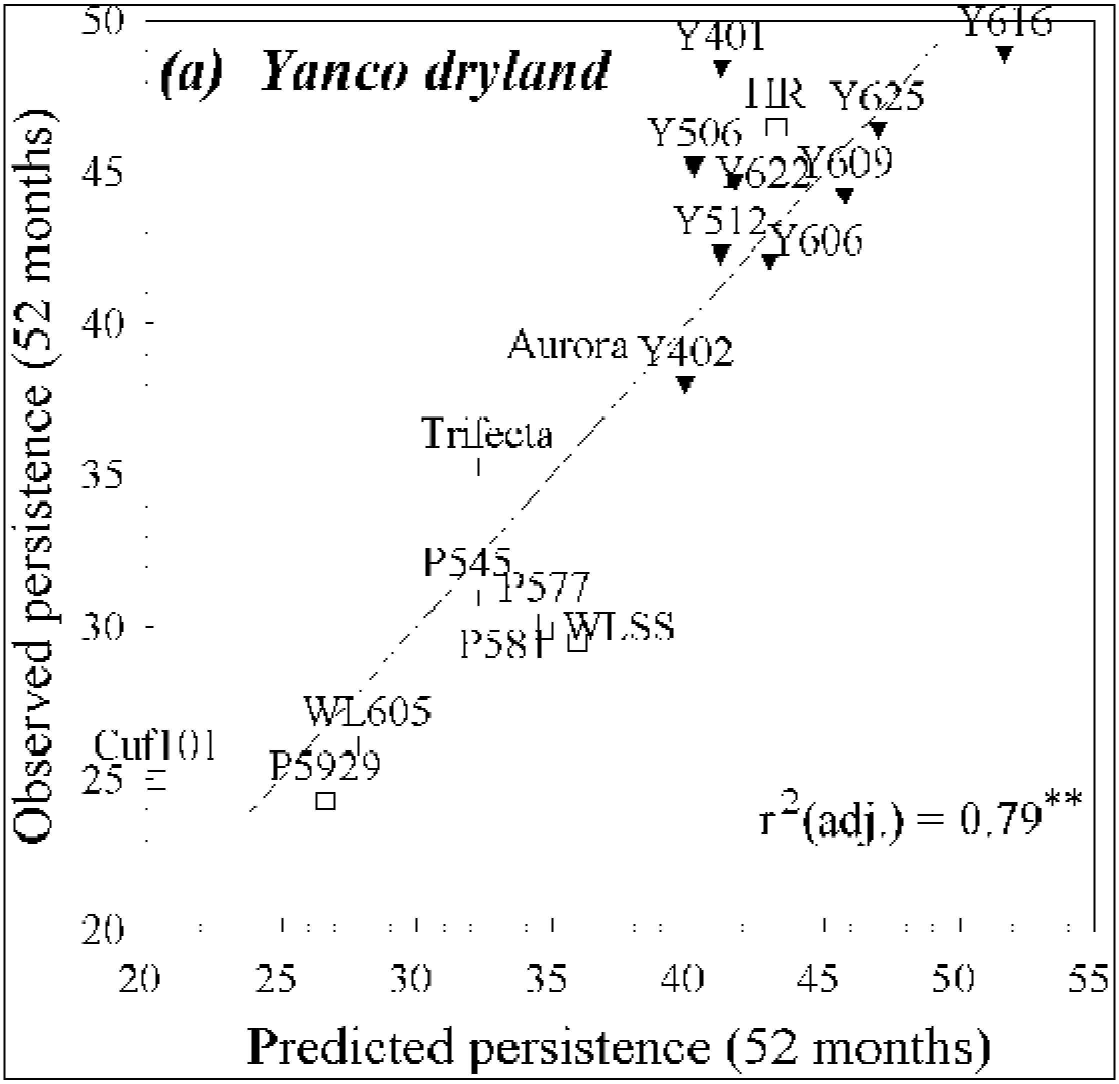
Variation in the rates of carbohydrate accumulation and its concentration in the roots is thought to influence the survival and regrowth of lucerne following cutting (5). However, the most persistent of the commercial varieties, Hunter River, had the lowest starch concentration of all those tested in the current study. It appeared that persistence was associated more with the stability of starch concentrations during regrowth and the minimum concentration during the regrowth cycle than the absolute concentration of starch at cutting. For example, starch concentration in roots after 13 days regrowth produced a slight, but significant improvement to models for persistence in the field after 16 and 52 months at Yanco. Change in starch concentration during early regrowth also produced slight improvements to models for persistence after 22, 27, and 33 months at Tamworth.

The inclusion of data from the water deficit experiment (*e.g.* RWUE) into the stem length models provided only minor improvements for predicting persistence at Yanco after 33 and 52 months. Survival in dryland pastures seems to require lucerne plants to cease top growth rather than expending or chasing declining water levels to maintain productivity. This may explain why yield under stressed conditions (RWUE) was relatively poorly associated with persistence.

The persistence of lucerne in high rainfall and irrigated trials is often dependent on adequate resistance to major pests and disease. However, persistence in the dryland trials seemed largely independent of differences in pest and disease resistance. Resistance to colletotrichum crown rot and spotted alfalfa aphids was significant only when incorporated in a model with several other traits and only for predicting persistence after 16 months at Yanco.

This current study agrees with earlier research which suggested that morphological traits were more reliable indicators of lucerne productivity than physiological traits (6). However, the success of summer stem lengths and winter dormancy as predictors of persistence may be at least partly due to their associations with other criteria. For example, highly winter-active varieties tended to have lower water use efficiencies and were generally more exploitive of root carbohydrate reserves during early regrowth than more dormant lucernes.

In general, models based only on the two simple measures of stem length under irrigation at Leeton were highly predictive of plant survival in old dryland trials at both Yanco and Tamworth. Models were least successful when differences among varieties were small (*e.g*. in the seedling year and when few plants survived near the end of trials). Broadly-adapted varieties bred in Australia such as Hunter River (HR), Aurora, Trifecta, and Y506 generally persisted better than predicted, whereas overseas-bred lines such as WL605, P5929, P581, and WL Southern Special (WLSS) were worse than predicted (Fig. 2). This suggests that lucernes bred in Australia may possess other traits which produce advantages over similar material bred overseas. As these traits could not be identified in this study, this highlights the continuing advantages of breeding lucernes in Australia.



(a) Yanco dryland
Observed persistence (52 months)
Predicted persistence (52 months)
r²(adj.) = 0.79**
Y401
Y616
HR
Y625
Y506
Y622
Y609
Y512
Y606
Aurora
Y402
Trifecta
P545
P577
WLSS
P581
WL605
Cuf101
P5929
20
25
30
35
40
45
50
55

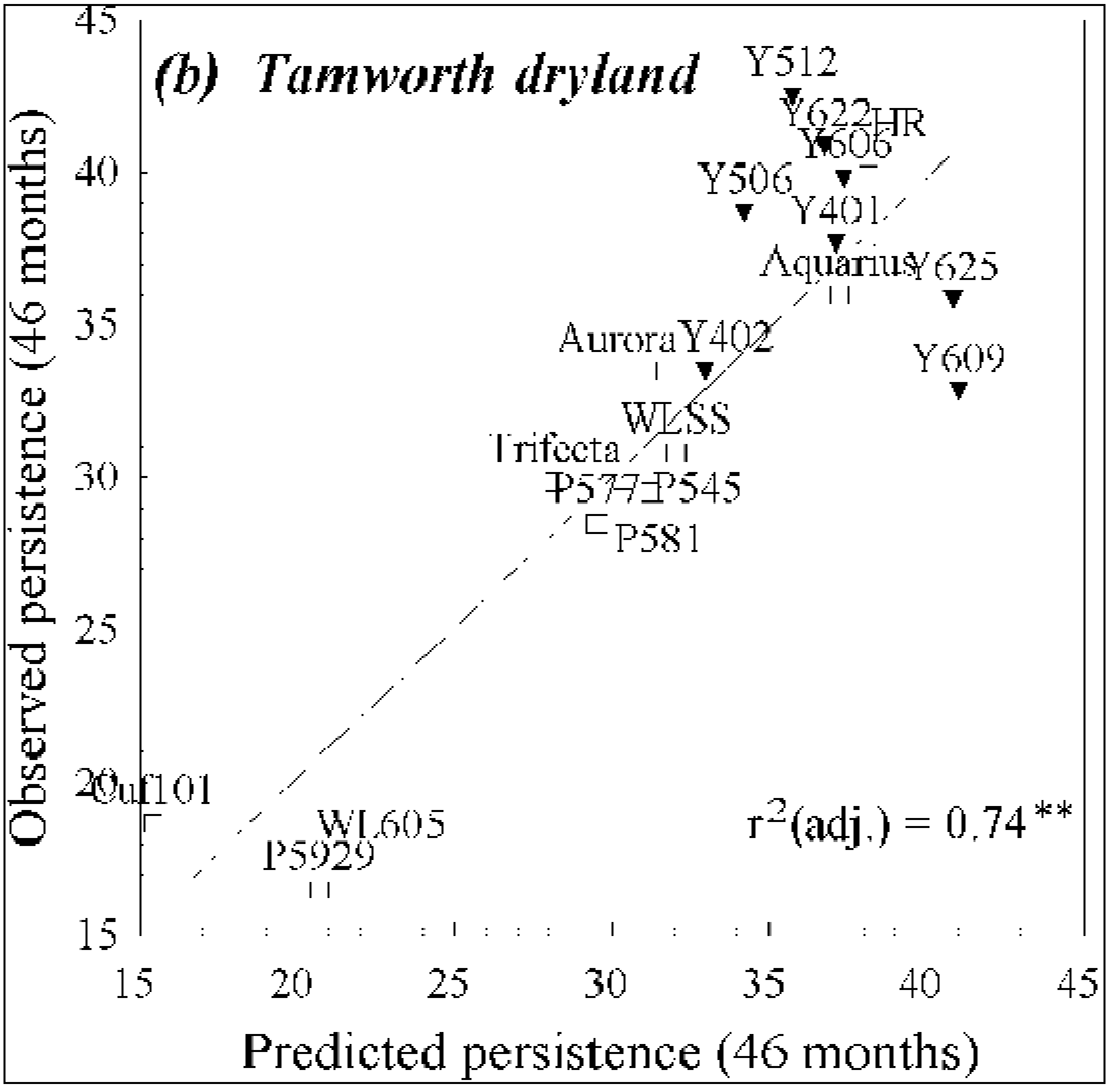


Figure 2. Persistence of lines predicted from stem lengths in summer and winter compared to that observed in dryland trials at (a) Yanco after 52 months, and (b) Tamworth after 46 months.

This study has developed simple and useful models for persistence based on two stem length traits. Ultimately this will provide specific objectives and improved strategies for increasing the survival and long-term productivity of new varieties. This should stimulate the use of lucerne in dryland pastures and crop rotations and increase the productivity and sustainability of farming systems in the pastoral zone.

ACKNOWLEDGMENTS

Funding was provided by Australian farmers through the International Wool Secretariat.

REFERENCES

1. Larson, K.L. and Smith, D. 1963. Crop Sci. 3, 234-237.

2. McKenzie, J.S., Paquin, R. and Duke, S.H. 1988. In: Alfalfa and Alfalfa Improvement. (Eds A.A. Hanson, D.K. Barnes and Hill, R.R. Jr.) (ASA:Madison, USA). pp. 259-302.

3. Escalada, J.A. and Smith, D. 1972. Crop Sci. 12, 745-749.

4. Lowe, C.C., Marble, V.L. and Rumbaugh, M.D. 1972. In: Alfalfa Science and Technology. (Ed C.H. Hansen) (ASA:Madison, USA). pp. 391-413.

5. Chatterton, N.J. and Carlson, G.E. 1981. Crop Sci. 14, 783-787.

6. Foutz, A.L., Wilhelm, W.W. and Dobrenz, A.K. 1976. Agron. J. 68, 587-591.