Developing grass curing algorithms for decision support tools

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Abstract

Algorithms describing a range of leaf growth and death characteristics were determined for four common grass species with differing growth habits in a glasshouse study. Incorporating these algorithms into agricultural plant growth models in commercially available decision support tools (DST) will enable the degree of grass curing (percentage of dead material in the sward) to be estimated. This will assist fire agencies with grass fire management and planning, at finer spatial scales and time frames than are possible through technologies currently used to assess grass curing rates. In this study, linear relationships were found between leaf life span (LLS), leaf senescence rate (LSR) and leaf elongation rate (LER), and the nature of this relationship was different between annual and perennial grasses. This indicates that it may be possible to indirectly estimate leaf life span and senescence rate from elongation rates collected early in the growing season, thus providing early warning for fire control agencies of future fire risk. The apparent commonality of relationships across annual and perennial species (LLS vs LER) and across pasture species (LSR vs LER) indicates that it may be possible to extrapolate these relationships to other 'like' species, although further validation is required.

Introduction

Curing is the term used to describe senescence and desiccation of grass material across the landscape, and is reported as the percentage of dead material in the sward. Grass becomes increasingly flammable as curing increases. Fire management agencies require accurate and timely assessments of curing for planning activities such as prescribed burning, implementing fire prevention measures, and for wildfire suppression (Cheney & Sullivan 2008). Agricultural decision support tools (DST) could provide current estimates and forecast future curing rates (for example Gill, King & Moore 2010), but greater accuracy would be achieved with the improvement of current algorithms to specifically model curing.

Modelling curing requires knowledge about leaf life span, the end of which signals the onset of curing, and leaf senescence rate, which determines the duration of curing in each leaf. Senescence rate not only determines how long a leaf takes to die, but when teamed with leaf length, will allow calculation of the proportion of live and dead material within the leaf blade before death is complete. This allows curing to be more accurately determined than is currently possible with current DSTs, where senescing leaves are often either considered to be either all live or all dead material.

Because the proportion of senescent leaves present in the sward depends on the appearance and life span of leaves (Calviere & Duru 1995), it should be possible to predict senescence rate with knowledge of leaf traits such as leaf appearance, elongation and life span, that are expressed earlier in leaf life (Lemaire & Agnusdei 2000; Vine 1983). This would potentially allow parameterisation of curing rates in additional species from measurements taken early in the growing season.

This paper reports on a controlled environment study to measure leaf growth and death in four common grasses for the purpose of calculating a number of leaf turnover rates, including leaf elongation rate, leaf life span and leaf senescence rate, and to explore relationships between these various indices.

Materials and Methods

Rates of leaf appearance, elongation and senescence were calculated (Thomas 1980) as a single thermal time value with base temperature of 0?C for each leaf of two annual (wheat (*Triticum aestivum* cv "Bob White"), annual ryegrass (*Lolium rigidum* cv "Wimmera") and two perennial (wallaby grass (*Austrodanthonia duttoniana* (Cashmore) H.P. Linder.), phalaris (*Phalaris aquatica* cv "Holdfast") grass species grown in glasshouse conditions. Life span was determined from leaf appearance to the beginning of senescence. Senescence rate represented the time taken from the first sign of yellowing at the leaf tip until the leaf was completely dead. Correlations between leaf rates were analysed with PROC CORR in SAS (SAS Institute Inc. 2002-3), and significant correlations were investigated using linear regression in PROC MIXED.

Results

Leaf elongation rate (LER) was significantly negatively correlated with leaf life span (LLS) (-0.42, P<0.0001) and positively correlated with leaf senescence rate (LSR) (0.37, P<0.0001), across all species combined, and these correlations were also significant in all individual species.

Fitted linear models for the relationship between LLS and LER and between LSR and LER are shown in Figures 1 and 2 respectively. In general, as LER increased, LLS decreased, however there was a significant interaction between species and LER ($F_{3,371}$=4.32, P=0.0052). Significant differences in slope were explored with posthoc pairwise tests for species within the model (Table 1). The scatter of observed LLS values meant that this model provided only modest explanatory power when observed values were regressed against those predicted by the model. The model accounted for 25%, 28%, 33% and 45% of the variation for annual ryegrass, wallaby grass, phalaris and wheat, respectively.
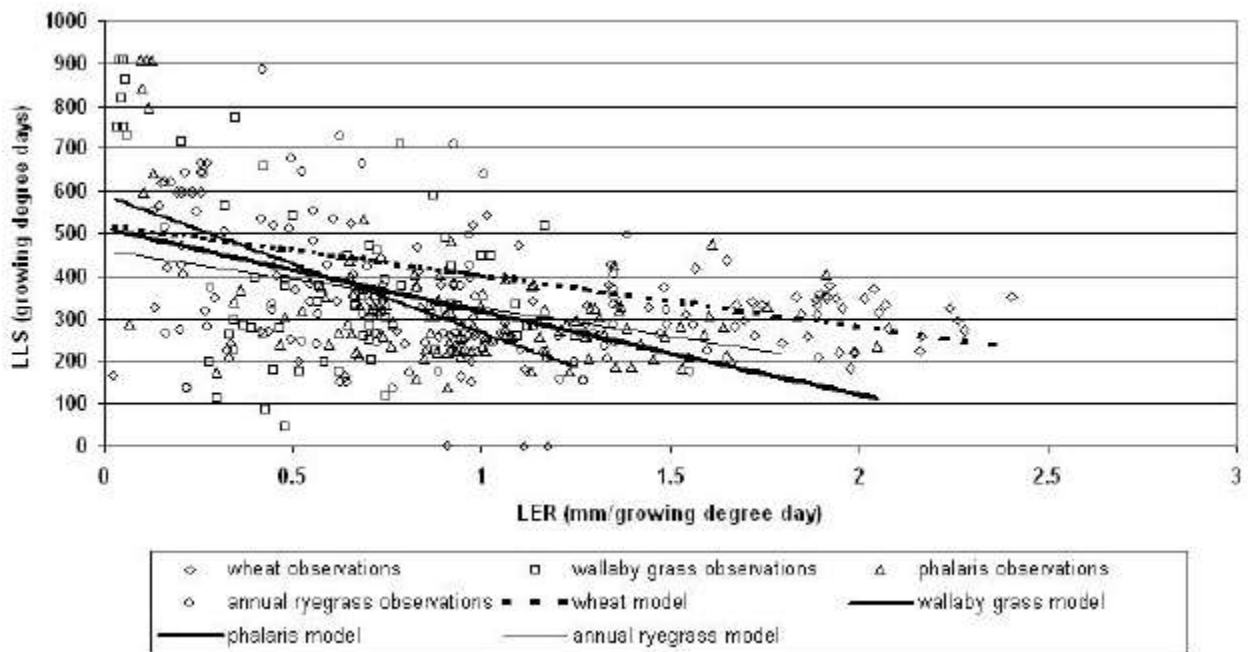

Figure 1. Models of relationship between leaf elongation rate and life span for four species.

Table 1. Differences between species in slope of the LLS model.

Species	Significant differences indicated by different letters

Wheat	A
Annual Ryegrass	A, B
Phalaris	B, C
Wallaby Grass	C

LSR could be explained by a linear model in which there was a significant interaction between LER and species ($F_{3,415}$=16.03, P<0.0001). LSR increased with LER in all species; however, the relationship was not as strong in wheat. There was no significant difference in the slopes of the models for wallaby grass, phalaris and annual ryegrass when wheat was removed from the analysis. Variation in LSR values led to relatively low explanatory power, with the model accounting for 44%, 33%, 29%, and 21% of the variation in wallaby grass, phalaris, annual ryegrass and wheat, respectively.
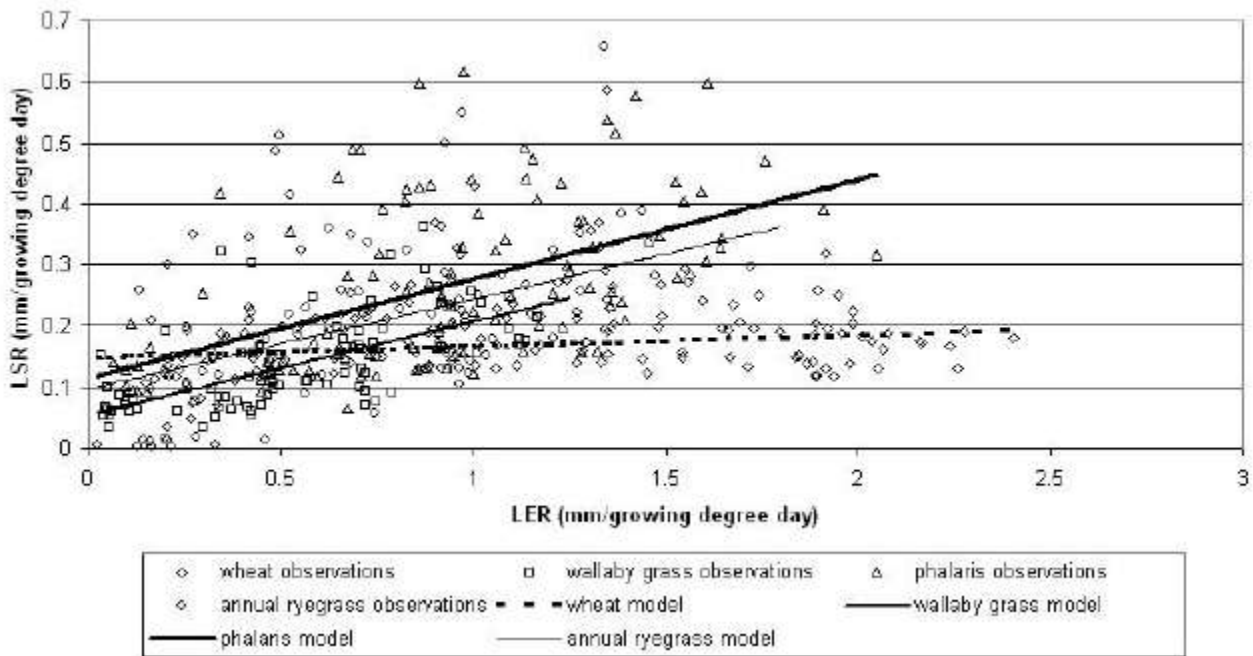

Figure 2. Models of relationship between leaf elongation rate and senescence rate for four species.

Discussion

This work provides some pointers to how such simple linear models might be extended to a wider range of grass species, required by fire agencies to determine grass curing rates in the field. While complementary work has sought to predict leaf senescence rate from data measured in previous years (Daily *et al.* 2010) the models described here potentially enable determination of onset and length of the senescence stage in grass leaves, from leaf elongation rate measured early within a single year or fire season. If successful, this could accelerate the assessment of leaf senescence rate in different species, cultivars or areas.

Estimation of leaf life span is necessary to determine the onset of senescence. It appears that the rate of decrease in leaf life span with increased leaf elongation rate may be different for annual and perennial species, but there may be similarities between species with similar growth habits. If this relationship holds with other annual and perennial species, then this will simplify the determination of life span in other grass species. That is, the existing algorithms may be a suitable substitute or provide a starting point from which to determine the values for other species of a similar growth habit.

However, more work on the link between leaf elongation and life span is needed with a range of other species to validate this concept. It may be that only the slowest elongating leaves tend to have longer life spans, and that no discernible relationship exists beyond LER values of 0.5mm/GDD.

There appears to be little relationship between the LER and LSR for wheat leaves, and if this holds with other cereals, then determination of the LSR from LER may not be possible in cereals. However the relationship between LER and LSR appears to be stronger and more consistent for the pasture species, with faster elongating leaves also being faster to senesce. Interestingly, this relationship covers both annual and perennial growth habits. Measurement of elongation rate on leaves early in the season may allow the rate of subsequent senescence to be established in grasslands composed of a range of pasture species.

LER has modest ability to describe LLS and LSR in the models shown here. This study has used all available data on leaf elongation to calculate relationships with life span and senescence rate in order to maximise statistical power. No account has been taken of leaf position in this process. It would be useful to isolate LER from a range of leaf positions to determine if a particular cohort of leaves, such as those produced early in plant life, have a particular relationship with life span and senescence rate. This may reduce the scatter seen between observed and predicted responses, identify the most suitable cohort of leaves for regression, and reduce the time required to conduct measurement on new species or cultivars. This may require greater numbers of plants in these (and other species) to be measured to establish if the explanatory power of these models can be improved. Alternatively, measuring the full cohort of leaves on greater numbers of plants may provide another means of increasing reliability of the models.

These models calculate the proportion of dead material over all leaves on the plant at any given thermal time. As with all modelling, extrapolation beyond the point scale assumes uniformity across the larger area, but will allow scaling to the percentage of dead material in the sward on a hectare basis. Whether these relatively modest relationships described here at the plant scale change significantly when averaged at the hectare scale remains to be seen.

Conclusion

Determination of leaf senescence rate and leaf life span can be achieved through direct measurement of leaf growth and death rates in the species of interest, and it appears from this work that this may be the most accurate way to parameterise new species. However, our data show that there is support for utilising the relationships between early expressed leaf characteristics such as leaf elongation rate and those expressed later to elucidate leaf life span and senescence rates in new species, or indeed new cultivars of the current species. Further work is warranted to test and strengthen these relationships. If similarities between species hold, then the potential to indirectly parameterise new species through the collection of leaf elongation rate data, early in the growing season, will provide far more timely advice to fire agencies than would be possible from waiting to directly measure leaf life span and then death, as this is likely to occur at the time at which the fire agencies most require the information.

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