Long-term modelling of lucerne and tropical perennial grass mixtures and monocultures

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Abstract: *SGS Pasture Model simulations over a 100-year period (1907–2006) for a lucerne (Medicago sativa)/generic tropical perennial grass mixture and monocultures of each of these pasture types were used to assess their likely comparative performance in a variable climate in inland northern New South Wales. Predicted growth rate and yield data, obtained from simulated cutting studies (monthly sampling) and predicted soil water content data, were used in simple and multiple linear regression analyses to explore observed effects. Predicted mean annual yields in the mixtures were 4.3 t DM/ha for lucerne and 5.2 t DM/ha for the tropical perennial grass and were 44 and 29%, respectively lower than for the monocultures. Predicted yield of each of the species in the mixture compared with the monocultures was lower in >90% of years. The difference in predicted annual cut yield between the mixture and the monoculture was negatively correlated with both mean soil water content on the first day of each month and the growth rate of the complementary species (r = 0.66 and 0.84, respectively for lucerne; r = 0.38 and 0.62, respectively for the tropical perennial grass). Multiple linear regressions of these parameters had r-values of 0.91 for lucerne and 0.75 for the tropical perennial grass. Predicted growth rate and water use efficiency values for each species are also presented for future reference.*

Key words: mixtures, monocultures, yield, growth rate, soil water content, water use efficiency

Introduction

There has long been an ongoing debate about the advantages and disadvantages of sowing pasture mixtures as opposed to growing the individual species in monocultures. Clearly, in legume mixtures there are obvious benefits of nitrogen (N) fixation by the legume for the other species in the mix. However, there are also disadvantages of mixtures in relation to species competition in seedling and established stands, restrictions on herbicide choices for broadleaf weed control in pastures sown with legumes, differing growth phases and conflicting grazing management requirements, and differences in root depth, water use efficiency and seasonal water extraction.

Management of a species mixture to maintain the production and persistence of the individual species can be complex and so often producers prefer to sow monocultures. In inland northern New South Wales (NSW), the two most widely sown pasture types are lucerne (*Medicago sativa*) and tropical perennial grasses (Lodge *et al.* 1991; Boschma *et al.* 2010) and both are commonly sown as monocultures. Lucerne because it is usually undersown into a winter cereal crop and tropical perennial grasses because of their requirement for sowing in late spring–summer and a lack of availability of suitable tropical legumes.

In this paper, we describe the use of the Sustainable Grazing Systems (SGS) Pasture Model (Johnson *et al.* 2003) to simulate the growth of lucerne and a generic tropical perennial grass when grown together in a mixture or as individual monocultures over a 100-year period of variable climate in inland northern NSW. These analyses highlighted marked differences between species yield performance in mixtures and monocultures that were related to both the presence of each species in the mixture and soil water content (SWC). We also document the predicted values for growth rate and water use efficiency (WUE, kg of dry matter (DM)/mm of water transpired/day) for lucerne and a generic tropical perennial grass.

Methods

The SGS Pasture Model was used to simulate the growth of a lucerne/tropical perennial grass mixture and monocultures of each of these pasture types growing at Gowrie (20 km south-west of Tamworth, NSW; 31.16°S 150.52°E; elevation 490 m a.s.l.). Parameterised values for lucerne and Rhodes Grass (*Chloris gayana*) were available within the model. The default values for lucerne gave an adequate representation of its growth in this environment. Those for Rhodes grass were adjusted to allow for growth rates of 100 kg of DM/ha/day; water and nutrients non-limiting) to reflect the data of Murphy *et al.* (2010) and were designated as a generic tropical perennial grass (TPG). Soil parameters for the generic clay-loam soil type were also adjusted to allow for higher rates of water infiltration into the profile and soil water retention, so that a soil water deficit (SWD) for plant growth (Lodge and Johnson 2008) did not occur until profile (2 m depth) stored soil water was <300 mm. Long-term (1901–2006) daily interpolated weather data for the site latitude/longitude coordinates were abstracted from the SILO Data Drill (Jeffery *et al.* 2001). For all simulations, fertiliser was applied to maintain soil N, phosphorus, sulfur and potassium at a growth limiting factor (Johnson *et al.* 2003) of 1.0. Each of the three pasture simulations (a lucerne/TPG mixture, a lucerne monoculture and a TPG monoculture) were for pastures cut on the last day of each month and were used to estimate predicted daily net positive growth rate (kg DM/ha/day) for a 100-year period (1907–2006). These predicted daily growth rate values were used to calculate predicted monthly and annual mean growth rate and yield (tonnes (t) DM/ha). Data were also available for calculating predicted values for daily water use efficiency and profile daily SWC (mm). Predicted daily SWC values were used to form a subset of SWC values for the first day of each month (SWCFOM, mm). Linear and multiple linear regressions were used to determine the relationships between the predicted mean growth rates of each of the species in the mixtures and monocultures and mean predicted SWCFOM.

Results and discussion

Mean predicted annual yield in the lucerne/TPG mixture was 9.5 t DM/ha (Figure 1*a*), with predicted mean annual lucerne yield being 4.3 t DM/ha (47% of the total) and predicted TPG yield being 5.2 t DM/ha (53% of the total, Figure 1*b*). These predicted mean annual yields for the individual species were considerably less than those for the individual species grown in monocultures, which were 7.8 and 7.4 t DM/ha, respectively for lucerne and TPG. Compared with the monocultures the predicted mean annual yields in the mixtures represented a decrease of 44% (a mean of 3.5 t DM/ha) for lucerne and 29% (2.2 t DM/ha) for the TPG and overall the total yield of the mixture was 37% lower. For the 100-year period (1907–2006), these decreases were consistent (Figs. 1*c* and *d*), occurring in 96% of years for lucerne and 92% of years for the TPG.

Based on predicted mean annual yield the proportion of lucerne in the mixture ranged from 24–67% (Figure 1*b*) and was lowest in the wetter years and highest in the drier years (Figure 1). Conversely, the proportion of TPG (33–76%, Figure 1*b*) was highest in the wetter years, indicating that there was probably an inter-species competitive effect occurring, that appeared to be influenced by rainfall and soil moisture. Monthly and seasonal linear regression analyses of the relationship between the difference in mean predicted lucerne yield in the monocultures and mixtures and SWCFOM, indicated that the best relationship occurred in January–May (r = 0.65), which also coincided with the period when growth rates of the frost-susceptible TPG were high.

Compared with the lucerne/TPG mixture the lucerne monoculture was predicted to have a mean of 111 mm higher SWCFOM each year, with the difference being highest in spring (39 mm). Based on SWCFOM, a SWD for plant growth was predicted to occur in the mixture on 670 occasions, which was about 20% more frequently than for the lucerne monoculture. Over the 100-year period the cut yield of lucerne in the lucerne/TPG mixture was predicted to be zero in 518 months (43.2 years), compared with 349 months (29.1 years) in the lucerne monoculture, which represented a difference of 169 months or 14.1 years.

Linear regression analyses of the relationships between predicted monthly lucerne or TPG growth rates and SWCFOM data (n = 1440), while significant (P<0.05) were often poorly correlated (r<0.4), because of the effects of low temperatures from May–August on growth rates. Aggregation of these data to annual means (n = 100), revealed two substantial relationships for lucerne, but were less well correlated for the TPG. The difference in predicted annual lucerne yield between the mixture and the monoculture was negatively correlated with both mean SWCFOM (r = 0.66) and TPG growth rate (r = 0.84). For the difference in predicted annual TPG yield between the mixture and the monoculture, these relationships were also negative, with r-values of 0.38 and 0.62, respectively. Multiple linear regression of these parameters indicated that the relationship between the difference in predicted annual yield between the mixtures and the monocultures and SWCFOM and the growth rate of the other companion species (i.e. either lucerne or TPG) had an r-value of 0.91 for lucerne and 0.75 for the TPG. Hence, in

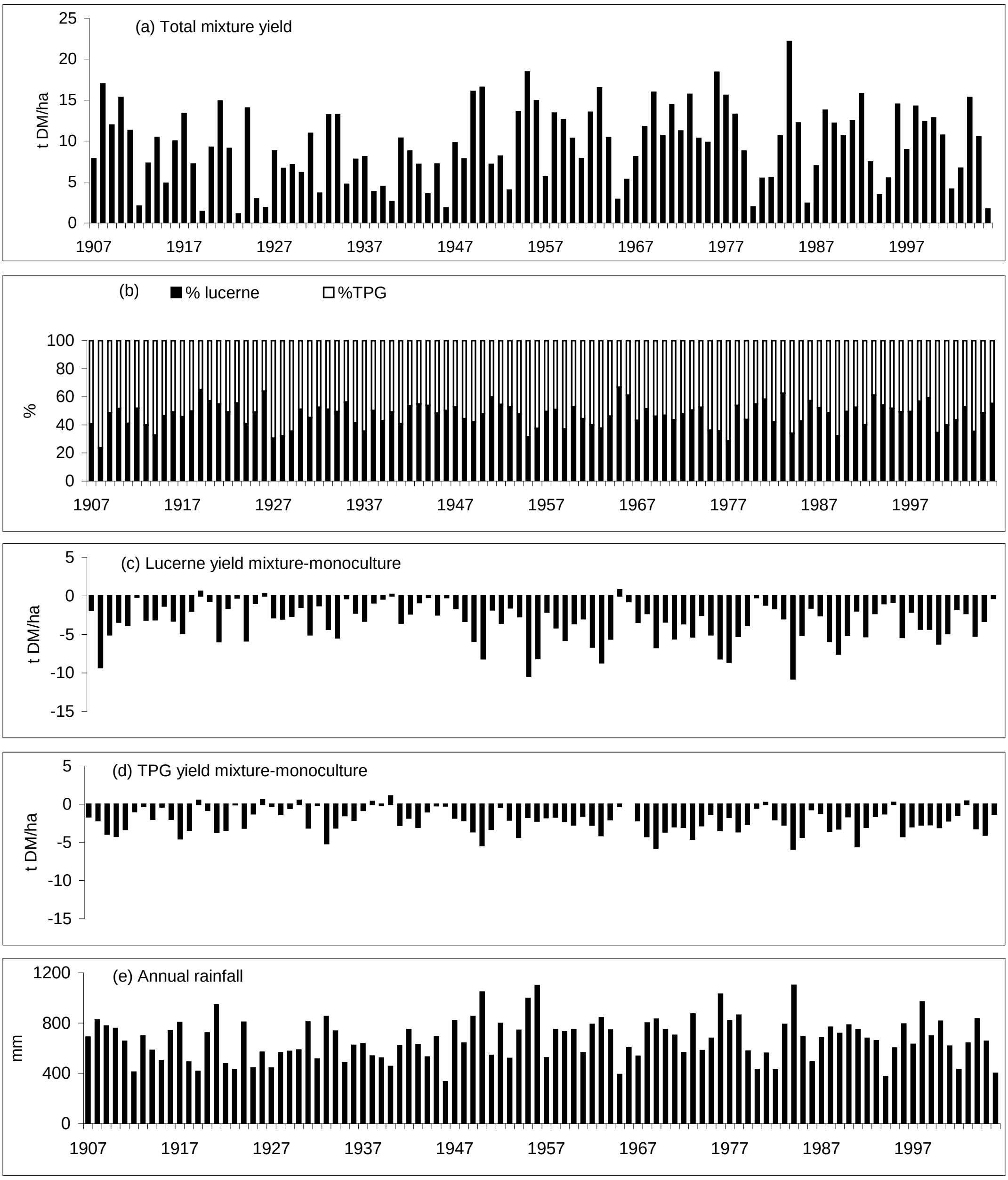

Figure 1. Predicted data for the 100-year period (1907–2006) for (*a*) total annual cut yield (t/ha) of a lucerne/TPG mixture, (*b*) the proportion (%) of lucerne and TPG in the mixture (based on yield), (*c*) the lucerne yield (t/ha) in the mixture minus that in the monoculture, and (*d*) the TPG yield (t/ha) in the mixture minus that in the monoculture, together with (*e*) the interpolated annual rainfall (mm).

this study both a higher frequency of predicted SWD for plant growth and the presence of a competitive companion species in the growing season appeared to be factors in the predicted lower growth and yield performance of lucerne and the TPG in the mixtures compared with the monocultures.

Highest predicted mean growth rates for lucerne occurred from October–December (~20 kg DM/ha/day, Figure 2*a*), but were much lower than those for the TPG, which ranged from 38–51 kg DM/ha/day from December–March (Figure 2*a*). Predicted growth rates in May–September were <7 kg DM/ha/day for lucerne and <3 kg DM/ha/day for the TPG (Figure 2*a*). Similar to predicted growth rate, the predicted WUE of both lucerne and the TPG was lowest in cooler months (Figure 2*b*). Mean predicted WUE ranged from 30–44 kg DM/mm of water transpired/day from October–April for lucerne (Figure 2*b*), compared with 30–43 kg DM/mm/day for the TPG for the same period.

Conclusion

The output from these model simulations strongly indicated that in the summer rainfall environment of inland northern NSW it was highly likely that the long-term yield performance of lucerne and a tropical perennial grass, when grown in a mixture, would be less than that of the individual species grown in monocultures. This outcome occurred both as result of reduced predicted SWC in the mixtures compared with the monocultures and the presence of a competitive companion species. However, it is acknowledge that on-farm there may be other benefits from using mixtures such as increased ground cover, N fixation from a legume, complementarities of species growth or growing season and/or water use patterns and improved feed quality that may partly offset the disadvantage of any likely yield declines.

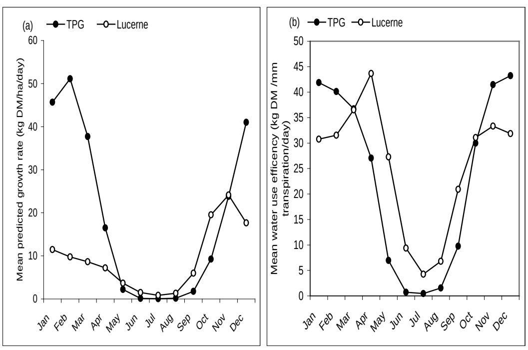

Figure 2. (*a*) Mean predicted growth rate (kg DM/ha/day) of lucerne and the TPG and (*b*) mean predicted water use efficiency (kg DM/mm water transpired/day) of each species in the mixture.

Acknowledgments

This study was partially funded by the Future Farm Industries CRC EverGraze northern NSW project and the NSW Department of Primary Industries. EverGraze is a Future Farm Industries CRC, Meat & Livestock Australia, Australian Wool Innovation and NSW DPI research and delivery partnership.

References

Boschma SP, Lodge GM, McCormick LH (2010) Recent tropical perennial grass research and their potential role in maintaining production in a variable and changing climate. In 'Proceedings of the 25th Annual Conference of the Grassland Society of NSW'. (Eds C Waters, D Garden). pp 85–92. (NSW Grassland Society Inc.: Orange) http://grasslandnsw.com.au/news/wp-content/uploads/2010/08/Boschma-Lodge-McCormick-2010.pdf

Jeffery SJ, Carter JO, Moodie KB, Beswick AR (2001) Using spatial interpolation to construct a comprehensive archive of Australian climate data. *Environmental Modelling Software* **16**, 309–330.

Johnson IR, Lodge GM, White RE (2003). The Sustainable Grazing Systems Pasture Model: description, philosophy and application in the SGS National Experiment. *Australian Journal of Experimental Agriculture* **43**, 711–728.

Lodge GM, McCormick LH, Dadd CP, Burger AE (1991) A survey of graziers and pasture management practices on the Northern Slopes of New South Wales. NSW Agriculture & Fisheries, Technical Bulletin No 43.

Lodge GM, Johnson IR (2008) Agricultural drought analyses for temperate Australia using a biophysical pasture model. 1. Identifying and characterising drought periods. *Australian Journal of Agricultural Research* **59**, 1049–1060.

Murphy SR, Lodge GM, McCormick LH, Johnson IR (2010) Using growth and dry matter estimates to devise year-round forage systems for the North-West Slopes of New South Wales. In 'Proceedings of the 15th Australian Agronomy Conference, Lincoln, NZ'. http://www.regional.org.au/au/asa/2010/pastures-forage/forage-crops/7224_murphysr.htm