The potential for tedera (*Bituminaria bituminosa* var. *albomarginata*) in mixed farming systems

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Abstract
Tedera (*Bituminaria bituminosa* var *albomarginata*) is a perennial legume herb showing promise for inclusion in mixed farming systems of Australia. In this research we compared two tedera lines with lucerne and an annual legume pasture at two sites in southern Australia, and developed an APSIM module to simulate tedera growth. Simulated tedera production was about one third that of lucerne in both wet and dry years. Tedera was also not as effective as lucerne, but more effective than sub clover, in extracting subsoil water. However, one of the tedera lines appeared to be particularly effective in extracting soil P, suggesting that (a) there is variation within tedera germplasm for P efficiency, and (b) that some tedera lines might be well suited to soils of low P status.

Keywords
Perennial pasture, phase rotation, pasture phase, Evercrop.

Introduction
Farming systems in southern Australia often include enterprises of both cropping and livestock, and this combination is referred to as ‘mixed farming’. Within a mixed farming system, both crops and pastures are important. Perennial pastures have been identified as suitable for inclusion in mixed farming systems for two major reasons: they are capable of producing good quality feed at times of the year when feed is often scarce (e.g. Cocks et al. 2001); and their deep roots can provide environmental benefits in terms of controlling water and nutrient losses (e.g. Ward et al. 2006) and providing groundcover. Tedera (*Bituminaria bituminosa* var *albomarginata*) is a perennial legume herb showing promise for inclusion in mixed farming systems by providing green biomass during the dry seasons and reducing the need for supplementary feeding in Mediterranean-like climatic environments of Australia (Finlayson et al. 2012; Real et al. 2014). In this research we use field trials in South Australia and Western Australia, in conjunction with simulation studies using APSIM, to investigate the potential for tedera in mixed farming systems for southern Australia.

Methods
Field trials
Field trials were established near Karoonda in SA and Arthur River in WA. In both trials, two advanced breeders’ lines of tedera (referred to as T15 and T47) were compared with lucerne (*Medicago sativa* cv SARDI Grazer) and an annual pasture (sub clover in WA, volunteer pasture in SA). Measurements included plant density, production, leaf area, and soil water using Neutron Moisture Meter (NMM) to a depth of 2.5 m. Both trials were sown in May 2015. The Karoonda trial included two landscape positions, with fine-textured soils on the flat, and coarse-textured soils on the hill. At the Arthur River trial, soil samples were collected in May 2016, and were analysed for nitrate, ammonium, phosphorus, and potassium.

Model development
A tedera module was developed based on the APSIM-lucerne module. Plant physiological parameters were estimated from a glasshouse experiment, performed under two different temperature regimes: 26°/18° (daytime/night time); and 22°/14°C. Plants were kept well-watered. Measurements were performed on 7 occasions over a 10 month period, and included main stem node number, plant leaf number, dry weight of leaf and stem at various times, and photosynthetic rate. Simulated dry matter production and soil water content from APSIM were compared with measurements from the two field trials.

For long-term simulations, weather records from Arthur River for the period 1951-2015 were used, along with soil parameters from the Arthur River site. Lucerne or tedera pastures were sown in May or early June. Grazing was simulated starting in March (i.e. about 9-10 months after sowing), and then every 3 months in June, September and December. Pastures were removed in January after 4 years, to allow crop production.

Results and Discussion

Both the tedera lines and lucerne were successfully established, with populations at Arthur River shortly after sowing of 9.0, 19.9, and 54.3 plants/m^2 for T47, T15 and lucerne respectively. By February 2016, densities were 11.0, 11.5 and 22.9 plants/m^2 respectively. At the Karoonda site, plant densities were 11, 13 and 23 plants/m^2 on the flat, and 12, 21 and 18 plants/m^2 on the hill.

Comparison of APSIM with field trials

APSIM generally performed well when comparing simulated results to results measured in the field trials at both Arthur River and Karooonda (Figure 1). APSIM was able to explain 64% of the variation in plant production, and 50-60% of variation in soil water content.

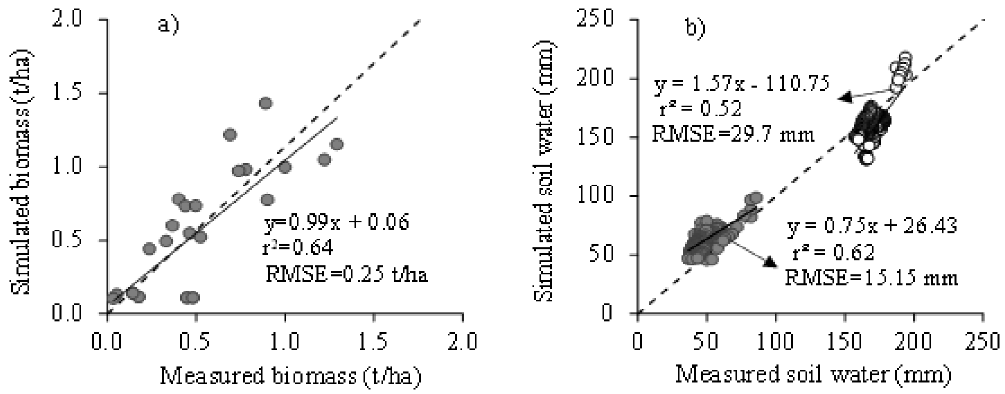

Figure 1. Measured and simulated above-ground biomass of two lines of tedera at Arthur River, WA and Karoonda, SA (a) and soil water content at the depth of 50 cm (solid circle) and 120 cm (open circle) at Arthur River, WA (b). Lines are the 1:1 relationship and the fitted regression between measured and simulated values

Long-term simulations

Years were grouped into terciles based on annual rainfall. Average annual production for tedera was lower than for lucerne in all season types (Figure 2), but was relatively better in dry years (tedera production 40% of lucerne production) than in wet years (tedera production 30% of lucerne production). Because of the large difference between lucerne and tedera in production, it is difficult to see a role for tedera in situations where lucerne is well-adapted. Tedera appears to be able to maintain green leaf under drought conditions (Real et al. 2014) by growing slowly, combining paraheliotropism with a strong midday and afternoon depression in stomatal conductance to avoid high temperatures and minimise water loss (Foster et al. 2013). However, tedera may still have a place in situations where lucerne is not well adapted or when summer and autumn production of reliable green biomass is important for reducing supplementary feeding in mixed farming (Finlayson et al. 2012; Real 2014).

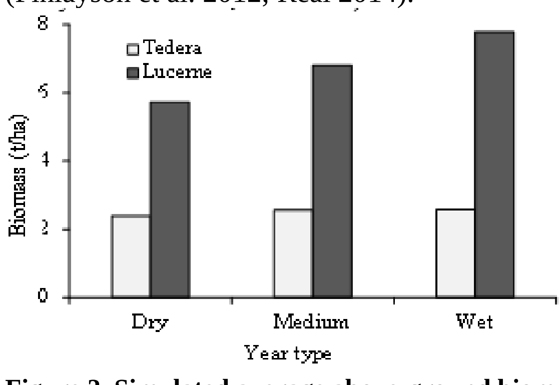

Figure 2. Simulated average above-ground biomass of tedera and lucerne under four cuts per year for different season types (dry, medium and wet) during 1952-2015 at Arthur River.

Soil water and nutrients

Since October 2015, a few months after sowing, soil in the top 0.5 m (sandy A horizon) under lucerne has consistently been about 10 mm drier than soil under tedera and sub clover at Arthur River (Figure 3). For soils between 0.5 and 1.2 m (the upper part of the clay B horizon), soils under lucerne and the two tedera lines were slightly drier than soils under the sub clover, with differences becoming apparent from January 2016. In January 2017 (18 months after sowing), the difference between the sub clover pasture and the perennial pasture was approximately 60 mm for lucerne, and 30 mm for the two tedera lines. For soils below a depth of 1.2 m, lucerne was able to extract an extra 30 mm of water relative to the other pasture options.

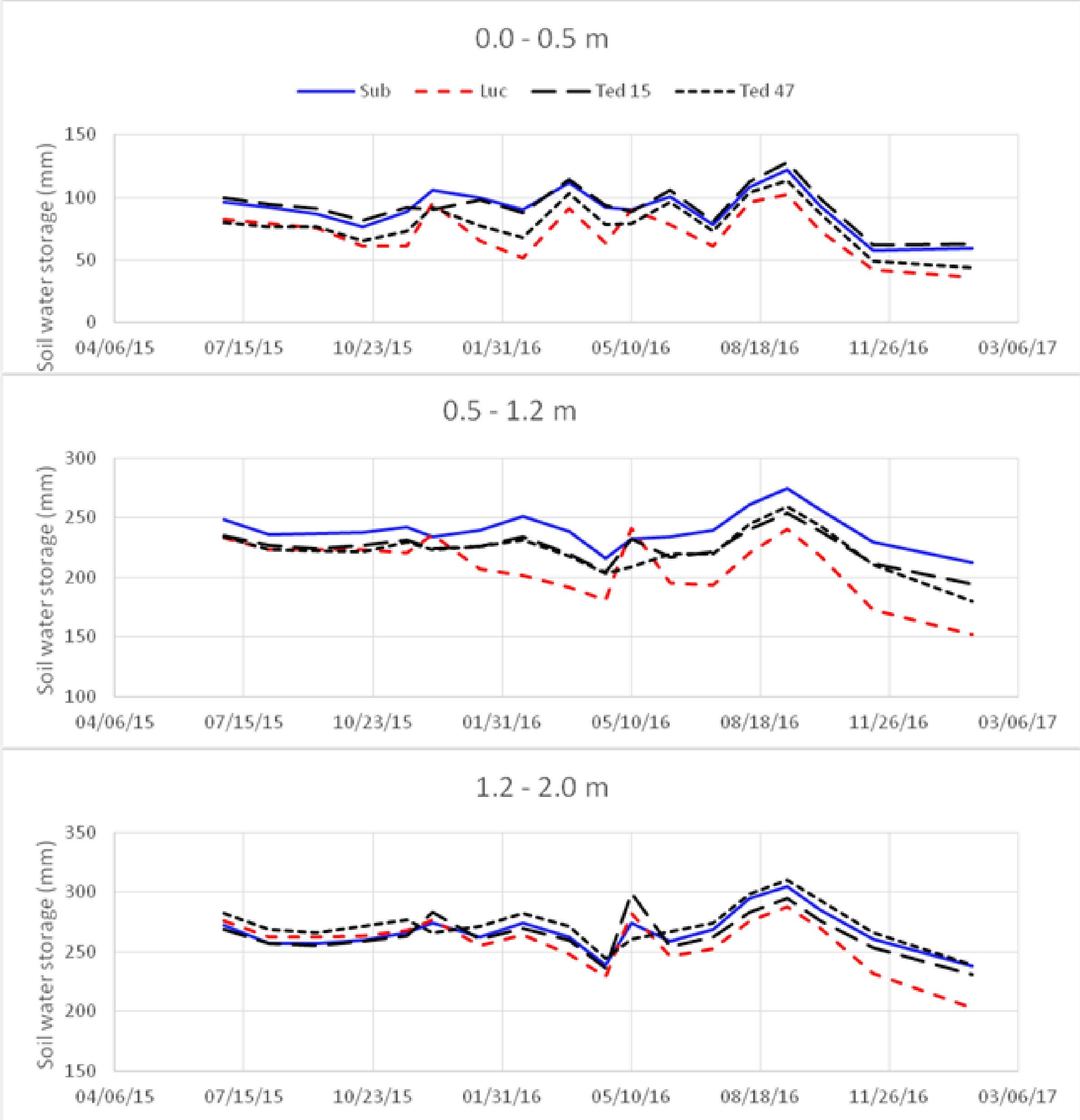

Figure 3. Soil water storage for various soil depth increments under lucerne, two lines of tedera, and a subterranean clover pasture.

Nitrate N was lowest under lucerne to a depth of 1.0 m, and T15 was also effective in scavenging soil nitrate in the surface soil (Figure 4). However, nitrate N values were considerably higher close to the soil surface under the sub clover and T47 pastures. Soils under the sub clover pasture were higher for ammonium concentration in the A horizon, but there were no consistent differences between the other pastures. The T15 line showed lower Colwell-P concentrations in the A horizon, but there were no consistent differences in Colwell-K distribution.

The differences between the two tedera lines in soil nutrients may be related to establishment, as there was approximately a two-fold difference in plant numbers at the time of measurement shortly after sowing.

However, by February 2016, plant densities were similar, so for the soil sampling in May 2016, differences in soil nutrient distribution are more likely related to differences between the lines in terms of uptake efficiency. In particular, the T15 line might be better adapted to low P conditions. Pang et al. (2011) also noted wide variation in tedera germplasm in relation to drought tolerance mechanisms. These studies suggest that there remains considerable potential for breeding to improve tedera growth and adaptation.

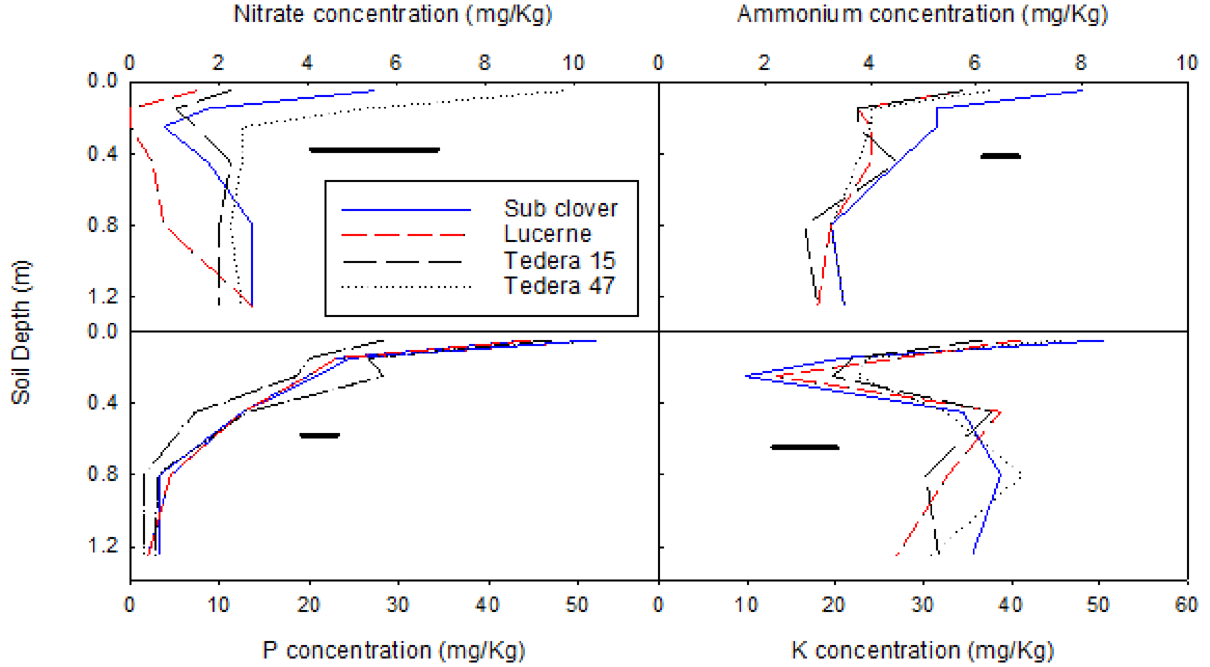

Figure 4. Nitrate, ammonium, Colwell-P and Colwell-K concentration in soils below the four pasture types at the Arthur River trial in May 2016, 12 months after sowing.

Conclusion

The slow growth and conservative water use of tedera suggest that its role in areas where lucerne is well-adapted will be limited. However, tedera may have a greater potential in areas where lucerne is not well-adapted, and particularly in soils of low P status or when summer and autumn production of reliable green biomass is important for reducing supplementary feeding in mixed farming systems in Mediterranean-like climate regions of southern Australia.

Acknowledgements

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