New perennial pasture legumes: Persistence and productivity of Australian *Cullen* species on deep acid sands in WA's low-rainfall wheatbelt.

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Introduction

The spread of dryland salinity in much of southern Australia's agricultural zone could be reduced, or even prevented, by the use of perennial pastures in rotations with annual crops. Perennial pastures integrate well with existing farm infrastructure and do not require large capital outlays. In addition, perennial pastures maintain short-term cash flow, offering farmers a profitable way to manage the water balance of their agricultural enterprise.

Several authors have suggested that new perennial pasture legumes to manage dryland salinity could be sourced from Australia's native plants (Cocks 2001). Native plants may be better adapted than existing perennial pasture varieties to use in areas of Australia's wheatbelt that have difficult growing conditions (Cocks 2001). Acidic soils, waterlogged soils, low rainfall and a Mediterranean climate limit the growth of introduced perennial pastures like lucerne (*Medicago sativa*) in large areas of the wheatbelt in Western Australia (WA). Native perennial legumes adapted to acidic or waterlogged soils in the low rainfall wheatbelt of WA would be extremely valuable tools for dryland salinity management. Native legumes from the genus *Cullen* appear to hold particular promise in this respect.

Several species of *Cullen* are highly productive and persistent. Field studies undertaken in Queensland on *C. australasicum*, *C. discolor*, *C. pallidum* and *C. patens*, a group of four potentially interbreeding species collectively called the *Psoralea eriantha* complex, revealed these can have equivalent productivity to lucerne when cut at 3 or 6 month intervals and had the ability to persist and regenerate after severe defoliation (Britten and De Lacy 1979). *Cullen australasicum* had similar productivity and persistence as lucerne and also persisted better and had higher productivity than *Lotus corniculatus* in the medium rainfall belt of New South Wales (Dear *et al.* 2007). Finally, *C. tenax* was shown to have equivalent dry matter production to *L. corniculatus* cv. San Gabriel in a glasshouse pot trial (Robinson *et al.* 2007). These results indicate that these species and potentially other *Cullen* species may be productive and persistent in perennial pastures.

The field studies outlined above were based on locally adapted populations from species naturally occurring in the regions. However, there are no records of *Cullen* species naturally occurring in WA's wheatbelt. This makes the selection of species and populations adapted to WA's wheatbelt difficult. Bennett *et al.* (2006) estimated the adaptation of *Cullen* species to WA's wheatbelt climate and soils using a broad-scale analysis of herbarium records. Their analysis showed many *Cullen* species naturally occur across a large range of soil types and climates. Ten perennial, herbaceous species were identified that appeared adapted to areas with less than 650 mm average annual rainfall, seven of which occurred on acidic or waterlogged soils. We therefore hypothesise that some populations from these seven *Cullen* species are adapted to the wheatbelt of WA.

Parallels can be drawn between the ecogeographic study by Bennett *et al.* (2006) and the trials in Qld and NSW. All of the species shown to have good persistence and productivity are included in the seven species advocated by Bennett *et al.* (2006), except *C. pallidum*. So, we would expect that some of these *Cullen* species may contain lines from natural populations that have adaptations that make them productive and persistent when grown in the low rainfall, Mediterranean climate of WA's wheatbelt. The study presented here tested this hypothesis by comparing the persistence and productivity of 120 populations from nine Australian *Cullen* species to two perennial *Lotus* species and to two lucerne cultivars in a field trial on sandy acidic soils in WA's low-rainfall wheatbelt.

Materials and Methods

***Germplasm*:** 120 populations from nine Australian *Cullen* species were sourced from collections at the Australian Medicago Genetic Resource Centre in South Australia, the Australian Tropical Crops and Forages Genetic Resource Centre in Qld and from a collection held at the University of Western Australia. The number of populations tested from each species is shown in Table 1. Germplasm was also sourced of *Lotus corniculatus* cv. San Gabriel, *Lotus australis* (Accession SA 33610, a native perennial legume under development by The Future Farm Industries CRC), and two commercial cultivars of lucerne, Sardi 10 and Sceptre. Seeds of all populations were germinated in Petri dishes on 31st July 2006 and planted into seedling tubes. Seedlings were grown in the glasshouse for six weeks and then transplanted to the field on 7th September 2006.

***Trial design*:** Three replicates, each containing three seedlings of each *Cullen* and *Lotus* population and 6 seedlings of each lucerne cultivar were planted over three blocks (24 m °— 15 m) in a 1 m grid.

Monitoring and management: Seedlings were hand watered two weeks after transplanting with 500 mL (simulating a 15 mm rainfall event). The survival, productivity and disease incidence of plants in the trial were recorded on 10 occasions at approximately monthly intervals. Plants remaining alive on 30th October 2006 were considered to be established and persistence was calculated based on this number. At each visit, productivity was visually rated based on the relative biomass of the entire plant and scored from 1 (low) to 10 (high).

All plants were cut back to 5 cm from the crown on 15th January 2007 following damage from Australian plague locusts (*Chortoicetes terminifera*) during November. A systemic insecticide (Maldison 5 ml L-1) was applied to the lucerne cultivars and *Lotus* species in April to control pasture webworm (*Hednota* spp.). Plants were again cut to 5 cm from the crown on the 26th September 2007, and leaf and stem portions were dried for seven days at 40 oC, separated and weighed separately.

***Field site*:** The trial site was located 22 km west of Buntine, Western Australia. The soil type was a deep sandy loam, with pHH2O range from 5.4 to 6.8 in the top 1.2 m. Rainfall at the site was 90 mm between planting and January 4th. The site experienced a hot, dry period between January 5th and April 29th with 4.6 mm rainfall, average maximum and minimum daily temperatures of 31 oC and 16 oC, respectively. The break of the winter rainfall period was during May.

Results

Persistence and productivity of populations

In September 2007, 8 months after cutting and 5 months after the break of the winter season, 23mpopulations of *C. australasicum* had higher persistence, 10 populations of *C. australasicum* had highermaverage biomass and 7 populations were higher in both measures compared to the best performingmlucerne cultivar (Figure 1). All *Cullen* species except *C. patens* had populations which persisted bettermthan Sardi 10 (Figure 1).

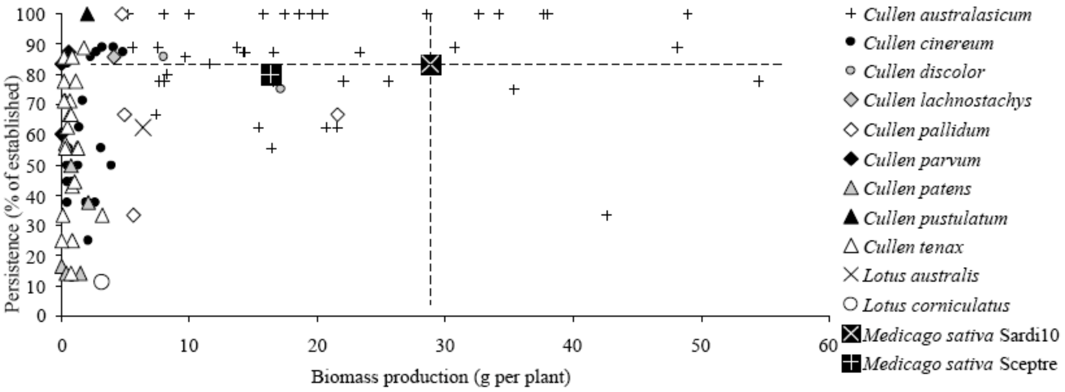

Figure 1. Persistence and biomass productivity (population averages) in September 2007 of *Cullen* species, two lucerne cultivars (Sceptre and Sardi 10), *Lotus australis* and *L. corniculatus*. Populations above or to the right of the dashed lines had better persistence or productivity, respectively, than Sardi 10 lucerne. Persistence values are percentage survival of established plants and productivity is average biomass per plant after 8 months regrowth.

The combined productivity and persistence of the best performing *C. australasicum* population was more than double that of Sardi 10 and around four times that of Sceptre (49.0, 24.2 and 13.0 g per established plant, respectively).

Seasonal persistence and productivity of species

When considered at the species level, *Cullen australasicum* and *C. pustulatum* both persisted better through the whole year than the best lucerne cultivar, Sardi 10 (Table 1). *Lotus corniculatus* displayed the poorest survival with one plant remaining alive in April which then persisted through to September. Of the *Cullen* species, *C. patens* persisted the poorest with around one quarter of plants surviving in September. All species except *C. discolor* and *C. leucanthum* persisted better over the winter period (April to September) than the preceding dry period (establishment to April).

Cullen australasicum, *C. pustulatum* and *C. lachnostachys* all had higher productivity ratings in April than Sardi 10 (Table 1). However, the September productivity rating of *C. australasicum* was second best to Sardi 10*,* whereas the September productivity rating of *C. pustulatum* and *C. lachnostachys* dropped further to the third and sixth lowest, respectively. *Cullen tenax* and *C. parvum* had consistently low productivity ratings. Productivity ratings of the lucerne cultivars were lowest in April and highest in September.

Table 1. Persistence and visual productivity ratings (species averages) of *Cullen* species, one native *Lotus* species, two lucerne cultivars, Sardi10 and Sceptre and *Lotus corniculatus* cv. San Gabriel in April 2007 after four months with hot, dry conditions and in September 2007, five months after the break of season. Persistence values are percentages of seedlings alive on 30th October 2006 and productivity scores are out ratings of 10. SE = standard error of the mean.

Spp	# populations tested	Persistence in April (SE)	Productivity in April (SE)	September persistence (SE)	September productivity (SE)
C. australasicum	39	88 (3.1)	4.4 (0.32)	85 (2.9)	5.0 (0.27)
C. cinereum	22	71 (8.5)	3.3 (0.06)	52 (5)	2.2 (0.22)
C. discolor	2	92 (10.2)	2.6 (0.35)	81 (12.3)	3.7 (0.43)
C. lachnostachys	1	100 (0)	5.1 (1.5)	83 (20.4)	2.5 (0.61)
C. pallidum	4	75 (10.2)	3.2 (0.28)	67 (11.8)	3.6 (0.23)
C. parvum	3	79 (7.3)	1.1 (0.07)	79 (7.3)	1.4 (0.12)
C. patens	6	33 (9.4)	2.4 (0.58)	24 (7.3)	2.1 (0.3)
C. pustulatum	1	100 (0)	5.3 (2.13)	100 (0)	1.8 (0.74)
C. tenax	22	68 (7.4)	1.7 (0.16)	58 (10)	1.6 (0.16)
L. australis	1	61 (24.5)	2.2 (0.95)	61 (24.5)	2.7 (0.82)
L. corniculatus	San Gabriel	11 (13.6)	0.0 -	11 (13.6)	3.0 -
M. sativa	Sardi 10	94 (6.8)	4.0 (0.4)	83 (0)	5.9 (0.5)
M. sativa	Sceptre	85 (9.4)	2.9 (1.16)	79 (3)	4.2 (0.95)

Discussion

The most important findings of this study are that some populations of eight *Cullen* species persisted better and seven populations of *C. australasicum* both persisted better and were more productive than Sardi 10. The excellent persistence observed here in populations of *Cullen* species is supported by the results of Bennett *et al.* (2006), who predicted that six of the species would be adapted to the WA wheatbelt soils and climate. These results provide strong support to our hypothesis that some *Cullen* species will contain populations that have both adaptations to survival and productivity traits that make them suitable for use or further development as perennial pastures in the low rainfall, Mediterranean climate of WA's wheatbelt.

Cullen australasicum was the best *Cullen* species overall, in terms of productivity and persistence throughout the year. Populations from *C. australasicum* were the most productive germplasm in September and the species was more productive than Sardi 10 in April. This is an important result, considering that wild germplasm is being compared to lucerne cultivars that have had many years of intensive breeding effort. However, several factors must be considered that acted to disadvantage lucerne. All plants were allowed to regrow for eight months following a cut in January and it has been shown in the past that longer cutting intervals favour the cumulative productivity of some *Cullen* species relative to lucerne (Britten and De Lacy 1979; Kerridge and Skerman 1968; Robinson *et al.* 2007). In addition, it would reasonably be expected that lucerne was not highly productive in April as it is better adapted to winter growth, looses its leaves under drought conditions and was affected by pasture webworm. Nevertheless, this result shows that *C. australasicum* may be well suited to use as a component of the animal feed base that is used strategically at times of low feed supply.

This study also found that *C. patens* was poorly adapted and *C. pallidum* was moderately adapted to the trial conditions. These results contradict the predictions by Bennett *et al.* (2006) that *C. pallidum* would not be adapted to the soils and *C. patens* would be adapted to the climate and soils tested here. This disparity may be due to the small number of populations tested of both species and the scale of the soil predictions and rather crude measures of climate adaptation used by Bennett *et al.* (2006). This reinforces the requirement for field testing of any predictions from climate adaptation modelling.

The poor productivity of *C. tenax* in this field trial was partly expected. Although *C. tenax* was productive in pot trials with optimum water availability (Robinson *et al.* 2007) and *C. tenax* is one of the species predicted to be adapted to WA wheatbelt soils and climate by Bennett *et al.* (2006), our result was obtained a region which experienced low rainfall and a long dry period between January and April. Bennett *et al.* (2006) noted that *C. tenax* appeared to be adapted to medium to high rainfall areas and that its tolerance to low rainfall environments was questionable. Our results appear to confirm that that *C. tenax* does not have great potential in low rainfall areas of WA's wheatbelt but it may still be useful in higher rainfall areas of the wheatbelt on soils that limit the growth of lucerne or other perennial pastures.

In summary, the field testing reported here has supported our expectation that some *Cullen* species will be of interest for further development as perennial pastures in the low rainfall, Mediterranean climate of WA's wheatbelt.

Acknowledgments

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