Are mixtures of annual pasture legumes more productive and persistent than monocultures on the low rainfall alkaline soils of southern Australia?

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Abstract

There is limited diversity of annual pasture legume cultivars for use in the low rainfall alkaline cereal/livestock zone of temperate Australia. The potential to introduce novel species into the dominant Medicago spp. background was investigated. The performance of three annual pasture legume species (M. littoralis cv Herald, Trifolium michelianum cv Frontier and Trigonella balansae, SA 5045) sown as monocultures, binary and ternary mixtures was compared over three years in a pasture/pasture/cereal rotation.

In the first year, seed yields of the monocultures ranged from 431 kg/ha (SA 5045) to 712 kg/ha (Herald). Total seed yields of the mixtures ranged from 382-536 kg/ha with Herald dominating when present and with only small contributions from Frontier and SA 5045, except in the absence of Herald. In the second year regenerating pasture phase, seed reserves of Herald were maintained or increased but dropped sharply for Frontier and SA 5045 in all treatments. At the end of the third year cereal phase, seed reserves of Herald fell to 335-548 kg/ha and continued to fall for Frontier and SA 5045 in all treatments (0-14, 3-39 kg/ha respectively).

Results so far have shown that the most persistent and productive treatment has been a monoculture of Herald, and that mixtures with and of other species were less persistent. The suggested benefits of species diversity were not realised in this experiment with the species tested and results highlight the need for better adapted and more competitive alternatives.

Key Words

Mixtures, monocultures, *Medicago*, *Trifolium*, *Trigonella*, pasture legumes

Introduction

Annual medics (*Medicago* spp.) are the dominant pasture legume species in areas of the Australian cereal-livestock zone, which have a low rainfall (<350mm), Mediterranean climate and alkaline soils. They produce relatively high levels of hard (or impermeable) seed (>80%) which enables them to persist through cropping sequences of one or more years. At their most productive they are an integral component of a mixed farming system where livestock contribute significantly to a balanced, economic and sustainable enterprise. In the naturally regenerating pasture phase, annual medics provide high protein livestock feed, fix atmospheric nitrogen and reduce the carryover of certain cereal root pathogens to following cereal crops. However, in recent years the reliability and productivity of annual medics in low rainfall areas has frequently been perceived to be inadequate for maximum production of following cereal crops (1). This unreliability is arguably exacerbated by a high dependence on a narrow genetic base, namely *M. littoralis* and to a lesser extent, *M. truncatula, M. minima* and *M. polymorpha*. The predominant *M. littoralis* cultivars are Harbinger (2) and more recently, Herald (3), an aphid resistant derivative of Harbinger. Thus much of the eight million hectares of low rainfall alkaline soil in Australia rely heavily on the Harbinger genotype, leaving the system potentially vulnerable to seasonal and management variations and pest/pathogen challenges.

The National Annual Pasture Legume Improvement Program (NAPLIP) has initiated an evaluation of a diverse range of annual pasture legume germplasm held within genetic resource centres. Some of these

species have features with the potential to improve pasture performance. These include improved seed harvestability, smallseededness, new insect resistances and different hardseed breakdown patterns (4).

However, little is known of the ability of these novel species to compete with and/or complement the existing background of annual medics. Annual medics have long proven themselves to be well adapted to the low rainfall, alkaline soil environment and will continue to play a major role in pasture systems either when sown or when regenerating from residual hard seed reserves in the soil. Incorporating the differing morphologies of existing and novel cultivars into mixed pastures however may well increase the complexity of their management, for example requiring different grazing strategies, herbicides and timing of herbicide applications, compromising the overall complementarity and stability of the pasture mix. The use of mixtures theoretically has the potential to increase species diversity, minimising risk and improving the overall robustness of the farming system but the practical reality may be quite different (5).

The following experiment compares the performance of three annual legume species sown in monoculture, binary and ternary mixtures.

Methods

The experiment was initiated in 1999 at a site near Mannum, SA (loamy sand, pH 7.2(H_2O); average annual rainfall 294mm) and was conducted over three years. The species used in this study were *M. littoralis* cv Herald, *T. michelianum* cv Frontier (6) and *Trigonella balansae,* SA 5045 (7). Frontier is the earliest maturing *T. michelianum* cultivar and SA 5045 is near commercialisation by NAPLIP. They are both aerial seeding, can be conventionally harvested and exhibit different hardseed characteristics. They were also readily differentiated in the mixtures at different stages throughout the year using morphological characteristics such as leaf markers, pod type, seed and seedling size.

Design

Inoculated seed was sown on 16th June 1999 as mono (Herald, Frontier and SA 5045), binary (Herald + Frontier, Herald + SA 5045 and Frontier + SA 5045) and ternary mixtures (Herald + Frontier + SA 5045) in seven combinations at a total sowing rate of 9 kg/ha for each treatment. Components of mixtures were sown @ 4.5 and 3 kg/ha each in the binary mixtures and ternary mixtures respectively. The seven treatments were arranged with three replicates in a spatially optimised design. Plot size was 12 x 1.5m. The rotational sequence in this study was “pasture/pasture/cereal”. The 1999 pasture establishment phase was allowed to regenerate in 2000 as pasture and to set seed. Frame wheat was sown @ 65kg/ha in the 2001 cereal phase with legume regeneration controlled by herbicide to prevent any further seed recruitment in this phase. This rotational sequence of a short-term pasture phase followed by a cereal is consistent with the anticipated role of some of the new aerial seeded cultivars.

Trial management

Insect, grass and broadleaf weed control were utilised in year 1 to maximise seed set and ensure the establishment of all the treatments for the following years. Summer weeds were controlled and in year 2, broadleaved weeds were also controlled. In year 3, regenerating legumes were controlled. The experiment was not grazed.

Measurements

Year 1 plant establishment was measured by sub-sampling each plot (8 quadrats x 0.12m^2) and plant regeneration in year 2 (10 x 0.1m diameter soil cores). Year 1 seed yields were measured (20 x 0.1m d. soil cores), as were cumulative seed reserves at the end of years 2 and 3 (10 x 0.1m d. cores).

Analysis

The method of analysis chosen for each response was a spatial linear mixed effects model which allows for the possible row and column effects present in the field. To measure the performance of the monocultures, binaries and ternary mixtures, between and within multiple comparisons, each with one degree of freedom from the final model for each response, were implemented and tested for significance using an approximate Wald statistic (8).

Results

Year 1 plant establishment and seed yields

Plant establishment in the first year was good in all treatments with all species present in proportions approximately relative to initial sowing rate and seed size (Table 1). Seed yields for all of the monocultures were also good, exceeding 430 kg/ha. However, in the mixtures where Herald was a component, seed yields for Frontier and SA 5045 were sharply reduced with Herald compensating by producing relatively more seed than would be expected from its initial sowing rate. The lowest yielding treatment was the binary mixture of Frontier and SA 5045 (Table 1, Fig. 1).

Year 2 plant regeneration and seed reserves

There was good regeneration in the second year of the monocultures (>900 p/m^2) for all three species. There was also good establishment in the mixtures in proportions relative to the 1999 seed yields, thus resulting in early plant dominance by Herald (Table 1). Cumulative seed reserves at the end of year 2 had increased for Herald in all treatments. However Frontier and SA 5045 were unable to recruit sufficient additional seed to prevent a sudden drop in seed reserves which declined sharply in every treatment, particularly the monocultures, (Table 1, Figure 1). The April-October rainfall for this year was 178mm and combined with a prolonged dry spell during September-October of 39 days in which only 2mm was recorded, may account for poor year 2 seed yields and thus some of the rapid drop in seed reserves.

Year 3 seed reserves

The cereal phase saw a further reduction of seed reserves in all treatments and components within mixtures. However, whereas the seed reserves of Herald remained adequate for future regeneration (335-548 kg/ha), they had fallen beyond recovery for Frontier and SA 5045 in every treatment (<40 kg/ha), (Table 1, Fig 1).

Table 1: Year 1 total plant establishment (1999 PE, p/m^2), seed yields (1999 SY, kg/ha); year 2 total plant regeneration (2000 PR, p/m^2), seed reserves (2000 SR, kg/ha); year 3 total seed reserves (2001 SR, kg/ha) of Herald (H), Frontier (F) and SA 5045 (T) and their mixtures. Figures in parentheses are percentage contributions of the cultivar components, in title order. Between and within mixture means are compared across rows independently. Figures followed by the same letter are not significantly different (P = 0.05).

	H	F	T	H/F	H/T	F/T	H/F/T
1999 PE	332*c*	587*a*	323*c*	378*b* (41*b*/59*a*)	322*c* (53*a*/47*b*)	396*b* (63*a*/27*b*)	408*b* (27*b*/44*a*/29*b*)
1999 SY	712*a*	444*cd*	431*cd*	509*bc* (93*a*/7*b*)	536*b* (86*a*/14*b*)	382*d* (40*b*/60*a*)	459*bcd* (76*a*/10*b*/14*b*)
2000 PR	2096*b*	3264*a*	927*d*	1651*bcd*	1549*cd*	1731*bc*	1321*cd*

				(74*a*/26*b*)	(90*a*/10*b*)	(78*a*/22*b*)	(65*a*/29*b*/6*b*)
2000 SR	726*a*	75*c*	233*b*	665*a* (97*a*/3*b*)	506*a* (95*a*/5*b*)	188*b* (36*a*/64*a*)	615*a* (93*a*/3*b*/4*b*)
2001 SR	548*a*	14*c*	39*c*	335*b* (100*a*/0*b*)	361*b* (99*a*/1*b*)	30*c* (17*a*/83*b*)	445*b* (98*a*/0*b*/2*b*)

Discussion and conclusion

In this study, the monoculture of Herald was the most productive and persistent treatment as measured by total seed reserves. Binary and ternary mixtures of Herald with Frontier and SA 5045 resulted in lower total seed reserves after three years, with Frontier and SA 5045 failing to persist as components and Herald becoming completely dominant (98-100%). The binary mixture of Frontier and SA 5045 was the lowest yielding mixtures treatment, with both components failing to persist.

The monocultures of Frontier and SA 5045 also failed to persist indicating their overall lack of adaptation to this environment. This was despite establishing well, producing adequate levels of seed in the first year and regenerating well in the second year. The subsequent rapid decline in their seed reserves is difficult to reconcile and suggests unaccountably high seed loss after year 1 and very poor seed recruitment in the harsh spring finish of year 2. Some leakage of seed from the system might be explained by false breaks although these were not observed to any degree. Partial imbibition and subsequent rotting by soil pathogens may also account for some of the recorded loss. Seed of Herald is provided with more physical protection from its lignified pod than seed of the more thinly podded SA 5045 and the much smaller dehisced seed of Frontier.

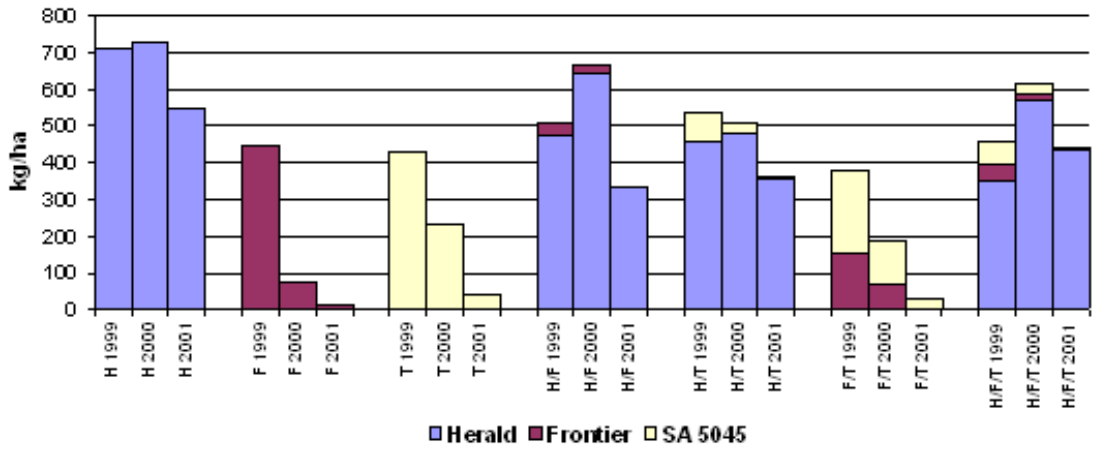

Figure 1: Seed yields (1999) and seed reserves (2000, 2001) of Herald (H), Frontier (F) and SA 5045 (T) in their monoculture, binary and ternary mixtures (pasture 1999, pasture 2000, cereal 2001).

SA 5045 and Frontier seed may thus be more vulnerable to arthropod predation and less buffered from soil moisture changes resulting in greater losses from false breaks. Although we attempted to utilise the most adapted genotypes of novel species available for this study, their subsequent failure in monoculture indicates a continuing lack of well-adapted alternative germplasm for the low rainfall alkaline soils of Australia.

The failure of Frontier and SA 5045 to persist in mixtures with Herald appears to be a function of both their lack of adaptation and their inability to compete with Herald's greater seedling vigour and more prostrate habit. The smaller seeded, less vigorous Frontier and the more upright SA 5045 were also much less able to compete with weeds (unpublished data) despite the use of selective herbicides. Dear et al (9) also found Frontier to be uncompetitive in mixtures with both sown and background *T. subterraneum*. This was linked to poor competitiveness after seedling emergence against the larger seeded and more vigorous *T. subterraneum*.

This experiment was not grazed which may have benefited one species in favour of the others. However a similar study at another site with the same species which was grazed, has also produced essentially similar results with Herald dominating (Howie, unpublished data).

The results highlight the current lack of other suitable pasture legume options in the low rainfall alkaline soil zone and the need to test newly developed pasture species in mixtures with the pre-existing dominant pasture type before recommending their use in this way. Development of earlier maturing *T. michelianum* germplasm is under way (Craig, pers. comm.) as is the selection of earlier maturing *Trigonella balansae* material. However until better adapted genotypes are developed, it will be very difficult to introduce novel species into the low rainfall alkaline soils where annual *Medicago* spp. are already dominant, unless they can be sown in niches where medics are largely absent.

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