Prospects for improving the performance of mixed pasture swards by spatially separating components in drill rows

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Abstract
Maintaining desirable species in a mixed pasture sward is an ongoing challenge for growers in south-west NSW, particularly in lucerne-based pastures. This study examined the prospect of addressing this concern through separating species in drill rows at sowing, a practice change which represents a minimal impost to the farmer. A sensitivity analysis using the ADOPT decision support tool showed that the relatively low level of investment required to try the practice meant that there was potential for relatively rapid adoption provided environmental and/or profitability benefits could be demonstrated. A financial risk analysis determined that, for the scenarios tested on a 1000 ha farm, whole-farm profitability could be increased by between \$523 and \$3162 for every 1% increase in pasture production. Results from field experiments at 5 locations showed that spatially separating species enhanced the persistence of subterranean clover in perennial-based swards but effects on biomass were mixed. Annual pasture production was never significantly greater where subterranean clover was planted in separate drill rows compared to where it was grown in mixed rows with lucerne or phalaris, but in year 1 at three sites, biomass decreased by as much as 130% due to the separation of subterranean clover in drill rows. The study also unexpectedly demonstrated an enduring legacy of the original sowing row, with soil microbial populations shown to be twice as abundant under the sowing row compared to between rows in the third year following sowing.

Keywords
Lucerne, phalaris, Subterranean clover, mixture, monoculture, pure sward.

Introduction
Lucerne (*Medicago sativa*) has traditionally been sown in mixtures with annual legume species such as subterranean clover (*Trifolium subterraneum*) which increases total nitrogen fixation and winter biomass. Lucerne-based pastures have long been a cornerstone of mixed farming production systems in NSW. Stands are typically maintained for 3-5 years for grazing livestock before they are replaced by annual crops commonly grown for 4-7 subsequent years. The lucerne provides valuable feed for livestock, particularly following episodic summer rainfall events, and fixes significant amounts of biological nitrogen (N) to enhance both livestock and crop production. However, maintaining multiple species in a pasture sward can be challenging, particularly under drier seasonal conditions. The study tested the hypothesis that spatially separating sward components in different drill rows at sowing would enhance the persistence of weaker species, leading to more balanced pasture composition over the life of the pasture.

Adoptability analysis
Altering the spatial arrangement of pasture components at sowing represented a low cost practice change that presented minimal disruption to existing sowing operations. No change to cropping rotation or livestock operations was proposed, but rather the farmer was buying the same seed to put in the same paddock with existing machinery. The only additional impost on the farmer was a modest level of time prior to sowing to reconfigure the seeder such that individual pasture species were delivered down pre-determined sowing tubes. The level of time required by the farmer depended on the particular sowing machinery being used, and the ease with which sowing configurations could be altered. A small number of growers in the Wagga Wagga region and elsewhere had adopted this approach to establishing pastures at a similar time that the EverCrop project began examining the issue. The owner of the equipment in Figure 1 reported that reconfiguring this seeder represented 2-3 hours of his time. The ADOPT model (Kuehne et al. 2017) supported the assertion that this practice change would be readily implementable by growers with mixed

crop/livestock enterprises, suggesting that near-peak levels of adoption after only 7 years were achievable if relative advantage could be demonstrated. However, a sensitivity analysis revealed that adoption by at least 50% of the target mixed farmer population required at least a moderate advantage in profit (or equivalent balance of environmental and profit outcomes) compared to existing seeding methods.

Figure 1. An example of a commercial seeder ordinarily used by a local Wagga Wagga grower to sow pasture components in alternate drill rows. Right: Flows to specific tynes can be blocked allowing different species to flow to separate tynes. In this example, lucerne was delivered from the fertiliser box while phalaris was delivered from the seed box.

Impact of pasture production on whole-farm income

A Sequential Multi-variate Analysis (SMA) was undertaken to assess the likely change in whole-farm profit of increasing pasture yields. Two model farms (1000 ha each) in the Temora (NSW; annual rainfall 520mm) and Rutherglen (Victoria; 590 mm) regions were analysed using assumptions of farm costs established by Hutchings et al. (2014). The farms were assumed to grow annual crops in rotation with pastures, and also run a self-replacing merino flock where the older ewes were joined to a terminal sire. The treatments in the analysis were selected to cover the range of practices considered typical in the mixed farming region, and included two sites, four crop rotations, four stocking rates and three pasture yield variations; 96 scenarios in total. Crop yields were estimated using historic rainfall at the sites (Oliver et al. 2009) and pasture yields were based on GrassGro outputs for the range of years for which rainfall data was available. All modelled scenarios assumed 80% equity. Financial risk was analysed using Tableau® software (www.tableau.com) which incorporated historical rainfall, commodity prices and yields over 2000 random decadal sequences (Hutchings and Nordblom 2011).

Table 1. Calculation of the incremental change in decadal cash margin (defined as the closing bank balance minus the opening balance) due to changes in pasture metabolisable energy yield, averaged over the 10 and 15 dse/ha stocking rate scenarios.

Rotation		Decadal cash margin ($) with pasture yield			Change in
Crop years	Pasture years	90%	100%	110%	margin/% yield
		Rutherglen			
1	4	-$1 727 127	-$1 385 510	-$1 121 808	$3 027
1	8	-$1 896 239	-$1 590 169	-$1 263 840	$3 162
5	4	-$175 276	-$149 064	-$70 673	$523
5	8	$236 696	$287 030	$355 176	$592
		Temora			
1	4	-$1 122 061	-$1 570 744	-$754 683	$1 837
1	8	-$218 470	-$726 442	$102 138	$1 603
5	4	-$383 176	-$313 881	-$224 887	$792
5	8	$357 611	$405 343	$520 030	$812

Crop and pasture yields and the subsequent energy that could be harvested by livestock varied substantially with time, driven largely by the variation in rainfall at the sites. For example, pasture metabolisable energy yield was calculated to be > 160 000 MJ/ha in 1973, and as low as 21 000 MJ/ha in 2006. Results showed that there was little difference in the decadal cash margin between the two sites. The optimum stocking rate for all rotations was shown to be 10-15 dse/ha. The scenario with the best financial outcome was the 5 crop- and 8 pasture-years rotation (~60% pasture to 40% crop). A series of simulations was run at both sites, varying the pasture grazing energy yield by 10% either side of the mean. Results showed that increasing pasture yield had more impact on the minimum decadal cash margin, than on the average or the maximum values. This indicates that the main benefit of increasing pasture yield may be due to a reduction of the size of cash losses at the whole-farm level; a valuable trend which may not be reflected in a change in the mean values. Over the range of scenarios tested, a 1% increase in pasture yield led to an annual increase of $523-$3162 in whole farm profit (Table 1).

Pasture production and persistence

Five field experiments were established in 2012 in south-west NSW to test the response of lucerne-based pastures sown in different spatial configurations with phalaris (*Phalaris aquatica*) and subterranean clover. Full details of experimental methods and results are described by Hayes et al. (2017). There were few consistent effects on total pasture biomass attributable to spatial configuration providing no clear signal of a universal benefit of changed spatial configuration, reflecting site-specific or season-dependant nature of results. However, averaged across sites, subterranean clover regeneration at the end of the experimental period was 29% higher and total cumulative biomass was 13% higher where subterranean clover was sown in alternate drill rows with lucerne compared to where both species were mixed together in every drill row. Increases in cumulative annual dry matter production were up to 16% in phalaris/subterranean clover swards, and up to 10% in lucerne/subterranean clover swards where the two species were planted in alternate rows compared to where they were planted in mixed row configurations. However, reductions in cumulative annual dry matter of the same treatments at different times and different sites were as high as 68%. This field study demonstrated that whilst subterranean clover persistence was consistently enhanced in lucerne swards where the two species were spatially separated, large increases in total biomass could not be anticipated, and decreased biomass was a possibility.

Soil microbiology

Changes in soil health as indicated by increased microbial populations and function (Doran and Zeiss 2000) would be of key interest to farmers as this directly impacts upon long term productivity and resilience. At the Wagga Wagga site, three contrasting treatments were sampled 27 months after pastures were sown, to quantify differences in the abundance of soil bacteria and fungi in the surface 0.1 m, both under and between particular sowing rows (Hayes et al. 2017). The treatments included pure subterranean clover (Subclover_Mono) and clover grown in alternate rows with either lucerne (Lucerne_Subclover_1:1) or phalaris (Phalaris_Subclover_1:1). Samples of moist soil were taken in September 2014 and microbial abundances were determined using group-specific primers (bacteria 16S rRNA; fungi – ITS region), following established methods (Gupta et al. 2014).

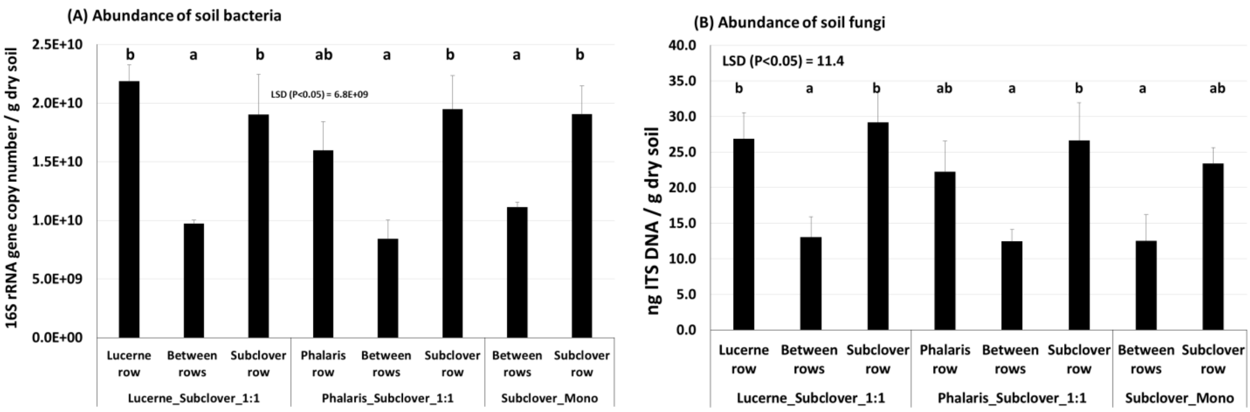

Figure 2. Localised spatial variation in the abundance of soil bacteria (A) and fungi (B) in pure and mixed pasture systems.

The abundance of bacteria and fungi were significantly higher in soil directly beneath the original sowing row for all species compared to between rows (Figure 2). This result was not expected in mature pasture stands, suggesting that even in the third year of pasture, plants may not be utilising the full soil resource in terms of biologically mediated functions and the rhizodeposition effects are mostly confined to the original sowing row only. Total abundance of bacteria and fungi was not significantly different according pasture species that were sown on the particular row, although the variation in community composition of bacteria and fungi between pasture species is still under investigation. Early findings suggested that sowing configuration has an enduring legacy on soil microbiology. Further research is required to understand i) the likely impact of this legacy on the long-term production capacity of the soil, and ii) if this legacy can be utilised more effectively to increase profitability of mixed farming/grazing systems.

Discussion and Conclusion

An examination of the practice of spatially separating components of mixed pasture swards in drill rows was undertaken as a means of improving species co-existence as previously proposed by (Boschma et al. 2010). Implementing the practice represents little impost on the farmer. The ADOPT decision support tool demonstrated that it would only take a relatively short time to achieve peak adoption providing the practice could be shown to have consistent net relative advantage. A sensitivity analysis was undertaken within a broader Sequential Multi-variate Analysis of farm financial risk and showed that for every 1% increase in pasture biomass, whole farm profit would increase by between \$523 and \$3162 based on two 1000 ha model farms. Initial investigations in the field showed that spatially separating subterranean clover from either lucerne or phalaris improved annual legume persistence and led to biomass increases of up to 16%. However, results were site- and season-dependant and there were other instances where spatially separating components actually led to decreases in annual biomass production of up to 68%. The profit-driver of this practice change is therefore perhaps not strong enough to anticipate widespread farmer adoption without significant environmental benefit. Nevertheless, the fact that some farmers have already adopted the practice suggests that they recognise some benefit of the practice, which could be associated with better annual legume persistence leading to higher inputs fixed biological nitrogen. An unexpected finding from the field experiment was the legacy of the original sowing row on soil bacteria and fungi 27 months after the pasture was sown, where the abundances of these soil microbes in the inter-row area were shown to be only half the levels observed beneath the original sowing row. This finding warrants further investigation to determine its full significance on the production capacity of the soil, such as to determine the functional composition of these microbial populations, and to determine what, if any, associated differences can be observed in the chemistry and nutrition of the soil. This component of research remains ongoing.

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