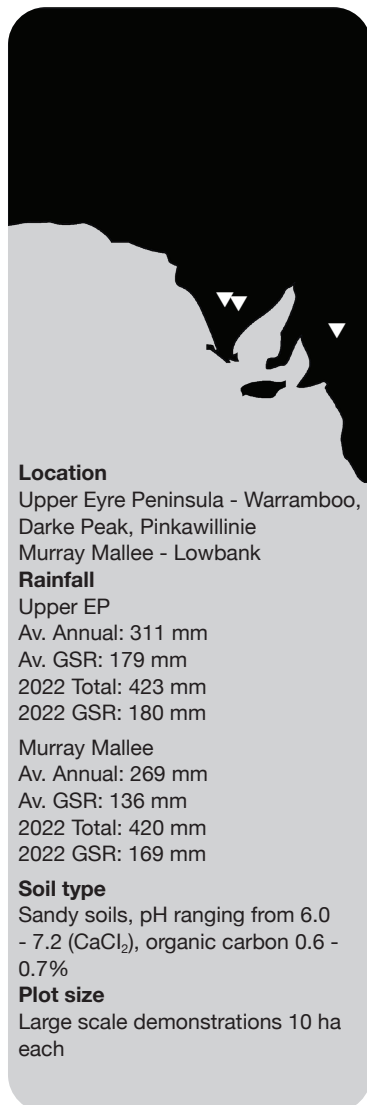


Pasture mixtures: potentials and challenges in low rainfall dune-swale ecosystems of South Australia

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- Each cultivar showed unique zonal preferences with French serradella dominating on deep sandy dunes, strand medics on mid-slopes and barrel medics the swale.
- At peak flowering, dry matter biomass production ranged from 4 t/ha on dunes to 3 t/ha on mid-slopes and 1 t/ha in swales.
- In the wet spring cv Seraph and French serradella did not develop Powdery mildew and phytoestrogen levels remained low to maintain livestock fertility.
- In 2024, after a rotation with a cereal, the mixed pasture cultivars successfully regenerated from the 2022 seedbank and maintained the persistent zonal preferences.
- The findings highlight the potential for improved pasture legume mixtures to enhance pasture resilience, persistence and productivity including maintaining ground cover for an extended period and addressing feed gaps in mixed farming systems in low rainfall regions.

rooting depth which can lead to efficient utilisation of soil water and nutrients to form complex plant communities that sustain ground cover, biomass and soil fertility.

Most of South Australia's low rainfall mixed farming areas consist predominantly of undulating plains with east to west elongated sand dunes and interdunal swales (Hughes et al., 2014; Thomas, 2001). These complex dune-swale systems create unique mosaics of soil challenges for pasture adaptation and plant performance is poorly understood. Low surface soil fertility combined with hostile subsoils, indicates poor return on input investment, limiting the potential for increasing production from pastures and livestock. The pastures are challenged further by highly variable climate, diseases, grazing pressure and herbicides leading to depletion of future soil seed bank reserves (Howieson et al. 2000, Loi et al. 2005). Annual medics are widely used as ley pastures in dry rainfall areas of South Australia. Most pastures rely on old regenerating strand medics (*Medicago littoralis* cv Harbinger, and rarely more recent cultivars Herald and Angel) and/or barrel medic (*M. truncatula*, cvs Cyprus and Parabinga), often grown as mono-species rather than mixtures. In general, medics are well suited to alkaline soils and have been widely grown in mixed farming areas. Their high levels of hardseed allow them to regenerate from soil seed reserves after 1-3 years of grain crops.

Key messages

- In 2022, mixed annual pasture legume systems comprising of French Serradella (*Ornithopus sativus* cv Fran2o), strand medic (*Medicago littoralis* cv. Seraph) and barrel medic (*M. truncatula* cv. Penfield) were established across dune-swale landscapes in Murray Mallee and upper Eyre Peninsula.

Why do the trial?

Pasture legume species are adapted to different soil types and using a mixture of species in a dune/swale system has the potential to lift overall production and sustain land-use practice through improving soil fertility and climate resilience benefits. Different pasture legume species vary in their growing habits and

Strand medics are recommended for loamy sands and barrel medics for loams. Farmers report that medics perform poorly on sandy soils. In the last two decades hardseeded French serradella have been developed and can provide increased dry matter on sandy soils with pH less than neutral. Together improved medic cultivars and alternative annual legumes have the potential to enhance productivity and climate resilience including the stabilization of neutral to slightly acidic sandy dune tops that remain bare of vegetation during most of the pasture phase and dry summers, creating an erosion risk. At present only limited species can colonize these sites. The unrelenting need to find a productive solution for mixed farming zones with adequate nutrition, a longer growing season, lower inputs and with sufficient resistance to disease, pests and herbicides is ongoing and likely requires a pasture legume combination that embraces this environmental variability (E), with suitable genotypes (G) of pastures and appropriate management (M) of these systems. This project wanted to see if sowing a mixture of barrel medic, strand medic and French serradella is viable pasture mixture for dune/swale systems.

How was it done?

In collaboration with local farm managers, farming systems groups AIR EP and Lowbank Ag Bureau, we established four 10-hectare pasture demonstration sites in low rainfall areas, comprising of a site

in Lowbank in the Murray Mallee and Warramboo, Darke Peak and Pinkawillinie on upper Eyre Peninsula. At each of these sites, seeds of the three annual pasture legumes, French serradella cv Fran2o, strand medic cv Seraph and barrel medic cv Penfield were mixed in equal proportions and sown @ total 9 kg/ha in June 2022 (Table 1). Seeds were applied with peat slurry rhizobia inoculants prior to sowing. The seed mixtures were uniformly sown across dune/swale landscape (i.e. zones of sandy, loamy sand mid-slope and loam/clay swale).

Data on ground cover, soil properties and feed quality were collected in early November 2022. Ground cover, plant biomass and soil samples were measured in random quadrats of 40 cm x 40 cm. Biomass samples were also collected from companion paddocks (existing local pastures) for comparison. Ground cover of a cultivar was visually estimated as a percentage of total plant cover. Feed quality and phytoestrogen content of samples were analysed in plant analytical laboratory.

Senescence stage of legume cultivars were evaluated in November 2022 (based on scores by Cai et al., 2016; Maliro et al., 2007), Table 2.

In 2024, a pasture sown in EP (Warramboo) in 2022 was re-assessed for its self-regenerating potential after rotation with a cereal crop. The remaining

sites were sown to cereal crops in 2024 and self-regeneration couldn't be assessed.

What happened?

The total dry matter pasture biomass at Lowbank ranged from 3.6 t/ha on dunes, 3.2 t/ha on mid-slopes and 1.2 t/ha in the swales. At the Warramboo site, biomass productivity ranged from 3.1 t/ha each on dunes and mid-slopes and 0.7 t/ha in the swales. The other two sites on EP were subjected to grazing, especially during the sampling period which might explain the lower dry matter biomass (Table 3).

The feed quality of the pasture mix in November 2022 did not vary between sites and are shown as average in Figure 1. The mean dry matter digestibility (DMD, %) was 57.2% (range 51 to 65%), crude protein (CP) 13% (range 8 to 18%), neutral detergent fibre (NDF) 49.5% (range 37 to 61%) and metabolisable energy (ME) 8.1 MJ/Kg, dry matter (DM) (range 7 to 9.5 MJ/kg DM).

Phytoestrogen content analysis revealed significantly higher coumestrol levels between the trial locations, and companion local pastures (old cultivar cv. Harbinger). The coumestrol levels ranged from 41 mg/kg dry matter on dunes to 412 mg/kg dry matter in the swales in the trial samples. The companion paddocks with medic cv harbinger were recorded at 909 mg/kg dry matter of coumestrol (range 181 to 1870 mg/kg dry matter), Figure 2.

Table 1. Cultivars used in the trial along with their traits and sowing rates (Ballard et al. 2022).

Cultivar	Type	Species	Desirable traits/reason for inclusion	Sowing rate
Fran2o	French Serradella	<i>Ornithopus sativus</i>	Hard seed, suited to acidic-neutral sandy soils, aerial harvested and suited to late summer sowing, expected to perform on neutral - acidic sandy dunes.	3 kg/ha
Seraph	Strand medic	<i>Medicago litoralis</i>	New cultivar, best adapted medic for local conditions, resistant to powdery mildew and bluegreen aphids. Tolerance to Sulfonylurea (SU) herbicides, expected to perform well on midslopes.	3 kg/ha
Penfield	Barrel medic	<i>Medicago truncatula</i>	New early season medic resistant to bluegreen aphids. Tolerance to SU herbicides, tolerant of high boron levels, expected to perform well in swale.	3 kg/ha

Table 2. Senescence scoring of different cultivars in the trial.

Score	Score explanation (Cai et al., 2016; Maliro et al., 2007)
1	A green and healthy plant with no symptoms of ill-health
2	Bottom leaves begin to yellow or become necrotic
3	Necrosis on a quarter of bottom leaves (25%) and yellowing on the rest of bottom half
4	Necrosis on the bottom half (50%) of the plant
5	Necrosis on the bottom half and yellowing appearing in the top half of the plant
6	Necrosis in the range 50%–75% of the plant
7	Necrosis on 75% of the plant
8	Necrosis on the whole plant with apical leaves still green/yellowing
9	Only stems and shoot tips remain green
10	Plant death

Table 3. Dry matter biomass (t/ha) from different landscape positions within the farm in 2022.

Farm locations	Landscape	Dry matter biomass (t/ha)		
		Medics	Serradella	Total
Lowbank	Dune	3.3	0.3	3.6
	Midslope	3.1	0.1	3.2
	Swale	1.2		1.2
Warrambo	Dune	1	2.1	3.1
	Midslope	1.8	1.3	3.1
	Swale	0.7		0.7
Darke Peak	Dune	0.6	0.2	0.8
	Midslope	0.5	0.3	0.8
	Swale	0.5		0.5
Pinkawillinie	Dune	0.03	0.2	0.23
	Midslope	0.7		0.7
	Swale	0.8		0.8

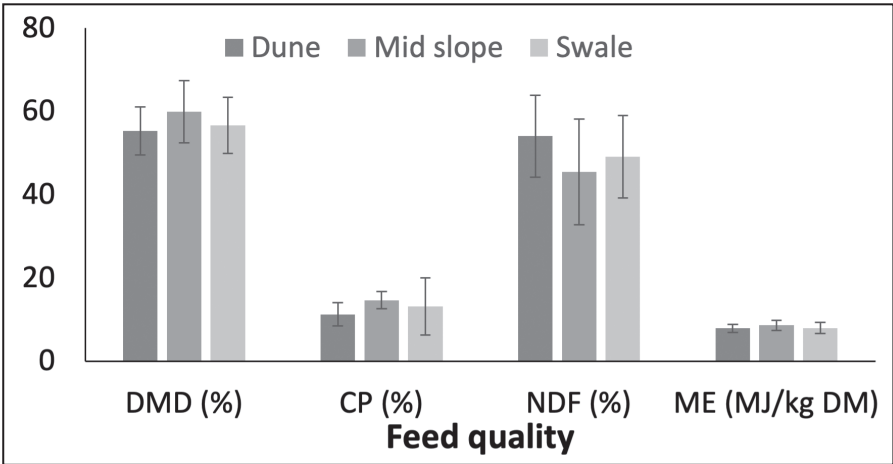


Figure 1. Feed quality analysis dry matter digestibility (DMD); crude protein (CP); metabolisable energy (ME) and neutral detergent fibre (NDF) across different landforms across dune-swale system in November 2022.

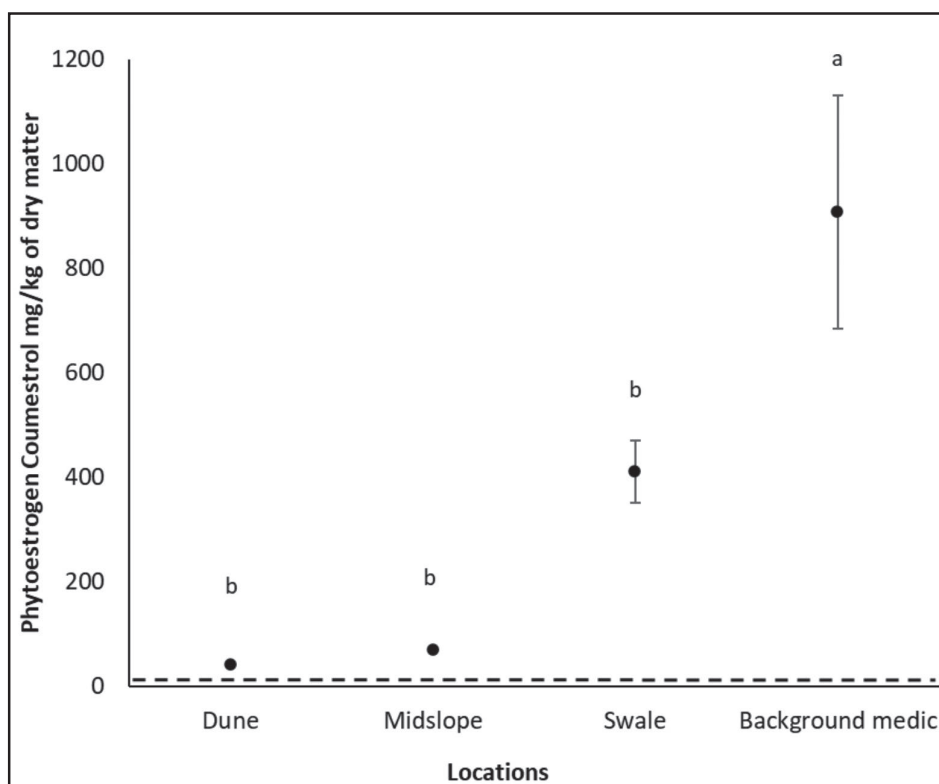


Figure 2. Phytoestrogen contents of the pasture along the dune-swale landscapes in comparison with existing companion pasture paddocks (background medic). Dotted line represents the concentrations of coumestrol of 25 mg/kg (dry matter forage) perceived to have adverse effects on livestock reproduction and reduce fertility (Reed, 2016). Bar represents standard deviation from the mean and different letters indicate significant difference ($P < 0.05$).

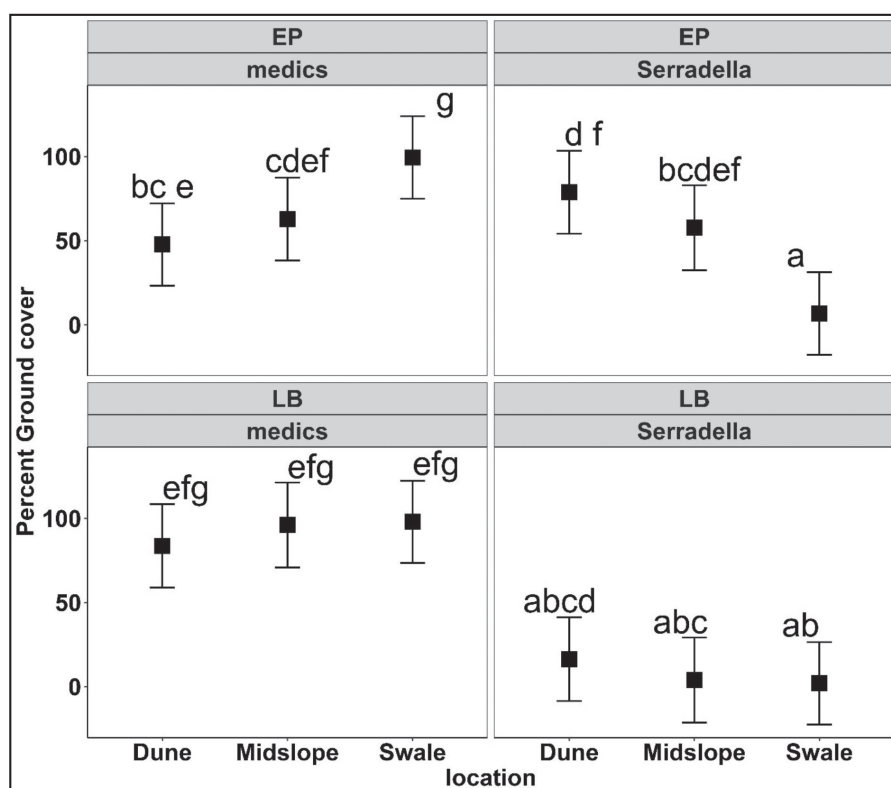


Figure 3. Mean plant cover of serradella compared to medics across the landforms at the two study sites measured in late November 2023 with their respective 95% confidence intervals represented by the error bars. LB = Lowbank.

During sampling in November 2022, serradella was green and healthy, with most plants flowering and setting pods (score 1) (Figure 4). Seraph recorded a senescence score of 3 because the plants were green on the top but recorded necrosis on a quarter of bottom leaves and yellowing on bottom half of the plants. Penfield recorded a score of 8 as the cultivar was at an advanced stage of senescence with necrosis on the whole plant with few apical (top) leaves green or yellow. Serradellas on the sandy dunes and mid slopes kept growing till the last week of November 2022.

The ground cover of Fran2o serradella on sandy dunes ranged from a mean of 16.3% (\pm 6.3 SE) to 78.8% (\pm 7.1 SE) at Lowbank and EP sites respectively. The cover decreased in the mid-slopes and swales for both the sites. In contrast, medic cover was high in the swale from 98%, decreased along the mid-slope (90%) to 60% on the dunes (Figure 3).

Extension of the growing season was recorded by the level of greenness in the pasture trials as compared to the adjacent local

medic paddocks (Figure 4 and 5). Fran2o serradella and Seraph medic were lush green in the trials as compared to senescing early cultivar Penfield. The background medics in the adjacent pasture paddocks were at a late senescence stage (mostly dried off) which could have possibly been accelerated by powdery mildew (Figure 4).

Ability to self-regenerate and persist

The sown pasture species from 2022 revealed their ability to self-regenerate and persist in 2024, after rotation with wheat in 2023 season. Serradella's plant emergence counts varied from 210 ± 61 (SE) plants/m² on dunes to 118 ± 61 (SE) plants/m² on mid-slopes and 20 ± 47 (SE) plants/m² in swales. For medic cultivars average emergence counts varied from 133 ± 61 (SE) plants/m² on dunes to 245 ± 52 (SE) plants/m² on mid-slopes and 538 ± 47 (SE) plants/m² in swales (Figure 5).

What does this mean?

Our results showed that when a mix of annual pasture legume species

were sown across the landscape, they self-sorted into specific zones within the landscape. French serradella dominated the dunes, strand medics the mid-slope and barrel medics the swale. The species' individual preference for soil texture is likely to be the main driver of performance in the different part of the landscape. Fran2o established well and grew successfully on dunes across the study sites consistent with a serradella trial in the Victorian Mallee (Latta & Moodie, 2022). Fran2o's dominance on the dunes can be explained by its preference to neutral to acidic deep sands as shown by our soil test. Being a deep rooted species it has the advantage to draw nutrients from deeper soil depths (Becquer et al., 2021) making them well-suited to P-deficient sites common in deep sands on dunes (Gladstones & McKeown, 1977). Deeper-rooted plants can often improve plant adaptation to lower rainfall regions (Cullen et al. 2009). French serradella is an indeterminate species and in 2022 with the wet spring was able to extend the growing season.



Figure 4. Mixed legume pasture trial versus the adjacent local medic pastures in Warramboo, Eyre Peninsula, November 2022. (Photo: Matt Denton)

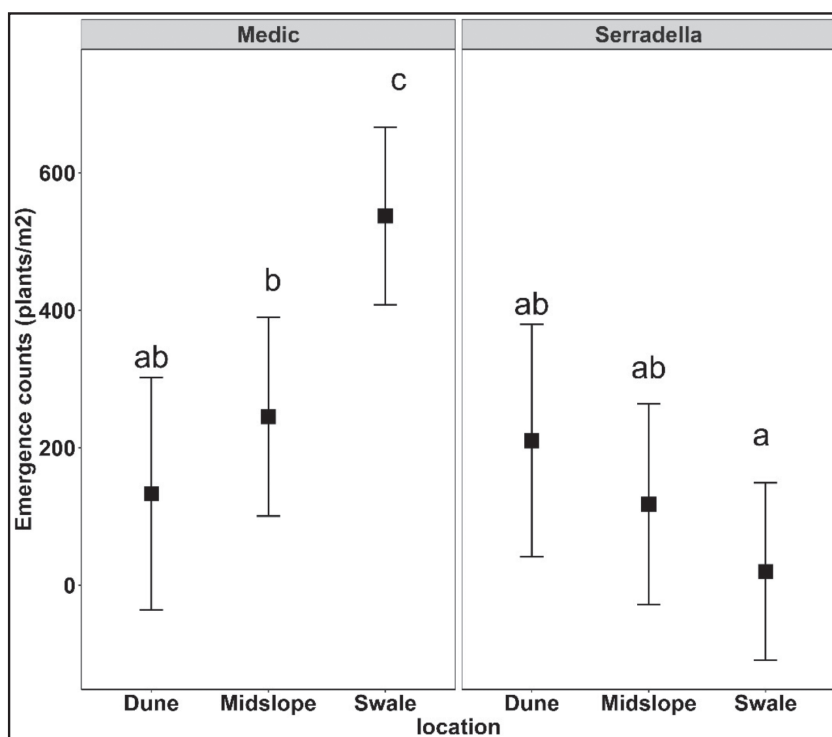


Figure 5. Self-regeneration of pasture mix from 2022's soil seed bank reserve at Warramboo, Eyre Peninsula showing persistent species-site preferences 2024.

In its development it was noted that Seraph has an intermediate habit and in 2022 with the wet spring it continued growing for longer than Penfield and local medics in the surrounding paddocks. Seraph grew well on the mid-slope transition between dunes and swales where they grew with Fran2o at the upper limit but gradually disappeared on the top of the dunes. On the other hand, Penfield was dominant in the swales, attributed to the species' preference for alkaline, heavier, sandy loam soils, and the limitation to grow on deep sands.

Pasture productivity and feed quality on dunes, mid-slopes and swales were governed by the type of dominant cultivar on that landform position. For instance, mid-slopes were dominated by Seraph and presented better feed quality compared with Fran2o and Penfield. Nevertheless, feed quality tests provided acceptable scores of DMD, CP, ME and NDF across the landscape which could be used to maintain condition in late season ewes leading into joining or ewe hoggets to get them to weight for joining.

The year 2022 experienced an abnormally wet spring which enabled cultivars like Fran2o and Seraph to respond positively by maintaining green foliage for a longer duration. They were also least affected by the powdery mildew (PM, *Erysiphe trifolii*) outbreak that devastated all local medic pastures in the companion paddocks. Seraph was bred PM resistant (IP_Australia, 2023) and was less affected, as did Fran2o which is not known to be susceptible to PM. Penfield (with a large amount of Caliph in its breeding) became covered in PM despite being slower to develop PM than the surrounding paddock of Harbinger strand medic, consistent with previous observations (Ballard et al., 2012). The PM resistant Seraph and Fran2o would have also slowed the spread of PM in our pasture mixture. PM elevated phytoestrogen levels (coumestrol) in the susceptible medic cultivars, which are reported to have adverse implications on livestock fertility (Reed, 2016). At the Lowbank site, native budworm (*Heliothis punctigera*) pressure appeared to be high during podding which reduced pod and biomass yield of

Fran2o. Monitoring for budworm at flowering/podding and applying insecticides when needed is recommended.

The importance of site-species match and the need for wider species selection and pasture mixtures for a climate-resilient sustainable land management strategy is highlighted in our study. Establishing these species in their preferred zones would not only reduce input cost and establishment failures but will also increase land use efficiency and biomass productivity per unit area. Our trial also showed the ability of pasture mixes to produce adequate amounts of hard seeds that can successfully self-regenerate after alternating a year with cereal crop, demonstrating the resilience and persistence of these species and a fit in the mixed farming systems.

Furthermore, managing ground cover on sandy soils during extended hot and dry summer seasons, remains a major challenge. Exploration of species and cultivars like Fran2o that showed potential to stabilize dune tops needs to be considered to maintain groundcover and protect dunes during dry summers. A deeper understanding of the adaptability of annual legume mixes within dune-swale landscapes is crucial for offering more pasture choices, matching species to site conditions, minimising plant establishment failures, and increasing pasture productivity and drought resilience.

Acknowledgements

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