Design and management of saltbush-based forage systems to improve productivity and reproductive performance of sheep

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Abstract
There is evidence that effective shelter can significantly improve lamb survival, but the majority of Australian studies have occurred in small paddocks where the ewes had no choice but to use shelter. In mixed farming systems with large open paddocks, it is unclear if ewes will choose to use shelter for lambing. Our multidisciplinary collaboration examines the use of woody shrubs as an opportunity to improve the survival of twin lambs. In a series of large experiments on commercial farms, we will evaluate the impact of different shrub planting configurations, orientations, and densities on microclimates at the sub-paddock scale. Twin-bearing ewes with GPS trackers will graze a mosaic of shelter options to identify lambing sites relative to climatic conditions at the time of lambing. Relatively palatable and unpalatable shrubs have been planted to explore trade-offs between the attraction of ewes to shelter against declining shelter value, because palatable shrubs are defoliated faster than relatively unpalatable options. A linked project is investigating the use of the same shrub systems to provide shade and antioxidants during joining when temperatures exceed the sheep thermal comfort zone for extended periods in summer. Hardy perennial shrubs such as saltbush offer an opportunity to improve profitability and climate resilience of farming systems, while improving landscape health. Multidisciplinary research is required to understand the benefits and limitations of these systems.

Introduction
Sheep production in Australia involves extensive systems where the animals are outdoors in large paddocks for most of their lives. Depending on the location and season, sheep can benefit from shelter during cold, wet and windy conditions or shade from excessive summer heat. Most research on shelter has focused on reducing cold stress on lambs and lambing ewes. Unanticipated poor weather may impact the welfare of mature sheep after shearing. An average of 8% (single) and 24% (twin) of all lambs born in Australia die within 3 days of birth, which accounts for 80% of total lamb deaths (Hinch and Brien 2014). The extent to which lamb deaths are attributable to hypothermia is uncertain due to other factors that contribute to lambs' susceptibility to cold, including mismothering, starvation, birth injury, and low birth weight.

A recent review on the effect of shelter on sheep reproduction by Masters et al. (in press) has identified areas for future research. The provision of shelter can improve lamb survival in areas where cold, wet, and windy conditions are likely during lambing. Eight published studies in areas where cold stress is anticipated at lambing have shown that the provision of shelter has resulted in an average reduction in mortality of 17.5% for twin-born lambs and 7% for single-born lambs (Masters et al. in press). One of the biggest limitations of these previous studies is that the treatment ewes generally lambed in paddocks where they had no choice about shelter use. In extensive mixed crop and livestock farming systems, paddock sizes are often larger than 300 ha and it is impractical to achieve uniform shelter across the entire area. In many areas, ewes are also given supplementary feed at the time of lambing. Ewe behaviour regarding grazing, seeking supplements, and the selection of a birth site could therefore have a significant impact on the use of shelter. Anecdotal reports from producers indicate that some ewes choose the most exposed areas of paddocks to lamb. Emerging sensor and tracking technologies offer the opportunity for researchers to get a better understanding of individual animal behaviour and physiology, relative to ambient conditions at the sub paddock scale.

The aim of our multi-disciplinary collaboration is to investigate the value of shade and shelter for sheep production systems in southern Australia. In a series of large on-farm experiments we will investigate the value of woody shrubs as a shelter option for ewes that are given a choice between shrub belts and open areas of paddocks. We will evaluate the impact of different shrub planting configurations, orientations, and densities on microclimates at the sub-paddock scale. Twin-bearing ewes with GPS trackers will graze a mosaic of shelter options to identify lambing sites relative to climatic conditions in the lead up to lambing. Relatively palatable and unpalatable shrubs have been planted to explore trade-offs between attracting ewes with nutrients and keeping her at the birth site, against declining shelter value as shrubs are consumed. The hypotheses being tested are that the majority of ewes will voluntarily choose to lamb in sheltered areas (in belts of shrubs planted perpendicular to prevailing winds) when the weather conditions are poor, and that they will be attracted to- and remain near- shrubs that have higher relative palatability and nutritional value.

Methods

Two 30 ha research sites were established in winter 2021 in the mixed crop / livestock zone of Western Australia in Pingelly (-32° 32' 2.40" S, 117° 05' 9.60" E) and Tammin (-31° 38' 27.60" S, 117° 29' 27.60" E) and two more were planted in winter 2022 at Cranbrook (-34° 17' 49.20" S, 117° 33' 14.40" E) and Kellerberrin (-31° 34' 51.60" S, 117° 58' 40.80" E). Each site is relatively flat and located away from remnant vegetation, rocks, gullies and trees. The sites have been fenced into three ~10 ha paddocks. Within each of the three replicate paddocks there are six subplots (100 x 100 m), that remain unfenced to allow for free movement of the ewes between treatments. The subplots are separated from each other by a 20 m buffer of annual pasture. Treatments (listed in Table 1) were randomly allocated to subplots within paddocks.

Table 1. Subplot treatments (1 ha) that are unfenced so that ewes can move freely between subplots.

Treatment	Relatively palatable shrub	Relatively unpalatable shrub	Orientation to 'killing' winds	Shrub density*
1	yes	no	perpendicular	high
2	no	yes	perpendicular	high
3	yes	yes	perpendicular	high
4	yes	yes	horizontal	high
5	yes	no	perpendicular	low
6	no	no	n/a	n/a

*High shrub density; double rows planted 2 m apart with shrubs planted 1.5 m apart within rows and a 10 m wide gap between the double rows. Low density (current commercial best practice); double rows planted 2 m apart with shrubs planted 2 m apart within rows and a 20 m wide gap between the double rows.

To minimise variation within shrub treatments in growth and density, we utilised vegetative clones of two contrasting and hardy species. The relatively palatable shrub genotype is Anameka™ saltbush (*Atriplex nummularia* L), a cloned selection that was commercialised in 2015 (Norman et al. 2016). The relatively unpalatable shrub genotype is a cloned selection of *Rhagodia preissii* Moq that has a similar growth habit to Anameka™. Both plants are native to low-rainfall areas of Australia and from the family *Chenopodiaceae*. Both of these woody shrubs are widely planted by farmers, have dense foliage, and grow to a height of approximately 2 m.

The plantations will be grazed with twin-bearing merino ewes fitted with GPS trackers during lambing in 2023 and 2024. The technology allows for identification of the birth site through ewe behaviour during lambing.

Figure 1 is an aerial picture of the Cranbrook site at the time of planting. Shrubs within subplots were hand-planted with tape measures at 1.5 m or 2.0 m intervals after using a commercial machine to deep rip and scalp the planting lines. Local historical weather station data and the knowledge of the host farmer were used to determine the most likely direction of the winds that lead to fatal cold stress

events during lambing. The treatments were orientated in a horizontal or perpendicular angle to the direction of the prevailing winds.

Figure 1. Aerial photograph of part of the Cranbrook research site at the time of planting.

Results and Discussion

At this stage the shrubs at the research sites are still establishing and they will be grazed with twin-bearing ewes in winter 2023. Industry consultation through field walks with farmers and ongoing social media conversations has provided useful observations that are informing the research activities as the project evolves. This industry consultation during the project design and establishment also means that producers are actively seeking information as it emerges from the research. Highlights from the consultation include;

- The host producer at Cranbrook decided to test our hypotheses with his commercial flock. In 2021 his twin-bearing ewes weaned 18% more lambs than those in traditional paddocks of open pasture (S. Lehmann *pers comm*). This outcome was potentially confounded by different flock sizes because the shrub paddocks were smaller than the pasture paddocks and evidence shows that smaller mobs sizes improve lamb survival (Lockwood et al. 2020). Other producers report that they routinely lamb in shrub paddocks because it improves lamb survival.
- Tree systems offer good shade and shelter but provide little edible biomass and inhibit growth of the understorey therefore lowering pasture productivity. Supplementary feed is therefore required in paddocks with tree cover, but this can encourage ewes to move away from lambs in the critical 48 hours after birth. We are now focussed on options that provide shelter and nutrients in the same place.
- Many producers offer ewes mineral supplements during lambing and joining. The shrubs that are being used in the research accumulate the key vitamins and minerals that are associated with antioxidant pathways (Norman et al. 2019). Oxidative stress is highest during lambing where there are large physiological demands on the ewe and during the hot summer when joining occurs. On top of the benefits from shade and shelter, could we improve reproductive success and lamb fitness through shrubs that produce and accumulate vitamin E, Cu, Se, Mn, S, and Zn?

Some leading producers provide other forms of shelter, by lambing their twin-bearing ewes into vegetative cereal crops or dedicated annual forage paddocks. Crops provide an advantage of high-

quality feed at the location of shelter and a lower opportunity cost within the farming system (i.e. shrubs limit the ability to grow a crop on the same land). Challenges with these systems include a reduction in crop yield and the risk of ewes and lambs losing contact and subsequent lamb mortality if the forage it too high. Furthermore, if the average height of the forage is too high then ewes may lamb where the crop is shorter and hence not maximise the use of available shelter, or if the average height of the forage is too low then there is no shelter benefit. Therefore, another component of the project is going to test crop height and twin lamb survival on four farms.

Conclusion and implications

There are no firm conclusions at this stage of the project – just more questions! The involvement of producers to host research and provide insights through field walks and social media has allowed the project to develop new hypotheses and seek to answer questions about the issues that would limit or enhance industry adoption of the work. We look forward to reporting the outcomes of the experiments.

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