Themeda triandra as a perennial seed crop in south-eastern Australia: what are the agronomic possibilities and constraints, and future research needs?

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Abstract
In Australia, the development of native perennial seed crops is an area of increasing interest. Reasons for this include the production of high-value seed, the significance of native plants to Aboriginal people and the importance of diversified cropping in building more resilient farming systems. One species of interest is *Themeda triandra*, a C_4 perennial tussock grass that dominated grasslands and woodlands across Australia prior to European invasion. Djaara, the traditional owner group representing the Dja Dja Wurrung people of Djandak (Dja Dja Wurrung country in central Victoria), is one group who seek to return *T. triandra* to the landscape as a seed-producing crop. This is due to the species holding for them significant cultural and social value, along with envisioned future economic opportunities. As such, this review is targeted towards temperate grasslands of south-eastern Australia where Djandak is located. This review summarises the agronomic possibilities and constraints relating to production of a *T. triandra* as a seed crop via an understanding of the genetic, environmental and management factors that influence the growth, development, and seed yield of this species. Future research and development needs are also identified.

Introduction
Themeda triandra (Forssk.) is a C_4 perennial tussock grass distributed across Africa, Asia, Australia and New Guinea (Dunning et al., 2017). In Australia, it is found in all states and territories (Figure 1) where it naturally dominates many grasslands. Since European invasion of Australia, modern farming practices and land disturbances more broadly have caused significant degradation and loss of *T. triandra* grasslands (BI Cole & Lunt, 2005). This has led to efforts to restore the species, with past studies being centred on the species' ecology and its role in land restoration (BI Cole & Lunt, 2005; Hill, 1985; Hutton, 1971; Mason, 2005; Snyman et al., 2013). Recently, the species development into a native perennial seed crop has been of increasing interest. This is primarily for the purpose of producing high-value seed for revegetation markets and grain for emerging food markets, as well as building more diversified and resilient cropping systems. Another driving reason is Aboriginal traditional owner groups (TOs) seeking to return native plants to the landscape as a cultural, social and economic pursuit (The University of Sydney, Institute of Agriculture, 2020; Canning, 2022). Djaara, the TO group representing the Dja Dja Wurrung people of Djandak, is one such group leading research into *T. triandra*'s development into a contemporary perennial seed crop (Cosoleto, 2019).

In the full review by Male et al (2022), global literature was reviewed to identify the agronomic possibilities and constraints around developing *T. triandra* as a perennial seed crop, and the future research needs in this area.

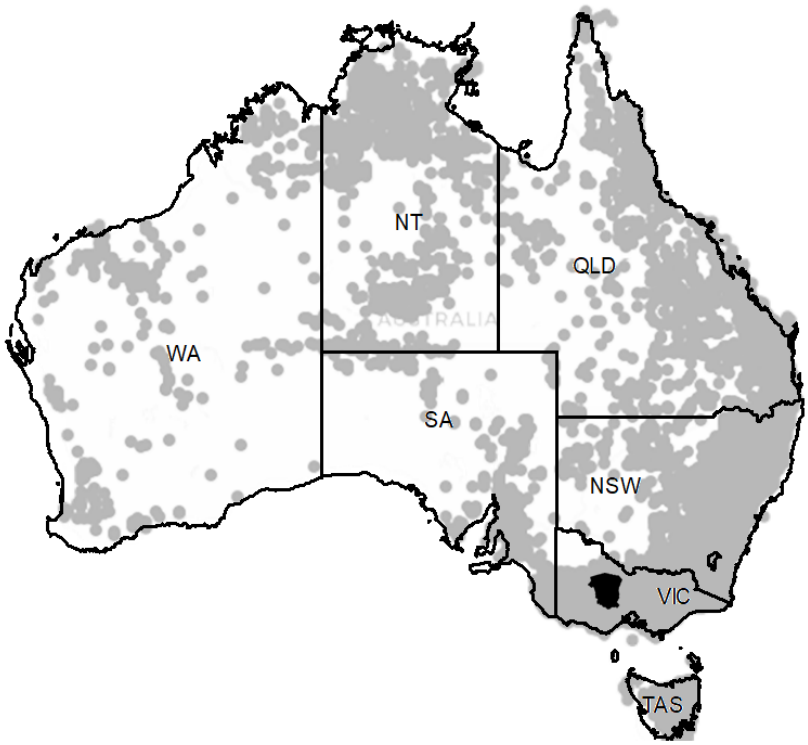

Figure 1: The distribution of *T. triandra* across Australia, overlayed with the location of Djandak (marked in black). Source: Atlas of Australia, retrieved online on 21/12/2022 from https://bie.ala.org.au/species/https:/id.biodiversity.org.au/taxon/apni/51291519

Agronomic possibilities

Themeda triandra has several key agronomic possibilities as a perennial seed crop. Firstly, it is likely to be a low-input crop. This is due to perennial crops only requiring a single planting event to establish a crop that can persist for years. The crop should also require fewer nutrient inputs compared to a commercial annual crop because of its adaptation to local soil conditions, ability to access forms of nitrogen unavailable to other plants (Farrell and Prober, 2021) and less nutrient export associated with lower seed yields. Once well established and managed, only low intensity weed management should be needed as it is a competitive species that can resist weed invasion (Morgan and Lunt, 1999). A crop can produce high-value seed every year and will be widely adapted to environments with different soils and variable climatic conditions, including annual rainfall from 300–6250 mm and soil types ranging from sands through to heavy clays (Snyman et al., 2013). A crop can have its seed yield improved through effective crop management, such as timely burning to remove accumulating biomass, along with selection of ecotypes that can produce larger seed (Stevens et al., 2020). Additionally, a *T. triandra* crop can contribute towards land regeneration e.g., year-round soil coverage reducing erosion, as well as protection of biodiversity and building of diversified cropping systems that are more resilient in a changing climate.

Agronomic constraints

Many of the key agronomic constraints of *T. triandra* as a broadacre perennial seed crop pertain to the structure and biology of the seed itself. The structure of native grass seed diaspores causes issues with seed flowability through sowing equipment (Berto et al., 2020), in *T. triandra* this is particularly due to the entanglement of awns. The seeds germination requirement for warm soil temperatures (>15°C) and good soil moisture (optimally near field capacity), along with characteristically low seed quality (high dormancy and low viability) further adds challenge to achieving good establishment. There is also currently limited knowledge of how effective agronomic management can maximise seed production. This includes difficulties knowing when the optimal sowing and harvest times are, along with what methods are most efficient. It includes the control of competitive weeds during initial establishment, particularly against fast growing annual monocot and dicot species following both seedling emergence and winter dormancy. It also includes limited knowledge of which ecotypes may be best suited for crop production and how to effectively manage accumulating biomass which may overtime smother plants and reduce seed production.

Future Research Needs

Several future research needs to support the development of *T. triandra* as a perennial seed crop have been identified. The top two priorities are to improve upon current sowing and harvest methodologies. In terms of improved sowing methodologies, this includes the need to identify the best time to sow seed and at what sowing rate to optimise establishment. It includes the need to develop and upscale seed cleaning technologies and processes to allow more efficient seed flow through modern-day sowing equipment, as well as to prepare seed for human consumption. E.g., through efficient separation of inedible seed diaspore structures from the grain. In terms of improved harvest methodologies, this includes the need to identify when the best time to harvest seed is and what crop signs can indicate this. E.g., seed colour and percentage seed shed. It also includes the need to develop harvest technology and equipment with a greater capability to harvest large areas. Other future research needs identified include: i) the need to improve weed management (e.g., by better understanding the crop safety of *T. triandra* to herbicides); ii) the need to identify ecotypes with agronomic traits desirable for cropping (e.g., ecotypes with more viable seed or larger grain); iii) the need to better understand how biomass management can optimise seed production (e.g., through timely burning, grazing and/or mowing); iv) the need to better understand the impact of seed storage on seed viability (e.g., does seed viability decrease after a certain length of time in storage?); v) the need to better understand the role of the dormancy-breaking techniques (e.g., is after-ripening sufficient?); vi) consideration of the role that plant breeding can have in improving seed production and vii) the need to better understand how genetic and environmental factors influence seed viability.

Conclusion

The aim of this review, reported in full in Male et al (2022), is to inform those seeking to grow *T. triandra* as a perennial seed crop in south-eastern Australia of the genetic, environmental and management factors that influence plant growth, development, and seed yield. The geographical focus is on Djandak (Figure 1), where Djaara seek to return the species to the landscape in pursuit of cultural, social and economic outcomes. The identification of the agronomic possibilities and constraints in the production of a *T. triandra* seed crop, and future research needs, will helpfully inform the development of this native grass species as a perennial seed crop.

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