The role of indeterminate growth, rooting depth and maturity time in establishing a legume seedbank under drought conditions

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Abstract
Drought can be catastrophic to pasture establishment resulting in establishment failure and financial loss. A range of annual legumes with varying characteristics (capacity for extended periods of indeterminate growth, varying rooting depth and differing maturity times) were sown in a replicated trial near Kikoira in central NSW where growing season rainfall was only 44% of the long term average. Biserrula, an indeterminate, deep-rooted legume produced more than 170 kg seed/ha with one-third produced prior to the end of October. French serradella, another indeterminate, deep-rooted species but of later maturity in our study produced more than 85 kg seed/ha. The early maturing gland clover was the most successful of the shallow-rooted species in producing seed, although its seed yield was significantly less than either biserrula or French serradella. Subterranean clover failed to produce seed and annual medics produced less than 10 kg seed/ha. *Trifolium diffusum*, a little-known species, produced 120 kg seed/ha and requires further assessment of potential. Overall, species with capacity for extended periods of indeterminate growth, deep root systems and/or early maturity were the most successful in establishing a seed bank under severe drought conditions.

Key Words
Biserrula, French serradella, Trifolium diffusum, seed bank, drought

Introduction

Severe drought conditions frequently result in establishment failure of newly sown pastures. In the lower rainfall regions (<450 mm) of NSW, highly variable seasonal conditions can also severely challenge establishment of pastures in non-drought years. Pasture systems in south-eastern Australia have traditionally been based on subterranean clover (*Trifolium subterraneum*) in mild to moderately acidic soils and annual medics (*Medicago* spp.) in mildly acidic to alkaline soils (Wolfe and Dear 2001). However, both of these traditional pasture legume groups are particularly vulnerable to drought conditions during establishment phase due to their relatively shallow root systems (Howeison et al. 2000). Changing climatic conditions and failure to maintain a seedbank as a result of sub-optimal seed set in dry spring conditions and seedling loss due to false breaks in autumn has resulted in the development of a suite of annual legume species for use in southern Australian farming systems (Howeison et al. 2000). Such species, including biserrula (*Biserrula pelecinus*) and French serradella (*Ornithopus sativus*) have deep, rapidly developing root systems and capacity for extended periods of indeterminate growth following initiation of reproductive growth (Carr et al. 1999). Gland clover is also shallow-rooted, but early maturing, and has resistance to pasture pests, including red-legged earth mite (*Halotydeus destructor*) (Howieson et al. 2000). The aim of this study was to assess the capacity of a range of annual legumes with differing growth characteristics, rooting depth and/or maturity time to establish a seedbank in the low rainfall mixed farming zone of NSW. A severe drought was encountered in the establishment year of this field study, offering an opportunity to examine further the role of these characteristics on seed production under very adverse growing conditions.

Methods

The field site was located near Kikoira, (33.6476 S, 146.7335 E) on a red chromosol soil. Twenty soil cores (40 mm diameter) were taken to a depth of 40 cm prior to sowing and divided into increments of 0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm. Analysis was undertaken by Nutrient Advantage Laboratory (Werribee, Victoria) with methods following Rayment and Lyons (2011). Soil samples were oven dried at 40°C, sieved to 2 mm and analysed for: pH $CaCl_2$ (Method 4B2), Phosphorus - Colwell (Method 9B2; 0-5 cm and 5-10 cm only), phosphorus buffering index (PBI; Method 9I2b; 0-5 cm and 5-10 cm only), available sulphur (KCl-40 extraction; Method 10D1), available potassium (18A1; 0-5 cm and 5-10 cm only), exchangeable cations including cation exchange capacity (Methods 15D3 and 15J1). Eight annual legumes (Table 1) were sown in the final week of May 2018 in a replicated trial (n=3) with individual plot size 2 m wide by 6 m

long. Sowing rates were 7 kg/ha for biserrula and gland clover and 10 kg/ha for all other species. Single superphosphate (125 kg/ha; 8.8% P, 11% S) was drilled at sowing.

Table 1. Annual legumes sown at the Kikoira, the days to flowering (from a May sowing) and maximum rooting depth reported in the literature.

Species	Cultivar	Days to flowering	Rooting depth (m)
Biserrula	Casbah	115[1]	1.2-2.06[5]
French serradella	Margurita	120[1]	1.0-1.86[5]
Gland clover	Prima	100[1]	0.86[5]
Trifolium diffusum	Exp. line	125-135[2]	unknown
Subterranean clover	Tammin	88[3]	
	Dalkeith	110[1]	0.6-1.2[5]
Spineless burr medic (*M.polymorpha*)	Cavalier	90-95[4]	0.6-1.0[6]
Strand medic (*M. littoralis*)	Herald	89[4]	0.6-1.0[6]

[1]Days to flower (dtf) at Wagga Wagga (Lattimore and McCormick 2012), [2] dtf Tasmania (Rob Dent, Ardent Seeds pers. comm.), [3] dtf Perth (Revell 2019), [4] dtf location undefined (Coffey, undated), [5] Loi et al. (2005), [6]Hamblin and Hamblin 1985) based on a range of annual *Medicago* spp.

Growing conditions were very poor in 2018 with only 83 mm of rainfall recorded for the growing season compared to a long term average of 189 mm. Due to poor seasonal conditions, plants remained small in size throughout the growing season and were confined to the sowing rows. Seed yield was assessed initially on the 31st October 2018 at four fixed points by counting the number of seed pods or inflorescences along a 1 m length of row. Thirty seed pods or inflorescences were then collected from elsewhere in the plot to determine the number of seeds per pod or inflorescence. All species except the biserrula, *T. diffusum* and serradella had fully senesced at this time. For the subterranean clover, soil was collected to a depth of 5 cm with burrs sieved and seed yield subsequently determined. The same fixed points were assessed again on the 17th December for biserrula, *T. diffusum* and serradella rows.

Results

Soil at the field site was acidic at the surface and increased with depth (Table 2). Available phosphorus and potassium were well above critical levels of 32 mg/kg P, 139 mg/kg K, respectively while sulphur was deficient (<8 mg/kg) (Gourley et al. 2007).

Table 2. Soil pH, available phosphorus, sulphur and potassium and cation exchange capacity of soil at Kikoira, NSW

	Depth (cm)			
	0-10	10-20	20-30	30-40
pH_{Ca}	4.9	5.0	5.4	5.5
Phosphorus (mg/kg)	45	21		
Phosphorus buffering index	86			
Sulphur (mg/kg)	3.2	1.3		
Potassium (mg/kg)	252	86		
Total CEC (c mol/kg)	12.3	6.6		

Low rainfall experienced at the site resulted in no seed being produced by the subterranean clover (Figure 1). The annual medics had fully senesced prior to the first assessment of seed production and neither produced more than 10 kg seed/ha. While gland clover had also fully senesced before the end of October it produced more than three times as much seed as either of the annual medics. *T. diffusum* showed symptoms of severe moisture stress in late October and had not commenced reproductive growth at that time; it subsequently recovered well with November rainfall (25 mm) and produced more than 100 kg seed/ha between late October and mid-December. French serradella had not commenced reproductive growth by late October but subsequently produced more than 85 kg seed/ha by mid-December. Biserrula produced significantly more seed than any other legumes (32% prior to 31st October), while still retaining 100% green herbage and a further 119 kg seed/ha was produced between late October and mid-December.

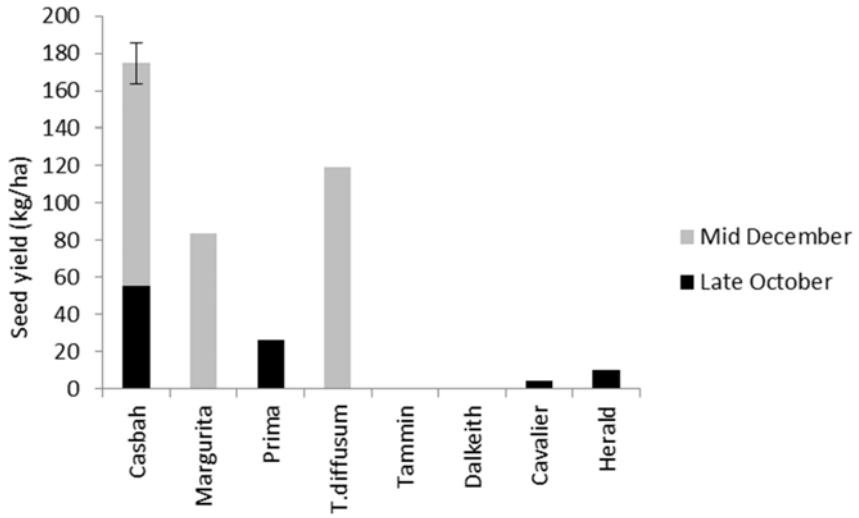

Figure 1. The seed yield (kg/ha) of biserrula (cv. Casbah), French serradella (cv. Margurita), gland clover (cv. Prima), *T.diffusum*, subterranean clover (cvv. Tammin and Dalkeith) and two annual medics (cvv. Cavalier and Herald) at Kikoira NSW measured on 31st October and 17th December 2018.

Discussion and Conclusions

Of the shallower rooted species, gland clover produced the most seed. Previous reports identify early maturity as a key factor in its ability to produce useful quantities of seed (Loi et al. 2005). In this study, based on days to flowering in the literature, the maturity time of gland clover was greater than both annual medics. Clarkson and Russell (1976) reported increasing moisture stress did not result in a change in days to flowering of a range of annual medics but did reduce the duration of flowering in some species. Whether mechanisms exist in gland clover to alter days to flowering and the duration of reproductive development are unknown and require investigation. It is possible that the small seed size of gland clover reduces maturation time. With respect to subterranean clover, its shallow root system coupled with a decreased capacity for stomatal regulation under increasing moisture stress may have been the cause of plants dying prior to producing seed (Socias et al. 1997; Loi et al. 2005).

In contrast, biserrula showed outstanding potential in establishing a seedbank under severe drought conditions with one-third of total seed produced prior to the end of October. Biserrula is a deep-rooted indeterminate species capable of producing green leaf and seed while moisture is available; previous research has shown it has greater capacity for stomatal regulation and leaf angulation under moisture stress than some other legume species (Loi et al. 2005, Foster 2015). While French serradella shares the same indeterminate, deep-rooted characteristics, the cultivar used in this study had not commenced reproductive growth prior to the first seed production assessment, despite only a five day difference in days to flowering reported in the literature (Lattimore and McCormick, 2012). This finding may suggest differences in response of the species to moisture stress with respect to initiation of reproductive growth. While an earlier maturing cultivar of French serradella (cv. Eliza) is available, it is 100% soft-seeded. We would suggest development of an earlier maturing cultivar with hard seed content equivalent to cv. Margurita may be advantageous to increase early-season seed production in the low rainfall zone where seasonal conditions can be highly variable. Further, we suggest that the exploration of the impact of differing moisture regimes and their impact on initiation of reproductive growth should be investigated in order to better quantify the impact of growing season moisture conditions on seed production.

There is little in the literature regarding the characteristics of *T.diffusum*. From our observations, it would appear to have a shallower root system than either biserrula or French serradella as evidenced by severe wilting in late October. However, it recovered well when rain was received in November and is worthy of further investigation in this and other regions.

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