New legume species as opportunistic summer crops for southern Australia – Part 1: Environmental suitability

Christy BP[1], Delahunty AJ[2], Norton SL[2], Wallace AJ[2], Riffkin PA[3], O'Leary GJ[2,4] and Nuttall JG[2,4]

[1] Agriculture Victoria, 124 Chiltern Valley Rd, Rutherglen, VIC. 3685, Email: brendan.christy@agriculture.vic.gov.au
[2] Agriculture Victoria, 110 Natimuk Road, Horsham, VIC. 3400
[3] Agriculture Victoria, 915 Mt Napier Road, Hamilton, VIC. 3300
[4] Centre for Agricultural Innovation, The University of Melbourne, Parkville, VIC. 3010

Abstract

Opportunistic summer legume crops such as mungbean and soybean may be a viable cropping option within southern Australia, however an important consideration is determining the suitability of climate. This paper presents multiple site/year results across Victoria where a range of legume species traditionally grown in sub-tropical growing regions of northern Australia were tested. The suitability of these species to Victoria was determined using climate analyses (to determine the opportunity to sow a crop) and extrapolation with crop modelling (to determine the potential yield if a crop was sown) of measured data across 10 locations in Victoria. Within southern Australia, opportunistic rainfed summer legume crops have the potential to increase break crop and fodder options, reduce dependency on nitrogen fertilizer and utilise out of season rainfall to improve farm profitability.

Keywords

Pulses, adaptation, climate, modelling

Introduction

The potential suitability of sub-tropical legume species (mungbean and soybean) that are currently grown across northern Australia are considered in this paper for rainfed production in Victoria. An important consideration in determining the potential for expanding legume crop options within southern Australia is their suitability to the climate. This is of importance for the species that have been identified as potential summer warm-season legume options: *Vigna* (adzuki, cowpea and mungbean), soybean, common bean and pigeon pea. Currently in Australia, the predominant production areas of *Vigna*, soybean and pigeon pea are in the sub-tropical regions of Queensland and New South Wales. Production in these regions is a mixture of dryland and irrigation. Additionally, production of common bean, soybean and some *Vigna* (mungbean) also occurs on the northern coast of Western Australia (Ord River region), where production is reliant on irrigation.

In northern Australia there are two main sowing windows; spring or summer, where the optimal sowing window differs depending on location and is critical for maximising yield and quality. Generally early spring sowing (September/October) is lower risk for crop failure, decreasing the chance of drought and high temperature stress during the sensitive growth stages of emergence and the reproductive period (Gentry, 2010). Sowing usually occurs following substantial rainfall, where sowing with adequate soil water reserves is important for establishment and early growth. For mungbean, sowing is recommended following three days of cumulative rainfall of >30 mm (Chauhan & Rachaputi, 2014) or soil water reserves of at least 90 mm (Gentry, 2010). This paper uses climate analyses to determine the potential opportunity to sow a crop in the Victorian spring and biophysical modelling to determine yield outcomes for soybean and mungbean from those sowing opportunities.

Methods

Climate analyses for nine Victorian locations was undertaken (Ouyen, Woomelang and Horsham in NW Victoria; Hamilton, Inverleigh and Bairnsdale in SW Victoria; Elmore, Dookie and Rutherglen in NE Victoria). The analysis determined the probability of rainfall events (>30 mm) falling within a 5-day consecutive period (with added criteria that rainfall also exceed potential evaporation over that period) within the months of October to December over 100 years (1919 to 2018).

To test the potential crop yield, measured data from two crops, mungbean (cv. Jade) and soybean (cv. Burrinjuck) were grown in agronomic trials in 2019 across a range of Victorian agroecological environments (Delahunty et al. 2021). Results of these experiments was used to validate the CAT biophysical model (Christy 2018). The CAT model could predict the measured grain yield of mungbean and soybean with a root mean squared error of 340 and 280 kg/ha respectively. Start of flowering phenology prediction was within 3 days of observed phenology for both crops across all sites. The simulation modelling was undertaken for 60 years (1960-2019), using location specific soil characteristics with a starting stored water reserve of 70 mm water (reset each year at sowing) distributed evenly down the soil profile to a depth of one metre.

Results

The analysis of historical weather data shows that at all nine sites there is a greater than 70% chance of an event of 20 mm of rain which exceeds potential evaporation over a 5-day period in the October to December period (Figure 1a). At two sites (Bairnsdale and Rutherglen) there is a 70% chance of 30 mm in this period. Soil temperature at sowing is important for establishment of some sub-tropical legumes, where soil temperature <16°C limits germination. The sites in Victoria with the highest potential to receive enough rainfall to initiate a break in the October to December period when soil temperature (at 10 cm depth) is greater than 16°C, are Bairnsdale, Rutherglen and Dookie (data not shown). Locations such as Hamilton, which is a high rainfall zone, are cooler climates where potential sowing windows may be later due to cool soil temperatures in October and early November. In contrast, at Ouyen, Woomelang and Horsham, soil temperatures are warmer in October, however, chances of a break opportunity for sowing are lower.

Importantly, within Victoria, summer crops are suited as an opportunistic crop option. The probability of rainfall event to initiate growth (Figure 1a) does not demonstrate the subsequent growth potential of a spring/summer crop. Figure 1b shows the probability of additional rain to support growth during a 90-day window after each sowing opportunity. At Bairnsdale there is an 88% probability of receiving at least 150 mm of rainfall within 90 days of a sowing opportunity, at Rutherglen 65%, Horsham 33% and Ouyen 29% (Fig 1b). For sites like Horsham and Ouyen, where there is a reduced chance of follow up rainfall a further consideration of stored water reserves at the time of sowing will need to be incorporated into the decision process.

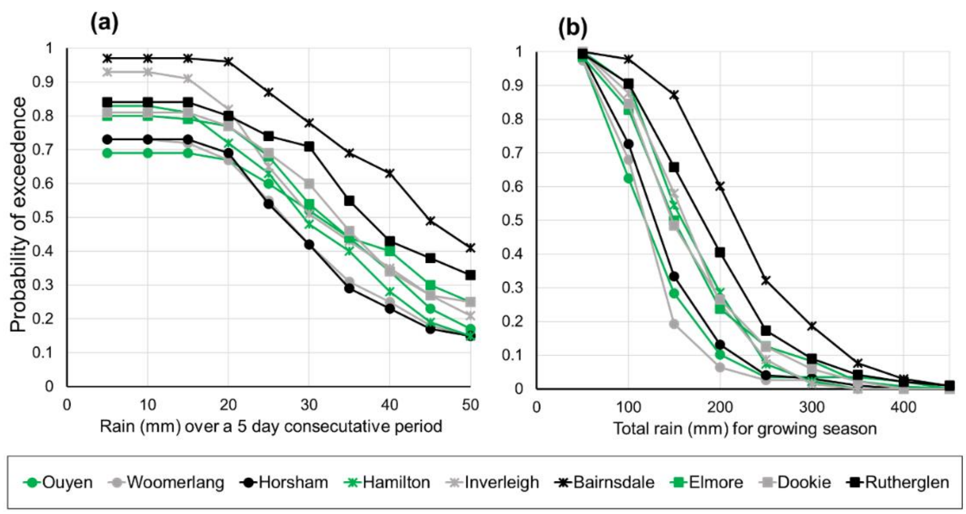

Figure 1: Probability of exceedance for (a) rainfall total over 5-day period (with added criteria that rainfall also exceeds potential evaporation over that period) and (b) rainfall total 90 days after the break (if that 5-day rainfall was greater than 30 mm of rainfall and exceeds potential evaporation over that 5-day period) between October and December for nine locations within Victoria.

Using the rainfall total probabilities in Figure 1 and a starting soil water store of 70 mm, the potential yield probabilities for the nine locations are shown Figure 2. For mungbean, there is a greater than 80% chance of a 500 kg/ha yield if sown in all NE and SW Victorian sites (Figure 2a). Horsham has a 70% chance of that yield and Ouyen a 43% chance. Bairnsdale has a 55% probability and Rutherglen a 25% probability of exceeding 1.0 t/ha yield over summer. For soybean, the southern Victorian locations (especially Bairnsdale) show the highest yield potential (Figure 2b). In NE Victoria Rutherglen and Dookie demonstrated a 40% probability of achieving a 1 t/ha yield and for these 2 locations along with the SW Victorian sites, starting soil water reserves of 35, 70 and 140 mm at sowing resulted in similar harvest yields for both soybean and mungbean (data not shown). At Horsham and Elmore, the probability of achieving a 1 t/ha yield was 25%. For Ouyen and Woomelang there was a 40 and 49% chance of exceeding 500 kg/ha respectively.

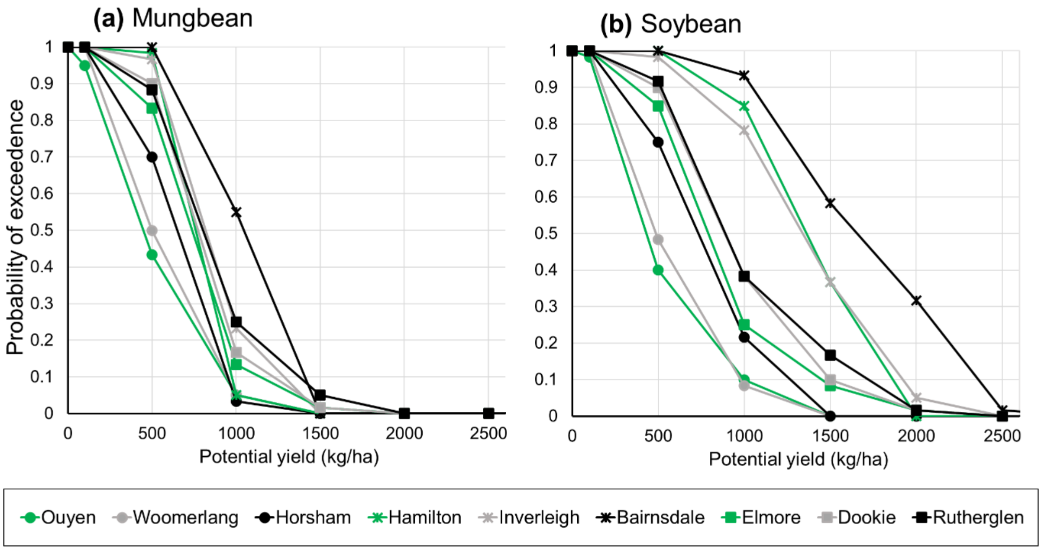

Figure 2: Probability of exceedance for potential yield (kg/ha) for (a) mungbean and (b) soybean for nine locations within Victoria when sown between October and December based on a break criteria (if that 5-day rainfall was greater than 25 mm of rainfall and exceeds potential evaporation over that 5-day period) for the years 1960 to 2019.

The difference in climate compared to current production regions is a major challenge in growing sub-tropical legumes in Victoria. These climatic factors will influence the frequency these crops are grown (opportunistic based on episodic rainfall events in spring and summer) and sowing time effects (soil temperature requirements), biomass accumulation, time to first flower, time to maturity and yield potential. The primary driver to successfully growing crops in Victoria over the spring/summer seasons is the availability of growing season water over this period. Currently for these crops in the northern regions of Australia water supply is from both available stored soil water and/or irrigation, and in-season rainfall. In defining an ideotype for Victoria, growth opportunities will need to incorporate seasonal risk and potential of available water for growth which includes the potential of having adequate soil water available in spring. Based on the probability of exceedance analyses of a range of variables including rainfall (as a break and subsequently) the frequency of summer cropping within regions in Victoria varies, where the higher frequency (if flexible on sowing time) coincides with higher rainfall areas, such as Bairnsdale and Hamilton. There is, however, a significant opportunity to select landraces with greater tolerance to growing environments in Victoria where water supply is more limited. Under evaluation in this project is additional global germplasm from the Australian Grains Genebank, with the expectation that increasing adaptation of these species for key traits, to a Victorian climate is possible. Modelling output will determine broad response to environments across the Victorian landscape and importantly the applicability of crop and species traits including phenology and yield, and the implication to the wider farming systems context.

Conclusion

Yield response of mungbean (Jade-Au) and soybean (Burrinjuck) showed that these two cultivars were the most widely suited to Victoria from the species tested. Crop biophysical modelling supports this crop and species evaluation process, where it mechanistically links climate, weather, soil type and crop growth habit of species within southern Australia.

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