New legume species as opportunistic summer crops for southern Australia – Part 2 Exploring global germplasm for increasing crop adaptation

Delahunty A[1], Wallace A[2], Norton S[3], Henry F[4], Riffkin P[4], Christy B[5], Brand J[2], Clancy A[2], Silwal S[6], Partington D[4], Walker C[2,6], Nuttall J[2,6]

[1] Agriculture Victoria, Cnr Koorlong Ave & 11th Ave, Irymple, VIC 3498, Email: audrey.j.delahunty@agriculture.vic.gov.au
[2] Agriculture Victoria, 110 Natimuk Rd, Horsham, VIC 3400
[3] Australian Grains Genebank, 110 Natimuk Rd, Horsham, VIC 3400
[4] Agriculture Victoria, 915 Mt Napier Road, Hamilton, VIC 3300
[5] Agriculture Victoria, 124 Chiltern Valley Road, Rutherglen VIC 3685
[6] Centre for Agricultural Innovation, The University of Melbourne, Parkville, VIC. 3010

Abstract

There is an opportunity to expand cropping options beyond autumn sowing systems within Victoria to also include opportunistic summer cropping of legumes. Genetic diversity within global germplasm provides opportunities to identify summer crop options adapted to this environment. Agronomic trials of species (e.g. mungbean, cowpea, adzuki bean, soybean, pigeon pea and dry bean) using commercial lines and global landraces were established across a range of agroecological environments (low, medium and high rainfall zones) in Victoria to understand species and environment interaction on growth and yield. Broad suitability assessment found mungbean is widely adapted, soybean and dry bean is suited to the high rainfall zone, and cowpea to hotter drier environments (low and medium rainfall zone). For germplasm across species (1148 genotypes), a significant proportion of lines had greater suitability (plant vigour, early maturing and yield) compared to commercial cultivars. This work confirms the potential for opportunistic summer cropping in Victoria, where germplasm provides the opportunity to increase adaptation to different growing environments in southern Australia.

Key words

Landraces, pulse, production, genetic diversity, Victoria

Introduction

Legume crops constitute 10% of grain production across south-eastern Australia which is predominately winter crops including lentil, chickpea, field pea and faba bean. There is the potential to capture greater value in the farming system through expansion into summer crop options. The addition of alternative legume crops has the potential to provide a diversified income stream as grain and/or fodder, enhance soil nutrition through additional nitrogen fixation and utilisation of out-of-season rainfall through summer cropping. Additionally, summer crops, within the high rainfall zones may increase production of subsequent winter crops through dewatering of the soil profile and limiting the effects of waterlogging (Harris et al, 2016). The summer legume crops being evaluated for suitability to southern Australia are currently grown extensively in central and southern Queensland, and northern New South Wales. In these regions they are grown both on dryland and irrigation systems, where summer climatic conditions are suited to crop growth.

This paper reports on the experimental program which evaluates the phenotypic and temperature adaptability of locally new species across a range of agroecological zones within Victoria (Part 1). The experimental program also assesses global landraces for adaption to south-eastern Australia (Part 2), where genetic diversity within landraces provides significant opportunity to increase adaption to Victoria. The agronomic data obtained through the experimental program has been used to validate and extrapolate the potential of summer cropping across Victoria (Christy et al, 2021).

Methods

Part 1 - Agronomic response of current commercial legume species

This paper reports the results from three trial locations which represent the three major agroecological zones of Victoria: Ouyen (low rainfall zone), Horsham (medium rainfall zone) and Hamilton (high rainfall zone). Trials were established in 2019 to test the suitability of 32 commercial varieties across 11 species, with the following times of sowing: Ouyen (27.11 and 17.12), Horsham (30.10 and 28.10) and Hamilton (30.10 and 26.11). The 11 species tested were *Vigna angularis* (adzuki bean), *Vigna mungo* (black gram), *Macroptilium bracteatum* (burgundy bean), *Vigna unguiculata* (cowpea), *Cyamopsis tetragonoloba* (gaur bean), *Lablab purpureus* (lab lab), *Vigna radiata* (mungbean), *Cajanus cajan* (pigeon pea), *Phaselous vulgaris (*black turtle, borlotti and pinto bean), *Crotalaria juncea* (sunn hemp) and *Glycine max* (soybean).

At each location, trials were a complete randomised block design which were replicated twice. Seed was inoculated with *rhizobia* and sown at a depth of 3 cm, with starter fertilizer (Mono-Ammonium Phosphate) applied, at the standard rate for each region. Irrigation was applied periodically using drip tape to ensure sufficient soil water to sustain plant growth, where the initial experimental focus was on temperature and photoperiod effects. Combined irrigation and rainfall throughout the growing season were 185, 235 and 203 mm for Ouyen, Horsham, and Hamilton respectively.

Part 2 - Genetic diversity within legumes for increased adaptation

Across 11 species (listed in Part 1), 1148 genotypes from the Australian Grains Genebank were screened over the 2019 summer period at Horsham, Victoria. The germplasm assessed was selected using passport data with the following phenotypic characteristics targeted; suitability to dry conditions, short maturity, high yielding, and adaptation to extreme temperatures. In addition to evaluation of the phenotypic characteristics, global germplasm with origins similar to cropping systems in Victoria were also targeted. For each genotype, plots of 1 linear metre were hand sown, with species specific inoculum (New Edge Microbials, North Albury, Australia) was placed over the seed, at sowing. Combined irrigation and rainfall was 277 mm throughout the growing season. In-season management of pests (insecticides), disease (fungicide) and weeds occurred at each site when required.

In-season measurements

For Part 1 and 2 of the experimental program, biomass and grain yield were recorded at harvest. At each site, weather data including temperature (screen at 1.2 m), rainfall, wind speed and direction, soil temperature (0-15 cm), solar radiation and relative humidity was collected.

Results

Average daily maximum temperatures were highest in the north-west (30 to 32°C at Horsham and Ouyen) and lower in the south-west (26 to 27°C at Hamilton). Temperatures above 40°C occurred at all sites with the highest temperature of 49°C recorded at Ouyen when plants were at the early vegetative phase (20.12.11). The range in average daily minimum temperatures across the sites was 11 to 15°C. Daily minimum temperatures of 4 to 7°C were measured at all sites. Average soil temperatures ranged from 19 to 23°C at Hamilton and Horsham, and 25 to 28°C at Ouyen.

Part 1 - Agronomic potential for production of alternative legume species

Several alternative legumes showed potential to produce significant grain yields at Hamilton, Horsham and Ouyen (Table 1). The highest yielding site was Hamilton which recorded the highest grain yield for adzuki bean, black gram, dry bean and soybean. Mungbean was one of the most consistent yielding species across sites; averaging 0.3-0.8 t/ha and showing potential to yield up to 2 t/ha. Ouyen was the highest yielding site for cowpea, and pigeon pea was higher yielding at Horsham than all other sites. Further opportunities exist to increase yield potential through optimising agronomic management within the region e.g. through improved establishment (data not presented).

This work also considers a range of plant traits (e.g. phenology and biomass) which indicate opportunities to increase adaptation through expanding the varieties tested (breeding material and landraces). Based on these traits, mungbean and lab lab (fodder) had the broadest adaption to growing environment (Fig. 1). Crops that performed well in the low rainfall zone were cowpea, guar bean and pigeon pea (phenology less suited) indicating suitability to warmer environments. For Hamilton which has a temperate climate, adzuki bean, soybean and dry bean were well suited. For the medium rainfall zone (Horsham) crops suited were, adzuki bean, cowpea, lab lab, pigeon pea and soybean (Fig. 1).

Table 1: Summer crop average grain yield (kg/ha) for alternative legume species grown across multiple sites within Victoria in 2019/20 (minimum and maximum for each trial are presented in parentheses). Grain yields are the average across all commercial varieties and times of sowing.

Species	Ouyen	Horsham	Hamilton
Adzuki bean	7 (0-14)	369 (47-572)	1037 (387-2424)
Black gram	355 (134-523)	190 (0-609)	838 (263 – 1925)
Cowpea	661 (250-1454)	107 (0-494)	118 (0-1036)
Mungbean	767 (343-1383)	511 (0-2001)	629 (11-1948)
Dry bean	0 (0-0)	83 (0-599)	444 (0-1263)
Pigeon pea	190 (3-721)	445 (0-895)	0 (0-0)
Soybean	0 (0-0)	595 (0-897)	826 (0-1814)

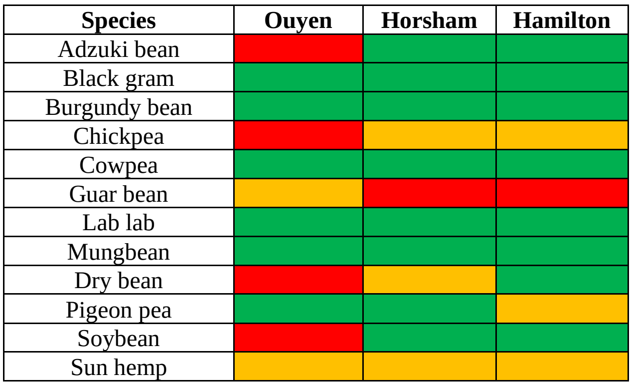

Figure 1. Suitability matrix for a range of alternative legume crop species grown as summer crops over three locations, representing different agroecological zones within Victoria. The 3-tier suitability index of high (green), moderate (orange) and low (red) reflect overall suitability of each species based on crop establishment, growth, phenology, grain set and yield at Ouyen, Horsham and Hamilton.

Part 2 - Genetic diversity within legumes for increased adaptation

For the landraces tested across the 11 species assessed at Horsham for genetic variation, there were substantial differences in canopy architecture, phenology and grain yield. At harvest (March and April 2020), over 95% of the genotypes produced grain yield. Grain yields greater than 1000 kg/ha were observed for mungbean (50% of lines), pigeon pea (45%), cowpea (18%), dry bean (17%) and soybean (8%). For mungbean, average yield of the 140 genotypes tested was 1160 kg/ha, which is more than the average Australian yield of 1000 kg/ha (Douglas, 2019), where yield was correlated with grain number (Fig. 2a).

In addition to mungbean, pigeon pea landraces showed significant genetic variation and potential (Fig. 2b). Pigeon pea is currently grown as a refuge crop, with growing interest in developing a grain export market in Australia (Rachaputi et al., 2018). Based on our prelimenary assesment, potential for pigeon pea production exists in Victoria. Across 148 genotypes assessed, the average yield was 1180 kg/ha and was strongly correlated with grain number. The variation in yield potential, as demonstrated by mungbean and pigeon pea grain yield, indicates that landraces provide the opportunity to select genetics which are better suited to the environment and agronomic requirements within Victoria.

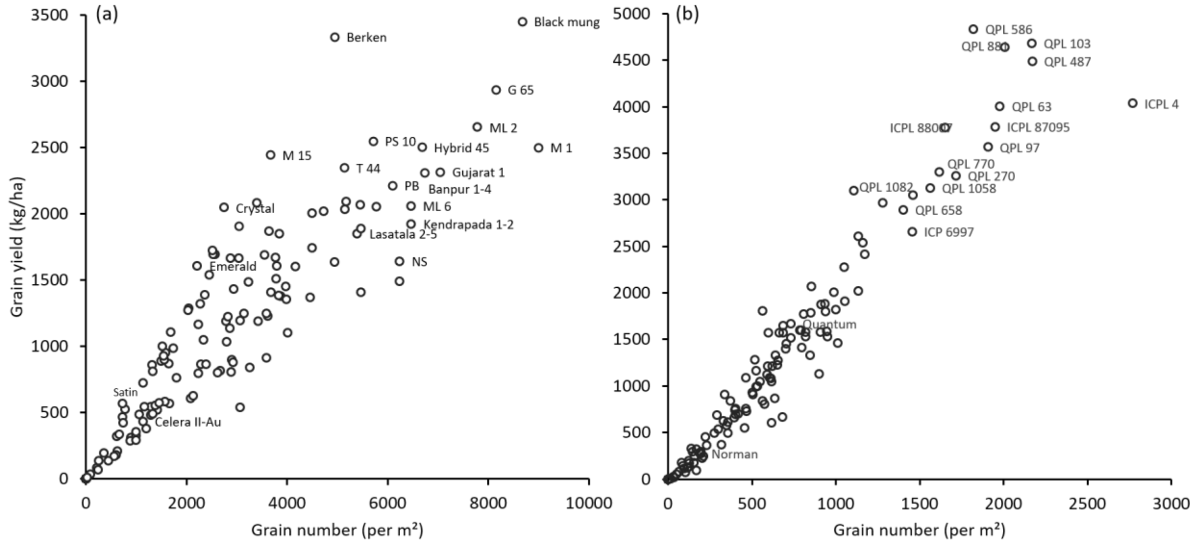

Figure 2. The relationship between grain number and grain yield for mungbean (a) and pigeon pea (b) germplasm assessed at Horsham in 2019/20 for suitability to south-eastern Australia.

Conclusion

There is significant potential to grow legume species for opportunistic summer sowing across the three contrasting agroecological regions in Victoria. Experiments showed that there is a high level of genetic diversity within the landraces screened, with broad adaptability for yield and other agronomic traits. Assessment of temperature and water thresholds across legume species identified in the first year of trials are now being isolated to evaluate suitability across agroecological zone. In addition to this, wider germplasm screening is ongoing, with increased focus on viable crops and traits, which will inform breeding programs and support ongoing development of summer legumes in Victoria.

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