Faba Bean Improvement - northern region

**PROJECT DETAILS**

**PROJECT CODE:** DAN00034  
**PROJECT TITLE:** FABA BEAN IMPROVEMENT - NORTHERN REGION  
**START DATE:** 01.07.2002  
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**SUPERVISOR:** DR IAN ROSE  
**ORGANISATION:** NSW DEPARTMENT OF PRIMARY INDUSTRIES  
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**Summary**

This project has developed new varieties of faba beans adapted to the northern grains region. Improved varieties have contributed to increased adoption of faba beans as a rotation crop in northern region farming systems. Cereal-based farming systems need to incorporate more broadleaf crops in rotations for management of disease and other factors. Faba beans are superior to other pulses for the control of crown rot (CR), root lesion nematode (RLN) and nitrogen (N) fixation. Cairo has been released, and SP01040 will be released in 2008. New germplasm has been developed with increased yield, disease resistance and seed quality. New varieties will be further improved, increasing profits from faba bean production.

**Report Disclaimer**
Conclusions

The sub-tropical environment of the northern region is sufficiently different from the Mediterranean environments of southern Australia for the National Faba Bean Improvement Program (NFBIP) to run a separate breeding and selection node. Biotic and abiotic factors both contribute to the current model for the ideal northern faba bean variety. It should be adapted to:

- Flower early in the short season areas. Southern varieties such as Nura are poorly adapted because of flowering being delayed until August. The optimum time to flower seems to be late June to mid-July, i.e. equal to or up to 14 days earlier than Fiord.

- Resist stem collapse from radiation frosts.

- Be adapted to high temperatures in early spring.

- Be adapted to increasing terminal drought stress.

- Be resistant to rust and viruses.

- Be tolerant or partially resistant to chocolate spot.

- Produce satisfactory seed size and colour for current human consumption markets.

During the course of this project:

- Varieties were released that show promise to meet these goals. Cairo appeared to show that the effects of frost and rust on yield and seed quality could be overcome by variety selection, and that grain growers in the region are ready to adopt faba beans as part of sustainable profitable farming systems.

- The northern breeding program developed facilities such as bee-proof enclosures and summer nurseries that allowed the development of a breeding methodology comparable to world’s best practice.

- Germplasm enhancement, crossing and line selection have established lines and populations that will ensure continued progress. In particular, high yield and seed quality combined with rust and virus resistance is an achievable goal for breeders.
The goals for breeding continue to be refined. Viruses continually show as a regionally specific issue that must be monitored and where possible resistant genotypes developed. During the course of this project, the thrip transmitted tomato spotted wilt virus (TSWV) has increased in significance. Bean yellow mosaic virus (BYMV) has been added to the breeding objectives alongside bean leaf roll virus (BLRV).

Growers are showing increased interest in a smaller seeded variety for stockfeed. The balance between human consumption and stockfeed needs to be addressed and perhaps separated as strands of the breeding program.

**Recommendations**

1. Continue the evaluation of material in the breeding pipeline in an ongoing project.
2. Continue to develop diversity in the germplasm being evaluated, particularly seeking different genetic resources for disease resistance, but also looking for further variation in phenology, growth habit, drought and temperature tolerance.
3. Conduct programs to identify genetic variability in both parts of the host pathogen interaction, particularly in rusts.
4. Further refine screening techniques for all diseases. A seedling test for genetic studies in rust would improve the efficiency of phenotyping this disease. Molecular markers would seem an obvious candidate to improve the efficiency of selection for virus diseases.
5. Review the need for human consumption and stockfeed specialty varieties.
6. Investigate the possibility of improving the use of faba beans in all areas of the food industry by investigating the variation for and effects on functionality of various protein types - similar to work being done in soybeans and lupins.
7. Identify the linkages between a viable faba bean production system and other components of the prevalent farming systems, to identify the value of the faba bean improvement work in solving issues of disease control and soil improvement in subsequent crops.

**Outcomes**

1. Increased adoption of faba beans as a rotation crop in northern region farming systems.
2. Increased profitability for grain producers through higher yields and reduced costs of production for the faba bean crop.
3. Improved profitability of the subsequent cropping program.

The release of Cairo\(^\text{P}\) in 2003 and its subsequent adoption saw the area planted with faba beans increase to over 30,000ha in 2006. This area will increase in future years if adequate soil moisture is available in the April-May planting window.

Cairo has delivered direct benefits to northern region producers. It has:

- Improved adaptation to northern region resulting in higher yields than previously achieved increasing returns to growers
- Improved tolerance to frost damage
- Improved seed quality suited to human consumption markets leading to higher farm gate prices
- Improved rust resistance leading to reduced production costs.

Benefits of growing faba beans as identified by northern region grain producers include:

- High N inputs for following cereal crops contributing to cereal profitability by improving yield and quality while reducing production costs.
- Reduction of CR inoculum for subsequent cereal crops, particularly important for durum wheat.
- Reduction of nematode problems.
- Improved soil structure.
- Excellent fit into minimum tillage rotation systems.
- An option for pulse producers to reduce reliance on chickpeas and minimise disease build-up in the pulse phase of the...
The line SP01040 is to be released as the variety Doza in 2008. It will further enhance the adoption of faba beans in cereal rotations by being an advance on existing varieties, including Cairo, for:

- Yield increases of a further 10%.
- Improved uniformity of both seed size and seed coat colour.
- Further advance in rust resistance and superior tolerance to chocolate spot.

Significantly earlier flowering will enhance the adaptation of the crop to shorter season parts of the region. Earlier commencement of flowering and earlier start to podset lengthens the period of reproductive growth and enhances yield potential in short season areas.

Germplasm has been identified with virus resistance. Following germplasm enhancement, lines have been used in the crossing program that will allow selection for resistance to virus diseases, particularly BLRV and BYMV. The progeny from those populations should allow selection of multiple disease resistant varieties by 2012 that will also retain current levels of seed yield, quality, early flowering and frost tolerance.

Recurrent selection populations have been established for continued yield improvement and enhanced seed quality.

Continued improvement in yield, disease resistance and seed quality will further:

- Encourage expansion of faba bean production in cereal-based rotations.
- Improve profitability of faba bean production.
- Contribute to sustainable and profitable farming systems.

**Achievements/Benefits**

The Breeding Program:

1. During the project, the program changed emphasis from germplasm screening and reselection to directed crossing (see Attachments 6 & 7). This was enabled by completion of the bee-proof enclosure in 2003. This structure has been used for growing space planted F2 populations, with up to 15,000 plants per season being evaluated.

   By 2004 F2 screening had been expanded to 432 F2 populations from 136 crosses and 1,000 single plant progeny established for further work. These populations, which totalled 15,000 plants, have parent lines with excellent yield and seed quality, early flowering, rust resistance, chocolate spot resistance, BLRV resistance and root rot resistance. This level of screening continued through 2005 and 2006. The parents used were expanded to include resistance to BYMV and southern program selections with superior chocolate spot and ascochyta resistance.

2. Each year, a summer seed increase nursery was established. Initially located at Hanging Rock, it was relocated to Armidale in the 2005/06 summer. The summer seed increase has a role in the increase of F1 plants under bee-proof (self pollinated) conditions and in the seed increase of F2 single plants selected at Narrabri in the previous winter. The summer nursery has enabled the breeding program to be accelerated as much as possible with this species, which is intractable to double haploid and difficult to manage for Single Seed Descent.

3. In each year of the project, yield trials and genotype evaluations were completed under irrigation at Narrabri and Breeza:
   - S1 trials of 1,000 to 1,500 entries are grown at Narrabri and selections made for flowering, frost, rust, seed quality and yield.
   - S2 trials with 100-150 entries are grown at both Narrabri and Breeza in unreplicated designs (with replicated controls). These two sites give information on the response to photoperiod and temperature. The Breeza site is also more likely to encounter viruses and chocolate spot at levels that enable screening for resistance.
   - Similar procedures are applied to replicated S3 trials at each site.
4. In each year, dryland S4 trials were established at a range of sites dependent on moisture availability for timely sowing. Until 2005 these trials were conducted by Linda Heuke as part of a pulse agronomy project funded by GRDC. From 2006 some of these S4 trials were run in conjunction with National Variety Trials (NVT) testing, some sites designated as NVT and others as breeders’ trials. Sites ranged from Gilgandra and Trangie in the south to Weemalah and Billa Billa in the north. In the two latter years, trials on the Liverpool Plains were expanded to include Quirindi and Mullalley.

5. In each year, screening nurseries for rust, chocolate spot and BLRV were established. Good results were generally obtained from the virus nursery at Breeza and the rust nursery at Narrabri. The BLRV nursery at Tamworth had difficulties establishing the aphid populations for effective screening. Successful screening for chocolate spot resistance was more difficult.

6. Screening methods for these disease nurseries have been continually developed and improved. A trial was established at Tamworth to develop a methodology to screen for resistance to BYMV.

A good correlation was found between resistance rankings in Tamworth and at the International Center for Agricultural Research in the Dry Areas (ICARDA), Syria, for BYMV.

Methods for the systematic inoculation of the BLRV nursery have been developed but there are still difficulties expanding the nursery to evaluate the full range of genotypes available in any one year.

Variety release:
1. The line SP95054 was released as the variety Cairo\(^{(1)}\) in 2003 (see Attachment 3). The performance of Cairo in 2004 exceeded expectations for yield and quality. The level of rust resistance proved adequate and the effect of frost on stem collapse was excellent. The only negative comments were associated with growers being poorly equipped to handle the larger seed size at planting. The commercial partners again undertook a large scale seed increase in 2004 with a further 800 tonnes of seed produced for the 2005 season. The performance of Cairo in 2004 and 2005 exceeded expectations for yield and quality. The level of rust resistance proved adequate and the effect of frost on stem collapse was excellent. Cairo has demonstrated potential for growing on a commercial scale in Western Australia (WA). Trials have shown yield to be excellent. Cairo has cercospora resistant plants at a higher frequency than other Australian varieties. Being heterogeneous for reaction has allowed progress towards more resistant selections derived from Cairo.

2. SP98066, combining high yield with early flowering, rust and chocolate spot resistance, was seed increased under outcrossing isolation plot conditions in 2004. Over 500kg of seed was available. The selection of a commercial partner was delayed in light of reservations expressed by Pulse Australia about the seed size of SP98066. SP01040 and SP01143 are derivatives of SP98066 that are closer in seed size to Cairo while retaining the agronomic advantages of SP98066. SP98066 is still available for release if sufficient demand for a smaller seeded type is expressed by the industry.

3. SP01040 was subsequently seed increased at Narrabri in 2006. Grain Trust Pty Ltd. was selected as a commercial partner and release will occur in 2008. Commercial cultivation should commence in 2009. The name Doza\(^{(2)}\) has been selected for SP01040. Doza flowers 10-14 days earlier than Fiord and Cairo, outyields Cairo by 8-10%, and is superior for rust resistance and seed quality.

Quality assessment:
1. Quality assessments have been carried out on samples from S4 trials conducted in 2000–2006 seasons. The genotype x environment (GxE) effects on these traits were analysed from core trials from 2000–2005. The drought of 2002 limited the number of sites harvested and therefore also limited the range of environments sampled for GxE calculations.

Statistical analyses have shown that seed size can vary with both site and season. Genotype rankings varied to some degree across both sites and seasons within New South Wales (NSW), however some trends were evident. Genotypes grown in South Australia (SA) yielded 0.4-12.5% larger seed sizes than those grown at Narrabri in 2005, except for Farah\(^{(3)}\) and Fiord which were 9.3 and 13.2% smaller, respectively, when grown in SA. There was no significant difference in size distribution over these two environments. Most varieties obtained 7-14% higher milling yields when grown in Narrabri compared to SA, except for Fiord and SP98066 which had 1-3% higher yields in SA. These results suggest that most but not all varieties grow larger seeds in the SA environment, however varieties grown at Narrabri are often easier to mill, obtaining significantly higher dhal yields that would be more profitable to the splitting industry. A larger trial comparing SA and NSW environments would be warranted to clarify and confirm differences.

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\(^{(1)}\) Refer to ‘Report Disclaimer’

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2. S2 and S3 trials were assessed for colour, seed size, and seed size uniformity. Advanced lines were screened for the additional tests, milling efficiency and imbibition properties. SP01040 is now the established benchmark for varieties targeting human consumption areas.

3. A screening method for tannin discolouration during storage was investigated using accelerated aging in a controlled humidity cabinet. Two batches of samples were tested in 2006 comprising six trials. The aim was to design methodology that could determine differences in discolouration between genotypes. We believe that the position within the cabinet was not a large factor but differences in the sample pots were significant. Obvious differences in seed darkening occurred within samples (i.e. some seeds discoloured more than others: approx. 20-30% of seeds in each sample did not darken significantly) and we believe this variation is accounting for at least some of the sample pot effect. A trial was undertaken to compare the discolouration of selections of light and dark seeds from these (and other) segregating lines. Results showed no significant difference between the mean discolouration (L*, a*, b*) of the light and dark selections. In addition, these selections still contained 8-27% seeds that did not discolour. The percentage of seeds that do or do not discolour could be due to either random sampling and/or genetic variation, and requires further investigation using a larger trial and pure seed.

4. In addition a different method using ultraviolet C (UVC) lights is being investigated as an alternative to the humidity cabinet to see if the same discolouration trend is reflected by this new (and quicker) aging method.

Faba bean pathology:

1. A disease screening nursery for chocolate spot has been established at Tamworth. A high level of mechanisation (development of a single row planter, use of large scale inoculation equipment) allowed the testing every year of over 1,000 entries with two replicates and systematic checks. However, the weather over the past funding period has been extremely unfavourable for the development of chocolate spot. The lack of rain could be partly compensated by a special irrigation system, but lack of water at the station prevented the use of irrigation in the past three years. Results of the chocolate spot screening at Tamworth have therefore been generally disappointing with only 2003 delivering useful screening results. During the next funding period, different activities in the national faba bean program will be rationalised and it has been decided to discontinue large scale chocolate spot screening at Tamworth.

2. Screening for virus resistance gets a high priority within the northern program. Growers perceive viruses as more threatening than fungal diseases as there are only limited control options available. BLRV is considered the most important of the faba bean viruses in the northern region because of its high and regular incidence and its potential to cause severe losses to infected plants. During the project period BLRV screening was moved from Tamworth to the Liverpool Plains Field Station (LPFS) to ensure adequate water supply. Larger plot size at LPFS required a change of inoculation techniques. Hill plots consisting of a highly BLRV susceptible variety are sown in the alleys next to the test plot and inoculated with BLR viruliferous aphids early in the season. Compared to inoculating all plants in a test plot, this method is less labour intensive, but has showed to be very successful.

3. Improved resistance, seeding density and seed treatment by a systemic insecticide were evaluated for their effectiveness to control BLRV in separate trials at LPFS. Lower seed densities did not change aphid colonisation rates, but did result in higher incidences of BLRV as well as the non-persistently transmitted BYMV. Seed treatment with imidacloprid at rates as low as 0.7g ai/kg seed, proved to be highly effective in reducing BLRV infection. The seed treatment had a season long effect and was more efficient on a moderately susceptible variety than on a highly susceptible one. The imidacloprid treatment did not have an effect on BYMV.

4. The recommended disease management package is now widely accepted in the region. This package is based on an early mancozeb spray to prevent the establishment of both rust and chocolate spot in autumn. Both these diseases are highly inoculum dependent to develop to economically significant levels in normal years. Prevention of autumn infections has therefore a season lasting effect. The disease management package will have to be adapted with the release of new varieties with improved rust resistance. Sprays will then only be needed to control chocolate spot, which broadens the choice of fungicides.
5. Yearly surveys were made of commercial and experimental crops throughout the northern region. These surveys provided valuable information on the status of fungal and viral diseases in the northern region. The disease status over the past funding period has not changed greatly, with rust still being the most important fungal disease. However, as most growers adhere to the recommended disease control package (and because of the general dry conditions over the past years), fungal diseases have not been of any significance. The surveys also acted as a vehicle to receive feedback from faba bean growers on the merits of new varieties and the pros and cons of growing faba beans in general.

Other research

1. Agronomic studies to investigate improving yield through changes to farming practices such as row spacing and population.
2. Studies on water use to best develop irrigated faba beans.
3. Epidemiology of viruses in pulse crops. The vectors (e.g. aphids) of most of the significant viruses are known but their ecology is not well understood.
4. Genetic studies of rust and virus resistance. Genetic control of host plant resistance to BLRV and rust. Possible student projects may target the improvement of screening methods, the identification of new sources of resistance, the genetic control of resistance and the identification of linked molecular markers. The agronomic implications (possible yield depression in disease free environments) of pyramiding multiple resistances could also be explored. A genetic population derived from a cross between a rust resistant and BLRV resistant genotype is available.
5. Feasibility of hybrid seed production using cytoplasmic male sterility. The identification of heterotic groups, the extent and stability of heterosis for yield and the optimisation of F1 seed production regarding potential research areas.
6. Nutritional characteristics of faba beans. Genetic variation, influence of environment and genetic control of metabolisable energy and anti-nutritional factors in faba beans could be explored.
7. Physiology and genetics of frost tolerance in faba beans. Good tolerance to frost has been identified and transferred into new varieties. However, the mechanisms of tolerance and their genetic control are unknown and could be explored.
8. Genotype x management system interactions. The adaptation of various pulse and oilseed crops to specific management practices could be explored. The existence of significant genotype x management practice interactions and identification of the key drivers of these interactions could have implications for variety development programs.
9. Examine the heritability of slow discolouring faba beans. This is an important seed quality trait in human consumption markets. Alternative methods for rapid screening are being investigated.

Intellectual property summary

Cairo\(^1\) and SP01040 have been commercialised via a tender process. The selection process in conjunction with GRDC aimed to select the commercial partner with the business plan best suited to rapid adoption of the new varieties in the northern region.

Pulse Breeding Australia (PBA) is seeking to select a commercial partner for the NFBIP. Varieties released following SP01040, developed as part of DAN 00034 or future projects, will be covered by this arrangement.

Additional information


Refereed Scientific Publications

van Leur JAG and H Gebre. 2003. Diversity between some Ethiopian farmer's varieties of barley and within these varieties among seed sources. Genetic Resources and Crop Evolution 50: 351-357.