FINAL REPORT

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

DAQ00128

National Mungbean Improvement Program

PROJECT DETAILS

PROJECT CODE:	DAQ00128
PROJECT TITLE:	NATIONAL MUNGBEAN IMPROVEMENT PROGRAM
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Summary

The National Mungbean Improvement Program (NMIP) has developed the next generation varieties and germplasm that will surpass Crystal(Φ) and deliver further productivity and reliability gains to the northern region growers and the Australian mungbean industry.

1. Two new varieties will be released in 2012/13.
   a. A large shiny type with improved yield (10%) and foliar disease resistance package over Crystal.
   b. A small shiny type with greater than 50 per cent yield, agronomy superior to Green Diamond(Φ) and with a Halo Blight resistance rating.
2. Germplasm was developed with superior Halo Blight, Tan Spot, Powdery Mildew resistance in adapted background. 252 new germplasm accessions were imported from the World Vegetable Centre.

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Conclusions

1. Crystal$^{\phi}$ and Satin II$^{\phi}$ have increased mungbean productivity and area planted by over 50% since their release in 2008.
2. Significant yield gains of up to 20 per cent demonstrated in this project have been achieved through increased genetic diversity in the breeding program and improvements in foliar disease resistance.
3. Improved disease resistance to Halo Blight, Tan Spot and Powdery Mildew has been identified from the germplasm collection and successfully introgressed into adapted backgrounds.
4. Grain quality of Crystal has strengthened Australia's position in international markets. The large shiny seed type will continue to dominate Australian production. However, Australia still lacks a sprouting variety with a yield and agronomy package attractive to growers.
5. The uptake of Satin II (dull-seeded type) reiterates that niche markets can be developed and/or reinstated with a product suitable to both grower and end-user, in particular green small-seeded types and to a lesser extent, yellow-seeded and Regur (black gram) types. Market intelligence is crucial to determining potential for niche markets and assigning program resources.
6. Australia's world leading expertise and capability in mungbean breeding and pathology is well integrated with the value chain, but lacks international linkages and access to germplasm. This situation was brought to the fore through recent visits to the World Vegetable Centre (which has the global mandate for mungbean improvement). Collaborative international relationships such as this one are essential for continued success of the Australian industry.

Recommendations

1. Germplasm. Access to new germplasm and accompanying passport and characterisation and evaluation data have been a significant challenge to this program since its inception. A new relationship with the World Vegetable Center (AVRDC), new pulse breeder Dr. Ram Nair, and Genetic Resources Centre staff will improve this situation considerably. As well as 252 lines imported in 2011, discussions are being held about new elite breeding lines from Thailand and ultra short duration mungbean varieties.
2. Agronomic support. New mungbean varieties are released with Variety Management Packages that draw mostly from agronomic research conducted on outdated varieties. There is a danger that new, high yielding varieties from NMIP are reaching the limits of existing agronomic knowledge. Dedicated agronomic research is required on two levels, i) to confirm or optimise existing management for new release varieties, and ii) new systems research that supports the paradigm shift of mungbean from an unreliable, opportunity crop to becoming a staple crop for dedicated northern growers. This research needs to be grower and industry led at a district and regional level.
3. Further development and application of the agricultural production systems simulator (APSIM) mungbean as a decision support for industry, as well as a tool for breeders to understand key traits that contribute to yield gains in new varieties and develop screening techniques.
4. Investigate the feasibility of a symposium to coordinate international mungbean research and re-establish international

research networks.

Outcomes

Economic benefits

Average yields of mungbean rose from 0.7t/ha to 1.3t/ha in the period 2004-07 to 2008-10 and production increased from 39,000 tonnes to 69,000 tonnes. The value of production of the Australian industry rose from $25.7 million (2004-07) to $55.6 million (2008-10)*. This increase was largely a result of new, high yielding NMIP varieties, Crystal(ф) and Satin II(ф) that were released at the start of this project in 2008 and now account for over 90 per cent of Australian mungbeans grown.

Two new varieties developed and identified in this project will be released in 2012-13 and are higher yielding than commercial checks Crystal (large seeded, 90% of market) and Green Diamond(ф) (small seeded, currently niche production). Improved yield and foliar disease resistance in this next generation of mungbeans will further increase productivity and reliability to support continued growth of the Australian industry to its target of 100,000 tonnes and a value of $80 M.

GRDC's own assessment of the mungbean breeding program was an estimated return of $109 million for a $6 million investment, a 18:1 benefit:cost ratio.

Environmental benefits

Mungbean is the only summer pulse crop available to northern dryland growers. Increased productivity and adoption of mungbeans through confidence in superior varieties developed in this project will result in more sustainable farming systems by increasing soil health and fertility, more efficient use of water and expanded weed control options.

With modest nitrogen (N) fixation, mungbeans are best considered a nitrogen neutral crop. Incorporation of pulses such as mungbeans in farming systems alleviates depletion of soil N and reduces reliance upon fertilisers derived from fossil fuels that would otherwise add to global warming. As a short season crop, mungbeans have a lower water requirement than other spring and summer options and provide wider options for weed control and management of herbicide resistance, in particular grass weeds such as feathertop Rhodes grass.

Social benefits

Mungbean production and the associated processing industries contribute to the economy of regional Queensland and northern New South Wales, providing 2616 jobs* and income for growers, labourers, contractors, agronomists, rural merchants, farm supply, processing and transport sectors.

* Data from the following sources

Mungbean Industry Profile. Australian Mungbean Association (AMA) (November 2011).

An Economic analysis of the GRDC Investment in the Mungbean Improvement Program. GRDC (2011).

Achievements/Benefits

1) Identification and pure seed production of elite new varieties

NMIP has seven lines from advanced trials in pure seed production. It is envisaged that from this material, one large and one small shiny-seeded variety will be commercially released in 2012-13.

Large shiny-seeded type background - 90% of Australian production, Crystal(ф) (2008) is the predominant variety.

M07213 yield is 10 per cent higher than Crystal in 28 trials across four years of testing.

M07213 has an improved foliar disease package over Crystal over three years of disease testing.

Tan Spot - Moderately Resistant (Crystal is MR/MS)
Powdery Mildew - Moderately Resistant to Moderately Susceptible (Crystal is MS)
Halo Blight - Moderately Susceptible (equivalent to Crystal)

M07213 has equivalent seed size, hard seed and visual quality to Crystal. This line has the potential to replace Crystal and become the predominant mungbean variety. 125kg pure seed was passed to commercial partner, the Australian Mungbean Association in June 2011. Commercial availability (at least 1000t available) is expected in spring 2013.

Pure seed production of six other lines was initiated in 2010-11 based on previous years' data. Subject to review of grain quality by an industry panel, progeny rows will be grown out in 2011-12.

M08019 yield is 21 per cent higher than Crystal in three years of testing (15 trials). Preliminary pathology testing (two years) indicates M08019 could have MR rating for all three foliar diseases. M08019 does not appear to have the robust grain quality of Crystal or M07213. This line requires further yield, grain quality and disease testing.

Small shiny seeded type - approx. 5 per cent of Australian production. Celera (released 1969) and Green Diamond(ф) (1997) are current commercials. Both are low yielding and highly susceptible to disease and lodging.

M08154 is up to 20 per cent higher yielding than Green Diamond and with similar disease resistances (MS). However, with new Halo Blight resistant lines performing well in Stage 2 trials in 2010-11, this line will more likely be an important parent (yield, plant type, grain quality).

Lines M09246 and M09350 have excellent Halo Blight resistance (rating of 1.0 and 1.3 on a 1-9 scale where 1 = no symptoms, Crystal = 5.3). In two years of testing (15 sites), these lines have yielded as much as 70 to 95 per cent higher than small-seeded check, Green Diamond. In yield trials with moderate levels of Halo Blight pressure, these small seeded lines exceed the yield of Crystal.

These lines and their Halo Blight resistant cohorts in early stage trials represent a quantum leap in over small-seeded commercials and in reliability for all mungbean growers.

Lines M07167 and M07216 were nominated for pure seed production on the basis of data up to 2010 (yield, Tan Spot, Powdery Mildew, grain quality), but will be dropped from pure seed production since their yield and disease performance has been surpassed by new superior material in 2010-11.

2) Germplasm development

Combination of superior yield and disease resistance in advanced lines.

Genetic gain in NMIP developed germplasm is demonstrated by yield and disease resistance in all stages of replicated trials.

Stage 1 trials (first year replicated testing in 2010-11) - 16 lines 10 to 23 per cent higher yielding than Crystal.

Stage 2 trials (second year testing, 15 sites) - 14 lines 5 to 16 per cent higher yielding than Crystal. Halo Blight ratings from 1.7 to 4.0 (Crystal = 5.3).

Stage 3 trials (third and fourth year testing, 28 sites) - four lines more than 10 per cent higher yielding than Crystal and with better disease resistance package.

Stage 1 and 2 Irrigated trials - four lines more than 10 per cent higher yielding than Crystal (preliminary data from a single site).

Halo Blight (HB)

Halo Blight is the most significant disease in mungbeans. It is seedborne and affects foliage at all growth stages. HB is present in all mungbean growing regions and losses can be most severe in spring crops. This pathogen has become the main priority for the breeding program since the specification of this project. NMIP has now identified three resistance sources from the Australian germplasm collection and introgressed these into adapted backgrounds. First resistance will be delivered in a small-seeded type (HB donors are M773 and OAEM58-62, HB score = 1.0). Lines are in Stage 2 multi environmental trials (METs) with 21 of these having HB score of less than or equal to 2.0, compared to commercial checks, Crystal= 5.7, and Green Diamond= 7.0.

Further HB resistance has been identified in a large shiny-seeded background in AusTRC321818 (score = 1.0, no symptoms under high artificial disease pressure). Seventy three lines in Stage 1 MET have an AusTRC321818 pedigree and ten of these had higher yields than Crystal in 2010-11. The foliar disease of these lines will be evaluated from 2011-12 onwards.

Fifty-one lines selected from disease nurseries in 2011 with HB score of 1.0 (Crystal = 5.0).
Forty one lines in Stage 2 trials with HB score of 4.0 and twenty lines with HB rating less than or equal to 2.0 (Crystal=5.3).
Eight lines in Stage 3 trials with HB score between 3.0 and 4.0.

Tan Spot (TS)

Tan Spot is a seed-borne bacterial disease which can cause widespread and serious losses. Plants are most susceptible when under heat and drought stress. Plant resistance is recognised as an important part of integrated pathogen management along with crop rotation and the use of clean seed. NMIP has continued to use AVRDC germplasm as TS resistance donors, in particular line VC2768A, which also conveys yield potential and excellent grain quality.

Four lines in Stage 3 MET with TS score less than or equal to 3.0.
Twelve lines in Stage 2 MET with TS score less than or equal to 4.0 (Crystal = 5.0).

A further 15 lines were selected from disease nurseries in 2011 with TS scores less than or equal to 3.0 (Crystal = 5.2).

Powdery Mildew (PM)

Powdery Mildew is a fungal disease prevalent under cooler temperatures. It is of greatest impact in very early sown spring crops or late autumn crops. Yields may be affected if infection occurs prior to flowering. Control can be affected with commercial sulphur products and by avoiding early or late sowing. This disease is of lower priority than other foliar diseases. Good resistance is available from germplasm in the Australian collection and is present in overseas breeding programs.

Five lines in Stage 3 MET with PM score between 2.8 and 4.0.
Twenty five lines in Stage 3 MET with PM score less than or equal to 5.0 (Crystal = 6.0).

Tobacco Streak Virus (TSV)

This virus has caused considerable crop losses in central Queensland during dry seasons. NMIP has screened for TSV response in commercial varieties (glasshouse) and 165 germplasm lines (field trial). No useful variation was found for virus reaction. Since physical separation from Parthenium infected pasture provides the best means of protection, no further research on TSV has been conducted, and breeding program resources have been concentrated on existing bacterial foliar diseases as described above.

New sources of disease resistance, program development

The three parent lines identified above have immunity to Halo Blight and are likely sources of major gene resistance. While easy to breed for this resistance, it is more susceptible to changes in the pathogen and breakdown of plant resistance. By contrast, Tan Spot and Powdery Mildew sources are partially resistant and indicate more complex inheritance. These disease resistant parents and their progeny represent the next generation of mungbean varieties for Australian growers and will deliver future benefits in productivity and reliability.

NMIP and the Australian Tropical Crops Genetic Resource Centre (ATCGRC) (Department of Employment, Economic Development and Innovation (DEEDI) Biloela, Curator Dr. Sally Norton) imported 252 new accessions from the World Vegetable Centre (AVRDC) in Taiwan; selected to provide the most potential value to the Australian industry. Key selection criteria were large, green, shiny-seeded types, diverse provenance and detailed characterisation data indicating suitability to Australian production (plant height, phenology).

Material was released from Post-Entry Quarantine in March 2011 and glasshouse increased at Hermitage Research Station over winter. A field increase will be completed in summer 2012. Germplasm and characterisation data will be lodged with the ATCGRC.

This important new influx of genetic material is the raw material for the next NMIP project (DAQ00172, refunded 2011-16). Agronomic, grain quality and disease testing will commence July 2011.

Improved efficiency, methodology

Statistical analysis

NMIP has been one of the first Australian plant breeding programs to implement multi-environment trial analyses with pedigree data This powerful statistical tool, developed under the GRDC Statistics for Australian Grains Initiative (SAGI) partitions observed performance of breeding lines into additive (heritable) and non-additive components. Analogous to the 'breeding value' used by cattle producers, this allows NMIP breeders to select the best parents in the crossing program, on a quantitative rather than empirical basis.

The mungbean program has been active in development and testing of the Katmandoo suite of plant breeding software with DEEDI biometricians and software developers. We have adopted electronic field book technology and now record all field data on PDA and tablets running the proprietary Fieldscorer software, realising considerable improvements in accuracy and efficiencies.

Pathology

NMIP has continued to refine disease screening nurseries for Halo Blight, Tan Spot and Powdery Mildew. Segregating F4 populations of specific crosses are screened under artificial disease pressure (HB, TS) and validated as F5 progeny rows under disease pressure in the following year. All breeding lines in Stage 2 and Stage 3 trials are screened for all foliar diseases.

Two Halo Blight resistant germplasm lines have replaced Berken as spreader rows in Tan Spot and Powdery Mildew trials to prevent confounding of disease reactions.

3) Industry leadership

- NMIP coordinated bi-monthly teleconferences with a management group (DEEDI, GRDC and AMA) and holds an annual project meeting with stakeholder and industry partners
- commercialised germplasm pipeline with the Australian Mungbean Association
- representation at CICILS International Pulse Trade and Industry Confederation (IPTIC) international pulse conference April 2010
- organising committees and speaker program for the Australian Summer Grains Conference June 2010
- coordinated responses to industry concerns regarding Crystal desiccation concerns and widespread nutrition/foliar symptoms in mungbean crops with AMA and Pulse Australia
- renewed relationship with AVRDC, Taiwan. Importation of new germplasm and discussions on future collaboration. Study visit and germplasm exchange undertaken by program in July 2011.
- study visit to ICRISAT in January/February 2011 including time spent with AVRDC South Asia Centre
- role in bilateral ACIAR project 'Enhanced Productivity of Tropical Pulses' SMAR2007/068. Agronomy trials and parameterisation of APSIM mungbean for the Crystal variety.

Other research

1) Pathology. This program relies on a small number of disease resistance sources. The inheritance and modes of action are not understood. Provenance and pedigree of donor lines are unknown and the project's three Halo Blight resistant parents may all be carrying the same gene. Genetic diversity studies, and at the least fingerprinting of key parents, is required to make more informed decisions in the crossing program and search for new resistance sources.

Combining Halo Blight, Tan Spot and Powdery Mildew resistance sources into new varieties needs to be a priority for subsequent breeding activities. A reliable glasshouse test for economic screening of early generation lines is required for Halo Blight. This will be addressed in follow-up project DAQ00172.

2) Engagement of students to pursue targeted, relevant projects that contribute to the breeding program through the Queensland Alliance for Agriculture and Food Innovation and AVRDC's South Asia Centre on the International Crops Research Institute for the Semi Arid Tropics Patancheru campus.

3) Continued monitoring of viral diseases, in particular mungbean yellow mosaic virus and mungbean yellow India mosaic virus which are the significant production constraints in Asia. NMIP will maintain links with the AVRDC and DEEDI/GRDC virology group in Brisbane.

Intellectual property summary

Intellectual property generated in this project is in the form of new mungbean varieties. All such material is eligible for and will be protected by Plant Breeder's Rights.