FINAL REPORT

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

DAQ00060

National Mungbean Improvement Program

PROJECT DETAILS

PROJECT CODE:	DAQ00060
PROJECT TITLE:	NATIONAL MUNGBEAN IMPROVEMENT PROGRAM
START DATE:	01.07.2003
END DATE:	30.06.2008
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Summary

The National Mungbean Improvement Program (NMIP) has delivered immediate productivity and profitability gains to Northern Region growers and set the foundation to deliver the next generation of varieties that will increase crop reliability and grower confidence.

The program has

1. Identified and released two new varieties with 20% gains in grain yield worth an extra $5.2 million each year.
2. Identified genetic resistance to powdery mildew, tan spot and new sources of yield and grain quality from the germplasm collection and incorporated these into agronomically adapted backgrounds.
3. Developed and implemented new glasshouse and field screening methodologies for powdery mildew and tan spot.

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Conclusions

The National Mungbean Improvement Program, DAQ00060, has re-invigorated mungbean breeding in Australia, identifying and releasing two varieties with 20% yield gains over the current mainstay cultivars. New varieties Crystal$^{\Phi}$ and Satin$^{\Phi}$ II will provide immediate productivity gains of $5.2M to growers in the GRDC Northern Region.

This project has also identified new genetic diversity, disease resistance to powdery mildew and tan ppot and incorporated this into agronomically adapted backgrounds. From this foundation, NMIP will develop the next generation of mungbean varieties which combine productivity gains, yield stability and specific adaptation to regional and irrigated production to further increase grower confidence and adoption of mungbeans.

This project has collaborated extensively with other GRDC projects in pulse crop agronomy, pathology, entomology and virology to develop and support mungbeans in northern farming systems. Close links with the pulse industry (e.g. Australian Mungbean Association (AMA) and Pulse Australia) have ensured rapid release, uptake of project outcomes and enhanced the support of existing varieties.

DAQ00003 "Integrating Integrated Pest Management for Major Insect Pests of Pulses, Soybeans, and Peanuts" (2002-05)
DAQ00059 "Minimising the impact of pulse diseases in Queensland" (2003-06)
DAQ00060 "Agronomic Solutions for QLD Pulse Growers" (2003-06)
DAQ00086 "Integrated Pest Management for Pulses in Northern Australia" (2005-08)
DAQ00108 "Reducing the Impact of Pulse Diseases in the Northern Region" (2006-09)
DAQ00118 "Epidemiology and management of Tobacco streak virus in sunflower and pulse crops of the northern region"

New varieties Crystal, Satin II$^{\Phi}$ and subsequently the crosses and selections made in this project are to be evaluated in stage two of NMIP (DAQ00128) and will deliver improved productivity, foliar disease resistance and yield stability, increasing grower confidence and adoption of mungbeans.

NMIP will support the Australian industry to achieve its goal of stable annual production of 50,000 tonnes by 2014. Higher volumes and stable mungbean production will create the opportunities for domestic value adding and development of new products that are required to grow the Australian mungbean industry.

Recommendations

1) New varieties. Crystal$^{\Phi}$ is the highest yielding mungbean variety for the large, shiny-seeded market that makes up 80% of Australian production. Crystal offers superior yield and has the most robust grain quality of all lines tested in regional trials between 2003 and 2008. Crystal has the same agronomic type as White Gold$^{\Phi}$ and Emerald$^{\Phi}$. Of the commercial varieties, it has the best available suite of disease resistances. Crystal has performed well under drought and favourable (including irrigated) conditions. In the latter case, Crystal has a marked yield advantage over older varieties such as Emerald and dedicated agronomic management practices are needed to exploit this potential. Crystal was released to growers in

September 2008 and commercial plantings are in the ground, supported by the Australian Mungbean Association's network of accredited mungbean agronomists and a Variety Management Package (VMP) published by Pulse Australia.

Satin II(Φ) is a new mungbean variety for the niche dull-seeded market. This variety will replace the older variety Satin(Φ) which has been out of production due to seed quality no longer meeting export standards. Satin II will reinstate access to these markets and initial production is forecast to be 5,000 tonnes. Export markets could potentially support greater volumes. Satin II adds value to the local industry if international buyers can source different bean types from Australia (e.g. large, small, dull, black, yellow).

3) Agronomic support and plant physiology. The Department of Primary Industries and Fisheries (DPI&F) through the Australian Centre for International Agricultural Research (ACIAR) project "Productivity and Profitability Enhancement of Tropical Pulses in Indonesia and Australia" (SMAR/2007/068) is undertaking field research to develop management practices that will exploit superior yield potential and specific adaptation of new mungbean varieties. The project will also develop the APSIM mungbean model and work to improve our understanding of mungbean physiology.

4) Disease management. Until new varieties with foliar disease resistance become available, NMIP and the Australian Mungbean Association are promoting best practice for control of tan spot and halo blight i.e. use of clean certified seed, rotation of mungbean paddocks and exclusion of infected crops from seed programs. Powdery mildew is not seed borne and fungicide sprays can be used in heavily infected crops. To some extent, the disease can be managed by time of planting. Tobacco streak virus (TSV) emerged as a problem in central Queensland mungbean crops in 2007. Cultural practices have been promoted by industry and offer good control. NMIP will begin screening of germplasm for tobacco streak virus reaction in DAQ00128.

5) New germplasm. In order to access new mungbean germplasm, NMIP needs to link to AVRDC, the World Vegetable Centre, which has the international mandate to conduct mungbean improvement. DAQ00060 imported 18 lines from AVRDC but has been unable to maintain contact due to staff turnover in the mungbean program at AVRDC. With recent correspondence received from AVRDC and contacts developed in the ACIAR project (point 3, above), NMIP is optimistic of re-establishing links to the AVRDC program.

Outcomes

Economic Outcomes

Mungbean is a high value export crop. Five year average production of 39,000 tonnes at a crop value of $700 per tonne is worth $27M per annum to Australia's balance of trade*. Yield improvements of 20% in new varieties released from this project will add $5.2M to the industry at its current size. This is double GRDC's target of 2% annual gain for pulse crops.

Further economic benefits and increased adoption will flow as growers become more confident in the productivity and profitability of mungbeans and realise higher prices from varieties with improved grain quality. Wider adoption of pulses will be supported through close industry links with partner, the Australian Mungbean Association, and packaging of new varieties with best management practice guidelines developed in previous GRDC agronomy projects (DAQ500, DAQ00060).

This will result in more profitable farming systems by increasing sowing opportunities, cash flow, soil nitrogen (N) level, water use efficiency and providing disease breaks in the cereal-based dryland systems of the Northern Region. Irrigated mungbeans also provide high returns per megalitre (gross margin $250-300/ha/ML) and are an attractive option for producers in the current environment of a depressed cotton market, reduced water allocations and the high price of nitrogen fertiliser. New varieties Crystal(Φ) and Satin II(Φ) are ideally suited to irrigated production.

New high yielding varieties that set new benchmarks for market acceptability and greater uptake in irrigated systems will support the Australian industry reach its target of a consistent 50,000 tonnes per annum crop by 2014*.

Environmental Outcomes

Wider adoption of pulse crops by northern growers results in more sustainable farming systems by increasing soil nitrogen levels, more efficient water use and expanded weed control options.

With modest N-fixation, mungbean is best considered a nitrogen-neutral crop. Incorporation in farming systems alleviates depletion of soil nitrogen and reduces reliance on fertiliser products derived from fossil fuels which would otherwise add to

global warming. As a short season crop, mungbeans have a lower water requirement than other spring and summer dryland crop options and provide wider options for weed control and management of herbicide resistance.

Social Outcomes

Mungbean production and the associated processing industries contribute to the economy of regional Queensland, providing 2600 jobs and income for farm labourers, contractors, agronomists, rural merchants, farm supplies and support industries. The marketing requirements of pulse crops create further jobs in the areas of grain handling, packing plants, road and rail transport. Total industry value is $43M and would increase to $54M with new varieties supporting industry growth over the next five years*.

* Figures taken from the Australian Mungbean Association's Industry Profile prepared by Deborah Wilson Consulting Services, August 2008.

Achievements/Benefits

Background

Mungbeans have been grown in Australia for forty years with the first commercial varieties Berken (1975) and Celera (1969) being direct releases from overseas programs. Dedicated breeding for local conditions was undertaken by CSIRO (e.g. project CSP361) and resulted in the release of varieties such as Emerald$^{\Phi}$ (1993), Green Diamond$^{\Phi}$ (1997) and White Gold$^{\Phi}$ (2002). These varieties established the Australian mungbean industry but the narrow genetics of this material have limited yield potential, disease resistance and opportunities to exploit specific adaptation.

This project undertook research in three main areas to address major constraints to growth of the Australian mungbean industry;

i. characterisation of genetic diversity in the Australian mungbean germplasm collection and identification of useful traits
ii. rigorous field evaluation of elite lines developed in CSP361 across mungbean production areas in Queensland and New South Wales
iii. development and implementation of screening protocols to identify resistance to powdery mildew and tan spot.

Outcomes

This project has reinvigorated mungbean breeding in Australia with key achievements being the release of two new varieties with yield gains of 20%. The identification and utilisation of novel genetic diversity will build on these productivity gains with the next generation of disease resistant mungbean varieties stabilising yields and further increasing grower confidence in the crop.

Major achievements

1. Variety release. Two new lines were released with superior yield, agronomy and seed quality. Widespread commercial plantings were made in September 2008. Crystal$^{\Phi}$ (45/52-21) is a large, shiny seeded mungbean, a market that comprises 80% of Australian production with 450 tonnes available in the 2008/09 season. Crystal will replace Delta, White Gold and in time, Emerald as the main variety grown in Australia. Satin II$^{\Phi}$ (3511-32) is a dull-seeded mungbean for niche markets with 22 tonnes available 2008/09. These varieties will add $5.2M to the value of the Australian industry.

2. Commercialisation and industry development. The Australian Mungbean Association (AMA) has been selected as commercial partner with first right of refusal to pipeline varieties in the second stage of project, DAQ00128 (2008-2011). Closer links with industry will ensure that NMIP is producing varieties that meet industry needs and the product will achieve or exceed specifications for export markets. NMIP is working to produce better varieties faster with AMA involved in commercial seed bulk up of promising lines at an earlier stage. In addition, the AMA is best placed to promote new varieties through its extensive network of resellers, agronomists, packing sheds, processors and exporters. NMIP participated in the development of AMA's 2009-14 Strategic Plan and Industry Overview (published August 2008 and available on the AMA website). New varieties are a critical part of the Association's target of stable annual production of 50,000 tonnes by 2014.

3. Regional evaluation trials. Thirty five regional trials encompassing spring and summer plantings, dryland and irrigated environments were completed between 2003 and 2008, evaluating 224 elite breeding and germplasm lines against seven

commercial varieties.

Analyses undertaken by biometricians in the DPI&F pulse team employ spatial analysis to account for variation within each site and also model genotype-environment (GxE) interaction through genetic variance and genetic correlations across sites to produce the most useful ranking of variety yield performance and grouping of environments. These analyses offer much greater resolving and predictive power than traditional fixed models and allow NMIP to identify elite genotypes with broad or specific adaptation.

Analysis of multi environment trials identified that ex-CSIRO germplasm was broadly suited to the Northern Region but had no specific regional or dryland and irrigated adaptation. Mungbean yields ranged from 0 (drought), 1.90 t/ha (dryland) and 2.05 t/ha (irrigated). Across all trials, both Crystal and Satin II yielded 20% higher than the varieties they will replace (Emerald and Satin$^{(b)}$ respectively). Satin II was the highest yielding of all lines in the program. Yields results from trials have been widely extended through GRDC, DPI&F, NSW Department of Primary Industries (NSWDPI, now NSW Industry & Investment), Pulse Australia and Australian Mungbean Association publications, websites, field days and events to support northern growers in their variety selection and planting decisions.

4. Germplasm characterisation. Seven hundred and fifty three lines from the Australian mungbean genetic resource collection were evaluated in central and southern QLD in 2003 and 2004 along with seven commercial varieties. Principal components' analysis described 27 groupings based on agronomic, seed quality and disease resistance descriptors. Four of these groups contained all seven of the commercial varieties indicating a high degree of untapped novel genetic diversity for phenology, plant height, lodging and shattering resistance, as well as foliar disease resistance traits in the germplasm collection.

5. Disease screening. Protocols developed and implemented for powdery mildew and tan spot. Four hundred and fifty seven lines have been screened for reaction to foliar disease. One hundred germplasm lines have been identified with tan spot resistance superior to White Gold in glasshouse screening (0-30% reaction of Berken, the susceptible control). Under field screening, twenty three lines have been identified with powdery mildew resistance superior to the best commercial variety (Emerald).

6. Crossing and program framework. One hundred and eighty eight parent lines (97 germplasm lines, 51 DPI&F crosses, 32 lines ex-CSIRO, and eight commercial varieties) have been used in 582 unique crosses. New diversity from the germplasm collection and disease resistance will broaden the genetic base of NMIP and has laid the foundation for the development of the next generation of mungbean varieties. These will build on productivity gains of Crystal and Satin II to deliver foliar disease resistance, yield stability and further increase grower confidence in mungbeans.

NMIP has employed DPI&F's Plant Breeding Software (PBS) database suite to create efficiencies and ensure the integrity of the program - managing mungbean crossing, pedigrees, seed inventory, trial data and pathology screening results.

A program framework has been developed that lists each cross, pedigree, disease reaction of parents and charts the selection pathway of each individual cross from early generations through to Stage 3 advanced regional evaluation trials.

In addition, NMIP has clearly defined short and medium term goals and developed criteria for key traits.

7. Evaluation of new NMIP developed lines. Two hundred and sixty new lines developed in this project were evaluated in Stage 1 yield trials at Biloela, Hermitage and Narrabri in 2007/08. Predicted yields ranged from 0.7 t/ha to 1.184 t/ha. There were 142 lines with grain yields higher than White Gold and Crystal. Elite lines yielded up to 20% higher than both White Gold and Crystal. Although these results are from three sites in a single season, they indicate promising yield potential in new NMIP material and further yield potential to be exploited with the wider genetic base that has been incorporated in the latest mungbean lines.

New NMIP lines were screened at Hermitage Research Station in 2007/08 and 193 resistant lines were selected from 450 F5 progeny rows grown under tan spot disease pressure.

8. Assessment of grain quality. NMIP has worked closely with the AMA and pulse exporters to ensure that lines developed in the program will meet or exceed export market specifications for grain quality. The program undertakes a suite of qualitative and quantitative grain quality measurements. All lines from yield trials are assessed for size (fifty seed weight), hard-seededness and then subject to visual assessment against commercial varieties by project staff. A subset of elite lines that combine superior yield and grain quality are then assessed by a panel of pulse exporters in blind testing. Both Crystal and

Satin II have been through rigorous quality testing and across five years of regional evaluation, their grain quality was shown to be the most robust of available lines.

The testing procedures in place will ensure that NMIP mungbean varieties provide Australian growers with the best available grain quality with which to compete with hand-harvested crops in international markets.

In addition, NMIP has investigated new options for objective testing. Minolta Colour Reader equipment and colour flat bed scanning have been evaluated but were not cost-effective and did not achieve the subtlety of visual assessment. NMIP will continue to explore these options in association with our commercial partner, the AMA, and is aware that objective methodologies and international trading standards are being developed in other pulse crops.

Benefits to Industry

The 20% yield improvements in Crystal and Satin II equate to gains of 4% per annum over the course of this project. This figure is double GRDC's own key performance indicator for pulse crop yield gain. With average annual mungbean production of 39,000 tonnes at a value of $700 per tonne, these new varieties are worth an extra $5.2M to the Australian industry.

The genetic diversity and superior disease resistances identified and used in this project have laid the foundation for NMIP to deliver the next generation of mungbean varieties in stage 2 (DAQ00128, 2008-2011). Resistance to foliar diseases powdery mildew and tan spot will significantly improve the yield stability of mungbeans, and in combination with the productivity gains of Crystal and Satin II will further increase grower confidence and adoption of mungbeans. In this way NMIP provides essential support to the Australian Mungbean Association's target of achieving stable annual production of 50,000 tonnes by 2014. Higher volumes and stable mungbean production will create the opportunities for domestic value adding and development of new products that are required to grow the Australian mungbean industry.

As the only summer pulse available to dryland growers in the GRDC Northern Region, mungbean is a valuable cash crop, providing a rotation in cereal-based farming systems, is self-sufficient for nitrogen and provides alternative weed control and herbicide resistance options.

Other research

1) DPI&F and GRDC have re-funded the National Mungbean Improvement Program (DAQ00128) from 2008-2011. The second project will build on productivity gains made in DAQ00060 by identifying the next generation of varieties with superior resistance to tan spot, powdery mildew and halo blight will deliver yield stability and further improve grower confidence in mungbeans.

2) DPI&F has begun an international collaborative research project with Indonesia through ACIAR that offers significant leverage to the National Mungbean Improvement Program. 'Productivity and Profitability Enhancement of Tropical Pulses in Indonesia and Australia' SMAR/2007/068 will initially run from 2008-2010. The project has a strong focus on adaptive research and will look to apply new varieties and cost-effective management practices using farmer-participatory adaptive research approaches in both countries.

For Australia, the project in particular will look at -

a. agronomic trials to develop best management practice guidelines for new, high yielding mungbean varieties such as Crystal$^{\Phi}$, Satin II$^{\Phi}$ and future releases through NMIP
b. using crop modelling applications to understand physiology and identify opportunities for yield gain and stability in mungbeans
c. improving links and potential for germplasm exchange between NMIP and overseas breeding programs such as Indonesian Legume and Tuber Research Institute (ILETRI) and the World Vegetable Centre (AVRDC) which is the world's main centre for mungbean improvement.

3) Recent correspondence from AVRDC, the World Vegetable Centre indicated it is planning to re-establish its mungbean program with new leadership and a new breeder. NMIP will explore opportunities for collaborative research and germplasm exchange.

Intellectual property summary

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

The Australian Mungbean Association successfully tendered for the commercial licence to Crystal$^{\Phi}$.

The Association subsequently won an open tender process for commercialisation rights (on first right of refusal basis) to germplasm developed by NMIP for the period 2008-2011. Satin II$^{\Phi}$ is the first variety to be released under the new commercialisation agreement.