New Australian soybean variety Richmond⊕ outperforms traditional varieties, Asgrow A6785 and Soya 791

Natalie Moore[1], Sam Blanch[1], Nathan Ensbey[1], Andrew James[2] and Stephen Morris[3]

[1]NSW DPI, Grafton

[2]CSIRO, Brisbane

[3]NSW DPI, Wollongbar

Agronomy

Key findings

- Richmond⊕ produced an average yield 7% higher than Soya 791 in advanced variety evaluations at early sowing dates (first week in December) over six seasons.
- Richmond⊕ produced an average yield 7.7% higher than Asgrow A6785 in advanced variety evaluations at late sowing dates (mid January) over eight seasons.
- In on-farm experiments, Richmond⊕ yielded 16% higher than Soya 791 in a wide-row system on the northern slopes, and 7% higher than Asgrow A6785 in a narrow-row coastal system.
- In addition to higher yield potential, Richmond⊕ is tolerant to lodging and pre-harvest weather damage, has clean leaf drop, large seed size and high protein, and is resistant to powdery mildew. This combination of traits provides greater crop security and a full range of market options for growers, and high quality grain for buyers and processors.

Introduction

The Australian Soybean Breeding Program develops varieties for diverse production environments across a 3000 km range from the Atherton Tablelands in far north Queensland (Latitude 17.2661°S, Longitude 145.4859°E) to the Riverina in southern New South Wales (Latitude 29.7503°S, Longitude 120.5530°E).

The program focuses on strategies to broaden the range of adaptation of new cultivars (James & Lawn, 2011), and to complete the transition from traditional dark hilum types that supply lower-value crushing markets to clear hilum types with the grain qualities required for human consumption markets. Advances in yield, disease resistance and other agronomic traits are also targeted.

Primarily, a single seed descent method is used to advance populations to the F4 level of inbreeding. Varieties from the Australian Soybean Breeding Program are not genetically modified (non-GMO). Regional evaluation and selection for environmental adaptation and specific regional traits is carried out across a wide range of environments in the target production regions. Typically, new soybean lines progress through stages of small-scale replicated evaluations for 6–8 seasons, with processors conducting small-scale grain evaluations. Advanced lines then complete evaluation in replicated on-farm experiments before commercial licensing and release.

This paper summarises data from multi-season replicated evaluations and on-farm experiments of Richmond⊕, a new variety for production in northern New South Wales.

Site details

Experiment 1. Multi-season advanced variety evaluation (Stage 2–3 equivalent)

Location	NSW DPI, Grafton
Soil type and nutrition	The experiment site was located on deep, well-drained river terrace soil with an acidic pH (4.9_{Ca}). The acidic pH of this site was specifically chosen as it enables soybean varieties to be screened for tolerance to acidic soils and manganese toxicity, which is associated with acidic cropping soils. Nutrient application for soybean evaluations at this site was based on soil test results. Potassium and sulfur were applied before sowing by broadcasting sulfate of potash at a rate of 130 kg/ha.

Phosphorus, molybdenum and calcium were applied as single Mo-Super phosphate fertiliser over the row at planting at 280 kg/ha. No other starter fertiliser was used. Group H soybean inoculant (formerly as the Becker Underwood® liquid and recently as a peat formulation) was used to inoculate all seed every season.

Rainfall

Average in-crop rainfall for this site for the seasons reported in this paper was 533 mm for early-sown experiments and 436 mm for late sown experiments.

Design and data analysis

Soybean evaluation experiments were designed and analysed by a biometrician using the principles of spatial analysis of field experiments outlined in Gilmour, Cullis & Verbyla, (1997). Estimates of pre-harvest and harvest traits for each variety were obtained after accounting for natural and extraneous sources of variation Gilmour, Cullis & Verbyla, (1997). Various commercial varieties were included in all experiments as benchmarks for particular traits. Each experiment was comprised of four replicates, which were used to collect data on all traits, except for weathering tolerance, which was replicated nine times. Weathering tolerance was measured by the amount of weather-damaged grain after a period of exposure to simulated rainfall (usually five days and two hours at temperatures of 19–22 °C) in a weathering facility. Data analysis was undertaken using R for windows and comparisons made via a general mixed linear model approach using the asreml package (Butler et al., 2009; R Development Core Team 2016).

Sowing date

Early variety evaluation experiments were sown between 2 December and 5 December each year. Late variety evaluation experiments were sown between the 11 January and 13 January each year.

Plant population

An established plant population of 360 000 plants/ha was used with a row spacing of 30 cm.

Weed management

Weed management typically included a post-plant pre-emergent application of glyphosate at a rate of 1 L/ha with Dual Gold® (960 g/L S-metolachlor) at 1 L/ha. Spinnaker® 700 WDG (700 g/kg imazethapyr) was applied 2–3 weeks after emergence at 100 g/ha. Verdict® 520 (520 g/L haloxyfop present as the haloxyfop-R methyl ester) was only applied at 150 mL/ha if required before canopy closure.

Insect management

Bug checking was conducted at regular intervals and an integrated pest management approach followed to conserve as many beneficial insects as possible. The following insecticides were used if required (note that not all insecticides were applied to all experiments in all seasons):

- ViVUS MAX® (5 × 109 nucleopolyhedro virus of *Helicoverpa armigera* per mL) at 150 mL/ha to control *Helicoverpa*
- Dipel SC® (*Bacillus thuringiensis* subsp *kurstaki* ABTS-351) at 4 L/ha to control soybean looper
- Pirimor WG® (pirimicarb 500 g/kg) at 500 g/ha to control only widespread or severe infestations of soybean aphid
- Wizard 18® (abamectin 18 g/L) at 300 mL/ha to control mites
- Altacor® (350 g/kg chlorantraniliprole) at 70 g/ha to control soybean stemfly
- Decis Options® (deltamethrin 27.5 g/L) at 2.5 L/ha to control pod-sucking bugs such as green vegetable bug, red-banded shield bug and *Riptortis*.

Disease management	If required, Folicur® 430SC (430 g/L tebuconazol) was applied at 245 mL/ha to manage soybean leaf rust.
Harvest date	The abovementioned sowing dates typically resulted in the harvest of early-sown variety experiments in the first half of April and late sown experiments in the second half of April to early May.

Experiment 2. On-farm evaluation Oakwood, northern slopes NSW

Location	'Narellan', Oakwood, NSW
Co-operator	Brad Schwark
Soil type	Black self-mulching clay soil with a neutral pH (6.8–7.0).
Rainfall	The total rainfall from the beginning of December 2012 to the end of April 2013 was 420 mm.
Design and data analysis	The design consisted of a randomised block layout, with two replicates of each variety; each plot was 0.168 ha (8 m wide × 210 m long). The entire plot was harvested and weighed to determine grain yield.
Sowing date	19 December 2012
Plant population	A wide row spacing of 1 m was used in this dryland experiment, with a target plant population of 180,000 plants/ha (Figure 1).
Harvest date	April 2013

Experiment 3. On-farm evaluation Harwood, North Coast NSW

Location	Watts Lane, Harwood, North Coast NSW
Co-operator	Tim McMahon
Soil type and nutrition	The paddock consisted of riverbank alluvial soil, classified as a deep, brown clay loam. It was a dryland (rain-fed) soybean production system in rotation with sugar cane. The farmer's practice for paddock preparation was followed for this experiment, which was conventional cultivation using an offset disc, ripper and rotary hoe. DAP fertiliser was applied as per the farmer's normal practice at 57 kg/ha at planting.
Rainfall	Total in crop rainfall was 414 mm with a drier than normal period during late January and February.
Design and data analysis	The experiment was designed with two plots of each variety per replicate, with three replications running the full length of the paddock in a randomised design. Each plot was 9 m wide (three planter widths) and 340 m long, with a 1 m gap to separate each plot for ease of harvesting. The harvested area to determine grain yield was 0.306 ha for each plot.
Sowing date	7 December 2015

Plant population	Soybean was sown into flat ground as per the farmer's practice using a Duncan model 3 m combine seeder (15 cm row spacing). Trimble GPS guidance was used for planting. The targeted plant population was 320,000 plants/ha, which was achieved with an even plant population established across the site.
Weed management	Dual Gold® (960 g/L S-metolachlor) at 1.4 L/ha was applied post-planting pre-emergence and Spinnaker® 700 WDG (700 g/kg imazethapyr) at 100 g/ha was applied before canopy closure.
Insect management	Bug checking was conducted at regular intervals to determine the identity of pest and beneficial insects in the crop. In-crop insect management consisted of one application of: • ViVus MAX® (5 × 109 nucleopolyhedro virus of *Helicoverpa armigera*/mL) at 150 mL/ha to control *Helicoverpa* early in the crop cycle • Dipel® SC (*Bacillus thuringiensis* subsp. *kurstaki* ABTS-351) at 4 L/ha to control soybean looper • Steward® EC via spray (150 g/L Indoxacarb) at 400 mL/ha to control an outbreak of *Helicoverpa* later in the crop cycle.
Disease management	None required.
Harvest date	April 2016

Treatments

Experiment 1. Varieties

Richmond⟨PBR⟩, Moonbi⟨PBR⟩, Zeus, Soya 791

Experiment 2. Varieties

Richmond⟨PBR⟩, Moonbi⟨PBR⟩, Soya791

Experiment 3. Varieties

Richmond⟨PBR⟩, Asgrow A6785

Results

Experiment 1. Multi-season advanced variety evaluation experiments (S2–3 equivalent) at early and late sowing dates

Average results for yield and important plant characteristics are collated in tables 1 and 2 for the early (first week of December) and late (mid January) sowing windows respectively. Lodging scores are provided for early-sown experiments only, as lodging is not usually severe in later-sown soybean crops. Differences between averages that exceed the estimate of least significant difference (l.s.d.) can be regarded as statistically important at the 5% critical value ($P<0.05$).

Table 1. Analysed data summary of soybean variety evaluations, early-sowing window (first week December) for six seasons between 2008–09 and 2014–15, NSW DPI Grafton.

Variety	Grain yield (t/ha)[◊]	Grain protein (% dry matter)	Weathering tolerance (% unweathered grain)	Seed size (g/100 seed)[◊]	Seed size (seeds/kg)	Maturity (P95/R8)[§]	Plant height (cm)	Lodging[¤]
Richmond[Φ]	4.6	42.3	73.7	22.1	4532	131	85	1.5
Moonbi[Φ]	4.1	42.6	72.5	21.8	4580	121	91	1.6
Zeus[€]	–	–	84.1	–	–	–	–	–
Soya 791[¥]	4.3	41.8	53.2	19.2	5217	139	99	2.9
l.s.d.	0.4	1.3	8.6	1.4	–	1.7	7.0	0.7

€ Zeus is included as the benchmark for highest weathering tolerance in all experiments
¥ Soya 791 is included as the benchmark for lowest weathering tolerance in early sown experiments
◊ at 12% moisture
§ days after sowing to reach harvest maturity
¤ lodging score 1 = nil up to 5 = severe

Table 2. Analysed data summary of soybean variety evaluations, late sowing window (mid January) for eight seasons between 2006–07 and 2015–16, NSW DPI Grafton.

Variety	Grain yield (t/ha)[◊]	Grain protein (% dry matter)	Weathering tolerance (% unweathered grain)	Seed size (g/100 seed)[◊]	Seed size (seeds/kg)	Maturity (P95/R8)[§]	Plant height (cm)
Richmond[Φ]	4.3	42.4	77.5	22.0	4540	118	59
Bunya[Φ]	4.1	40.4	73.0	24.8	4040	116	71
Hayman[Φ]	4.1	43.8	79.6	23.5	4260	122	94
Asgrow A6785	4.0	39.4	77.7	15.3	6540	111	77
Zeus[€]	–	–	86.4	–	–	–	–
Warrigal[¥]	3.9	41.0	57.9	19.7	5070	118	87
l.s.d.	0.35	1.1	6.4	1.0		3.2	7.7

€ Zeus is included as the benchmark for highest weathering tolerance in all experiments
¥ Warrigal is included as the benchmark for lowest weathering tolerance in late sown experiments
◊ at 12% moisture
§ days after sowing to reach harvest maturity

Experiment 2. On-farm evaluation,Oakwood, northern slopes NSW

Richmond[Φ] produced an additional 0.42 t/ha or 16% more grain than Soya 791, with similar days to maturity, less lodging and cleaner leaf drop, which improved the ease of harvest according to the grower. At the time this experiment was conducted, the End Point Royalty (EPR) for new soybean varieties was $12/t. In 2017 it was reduced to $6/t. Both rates are used in the economic comparison for the experiment results presented in Table 3. A conservative grain price of $500/t is used.

Table 3. Grain yield and economic comparison of a soybean variety evaluation on-farm experiment conducted at Oakwood, NSW, in summer 2012-2013. Data represents averages of two replicates.

Variety	Grain yield (t/ha)	Yield increase compared with Soya 791 (%)	Gross income from grain less EPR of $12/t ($/ha)	Gross income from grain less EPR of $6/t ($/ha)
Richmond[Φ]	3.07	16	1498	1517
Moonbi[Φ]	2.92	10	1425	1442
Soya 791	2.65	–	1325	1325

Note: Grain price = $500/t. EPR deductions are applied to Richmond[Φ] and Moonbi[Φ] only.

Figure 1. Richmond(d) (3.07 t/ha) out-yielded Soya 791 (2.65 t/ha) by 16% in this wide-row spacing (1 m) dryland experiment at Brad Schwark's property near Oakwood on the northern slopes of NSW.

Experiment 3. On-farm evaluation Harwood, North Coast NSW

Richmond(d) produced an additional 0.27 t/ha or 7% more grain than Asgrow A6785, with similar days to maturity, much less lodging and cleaner leaf drop than A6785. Tolerance to lodging and pre-harvest weathering are important traits to avoid fungal diseases and maintain grain quality in coastal production environments. Two rates are used for EPR in the economic comparison of the experiment results due to a recent change in pricing structure (Table 4). A premium edible grade price of $612/t is used.

Table 4. Grain yield and economic comparison of an on-farm soybean variety evaluation experiment conducted near Harwood, NSW, in summer 2015–2016. Data represent averages of three replicates.

Variety	Grain yield (t/ha)	Yield increase compared with A6785 (%)	Peak shoot biomass (t dry matter/ha)	Gross income from grain less EPR of $12/t ($/ha)	Gross income from grain less EPR of $6/t ($/ha)
Richmond(d)	4.19	7	8.02	2514	2539
Asgrow A6785	3.92	–	9.39	2399	2399

Note: Grain price = $612/t which is premium edible grade. EPR deduction is applied to Richmond(d) only.

Conclusions

The Australian soybean variety Richmond(d) produces large grain (22 g/100 seed) with a clear hilum and high levels of protein (42% dry matter), which is suitable for all markets including human consumption and export. The traditional variety, Asgrow A6785, has small grain (<16 g/100 seed) with a brown hilum and protein levels less than 40%, which limits the range of markets to which it is suited. The traditional variety, Soya 791, has average sized grain

(19 g/100 seed) with a light brown hilum and high levels of protein (42%). Both A6785 and Soya 791 are prone to excessive vegetative growth, especially at an early sowing date. However, this is not necessarily converted into grain yield as demonstrated in the on-farm experiment at Harwood.

Richmond[ϕ] is superior to A6785 and Soya 791 in terms of grain yield, tolerance to lodging, tolerance to pre-harvest weathering and clean leaf drop. Richmond[ϕ] offers a summer legume option with high yield and high grain quality for early, mid or late sowing windows in northern New South Wales. The variety's performance was not adversely affected by the range of soil types and farming systems reported in this paper; it was superior to A6785 and Soya 791 in all situations. Richmond[ϕ] is resistant to powdery mildew. This package of traits represents a significant advance in soybean varieties for the North Coast, Tablelands, Northern Slopes and Liverpool Plains production regions of northern New South Wales.

The results of the on-farm experiment of Richmond[ϕ] versus Soya 791 in a wide spacing, single row system at Oakwood demonstrates the variety's ability to compensate for wide rows and the associated lower plant populations in dryland systems. Row spacing and plant population interactions of new soybean and mungbean varieties are being investigated in the current NSW DPI–GRDC project DAN00171.

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