Why grain legume rotations work in sugar-based farming systems

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Take home message

- Embrace legume rotations: Incorporating legume crops, such as peanuts and soybeans, into your sugarcane farming system can significantly enhance productivity and soil health, potentially improving sugarcane yield, with the potential to reduce nitrogen fertiliser input in the plant cane crop
- Optimize soil nutrition: Conduct soil tests to inform your legume crop nutrition strategy. Address any deficiencies – particularly soil pH, phosphorus, potassium, sulfur and micronutrients – to maximise legume and subsequent sugarcane productivity. A targeted nutrition program can boost legume yields significantly, resulting in improved overall system performance. Be aware of the impact of starting soil nitrate levels on the establishment of functional nodules and associated nitrogen fixation
- Manage foliar diseases: Be proactive in monitoring and managing foliar diseases in soybeans. Disease resistance should be a critical focus of the soybean breeding program
- Leverage economic benefits: Recognise the financial advantages of legume rotations as a diversified income stream in conjunction with sugarcane. Beyond improving soil health and reducing fertiliser costs, these crops can provide an additional income stream if grown with the objective of obtaining a high-quality grain yield.

Background

Research conducted in the early 2000's as part of the Sugar Yield Decline Joint Venture, highlighted four key principles to improve the sustainability of the Australian sugar industry. These were:

i. legume rotations
ii. organic matter retention
iii. reduced tillage and
iv. controlled traffic.

Of these, the most widely adopted has been the inclusion of a legume rotation crop between sugarcane crop cycles. Legume rotational crops have been shown to improve sugarcane productivity, reduce populations of plant-parasitic nematodes, and enable nitrogen fertiliser inputs to be reduced in the plant cane crop. Legume crop residues also provide short term soil cover, which helps reduce soil erosion while also contributing organic matter to the soil. Legume rotations have become an important component of a sustainable farming system in most sugarcane growing regions; however, the system differs between regions. In the wet tropics, legumes are mostly grown as a green manure cover crop over the wet season, whereas in the southern region, conditions enable legume grain to be harvested, providing an opportunity for growers to diversify farm income.

Cane response to rotations

Research conducted as part of the combined GRDC/DAF Growers Solution project and SRA/DAF Southern Sugar Solutions project, highlighted that peanut and soybean rotations improved the productivity of the subsequent plant cane crop by 35.7% and 49.4% respectively compared to a plough-out re-plant (cane monoculture) in Bundaberg.

Whereas a large, replicated strip trial conducted in the Burdekin demonstrated that despite a 44-day delay in cane planting due to growing peanut and soybean crops through to maturity, there was no cane yield reduction when compared to a bare fallow with yields of 152.7, 143.2, and 153.2 tonnes cane/ha respectively. Furthermore, the same experiment highlighted that nitrogenous fertiliser reductions of 65kg N/ha following peanuts and 55kg N/ha following soybean, did not significantly (P=0.05) reduce sugarcane yield. The same cane yield combined with the income from the legume crop increased gross margin by $2,737/ha for the peanut rotation and $1,641 for the soybean rotation (without considering the additional potential fertiliser input cost reduction). However, it should be noted that not all soils are suited to peanut production.

Nutrition

Optimising legume production relies on getting many things right and crop nutrition is no exception. Research conducted in Bundaberg highlighted the value of soil testing and basing a crop nutrition program on those results, boosting soybean yield by 460kg/ha or 12% over the control plot yield (3.79t/ha), Figure 1. The soil test identified that whilst soil pH was fine, sulphate sulphur was low at 1.8 mg/kg; phosphorus (Colwell P) was low at 8.3 mg/kg; potassium was low at 0.03 meq/100g; and micronutrients zinc and boron were sub-optimal.

To address the nutrition constraints the *Bell/Halpin Rec* treatment included: zinc heptahydrate applied at a rate to supply 10kg Zn/ha; sodium molybdate at 500g/ha and Solubor® (20.5% boron) at 2kg/ha, sprayed onto the soil surface prior to the last working. LegumeMax® (4% nitrogen, 9% phosphorus, 19% potassium, 5% sulphur) fertiliser was also applied at 260kg/ha at planting in bands 5cm below and beside the planting drill. Other treatments included *Control* where no fertiliser was applied; a treatment where only potassium was applied (50kg K/ha) and a *Supra-optimal* treatment whereby crop nutrition was based on the *Bell/Halpin Rec* plus fortnightly sap testing to identify constraints.

This trial highlighted that using petiole sap testing regime did not offer a crop productivity boost over and above a nutritional program based on a soil test (*Bell/Halpin Recs* treatment).

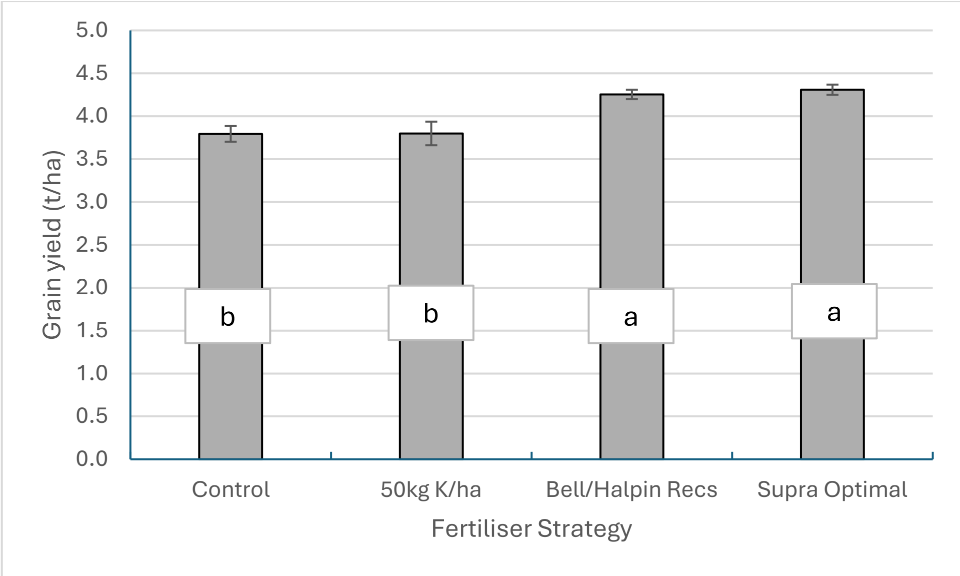

Figure 1. The impact of fertiliser strategy on soybean grain yield. Treatments with the same letter are NOT statistically different (P=0.05). Error bars are +/- standard error of treatment mean.

Other research focused on evaluating in-crop nitrogenous fertiliser applications as a mechanism to increase soybean protein concentration and/or protein yield. Data from this one field trial demonstrated that the application of 66kg N/ha applied (as urea) to a soybean crop in the R4 to R6 growth stage significantly improved dry matter production, grain yield and protein yield by 9.5%, 14.6% (Figure 2) and 22.7% respectively.

However, this trial was established in a field with a long history of peanut production. Nodulation of the soybean crop was assessed in the nil nitrogen plots at the R2 crop growth stage and the ratings ranged from none to poor. Soil testing prior to crop establishment identified a soil nitrate nitrogen concentration of 19 mg/kg and ammonium nitrogen concentration of 7 mg/kg. These values are high enough to hinder but not completely stop nodulation (Dr Nikki Seymour *pers. comm.*).

On the other hand, a trial conducted following sugarcane (with depleted soil nitrogen status) where the soybean crop was well nodulated, demonstrated that the addition of in-crop nitrogen had no effect on grain yield (P=0.355) (Figure 3). Similarly, there was no significant impact on soybean grain nitrogen concentration, with values ranging from 7.09%N for the zero N control treatment (N0) to 7.14%N for the 99kgN/ha treatment. This highlights the impact of starting soil nitrate levels on the establishment of functional nodules and associated nitrogen fixation. Growers need to be mindful of crop rotation and sequencing if they want to maximise legume nitrogen fixation.

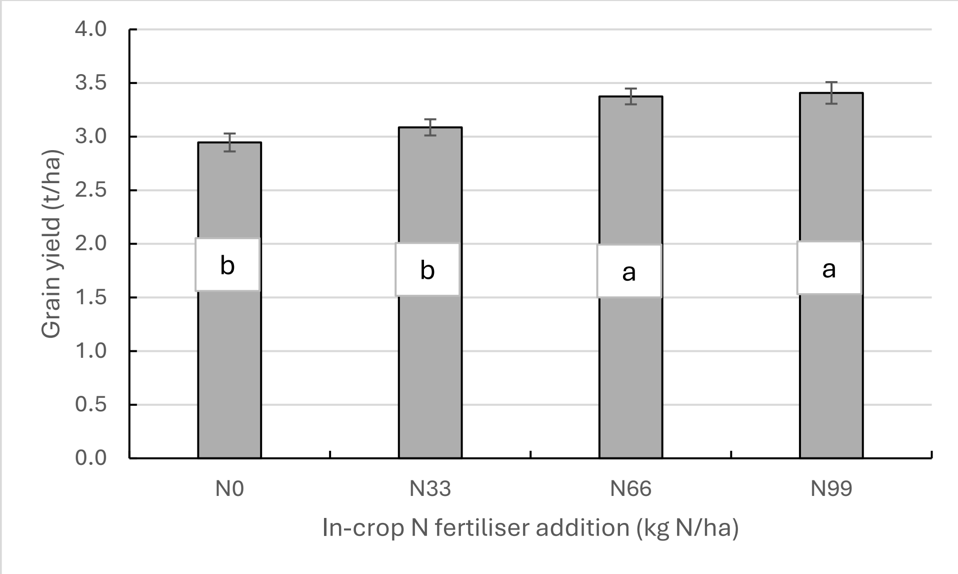

Figure 2. The effect of in-crop nitrogenous fertiliser application on soybean grain yield (cv Kuranda⒫). Treatments with the same letter are NOT statistically different (P=0.05). Error bars are +/- standard error of treatment mean.

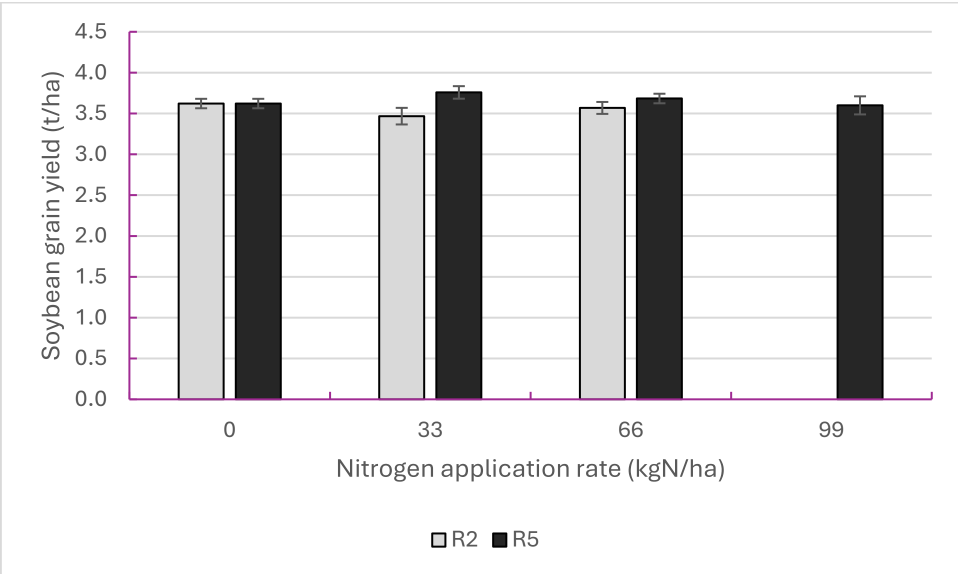

Figure 3. The effect of in-crop nitrogen application rate and timing of application on soybean grain yield of a well nodulated crop (cv Hayman⒫). Error bars are +/- standard error of treatment mean.

Foliar disease management

There has been increased incidence of foliar diseases like target spot and Anthracnose having an impact of productivity of soybeans grown in coastal environments since the 2020/21 summer crop. The opportunity was taken to evaluate the effect of fungicide applications on soybean yield in the 2022/23 season. Treatments are listed in table 1.

Table 1. Treatment list for the Bundaberg soybean fungicide trial 2022/23.

Treatment##	Active Ingredient Conc.	Application rate	
Control	Nil	Nil	
Prosaro® 420 SC#	210 g/L prothioconazole and 210 g/L tebuconazole	@ 400 mL/ha twice in crop	
Veritas® Opti ###	222 g/L azoxystrobin and 370 g/L tebuconazole	@ 400 mL/ha twice in crop	permit PER92329 (expires April 2027)

Prosaro is registered in soybeans for the control of Sclerotinia stem rot and rust, and for the suppression of frogeye leaf spot and cercospora leaf blight, but has no label claim for control or suppression of either target spot or Anthracnose. The specified rate relates to control of Sclerotinia stem rot.

Note that chlorothalonil was also tested in this trial under permit PER 92374 which expired in September 2024. Thus as the use of chlorothalonil in soybean is no longer supported by label or permit, data has not been presented.

Permit PER92329 specifies the use of Veritas Opti in soybeans for the control of Anthracnose only. No other diseases are specified. Results from this one experiment demonstrated that crop protectants Prosaro® and Veritas® Opti significantly improved grain yield by 10% and 14.7% respectively, compared to the untreated control, when applied to soybean variety Hayman.

In the Burdekin, a soybean variety by fungicide trial was conducted in 2022/23. The treatments were No fungicide; and Veritas® Opti (ac azoxystrobin 222 g/L and tebuconazole 370 g/L) @ 400 mL/ha twice in crop (permit PER92329). Unfortunately, the trial was compromised with an inadvertent herbicide application to some of the treatments. Notwithstanding, there appears to be a similar trend with the application of Veritas® Opti improving productivity in that season.

However, a repeat of the Bundaberg trial was conducted in the 2023/24 season and there was no impact of fungicide application on productivity (P=0.498) with the trial having a mean yield of 3.3t/ha.

This research suggests that foliar disease poses a productivity constraint to soybean production in coastal farming systems in some seasons. The ultimate goal would be that foliar disease resistance be made a priority in the soybean breeding program. However, until such efforts are realised, work needs is needed to develop a better understanding of foliar diseases so that a management program for coastal soybean production can be developed.

Conclusion

Grain legumes and soybean in particular, are a well-suited rotation crop in sugar-based farming systems. They not only address adverse biology that can dominate a sugarcane monoculture, legumes also provide an additional income stream / income diversification and offer the potential to reduce nitrogen fertiliser inputs in the plant cane cropping phase.

Growers should soil test prior to growing grain legume crops to maximise yield potential and be mindful of factors that influence nitrogen fixation if they want to realise the full nitrogen benefit.

Research is required to develop foliar disease management decision support tools to maximise soybean productivity until such time as foliar disease resistance (over and above rust and powdery mildew) is available in commercial soybean varieties.

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