SRA Grower Group Innovation Project Final Report

Ameliorating clay sub soils to improve crop yields

SRA Project Code	**2013/072 (GGP072)**		
Project Title	Ameliorating clay sub soils to improve crop yields		
Group Name	The DAG Group		
Chief Investigator(s)	Glen Grohn		
Project Objectives	(a) Complete analysis of soil samples from existing proof of concept replicated trial. (b) Use the soil tests to determine what has changed in the clay to produce the yield response (c) Complete the construction of the machine (d) Take soil tests of the clay sub soil on potential demonstration sites (e) Apply the deep ripping, deep rip compost and deep rip mill mud to the demonstration sites (f) Hold field days at two demonstration sites advertised via radio interview (g) Plant the demo sites with sugarcane (h) Complete economic feasibility study of the new process (i) Publish newspaper and magazine articles (j) Final Report prepared using the template from the SRA website		
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Reason for delay			
Milestone Title	Final Report		
Success in achieving the objectives	☒ Completely Achieved ☐ Partially Achieved ☐ Not Achieved		
SRA measures of success for key focus area			

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PART A

Section 1: Executive Summary

There are large areas of sodic duplex clay soils across the Australian sugarcane industry. Often, the sub soil on these soils is not conducive to sugarcane root growth and as a result the sugarcane roots can only explore the top 250-350mm of soil. This reduces the amount of water and nutrients available to the crop and reduces yield potential accordingly. An existing proof of concept trial showed that the sub soil can be ameliorated with organic amendments resulting in a 10% yield increase over a control. In this trial, the ameliorant was applied with a rudimentary applicator that was unsuitable for commercial use. Three questions were raised from this trial; firstly, what happened to the sub soil to produce this yield response, secondly can a commercially suitable applicator be constructed as they cannot be purchased from machinery manufacturers, and thirdly is sub soil amelioration a commercially feasible practice on a sugarcane farm? Through this project the DAG Group sought to answer these questions by testing the sub soil on the proof of concept trials for physical and chemical changes, constructing a prototype commercial applicator and establishing commercial sized trials.

To test the sub soil on the proof of concept, trial soil samples were collected in November 2014 after harvest of the 2nd ratoon crop. This was 3 years after the ameliorants were applied in August 2011. They were analysed at the Queensland Department of Natural Resources and Mines soil laboratory in Brisbane.

The DAG Group has a long history of successfully designing and building a range of novel machinery by utilising a combination of innate ingenuity and formal trade qualifications. These machines are not designed on paper with a detailed blueprint. They manifest from the group's imagination and sketches on the workshop floor. To an engineer this process sounds haphazard, however the end result is far from that. The machinery constructed is functional, high quality, reliable and ingenious, so the group was confident they could build the prototype sub soil applicator as required by the project.

To assess the commercial feasibility of ameliorating sodic duplex clay soil commercial scale trials were established in Maryborough and Bundaberg. These trials used different ameliorants on different soil types and will be harvested in 2016.

This project produced beneficial outcomes that represent a lucrative return on investment for Sugar Research Australia and the sugarcane industry. Firstly, it was found that organic ameliorants significantly altered the soil chemistry to produce a sub soil environment that is more conducive to sugarcane root growth. Secondly, a machine capable of applying 10-20 tonnes/ha of organic ameliorants up to 400mm deep into a clay sub soil was successfully constructed. Thirdly, several commercial sized demonstration trials were established in Maryborough and Bundaberg. These trials will improve industry knowledge on the benefits and applicability of sub soil amelioration and also promote the practice to the wider industry.

This project has resulted in the commercial adoption of sub soil amelioration by members of the DAG Group. This will improve the base line yield on their sodic duplex clay soil by 10%. There are large areas of sodic duplex clay soils elsewhere in sugarcane growing districts, so there is potential for a considerable increase in industry wide productivity. This potential is reflected in the significant attention that the project has generated throughout southern Queensland. The project also developed the mechanical principles for the machinery that is needed to adopt this practice.

Further work is required to tailor the ameliorant for different soil types and to determine if amelioration is required every crop cycle. A decision making tool is also required to identify sugarcane fields where there is potential for sub soil amelioration.

Section 2: Background

Project rationale

More than 30% of the soil in the Maryborough cane supply area is sodic duplex clay. This soil has an A-horizon (top soil) that usually has chemical and physical characteristics that are conducive to the growth of sugarcane roots. The B-horizon on these soils occurs at a depth of 250-350mm and is a clay, or clay loam that is acid and often has high levels of exchangeable aluminium, manganese and chlorine which make it chemically inhibitive to sugarcane root growth. Additionally there are often high levels of sodium and/or magnesium in the B-horizon. These cations disperse the clay particles thereby making the clay layer physically impermeable to root growth. These soil attributes create an environment where sugarcane roots only explore the A-horizon, effectively limiting the available nutrient and soil moisture resources to the top 250-350mm of soil. In other words, these soils have a sub soil constraint.

These soils and their associated problems are widespread in Australia so it is unsurprising that there has been recent research on ameliorating sub soil constraints to improve agricultural productivity. In southern Australia the B-horizon on sodic duplex clays has been ameliorated with organic amendments such as chicken manure and pelletised lucerne hay with remarkable positive yield effects in trials with wheat and canola. Following these results in southern Australia we postulated that we could ameliorate sodic duplex clay soils in Maryborough and achieve positive yield results in sugarcane. Accordingly, a "proof of concept trial" was established using a rudimentary sub soil applicator at the Cronau farm in the Yera district of Maryborough.

The trial showed a positive yield response to sub soil amelioration and as a result the Cronau family decided to commercialise the practice on their farm. To do this they needed a sub soil applicator to set up commercial scale trials.

There are no commercially manufactured machines that are designed to apply organic amendments into the clay B-horizon so a completely novel machine is needed. Finding a solution to this impediment to commercial practice by designing and building a prototype commercial applicator was the basis and justification for this project.

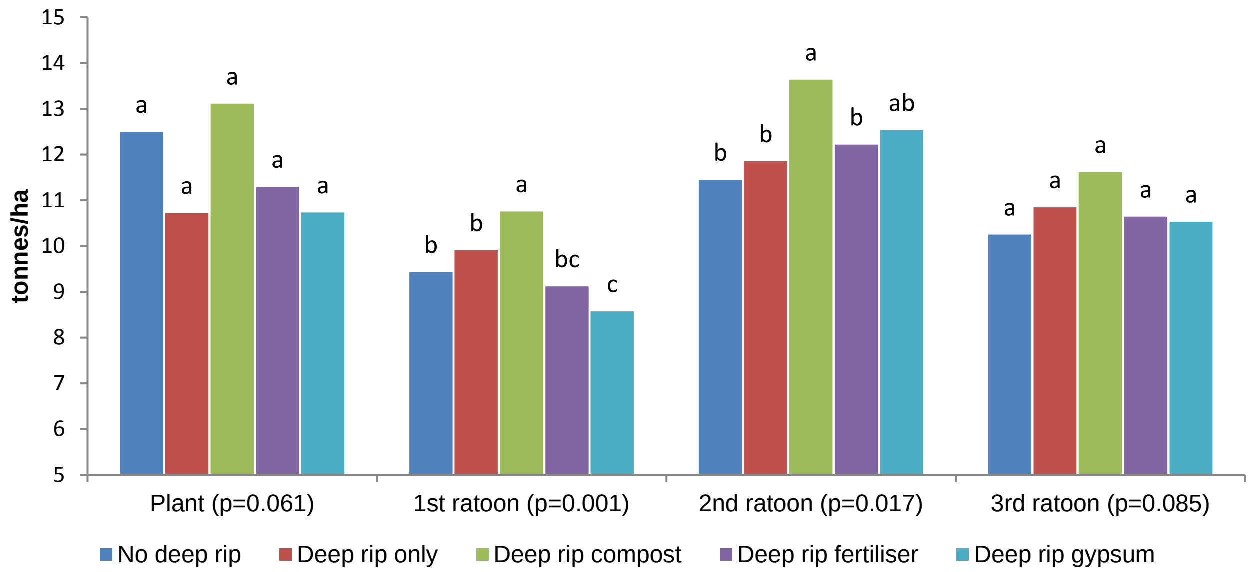
Proof of concept trial

This project also involved work on the existing proof of concept trial. The trial was set out in a latin square plot design with four 1.65m wide and 30m long sugarcane rows in each plot. There were five treatments that were designed to identify the causal factor should a positive yield response to amelioration occur (Table 1). The ameliorants were applied to the sub soil with a modified deep ripper with a 10 cm diameter tube attached to the back of the ripper tine. A steel box was attached to the ripper above the tine and the ameliorants were deposited into the tube with shovels.

Treatment	Description	Reason for treatment
No deep ripping	Standard management practices.	Control
Deep rip only	Ripping before planting with the deep applicator along the plant line	Determine if any yield response was from deep ripping
Deep rip compost	Applying compost at 10 dry tonnes/ha into the B - horizon	Determine if any yield response was from applying an organic ameliorant to the B - horizon
Deep rip fertiliser	Nutritional composition of the compost calculated and applied as mineral fertiliser into the B - horizon	Determine if any yield response was from the minerals present in the compost
Deep rip gypsum	Gypsum was applied at 10 tonnes/ha into the B - horizon	Determine if any yield response was from the effects of calcium in the soil solution

Table 1-Treatments applied and the reason for the treatment.

The yield results of the proof of concept trial are shown in Figure .1, the compost ameliorant treatments yielded significantly higher than other treatments in the 1st and 2nd ratoon crops.



Section 3: Outputs and Achievement of Project Objectives

Complete analysis of soil samples from existing proof of concept replicated trial

The soil samples were collected in November 2014 after harvest of the 2nd ratoon crop, this was 3 years after the ameliorants were applied in August 2011. Two cores were taken from each plot from the clay immediately below the ameliorant treatment. The two cores from each plot were mixed, and a subsample was sent to the Queensland Department of Natural Resources and mines for analysis.

Use the soil tests to determine what has changed in the clay to produce the yield response

The table below (Table.2) shows the relevant results from the soil tests.

Attribute or Analyte	No deep ripping	Deep rip only	Deep rip compost	Deep rip fertiliser	Deep rip gypsum	P	LSD
Clay content (%)	42.1	43.1	43.4	41.1	44.6	0.88	ns
Silt content (%)	19.7	18.3	16.8	19.1	17.9	0.81	ns
pH (H_2O)	4.82^{bc}	4.76^{bc}	5.46^{a}	5.02^{b}	4.68^{c}	0.001	0.29
Al (cmol(+) kg^{-1})	2.246^{a}	2.602^{a}	0.344^{b}	1.728^{a}	1.974^{a}	0.005	1.05
Ca (cmol(+) kg^{-1})	3.556^{b}	3.612^{b}	7.330^{a}	4.322^{b}	6.146^{a}	0.001	1.534
ESP	5.258^{a}	4.178^{ab}	5.220^{a}	4.740^{a}	3.550^{b}	0.035	1.166
NO_3 (mg kg^{-1})	3.4^{b}	5.4^{b}	12.4^{a}	5.2^{b}	4.4^{b}	0.001	3.442

Table 2-Results from the sub soil samples taken in November 2013

There was no difference between treatments in the clay and silt content. This suggests that the soil samples were taken from the same section of B-horizon in all the plots and that top soil or compost was not inadvertently sampled.

There was an improvement in the soil chemical attributes that are detrimental to plant growth in the compost treatment. The pH of the deep rip compost treatment was significantly higher (p=0.001) than all the other treatments. Conversely, the level of exchangeable aluminium was significantly lower in the deep rip compost treatment.

The level of nitrate in the deep rip compost treatment was significantly higher than the other treatments. This indicates that the yield response could be attributed to nutrient availability as well as the improvement in soil chemistry.

Complete the construction of the machine

The sub soil applicator was completed in early 2015 and was operable with only minor commissioning problems. It has the following features.

- A second hand manure spreader was purchased to act as the feeder bin for the machine. This was sourced from Sydney and is large enough to allow the machine to go up and back on long rows (400m) without filling up.
- A “goose neck” assembly was designed that joined the feeder bin to the ripper assembly. This allowed the machine to turn on narrow headlands whilst allowing the ripper assembly to pivot should it break a sheer pin.
- The ripper assembly is very innovative. A furrow tine in front of the ripper tine removes the top soil to reduce the horse power requirement and prevent top soil from falling into the trench created by the ripper. Two discs behind the ripper replace the top soil.
- A hydraulic motor driving an agitator encourages the flow of the mill mud or compost down a pipe at the back of the ripper.
- After application the row is left with a low bed with a curved profile. This allows for direct drill cane planting if desired.

The following pictures show attributes of the completed machine:

Photo 1 – Covering discs and feeder shoot. The covering discs leave a bed with a curved row profile that is appropriate for harvesting.

Photo 2 – The goose neck assembly allows the machine to turn on narrow headlands

Photo 3 – The agitator system ensures a consistent flow into the feeder.

Photo 4 – The end result, compost or mill mud can be applied to a depth of up to 400mm into clay sub soil.

The sub soil ameliorator can apply 10 to 20 tonnes/ha of compost or mill mud ash to a depth of 400mm.

Take soil tests of the clay sub soil on potential demonstration sites

Soil tests were not taken at the demonstration sites. This is because adequate descriptions of the B-Horizons are available on the soil maps that are accessible on "Queensland Globe". As shown in Photo.5 the sub soil at the demonstration sites was showing all the characteristics of a sodic soil.

Photo 5 – Clay sub soil from the MSF demo site after 10mm of rain, note how the clay has dispersed and the surface has "hard set".

Apply the deep ripping, deep rip compost and deep rip mill mud to the demonstration sites

At the time of writing four commercial sized demonstration sites have been established:

1. Commercial application at the Cronau's farm in Yera. An entire block of approximately 2ha has been treated next to an untreated block on the same soil type
2. Two commercial sized strip trials on two different soil types at an MSF Sugar Limited farm in the Bidwill area of Maryborough. Approximately 2ha has been treated at this site.
3. A commercial sized strip trial at a Bundaberg Sugar farm in Bundaberg. Approximately 6.5ha has been treated at this site that compares a range of different ameliorants including mill mud and mill mud mixed with ameliorants such as silicon fertiliser.
4. A commercial sized strip trial at Tony Chapman's farm in the Alloway area of Bundaberg. Approximately 0.5ha has been treated at this site.

All the users of the machine reported relatively trouble free operation. It was noted that when using mill mud or mill mud ash that drying of the product was required for trouble free application. This was achieved by agitation with a front end loader or by allowing the mill mud to dry in situ before use.

Hold field days at two demonstration sites advertised via radio interview

There have not been two field days at two demonstration sites at the time of writing. However there have been two field days at the MSF Limited demonstration site. One involved approximately 50 Maryborough growers on the Maryborough Cane Productivity Services annual bus tour. The other involved approximately 30 growers from southern Queensland on a Sugar Research Australia organised bus tour. These field days were not advertised by radio, however text messaging and newsletter articles ensured a thorough coverage of the field day advertisement across southern Queensland growers.

Plant the demo sites with sugarcane

All the demo sites have been billet planted with sugarcane and a commercial crop has been established.

Complete economic feasibility study of the new process

Capital cost

The cost of constructing a commercial sized machine capable of applying mill mud or compost to a depth of 400mm was calculated by MSF Sugar Limited farm engineering team. It was important that the machine was capable of holding enough ameliorant to allow a return trip on a 400m long row, in other words be able to travel 800m without filling up. If the machine was not capable of this there would be a significant reduction in field efficiency. It was also decided that a commercial scale machine would only be a single row machine because a multi row machine would be overly complex and unwieldy when turning on narrow headlands.

The team estimated that a machine with these attributes would cost approximately $120000 to build assuming that a new manure spreader was purchased and modified for purpose. It is important to note that the purchase or hire of a "telehandler" is also required to load the machine. A good second hand telehandler would cost approximately $50000.

Operation cost

The Queensland Department of Primary Industries Farm Economic Analysis Tool (FEAT) was used to calculate the operation costs as follows. This analysis does not include the operating cost of the telehandler.

Assumptions	
Tractor horse power†	160
% of horsepower used	65%
Fuel cost after rebate	$1.36 (ex GST)
Productive life of machine	10 years
Total life cost of repairs and maintenance (sub soil machine)	$15000
Width of pass‡	2.0m or 1.65m
Speed	8.0 km/hour
Field efficiency*	55%
Operators wages	$32.00 hour
Costs (2.0m spacing)	
Work rate	0.9 ha/hour
Labour rate	1.14 hours/ha
Operation cost (less labour)	$31.74 hour
Operation cost (including labour)	$72.44 hour
Proposed contractor charge out rate∞	$161.39 hour
Costs (1.65m spacing)	
Work rate	0.7 ha/hour
Labour rate	1.38 hour/ha
Operation cost (less labour)	$30.87 hour
Operation cost (including labour)	$86.59 hour
Proposed contractor charge out rate∞	$177.14 hour

†A large tractor is required because of the heavy load of ameliorant, not because excessive horsepower is required to pull the single ripper tine.
‡Two analyses were done one for a controlled traffic 2.0m spacing and one for non-controlled traffic 1.65m spacing
*Assumes sub soil machine operator is loading the machine with ameliorant i.e. a one person job
∞ Assumes 7% interest rate on machine, $32 hour labour costs and a 10% profit

Return on investment

This report does not calculate a return on investment because of the vagaries of input costs and yield responses.

- It is not known if the approximate 10% yield response varies according to yield. In other words we do not know if the yield response is proportionally greater at a lower yield compared to a higher yield.
- The cost of mill mud varies considerably between mill areas.
- The amount and type of ameliorant required is dependent on soil type
- It is not known if the ameliorant would only have to be applied once or if an application is required every crop cycle.

We recommend that growers make their own economic analysis using the information above and a predicted yield response from a demonstration trial before adopting the practice commercially.

Publish newspaper and magazine articles

A story on the machine and the practice of sub soil amelioration has been published in the Sugarcane Research Australia *Cane Connections* magazine. There have also been articles in the Maryborough Cane Productivity Services Magazine (*The Billet*).

Section 4: Intellectual Property (IP) and Confidentiality

There is no intellectual property of confidentiality issues. The members of the DAG group are firm believers in the sharing of information for the betterment of the sugarcane industry. Growers from across Australia are welcome to contact the DAG group to discuss the machine and the trials.

Section 5: Industry Communication and Adoption of Outputs

Key messages

There are three key messages as a result of this project:

1. The construction of a reliable machine that is capable of commercially applying compost or mill mud to a depth of 400mm is feasible.
2. There are definite chemical changes that occur in sodic clay sub soil as a result of the application of and organic ameliorant. These changes make the soil more conducive to root growth.
3. Commercial amelioration of a sodic clay sub soil is a feasible management practice to increase base line yields.
4. There is strong interest in this practice across the Australian sugarcane industry.

These messages have been communicated to a number of PEC group officers, a large number of farmers and presented at the 2015 productivity services conference.

Adoption of project outputs

At the time this report was written the following has occurred:

- Two cane farming enterprises in Maryborough have adopted the practice commercially
- MSF Sugar Limited is investigating the construction of two sub soil amelioration machines based on the DAG group design
- MSF Sugar Limited has established 2 strip trials to assess the economic feasibility of the practice.
- Bundaberg sugar have established a 6.5ha strip trial to assess the commercial feasibility on their farms in Bundaberg
- A cane farmer in Bundaberg has established a strip trial
- Wilmar has expressed an interest in the practice and would like more information.

Media coverage

At the time this report had been written there has been the following media items related to the project.

- An SRA *Cane Connections* article
- Two articles in the Maryborough Cane Productivity Services newsletter (*The Billet*)
- Video documentation of the project by SRA with the intent to produce a *Cane Clip*

The project has also been discussed informally at various industry events and meetings. This was a very novel project and there was strong interest.

Further opportunities to disseminate information

It is likely that an Australian Society of Sugarcane Technologists paper will be published in 2017 as it is already partly written. This paper will cover the construction of the machine and the replicated trial. There is also scope for further field days at demonstration sites.

Section 6: Environmental Impact

There are no proven adverse environmental impacts associated with this project. The application of nitrogen rich ameliorants deep in the soil could increase the risk of nitrate leaching. However because sugarcane roots are exploring deeper into the profile they could actually capture nitrates as they leach through the profile.

There are no proven environmental benefits, however potential benefits could include:

- The practice could be a methodology for carbon sequestration because an organic carbon source is placed well below the cultivation layer.
- Leached nutrients such as nitrates and potassium could be captured by sugarcane roots that are exploring deeper into the profile

- The project could also lead to more sustainable use of mill mud ash. This is because the value of mill mud is increased when used as a sub soil ameliorant. This means that it could be transported further from the sugar mill.

The Queensland Department of Environment and Heritage Protection have expressed an interest in the potential for capturing leaching nitrate in the Great Barrier Reef catchments.

Section 7: Recommendations and Future Industry Needs

This project has proved that effective organic ameliorants can be applied at rates of 10-20 tonnes/ha into a sodic clay sub soil. Further work is required to increase the effectiveness of this practice, for example; tailoring the ameliorant to suit the soil, assessing the impact on higher yielding crops and determining if the practice is required every crop cycle.

A better understanding of the occurrence and distribution of soil with sub soil constraints is also required. This will allow a determination of the potential benefit of sub soil amelioration across the industry. It would also provide a decision making tool

Section 8: Publications

Cane connection article

SRA Adoption Support Officer Jarrod Sartor and Maryborough cane farmer Darryl Cronau with the mechanical subsoil applicator.

EXTENSION

Sub soil amelioration produces above par results

The adoption of sustainable soil health practices is vital to profitable sugarcane cropping and the long term viability of the industry. ***By Kate Daly and Jarrod Sartor***

Ameliorants such as gypsum, lime and organic matter have long been used to improve the physical, chemical and biological condition of the top soil in agriculture. Now, an emerging body of work looking into addressing subsoil constraints through similar practices is gaining attention throughout the industry.

In Maryborough, Andrew Dougall, Group Agronomist from MSF, and local growers Darryl, Lester, and Brad Cronau have undertaken practical trials to assess the effect of deep soil ameliorant application on sugarcane crops that are limited by sub soil constraints.

Such conditions are common in Maryborough with up to 40 percent of the agricultural production area located on a sodic duplex soil type. Compaction, poor aeration, reduced water-holding capacity, stunted root growth, increase of plant available aluminium and manganese are among the sub soil constraints which limit yield in the region.

The Cronaus' philosophy is to look for management options which improve yield and profitability, while adopting good soil health practices.

Darryl Cronau considers the implementation of improved soil health management an integral part of their long term farm plan and essential for profitability in the future.

This led to the exploration of the use of subsurface applied compost in 2012. In these practical trials, compost was incorporated at a rate of 10-15 t/ha into the subsoil by deep ripping with a compost applied through a tube attached to the back of a tyne.

The results were rewarding with yield increases of 6-10 percent attributed to improved subsoil aggregation, increased water holding capacity and better soil biological activity.

However, the application was labour intensive and not commercially viable in a system where yield averages are 80 t/ha.

But through adversity comes innovation and the Cronaus could see the benefits were there, if they could make their concept practical and economical. Thus the idea for a mechanical sub soil applicator was conceived.

The Cronaus, working as the DAG grower group, received partial funding and support through an SRA Grower Group Innovation Project and a Reef Rescue Water Quality Improvement Grant, which allowed them to work on their ideal machine.

There were no blueprints to work from, just a few chalk drawings on the cement floor of the shed and the rest was in Darryl's head.

The mechanical sub-soil applicator works exceptionally well and a larger feed belt is the only modification that the Cronaus would alter in a re-design.

Andrew, who has supported the project, explained that the process opens a window into the subsoil allowing for healthy root growth.

"The compost window improves root penetration, nutrient uptake and moisture availability," he said. "The applicator gives us the capacity to apply compost to sub soil layers at depths of up to 40cm conveniently and cost effectively meaning we can increase the area treated, assess the most beneficial application rate and determine the economic viability of the treatment," he added.

In subsoils where aeration, soil water-holding capacity and root growth are impeded, amelioration applications such as compost may assist in the prevention of waterlogging through enabling drainage to the deeper soil profile.

SRA's Dr Barry Salter is currently leading a project to determine the varying response rates in treatments that are applied to different soil types and to determine the long-term feasibility of subsoil ameliorant applications.

Interest in this field is growing with a number of other projects underway throughout the industry and our knowledge of farming on marginal soils steadily improving.

Above image: MSF Group Agronomist Andrew Dougall.

Left image: Highlighted in the red circle is where the compost was originally placed in 2012. You can see the higher density of root mass in this area 'opening a window' for root growth in the surrounding sub-soil; ideally increasing the available moisture and nutrient uptake.

NCEA receives funding for smarter irrigation

Dr Joseph Foley and a team of National Centre for Engineering in Agriculture (NCEA) researchers have started working with 16 R&D partners and up to 19 farmer-managed learning sites in a $3.7 million Federal Government funded Rural R&D for Profit programme to improve the profit of each individual irrigator enterprise across the cotton, dairy, sugar and other agricultural sectors by $20,000-$40,000 per annum.

This project is being led by the Cotton Research and Development Corporation (CRDC) in conjunction with three others RDCs; Sugar Research Australia, Dairy Australia, and the Rural Industries Research and Development Corporation (RIRDC).

"This is a large-scale, ambitious project designed to achieve a 10-20 percent improvement in water productivity, efficiency and farmer profitability, while also improving cross-sector industry research collaboration," said Bruce Finney, Cotton Research Development Corporation Executive Director.

"It is designed to increase on-farm profitability by integrating new irrigation scheduling and delivery technologies into good irrigation practice.

"It will build on previous research to drive additional improvements in cotton and rice, and will transfer learnings from the cropping industries to dairy.

"Our aim is to increase on-farm profit through the adoption of automated and precision application technologies across all industries."