

INTERCROPPING

The growing of two different crops simultaneously

A report for



By Bryan Granshaw

2012 Nuffield Scholar

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Executive Summary; Intercropping in modern agriculture

Sugarcane is a Monoculture, and it is a perennial. It is a row crop that is grown for (in Queensland) a 12-month growth cycle. Granshaw Farming has been growing soybeans as a rotation crop in our fallow sugarcane fields every five years with good results in soil health and productivity in the following sugarcane crops. Granshaw Farming decided that it needed to have these results more often than every five years so in 2002 they intercropped soybeans with sugarcane. Providing a very interesting result, actually 15% more yield and lower input costs, however with subsequent trials the results were not so repeatable, hence the reason for this study.

What was discovered as a result of these studies is that intercropping is a fairly rare practice (in a commercial sense) however people who are pursuing this practice are having success. This involved travelling to Saskatchewan and Manitoba Canada to visit two research stations and a farmer, who is showing positive results with intercropping canola and field peas. You might ask what does this have in common with sugarcane; actually the principals are the same. These farmers have found plants that are synergistic. Although the people that were met grew different crops and lived in different climates, the principals of finding species of plants that complemented each other was common, so were the resultant productivity gains.

What has become apparent is that there has to be a shift in thinking by “main stream” agricultural research providers; there has to be a more open-minded approach to natural systems. This is not to suggest that organic farming is the Answer. However, there is a need to mimic nature and learn more from natural systems and not rely so much on inputs “out of a bag”. For too long commercial drivers have neglected the farmers most valuable asset, the soil. It must be said, that there is a cost to changing a management style, however throughout the course of this study, there are people who see it as an investment which delivers a lower input and more resilient farming system that remains productive.

The Queensland Sugarcane Industry has been in the spotlight recently due to its proximity to the Great Barrier Reef; productivity is flat lining, so it is time for a “paradigm” shift. The sugar industry needs to understand that there is more to be learnt by looking outside of their industry.

- Governments and the community need to see that it is possible to farm using innovative and truly sustainable farming systems that will do no harm.
- Industry leaders need to focus on longer term investment in soil health if they are to realise improved productivity, and lower input costs for the future of sugarcane production in Australia.

Contents

Executive Summary; Intercropping in modern agriculture.	iii
Contents	iv
Foreword	v
Acknowledgments	vi
Abbreviations	vii
Objectives	8
Introduction	9
Chapters	11
The Concept	11
Canada	12
Melita, Manitoba, Canada	15
Conclusions	34
Recommendations	336
References	377
Plain English Compendium Summary	38

Foreword

Modern agriculture is driven by production (outputs) and costs (inputs); somewhere in the middle is where farmers make a profit. Granshaw Farming is a sugar cane enterprise that sells sugar on the world market and therefore is at the whim of fluctuating sugar prices. This plus the sugarcane industries proximity to The Great Barrier Reef, has put significant pressure on us to be able farm sugarcane efficiently and with minimal risk of offsite environmental impacts.

There has been much research done by industry regarding farming systems and potential benefits derived from management of the sugarcane farm as a whole farm approach. There have been four “building blocks” that have been identified as corner stones of what a sustainable sugarcane farm management system would look like.

1. Trash retention (GCTB)
2. Controlled Traffic (all axle spacing's of machinery trafficking the field match row spacing's and is guided by RTK GPS)
3. Minimum Tillage.
4. Legume fallows.

My study topic takes the Legume Fallow concept to a new paradigm. Due to the fact that sugarcane is a perennial crop and could be in the same field for up to six years, this creates little opportunity to break the monoculture. Our concept is to grow a “complementary” (crop / legume) whilst producing a sugarcane crop therefore “Intercropping” has been the basis for my Nuffield Scholarship study.

The Queensland Sugarcane Industry has the potential to be the “Green Powerhouse” of Australia, this industry can produce copious amounts of renewable electricity, and renewable fuels ‘Ethanol’. For this reason, it is imperative that as an industry we can prove our sustainability and environmental responsibility, intercropping has the ability to address both of these issues, achieving improved soil health and diversity while reducing chemical inputs therefore reducing off site impacts.

What this study has shown is that intercropping is viable, and other industries have invested in appropriate research to learn how to manage a combination of crops. The findings have been positive showing in cases up to 15% increases in overall combination yields.

This scholarship is a first for a sugar industry participant and was made possible due to the leadership and generous sponsorship from Sugar Research & Development Corporation.

Acknowledgments

As this is the first Nuffield Scholarship devoted to the sugar cane Industry I need to thank the board of the “Sugar Research & Development Corporation” and especially the C.E.O Ms Annette Sugden for their vision to provide this opportunity for me and industry participants that will follow.

The Nuffield Australia organisation. I have never experienced such a proactive, professional, and generous group of people.

My fellow Scholars that accompanied me on our Global Focus Program, Ray Vella, Natalie Williams, Rhys Arangio, Ryan Smart, Dave Reilly, Damian Murphy, and Crosby Devitt. A big thank you to you all for guiding me through my first overseas adventure, I learnt a tremendous amount about life from your inspiring stories.

My Father John and my brother Terry, for doing my share when I was not around to do it. And having faith in this new “Nuffield experience”.

My family Sue, Emily, Caitlin, and Riley for doing without their husband and father for a couple of months at a time.

Sucrogen Executive General Manager Craig Doyle for Sucrogen’s support with my travel expenses.

CANEGROWERS Suzi Moore for also providing some financial support in aiding my overseas travel.

The team from Indian Head Agricultural Research Foundation, Saskatchewan Canada.

Nuffield Scholar Jim Halford for his hospitality.

Scott Chalmers from Westman Agricultural Diversification Organisation, Melita Manitoba Canada.

Colin Rosengren farmer from Midale Manitoba Canada.

2011 Nuffield Scholar Kelvin and Shelly Meadows for their hospitality.

Chuck Zumbrun farmer from Churibusco Indiana U.S.A.

Professor Susanne Schmidt, School of Agriculture and Food Sciences University of Queensland.

Dr Richard Brackin, School of Agriculture and Food Sciences University of Queensland.

Abbreviations

(IHARF) Indian Head Agricultural Research Foundation

(WADO) Westman Agricultural Diversification Organisation

(LER) Land Equivalent Ratio

(SYDJV) Sugar Yield Decline Joint Venture

(GCTB) Green Cane Trash Blanket

(RTK) Real Time Kinematics

(GPS) Global Positioning System

Objectives

The primary objective was to find evidence that the concept of intercropping is valid, and able to be managed in a commercial cropping system. Specifically, this report aimed to:

- Find researchers who have studied such a concept (intercropping) with scientific rigour.
- To meet with farmers who have implemented such a system in a commercial farming enterprise.
- Find a way forward to implement an intercropping management system into our commercial sugarcane farm.

Introduction

Sugarcane was brought to Australia by the first fleet in 1788, and efforts to grow it in the port Macquarie area were futile. It was not until 1862 that the first commercial sugarcane plantation was established near Brisbane, Queensland, and it wasn't until two years later that the first sugar mill was built.

Around this time people started to settle the northern coastal regions of Queensland and as was common of that time "indentured labour" was brought in to work in the sugarcane plantations, this occurred until 1904. This is when laws were changed to prevent the use of such a labour force. This event necessitated a new labour force and this came in the way of immigrants from Italy and other European countries.

Cutting and loading sugarcane by hand is very arduous and difficult work and this was the way forward for the industry until the early 1940's when farmers started to develop mechanical cane loaders and then in the 1960's progressed to mechanical harvesters of varying types. In fact, commercial cane harvesters were designed and built in Bundaberg Queensland and exported around the world, it was started by the Toft Brothers and was eventually bought out by Case IH, and are now being produced in Brazil.

The fact that the Queensland sugarcane industry lies adjacent to one of the "seven wonders of the world" the Great Barrier Reef has also had an influence on the way that industry operates and has been a major driver for changes in farming practices. The fact that sugarcane is farmed in the wet tropics with high annual rainfall, and situated in or around large river catchments, makes off farm water management crucial. In fact, Queensland Government enacted legislation on the 1st of January 2010 that limited and dictated some chemical and fertiliser uses, and stringent record keeping of farming operations. Farmers are required to calculate the optimum amount of nitrogen and phosphorus to apply to sugarcane to achieve the district yield potential. And there is a requirement to keep records of soil test results; how the optimum rate was calculated; and the rate and the method used to apply the fertiliser.



Figure 1: Proximity of Queensland Sugar Cane Industry to Great Barrier Reef

The other major contributing factor for the evolution of the Queensland sugarcane industry is that 85% of all sugar produced is sold directly into the world market in U.S dollars so we are subject to the fluctuations of world supply and demand, and a strong Australian dollar. So minimizing input costs whilst maintaining high levels of production whilst minimizing potential off farm environmental impacts competing in a global market place requires innovation and adaptability.

My study topic, the practice of intercropping has the potential to deliver outcomes on three of those pressure points that the industry faces.

Reduced input costs; a legume can be used to supplement nitrogen for a sugarcane crop, and can add diversity to an otherwise monoculture crop.

Adding soil health benefits; water and nutrient holding capacity, healthy soil will be more productive.

Offsite environmental impacts; a legume crop will have a slow mineralisation of nitrogen thereby more chance of nitrogen uptake by the sugarcane crop and less potential off farm movement. Also the need for less herbicide due to the shading effect of a legume intercrops, that act as a natural suppressant to weed growth.

Chapters

The Concept

Intercropping

Intercropping is not a new concept and has been around nearly as long as man himself. It is nature's way of adding diversity, and in simple terms, if you walk into a natural landscape (the Bush) you will find everything growing from grasses to climbing vines, small shrubs, to large trees, Diversity. There are numerous examples of uses of intercropping, one of the most well know is of the Indian people of the Americas pre, arrival of Europeans, it is known as 'The Three Sisters'. This system was the planting of corn (maize) and pole beans together. The cornstalk would serve as a trellis for the beans to climb, while the beans would fix nitrogen, which also benefited the corn. The inclusion of squash with these two plants acted as a weed suppressant and shaded the soil preserving moisture, completes the Three Sisters technique.



Figure 2: American Indian “Three Sisters Farming Technique”.

(World Wide Web “Unknown”, artist rendition)

Modern agriculture is primarily a monoculture system and due to the complexity of managing multiple crops most farmers shy away from such a system. A multi species crop requires much more micro management, in todays mechanised farm systems, how do we harvest two crops? How do we do this on a commercial scale? Some people though believe that there is a way and believe that there are very real benefits to overcoming such challenges.

Canada

Indian Head Agricultural Research Foundation

A meeting was arranged with Dr Guy Lafond, and Colin Holzphel to speak about their work with Canola and Field Peas. These guys have been doing some very rigorous work comparing different treatments; the primary objective of their work was to gain experience with intercropping field pea and canola while demonstrating the potential merits of this practice to local producers. Additional objectives included demonstrating alternating versus mixed-row configurations for field pea-canola intercrops along with the effects of nitrogen (N) fertility on the performance of pea-canola intercrops relative to monocrop canola.

Producers on the Prairies are interested in the practice of intercropping as a means of increasing overall productivity and potentially reducing fertilizer use in canola production. Large gains in both total grain yield and land equivalent ratios (a measure of the productivity of intercrops versus monocrops on a per land area basis) have been reported on the Prairies by both producers and researchers, but results have not always been consistent.



Figure 3: The Indian Head Research team (Guy Lafond, Andy Jones, Chris Holzphel) taken Indian Head Saskatchewan Canada.

(Bryan Granshaw)

Two separate demonstrations were conducted at multiple locations and over two growing seasons. The first simply compared intercropped field pea and canola to monocrops of the same two species. The second was a two-factor

demonstration evaluating the effects of row-crop type configuration (mixed versus alternating rows of field pea and canola) and potential interactions with N fertilizer.

For both demonstrations, the land equivalent ratio (LER) was calculated by dividing the intercrop yield of each crop type by the yield of the corresponding monocrop.



Figure 4: Field Pea and Canola in alternating rows. Indian Head Research Farm Saskatchewan, Canada

(Chris Holzphel)

Land Equivalent Ratio is a measure of productivity that simultaneously takes into account beneficial and detrimental interactions between crops, whereby an LER value greater than 1 indicates an advantage to intercropping and an LER value lower than 1 indicates a disadvantage. For example, a LER of 1.25 indicates that two monocrops planted in equal proportion would require 25% more land to produce the equivalent yield achieved by intercropping the two crops.

There were some fairly clear outcomes from these exhaustive studies, overall, intercropped field pea and canola performed as well or better than the same two crops grown in a monoculture.

In Demonstration #1 at the heavy clay site (Indian Head Research Farm), total yield advantages of 294-435 kg ha⁻¹ were observed with intercropping over the two-year period. This resulted in average LER values of 1.15-1.19

indicating that, over yielding was occurring with intercropping and the magnitude was 15-19%. At the loam site, a mean LER of 1.53 was achieved with intercropping; however, overall variability was high. Interestingly, the absolute field pea yields were actually higher when intercropped with canola at this site, presumably a result of the relatively severe lodging observed in the monocrop field peas.

For Demonstration #2, results were consistent with Demonstration #1 in that intercropping typically resulted in slightly higher yields than monocrop field pea and canola and the total yields tended to be higher with mixed as opposed to alternating rows of these two crops. Generally speaking, canola was favoured in the alternating row treatments while field peas performed significantly better in mixed rows. Nitrogen fertilizer significantly increased canola yields in the intercropped treatments and, in mixed row configurations, intercropped canola responded to N fertilizer in a similar manner as the canola monocrops.

Other general observations with intercropped field pea and canola included visibly less shattering in the in the intercropped canola relative to the monocrop canola at similar N levels, presumably due to the heavier, more densely entangled crop canopy. Field peas grown with canola stood much taller than monocrop peas and continued to stand after reaching maturity, thereby making combining easier and reducing potential harvest losses in field peas.



**Figure 5: Canola Field Pea intercropped Indian Head Research Farm Saskatchewan Canada
(Chris Holzphel)**

Farmers on the Prairies and researchers alike have reported substantial yield benefits to growing more than one crop simultaneously on the same piece of land, or intercropping. For annual crop mixes, field pea and canola are

two species that appear to grow reasonably well together and, over a two-year period, field demonstrations were conducted on contrasting soils in Saskatchewan to demonstrate and evaluate the potential merits and/or pitfalls of field pea-canola intercrops and to improve the ability to successfully grow these two crops together. Canola tended to perform better when grown in alternating rows with field pea and all N fertilizer was directed to the canola rows; however, field yields and total seed yields were highest when canola and field pea were grown together in mixed rows.

While there could be some added costs associated with intercropping, they are relatively minor and the major impediments to adoption going forward are more likely to be due to logistic challenges rather than financial restraints. Aside from potential modifications to seeding equipment and a one-time investment in cleaning equipment, the only added variable cost of intercropping comes from the process of separating the grain after harvest. While intercropping will certainly not appeal to all growers these demonstrations show that this practice can result in significant yield benefits relative to mono-cropping. (Information sourced from IHARF Annual Report 2012).

Melita, Manitoba, Canada



Figure 6: Growers from the Melita district, Manitoba Canada

(Bryan Granshaw)

Westman Agricultural Diversification Organization

This was the second year of a pea-canola intercropping trial, mixed plots of pea and canola were tested against seeding rates of the component crops. Achievements in over-yielding occurred in 2009, but obvious improvements on the idea were needed in dealing with applied nitrogen and the interaction with pea production, and a closer look at the behaviour of pea and canola crops in row proximity. The idea was to improve pea and canola growth conditions based on nitrogen need but still attempt to preserve and better understand over-yielding in intercropping behaviour. It was decided that row arrangement would need to be examined in a canola-pea system to understand the effect on yield, grain shatter, disease suppression, and soil health benefits. Evaluate nitrogen placement and how it influenced yield, of the two crops in question.

Due to the nitrogen fixing capabilities of the field peas it was decided to apply nitrogen only to the canola rows, the thinking was that this will not entice the field Peas to become inefficient when fixing nitrogen from the atmosphere. Rows were planted in 9.5 inch rows and divided into plots where alternate rows of field peas and canola were established, plots were maintained with farming practices considered conventional in the Melita farming district.

(Crop Treatments are as outlined in Table 1. Wado annual Report 2010 page 141 in Appendix)

Crop monitoring included collecting, date of flowering, plant density, leaf and seed density, after harvest soil testing and more. Soil tests were taken to evaluate the average plot nutrient levels, to avoid the over fertilised canola rows or the under fertilised pea rows



Figures 7, 8, and 9: WADO field plots Melita, Manitoba Canada

(Scott Chalmers)

As in previous trials conducted by WADO there was a positive intercropping effect compared to monocrop peas or canola. From this work it appears that there is a benefit to be had from intercropping, it has been observed that field pea in a mixed row situation seem less efficient in nitrogen fixation. However, in double row situations, peas

appear to be physically removed enough from the applied nitrogen that they need to fix nitrogen. Regardless of row arrangement or fertility practice, there still seems to be a row separation benefit with intercropping compared to monocrop treatments. This benefit may be discovered as simply coming from a more efficient use of light and/or water. It has been observed that an intercropped pea canola crop provides a more effective plant stand to help against lodging and also soil contamination which results in higher seed quality, easier harvest.

(Information from WADO annual report 2010).

Colin Rosengren, Commercial Farmer, Midale, Manitoba, Canada

Colin is a large grain grower in Manitoba Canada, he has been “intercropping” now for a period of 4/5 years and has had good results from intercropping, in fact it is the only way he farms now. He farms Canola in conjunction with Field Pea, and Corn and Soybean. He has adapted machinery and harvests the combined crops into the combine, and then separates the grain through a modified grain cleaner. He has also modified his air seeders to be able to plant two seeds at different depths, to accommodate for different maturity times of the two different crops. He has observed the same effects that the researchers have plus a few more, he has observed that when harvesting two different grains at different moisture levels, the dryer grain absorbed the moisture from the “wetter” grain lowering the overall moisture content.

After some experimentation (Colin explained to me) that he has a System that is more productive, more flexible (he now has two commodities to market) lower input costs (reduced chemical and fertiliser inputs) and more sustainable. (Colin Rosengren March 2013).



**Figure 10: Field Pea and Canola intercropped in Midale, Manitoba, Canada
(Colin Rosengren)**



**Figure 11: Field Pea and Canola in Combine bin before separation, Midale, Manitoba Canada.
(Colin Rosengren)**

Chuck Zumbrun, Churibusco, Indiana, U.S.A

Chuck is predominately a Corn and Soybean grower who farms in a dry land situation therefore soil moisture is an important factor in his farming system. Also due to the undulating nature of his farming land snow melts and soil erosion are also major concerns for Chuck to manage. This is why Chuck explained to me that he always planted cover crops and adopted minimum tillage.



**Figure 12: Rye Grass that was intercropped with Corn that has grown on after corn harvest. Churibusco
Indiana U.S.A.
(Chuck Zumbrun)**

In the 2012 growing season Chuck decided to try intercropping crimson clover into a growing corn crop he explained his reasons for doing this were the usual reasons for growing a cover crop:

- To have something growing in the soil to prevent wind and water erosion
- To recycle nutrients instead allowing them to leach away
- To build organic matter in the soil
- To prevent compaction from raindrops splattering on bare soil
- To add nitrogen for the next crop

The clover was broadcast into the corn crop about six weeks after the corn was planted. Cover crops are typically planted when the cash crop is mature or has been harvested. There were some good reasons behind seeding the clover early. Clover was chosen due to the fact that it could be seeded after the corn had been established (as in Figure 13) this would allow the clover to grow but not out compete the corn. As the corn grew there is limited sunlight reaching the low growing clover, keeping it almost dormant, however when the corn began to drop its leaves more sunlight was intercepted and the clover began to flourish into a thick ground cover. Because Clover is low growing it does not interfere with the harvest of the “cash crop” corn, and provides excellent ground cover, and a living plant. Also has provided a rotational benefit of a warm season grass (corn) with a cool season broadleaf (clover).

There have been numerous discussions at soil health conferences and Chuck informed me of one he attended personally the 2012 National No-Till Conference, where the mixing of crops had the perceived benefits of one plant roots taking up the exudates of the other plants roots in the immediate area. Just as some plant have an allelopathic effect on their neighbours, it is considered that some species might actually benefit from other species in close location. As was the aim of Chucks trials, to see if corn may actually benefit from clover being intercropped with it.

A check strip in the field was left and there was no significant difference in yield. Where there was clover it yielded 145.2 bushel/acre vs. 145.9 where there wasn't clover. These were outstanding yields given the very hot and dry conditions. (Personal communication with Chuck Zumbrun February 2013).



**Figure 13: Seeding red clover into a growing corn crop Churibusco Indiana U.S.A
(Chuck Zumbrun)**



**Figure 14: Clover at Corn Harvest, Churibusco, Indiana U.S.A
(Chuck Zumbrun)**

Granshaw Farming, Dalbeg, North Queensland, Australia

At the conclusion of the author's studies it was obvious that there had been no specific investigation of intercropping in sugar cane, and there was merit in exploring this further. It had become apparent that this idea of two plant species complimenting each other did have a valid scientific base as had been observed in the research for this report. The fact that the sugar industry is a monoculture and a perenial with declining soil health and productivity is why such a system needed to be investigated. Susanne Schmidt, Professor at School of Agricultural and Food Sciences at University of Queensland was approached and subsequently agreed to undertake a three-year study. This study included three sites in Queensland, (Rocky Point) Granshaw Farming, (Burdekin) and Accenerno Farming (Ingham).

A long narrow first ratoon block of around nine ha whose plant crop had been harvested on August 23, 2002 was selected. Two rows in the centre of the block were set aside. The remainder of the block was fertilised with 230 kg/ha N and 50 kg/ha K in late September – early October 2002, while the two rows in the centre received 50 kg/ha K but only 60 kg/ha N in early October. In both areas the 60 kg/ha N was applied as Ammonium Sulphate using a stool splitter, as soil tests indicated a sulphur deficiency. The additional 170 kg/ha applied to the bulk of the crop was as urea.

The SYDJV double disc opener legume planter was made available to the Granshaw's and their experiment was underway. They directly planted a row of soybean each side of the two cane rows left in the centre of the paddock on October 20, 2002 and achieved good establishment and very good subsequent soybean growth. When it came to weed control they applied a mixture of 3.5 kg/ha Commanche and 1 l/ha Gramoxone to the bulk of the crop but provided good weed control without any herbicide application. The adjacent rows that weren't sprayed were full of vines and various weed species. It was observed that "the soil where the soybeans were growing remained wetter" and thought this was probably due to "the roots of the soybeans making pores in the soil, thus giving a better soil structure and therefore holding more water". (Dr Alan Garside SYDJV 2003).



**Figure 15: Soy's emerging through thick sugarcane residue 2002 Dalbeg QLD Australia
(Bryan Granshaw)**



**Figure 16: Soy's at full canopy December 2002 Dalbeg QLD Australia
(Bryan Granshaw)**

The cane was harvested in early September 2003 with the weights and ccs from the three areas – bulk of the paddock, rows that received the same as the bulk but without herbicide, and the companion planted area – being recorded separately. The yields were most encouraging:

Bulk of paddock (8.96 ha)	149 t/ha at 15.53 CCS
Area not sprayed (0.19 ha)	134 t/ha at 15.47 CCS
Companion planted area (0.29 ha)	176 t/ha at 16.00 CCS

Although the big difference in area harvested of each treatment would certainly bias the results towards the smaller companion planted area the results are encouraging, particularly when the savings in nitrogen fertiliser are considered.



**Figures 17 and 18: Mature Sugarcane harvested from intercropped trial area September 2003 Dalbeg,
QLD, Australia
(Bryan Granshaw)**



Figure 19: Soya Bean planting into growing Sugar Cane crop 2013 Dalbeg, QLD, Australia

(Bryan Granshaw)

Legume establishment was successful in the Burdekin site. However, the crop was patchy due to a number of factors. These factors largely relate to the positioning of the legume seed sowing. Legumes were planted along the centre of the (dual) sugarcane rows, which resulted in too much shade, and low water availability for the legume. This resulted in most legumes being out-competed by sugarcane earlier than intended. A low level of herbivory by wallabies from nearby bushland compounded these issues.



Figure 20: Emerging Soy's planted December 2014, Dalbeg, QLD, Australia

(Bryan Granshaw)

A main objective of the first season of trial operation is to allow growers to adapt their management operations to optimise legume-sugarcane intercropping for each of the three trial sites. Based on observation of legume establishment at the three sites, steps were taken to further improve legume growth for the upcoming season. At the Herbert trial, baiting of cane rats will take place prior to legume planting in an attempt to reduce pressure on the legume intercrop. At the Burdekin trial, legumes will be planted at a higher sowing rate, and also be cut into the sides of the row as well as through the centre. At all three sites efforts will be made to plant legumes earlier: however this is dependent on rainfall and the timing of harvest. These minor adaptations to the methodology will be the best approach to the agronomic and external issues, which hindered good legume establishment at the Herbert and Burdekin sites.



Figure 21: Mature soybean plants successfully intercropped with sugarcane at the Sunshine Coast trial site, May 2014

(University of Queensland)

Data has been collected by UQ on legume biomass (above and below ground), soil nitrogen levels, and soil moisture. Growers have collected data on irrigation and rainfall events, climatic conditions, and farm management practices.

Some key results and preliminary outcomes are presented below from the Sunshine Coast site, indicating that

- 1) legume biomass and nitrogen contents are not affected by nitrogen fertiliser application (Figure 1), and
- 2) legume intercropping has (as of May 2014) been successful in providing nitrogen to the sugarcane crop (Figures 2,3).

These outcomes will inform our management decisions in the trials for the 2014-15 cropping season. Preliminary estimates of sugarcane production have been conducted via sub-plot stalk count and harvest at the Sunshine Coast trial. Estimates via satellite imagery are in progress through our collaborator Andrew Robson at the University of New England. Final yield data collection will occur at all three sites at the time of harvest – This is estimated to occur in August (Herbert trial), October (Burdekin trial) and October (Sunshine Coast), contingent on suitable

weather conditions, and harvesting contractor availability. Final yield data collection will provide a much better resolution of data, as we will get biomass data from the entire field trial rather than the small sub-plots assessed here.



Figure 22: Soil sampling in progress at Herbert site, May 2014

(University of Queensland)

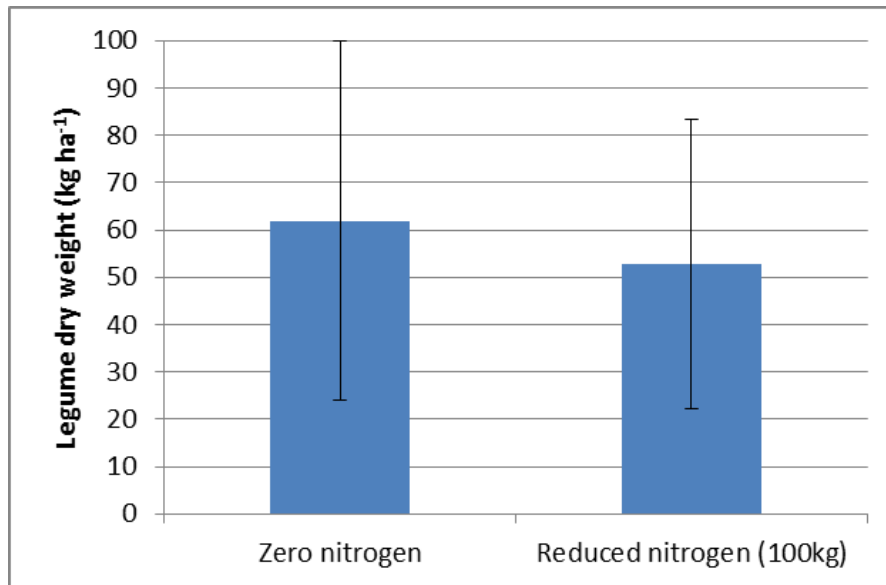


Figure 1: Legume biomass at Sunshine Coast site under 0kg N/ha and 100kg N/ha fertiliser treatments in May 2014. N fertiliser application does not have a significant impact on legume production.

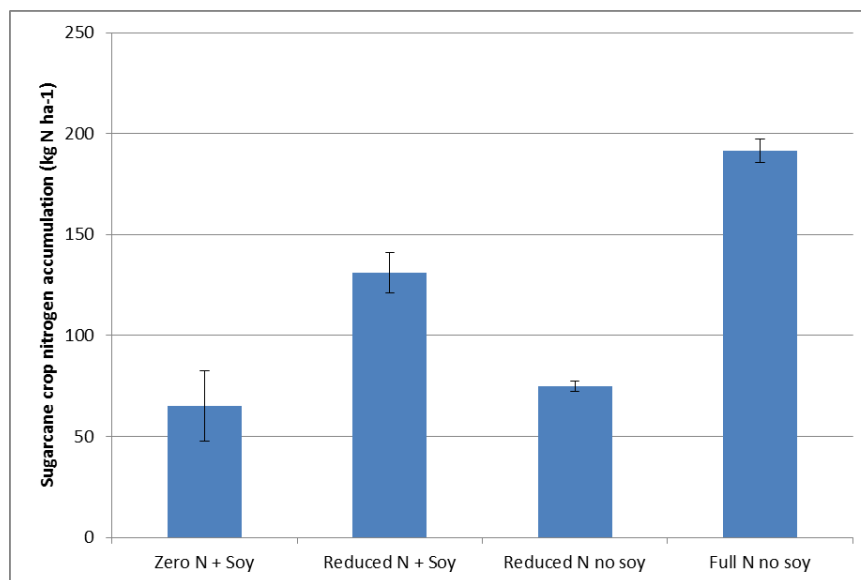


Figure 2: Sunshine Coast sugarcane crop nitrogen acquisition at May 2014 (from sub-plot stalk count and harvest). Legume intercropping has resulted in increased nitrogen acquisition by sugarcane plants in the reduced nitrogen treatments, indicating that the intercrop has been successful as a nitrogen delivery mechanism.

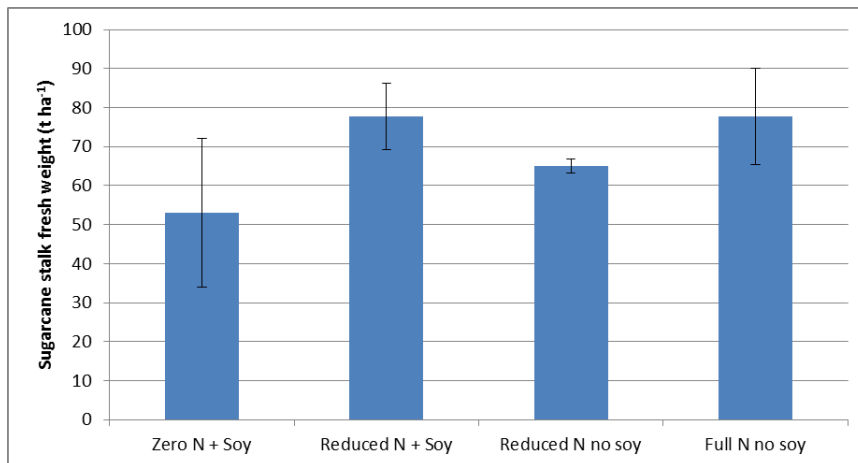


Figure 3: Sunshine Coast sugarcane crop stalk yields at May 2014 (from sub-plot stalk count and harvest).

Legume intercropping has resulted in increased stalk weights in the reduced nitrogen treatment, indicating agronomic success of the technique at this site at this date.

Herbert Trial

Harvest occurred on 12/08/14 at the Herbert trial. Fertiliser application for the 2014-15 season occurred on 8/10/14. Legumes were planted on 16/12/14, later than intended. This delay occurred due to dry conditions in the Herbert region, which would have prevented legume germination. Legumes germinated and grew well. Legume herbivory by rodents did not occur this season, and the intercropping treatments have been established successfully.



Figure 23: Sugarcane harvest being conducted at Herbert site, 12/08/14 Ingham Nth QLD Australia

(University of Queensland)



**Figure 24: Legume planting being conducted at Herbert site, 16/12/14 Ingham Nth QLD Australia
(University of Queensland)**

Burdekin Trial

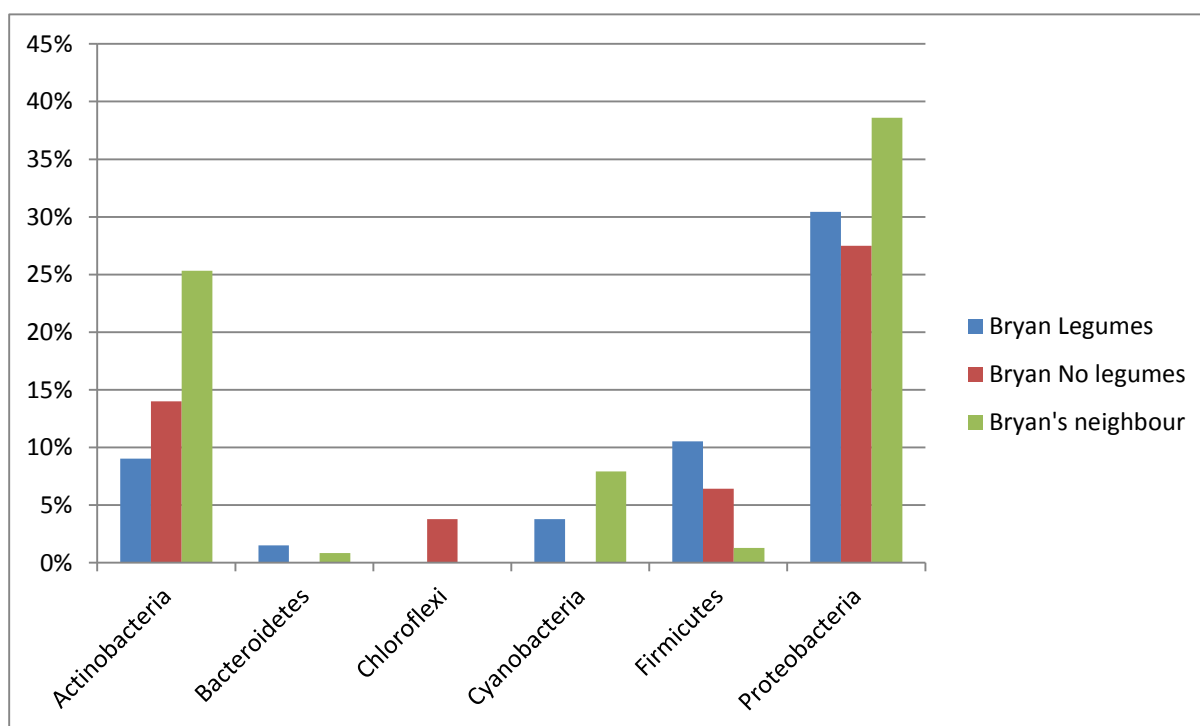


Figure 4: The author's two soils (legumes and no legumes) have similar microbial communities which are distinct from all other soils sampled (including author's immediate neighbour). Other soils measured include the legume trial at Abergowrie, and a number of farms in the Ingham district using a variety of managements, including biochar, addition of farmer-brewed microbial solutions, and conventional management. The breakdown of the soil

microbial community by phylum. The main difference between the author’s two soils and other soils surveyed is a reduced percentage of Actinobacteria, and increased percentage of Firmicutes. The reason this information is included in this report is that, during personal communication with Dr Richard Brackin who is overseeing the trial, he stated that this was something that he had not seen in sugar cane fields before. “They are actually a fairly recently discovered group – they can’t be cultured, so we’ve only known about them since DNA technologies have come in.” (Dr Richard Brackin University of Queensland)

The populations of certain microbes as shown (Figure 4) were in his view based on a combination of the farming system implemented by the author and secondly the mix of plant species, i.e. soy bean and sugar cane.

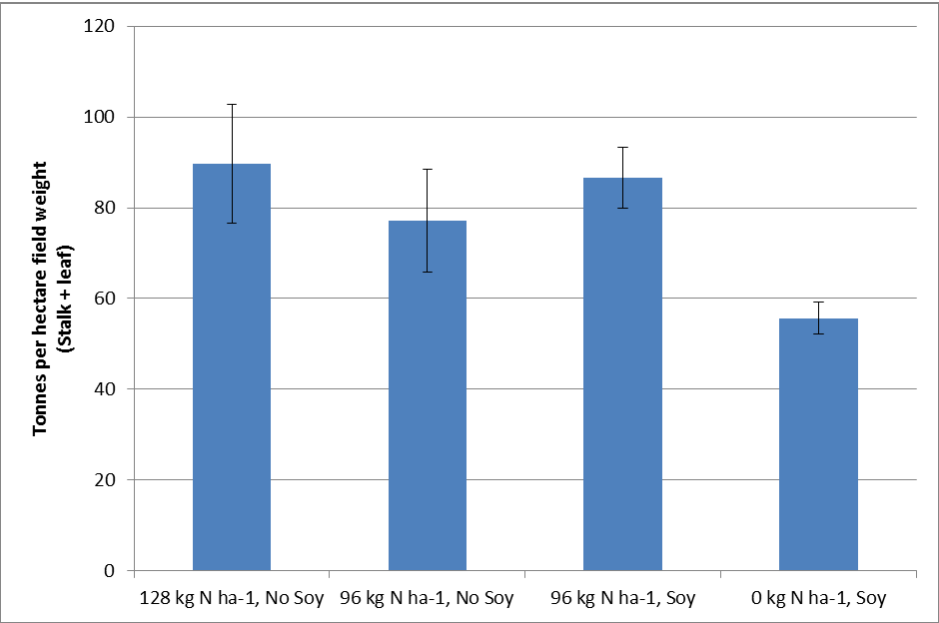


Figure 5: Maroochy river trial site cane biomass final harvest weights October 2014

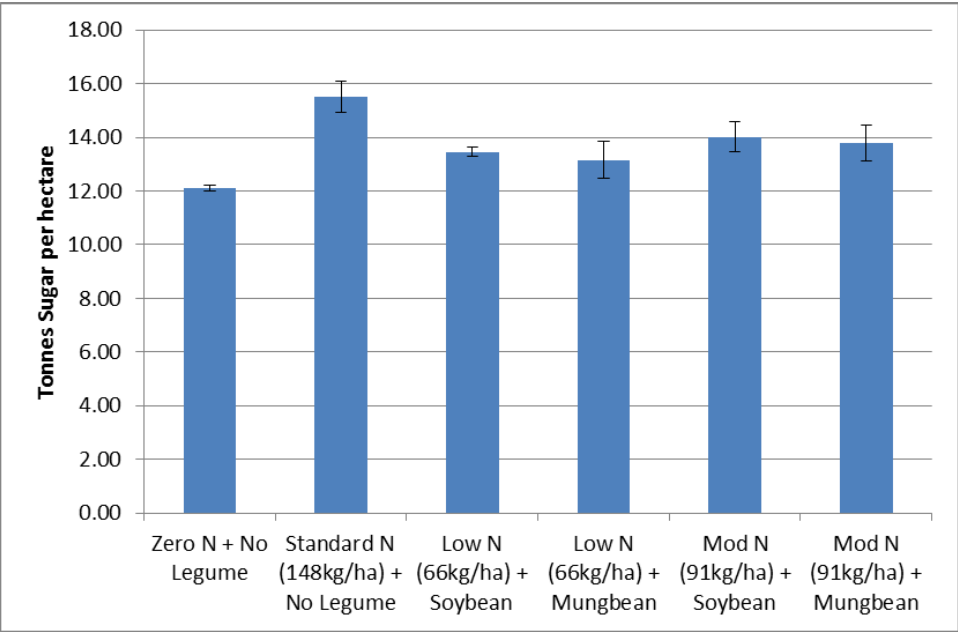


Figure 6: 96kg N per hectare with soybeans produced higher biomass than the equivalent fertiliser without soybeans.

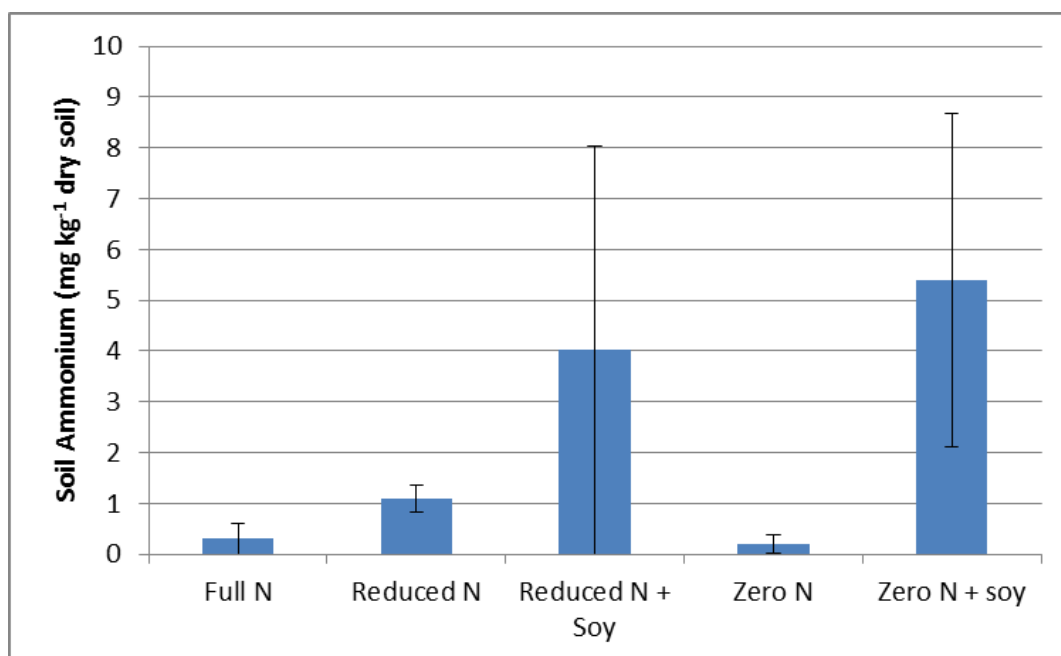


Figure 7:

Maroochy River figures 5, 6, 7, are results from the trial conducted during the 2014 harvest season, and show that a combination of intercropped legumes with a sugar cane crop is a viable farming system, for a number of reasons.

Figure 5, is a measure of total biomass that has been collected from the various nitrogen and soy combinations and also illustrates that there is very little difference in outcomes, suggesting that given the input savings from lower nitrogen applications a legume sugar cane intercrop is a commercial alternative.

Figure 6, shows that there is very little difference in tonnes of sugar per hectare from what is considered conventional treatment (148 kg/Ha nitrogen), when compared to 66 kg/Ha nitrogen with intercropped soy. This also corresponds to a cost saving of \$50 per Ha for nitrogen inputs.

Figure 7, demonstrates the soil ammonium concentrations, April 2014. Higher ammonium in treatments with soybean provides evidence that soybeans are bringing nitrogen into the system via N fixation. This soil nitrogen is available to the sugarcane crop.



**Figure 25: Sugarcane hand harvest being conducted at Sunshine Coast site, 7/10/14 Rocky Point QLD
Australia.**

(University of Queensland)

Information sourced from Milestone reports 4, 5, for AOTRG2 – 0045 project.

Conclusion

The results of this research are not what were envisaged at the onset. What has become apparent is that this is a unique topic in a commercial sense in the sugar cane industry. That being said this study has shown that there is scope for such a concept to be beneficial for the Australian sugar cane industry. The only commercial example of intercropping was from a winter cropping system in a temperate zone in Saskatchewan and Manitoba Canada, involving grain crops. That being the case, the research collated shows that there are some principles that are common across different climates and different crops, plants are complimentary if grown in the correct combination. The corn/clover example from Indiana is not as easy to quantify due to the United States Department of Agriculture's policy regarding crop insurance, which excludes farmers from growing two crops in the same field simultaneously. However, there are soil health benefits, although not expressed in a dollar figure. From Zumbrun's observations, water holding capacity, soil structure and grain yields have improved. The examples that have been discussed and the science behind them, reduction in costs (nitrogen, herbicides) increase in productivity as described as (land equivalent ratio) quality benefits as described by Colin Rosengren. Colin was not comfortable sharing economic data. However, he did say that the system is profitable and he is continuing to farm this way.

The trials from the original (Granshaw 2002) trial showed significant cost savings with herbicide, applied fertiliser, and water use efficiency, which equated to a return of \$5,935 per hectare in the companion cropped area and \$4,478 per hectare return from standard practice (no inter cropping) a difference of \$1,457 per hectare. The data from the current trial is not useable, as the soy trial did not establish successfully and was not sufficient to prove any value to the sugar cane crop.

2012 Nuffield Scholar Ashley Fraser, explored growing peas and canola together in North-east Victoria. He found that the combination produced higher gross margin than the individual crops. Baker Seed Company, at Rutherglen, has planted an 18ha trial crop of a mix of the pulse and oilseed. If it is successful, Baker Seed general manager Ashley Fraser said it could incorporate the system into its operation. *"We tried this after I talked to Bryan Granshaw, a sugar cane farmer in far north Queensland,"* Mr Fraser said. *"As a Nuffield scholar, he was researching cover and companion crops in sugar cane. One of the things he looked at was using peas in canola in Canada. They had a 15 per cent better growth margin after grading with peas and canola planted together compared to the gross margin for just canola"*. This year the family-run operation sowed the mix into one paddock.

Within the sugar cane system these benefits have also been documented, with the same 15 per cent increase in yield with intercropping that has been reported in the Canadian grain experience. An increase in quality of

concentrated cane sugar (CCS) was also recorded, along with decreases of synthetic nitrogen and herbicides. As a result of this study, the University of Queensland has partnered with the author and two other sugar cane farmers in Queensland, to conduct a three-year study into the specific practice of intercropping a legume with a growing sugar cane crop. The results so far have shown that there is indeed potential for an intercropping system to be beneficial in a sugar cane farming business; there are significant challenges to manage. Timeliness of planting the intercrop (the stage that the sugar cane plant is at), the ability to get on to the paddock to plant the intercrop and the ability for the legume crop to survive to maturity, (i.e. avoiding being eaten by rodents or native wildlife). Further to the author's study and trials, Simon Mattsson, a 2013 Nuffield scholar, is extending this intercropping idea to include multiple species of plants that have the potential to be cash crops, to compliment the financial benefit from the sugar cane crop.

When considering the idea of intercropping, there a number of main principles that need to be taken into account. It is important to understand what the grower is wanting to achieve; for example, the farmer managing the above sugar cane trial is trying to address a perennial monoculture. This crop can be the only crop in the ground for five or more years, so pathogen build up is a big reason for intercropping a legume with a C4 grass, so understanding the species of plants is important. For example will the intercrop effect the harvest of the main "cash" crop, for example a climbing vine like Lab Lab, a legume, would render a sugar cane crop un- harvestable. However, in Colin Rosengren's situation, the field peas used the erect canola as a trellis, which was advantageous and improved the quality of seed from the peas whilst not adversely affecting the canola. The region that is farmed is also important, species must be able to thrive in the environment that they are planted, so a cool climate species that looks great on paper, may not be the best fit for a temperate farming zone.

Recommendations

The following recommendations apply to all intercropping situations. It is important in considering intercropping that the farmer:

- knows what he wants to achieve from intercropping.
- understand which crops are likely to be synergistic.
- understands the logistics of managing two crops simultaneously.
- preferably conducts small scale trials.
- has a good knowledge of the physical and chemical soil properties on the farm

References

2012 Annual Project Report for the Agricultural Demonstration of Practices and Technologies (ADOPT) Program

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Plain English Compendium Summary

Project Title: Intercropping growing two crops simultaneously	
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Scholar:	Bryan Granshaw
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Objectives	<p>The primary objective was to find evidence that this concept is valid, and able to be managed in a commercial cropping system and;</p> <ul style="list-style-type: none"> • To find researchers who have studied such a concept (intercropping) with scientific rigour. • To meet with farmers who have implemented such a system in a commercial farming enterprise. • To find a way forward to implement an intercropping management system into our commercial sugarcane farm.
Background	Granshaw Farming has previously done its own trial work in intercropping soybeans with sugarcane as documented; this Nuffield Scholarship has enabled us to further improve our understanding of this concept.
Research	These studies took me mainly to North America, Saskatchewan, Manitoba, Canada, Indiana and Michigan, U.S.A.
Outcomes	<p>This report finds that intercropping is a valid farming concept and that there are research trials and commercial farmers who are achieving benefits which are economic, environmental, and productive. Granshaw farming has been successful in attracting University of Queensland to conduct a three-year study into intercropping in the sugarcane farming system.</p>
Implications	For the Sugarcane Industry the implications can be very beneficial especially with regards to diversity in crop species, breaking monoculture, and soil health.
Publications	WADO, annual report 2010, IHARF, Agricultural Demonstration of Practices and Technologies (ADOPT) Program (2012)