Cover Crops

A report for 

by Robert Blatchford
2011 Nuffield Scholar
June 2012
Nuffield Australia Project No. 1114

Sponsored by: Grain Growers Limited 

Scholar Contact Details
Robert Blatchford
Blatchford Pty Ltd
Innesfail
Gurley NSW 2398
Phone: 0267546789
Fax: 0267546787
Email: rob@blatchford.id.au

In submitting this report, the Scholar has agreed to Nuffield Australia publishing this material in its edited form.

Nuffield Australia Contact Details
Nuffield Australia
Telephone: (03) 54800755
Facsimile: (03) 54800233
Mobile: 0412696076
Email: enquiries@nuffield.com.au
PO Box 586 Moama NSW 2731

Foreword

The aim of the research was to find a cover crop, preferably a legume that was fast growing, would leave a heavy stubble residue after knock down, increase the fertility of the soil and reduce soil erosion.

The research was important because in a cotton rotation, the requirement of pupae busting after cotton picking leaves the fallow with little cover. Millet is the favoured cover at the moment but the application of fertiliser is required to compliment the cover and feed the soil for the next crop.

To find a cover species that may increase the fertility and improve the soil biology as well as provide cover necessary to protect from erosion and increase soil moisture would be of benefit to all landholders in a cotton rotation or practising minimum or no till farming.

Over the past three growing seasons our on farm rotation has been cotton followed by a millet cover crop. This decision has put greater importance on planting the most effective cover to meet all the demands of a fallow with minimal stubble residue in sloping country.

Cover crops were observed in many countries grown with the purpose to minimise soil erosion, soil subsidence, maximise water retention and enhance the fertility of the soil.

A cover crop may be grown as a single crop (monoculture) or as a polyculture where more than one species is planted as a means to vegetate or cover the soil with the intention not to harvest for commercial purposes.

Not one cover crop was observed as the optimal crop; it was realised that many species can be used as a cover and that many species in the one mix may provide the landholder with a solution that not only provides protection to the soil but improves the overall biology of the soil.

Research found that one single cover crop may not be the answer. Several covers referred to as a ‘cocktail’ could be of greater benefit.

Cover crops which provide vegetative cover are a form of soil conservation which works with the purpose of providing a soil cover or barrier against soil erosion. Cover crops are grown as an integrated farm management activity with other improvements and in connection with all other soil conservation works within the farm conservation plan.

This paper outlines cover crops seen in Brazil, USA and France, their purpose, and the idea of planting more than one cover species in a fallow.

Landholders should be thinking outside the normal parameters of planting just one species in their cover crop rotation. A mix of species ‘cocktail’ may provide an ideal balance between achieving healthy soil biology, increased fertility and water infiltration along with a good stubble cover to reduce erosion and also setting up the farming system for improved yields in the subsequent crop.

Grain Growers Limited funded the project.

Acknowledgements

Rabobank	Brazil
Bayer	Brazil
Syngenta	USA

Abbreviations

CMA	Catchment Management Authority
GM	Genetically Modified
GRDC	Grains Research & Development Corporation
LFA	Landscape Function Analysis
NSW	New South Wales

Contents

Executive Summary

I would like to thank Grain Growers Limited for their generosity in funding this research into the benefits of cover cropping.

When researching cover crops the key issues were soil protection and moisture management. Minimising soil erosion, soil subsidence and maximising water retention in the soil are critical to maintaining a sustainable, productive farm in a sloping dryland cropping system.

Initially the research was to look for the ultimate one vegetative cover to reduce evaporation from the soil surface and store moisture for future crops as well as a cover that would protect the soils from high intensity rainfall events, reduce weed growth and improve the fertility of the soil.

Travelling extensively through Brazil, USA, France, Turkey and Ukraine various cover crop varieties were observed being planted as a cover. Plantings ranged from one cover crop (mono culture) to a cocktail of covers (poly culture) in the one field. The overwhelming reason why cover crops were being included in the rotation was for the purpose of soil conservation. Cover crops in broad soil conservation terms were adopted for erosion control, for increasing organic matter and improving soil biology, fixing nitrogen, recycling nutrients, increasing beneficial organisms and for controlling weeds.

In turn the activity of planting a non-financial cover crop has resulted in reduced soil erosion, improved soil biology and increased the water use efficiency for the following financial crop. Cover crops are a vegetative cover and are an integral management activity and as such are an integrated system to the overall farm management.

A cocktail or mix of cover crop species is certainly worth trialling and it may be the silver bullet is not held in one species of cover but a mix of cover crops to achieve reduced soil erosion, maximise moisture storage and improve the overall biology of the soil.

Introduction

I am a dry land cotton grower from Gurley south of Moree in North West New South Wales.

I have been growing cotton in rotation with cereals for the past 20 years. Since the introduction of genetically modified (GM) cotton and the influence of lower commodity prices, cereals in the short term have been dropped from the rotation and now only include cotton and millet.

This rotation has been adopted for the past four growing seasons. Cotton is the only cash crop currently grown on farm with millet planted with the sole purpose to support the dry land post cotton fallow as a soil cover.

Monsanto GM Cotton has a licence requirement that at the end of the growing season, the soil must be disturbed to break the emergence tunnel of overwintering pupae in the soil. Cultivation disturbs the soil in its entirety and as a result the soil is left with very little cover or post-crop residue. The soil is very prone to erosion in the exposed state.

In the past cereal (stubble) residues were used as a cover in the fallow and cotton planted into the residue. Since cereals have been dropped from the rotation it was essential to maintain soil cover before and after cotton and therefore millet has been planted following cotton to provide the residue in the fields until cotton is planted again.

The choice to research cover crops was selected with the priority to find a single vegetative cover that would provide an excellent cover to reduce soil erosion after the soil was left bare following cultivation of the cotton stubble. The cover crop should reduce water evaporation, store moisture in the soil profile in the fallow and provide increased nutrients to the soil to benefit the following cotton crop. This may indicate the use of a legume rather than a cereal (stubble like) residue as a cover crop alternative.

In order to research cover crops travel was undertaken in Brazil, USA – Georgia, North Dakota and Iowa, France, Ukraine, Turkey. The research included site visits to trials of

different covers in both cereal and cotton rotations and meeting with farmers experimenting and growing cover crops on farm.

Objectives

The objective of the research for cover crops was to;

- discover a single vegetative cover that would provide an excellent cover to reduce soil erosion after the soil was left bare from cultivating the soil to destroy diapausing pupae,
- a cover that may reduce water evaporation and store moisture in the soil profile in the fallow,
- provide increased nutrients to the soil to benefit the following cotton crop,
- to find a legume rather than a cereal which provided plant residue as a cover crop alternative,
- to observe what other farmers outside Australia are planting as a cover crop.

Chapter One

What is a Cover Crop or Vegetative Cover?

In simple terms a cover or vegetative cover is;

- a crop grown for the protection and enrichment of the soil,
- a crop planted between periods of regular crop production to prevent soil erosion,
- provide a soil cover or barrier against soil erosion,
- a crop grown for the purpose of cover only and not harvested.

There are many benefits of cover crops including erosion control, increase in organic matter, recycling nutrients, weed control and a possible feed source.

Cover cropping is essential in a rotation where Monsanto GM cotton is grown. The licence requirement is that the grower must destroy the pupae. Pupae destruction is the mechanical cultivation of soil aimed at destroying wintering pupae. This on farm activity is to combat the development of resistance and destroy any larvae that may confer resistance to subsequent generations of heliothis. Cultivation is required to a depth of 10cm across the entire surface of the land where Bollgard II cotton has been grown. The disturbance must occur prior to the 31st of July each year. As a consequence of this full soil disturbance very little if any residue is left on the surface and therefore is vulnerable to soil erosion, which emphasises the importance of planting a cover crop.

Cotton Field post full pupae bust minimum stubble residue, Gurley NSW August 2012

The most common form of cover cropping is grown as a monoculture, consisting of one cover species. In Australia and Brazil this seems to be the most practised form of cover cropping.

In cotton growing areas of North West NSW and Darling Downs Qld, the most common cover crop planted is French White Millet.

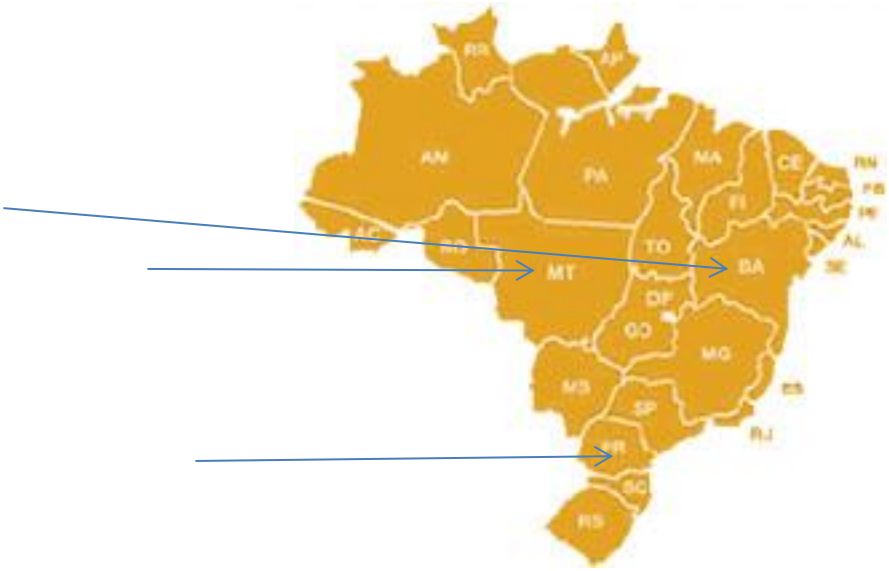
Brazil

In Brazil covers varied between farming regions. In the Ponta Grossa in the south, wheat, black oats and Brazilian hairy vetch, cereal rye and forage radish were grown. In the Mato Grosso, milheto (a cross between corn and sorghum) was planted and, in the Western Bahia in the north of the country, *Brachiara brizantha* (a type of grass) and milheto were common covers. *Brachiaria brizantha* is a grass type cover that has a fibrous root system. It is not native to South America and originates from tropical Africa. It provides an excellent cover and is good for weed control. Brachiaria requires soils of medium to high fertility for optimum growth and is best adapted to rainfall of 1500 - 3500 mm. It can withstand dry seasons of up to 3 - 6 months where the leaf remains green without browning off. The root system grows up to 3 metres in depth. Growth in height is up to 180 cm. (Sementes Paso Ita, 2011)

In Brazil, the cover species were selected depending on the climate, rainfall, soil type and topography of the region. Brazilian farmers also considered covers as a crop with the option

of feeding to cattle. This was dependent on the type of farm and in particular the soil type and whether it was vulnerable to wind and water erosion and soil compaction.

Map of Brazil



The above map of Brazil outlines each state.

States visited from top arrow down

the west of Bahia (BA), Mato Grosso (MT) & Ponto Grossa (PR)

Ponto Grossa (PR)

The Ponta Grossa region north of Parana, is undulating, with cleared, rolling hillsides. According to (Ortiz, 2012) our organising host, the Parana region of the Ponta Grossa is the birthplace of the no-till system in Brazil. The region receives consistent good rainfall throughout the year. Carambei (www.worldweatheronline.com) rainfall received per month is on average 100 mm with January the highest with an average of 150mm. June to August are the coldest months. Frosts are not uncommon and the range of temps range from a low of 5 degrees C to a top of 26 degrees C in summer in January.

The consistent high rainfall makes it essential for the farmers to cover the soils and protect from soil erosion and soil subsidence. The soils in the Ponta Grossa region are deep red clay based soils.

During the growing season the rain is used to grow the crops. Common crops to this region are wheat, soybeans, corn and cereal rye for forage. Cotton is not grown in the Ponta Grossa region. Stubble residue from previous crops protect the soil from erosion in most rotations.

The high rainfalls particularly in the winter season can cause severe erosion on unprotected soils. As a result of the high risk of soil erosion farmers have taken advantage of the rainfalls by using during these months (June-August) to grow cover crops. Fields that grow summer soybeans were covered with wheat, black oats and forage radish. Triticale and hairy vetch are also planted.

The ABC Foundation (Djkistra, 2011) located near the town of Carambei has carried out a number of trials with different covers. The ABC Foundation is a private research organisation owned by farmers in Brazil. The ABC Foundation is run as a co-operative and established the no-till farming system in the region 25 years ago during the late 80's. Members of the ABC Foundation are able to receive all trial data for a fee 50 Rio per hectare per year and are encouraged to purchase inputs such as fertiliser and chemicals and market their crops and milk via the Foundation for a 1% charge. (Djkistra, 2011)

At Carambei trials for Winter cover crops observed included Brazilian hairy vetch, black oats, cereal rye and forage radish.

Brazilian hairy vetch is a slow growing legume, which does best in high soil fertility, good soil with good moisture.

Black oats are used as a cover crop which gives a good heavy cover but must be sprayed out prior to setting seed. Black oats may also be grown for forage.

Cereal Rye is often used as a cover before corn, timing for spraying out cereal rye is important. In October the plant is easily killed however it is difficult to kill in earlier months of August to September. Rye can become a problem however it does provide a good cover and does not get affected by the regions frosts.

Forage radish is good for the soil due to the different root type, however does not leave a good enough cover to last through to planting the next crop.

Ponta Grossa, Brazil

Ponta Grossa Carambei ABC Foundation Co-Op Cover Crop Trial site

'FrankÁnna property Carambei August 2011

Photographs from L-R

Black Oats

Rye Grass

Photographs from L-R

Brazilian Hairy Vetch

Cereal Rye planted into corn stubble residue, soil - deep red clay

Mato Grosso (MT)

Travelling further north to the Mato Grosso and Western Bahia the rainfall is extremely seasonal and landholders can almost name the date when rains begin and end. (www.worldweatheronline.com)

Due to the extremes in rainfall, the soils are quite vulnerable to erosion. Heavy consistent rain with little vegetative cover from increased mass clearing followed by hot temperatures and winds has resulted in the soils being quite powdery and of little substance and nutrition. Cover crops therefore are critical to protect them from water erosion during the wet seasons and prevent soils from wind erosion in the hot dry seasons. A residue is essential for these areas to maintain the health of the soil and build up the soils which appeared to be lacking in organic matter.

Mato Grosso, Brazil

From L-R

Adriana ADR-7020 Milheto cover after cotton, August 2011

Adriana experimental cover crop site soybeans planted over stubble residue

From L-R

Girassol Agricola - powdery light soil

Roadside - contour bank no cover post cotton

Farm Adriana (www.sementesadriana.com.br) in the Mato Grosso region like many farms of this region are very large (30,000 ha plus) and were established in the 1980's (Boas, 2011), many remain family owned like Adriana (Souza, 2011). The Adriana landholding is approx. 60,000 ha. Adriana employs 430 people with many living on farm. On the Adriana farm cotton is grown in rotation with its main crop soy beans and corn. Adriana is the largest

supplier of soybean seed to Brazil and has a state-of–the-art research centre for soybeans located on farm. The company also sells other seed including milheto and sorgo.

The Farm Manager was very passionate with respect to the cover crops planted on farm. Milheto (ADR-7020, ADR-300 Hibrido de Milheto, 2011) is a pearl millet hybrid. Milheto is deep rooted and has the potential for high bio-mass production. It is a plant that recycles most of its nutrients through straw. It is a dual purpose crop which aims at high production of straw to tillage and production of grains. Milheto is good for recycling nutrients and reducing nematodes for the next soybean crop.

Adriana Farm Manager says *"Milheto is known to significantly reduce the population of the nematode parasite and raises the production of the succeeding crops"* (Souza, 2011).

The planting season in the Mato Grosso for clay soils is from February 1 – March 15 and on lighter sandy soils February 1 to February 28. For sowing the recommended planting depth is 3-4cm with seeds varying from 22 to 25 dependent on the row configurations.

Milheto on farm Adriana was planted in rotation with cotton although not always exclusively as a cover and was harvested to collect seed for sale or future on farm seed requirements.

Sorgo a grass type forage (ADR-500 Sorgo - Super Massa , 2011) was another cover crop planted. It is a fast growing, high forage producing crop. On Adriana sorgo is used exclusively as a cover. However, the more common use is for livestock as it has excellent nutritional value.

Sorgo is planted in the Mato Grosso between October and March.

'Cover crops on Adriana are usually planted to soften the soils as without them the soils were very hard' said (Souza, 2011). The soils observed were a heavy red loam.

A cover crop observed on Adriana at its cover trial site was a nitrogen-fixing legume called crotolaria (in the USA sometimes referred to as rattlebox flower) – a tap root legume with a yellow flower that smelt like a pea. The pods hold 10 – 20 glossy black heart shaped seeds

which often detach and rattle in the pod. The rattle sounds like a ‘rattle snake’ and like the rattle snake if eaten is toxic to humans and livestock. The crotolaria is a legume and was planted on Adriana to improve soil fertility and is also a soil-building cover crop. It may improve the yields of the following crop. The legume is also good for controlling weeds during the fallow. Crotolaria may be used as an intercrop legume with corn. It is a legume that should not be grown too often as it may cause a build up of disease in the soil. The crop is sprayed out to finish the growth.

No Adriana seed varieties are available in Australia.

What makes agriculture work in Brazil and in particular the Mato Grosso and newest farming region the Western Bahia further north, is the reliability of water in the wet season. The concept of planting a crop and just adding water appears to be working well in these regions in the short term. However the yields will more than likely plateau if cover crops are not undertaken as an essential management activity in the rotation. It will also be necessary to protect the soils from water and wind erosion. Building up the organic matter and natural fertility of the soils will be necessary for the future productivity of Brazil’s agricultural regions.

Western Bahia (BA)

The Western Bahia is Brazil’s newest agricultural frontier with 30% of Brazil’s cotton, 5% soybeans and 3 % corn produced in the area. (AIBA)

Western Bahia, Brazil

From L-R

Brachiaria Brizantha 'Agropecuaria Sao Vicente’ Farm August 2011

Brachiaria Brizantha cover being fed off to cattle

Western Bahia, Brazil

From L-R

Milheto stubble residue ready for cotton, 'Grupo Adeco' farm August 2011

Sementes pasoita - milheto seed in store

In Western Bahia on two farms visited (Grupo Adeco and Agropecuaria Sao Vicente) outside Luis Eduardo Magalhaes (LEM) the most common cover crop planted was *Brachiaria brizantha* and milheto. The cover is generally planted straight after a soy bean crop in March or April and prior to the next cash crop cotton. The crop is usually seeded at 7kg/ha. (Santos, 2011)

Bayer Agronomist (Wazne, 2011) said '*ideally the cover is planted with a spreader across the top of the standing soybean plant prior to its harvest to take advantage of any in crop soil moisture before the dry season takes hold*'.

Otherwise the seed is planted after the soybean harvest with a crop planter or by plane. (Santos, 2011)

Before seed sets the brachiaria is sprayed out, due to the dry season (July-Oct) it is not recommended that the cover is fed off. Because the soils are so dry and the weather so hot and windy feeding the cover off to cattle increases the soil compaction dramatically. (Wazne, 2011)

On the large corporate cotton farm visited 'Grupo Adeco' the covers planted were used solely as a cover only, however the second visit was family owned 'Agropecuarla Sao Vicente' farmed a mixed operation which included cattle and cattle lot feeding, planted the cover to feed off as well.

In Western Bahia, the cotton growing was not the latest Monsanto technology available in Australia. The most common cotton planted observed was Deltapine Opal – this crop is not genetically modified. Because of this the farms in this region and in Brazil in general did not have to pupae bust like the Australian GM Cotton farmers. Opal has resistance to Blue Disease – a major problem in Brazil. (Wazne, 2011)

Because pupae busting is not a component of the management there is a greater amount of stubble residue left over from cotton than on Australian farms. On farm 'Grupo Adeco' where cotton picking was in full swing (August) the cotton was grown to heights of 1.5 metres which left a considerable amount of residue to slash and mulch back into the soils.

The covers planted were used to compliment this residue and prevent for the most part wind erosion and the loss of top soil during the dry season and added critical biomass to improve the soil fertility for the next crop (Santos, 2011).

United States of America

North Dakota

One farmer who has taken cover cropping to a new level is Gabe Brown (Brown, 2012) of North Dakota, USA. He has progressed from growing cover crops as a monoculture to a poly culture of cover crops species.

Initially, this research aimed to find the ultimate cover crop which would provide good thick cover, perhaps replace a wheat stubble-like cover, was easy to knock-down and increased nitrogen in the soil. This ultimate silver bullet may have been a leafy, fast-growing legume to complement the cotton rotation.

However, after meeting organic farmer Gabe Brown – the realisation was made that this probably did not exist and that diversity in cover cropping may be the key. Browns Ranch is farmed under an organic system so to shut down the process of plant growth a crimper behind

a tractor was used otherwise the cover was grazed off. They were not concerned with compaction as the animals were moved regularly.
Brown explained that his land was managed under a polyculture system. He believed that cover crops should mirror nature, and where nature was left to grow without intervention, many species grew to cover the land. With this in mind he developed a system using a range of species which included grasses and broadleaves with both fibrous roots and taproots. (SANTFA, 2012). He believed the manure from the cattle was part of the nutrient cycle and complimented his theory of diversity, which offset any issue he may have with compaction.

'Diversity provides the food (carbon) that feeds soil life. Soil life in turn supplies the nutrients needed for the crops'. (Brown, 2012)

The diversity in the covers has enabled the different species to feed soil life, prevent soil erosion, reduce subsidence and evaporation and provide soil with increased organic matter.

The mix of cover crops may include, at different times, hybrid pearl millet, sorghum or Sudan grass, soybeans, cowpeas, sunflowers, sunn hemp, radishes and turnips.

'*A key to improving soil health is keeping the ground covered at all times. This is achieved with both living cover crops and crop residues. A farm managed under this system provides the armour to protect the soil from wind and water erosion and acts as a buffer to protect soil life from extreme temperatures'* (Brown, 2012).

Another idea that Brown mentioned was planting local native species as a cover. He made the point that planting species which grow in nearby pastures or which are similar to native fauna may be more successful than planting introduced species (Brown, 2012). However, planting a native legume cover crop would be challenging given in Australia there is no method to acquire seed and no available seed stock for native legumes (Mackinnon, 2012).

Brown in the USA was not the only farmer combining cover crop species.

France

In the South of France, Sarah Singla (Singla, 2011) farm ‘Le Caussanel’ grows radish (turnip), buck wheat and nitrogen fixing crops such as lucerne, vetch, peas, faba beans and clovers in her no-till farming system as cover crops. Sarah’s main objective for cover cropping was to increase fertility of the soil above the restrictions for fertiliser use imposed by the French government.

Cover crop combinations of buck wheat, radish and vetch were planted as well as Lucerne and radish depending on the season and prior cash crop.

In an email Sarah (Singla, Cover Crops, 2012) said ‘buckwheat *is helpful to solubilize phosphorous and has a strong allelopathic effect’*. This means that the buckwheat will exude chemicals that prevent weeds and other plants from growing.

‘*For the nitrogen, you must use a legume. The radish (turnip) has a large root system and is mainly planted to decompact the soil. The turnip won’t build up nitrogen in the soil but will help to recycle the nutrients which would go away if we didn’t have any root system’*. (Singla, Cover Crops, 2012)

The radish has a long, strong tap root with a medium carbon to nitrogen ratio, and high sulphur recycling. (Sue Roseler)

For Singla, the radish is an excellent choice in the mix as it not only helps with deep pan disturbance it also is a great storage for nitrogen which releases slowly and benefits the following cash crop.

The crop rotation on ‘Le Caussanel’ of wheat, barley and canola combined with the cover crops left the soil with a lot of organic matter. The soils are very shallow and acidic so increasing the biomass between cash crops is an excellent outcome for Sarah’s move to no-till farm management and cover cropping.

South of France

Sarah Singla with Radish, South of France, October 2011

Growing covers in the northern hemisphere also had the advantage of extreme temperature when it came to the knock down of the cover crops. In France and North Dakota there can be variability in temperature of 50 degrees Celsius. The plants naturally shut down rather than having to use herbicides or mechanical implements as a knock down. The extreme in temperatures prevented their crops from growing outside the desired season.

On Brown's property in North Dakota USA, it snows in the winter. An alternative to herbicide knockdowns on Browns organic property was grazing or using a roller.

Both Singla and Brown stand behind the fact that a mix of broad leaves and grasses as long as they are established in their preferred planting window is the best option for cover cropping, following the principle that the more diversity the better.

Browns Ranch North Dakota USA, photos by (Brown, 2012)

From L-R Corn stubble residue

'Cocktail' of cover crops seeded as a mix

Browns Ranch North Dakota USA, photos by (Brown, 2012)

From L-R

Close up of a poly culture cover crop mix

Seeding into cover crop residue

Australia

Over the past few years there have been a number of trials carried out across Australia and in particular north west NSW. The GRDC website has a number of research papers where trials of cover crops have been conducted (www.grdc.com.au). In most cases the research undertaken has been in a cereal (wheat) and summer crop (sorghum and sunflowers) rotation using one species of French white millet.

The overwhelming conclusions are that growing cover crops purely for ground cover delivered valuable benefits such as reduced erosion, an increase in water use efficiency, improved yields in subsequent crops. Millet also had the ability to increase water infiltration as the roots helped take water deeper into the soil, with an additional benefit of weed suppression.

There does not appear to be a great deal of research where cotton is the dominating rotation or with using more than one species in the mix.

When speaking with (Brown, 2012) he put out the challenge of planting many species as the cover crop including hybrid pearl millet, cow pea, flax and radish. With other possibilities being Ethiopian cabbage, hairy vetch, crimson clover, sunflowers and sun hemp. Sun hemp

has to be well managed if the sun hemp grows too high it causes a roping effect making the planting of the cash crop difficult.

Hairy vetch and crimson clover, being legumes, are high nitrogen fixers.

Vetch sown in a mix with oats is a common mix in southern Australia for cover crops where it is grown to feed cattle. The issue with vetch and oats is the amount of fertiliser, especially nitrogen, which this mix requires.

Another idea could be to plant native species as a cover. This is an interesting concept and one that requires further research. Brown did mention that native legumes could be an option. (Brown, 2012)

Two species that could be considered in north west NSW is the native *Lotus australis*, a native legume that is a good ground cover. This native cover germinates in late spring early summer and has a hard durable seed and a deep tap root. The second native ground cover is the Darling Pea which grows thick across the ground.

However removing these native ground covers may be difficult for the incoming cash crop and also acquiring seed of any volume would also be challenging as no seed stocks are available, according to the Border Rivers Gwydir Catchment Management Authority (BRGCMA). (Mackinnon, 2012)

In addition to researching the benefits of planting more than one species in the cover crop would be important to undertake landscape function analysis (LFA) (Reid, 2012). LFA measures the soil erosion benefits of planting a single cover crop, or a mixed species cover crop, compared with no cover crop at all.

After looking at many cover crops across a diverse range of soils and landscapes it became apparent that land managers were growing cover crops as a means of building up the organic matter and to improve the productivity of the next financial crop. However, the overwhelming driver was to protect the soils, to manage soil erosion and increase soil fertility, as without a

good healthy top soil there was no soil to build organic matter, maximise moisture, and ultimately grow a productive crop with financial benefits.

Cover crops whether they are in a monoculture or polyculture ‘cocktail’ of plant species are critical to the solution of minimising soil erosion in sloping dryland cropping systems. This is especially true where the cropping rotation includes the growing of a GM cotton crop.

Around the world farmers are integrating cover crops into their farming systems and practising soil conservation works.

Conclusion

There is no one species that can be defined as the ultimate cover crop.

In Australia, the most common crop planted is French White Millet, grown as a mono-culture.

Millet does provide excellent biomass, reduces water evaporation and stores moisture for the subsequent crop, however it may not meet all the nutritional needs of the soil.

Brazil similar to Australia sees advantage in growing one cover species to protect the soil from both wind and water erosion.

However, travel to the United States and France has highlighted that to find the ultimate cover crop a combination of species is recommended.

The ‘cocktail’ mix is the latest trend in cover crop farm management. Moving away from a mono-culture towards a poly-culture of at least two species. From planting buck wheat to mineralize phosphorous in the soil, forage to provide bio-mass combined with radish to store nitrogen in the profile.

The take-home message is that it is important to maintain a vegetative cover at all times between crops to protect and prevent soil erosion.

To achieve my goal of finding the ultimate cover crop, experience this past year in Australia and abroad has led me to conclude that a combination of broad leaves, legumes and grasses is the silver bullet – the more diversity the better.

Recommendations

Key recommendations for research agencies;

- carry out formal trials with landholders as an extension of their existing research,
- trials to include a mixed species of cover crops – the cocktail concept,
- trial native legumes as potential cover crops, and
- include landscape function analysis in all trials.

Key recommendations for landholders;

- plant at least one cover crop species after a complete GM cotton pupae bust,
- trial various cover crops on-farm independently,
- plant more than one cover crop species at a time, mixing various seeds together in the planter box which are suitable to location, season and price point.

Appendices

Glyphosate Resistance

Many farmers throughout the world would agree that glyphosate is the most valuable herbicide in agriculture. Therefore it is critical to preserve the effectiveness of this cheap and highly effective non-selective herbicide.

In the USA, the over-reliance on glyphosate for weed control in fallows and in Roundup Ready (RR) crops especially cotton and soybeans has led to the development of resistance. The state of Georgia, USA is testimony to this (Prather, 2011). Since the introduction of Roundup ready (RR) crops and the huge uptake where corn, cotton and soybeans are almost exclusively planted the over use of glyphosate has increased dramatically. Professor Powles, University WA , Perth says that '*nearly all of the US's massive soybean crop - 35 million hectares – all of its massive 40 million hectares of corn and 95 percent of its 2.5 million hectares of cotton are RR varieties*' (Bettles, 2012)

The most obvious weed resistance observed in Waynesboro, Georgia was the Palmer amaranth (Palmer pigweed). The weed was prolific along road sides, fallows and in cotton crops. It would appear that hitting a hole in one at Augusta would be more achievable for the farmers of Georgia than controlling the glyphosate-resistant weeds overtaking the farms, in particular the Palmer amaranth.

Waynesboro, Georgia

L- R

Palmer amaranth with Cleeve Mobley

Palmer amaranth in seed

The Palmer amaranth is a fast growing summer annual weed. The weed can reach heights of three metres if not controlled. The plant has a fibrous root system extending from a well developed taproot. It has one central stem from which several lateral branches arise. The flowers are terminal spikes that grow up to 60 cm in length. Each plant is capable of producing more than 500,000 seeds (University of Florida). It has become difficult to control due to its fast growth rate, high seed production and increasing resistance to glyphosate.

In order to control this weed, cotton farmer Cleeve Mobley (pictured above) carries out a weed control measure called 'wicking' or 'weed wiping' as it is referred to in the UK. Wicking or weed wipers may be used in any growing crop, providing the chemical does not touch the crop. Mobley (Mobley, 2011) emphasized that the wicking practice (University of Georgia) was critical to controlling in crop Palmer amaranth. And the need for diligence as the weed continually reinvented itself where it was not killed off in its entirety.

'*Any weeds that are not killed from a full field glyphosate spray or from wicking require hand weeding. For full control the weed when hand-picked must not be left to die but gathered and burnt as the seeds will continue to regenerate*'. (Mobley, 2011)

The UK Monsanto website recommends that weed-wiping should be timed for when weeds are at or near their stage of growth for optimum translocation. Perennial broad-leaved weeds

should be at or near flowering and perennial grass weeds should have at least 10 - 15cm of new leaf growth. All weeds susceptible to glyphosate can be controlled by this technique provided they are sufficiently taller than the crop and are at a susceptible stage. The target areas of weeds are the green leaves and green stems. (Monsanto)

According to local Waynesboro chemical supplier George Tedder (Tedder, 2011) regardless of which system is adopted for Palmer amaranth management, a "program" approach is essential to success. The technology must be used in combination with a well-planned burndown, pre-emergence, post-emergence, and layby program. Additionally, it is important to time post-emergence applications to small (2 - 8 cm) weeds. Targeting large weeds, regardless of herbicide resistance, can easily lead to lack of control and lost crop productivity.

It would appear from speaking with local farmers and chemical suppliers that many farmers do not control the Palmer amaranth weed to this extent and therefore it is difficult to see a future in Georgia where the weed is controlled. Only a state wide or nationwide coordinated blitz through the United States Department of Agriculture (USDA) could eliminate this weed.

It is also important for Australian farmers to be aware of what the Palmer amaranth weed looks like. Tedder (Tedder, 2011) warned that he knew of five round bale cotton pickers that had been imported into Australia from the Waynesboro, Georgia area. Despite excellent Australian quarantine standards for importing second hand machinery (Department of Agriculture, Fisheries and Forestry) the risk of infestation from glyphosate resistant countries should never be underestimated. Australian farmers buying or employing contractors to pick their cotton crops with machinery imported from the USA should be aware that it only takes one Palmer amaranth seed to get through the system. It is critical to monitor their fields for any unusual looking weeds.

Mobley could not have been any clearer '*you do not want this weed anywhere near Australia!'* (Mobley, 2011).

For Australian farmers the best option to prevent glyphosate resistance in any weed is to remain proactive, and to prevent any survivors of a herbicide application from setting seed

and germinating. An integrated weed management (IWM) program is essential to achieving this.

Innovative farming techniques and alterations i.e. use of on-farm machinery

Pupae busting in GM cotton is an essential farm management tool to combat the development of resistance to the Bt proteins expressed in Bollgard II. (www.csd.net.au).

Mechanical cultivation includes many passes in the field. These passes are time consuming and expensive with respect to the machinery required, fuel and labour.

Passes may include slashing, root cutting, mulching, cultivating and kelly harrowing. These activities may be combined depending on the type of machinery available on farm or from contractors.

Over the past four years our management strategy has included a custom designed 12 metre slasher/root cutter followed by a cultivation and finishing with a pass with Kelly harrows.

L-R

12 m slasher/root cutter, Gurley NSW 2012

Cotton residue post slash/root cutting

Final pupae bust, 3- in-1 cultivator, fertilising & Kelly harrows, Gurley NSW July 2012

Therefore as part of this study an interest was to seek out machinery that is being used in other countries to manage the post cotton management phase.

In Brazil in both the Mato Grosso and Western Bahia regions where cotton is grown, pupae busting was not considered essential as they were not using the current GM cotton varieties available in Australia and therefore did not have the legal requirement to till the soil to 10cm.

Two pieces of machinery of interest were in the Mato Grosso region of Brazil.

Coulter Disc, BDM Group Farm, Rondonopolis Mato Grosso, August 2011

The Brazilian made coulter disc with a large offset was used to remove the cotton roots followed by discs to fill in the row made by the coulter. This appeared to be very successful cutting to a depth of 15 cm, although the soil type lent itself to this practice. This implement may not be as effective in heavier soils.

Coulter Disc digging up cotton roots, BDM Group Farm, Rondonopolis, Mato Grosso, August 2011

Hydraulic root cutter, Girassol Agricola Farm, Pedra Preta - Mato Grosso, August 2011

This Australian invention, the hydraulic root cutter, was observed in the Mato Grosso working after the cotton had been slashed and mulched. The soil type was powder like and therefore the discs penetrated the soil well. This machine is used in Australia under irrigation where the cotton is grown on hills. In a rain grown system the root cutters have been found to be less effective due to the machine not being able to penetrate the flat soil profile.

On both farms the machinery used was four metres wide, pulled by basic small cab-less tractors. Most of the machinery appeared to be second-hand in the Mato Grosso, perhaps imported from USA. GPS Systems are not common in Brazil. Only farms in the Ponta Grossa region in the south had Brazilian made JD 4630 boomsprays with GPS systems installed. The Ponta Grossa is far more undulating with smaller fields than those seen in the Mato Grosso and Western Bahia.

Employees are plentiful and inexpensive and farms like Girassol Agricola employ hundreds of people who all live on farm. Therefore the farm manager did not think it necessary to spend

additional capital on upgrading their machinery to the GPS systems to become more efficient (Nantes, 2011). However, they are considering the JD 7760 round cotton bale machines in the future. And he believed there was at least one such machine in the Mato Grosso for the 2010/11 cotton season.

The Western Bahia is considered a new agricultural frontier in Brazil, with the region boasting in 2010/11, 30% of the Brazilian cotton production, 5% of soybean and 3% of corn.

The Association of Agriculture Irrigation Bahia (AIBA) has encouraged investment in the region including uptake of more modern machinery. This has meant educating the farm workers by setting up technical centres as well as higher education institutions to train up agronomists to meet the growing demand of the more progressive farms. (AIBA)

The international companies selling machinery in Brazil take their regional sales boundaries seriously. At Luis Eduardo Magalhaes the John Deere dealership Agrosul stamps its weights to ensure only machines purchased from the store are serviced in house.

Stamped tractor weights John Deere Agrosul Dealer, Luis Eduardo Magalhaes, August 2011

References

ADR-300. (2011). Alto Garcas, Mato Grosso, Brazil: Sementes Adriana.

ADR-500 Sorgo - Super Massa . (2011). Alto Garcas, Mato Grosso, Brazil: Sementes Adriana.

ADR-7020, ADR-300 Hibrido de Milheto. (2011). Alto Garcas, Mato Grosso, Brazil: Sementes Adriana.

AIBA . (n.d.). *Western Bahia Region Yearbook 2010/11*.

Bettles, C. (2012, March). Weeds winning USA war - professor. *Grains Outlook*, pp. 16,17.

Boas, R. d. (2011, August). Rabobank Rondonopolis Mato Grosso Brazil. (R. Blatchford, Interviewer)

Brown, G. (2012, March). Cover crop - cocktail mix. (R. Blatchford, Interviewer)

Department of Agriculture, Fisheries and Forestry. (n.d.). *Importing machinery into Australia*. Retrieved August 2012, from DAFF: www.daff.gov.au

Djkistra, R. (2011, August). Farmer. (R. Blatchford, Interviewer)

Mackinnon, L. (2012, August). Native ground covers found at Gurley NSW. (R. Blatchford, Interviewer)

Mobley, C. (2011, September). Cotton Farmer, Waynesboro, Georgia. (R. Blatchford, Interviewer)

Monsanto. (n.d.). *Monsanto*. Retrieved August 2012, from Weed Wipers: www.monsanto-ag.co.uk

Nantes, T. d. (2011, August). Farm Manager Girassol Agricola. (R. Blatchford, Interviewer)

Ortiz, C. (2012, May). Manager Country Banking Rabobank. Sao Paulo, Brazil.

Prather, L. (2011, September). Georgia Territory Manager - Syngenta. (R. Blatchford, Interviewer)

Reid, N. (2012, August). Professor Ecosystem Management UNE Armidale. (R. Blatchford, Interviewer)

SANTFA. (2012). Integrating livestock in a no-till cropping system. *Viterra 14th Annual SANTFA Conference* (p. 5). SANTFA.

Santos, M. (2011, August). Farm Manager Grupo Adeco. (R. Blatchford, Interviewer)

Sementes Paso Ita. (2011). Brachiara Brizantha. *aqui tem Qualidade* . Luis Eduardo Magalhaes, Western Bahia, Brazil: Sementes Paso Ita.

Singla, S. (2011, October). Radish as Cover Crops in no till systems. (R. Blatchford, Interviewer)

Singla, S. (2012, February 1). Cover Crops . Canet de Salars, France.

Souza, P. R. (2011, August). Adriana Farm Alto Garcas MT . (R. Blatchford, Interviewer)

Sue Roseler, L. A.-M. (n.d.). *No-till And Cover Crops Thrive in Brazil.* Retrieved 2012, from No Till Farmer: www.no-tillfarmer.com

Tedder, G. (2011, September). Branch Manager Helena Chemical Company Waynesboro Georgia. (R. Blatchford, Interviewer)

University of Florida. (n.d.). Retrieved August 2012, from www.edis.ifas.ufl.edu/ag346

University of Georgia. (n.d.). Retrieved August 2012, from Weed Science: www.gaweed.com

Wazne, F. (2011, August). Agronomist Bayer LEM Bahia. (R. Blatchford, Interviewer)

www.grdc.com.au. (n.d.).

www.sementesadriana.com.br. (n.d.). Retrieved 2012

www.worldweatheronline.com. (n.d.). Retrieved 2012

Plain English Compendium Summary

Project Title:	Cover Crops
Nuffield Australia Project No.:	1114
Scholar:	Robert Blatchford
Organisation:	Blatchford Pty Ltd (RJ & PL Blatchford)
Phone:	0427546789
Fax:	0267546787
Email:	rob@blatchford.id.au
Objectives	To investigate cover crops in dry land cropping systems.
Background	Cultivation of GM cotton stubble leaves the soil bare. Inconsistent rainfall has driven the need for groundcover to reduce evaporation from the soil surface and store moisture for future crops. Desire to reduce fertiliser inputs and find a cover to minimise soil erosion and increase biomass.
Research	This study consisted of the Global Focus Programme visiting India, Bahrain, Turkey, Ukraine, France and USA. Following this saw return visits to the USA travel to Argentina, Brazil and South Australia. In this time I visited landowners, farm managers, bank managers and agronomists to observe what, why and how cover crops are being grown overseas. I also travelled to areas where severe glyphosate resistance is evident and enjoyed looking at the varying qualities of on-farm machinery modifications across three continents.
Outcomes	Cover crops are diversifying from a mono-culture planting to a unique 'cocktail' mix of cover crop species. A diverse mix of legumes, grasses and forages is the new strategy targeting the various demands of soils. A mix of species can be grown in one field dependent on the location, price and availability of planting seed.
Implications	As farmers look at different ways of maximising moisture, reducing fertiliser inputs and increasing the bio-mass in fields in particular after GM cotton, a mix of cover crops may be a viable alternative. The success of a good cover crop(s) is determined by whether or not a subsequent crop may be planted on minimum moisture and inputs. Cover crops have the potential to increase the chance of getting a future crop planted and improving yield reliability. This in turn increases on farm profitability.
Publications	Nuffield Spring Conference Toowoomba 26th October 2012