2004 SCHOLARSHIP REPORT
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Topic:

Weed and insect control, beyond pesticides

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Executive Summary

What is the current biggest threat, common to all agricultural production in Australia, apart from climate change?

Soil erosion? Environmental legislation? Red tape?

In my opinion it is herbicide resistance!

Glyphosate is to agriculture as penicillin is to the medical world.

In Australia we have the worst incidence of herbicide resistance in the world with currently 33 weed species resistant (Preston), including a ryegrass population that is resistant to 4 different groups of chemical, and that is not including glyphosate resistance.

Could we economically and environmentally farm without herbicides?

My approach was to look at ideas and systems to combat resistant species that our research bodies like GRDC could look at applying here.

For example bio herbicides that are specific in controlling wild oats and rye grass. These work in a similar way to the herbicides Hoegrass ® or Achieve ®, but would reduce the competitive ability of the root systems.

Not only has research shown these bio herbicides reduce the competition of a pest species (wild oats) but also to produce a hormone which stimulates crop growth.

Another promising area I studied is allelopathic plants that have activity on weeds.

For example, varieties of wheat and barley that have activity against ryegrass and brassica with high glucosinolates that kill weed seeds. Such brassica have been shown to achieve results similar to methyl bromide that is 100% weed control. The focus was to look at specific glucosinolates and apply seed meal which is more effective than plant material.

I looked at parasitical insects that prey on problem insects and reduced the problem insects to a non threatening level. The models I was shown were cost effective.

I also visited a researcher developing a new system of spray technology that claims to achieve similar levels of weed and insect kill with a 50% reduction to current chemical rates. It uses two jets to deliver fine droplets to a plant surface, yet without drift issues that one would normally have.

Acknowledgment and Thanks

Firstly to Jane Greenslade for introducing me to Nuffield and together with Emma Leonard, for their constant encouragement and support in the program.

To the Nuffield Program, for giving me the incredible opportunity, to travel and learn about agriculture related issues, encompassing areas of cultural systems, economics, beliefs, trade and politics.

I thank those who opened their homes to a stranger and were patient to explain issues and willing to give well thought out points of view.

To GRDC for its financial support. An organisation that is independent, at the cutting edge and the envy of many research and farm groups abroad.

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Finally to the Group of guys that I was fortunate to travel with, for their company, stimulation, patience and humour……… Giddy Goat!!!

Aims

Upon writing this report I wanted to present new ideas and information, not rehash present technologies; consequently much of the information is raw and may not be fully validated.

My initial focus was to be on sub soil nutrition and the benefits one may achieve from improving root development. But as I travelled and queried I found that most people considered Australia to be leading this area of research.

When topsoil depth of 1-2 metres is the norm and 60 metres not unusual, one can see why sub soil nutrition is not an issue in most areas. In many areas trace element work is very new, not because they are necessarily unaware of the benefits but because many soils are very high in these elements.

Therefore, I changed my focus to an issue that I think is critical to the future of agriculture that is, our ability to control plants and insects that are not desirable in our current farm systems.

Resistance to pesticides starts as soon as one uses these chemicals, it's a numbers game.

Current no till farming is not sustainable, because of the reliance on herbicides.

Even a sheep enterprise is at risk of resistance.

The focus of my study has been on new technologies that I consider to have potential in our farming systems, ideas that need further evaluation from research bodies (GRDC etc.) to ascertain whether they are in fact feasible and applicable to our farming systems.

It only takes a small problem or issue to scuttle a good idea, but likewise many good ideas in the past that haven't worked, can with small changes in technology or some lateral thinking become significant mainstays of the way we do things.

No till is one example. This technology was developed many decades ago, but only with developments of rotation, herbicides and machinery in the 1980's, has this system become the mainstay of current broad acre agriculture with approximately 40% of all crops in Australia sown with no till.

For this reason I believe we need to constantly be reviewing how and why we do things and to have an open mind and lateral approach to new and past technologies.

Introduction

My research has been relatively minor, gathering information and adding some ideas and assumptions to this, and is not meant to give all the answers, only to promote interest and awareness, to encourage one to “look outside the box” and ask more questions.

Information I gathered was from short meetings or even conversations over the phone followed up by further research from other researchers and papers. I tried to validate and cross reference information as much as possible but due to some of the cutting edge research and my short research time (3 months research to report) there are many issues and areas that I would have liked to have delved and explored more thoroughly.

For more information and detail I ask that you follow up with the experts whom I so much enjoyed listening and interacting with; as found in the acknowledgement section.

“Imagination is more important than knowledge. For knowledge is limited to all we now know and understand, while imagination embraces the entire world, and all there ever will be to know and understand.” *Albert Einstein.*

Weed control where have we come from?

Tillage has been the focus for weed control for many hundreds of years, with a shift to chemical control during the last century. The advantages have been many, better soil health, less erosion, leading to more intensity of cropping and greater profitability.

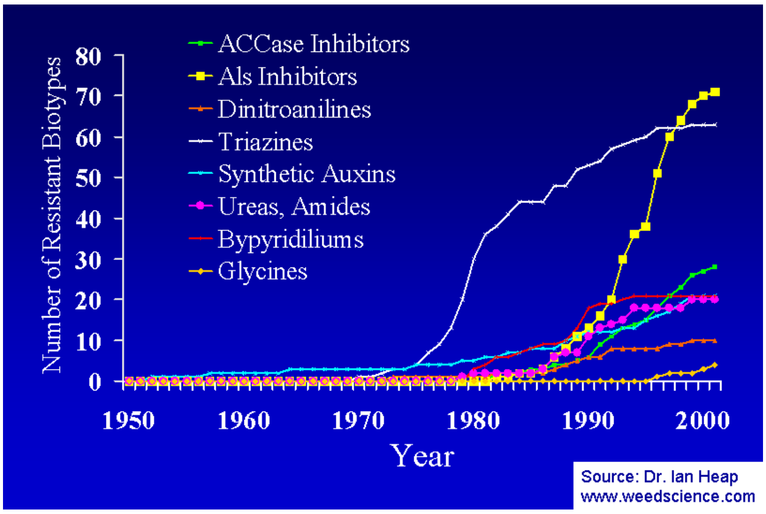
The major disadvantage has been the onset of herbicide resistance.

Pesticide resistance started as soon as we started using chemicals, becoming visible in the 1980’s in Australia (and in 1960’s in USA).

Australia currently has the worse case of resistance in the world, with herbicide resistance to ryegrass being our greatest issue and having the largest economic impact.

That is we have a ryegrass population that is resistant to 4 different groups of chemical (A,B,C,D) and ryegrass that is resistant to glyphosate in broadacre populations, at the last count 24 cases. (44 including horticulture).

Figure 1: graph showing different chemicals resistance over time.



Many other plants and insects have developed resistance, the more we use pesticides the quicker resistance will develop (see Table 1).

The only way to avoid chemical resistance is not to use them. For this reason resistance is inevitable and non chemical strategies are important in any farm system.

Table 2: Estimated numbers of applications before resistance develops.

Chemical	**Applications**
Glyphosate	15-20
SU's	3-5
Triazines	7

Reasons for resistance in Australia:

1) Widespread adoption of technology. Australian framers are rapid adopters of new technology.
2) Fragile soils and the promotion of reduced and no tillage. This means herbicides for weed control.
3) Cereal root diseases have been a major problem, and the use of herbicides to control grasses and volunteer cereals.
4) Large areas farmed with minimal labour, low inputs and no subsidies. The only effective and cost-effective way to manage weeds under these circumstances is herbicides.

5) Winter annual grains are dominated by wheat. Lack of rotational options and ways to break the weed lifecycle. For example, one of the biggest problems occurred in WA, in the wheat/lupin rotation.
6) Heavy dependence on selective graminicides and suylfonylureas. Resistance occurs easily and readily to these herbicides compared to triazines.

With few new herbicides being released (Syngenta has just released one!) it is only a matter of time before we run out of herbicide options. Some previously expensive options (Group K) have become affordable giving us a few years grace. We may get access to the basta line (GMO) giving us another short period, but where to from there?

My focus was to look at other weed and insect control options from transgenic technology to biological approaches.

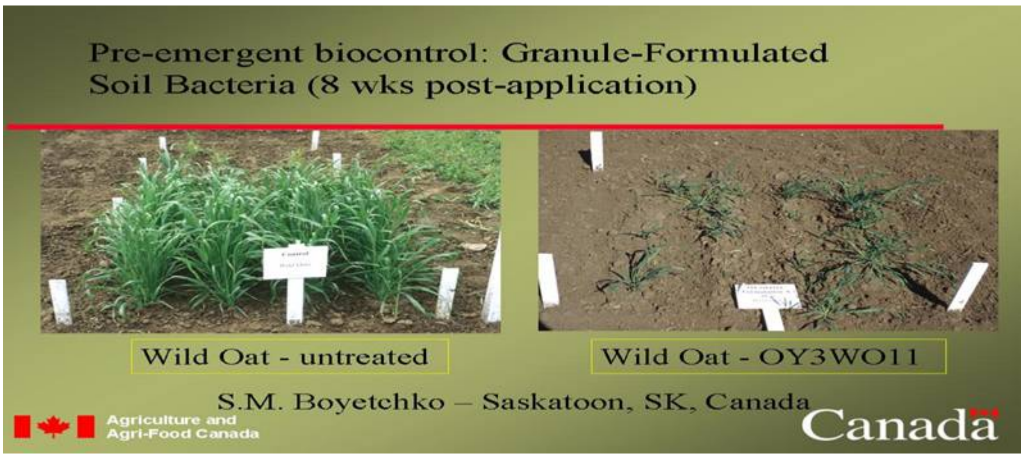
Bio Selective Herbicides

I visited Susan Boyetchko, at the Saskatoon Research Centre, Canada, to look at a soil bacteria used to control green foxtail grass and wild oats in crop.

Professor Gavin Ash of Charles Stuart University Australia is also focusing on soil bacteria, that have activity against rye grass.

I think this work is quite exciting giving around 80% control in wild oats, and that is not taking into account competition from a wheat crop. Greater control may be achievable when used with “in crop” applications depending on how competitive a crop is.

Figure 3: Showing wild oat control using this bacteria.



Not only does this soil bacterium reduce the competition of a pest species (wild oats) but as a by-product, a hormone is produced that stimulates plant growth of the desirable crop.

This growth enhancing hormone is not plant species specific. Work is being undertaken in an attempt to make it specific so as to benefit a target crop type and not other weed species.

Hormone benefits, of crop competitiveness or extra yield have not yet been measured.

How does it work?

The focus is on applying a deleterious rhizobacteria (root colonizing bacteria that has an inhibitory effect) to a target weed seed. This bacterium (un-named due to commercial security) colonises the roots affecting the plant's metabolism, delaying root growth and, therefore reducing competition and plant growth.

The bacterium is mixed with a pasta base carrier (called Pesta), which is based on semolina flour, with other ingredients added, to make a dough. The dough is put through a twin screw extruder resulting in fine strands which are broken into small pellets about 1mm long.

Pellets are dried in a bed dryer to 10-12% allowing bacteria to survive, similar to a legume inoculant. The current bacterium attaches itself to the roots of germinating plants and produces a chemical that restricts root growth and development.

Gavin Ash is currently looking at a new bacterium that has two types of action: one restricts root growth, while the other releases chemical compounds to prevent the germination of the weed seeds. The bacteria needs to be placed in close proximity to the weed seed; if applied post emergent, as a spray is thought not to work effectively as the bacteria is not likely to survive.

Broadacre Application

In Canada they are still evaluating application technology, but are currently looking at mid or side row banding. This is seen as a way of getting the bacteria in close proximity to the weed seeds. Another option is putting the bacteria pellets through an airseeder, similar to the granular herbicide systems that are common in Canada.

In Australia other application methods are currently being looked at; methods that are more suitable to current Australia farm practices, such as a seed coating product. Although this and other issues such as compatibility with other seed pickles and fertiliser toxicity still need further evaluation.

Some seed dressings have been found to have a negative effect on the bacteria, although Gavin Ash suggested that some synergies may exist as well. As soil bacteria it would need to be handled with the appropriate care. Susan Boyetchko suggested that some "pre-sowing" herbicides and insecticides could be toxic.

Resistance

The Mode of action of this "bio-herbicide" is different than conventional herbicides, meaning it would have activity on current resistant weeds. It is thought that because this bacterium is not actually stoping the growth of the plant that resistance is less likely. After a period of time some weed species are thought to become more competitive, but the bacterium will still have activity on these weeds.

With the Canadian bacteria at least two or more modes of action occur within the one bacterium species, therefore resistance is less likely to occur. If two or more bacteria species can be combined within one bio herbicide then four or more modes of action could be achieved within a single product!

This would be like having a product that has activity of groups A (fops dims), B (SU's), C (ureas and triazines) and D (dinitroanilines) all in the one package! Something that is very robust and has the broad coverage that no current herbicide can claim, nevertheless resistance still is able to occur with this system. Just because a weed control system is biological, doesn't necessarily mean it can't become resistant. It is envisaged that this product would be used in conjunction with current weed management programs.

Options and questions

What crops can this bacterium be used on?

The research focus has been on wheat. It is presumed that all current crops may be able to carry this bacterium, although work is still being done to confirm this.

Are there other types of bacteria that are more effective and robust than what is currently being worked on?

Other bacterial strains are currently being looked at, with work done to try to identify the most effective species that exist in Australia

How long will this bacterium stay within the soil?

The bacteria may exist at low levels from year to year under certain soil and climatic conditions, but it is thought that reapplication would be necessary for effective activity.

Are there other bacteria or biological species that can be used to control other major weed species?

Gavin Ash and his team are looking at a species of phomopsis, a fungus (new and not yet named) that has activity against capeweed, scotch thistle, fireweed, noogura burr and saffron thistle.

What interaction is there of the bacteria and root diseases, leaf diseases and soil biota?

Unsure as this area is not yet tested, but it is thought that the bacteria may have some activity against some bacterial root diseases.

What other combinations or options (i.e. allelopathies) can we use with this system?

One may be able to breed a competitive wheat plant (increased root biomass and vigour), that has inbuilt activity against ryegrass (allelopathy), coated with this bacterial strain to have additional activity (another “mode of action”) on rye grass or another species.

Allelopathy

During my second trip I visited a number of centres in Canada and US that had done work on brassica fumigation. This prompted and created an interest to look further to other plant allelopathies that may be suitable. Darryn Johnston put me onto some relevant and interesting work done by Professor Jim Pratley and his team at Charles Stuart University.

Allelopathy is the chemical inhibition of one species by another. The "inhibitory" chemical is released into the environment where it affects the development and growth of neighbouring plants. Allelopathic chemicals can be present in any part of the plant, leaves, flowers, roots, fruits or stems.

Target species are affected by these toxins in many different ways, inhibition of shoot root growth, nutrient up take or they may attack a naturally occurring symbiotic relationship, thereby destroying the plants usable source of a nutrient.

Many different crops are allelopathic, including species of sorghum, wheat, barley, brassicas, sunflower, rice and pea.

Weed species for example, silver grass (vulpis) and wire weed (not yet proven) are also considered to have allelopathic effects. Both can slow and even stop germination of wheat, lupins and pasture species. (Pratley, Haig).

Work done by Prof Jim Pratley and associates from Charles Stuart University Australia showed that seedling wheat plants have an allopathic effect on rye grass. These wheat plants emitted compounds (alkaloids) that were restricting the root growth of adjacent rye grass.

It was found that in the first three weeks of wheat plant growth, alkaloids were generated which affected the root growth of adjacent rye grass. After three weeks (wheat growth) it was found that the effects of these alkaloids would taper off. The exact mechanisms of how these alkaloids restrict root growth are not yet known, with work currently being done to investigate this area.

Wheat stubble also has some allelopathic effect, producing phenolic acids, however this is thought to have less activity than the seedling allelopathies.

To my surprise nearly all wheat varieties are allelopathic, (453 varieties from 50 countries have been tested), although there are large activity differences between varieties.

Based on biological screening two distinct groups have been identified, varieties with a Condor background (strongly allelopathic activity) and a Pavon background (weak allelopathic activity). The 63 strongly allelopathic types (Condor) inhibited root length of ryegrass by around 81% with an average root length of ryegrass of 8.6mm +/- 1.1mm (control of 55mm). These varieties originated from 23 countries, mostly from Australia (15), Mexico (11), South Africa (7), Brazil (4), Germany (3), Russia (3).

The 21 least allelopathic types (Pavon) inhibited the root growth of ryegrass by <45% with an average root length of ryegrass of 34.2mm +/- 5.1mm (control of 55mm). The ten countries with wheat varieties, that had the strongest allelopathic activity are as follows: (strongest first) Hungary, Peru, Germany, Bangladesh, Israel, South Africa, Kenya, Malta, Mexico and the UK.

Australia is number 27 out of the 50.

What current Australian varieties are the best?

Condor background varieties (strongest Allelopathy) include Tasman, Triller, Wilgoyne, Meering, 3-J27, Nabawa, Sunstar, 3-J67, CH31 and AUS375. While Janz in not included in this list it is considered strongly allelopathic reducing ryegrass length to 11mm (compared to the control of 55mm); I found this interesting as Janz is not seen as a strongly competitive crop.

Amongst the list of weakest allelopathies are Sunstate and Excalibur. Study has found that allelopathic potential does not correlate to crop height (Olofsdotter and Navarez 1996) and to the root biomass of plants (Bass Jensen 1999). These findings indicate that the competitive trait and allelopathic trait may not be genetically linked. This may give us the ability to breed for crop competitiveness coupled with allelopathy for weed suppression!

Research has shown that allelopathy is a bi directional activity. There are examples of some plants being able to react against other plants, of being able to release compounds to inhibit growth. An example of this is Knap weed in the USA, which is a significant problem on the prairies. In its native environment (Asia), it is thought that other species are able to produce compounds that restrict the impact of Knap weed; but only do so when this weed is present.

Economic benefits?

The 80% reduction in ryegrass root growth has not yet been transferred into growth data or yield benefit, so it is unknown what economic benefit or impact this research may have. Further work needs to be done in this area.

Other questions yet to answer?

- **Is the three weeks activity (wheat plant) against rye grass long enough, for ryegrass suppression/control?**

  If not can we extend this period?
- **Can we isolate these allelopathic genes and insert into different plant species?**
- **Can we combine them with competitive traits of plants?**
- **What is the potential for plant resistance or plant adaptation to allelopathies?**

The potential for weeds developing resistance is totally unknown. One theory suggested, that because of the way the natural process of allelopathy works, resistance is less likely. If the allelopathy has more than one point of activity (more than one action against a plant) then resistance is less likely to occur.

- **What other plants have activity against ryegrass?**

There are three other plant species which produce chemicals that have good activity against ryegrass, but due to commercial reasons the identity of these are not able to be released.

Weed control is said to be very good, although I was told, more work needs to be done.

Summer Weeds let them grow!?

Our southern Australian farming systems tend to be dominated by winter crops, with the paddocks being left out of production over the summer period. Small infrequent rainfall events during this summer period often encourage many summer weeds to grow. Currently our focus has been to remove these weeds from our farm systems, but perhaps we should look at them differently?

Some of these “weeds” have allelopathic traits (for example wire weed). If we can identify which species are allelopathic we may be able to use them, not only to give us weed or disease control, but to build up carbon levels in our soils. We may even plant “weeds” to give us these benefits. We would need to understand the toxicity of these weeds and plant back periods for recropping.

Some “weeds” may even be selective meaning that we would plant them prior to a specific crop, knowing that the “weeds” allelopathic traits would not have any negative effect on the desired crop. The allelopathic activity may not be isolated to weeds but may have activity on disease or insects, similar to effects of the brassica family. There are many unknowns about allelopathies of these “weeds” as very little work has been done in this area.

Other allelopathic examples

A study has shown that ryegrass (perennial) affected by crown rust (puccinia coronata) has suppressed the yield of clover plants, compared to healthy ryegrass plants, showing that a pathogen may influence allelopathy between plants and that crown rust may enhance ryegrass allelopathy against clover.

Biomass reduction of 36% was recorded (on clover) even though the ryegrass biomass was reduced 56% by the crown rust, (Mattner and Parbery).

Beneficials

A common soil-borne fungus that exists on the surface of some cereal crops seeds, has shown to significantly stimulate seedling growth of maize. Aspergillus japonicus saito produces secalonic acid F (SAF), the main allelochemical from the fungus. Root length, numbers and oxidation was shown to increase, 31% to13% and 370% respectively but at higher concentrations (10 times the amount) the reverse happened and plant growth was inhibited. (Zeng R, Luo S, Shi Y 2004)

Brassica's have been looked at for a while regarding their biofumigatory effects, particularly in regards to soil diseases and insects. Little work however has been done on weed control. I visited Professor Jack Brown at the University of Idaho USA who has shown that excellent weed control can be achieved by Brassica fumigation.

Brassicas what are they?

Brassica family include canola, radish, mustards, turnip, cabbage, rapeseed and broccoli. All members of the Brassica family contain glucosinolates. Other families that contain glucosinolates are Capparales (e.g stinkweed), Resedaceae (Mignonette), Capparaceae (common startwort) and Moringaceae (horseradish tree). My focus being on the brassica family.

Glucosinolates consist of a glucose molecule, a sulphur moiety, and a side chain, (this determines their properties). Glucosinolate molecules are not toxic but are enzymatically hydrolysed giving a variety of biologically active products, including isothiocynates (the most toxic and most common), ionic thiocyanates, nitriles, oxazolidinethiones, organic cyanates and epithionitriles.

Myrosinase, the enzyme responsible for glucosinolate breakdown, is located in separate plant cells to the glucosinolate molecules. To activate this breakdown, tissue disruption (such as mowing, tillage or processing) is needed. Glucosinolates are then changed into biofumigatiory products.

Glucosinolate (G/C) types in plant species are highly variable. For example, the main G/C in radish seed is 4-methylsulphinyl-3-butenyl G/C, while mustard seed (brassica juncea) is dominated by propenyl G/C.

Figure 4: Different amounts of Glucosinolates from 3 types of Brassica

Glucosinolate	Rapeseed	Oriental mustard	Hybrid
Allyl	-	163	152
3-Butenyl	23	1	22
4-Pentenyl	15	-	12
2-OH-3-But	60	-	50
Total	98	164	236

Table above shows different types and amount of G/C in rapeseed, oriental mustard and a more recently developed hybrid.

Different types of G/C have different activity on weeds and insect pests. There being 210 different types of G/C, giving potentially 210 different types of activity, although not all have activity on weeds.

The following G/S are derived from canola and mustards:

- Allyl glucosinolate kills insect pests and nematodes
- Hydroxibenzal and indolylmethyl has activity on weeds even perennials and seeds
- 3 butynl G/C kills bacteria such as take all.

Concentration of G/C's within a plant can vary, depending on nutrition (P and N levels), and climatic conditions. (Mailer and Pratley 1990)

Maximum levels of glucosinolates (G/S) in the plant tissue occur just prior to flowering and maximum whole plant concentration occurs at maturity.

Glucosinolates in plant growth

The potential role and function of all of the 210 glucosinolates (G/S) is not yet known, giving potentially many options for future developments. It may be able to breed or place selected traits of glucosinolates into desired canola or mustard varieties to achieve various weed or insect control requirements.

Or it may be possible to combine a concoction of G/C in one variety that suits a particular pest problem or market. This would be just like selecting G/C's off the shelf to suit a specific requirement; perhaps they could be called "designer fumigation plants".

For example:

(a) One G/S will attract insects (perhaps beneficial, like lady bugs or bees for pollination) and another two G/C's may give low polyunsaturates so the oil will be more suitable for bio fuel (lower NO+ emissions)

(b) A cropping area may have problems with slugs and bronze field beetle at seeding, then healiothis at flowering.

    One may be able to breed in Ally or butynl G/S to give the crop a distinctive sharp bite taste so as to be non palatable to insects and then switch this off for seed development, so that the meal is still low in G/S and palatable for stock feed.

(c) One may be able to remove the 4 pentanyl gluclosimilate which identifies the plant as "good to eat" so that insects while present will not attack the plant.

(d) Bio selective herbicides may also be attainable, using different G/C that have activity on specific weeds and not on others e.g. Benzyl isothiocyanate completely suppressed seedling growth of velvetleaf. Wheat root length, on the other hand was only slightly reduced by this compound. (Haramoto and Gallandt 2004)

Canola is one of the most malleable plants and can be modified relatively easily, more so with transgenic technology (GMO).

While development of this is more complex than explained here, the options and possibilities are only limited by ones imagination.

Bio fumigation

In the past much of biofumigation work has been done using brassica plant residues, including green manures, focusing on insect and disease control. In Australia much of this work has been executed by John Kirkegaard. In USA Professor Jack Brown from university of Idaho has focused his attention on mustard meal as a soil fumigant for weed control. Jack has worked on yellow mustard meal (*sinapus alba)* which is high in specific G/C's. He used rates of 2.5 tonne/ha of meal applied and incorporated into the soil.

The G/C's in the meal when wet down, immediately changed to isothyacynates which were toxic to weeds and nematodes. Results were similar to a methyl bromide application, in that all weed seeds and nematodes were killed!

Note that when the meal is wet down isothyacynates are released without tissue maceration (tissue disruption). This is because myrosinase activity and G/C are preserved in cold-pressed meal and are no longer physically (incellularly) separated. Thus adding water immediately results in the production of the toxic isothiiocyanates.

Why are these results so distinct, when other work has given such variable results?

G/C content is 20% higher in meal than vegetative tissues; so if a meal is used, we have a product that is more active than brassica plant residues. It is thought that the application of water releases the isothiocynates immediately, leading to an instant and concentrated fumigation of the soil (as apposed to green manure, which is more gradual).

Jack Brown's focus has been on using *sinapus alba* (yellow mustard meal); the yellow mustard being high in specific G/C's; on breakdown produce all isothycynate, which has good activity on weeds.

Weed control is said to be 99.9% effective, even having good activity on established plants like Canadian thistle or bindweed that are not able to be controlled with cultivation. In addition to excellent weed control some 160kg/ha of organic N is applied to the system. This comes from the breakdown of the processed meal which is high in crude protein (at around 35%). So not only does one get good weed control, but also an application of organic N. Organic N does not leach readily through the soil profile as other synthetic forms of nitrogen (i.e. urea) can. Something that would be valuable to the sandy loam high rainfall areas (southern regions of western and south Australia) where nutrient leaching is a real issue.

Plant back after application is two weeks minimum, so one can fumigate and sow into a totally clean seedbed in the same season. Results with plant inhibition are not always clear however and sometimes appear inconsistent or contradictory e.g. a trial using *brassica napus* (canola) in one trial gave better weed control than *sinapus alba* (mustard) even though *sinapus alba* has different and higher levels of glucosinolates. Differences in soil moisture and nutrient status may be behind some of these differences.

I believe this is all the more reason, increased research needs to be undertaken.

What is the impact of the loss of nematodes and soil fauna, flora?

This area still needs to be looked at.

Costs

Following are some cost comparisons of applying a treatment of mustard meal compared to a green manure treatment. Mustard meal is applied at 2.5t/ha by gypsum spreader and incorporated with an offset disc. A wheat crop would be planted two weeks after incorporation. The green manure example includes planting and fertilising a legume crop, following up with chemical desiccation and slashing.

Weed control methods table

Fig 5: Green Manure vs. Fumigation, cost comparison.

Explanation of headings left to right. Cost per ha of treatment, minus the nitrogen benefit (at $1/unit of N), the gross margin of a wheat crop and the net financial benefit.

		System		
Margin	**Cost/ha**	**taking account N benifit**	**G/M wheat**	**Net/ha**
G/M	140	40		-40
Fumig	365	205	490	285

Using green manure a net loss of $140/ha is incurred with weed control for one year.

With fumigation, costs are $365/ha including spreading and incorporation. Under fumigation a crop can be grown in the same season giving a net margin of $285/ha (4t wheat crop) as apposed to a negative $40/ha for a green manure. The main benefit is that fumigation is able to remove most of the hard weed seeds, effectively giving one a “clean slate” to work with, where green manure only removes weeds for one year.

Rye grass needs 3 years of total control to achieve a very low seed bank. For weeds like wild oats and wild radish a period of around 7 years is needed. Under fumigation, most of these hard weeds would be destroyed!

Safety

Despite popular belief, organic doesn't necessarily mean safe. Mustard meal can result in wet perspiring arms being blistered, and eye contact with the product may require medical treatment. This product however can be consumed without poisoning.

Resistance

If you were to apply the same brassica every year to the soil resistance could develop. Yes, similar to synthetic herbicides, bio herbicides have modes of action and therefore resistance is possible. But there are 210 different types of G/C's to choose from, or 210 different modes of action, although not all have activity on weeds. Management and rotational programs would need to be developed, similar to the current synthetic pesticide programs currently in place.

Other options for canola

There are many other options for brassica's and by products:

- Bio diesel with excellent conversion rates (better than any type of combustible fuel including ethanol). (Hobbs)
- Replacement for methyl bromide.

  Methyl Bromide is a soil sterilant used by the horticulture industry ($6200/ha cost), in weed quarantine breeches and has been used by various oyster growing areas where the sand bed is sterilised for worm control. It was banned in 2005 under the Montreal protocol as it has ozone depletion properties.

  There may be an option for mustard meal fumigation to be used against the quarantine breech of broomrape in South Australia.

- As a meat filler.

  A process has been developed to neutralise the enzyme myrosionese which in effect takes the "bite" out of canola meal. Meal is classified as a spice (US) and it is not necessary to stipulate how much spice (meal) is present in a hot dog, therefore one could have a hot dog that is 99% canola meal and be classified as 100% beef!

- Pharmaceuticals

  Using the by product glycerol, refined as an emulsifier and stabaliser in creams and associated products i.e lipsticks and toothpastes. Vitamins can be extracted and used as supplements.

- Spray surfactants

  Brassica oils are often used as surfactants and spreaders, often giving better performance compared to mineral oils. They tend to have longer molecule chains (ie 12 chain carbon) than mineral oils, meaning that they have higher crop safety and are less likely to burn the plant leaf in hot conditions. In cold conditions brassica oils are less likely to “glug up” as some mineral oils do.

Recommendations

We need to understand the 210 different G/C and their potential roles and how nutrition and climate affect G/C’s within the plant.

Summary

In the past poor research has given allelopathic systems a bad name, but recent more accurate programs have proved that this is an area worth pursuing, i.e. “Fateallchem” program in Europe, University of Cadiz in Spain and active programs in Japan and China.

It is a huge area, knowing that many of our plants have allelopathies, but further work needs to be undertaken to firstly identify them, and to see if their responses are economical. There are many possibilities, limited only by imagination, of combining competitive genes, and other transgenic technology to give us whole systems that can better suit our environment and farm systems Bio Control using insects.

On travelling through the Ukraine I stumbled across a production plant for a parasitical insect control product that is used to control European corn borer (*ostrinia nubilolis*) and other insects. These wasps are parasitise pest insects, thereby increasing their population leading to further parasite infection until the pest population is reduced.

Upon following up, I found that in Australia we could use a similar system to control problem insects. My focus was on the Trichogramma species, because many of the species they predate on are present in the Australian broad acre cropping. Another reason for my interest was the potential for the use of existing Australian trichogramma species and the comparable cost to insecticide application. Production out of Dnepropetrovsk in the Ukraine was commercially competitive at $2 US/ha.

History

Trichogramma was first discovered as a parasitical insect in the early 1900's.

With the advent of DDT, interest in the US dwindled. This was not the case in the then Soviet Union and China, where production was less expensive and less sophisticated than for synthetic chemicals and where labour was cheap and readily available.

Adult Trichogramma wasp mounted on microscope slide. (W. Sterling)

Consequently the countries of the former Soviet Union led in trichogramma production, followed by China and Mexico. In the former Soviet Union another 10 species of parasitical and predator insects have been used in control programs, but had been lost during the break-up of the Soviet system, the current species of trichogramma was kept stored in secret during that time. Current Ukrainian research has lost momentum since the break up of the soviet countries, and current production plants struggle with the new concept of a market based economy.

Trichogramma in Australia

In Australia one species (trichogramma pretiosum) was introduced into the Ord River district in Western Australia in the 1970's and latter into SE Queensland (1995). I am unsure about the background of other trichogramma species.

Trichogramma is one of 80 in the family Trichogrammatidae. All members of this family are parasites of insect eggs. Trichogrammatidae includes the smallest of insects, ranging in size from 0.2 to 1.5 mm. Within the trichogramma family there are 145 described species worldwide; 30 species have been identified from North America and an estimated 20 to 30 species remain to be described.

Species that are susceptible to trichogramma

Trichogramma prey on some 28 different caterpillar pests, borers, bollworms, moths, butterflies, lucence leaf roller, wasps, including heliothis, lacewings, loopers, diamond back moth and aphids.

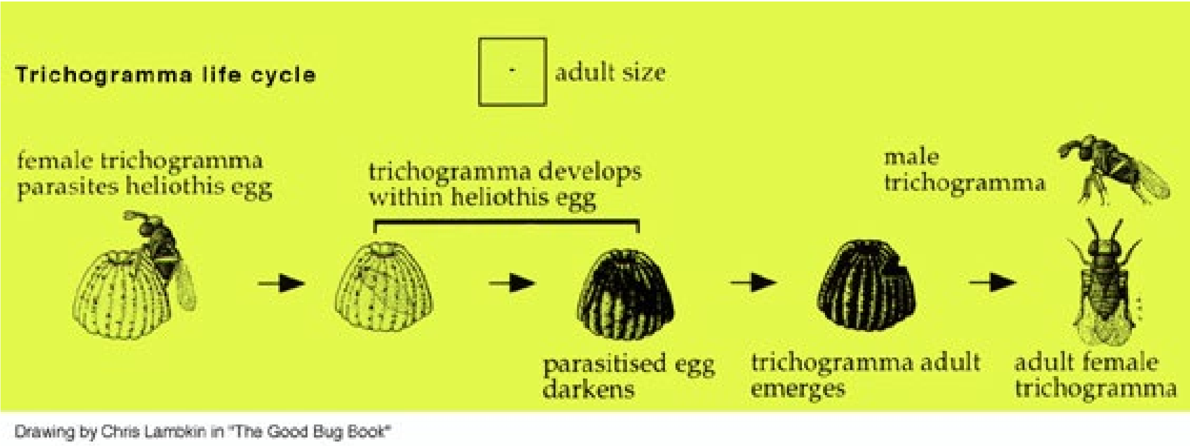
Picture 7: Grain borer eggs used as a host to breed trichogramma. (Dnepropetrovsk, Ukranine)

Breeding

Grain borer eggs are used as a host. Seven days after impregnation the eggs change colour to black, indicating that they are ready for release. At this time they are able to be stored for up to one month under refrigeration. A 70% female population is preferred, with assessment done under a microscope (female are smaller and have antenna). Temperature variation and other (classified) procedures are used to regulate the male/female ratio.

Insects are released to parasitise problem insects. The parasitical insects lay eggs inside the problem pest eggs and upon hatching (8-20 days later) the parasitical insects search out new eggs and the process continues. A female trichogramma will live for about 5-14 days and can parasite around 50 eggs during that time. Mated female wasps will produce both male and female offspring. Unmated females can parasites eggs but will only produce male offspring.

Picture 8 Life cycle of Trichogramma (The Good Bug Book)



Application

In the Ukraine eggs are spread from an aircraft or spreader at about 150,000/ha in a mixture of cereal meal 1 to 3 times a season depending on the pest species and environment. A "card" system has been developed to further reduce reapplications. The "card" a small piece of cardboard that is folded over, protects the eggs from weather extremes (eggs are stuck to the card) allowing the trichogramma to hatch and release in a safer environment. Problem insects are killed before any damage can occur, as the parasitical insects lay its eggs within the pest species eggs.

Timing

The ideal time to release trichogramma are when the problem insects have laid eggs, prior to any hatchings of problem insects. This would be earlier than traditional chemical control programs. Monitoring of crops is imperative.

Chemicals with Trichogramma

Although Trichogramma are sensitive to many insecticides they are able to used in conjunction with a number of different products.

Table 9: table showing insecticides and toxicity (source bio resources)

Product	Trade Name	Toxicity	Residual
Bt products	Dipel	Nil	Nil
NPV products	Gemstar, Vivus	Nil	Nil
Methoxyfenoxide	Prodigy	V low	1 day
Indoxycarb	Steward Avatar	Low	3 days
Abamection	Agrimec	low-mod	3 days
Pymetrozine	Chess	low-mod	3days
Imidacloprid	Confidor	Mod	5 days
Thiomethoxam	Actara	Mod	5 days
Fipronil	Regent	Mod	5 days
Spinosad	Tracer, Success	mod-high	3 days

Key

Low toxicity = nil or low impact on beneficials

Moderate toxicity = beneficial activity significantly reduced but can recover in a week or so.

High toxicity = a high proportion of the beneficial population is killed and re-establishment is not possible for several weeks

Residual = suggested waiting time after application of the product before introducing beneficials

Fungicides can be toxic too, particularly any sulphur based products. Mancozeb and carbenzim are a low to moderate rating but need to be rotated with softer options

Weaknesses of this system

Some conditions can reduce trichogramma; these are:

- Several days of extreme heat, especially if the crop is water stressed and the air is dry.
- Several days of wet weather will reduce adult wasp activity, so if pest eggs are laid in the crop just before or immediately after the rain many of these may not be parasitised.
- Very low egg pressure (pests) for more than 10 days will severely reduce wasp numbers unless alternative moth egg hosts are available.
- High predator (eg lady bugs) counts may reduce the number of parasitised egg yielding wasps.
- Incompatible chemical applications

Crops

In Australia trichogramma are currently used in corn and soybean and cotton (at a reduced amount due to bollgaurd) crops. It is thought that nearly all broadacre crops are suitable for trichogramma although use in chickpeas is not recommended as acid that is secreted from the leaves is toxic to trichogramma.

Non target species

Very little known work has been done on non target species in the Ukraine.

In Australia trichogramma are thought to have had little effect on native insect populations as their populations are deemed not high enough to support sustained populations of trichogramma.

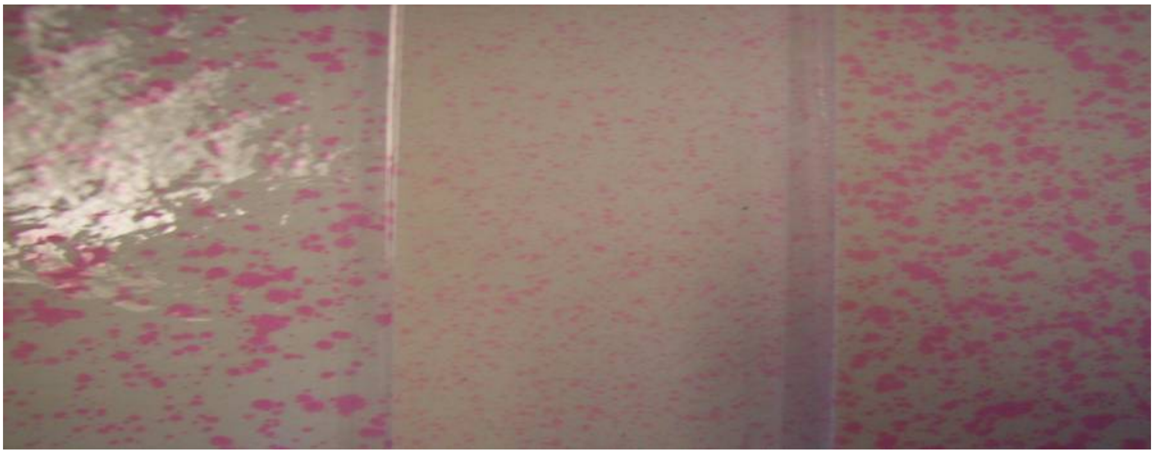
Conclusion

I like this system as I see it as economical (comparable to insecticides), potentially more robust and even easier to use. There may be more control posabilities with other species of Trichogrammma but the associated introduction issues would need to be addressed. At this stage it is cheaper and easier on many insect problems to use insecticides, but as resistance increases, environmental legislation tightens, and our understanding of our farm systems grows I believe it is an area that we need to increasingly look at.

Redux Double Jet spray System

I was fortunate to be able to visit Dr. Roger Downer and team at Ohio State University who is working on a spray system that is claimed to be much more efficient than current systems. Claims of chemical rate reductions of 50% down to 20% have been made without loss of efficacy. This is a huge chemical saving!

Research has found that smaller droplets (diameter<150um) are biologically more effective than larger droplets (diameter>300um), the larger droplets contribute comparatively little to the efficacy of the spray even though they comprise greater than 75% of the volume of the spray.



Picture 10 Different nozzle size, same water rate, giving greater coverage. (Ohio USA)

A large number of small droplets can cover the canopy more effectively than a single large droplet. What is more effective? A single 1mm diameter droplet (volume .39mm cubed) or a thousand 0.1mm diameter droplets (same volume) distributed evenly over a leaf.

If small is so much better why not use only fine nozzles?

By eliminating the larger droplets one increases drift. The larger droplets in the spray cloud provide the kinetic energy to carry the biologically active smaller droplets into the canopy. The scientists solved the problem of supplying kinetic energy via the larger droplets while conserving active ingredient (A1) by not putting A1 into these larger droplets. This results in substantial savings in pesticide costs without compromising efficacy or increasing drift.

How does it work?

Two jets are set up, one in front spraying back against the direction of travel, on a 45 degree angle and the other vertical so both intercept at around crop canopy height. One jet delivering active ingredient (A1) and one delivering water. Both subsystems work exactly the same way a conventional system does, but the A1 subsystem produces a fine spray cloud that is captured and carried along by the larger, more energetic spray cloud from the water subsystem. It could be described, similar to a bike being pulled along in the slipstream of a bus.

Picture 11 Professor Robin Downer and testing platform

The front jet sprays chemical through a fine jet 0.067, with the back jet (0.3) spraying just water at a ratio of 3.5 to 1. Water rates of 80-100 l/ha are used which are common in US spray culture. Work is yet to be done to determine effectiveness of the lower rate models that are currently used in Australia. It is thought that 50 l/ha on the water line and 20 l/ha on the A1 line may work.

Most popular spray rate controllers can be used on the A1 line and experience has showed that the water line does not need to be controlled.

Drift

Drift is said to be comparable with existing conventional systems. That is using jet sizes of 015's or 02's at similar speeds

Speed

Most users were spraying at speeds of 15-20km/hr.

50% rate reduction is it real?

My interpretation

US label rates are higher than Australian label rates (climatic differences) and Australian farmers tend to be more flexible with label rates: for example, a label rate of 2 litres of glyphosate to kill 3-4 leaf volunteer cereals , when 500mls of glyphosate would achieve the same result (75% less). So halving rates on conventional spray systems would possibly achieve the same results. My assumption is that a 50% rate reduction would not be attainable compared to existing systems, but trial work would need to be done to validate this.

The real benefits of this system I believe, would be greater penetration of chemical into the crop canopy and much better plant coverage, due to the large number of small active particles.

I think this system may be compared with the air assist booms and jet systems that are currently on the market. In comparison to these other systems, I see the redux double jet as a simpler system and considerably cheaper product.

Another possible option of this system is to spray pre emergent herbicides through the back coarse jet and “spot spray” high weed or insect areas with the front line.

Issues that may require further investigation:

What droplet size and plant coverage is required for best efficiency?

What about possible interaction of A1 chemical and large water drops?

Would the larger water drops wash off the A1 chemical, or is there improved chemical performance due to higher water rates?

Summary

Public perception of Agriculture has changed with growing concern raised about food contaminated with chemicals, plant alteration (GMO) and environmental contamination; at times these perceptions are real.

If this technology is proved to work then both environment and financial savings are to be made.

Economics and our agricultural future?

The Nuffield program introduced me to the larger economic picture and trade issues, and as I travelled I became increasingly aware and interested in these areas. These are some of my interpretations and opinions.

Repeatedly we were told the longer term outlook on agriculture commodities is not positive. It seemed to be a re-occurring message wherever I went. We cannot control the end price we receive for our commodities. Our costs tend to follow inflation, but our income, in real terms continues to fall. The message was we will need to continue to produce more for less.

This trend will continue and yes we will continue to get bigger and more efficient, driverless tractors will be the norm, transgenic technology and greater understanding of our soils and rotations will occur, but at the end of the day can we produce grain as cheap as other countries?

The answer?

A few brave solutions were given, that under current political and social systems are not seen as attractive. The most attractive solution to me, was of a single global pool system, handling all the worlds exported grain. It would mean that a central body would dictate the price for a commodity, therefore having the ability to link the price of that commodity to inflation. Countries would need to be allocated quotas with excess production consumed domestically. The obvious positive is of a stable standard of living, enabling the industry to pass on cost increases. Problems start with allocating acceptable quota’s and inflation rates to align prices with.

The future?

We need to either produce more for less, or divest or value add. Value adding can be beneficial if it is able to lock a commodity into a market that increases with inflation (making it more sustainable) i.e. become price setters rather than price takers. It also has the advantage of removing “the traders or in between people” enabling the producer to capture the margins that each step produces.

The breakdown of every dollar spent at the supermarket - “Where the money goes”

5% farmer

20% wholesaler

25% manufacturer

50% retailer

Value adding the business; is it economic?

Again we need to be competitive. Often it is cheaper to export and process overseas, although higher fuel and associated costs will have some bearing on this. Vertical integration may not be the best system to use as it often involves a high capital expense to establish as processing and value adding infrastructure is often needed.

Risk is not often reduced as a drought or production shortfall will affect the value added part of the business as well as the primary production component, because of the vertical connection.

Other options

A lateral low cost divestment may be more sustainable.

Of connecting to a service industry that is quite independent from farming:

- A pest control business that does roadside spraying, rodent and insect removal. It has some similarities physically but is removed from the risk of weather and traditional agricultural markets risks.
- A consultancy type operation, journalism, accountancy.
- Having off farm income i.e. husband/ wife involved in off farm work.

Product (services) pricing is more robust as one shifts from a price taker to a price maker.

One of the disadvantage of this system is one would miss out on the benefits of margins, compared to the vertical integration model.

There are two directions for the future of our agricultural businesses:

- To continue to get larger, producing more for less with our communities further contracting as farms get bigger.
- To divest or add value to our existing businesses and production systems.

Conclusion

Although I looked with some trepidation upon doing a written report, I have thoroughly enjoyed doing it, particularly the interaction with the researchers and fellow farmers who shared valuable insights. My exposure to the trade and economic issues stimulated more interest and even more questions than I thought it could! An area I find as fascinating as I find frustrating!

Weed control is about using as many different options and techniques as possible.

The options for weed control are only limited by our imagination and the willingness to try new ideas. Some will be impractical or uneconomic but we will need to look and try many ideas to identify the ones that work

Do we have we an open mind? Most importantly are these ideas going to be economically sound and more secure than the systems we currently use?

Understanding each area is one thing but we need to understand the whole program, the impact on soil, flora, fauna, mhycroiza, disease, soil ph, pesticides, nutrition and interactions and balances in these systems.

This is the challenge, to understand the whole complex system.

Nuffield has given me the opportunity to see more of the bigger picture, and given me the curiosity to look and explore new options. It has given me the ability to see things more objectively and the confidence to question many conventional thoughts and practices.

I now have greater courage to try new approaches on farm with a fresh mind to look forward, to grab onto these ideas as they come through the system.

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