2005 SCHOLARSHIP REPORT
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Production and management of high yielding crops
- Disease management
- Stubble management
- Improving nitrogen use efficiency

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Acknowledgments

I would like to thank Nuffield Australia for giving me the opportunity to study my chosen topic. As I travelled the world I realised the enormity of the network available through Nuffield.

I give special thanks to my sponsors: CBH, Grain Pool, and CSBP for their financial support.

I thank everyone left behind who kept "the show on the road" while I was away. My wife Sally-Anne, parents Geoff and Helen, and neighbour Allen Stephens who all had to endure one of the wettest and coldest seasons in memory.

To the hospitality of the international Scholars and their families, universities, businesses, research groups and farmers who gave up their time to assist me in my goals.

Executive Summary

The aim of my study tour is to investigate a proactive and sustainable approach to high yielding cropping systems in the high rainfall coastal zone of Western Australia.

This will be achieved by investigating the three major agronomic issues (nitrogen management, stubble management, and leaf disease) associated with high yielding cereal crops, and their affect on each other in a continuous cropping system.

Rising input costs in cropping has led me to continually question recommended nitrogen rates. There is a need to find a way to ask the plant how it is responding to nitrogen in any given season and apply accordingly, rather than use rates devised at the start of the season. According to *Raun 2005 (pers comm.)* world wide nitrogen use efficiency is only approximately 33%. Environmentally, the thought of two thirds of all nitrogen ending up in 'the river' is disastrous enough but the financial cost to a farming business is horrifying.

To manage nitrogen at planting, apply enough nitrogen for spikelet formation and seedling vigour, 20% to 30% of budgeted nitrogen. Apply nitrogen-rich strips across all management zones at 150% of budgeted nitrogen. Before in-season applications of nitrogen, measure the responsiveness of the crop to bagged nitrogen using the "Green-Seeker" and web based calculator. The calculated rate will take into account current seasonal conditions and plant health.

Stubble management of crops vary according to the following crop type. If the following crop is a nitrogen responsive crop (cereal or canola), leave the stubble as tall as possible away from the soil. This will reduce the tie up of in-season applied nitrogen.
If going into a legume, finely chop straw and spread uniformly to maximise straw/soil contact. The legume phase must be used to break down stubbles as the process which uses nitrogen will not affect the performance of the crop.

In dealing with disease management, control volunteer cereals to reduce leaf disease carryover. In a high disease risk year, be proactive with fungicides, not reactive, and mix fungicide groups to reduce the onset of resistance and widen the spectrum of control.

Study Aims

The aim of my study tour is to investigate a proactive and sustainable approach to high yielding cropping systems in the high rainfall coastal zone of Western Australia.

This will be achieved by investigating the three major agronomic issues (nitrogen management, leaf disease, and stubble management) associated with high yielding cereal crops, and their affect on each other in a continuous cropping system.

I do not want precision agriculture, high technology systems or expensive machinery to dominate my research. It is important to recognise the part that technology plays in agriculture today, however my primary focus is on improving basic agronomy.

I aim to also bring home any new ideas/technologies that I may come across outside of my study topic that can assist the profitability of south coastal farmers.

It is important to consider that as I undertake my study tour, my current aims may alter depending on what I encounter.

Introduction

Background

The south coastal zone of Western Australia has traditionally and predominately been an area of livestock grazing. The downturn of the livestock industry in the late 1980's and early 1990's transformed the majority of this high rainfall zone to wheat, canola and barley production.

The south coast of Western Australia has a winter-dominant rainfall, however up to one-third of the average annual rainfall can fall outside the winter growing season of April to October.

The high rainfall and cool spring of the area offers the potential to grow high yields that are not possible in the traditional grain growing areas of Western Australia.

High rainfall problems

In relation to my experiences with grain production, high rainfall has its advantages, and it also has its problems. The first problem I have encountered especially in the south coastal lighter soils is nutrient leaching, particularly nitrogen. According to *Raun 2005 (pers comm.)* world wide nitrogen use efficiency is only approximately 33%. Environmentally, the thought of two thirds of all nitrogen ending up in 'the river' is disastrous enough but in this day of increasing fertiliser prices the financial cost to a farming business is horrifying.

Another problem is disease pressure. The increase of cropping areas, yields, and stubble loads has corresponded to an increase in disease levels. Summer rainfall in the south coast region allows volunteer plants to survive through the summer. This causes a "green bridge" for leaf disease to carry over from one season to the next.

Disease control through fungicide applications was virtually unheard of six years ago in Western Australia, but today two to three fungicide applications per year may be necessary.

Another problem that has appeared is stubble management. As yields have increased, stubble dry matter has increased. This creates problems at seeding with trash flow, seed placement, nutrient tie up, and weed control. Less livestock in the farming system has also contributed to the problem with stubble management as livestock are not there to assist in breaking down stubble loads and control the volunteer weeds.

Nitrogen questions

In my entire career as a farmer I have continually questioned why sometimes an application of nitrogen, whether it be an application of dairy effluent applied to a pasture, some ammonium sulphate on grass, or top dressing of urea on a wheat crop will not seem to make much of a difference and other times the difference between the applied and control is chalk and cheese. We all stand around afterwards and come up with theories to do with the weather or management practices as to why the crop did or did not respond to the investment.

More recently our broad acre cropping enterprise has expanded and with increasing inputs I have been asking my consultants and agronomist to explain why they have recommended a certain rate of nitrogen. Their responses are usually based on simple nitrogen budgets that take into account yield goal and organic matter. These rates are generally the same across soil types, varying stubble loads and different yield potential. At the end of any season we will have fields that have been fertilised for 5t/ha and only do 3t/ha and vice versa. Our local research groups will show annual nitrogen trial results and will tell you that in any one year there was not a response to nitrogen above a certain rate and the next year the trials will say something totally different. At some sites in some years there have even been negative responses to applied nitrogen.

This information I believe is pointless because the money has already been spent. The fields have nearly all been over applied, costing money or under applied costing lost yield. I compare this to entering a race track and betting on races that have already been run. We try to take into account as many things as possible when working out nitrogen rates but it still ends up being nothing more than a whole lot of educated guesswork and human emotion.

Figure 1 shows how dramatically different nitrogen requirements are from year to year.

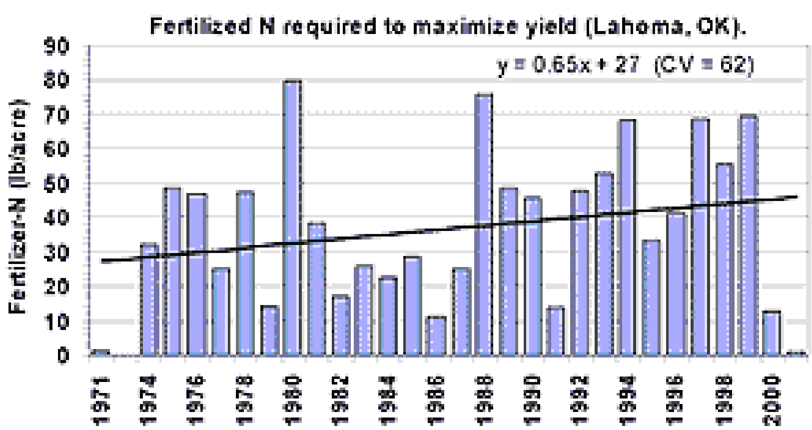


Figure 1: Nitrogen fertiliser required to maximise yield in wheat (Source: Oklahoma State University website - Soil testing)

The obvious answer to this problem is to find a way to ask the plant how it is responding to bagged nitrogen in any given season and apply accordingly.

The next question, after how much nitrogen does the crop need, is when we apply the calculated amount, how much of the product gets to the plant and can be turned into yield? We ask the agronomists and research groups, and add in a few more estimations, and off we go.

Finally, the timing of nitrogen applications. Rules for this are constantly changing. Best practice ten or even five years ago seem to be totally different to what we are doing today. Our soils are changing in depth, structure, fertility and organic matter, therefore it is reasonable to suggest that our management practices must change too.

In this report I will investigate my study aims of nitrogen management, leaf disease, and stubble management in order of the countries I visited.

The importance of nitrogen

To avoid nitrogen deficiency, nitrogen must be available to the plant in an inorganic form for crop uptake when needed to support crop production. Crop nitrogen uptake is greatest during the period of most rapid crop growth, between shoot elongation and flowering and so it is important that it be present in the soil at that time (Figure 2).

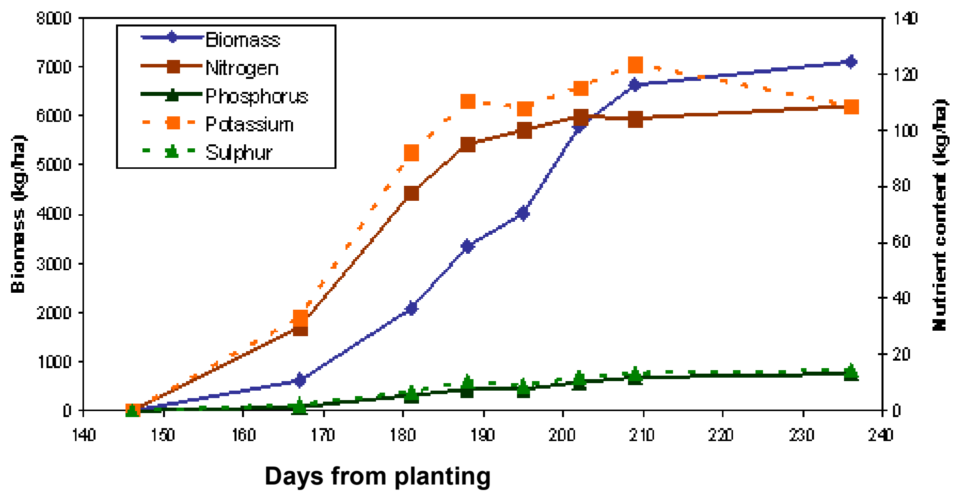


Figure 2: Biomass and nutrient accumulation in AC Barrie hard red spring wheat at Melfort, Saskatchewan. (Source: Grant 2005)

Inorganic nitrogen in the soil is subject to losses to the environment. The longer the nitrogen is in the soil solution prior to crop uptake, the greater the potential for nitrogen losses.

However, the risk of loss is greatly affected by soil moisture and temperature, with losses of in-soil nitrogen being greater under wet conditions with warm soil temperatures. Losses can be very low if temperatures are cold or if soils are dry (Grant 2005).

United Kingdom

Overview

The United Kingdom (UK) has an extremely long growing season which may last up to eleven months, and a mild spring and summer. Their soils can have organic matter levels up to 7% and a very high water holding ability. From this, it is easy to see why their wheat yield regularly exceeds ten tonnes to the hectare.

Historically stubbles were ploughed in, reducing issues associated with retaining them as mentioned in the introduction. Stubbles can also be baled, used as livestock bedding, or used as biofuel for electricity production. The damp mild conditions also increase the speed of natural breakdown of residue.

The slow swing toward reduced tillage is increasing the incidence of stubble borne diseases such as yellow spot and septoria, but the cost of chemical control is easily offset by the reduced cost of tillage.

Nitrogen management is changing as farmers are forced to reduce costs. Previously it was a case of applying all the nitrogen in early spring at a very high rate. Over applying would cause lodging and this was remedied by the application of plant growth regulators.

Canopy Management

In the United Kingdom I encountered a move toward "canopy management". The early spring application of nitrogen is used to influence the number of tillers. The goal is to end up with between seven and eight hundred tillers per meter (Pratt 2005 *pers comm.*). Nitrogen (N) is then applied during the season as required. This approach is also reducing early lush growth which assists in the management of leaf diseases. The majority of nitrogen is applied as Urea-Ammonium Nitrate (UAN) in liquid form. It is applied through conventional boom sprayers fitted with dribble bars or stream nozzles.

I saw the "N Sensor" being used to vary the rate of later applications of nitrogen to reduce lodging and wasted nitrogen.

The Hydro N Sensor is a remote sensing system mounted to the nitrogen applicator. It measures the spectra of sunlight reflected by the crop as the machine moves across the field. The signal which is closely related to the nitrogen status of the plants is interpreted and then used to adjust the application rate within farmer set parameters (Figure 3). The thinking behind the N sensor is to reduce the application rate on good areas and increase the application rate on the thinner poorer areas of the paddock.

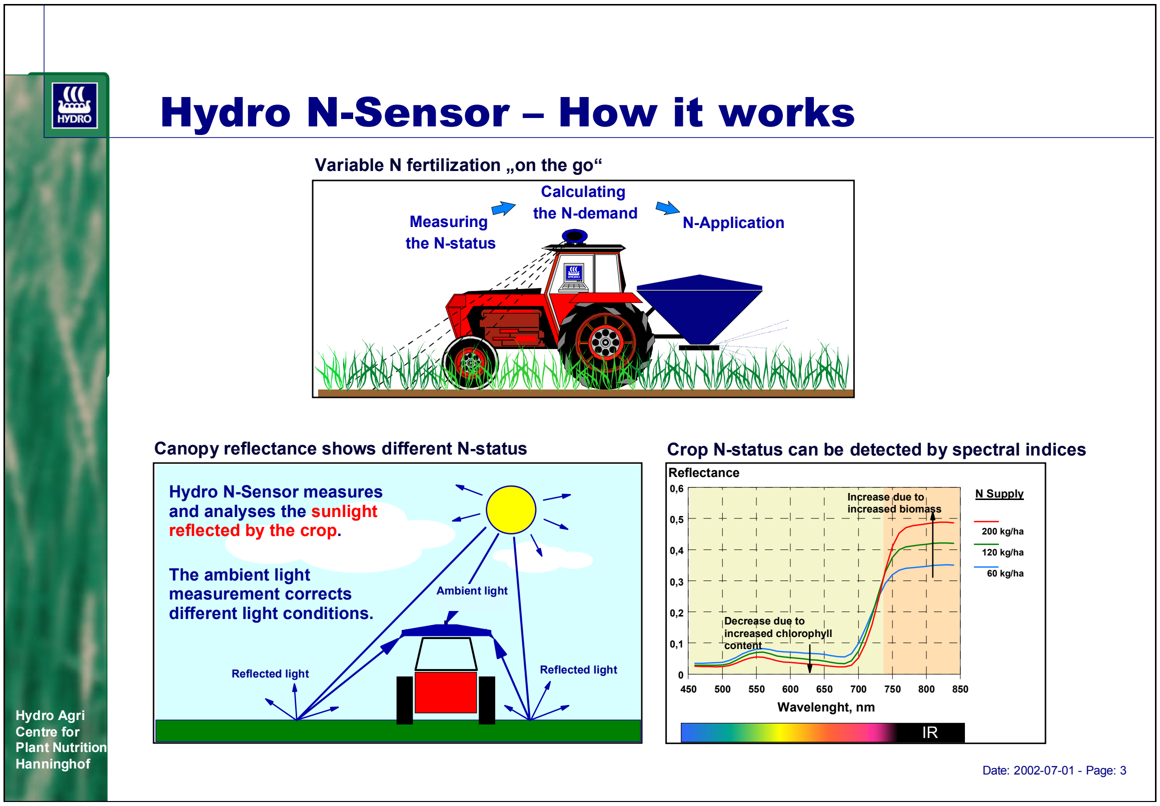


Figure 3: How the Hydro Nitrogen sensor works (Source: www.arablefarmer.net 2005)

The main problems I see with the Hydro Nitrogen sensor system are:

- If crop growth is restricted by something other than nitrogen i.e. sulphur or disease, the adding of more nitrogen will exacerbate these problems.
- Very poor areas where adding more nitrogen is a poor investment.
- One sensor for the full width of the applicator is not accurate enough for the job trying to be achieved.
- System is only accurate during good daylight hours making the $40 000 (AUS) cost seem expensive.

Disease management

The main diseases affecting cereal crops in the UK are septoria, leaf rust (brown rust) and yellow (stripe) rust in wheat and powdery mildew, leaf rust and net blotch in barley (Riley 2001). These diseases are being successfully controlled by an intensive fungicide regime. Fungicides are mixed to increase spectrum and rates are high. Crops will usually come into the spring season without any disease. The first application would be at Zadoks growth stage GS 3.1 (Appendix 1). Barley would be sprayed again before flag emergence and then at full head emergence. The flag is not thought to be very important for grain fill but the awns are. Wheat will be sprayed at flag emergence and then a head wash (full head emergence) (Pratt 2005 *pers comm.*).

Canada

Overview

Canadian croppers are challenged with an extremely short growing season with thawing ground delaying seeding, and frosts and snow stopping harvest.

Most crops are grown on stored moisture from snow and winter rain with growing season rainfall limited. All nitrogen is either put down in the fall as anhydrous or at seeding as liquid. Phosphorus (P) is put with the seed. With Nitrogen (N) rates being around 60 units, a lot of work is being done on side banding *et al* so it can all be done in one pass. The dry growing season does not usually lend itself to in crop applications of urea due to the high risk of volatilisation. Although with the increasing cost of nitrogen there is work being done on split applications of nitrogen thus spreading the risk and also being able to adjust the rates as the season demands.

Nitrogen application

Dr Cynthia Grant of Agri food Canada has been addressing some of the nitrogen application issues with her work at the Brandon Research Centre, Manitoba.

There is a swing away from the traditional fall application of anhydrous ammonia to applying 60% to 70% at planting and coming back at tillering with an adjusted rate of nitrogen.

The two major problems to be addressed are:- seed safety with high rates of nitrogen being applied with the seed, and reducing losses of nitrogen to the environment when applying nitrogen later in the season. Some of Cynthia's work has involved the use of a product called AGROTAIN. AGROTAIN is a urease inhibitor. N-butyl thiophosphorictriamide (NBPT) is added to the nitrogen product to control the release to reduce volatilisation and increase seed safety. The product greatly increased the safety of nitrogen at higher rates when placed next to the seed. Figure 4 shows that in an environment where losses can be high, these types of products can greatly reduce volatilisation.

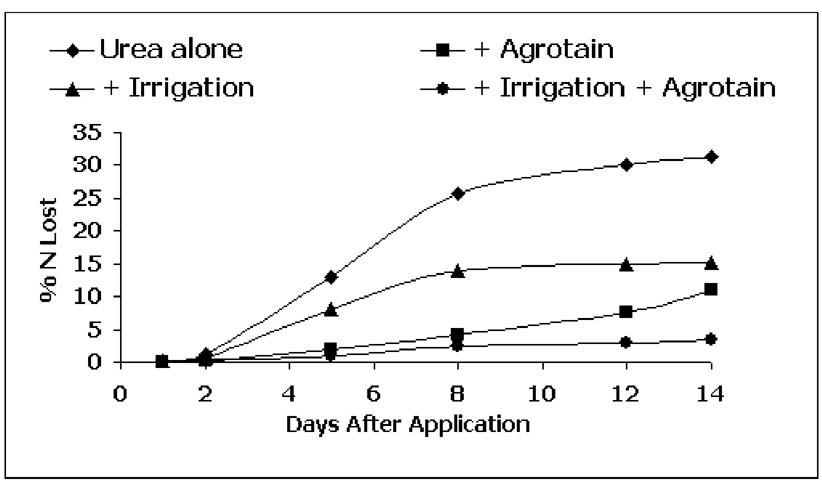


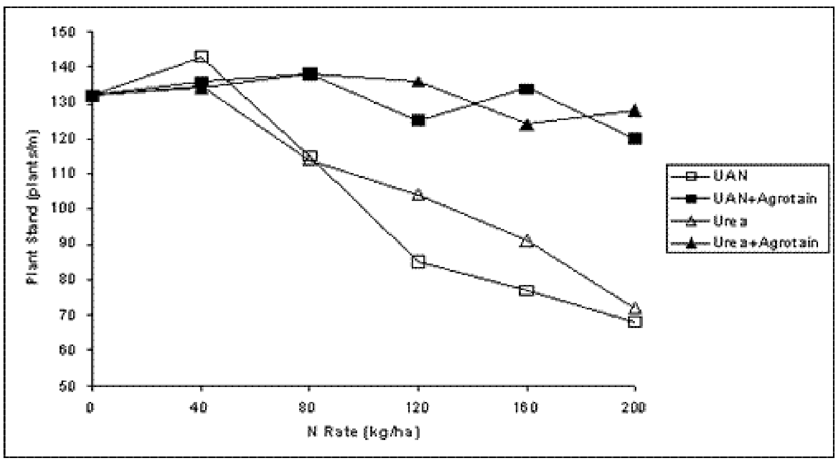
Figure 4: Effect of NBPT and irrigation (2.0 cm on day 4 and day 7) on volatilization loss from surface-applied urea (Rawluk et al 2000)

Fertiliser placement

The first step in seed safety is the placement of the fertiliser in relation to the seed. With some of the big names in tillage operating in Canada, I found Bourgault tools were addressing these problems both in Canada and Australia. For the Australian market, Bourgault tillage tools tend to manufacture tools that cultivate under the seed, unlike the Canadians.

The most common planting tools demanded by Canadian growers do not cultivate under the seed. This allows the seed to be placed on moist undisturbed soil increasing germination and minimising drying out of the seed bed. The phosphorous is placed with the seed and the nitrogen is applied to the side as liquid or granule. The old rule of thumb was to place nitrogen 25ml to the side and 25ml below the seed. This, as Figure 5 shows is only satisfactory up to 40 units of N without the use of a urease inhibitor. To safely apply higher rates at planting in a concentrated band under the soil and away from stubble residue, a MRB (mid row bander) has been developed (Figure 6).

Figure 5: Effect of urea and UAN fertilizer, side-banded with and without Agrotain, on stand density of canola on a clay loam soil (average of three years) (Grant et al 2001b)



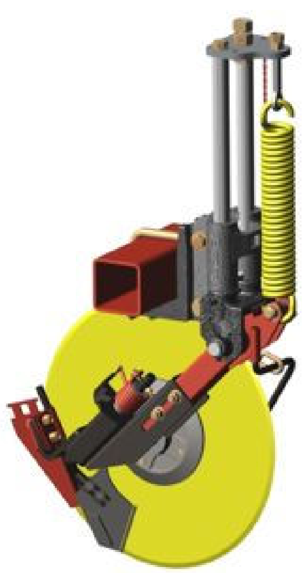
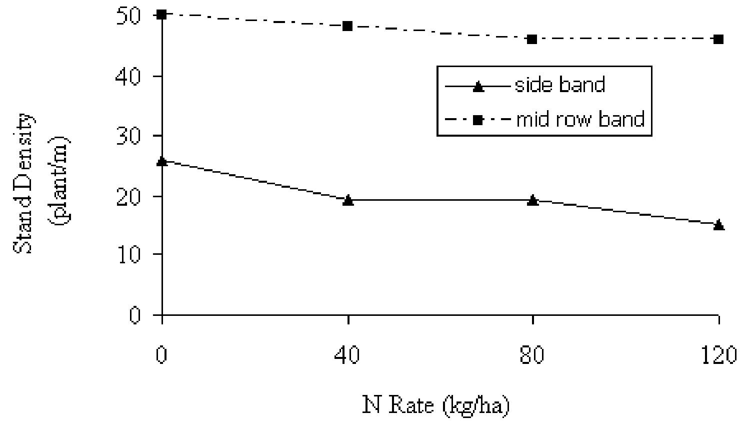


Figure 6: Mid Row Bander
(Source: Bourgault tillage tools 2005)

The Mid Row Bander (MRB) is a single disc opener that is placed between every second seeding tyne (Figure 6). With most tyne spacings between 20cm and 30cm, this gives a distance of between 10cm and 15cm from the seed to the N fertilizer. The MRB also have a secondary benefit of improving trash flow by cutting stubble and vining weeds.

Figure 7: Effect of rate and placement of urea on stand density of canola at Indian Head, Saskatchewan in 2001 (PAMI 2003)



Brandon Research station has possibly some of the best conditions for nitrogen losses through volatilisation. High pH, warm humid conditions and little rain to wash in surface applied nitrogen. Although these conditions are extreme compared to the south coast of WA it does show the possible benefit of these products in the future.

Under these conditions with heavy retained stubble, the most cost effective and practical way to apply nitrogen in crop is as a concentrated stream of UAN. The more concentrated the stream the less is available to be locked up by stubble or be prone to volatilization and the more it will penetrate the soil and be stabilized until rainfall or irrigation (Grant 2005 *pers comm.*)

Nitrogen Management

Mr Guy Lefond of Indian Head Research Centre, Saskatchewan has been doing a lot of long term work with "no till" and split applications of nitrogen. The big question regarding nitrogen applications is always how much to apply. Using the 'GREEN SEEKER', Guy was able to make a better judgment on the requirements of the crop. He is working on improving the Greenseeker algorithms to better calculate nitrogen requirements.

The green seeker is used to compare a "nitrogen rich strip" with the rest of the field. A nitrogen rich strip is defined by an area of the field that has had enough extra nitrogen applied early in the season so that nitrogen is not the limiting factor in crop development. This is usually between 150% and 200% of budgeted Nitrogen. The NDVI (Normalized Difference Vegetative Index) (the biomass of the crop) are the areas measured with the green seeker and the difference is calculated. An optimal rate of nitrogen can then be applied, thus reducing the risk of under applying leading to lost yield potential or wasting nitrogen by over applying.

Disease management

The short length of the Canadian growing season makes timing of foliar applications difficult. The very long days and good growing conditions enables the plants to out grow most diseases. Foliar diseases are mainly controlled through breeding. At Brandon Research Centre, Manitoba they will start each year with up to 7000 lines of barley. Initial cullings are always based on disease. Diseases are similar to those affecting WA barley crops. An interesting fact is that the barley variety that is used as the "infector" is Harrington which is a malting variety still used in WA. Of the 7000 initial lines, 2 to 3 new varieties are released to be commercially grown each year. Mario C. Therrien, plant breeder of Agri food Canada stated that mildew, leaf rust and spot-type net blotch were not a problem for barley producers in Canada because it is bred out. Farmers continually have new varieties coming through to replace older ones that have started to fall down with disease.

United States of America -The mid west

Foliar disease control in wheat

Due to government policy restricting the imports of cheap off patent chemicals, the use of fungicides on wheat is generally uneconomical. Disease is managed mainly through conventional breeding programs similar to Australia

Nitrogen management

In most Western Australian cropping rotations a legume is grown every two to four years for two main reasons:-

- to provide a disease break, and
- to return nitrogen to the soil for future crops.

The most common legumes in WA are lupins followed by peas and beans. Mixed farming operations may use a legume pasture or lucerne.

The weed and disease management benefits of legumes are quite clear but I have in the past continually found myself questioning the actual amount of nitrogen left in the soil after an annual legume crop.

Iowa

Dr Alfred M Blackmer from the Iowa State University was able to shed some light on the actual amount of nitrogen left in the soil after an annual legume crop.

A lot of his work with the department of agronomy has been working to improve nitrogen use efficiency in corn production in a corn/soy bean rotation.

He found that soybean crops and other annual legume crops did not leave more "plant available" nitrogen than corn. More fertiliser nitrogen needs to be applied to a corn crop that follows corn rather than soybeans, not because of the "nitrogen credit" left by the soybean crop, but the fact that nitrogen is consumed as plant residues are decomposed in soils and corn, or in our case wheat or barley leaves a lot more residue than beans or lupins (Blackmer 2005 *pers comm*.).

Nitrogen fertiliser needs

Dr Blackmer is re-evaluating "old school" fertiliser guidelines based on yield goals and credits.

A simple model for estimating nitrogen (N) fertiliser needs is

N fertiliser needs = yield goal x 1.2 – credits.

(Source Blackmer 2005)

A flaw in this type of guideline is that they assume "availability" of nitrogen can be defined.

Some common nitrogen credits that could be questioned are:

- Is the nitrogen available? If the nitrogen was applied as manure and is still in organic form.
- Is the nitrogen available? If nitrogen applied at seeding leached into the river with heavy winter rains.
- Is the nitrogen available? If the nitrogen is in the form of urea and is still in the shop.

He was able to get a better idea on plant requirements by soil nitrate testing after fertilisation, after April rain and before the corn plants started to grow.

The nitrogen management is then 'ground truthed' at the end of the season with a corn stalk nitrate test.

By asking the soil how much nitrate is available then asking the plant how much it got was a good way to assess the efficiency of current nitrogen strategies.

Two findings of Dr Blackmer are that early season rainfall is a major factor affecting N-sufficiency levels in cornfields and that there was an inverse relationship between N-sufficiency levels in fields and nitrogen concentration in rivers.

Nitrogen products

Gaylia Ostermeier, PhD at Iowa State University, Ames, showed her work with nitrogen management. She had done extensive trial work trialling polymer-coated urea (PCU).

The PCU is a new product called ESN. It is designed to control the release of N to be more nearly synchronized with plant uptake and prevent losses of N before the plant grows.

Unfortunately all of the trials showed very little difference to conventional nitrogen sources.

Long term trials in Kansas with this type of product had shown that it is very effective in increasing seed safety when applying urea with the seed at seeding.

Results showed that spring-applied PCU performed essentially the same as spring-applied urea in yield produced (Table 1).

Table 1: Comparison of corn yield with nitrogen fertiliser applied as urea and PCU at 2 different rates (Source: Ostermeier et al 2005)

	Yield	
Rates	**PCU**	**Urea**
lb	----- bu/acre -----	
75	159	162
125	172	176

Nitrogen applications

In the corn belt area, the majority of nitrogen is applied to corn fields in the fall prior to planting as anhydrous ammonia. If in-crop applications are required then the question must be asked, how to affectively apply the nitrogen without the risk of losses to the environment?

It is known that ammonium fertilizers perform better when placed under the soil rather than on the soil. However placing fertilizer under the soil often increases application costs, is very slow and risks crop damage. Studies were conducted to compare the performance of dribble (picture 1) and injected (picture 2) UAN (Urea-Ammonium Nitrate).

The average difference in yield due to placement was 5 bu/acre and remarkably consistent across years (Table 2). This difference is smaller than can be detected in most small-plot studies.

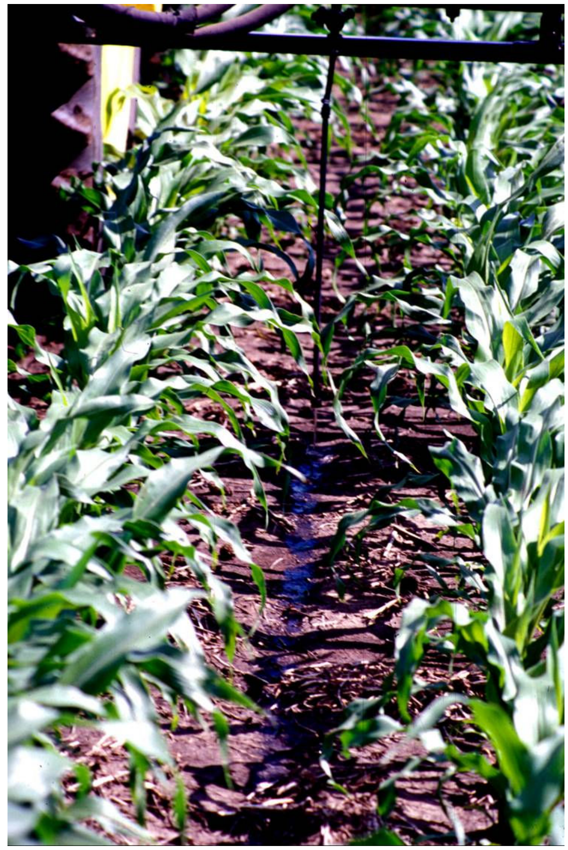
The observed effects of placement were substantially less than often observed when fertilizers are applied when the surface inch of soil is wet (Ostermeier et al 2005b).

Table 2: Results of field scale trials using injected vs. dribbled nitrogen fertiliser in corn (Source: Ostermeier et al 2005b).

Summary of Results of Field Scale Trials

		Yields	
Year	Rate	Injected	Dribbled
	----lb N/acre----	-------bu/acre-------	
2002	100	176	172
2003	100	151	146
2004	100	194	189
Mean	100	174	169

Picture 1: Dribbled Urea Ammonium Nitrate (UAN) on corn (Source: Ostermeier et al 2005b)



Picture 2: Injected Urea Ammonium Nitrate (UAN) on corn (Source: Ostermeier 2005b)

Nitrogen management

Both Dr Blackmer and Ostermeier showed how relatively inexpensive aerial photos can be used to track management practices.

Picture 3 shows how a blocked nozzle at nitrogen application can show up from the air but is very difficult to pick at ground level. Care would have to be taken when soil or tissue testing in this field as results would vary and false recommendations may be made.

Picture 3: Aerial view of a corn paddock that had a blocked nozzle when nitrogen was applied (the yellow stripping) (Source: Ostermeier 2005)

Kansas

Stockosorb Agro

In Kansas I came across an interesting product called Stockosorb Agro.

Stockosorb AGRO is a potassium based, high molecular weight, dry polyacrylamide (crossed linked) crystal. When water comes in contact with the crystal, it forms a hydrated gel, absorbing many times its own weight in water (C.A. Thomson 1999). Cross linked polyacrylamide has been used in the diaper industry for many years but has only recently been considered for use in agriculture.

Availability of soil nutrients can decline under droughty conditions or when they are leached below the rooting zone of the growing crop. Any product or procedure that can extend the availability of nutrients has to be beneficial to the crop. The idea behind adding the crystal to banded fertilizer is that as well as absorbing water it will absorb the soluble nutrients and hold them for the plant to access later. This should in theory make nutrients and water available later and more evenly through the season.

Trial work was being done at the Kansas State University until 1999 when C.A. Thomson retired and the work was not continued.

Table 3 shows that on its own, even at high rates the product had little effect on yield but when banded with nitrogen fertilizer the yields were convincingly higher by between 5 and 20% for a relatively low cost of $3/ac. (highlighted lines).

These trials were conducted an loamy soils with a reasonable clay content and nutrient holding ability, therefore I believe similar if not greater responses should be possible on our sandy soils on the south coast of WA.

Table 3: Five-site summary of 1999 winter wheat yields as affected by Stockosorb AGRO applied with and without starter fertilizer, all placed in a band with the seed at planting under dryland conditions, KSU Agricultural Research Center–Hays, Kansas (Source: C.A. Thomson 1999).

Stockosorb Rate w/seed (lb/a)	Starter fertiliser w/seed	Yield (bu/a)					
		Site 1	Site 2	Site 3	Site 4	Site 5	Five site average
0	No	33.3	59.8	20.7	51.4	19.6	37.0
1	No	34.3	60.7	22.0	51.7	20.6	37.9
2	No	34.4	62.6	22.2	54.0	21.9	39.0
3	No	36.4	62.5	23.4	54.2	22.5	39.8
0	Yes	42.8	64.0	30.2	64.9	32.4	46.9
1	Yes	48.8	70.5	36.4	73.8	39.9	53.9
2	Yes	49.0	71.4	37.2	76.2	40.7	54.9
3	Yes	50.3	71.6	38.4	79.9	43.8	56.8

Oklahoma

GreenSeeker

The high point of my trip was spending time with Dr Bill Raun and PhD student Kyle Freeman at Oklahoma State University (OSU). The team at OSU are passionate about improving world nitrogen use efficiency. They are using a hand held "Green seeker™" to measure the responsiveness of crops to nitrogen applications.

It measures, using infra red and near-infrared technology the NDVI (Normalized Difference Vegetative Index) (the biomass of the crop).

Its use is quite simple. After planting, a nitrogen-rich strip is applied to each management zone of about 150 per cent of the budgeted nitrogen. The nitrogen-rich strip only needs to be a couple of meters wide and long enough to be representative of the zone.

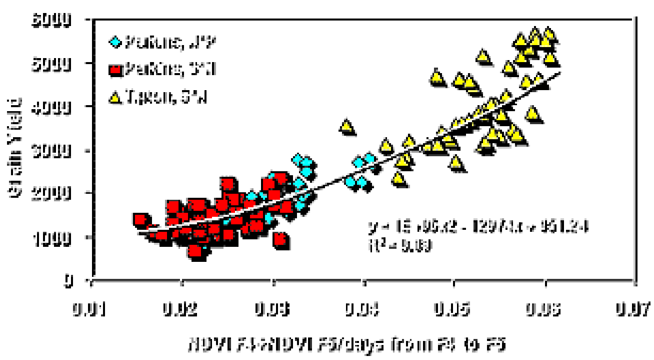
The aim of the strip is to provide an area of comparison that has no nitrogen limitations.

Before every application of nitrogen, the difference between the nitrogen rich strip and the farmer practice is measured (Picture 4). Along with days from planting and maximum potential yield, the two NDVI readings are entered onto a web-based calculator. The calculator will give a nitrogen response index, an in season yield prediction with and without added nitrogen and a recommended rate of nitrogen to apply.

Picture 4: Measuring NDVIs' at Esperance WA September 2005

OSU started using the Green seeker for optical sensing in 1991 to sense weeds for spraying. The system was then used to apply nitrogen, initially to turn the applicator on or off when plants were or were not present. In 1994, the sensors were used to vary the rate of nitrogen using an inverse n-rate, NDVI scale. Where the crop was poorest more nitrogen was applied and vice versa. In 1995, it was found that in-season treatment is necessary whereby the influence of the environment is integrated into treatment application.

Using the hand held sensor, NDVI readings of wheat crops during the growing season were plotted against final grain yield and the in season estimated yield (INSEY) index was developed (Figure 8).



The first attempt to combine sensor readings over sites into a single equation for yield prediction was initiated in the fall of 1997, and tested in 1998. A modification of this index would later become known as INSEY (in-season estimated yield),

Figure 8: The first attempt to combine sensor readings over sites into a single equation for yield prediction was initiated in the fall of 1997, and tested in 1998 (Source: OSU soil testing website)

In 2000, Dr. Gordon Johnson discovered that the N fertilizer rate needed to maximize yields varied widely over years and was unpredictable in several long-term experiments (OSU website 2005). This led to his development of the RESPONSE INDEX.

The response index (RI) was created by dividing the NDVI of the N-rich strip by the NDVI of the farmer practice.

Ensuing work by the Soil Fertility Project aimed to predict what the potential response to applied N would be using sensor measurements collected in-season. This approach allowed OSU to predict the magnitude of response to topdress fertilizer, and in time to adjust topdress N based on a projected 'responsiveness'.

Using the in-season response index (RINDV), OSU were able to project responsiveness to applied N, which changes from location to location based on climatic conditions specific to each parcel of land, and that changes on the same land from year to year

Finally, all the calculations (based on two sensor readings) were put together and the sensor based nitrogen rate calculator was developed.

The calculator is available on the internet free of charge to anyone, at www.soiltesting.okstate.edu (Figure 9).

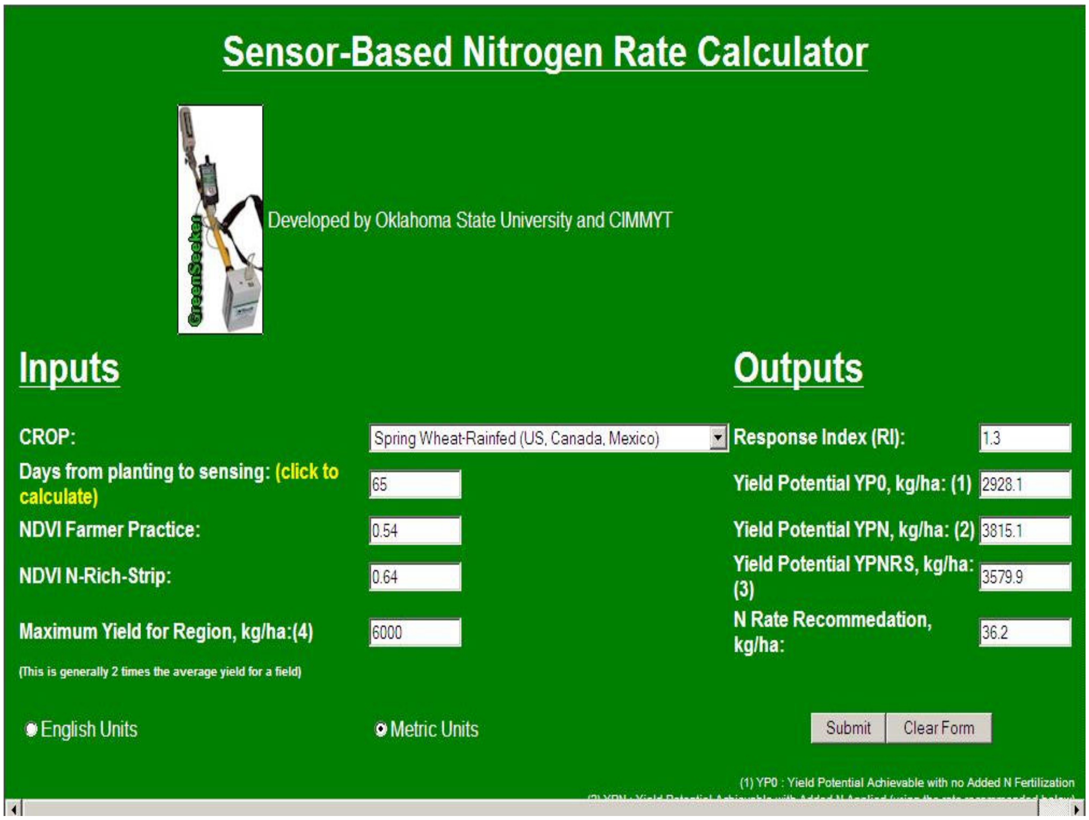


Figure 9: Sensor based nitrogen rate calculator found on the website.

Recommendations

Stubble management

- Harvest residue must be spread uniformly across the paddocks.
- If the following crop is a nitrogen responsive crop (cereal or canola), leave the stubble as tall as possible away from the soil. This will reduce the tie up of in-season applied nitrogen.
- If going into a legume, finely chop straw and spread to maximise straw/soil contact. The legume phase must be used to break down stubbles as the process which uses nitrogen will not affect the performance of the crop.

Disease management

- Control volunteer cereals to reduce leaf disease carryover.
- In a high disease risk year, be proactive with fungicides, not reactive.
- Mix fungicide groups to reduce the onset of resistance and widen the spectrum of control.

Nitrogen management

- At planting, apply enough nitrogen for spikelet formation and seedling vigour, 20% to 30% of budgeted nitrogen.
- Place nitrogen under the surface, away from stubble.
- Higher rates of nitrogen (+40 units) must be placed as far from the seed as possible.
- Avoid burying old stubbles at planting. They will tie up in-season applied nitrogen.
- Apply nitrogen-rich strips across all management zones at 150% of budgeted nitrogen. It is important that the nitrogen source used for the n-rich strips is the same as product to be used for the in-season application of nitrogen.
- Before in-season applications of nitrogen, measure the responsiveness of the crop to bagged nitrogen using the green seeker and web based calculator.
- Delay main nitrogen application to growth stage gs30/32
- If using UAN in crop apply in a concentrated stream where all plants have equal access to nitrogen. For example, if the crop is grown on 22.5cm centres then apply UAN at the same.

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Appendix

Table 4: Zadoks decimal growth stages (Z0.0 to Z9.9) (Source Zadoks et al 1974)

main stage	DESCRIPTION	*sub-stage*	main stage	DESCRIPTION	*sub-stage*
0	germination	*0.0-0.9*	5	heading	*5.0-5.9*
1	MS leaf production	*1.0-1.9*	6	anthesis	*6.0-6.9*
2	tiller production	*2.0-2.9*	7	grain milk stage	*7.0-7.9*
3	MS node production (stem elongation)	*3.0-3.9*	8	grain dough stage	*8.0-8.9*
4	booting	*4.0-4.9*	9	ripening	*9.0-9.9*

MS = main shoot or parent shoot