Grower evaluation of nitrogen application timing and decision tools in uncertain seasons.

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Abstract

Optimum nitrogen fertilisation is dependent on matching nitrogen fertiliser to crop yield potential as determined by seasonal conditions. Many decision support systems are available to assist growers quantify likely responses to additional N fertiliser during the growing season but all tools depend on some estimate of potential or maximum attainable yield which becomes more evident as the season progresses. Even at booting there can be major changes in seasonal prospects as five to eight weeks of the critical spring season remain.

Grower members of the South East Premium Wheat growers Association (SEPWA) investigated nitrogen rates and application timing over a period of five seasons with assistance from Department of Agriculture and Food WA staff. Results from many paddock scale experiments over 5 seasons were compared with decisions made using decision support systems including Potential Yield CALculator (PYCAL), Select Your Nitrogen (SYN) and in the 2005 to 2007 seasons, Yield Prophet. Small plot experiments were also conducted to increase the number of treatments compared to the limited number possible in paddock scale experiments.

Deferred application allows assessment of seasonal conditions prior to N application. In the course of the project growers developed confidence to defer the majority of fertiliser N applied to first node (GS31) and as late as booting (GS45) if seasonal conditions are favourable.

Lessons learned in the course of the project are being rapidly adopted at a commercial scale. Growers are sowing crops with smaller amounts of N fertiliser (less than 20kgN/ha) and deferring decisions on further application to first node (GS31) and booting (GS45).

Key Words

Seasonal fertiliser response

Introduction

In WA most nitrogen fertiliser has traditionally been applied at sowing or in the first few weeks after sowing. The timing was developed in the era when cereal yields were around 1.5 to 2.5 t/ha and cereals were largely grown in nitrogen fertile paddocks after a year or two of good pasture legumes. Only a small proportion of crop N requirement was supplied as fertiliser.

With increased cropping intensity, less frequent legume break years in rotations and higher yields much higher amounts of N fertiliser are now applied to cereals. Associated with this has been a general decline of grain protein levels and greater variation of grain protein as determined by seasons. Dry seasons have high protein grain with excessive screenings and good seasons with a mild spring have seen grain protein as low as 7-8%, foregoing potential yield and attracting large discounts for low protein.

Grower members of the South East Premium Wheat growers Association (SEPWA) concerned about declining wheat protein and meeting market requirements initiated a project with the Department of Agriculture and Food WA in partnership with GRDC to investigate nitrogen management for wheat protein.

The main questions to be answered through project activities were:-

- How much nitrogen fertiliser is required for optimum economic return?
- What are the best methods for estimating paddock N supply for a given season?
- What decision support systems are most useful in making these decisions?
- When is the most effective time for N fertiliser application?
- What is best way to manage fertilizer N when seasons are uncertain?

Methods

At the beginning of each season, meetings with local grower groups reviewed the previous season's farm and experiment protein results and identified further questions about nitrogen management. Members of each group volunteered to conduct experiments for their local area. 45 farm scale experiments were conducted over five seasons.

Decision support systems (DSS) were evaluated in the course of the project, initially using the WA developed Potential Yield CALculator (PYCAL) (Tennant 2000), the Nitrogen Calculator (Bowden and Diggle 1996) and Select Your Nitrogen (SYN) (Bowden *et al*. 2003). In 2005-2007 Yield Prophet was included in the project. Pre-sowing and end of season comparisons of DSS outputs and actual crop treatment results were compared. Almost all sites were fully characterized for soil type, paddock history, nitrogen status, and daily rainfall.

A high level of grower ownership of the project results was achieved through most investigations being conducted by farmers using their machinery in their paddocks. Fertiliser type depended on farmer preference with many growers using Urea Ammonium Nitrate (UAN) liquid. Nearly all farmer experiments were sown with a low rate of N from compound fertilser with nitrogen treatments in addition to this. All operations were performed by growers including harvest - measuring grain yields with a weigh trailer. Many growers were using tramlines with matched machinery widths making experiments very easy to conduct. DAFWA staff assisted with site selection and characterisation, experimental design, crop sampling and monitoring and analysis of results. Sites were designed to be statistically robust with replication and effective control treatments.

Growers soon realized that farm machinery scale experiments could not have enough treatments to fully investigate the key questions. Five small plot experiments were conducted in the 2004 to 2006 seasons in a range of rainfall environments to form a better understanding of N responses at a wider range of application rates and times from sowing to booting.

After the initial two seasons, 2003 and 2004, it was apparent that managing seasonal variability is the key to managing N applications. More emphasis was placed on N fertiliser timing in the experimental program as a way to manage seasonal variation by later application when seasonal conditions are more certain.

Results

Experiments conducted through the project showed a range of yield responses to additional N from large increases to negative responses. Almost all sites showed increases in protein levels in response to additional nitrogen.

The initial 2003 season of experiments was about decile 8 rainfall with a soft spring leading to high yields, low screenings and on some sites, low protein. Yield responses varied between none and 1.0 t/ha. Table 1 shows a typical result for the season with a small yield response to additional nitrogen banded as urea at sowing.

Table 1. Wheat response to urea banded at sowing on pulse stubbles, Grass Patch 2003.

extra N kgN/ha	grain yield t/ha	protein %	screenings %	2003 return to N $$s > nil

beans 2002				
0 N	4.04	9.1	1.0	
15 N	4.38	9.2	1.2	$47
30 N	4.42	9.5	1.2	$60
60 N	3.99	10.6	2.1	$2
lsd 5%	0.202	0.42		

The 2004 season had a dry spring after reasonable winter growth and many sites showed a negative yield response and increasing screenings to increasing rates of nitrogen fertiliser. High screenings from too much N negated payments for high protein. Table 2 shows a typical negative yield response to additional N after a sowing rate of 17 kgN/ha on a pea stubble in a continuous crop rotation. Post sowing N was applied as UAN. The site had an OC level of 0.8% and 20 kgN/ha was the optimum rate from Select Your Nitrogen using a 3.5 t/ha target yield. The boot applied N was taken up by the crop as indicated by the protein response but the high rate of N (40kg/ha) was less damaging to yield and screenings than the same rate at tillering.

Table 2. Wheat response to additional nitrogen as UAN at tillering and booting, Grass Patch 2004

kgN/ha and timing.	heads/m2	grain yield t/ha	protein %	screenings %	2004 return to N $$s > nil N
NIL	300	2.69	10.0	7.6	
10 N tillering	321	2.56	10.5	8.7	-$ 36
20 N tillering	332	2.51	10.9	11.0	-$ 87
40 N tillering	362	2.31	11.6	13.2	-$ 140
10 N booting	285	2.52	10.4	7.6	-$ 35
20 N booting	326	2.47	10.7	10.1	-$ 88
40 N booting	310	2.52	11.2	9.5	-$ 74
10 N t + 10 N b	330	2.50	11.1	12.0	-$ 95

2005 was a good growing season with high yields even in low rainfall areas. The effectiveness of deferred and split applications was well illustrated in an experiment at Salmon Gums. In this experiment, there was a yield and protein response up to 40 kgN/ha. There was a yield benefit from deferred timing of 40 kgN/ha.

Table 3. Wheat response to rates and timing of N as UAN, Salmon Gums 2005.

treatment	total extra kgN/ha	heads/m2	yield t/ha	protein %	screens %	2005 return to N $$s > nil N
nil extra N	0	292	2.43	8.6	0.6	$0
20 N at tillering-T	20	323	2.66	9.0	0.7	$14
40 N at tillering-T	40	345	2.82	9.7	0.7	$30
40 N at elongation-E	40	333	3.06	9.7	0.7	$68
20N E+20N boot - B	40	310	2.97	10.0	0.5	$61
20N T+20N E+20N B	60	311	3.03	10.4	0.6	$43
lsd 5%		25.6	0.16	0.64	0.21 (ns)	

Small plot experiments complemented the farmer scale sites with a wider range of N rates and application times. As an example, one site at Esperance Downs in 2004 confirmed many of the observations made in farmer conducted experiments. The site was canola stubble after several years of pasture. The experiment was sown with a compound fertiliser supplying 13 kgN/ha except for a nil N treatment sown with P only. In this experiment N fertiliser applied as urea was equally effective from tillering to booting for grain yield and protein. Figure 1a shows equivalent yields for rates of urea nitrogen up to 100 kgN/ha applied at various times and splits of the same rate. High rates of nitrogen applied at boot did not yield as much as at tillering or first node. In this experiment N rates up to 100 kg/ha applied at booting increased protein compared to earlier times but higher rates of nitrogen increased protein by a similar amount irrespective of timing (Figure 1b).

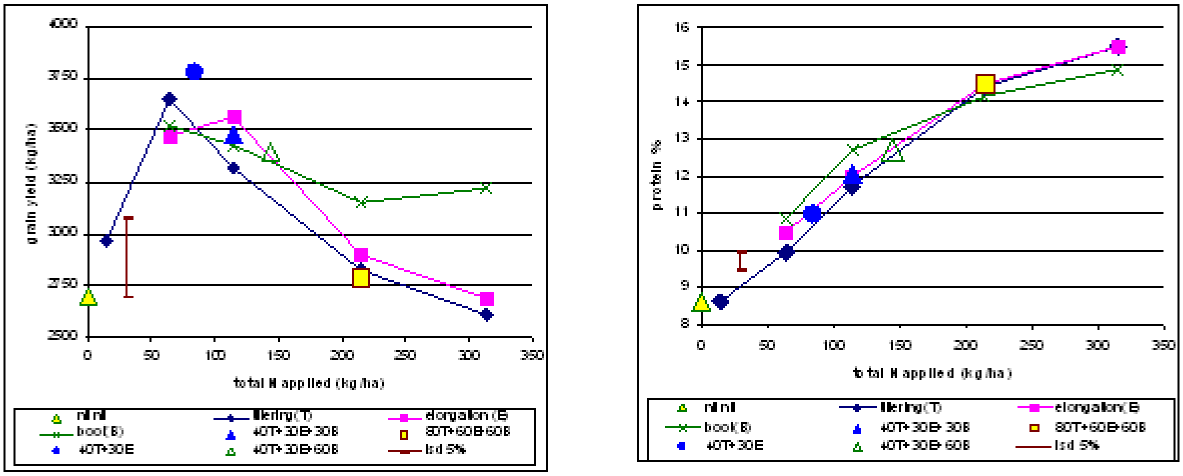
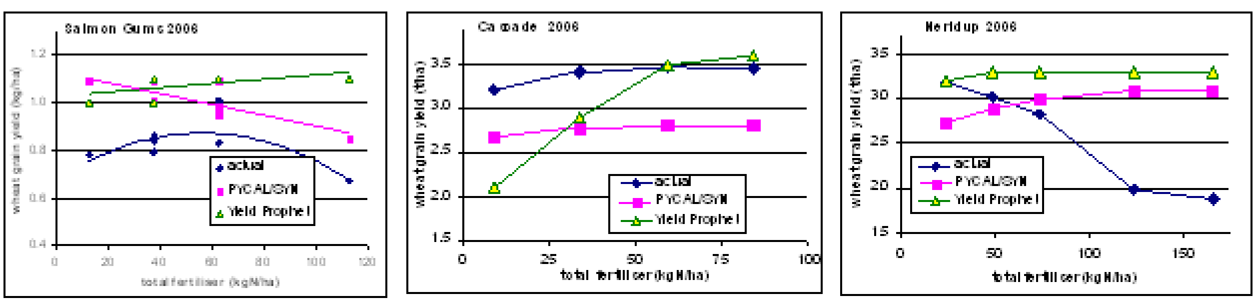


Figure 1a and b. Wheat grain yield and grain protein from various rates and times of nitrogen fertiliser applied as urea at Esperance Downs in 2004.

Fourteen end of season comparisons of decision support systems were conducted with most sites yielding useable results. Only three of these are presented showing a range of outcomes.

A Salmon Gums site in 2006 had divergent results (Figure 2a) where PYCAL/SYN indicates a declining yield from additional N while Yield Prophet indicates a positive response. The farmer was confused from mixed messages during the growing season as target yield was reduced due to dry conditions.

At Cascade (Figure 2b), Yield Prophet modelled a strong response to nitrogen where maximum yield (at high N) was closely simulated. PYCAL/SYN simulated a much lower yield than actual but more accurately predicted the smaller response to fertiliser N. At Neridup, (Figure 2c) crop yield declined with additional N indicating higher paddock fertility than measurements or estimates used to run the DSSs. With low fertility parameters, neither DSS predicted the negative response to nitrogen. Yield Prophet was closer to actual yield response with no yield increase indicated beyond 45 kgN/ha while PYCAL/SYN indicates a response up to 130 kgN/ha.



Figures 2a, b and c. End of season modelled and actual wheat grain yield response curves at Salmon Gums, Cascade and Neridup in 2006.

Discussion

Experiments across the range of sites and seasons in this project provided a challenge to unify the results. The small plot experiments showed yield increases as N fertility increased and yield penalty or ‘haying off’ as N became excessive. The farmer conducted trials generally reflected the N responses observed in small plot trials. Most experiments showed that split applications allow flexibility to match N to a good season without compromising yield compared to the commitment of high N rates early in the season.

For the SE of WA, APW and AH are the main grades of wheat delivered and there is no economic benefit from fertilising for more than 10-11 % protein. The most certain economic response is to increase yield which in this environment raises protein to about 10.5% at maximum yield. The recent large increases in all fertiliser prices need to be accounted for when using decision support systems for N fertiliser rates.

Decision tools evaluated did not always reflect actual responses from experiments but still provided growers with a quantitative guide and are able to present sensitivity analyses. Each DSS tested has its own strengths. Yield Prophet is good for looking at seasonal sensitivity but rarely shows negative yield responses to excessive N fertiliser when run with high N rates. PYCAL and SYN are simpler programs requiring less input data but are not available as a commercial service. Protein outputs were not compared as modellers agree that protein outputs are inaccurate.

A simple decision tree was developed to assist growers with a framework of N tactics according to seasonal conditions (Figure 4). The strategy is to set three possible yields and N requirements before sowing for expected poor, average and good seasons. The crop can be sown with enough nitrogen for a low yield. If the season is poor there is enough N applied at sowing for the expected yield with no concerns about ineffective application under dry conditions. If the season develops with an average outlook during tillering, additional nitrogen can be applied at first node to match the now average outlook. During stem elongation further crop monitoring and the seasonal outlook can be used to determine the need for additional N at boot. If conditions are too dry around booting for application, additional N is not likely to be useful.

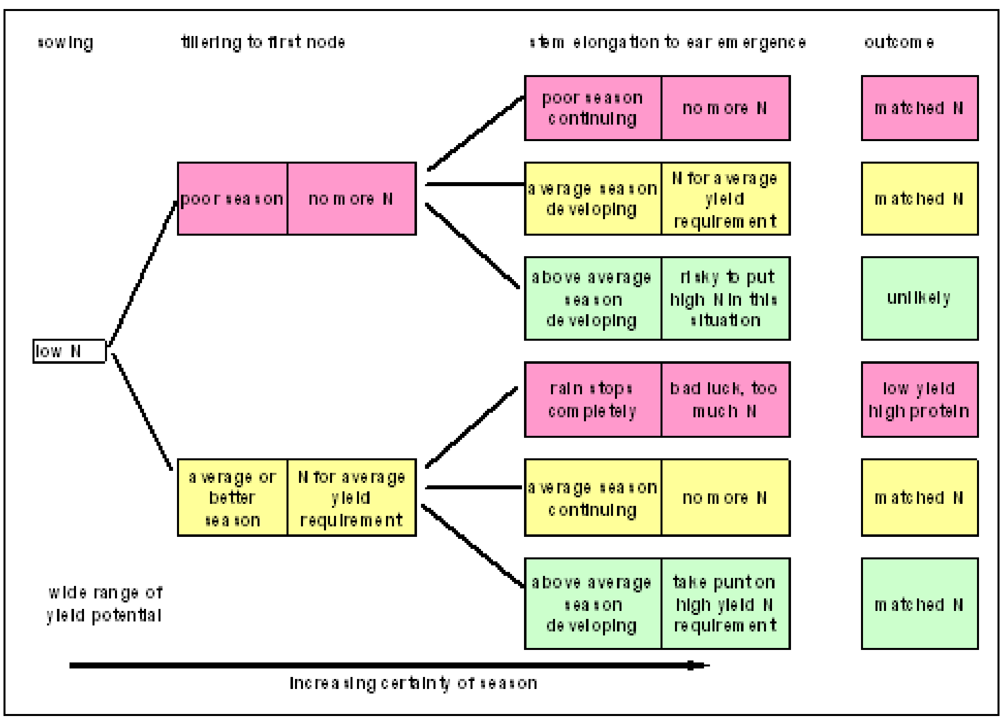


Figure 4. Crop development and nitrogen fertiliser decisions for growth stages. (modified from Baldock et al 2003) (in Lemon 2007)

Conclusion

Later application of N can reduce the risks of over-fertilising. Crop prospects are more certain as sowing time, establishment, weed and disease control are known. Soil moisture can be estimated or measured and seasonal outlooks taken into consideration. If N fertiliser is applied at booting and there is little following rain, crop yield and screenings are less affected than from similar rates applied during tillering. While this may be due to less effective N uptake, the economic penalty from excessive N applied at booting is less than excessive N applied up to first node. If seasonal conditions during flowering and grainfill are good, then late nitrogen is no less effective than at tillering. At this stage of the growing season there is more certainty about seasonal outcome (but not complete certainty) and a decision can be made to withhold additional N if prospects are poor.

While it is still difficult to be precise about optimum N fertiliser for cropping, grower understanding of interacting factors has increased and growers are managing N applications through deferred timing and adjusting rates of application to changing yield potential as the season progresses up to booting. Growers are more confident to use the outputs of decision support systems and seasonal monitoring with a better understanding of season outcome probabilities. Growers largely use advisers and personal experience to decide on paddock fertility and crop N requirements rather than individually use decision support systems. No DSS proved to be more reliable but each has its own strengths. User experience and skill improves the interpretation of DSS outputs. Probabilistic outputs and sensitivity analyses allow growers to better manage nitrogen timing and rates according to risk preference.

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