2014 Seasonal effects of strategic stubble treatments on nitrogen response in wheat in CWFS districts

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GRDC project CWF00018 – Maintaining profitable farming systems with retained stubble in Central West, NSW

Background

CWFS are conducting trials at its regional sites that

- investigate the impact of different stubble treatments imposed towards the end of the fallow have on nitrogen response (applied as urea) in wheat yield and quality
- evaluate the widely used advisor/farmer benchmark of 20 kg actual N required per tonne of expected yield.

During 2014 CWFS conducted a trial at 6 locations Nyngan, Alectown, Gunning Gap, Lake Cargelligo, Ungarie, and Tullamore. Co-located with these trials another trial was conducted that investigated the impact of different stubble treatments imposed towards the end of the fallow have on the yield of wheat and barley without any topdressing. This trial will be reported separately but should be considered a sister trial to this nitrogen trial report. Collectively these 2 individual trials investigate the agronomic influences impacting production in stubble retained systems in the Central West.

Key Points

- During 2014 stubble treatments imposed late in fallow generally had no impact on N response.

- During 2014 generally farmers in the absence of frost or unusual rainfall events during the season were able to reliably predict final yield before sowing. Where a site was N responsive, an N fertilizer rate of 20kg actual nitrogen/ha/per tonne of expected yield produced the most profitable result.

- During 2014 split N applications only improved yield and protein at Nyngan which experienced a well above average growing season rainfall.

- During 2014 split N applications would have possibly reduced risk at two sites, Lake Cargelligo and Ungarie where a decision not to apply

the final 1/3 topdressing may have been made due to soil moisture and rainfall outlook.

- The benchmark of 20kg/ha of actual N per tonne of expected grain yield assumes unrealistic N recover rates from soil and fertilizer but never the less it continues to be a widely used “number” during the commercial decision making process to topdress crops.

Agronomic issues

The nitrogen demand for maximum yield and protein of dryland crops in Central West NSW is unpredictable until late crop development because of variable Spring weather conditions, particularly rainfall. Potentially nitrogen fertiliser can be one of the largest variable costs in wheat production. These two issues have seen farmers adopt topdressing with urea as an important management strategy to balance the seasonal risks and rewards of nitrogen fertilizer. Various approaches to N budgeting have been developed that assist growers to justify how many dollars in the form of nitrogen to risk in an attempt to maximise returns in any one year.

A common rule of thumb used to determine crop nitrogen application rates is 20kg/ha of actual N per tonne of expected grain yield. In agronomic N accounting logic this benchmark assumes unrealistic N recover rates from soil and fertilizer. The number also fails to account for any soil N at sowing or any N that may have mineralised incrop. Never the less it continues to be a widely used “number” during the inseason decision making process to topdress crops were growers are not using computer based decision support tools to decide topdressing rates. Growers using the benchmark consider observations of crop performance, a “gut feel’ about how the season will finish and a knowledge of their business position and market expectation to decide to spend (risk) money on N fertilizer.

Organic N in the soil profile provides the basis for N mineralisation in addition to the crop residues that are cycled near the soil surface. Recent research (Angus, CSIRO, 2013 Forbes GRDC Update) suggest that organic N declines by 2-3% in continuous cropping systems. Fertilizer applications or growing grain legumes reduces the rate of decline but does not maintain the level. To maintain yields with continuous cropping it is suggested that the application of N fertiliser will need to double over the next forty years. Currently urea fertilizer manufacture requires a significant amount of natural gas with modern manufacturing facilities approaching thermodynamic maximum. The outlook is that whilst the availability of natural gas is unlikely to limit N fertiliser supplies the cost of manufacturing will not fall due to improved production efficiency.

These two individual issues alone are pushing producers to use N fertilizer more efficiently. Testing the 20 kg/ha per tonne benchmark under a range of stubble conditions over a number of seasons will either confirm the number for Central West Farming Systems districts or help develop options for more efficient benchmarks.

Trial design
The trial is 9 ranges and 7 rows, and consisted of 3 replicates. Each replicate is 3 ranges and 7 rows. There are 3 stubble treatments; standing, burnt and cultivated. The wheat cultivar is Suntop. Sowing rate was 35 kg/ha, 40 kg/ha of MAP (4.4 kg N per ha) was also applied to all treatments to (try to) ensure phosphorus was not limiting.

At each site 7 treatments were developed based on the cooperating farmers yield expectation for the trial site. 4 treatments including a zero rate were developed for N application up front with the hope that a N response curve for the site could be developed. 3 treatments which represented 20 kg of N per tonne of expected yield/ha were developed. 1 all applied at sowing, another split 50/50 upfront and Z21 and another split 3 ways upfront, Z21 and Z30.

2014 trial sites and results:

Reported financial returns from N application are based on the following assumptions; Urea $550/tonne, average of several daily cash prices for Condobolin November 2014 for AGP1 $245, ASW $248, APW $256, AUH2$265, H2 $276, APH2 $296. Naturally these prices will vary over time and location and the impact of changes would need to be considered in any decision making based on these findings.

At sites where no N response was observed no financial returns have been calculated. Effectively the cost of fertiliser at these sites made the nil rate the most profitable option and reduced all crop gross margins involving fertiliser by the cost of any fertiliser applied.

Alectown
Co-operator; Ian Westcott
Paddock History; Full stubble retention system with sheep grazing fallows. Management target is to maintain ground cover at all times. 2011 oats for grazing and grain, 2012 fallow, 2013 Wedgetail wheat for grazing and grain,
Soil Type; Sandy loam
Stubble treatments imposed; 9 April 2014
Sowing Date; 20 May 2014 Seeding rate 35 kg/ha, 63 kg/ha MAP fertiliser into moist seedbed
Harvest date; 24 November 2013
Special notes; Cultivation treatment imposed with offset discs. Stubble conditions at 9 April was 100% cover generally about 300mm high with an average load of 4.5 t/ha, ranging from 3.3 to 6.2 t/ha. The amount of standing stubble varied from 15 to 31% of total load. Available N to 120cm across the replicates varied from 168 to 193 kg/ha. 0-10 cm Cowell P values varied from 33 to 53 across the replicates with the 10-30cm varying from 9 to 16. PredictaB tests rated 1 replicate at high risk of crown rot infection with others below detectable levels.

Results
Fertiliser at sowing

- No response to stubble treatment or interaction with fertiliser rate
- No yield response to nitrogen fertiliser at sowing but protein and screenings were increased and test weight reduced at 60 units and above.
- The high protein at nil fertiliser (12.1%) would suggest the crop was not nitrogen limited.

Nitrogen at sowing (kgN/ha)	Yield (t/ha)	Protein (%)	Screenings (%)	Test weight
0	2.84	12.1	5.8	81.9
30	2.83	12.1	5.4	82.1
60	2.80	13.1	6.7	80.9
100	2.81	13.7	8.1	80.0
120	2.59	13.5	7.6	80.6
Lsd (0.5%)	0.35	0.4	1.2	0.8

Delayed N application

- No response to stubble treatment or interaction with fertiliser rate
- No yield or screenings response to timing of nitrogen fertiliser
- Grain protein was higher and test weight was lower with upfront nitrogen application.

Sowing (kgN/ha)	Z 21 (kgN/ha)	Z 30 (kgN/ha)	Yield (t/ha)	Protein (%)	Screenings (%)	Test weight
100	0	0	2.81	13.7	8.1	80
50	50	0	3.09	13.1	6.8	81.1
33	33	33	2.85	13.2	7.1	80.6
Lsd (0.5%)			n.s.	0.4	n.s.	0.8

Discussion

Overall this site performed well below farmer expectation at sowing of 5t/ha. Soil moisture at sowing was good, soil N levels were high and incrop rainfall of 167mm would have provided in season confidence to "push" the crop. The hot dry finish experienced at the site was disappointing but started after Z30 so the commercial decision to top dress would have already been made.

The cause of the low yield and high screenings cannot be fully determined from data collected. It is reasonable to suggest either disease or frost. Nearby commercial crops where apparently affected by frost. Although the number of "whiteheads" observed in the trial was not unusual. Analysis of postharvest stubble samples may assist in understanding if disease was a major factor, this analysis will be reported in a separate trial report once completed.

Gunning Gap

Co-operator; Pat O'Connell
Paddock History; 2011 wheat, 2012 Monola, 2013 wheat yielded 4.1 t/ha with the stubble baled and removed
Soil Type; clay loam
Stubble treatments imposed; 9 April 2014, Burning treatments were difficult to impose due to lack of ground cover due to baling. In a commercial situation the paddock would not have been able to carry a fire at this time.
Sowing Date; 14 May 2014 Seeding rate 35 kg/ha, 63 kg/ha MAP fertiliser into moist seedbed
Harvest date; 20 November 2014
Special notes; Cultivation treatment imposed with off set discs. Stubble conditions at 9 April was 100mm high standing stubble in the 2013 crop rows, ground between the rows was generally bare. Available N to 120cm across the replicates varied from 33 to 53 kg/ha. 0-10 cm Cowell P values varied from 31 to 44 across the replicates with the 10-30cm varying from 6 to 8. PredictaB tests for crown rot rated the 3 replicates differently 1 replicate at high risk, 1 at low risk and 1 below detectable levels.
Trial management for this site was a co-operation between CWFS and Matt McRae, Ag n Vet, Forbes.

Results
Fertiliser at sowing

- No response to stubble treatment except that screenings were a little higher on the cultivated plots
- No interaction between stubble treatments and nitrogen fertiliser rate
- Yield response to nitrogen fertiliser up to 70 units
- Protein increased with every additional rate of nitrogen
- Screenings low and unaffected, and very small test weight responses
- Apparent fertiliser recovery in the grain averaged 41%
- The additional return (grain value less fertiliser cost, but not including spreading and grain cartage) was as high as $200 for the 70 kgN/ha rate, a return on investment of about 2.5:1.

Nitrogen at sowing (kg/ha)	Yield (t/ha)	Protein (%)	Screenings (%)	Test weight	Additional grain less fertiliser ($)	Fertiliser recovery in grain (%)
0	2.72	8.7	2.9	82	-	-
20	3.07	9.2	2.7	82.4	63	41
40	3.42	9.7	2.5	82.5	125	42
70	3.78	10.8	2.8	82.4	208	43
90	3.77	11.4	3.0	82.1	182	38
Lsd (0.5%)	0.20	0.2	n.s.	0.3		

Time of N application

- No response to stubble treatment or interaction with fertiliser rate
- Up front gave significantly higher (P=0.8) yield and protein than split applications. Nitrogen recovery in the grain was about 10% higher with N applied at sowing. Screenings and test weight were unaffected.

Sowing (kgN/ha)	Z 21 (kgN/ha)	Z 30 (kgN/ha)	Yield (t/ha)	Protein (%)	Screenings (%)	Test weight
70	0	0	3.78	10.8	2.8	82.4
35	35	0	3.59	10.3	2.7	82.4
23	23	23	3.59	10.1	2.8	82.6
Lsd (0.5%)			0.19	0.3	n.s.	n.s.

Discussion

This site performed very close to the initial farmer expectation of 3.5 t/ha. The benchmark of 20 kg of N per tonne of grain appears correct at this site this season in a very low starting soil N environment. With the hindsight of the season and harvest data it is observed that the highest risk option of all N up front would have produced the highest yield and protein combination.

Lake Cargelligo
Co-operator; The Davis family
Paddock History; No till no sheep for last ten years.
2011 wheat; 2012 canola; 2013 wheat. The longer term rotation is generally wheat.
Soil Type; Red sandy loam
Stubble treatments imposed; 14 March 2014. Burning treatments were difficult to impose due to lack of ground cover. In a commercial situation the paddock would not have been able to carry a fire at this time.
Sowing Date; 21 May 2014 Seeding rate 35 kg/ha, 63 kg/ha MAP fertiliser into moist seedbed with good soil moisture
Harvest date; 12 November 2014
Special notes; Cultivation treatment imposed with offset discs. Stubble conditions at 9 April was 200mm high standing stubble in the 2013 crop rows, ground between the rows was generally bare. There was no evidence of older crop residue from the canola or prior wheat crops. Available N to 120cm across the replicates varied from 88 to 192 kg/ha. 0-10 cm Cowell P values varied from 25 to 50 across the replicates with the 10-30cm varying from 6 to 10. PredictaB tests for crown rot rated the 3 replicates all at no detectable risk.

Results
Fertiliser at sowing

- No yield or grain quality responses to nitrogen
- Even with no additional N, grain protein was 13.6% suggesting that soil N supply was at luxury levels for the rainfall received
- Screenings were high, reflecting the dry season

Nitrogen at sowing (kg/ha)	Yield (t/ha)	Protein (%)	Screenings (%)	Test weight (kg/hl)
0	1.47	13.6	7.4	79.8
30	1.7	13.4	7.3	80
50	1.63	13.2	6.5	80.6
60	1.59	13.2	6.6	80.4
90	1.72	13.5	6.4	80.4
Lsd (0.5%)	n.s.	n.s.	n.s.	n.s.

Delayed N application

- No yield or quality responses to nitrogen timing, reflecting the high N supply of the site given the low in crop rainfall.

Sowing (kgN/ha)	Z 21 (kgN/ha)	Z 30 (kgN/ha)	Yield (t/ha)	Protein (%)	Screenings (%)	Test weight (kg/hl)
17	17	17	1.53	13.2	6.5	83.6
25	25	0	1.79	13.1	6.6	84.0
50	0	0	1.63	13.2	6.5	83.5
Lsd (0.5%)			n.s.	n.s.	n.s.	n.s.

Discussion

Soil tests at this site suggested that there was little no opportunity for N response at the farmers yield expectation of 2.5t/ha. Again similar to other sites reasonable variation existed between soil N levels measured in different replicates. Whilst incrop rainfall was good during crop establishment no significant rain fell after August resulting in crop stress for most of the time. The high screenings at harvest are more than likely due to water stress since PredictaB testing rated the site at below detectable risk. Analysis of postharvest stubble samples will hopefully quantify any impact of crown rot and will be reported separately. Again pre sowing the farmer was able to predict optimum target yield in terms of highest economic response to additional fertilizer. With the hindsight of the season and harvest data it is observed that the only advantage of split applications was risk management rather than any yield or protein improvement. In a commercial situation it is likely that the final application in the N split 3 ways approach would not have been applied resulting about a $24/ha saving in cost of production.

Nyngan

Co-operator; David Carter

Paddock History; 20 year no till continuous cropping paddock, with rotation dependant on soil moisture at sowing and market outlook. Legumes have not been part of the crop mix. Cattle are sometimes grazed over summer if feed is

required but stocking rate is too low to be considered significant. 2010 barley, 2011 canola, 2012 wheat, 2013 long fallow.
Soil Type; Clay loam
Stubble treatments imposed; 2 April 2014
Sowing Date; 7 May 2014 Seeding rate 35 kg/ha, 63 kg/ha MAP fertiliser into moist seedbed with good subsoil moisture
Harvest date; 3 November 2014
Special notes; Cultivation treatment imposed with offset discs. Uneven stubble conditions across the paddock existed on 9 April. Generally it ranged in height from 200 to 300mm high with an average load of 3.5 t/ha, ranging from 1.6 to 6.0 t/ha, ground cover varied from 0 to 100%. It is reasonable to suggest that this variation was due to the way water had drained and settled on the surface during the fallow. The amount of standing stubble averaged 14% of the total load but varied from 4 to 22%. Available N to 120cm across the replicates varied from 168 to 193 kg/ha. 0-10 cm Cowell P values varied from 33 to 53 across the replicates with the 10-30cm varying from 9 to 16. PredictaB tests rated 1 replicate at high risk of crown rot infection with others below detectable levels.
Trial management for this site was a co-operation between CWFS and Greg Brooke NSW DPI.

Results
Fertiliser at sowing

- No response to stubble treatment or interaction with fertiliser rate
- Yield was increased by 20 units of N fertiliser at sowing, and at this rate apparent fertiliser recovery in the grain was very high (58%). The return on investment was better than 4:1.
- Additional N fertiliser gave small, often insignificant yield increases and higher grain proteins. This raised grain grades from APH to H2, and the additional return (grain value less fertiliser cost, but not including spreading and grain cartage) was as high as $200 for the 60 kgN/ha rate, a return on investment of about 2.3:1.
- Fertiliser recovery at these higher rates was about 30%.

Nitrogen at sowing (kg/ha)	Yield (t/ha)	Protein (%)	Screenings (%)	Test weight	Additional grain less fertiliser ($)	Fertiliser recovery in grain (%)
0	4.23	10.6	2.5	83.7	-	-
20	4.72	10.9	2.4	83.8	63	58
36	4.67	11.1	2.4	83.6	125	34
60	4.78	11.5	2.7	83.5	208	30
90	4.94	11.9	3.3	82.8	182	27
Lsd (0.5%)	0.29	0.4	0.4	0.4		

Delayed N application

- No response to stubble treatment or interaction with fertiliser rate
- Slightly higher yield with fertiliser split between sowing and Z21 than all upfront.
- No differences in grain quality

Sowing (kgN/ha)	Z 21 (kgN/ha)	Z 30 (kgN/ha)	Yield (t/ha)	Protein (%)	Screenings (%)	Test weight
36	0	0	4.67	11.1	2.4	83.6
18	18	0	5.04	11	2.5	84.0
12	12	12	4.95	11.1	2.6	83.5
Lsd (0.5%)			0.32	n.s.	n.s.	n.s.

Discussion

The season experienced at Nyngan was well above average with 200 mm of incrop rainfall. The majority of this rain fell in 2 steady, well timed rainfall events, 73 mm in June and 88 mm in August which resulted in crop performance being higher than initial farmer expectation by approximately 3 t/ha. With the hindsight of the season and harvest data it is observed that profitable N responses were achieved at all application rates despite the high soil N recorded presowing. In a more typical Nyngan season (the farmer's expectation) the high rates earlier would have more than likely promoted lush early growth which would have "hayed off" in the early Spring resulting in poor yields.

The option of 50% upfront followed by 50 % at tillering produced the highest yield which may suggest some leaching of N from the top of the soil profile. The rainfall in August allowed the last application in the N split three way strategy to be used by the crop, this will not always be the case at Nyngan.

Tullamore

Co-operator; Neville Jones
Paddock History; No till cropping for over 5 years. In 2011 controlled traffic and interow sowing were introduced. Rotation is generally wheat, barley then canola. 2013 crop was 3.2 t/ha wheat crop
Soil Type; Clay loam
Stubble treatments imposed; 3 April 2014
Sowing Date; 2 May 2014 Seeding rate 35 kg/ha, 63 kg/ha MAP fertiliser into moist hard seedbed
Harvest date; 4 November 2014
Special notes; Cultivation treatment imposed with off-set discs. Stubble conditions at 3 April was 100% cover generally about 400mm high with an average load of 3.7 t/ha, ranging from 2.9 to 4.8 t/ha. The amount of standing stubble varied from 18 to 60% of total load with and average load of 40%. Available N to 120cm across the replicates varied from 102 to 201 kg/ha. 0-10

cm Cowell P values varied from 29 to 44 across the replicates with the 10-30cm varying from 11 to 14. PredictaB tests rated 1 replicate at high risk of crown rot infection with others below detectable levels.

Trial management for this site and a nearby canola trial was a co-operation between CWFS and Grains Orana Alliance.

Results
Fertiliser at sowing

- There was some interaction between stubble treatment and nitrogen rate, with the burnt treatment being lower yielding at low fertiliser rates but not at higher rates
- Significant yield responses up to 60 units of nitrogen
- Protein was low (8.4%) at nil fertiliser, suggesting the site was N deficient
- Fertiliser recovery in the grain was good (37-50%) at all but the highest rate and gave economic responses.
- The additional return (grain value less fertiliser cost, but not including spreading and grain cartage) was as high as $232 for the 60 kgN/ha rate, a return on investment of about 3.2. The return on investment ratio was almost 5 for 20 units and about 3 for 40 units of N.

Nitrogen at sowing (kg/ha)	Yield (t/ha)	Protein (%)	Screenings (%)	Test weight	Additional grain less fertiliser ($)	Fertiliser recovery in grain (%)
0	2.38	8.4	2.9	83.8	-	-
20	2.96	8.7	2.6	83.9	118	50
40	3.15	9	2.7	84.4	143	37
60	3.61	9.4	2.8	84.4	232	41
90	3.34	10.6	4	84	155	30
Lsd (0.5%)	0.31	0.5	0.6	0.3		

Delayed N application

- A significant (P=0.06) response to stubble treatment, with lower yield for the burnt than the cultivated or standing stubble treatments.
- No significant response to timing of N application on grain yield or quality

Sowing (kgN/ha)	Z 21 (kgN/ha)	Z 30 (kgN/ha)	Yield (t/ha)	Protein (%)	Screenings (%)	Test weight
60	0	0	3.61	9.4	2.8	84.4
30	30	0	3.31	9.3	2.7	84.2
20	20	20	3.32	9.6	3.1	84.5
Lsd (0.5%)			n.s.	n.s.	n.s.	n.s.

Discussion

At this site measured soil N should have been sufficient to achieve the farmers' initial expectation of 3 t/ha yield despite the variation between the replicates ranging from 102 to 201 kg/ha. Expected yield was achieved with 20 kg/ha of fertilizer N which most likely assisted the crop at establishment and this initial head start was maintained until harvest. Visually the plots with fertilizer at sowing always appeared better. Applying fertilizer at the benchmark of 20 kg N/ha/tonne of expected yield did produce the highest economic return. With the hindsight of the season and harvest data it is observed that the only advantage of split applications was risk management rather than any yield or protein improvement. Further work is needed at this site to understand what is limiting protein accumulation as soil tests predict commercially acceptable levels of N to achieve higher wheat grades at harvest.

Ungarie

Co-operator; Graeme Mason
Paddock History; No till, no stock, continuous cropping paddock since 1998 it target rotation of wheat/canola/wheat/lupins. 2012 canola, 2013 wheat.
Soil Type; Sandy loam
Stubble treatments imposed; 13 March 2014
Sowing Date;14 May 2014 Seeding rate 35 kg/ha, 65 kg/ha MAP fertiliser into moist seedbed with good subsoil moisture.
Harvest date; 27 November 2014
Special notes; Cultivation treatment imposed with off set discs. Stubble conditions at 13 March was a thick 100% cover between 400 and 500mm high with an average load of 7.3 t/ha, ranging from 5.6 to 8.9 t/ha. The amount of standing stubble varied from 29 to 48% of total load with and average load of 36%. Available N to 120cm across the replicates varied from 59 to 81 kg/ha. 0-10 cm Cowell P values varied from 36 to 55 across the replicates with the 10-30cm varying from 11 to 13. PredictaB tests for crown rot rated 1 replicate at high risk of crown rot infection and 2 at low risk.

Results
Fertiliser at sowing

- No response to stubble treatment or interaction with fertiliser rate
- There was a small yield response to 50 units of nitrogen
- Protein increased up to 50 units of nitrogen but screenings were high at all N rates, putting the grain in to AGP1 and AUH2 grades, reducing the economic returns from nitrogen
- Overall, there was a low return on investment to nitrogen application
- Fertiliser recovery in the grain was low, a common finding once grain protein levels exceed 11.5%

Nitrogen at sowing (kg/ha)	Yield (t/ha)	Protein (%)	Screenings (%)	Test weight (kg/hl)	Additional grain less fertiliser	Fertiliser recovery in grain

					($)	(%)
0	2.03	11.4	6.4	81.3	-	
30	2.07	12.2	6.6	81.1	16	12
50	2.28	13.1	6.8	80.8	47	24
60	2.06	13.2	7.2	80.7	-23	12
90	1.97	13.4	6.9	80.4	-82	6
Lsd (0.5%)	0.15	0.6	n.s.	0.4		

Delayed N application

- No yield response to stubble treatment but protein and screenings were both higher with standing stubble than where burnt. There was no interaction with nitrogen fertiliser timing
- No significant effects of timing on yield or grain quality

Sowing (kgN/ha)	Z 21 (kgN/ha)	Z 30 (kgN/ha)	Yield (t/ha)	Protein (%)	Screenings (%)	Test weight
50	0	0	2.28	13.1	6.8	80.8
25	25	0	2.04	12.8	6.7	80.8
16	16	16	2.2	12.9	7.3	80.6
Lsd (0.5%)			n.s.	n.s.	n.s.	n.s.

Discussion

Soil tests at this site suggested that there was good opportunity for N response. Whilst incrop rainfall was good during crop establishment the conditions from early August through to harvest resulted in crop stress for most of the time. A rainfall event during September more than likely saved the crop. The high screenings at harvest are more than likely due to these conditions although frost and crown rot may have also contributed. Results at this site are similar to nearby Lake Cargelligo which experienced similar weather during the season. Analysis of postharvest stubble samples will hopefully quantify the impact of crown rot which will be reported separately. Again pre sowing the farmer was able to predict optimum target yield in terms of highest economic response to additional fertilizer. With the hindsight of the season and harvest data it is observed that the only advantage of split applications was risk management rather than any yield or protein improvement.

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