Minnesota Wheat Research and Promotion Council

On-Farm Research Trials 2014

Does split applying nitrogen increase yields or protein and when is it cost effective?

Prepared by

Garth Kruger, Ph.D.
EvaluationGroup, LLC

Dave Willis
Agassiz Crop Management, Inc.

Dave Torgerson
Executive Director
Minnesota Wheat Research & Promotion Council

Missy Geiszler
Research Assistant
Minnesota Wheat Research, On-Farm Research

Does Split Applying Nitrogen in Spring Wheat Increase Yields or Protein and is it Cost Effective?

Background [i]

Relevant Current/Past Nitrogen Research

Split applying nitrogen on grain (also called top-dressing) is the process of applying significantly less nitrogen at planting than is required for yield goals with the intent to put the remaining nitrogen on later in the season. The purpose for this is 1) to decrease potential nitrogen loss and 2) to avoid lodging before heading as it can significantly decrease yields in years where conditions produce lush foliage.[1]

- For growers with large wheat acreage this can be difficult to accomplish in a timely fashion, especially in difficult years.

* Very few studies have examined the effectiveness of this strategy across a wide range of environmental, varietal and soil conditions.

- Studies in the past conducted at sites in heavy soils (e.g. Crookston and Fargo) have not found split applications to improve yield as long as pre-plant nitrogen is sufficient.[2,3]

* Studies conducted in the early 90's in Manitoba found that split applying fertilizer increased wheat yields.

- Applying 35lbs of nitrogen at anthesis increased yields slightly (2-7 bu/ac) in four out of six years studied. [4]

One area of confusion for hard red spring wheat growers may be that much research exists exploring the benefits and amounts of topdressing nitrogen on winter wheat. It has been shown to be beneficial for both yield and protein. This body of research should not be confounded with hard red spring wheat as management approaches differ. Another area of potential confusion is topdressing versus post-anthesis application -whose primary goal is to boost protein.

Crop production nutrient management covers three broad areas, 1) amount, 2) methods and 3) timing.[5] Studies pertaining to topdressing in these three areas suggest the following:

Amount to Apply

* Nitrogen should be applied before planting based on yield goals with some consideration of soil organic matter content and previous crop. For specific guidelines see Franzen (2014a) and Sims, Rhem & Lamb (2008).[6,3]

- Topdress amounts are highly situation dependent but typically range anywhere from 75% of nitrogen goals to 25%.

* Financial return relative to recommended total nitrogen rates have been recently optimized for hard red spring wheat in North Dakota and are generally applicable to northern Minnesota.[6]

- To access the online wheat nitrogen recommendation calculator, see: http://www.ndsu.edu/pubweb/soils/wheat/

Methods of Application

* The most recommended method of topdressing is using spray bars to apply10-20 gallons/acre of 28-0-0 over the wheat.

* Broadcasting Urea also works, however the risk of nitrogen loss is greater. Poly coated Urea can be used to mitigate risk of nitrogen loss when broadcasting.

Timing of Application

* The bulk of nitrogen used by HRSW is taken up between tillering and boot stages. This time period is the window for managing nitrogen to maximize yield potential and provide sufficient opportunity for protein development.
* The risk with split applications is that excess moisture may prevent timely treatment and dry weather might prevent fertilizer from reaching crop roots (see www.nutrientstewardship.com).
* Schatz (2012) at the Carrington Research Extension Center applied an additional 50 lbs of nitrogen at the boot stage affected protein by nearly one percentage point.[7]
* Approximately 20% of the time when nitrogen is applied post anthesis, there is no effect on grain protein. 80% of the time there is between half to a point gain in protein.[2] However, the timing for this application is different (later) than when split applying nitrogen.

Protein sampling from the combine hopper: 2014

Research Methods

This study compared a split nitrogen application vs. 100% yield goal nitrogen down at pre-plant as Urea (or whatever choice of N worked best in participants operations). For the split application, participants were allowed to apply whatever level of nitrogen they needed to meet their yield goals minus 45 lbs. This equates to 15 gallons of 28% N or 100 lbs of urea.

- Two of the sites used urea at pre-plant, the rest used anhydrous. All but one site completed topdressing with 28-0-0.
- Randomized complete block design was used and a minimum of three replications were completed at each location, most had four.
- Multiple protein samples were probed from the hopper from each strip (see picture at above) and yield was calculated using a weigh wagon after each strip was harvested.
- Sample yields were standardized to 13.5% moisture and 60lb test weight.
- Each trial strip was approximately 1 acre.
- Topdress was applied atthe 5 leaf stage.
- All participants received adequate moisture to ensure that nitrogen reached the root zone once the topdress was applied.

Test strip harvesting: 2014

- Participants were responsible for purchasing the nitrogen used and applying it according to study protocols.
- Participants were paid $1,500 to help meet costs associated with their involvement in the study.

Results

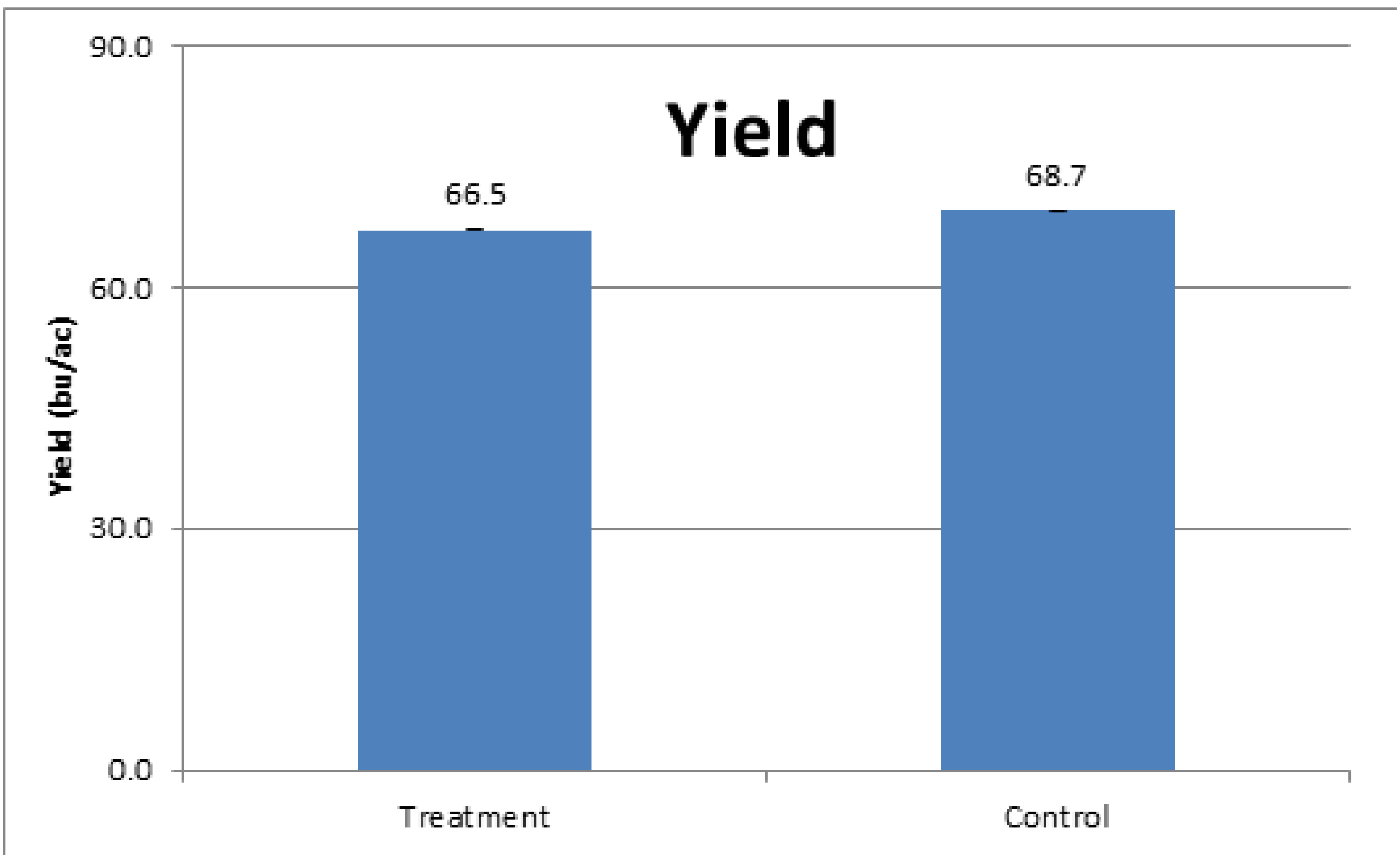
Yield

Treatment	Field-Yield								Mean
	Fosston	Fosston[2]	Manvel	Oslo	Warren	Argyle	Stephen	Roseau	
Prev. Crop	*Soybeans*	*Soybeans*	*Prev. Plant*	*Soybeans*	*Soybeans*	*Wheat*	*Soybeans*	*Soybeans*	
Top-dress	95.4	57.1	53.1	57.5	67.8	42.8	79.2	78.8	66.5
No Top-dress	100.2	54.3	59.2	61.0	70.0	46.4	81.1	77.6	68.7
Mean	97.8	55.7	56.2	59.3	68.9	44.6	80.2	78.2	--
# of reps	4	3	4	4	4	3	3	4	29
Sig test	*p<.05*	ns	ns	ns	*p<.10*	*p<.05*	ns	ns	*p<.05*

Orange cell coloring highlights that a significant difference was found for a negative yield effect with topdressing.

A paired samples t-test was calculated to compare the mean differences between all treatment and control conditions on yield. Average yields across the eight sites were significantly lower in the topdress treatment group at 66.5 bushels than in the no topdress control at 68.7 ($t(28) = -2.5$, $p<.05$).

In three sites yields were significantly lower in the top-dress condition (Fosston, Warren and Argyle). This was likely due to excessively wet and muddy ground conditions during the application of nitrogen. In many of the test plots substantial ruts were created. With denitrifying weather scenarios where additional nitrogen might be desired, substantial crop damage in wheel tracks may be expected. A solution to this would be the establishment of tram tracks early in the season. Plants adjacent to the tracks then have the opportunity to make up for yield loss in the tracks. Other yield inhibiting effects can include leaf burn due to nitrogen application. However, the field coordinator for this study visually found no significant leaf burn after the topdressing as precipitation typically followed immediately after topdressing.



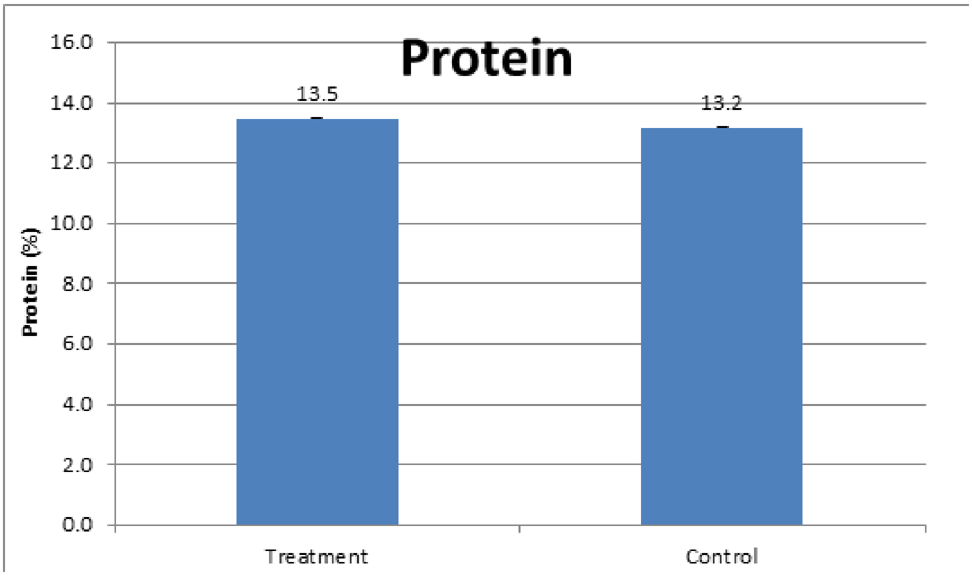
Protein

Treatment	Field-Protein								Mean
	Fosston	Fosston[2]	Manvel	Oslo	Warren	Argyle	Stephen	Roseau	
Top-dress	12.5	14.3	15.5	12.0	11.7	15.9	11.7	14.5	13.5
No Top-dress	12.0	13.7	14.2	12.2	12.2	15.6	11.8	14.3	13.2
Mean	12.3	14.0	14.9	12.1	12.0	15.8	11.8	14.4	--
# of reps	4	3	4	4	4	3	3	4	29
Sig test	*p<.15*	*p<.15*	*p<.10*	*p<.20*	*p<.15*	*p<.05*	*ns*	*p<.05*	*p<.05*

Green cell coloring highlights that a significant difference was found for a positive protein effect with topdressing

Orange cell coloring highlights that a significant difference was found for a negative protein effect with topdressing

A paired samples t-test was calculated to compare the mean differences between overall treatment and control conditions on protein. Average protein was significantly higher across the sites in the treatment group M=13.5% than in the control, M=13.20%, (t(28) = 2.05, p<.05). In five locations (Fosston, Fosston[2], Manvel, Argyle and Roseau) protein went up significantly (from 0.2% to 1.3%, average increase = 0.58%). At two locations (Oslo and Warren) it went down significantly (0.2% and 0.5% respectively), and at one site (Stephen) there was no statistical change. In other words, applying additional nitrogen increased protein 62% of the time (an average of 0.58% percent), and 38% of the time either decreased it or had no effect.



The table on the following page contains the data for protein and yield for all 29 replications at the eight sites. It additionally identifies the variety. Several noteworthy observations include:

- There is a wide range of yields from a low of 44.1 to a high of 98.6.
- There is great variability in proteins ranging from a low of 11.1 to 16.0.
- There are 4 different varieties identified in the trials.
- Soren wheat represents 44% (n=11) of test replications where the variety was known.
  - o The average yield for the Roseau site (strip# 12-15) was 78 bu/ac and it had an average protein of 14.3 (control) to 14.5(treatment).

			Yield			Protein		
Count	Variety	Rep	Treatment	Control	Diff	Treatment	Control	Diff
1	Albany	1	98.6	100.0	-2.2	12.1	11.6	0.5
2	Albany	2	97.0	98.8	-2.1	12.5	11.4	1.2
3	Albany	3	97.1	101.5	-5.2	12.9	12.4	0.5
4	Albany	4	88.9	100.1	-12.8	12.6	12.8	-0.1
5	Rollag	1	60.0	48.8	11.1	14.7	14.1	0.6
6	Rollag	2	59.0	58.1	0.9	14.6	13.6	1.0
7	Rollag	3	52.1	55.9	-3.8	13.5	13.3	0.2
8	Soren	1	56.3	55.6	0.7	12.6	12.4	0.3
9	Soren	2	53.6	50.3	3.3	11.7	12.1	-0.4
10	Soren	3	54.5	65.9	-11.4	11.8	12.2	-0.3
11	Soren	4	65.4	72.2	-6.9	11.8	12.2	-0.4
12	Soren	1	77.8	77.6	0.2	14.7	14.6	0.1
13	Soren	2	79.7	76.5	3.2	14.5	14.3	0.3
14	Soren	3	78.8	79.4	-0.7	14.5	14.1	0.4
15	Soren	4	78.8	79.9	-1.1	14.4	14.2	0.2
16	Faller	1	68.4	71.9	-3.5	12.7	12.9	-0.2
17	Faller	2	70.0	70.7	-0.7	11.4	12.3	-0.8
18	Faller	3	64.2	69.1	-4.9	11.1	11.8	-0.7
19	Faller	4	68.6	68.4	0.2	11.4	11.8	-0.4
20	Faller	1	78.2	76.0	2.2	11.4	11.7	-0.3
21	Faller	2	81.1	84.5	-3.4	12.2	11.9	0.3
22	Faller	3	78.4	83.0	-4.6	11.5	11.8	-0.2
23	Soren	1	45.1	48.1	-3.0	15.9	15.6	0.3
24	Soren	2	39.1	44.3	-5.2	16.0	15.8	0.2
25	Soren	3	44.1	46.8	-2.7	15.9	15.5	0.4
26	---	1	50.3	52.2	-1.9	15.5	12.8	2.7
27	---	2	50.3	66.9	-16.6	15.7	14.3	1.4
28	---	3	63.1	60.3	2.8	15.8	14.9	0.9
29	---	4	48.9	57.4	-8.5	14.9	14.7	0.2

Totals		Yield Treatment	Yield Control	Yield Diff	Protein Treatment	Protein Control	Protein Diff
	Mean	67.2	69.7	-2.5	13.5	13.2	0.27
	St. Dev	16.67	16.90	5.30	1.68	1.36	0.70

Harvesting topdress test strips: 2014

Cost/Benefit Analysis

* ***Average total cost for treatment condition = $47.60/acre (* one site topdressed with urea)***

cost per ton (est.)	cost per pound	rate applied per gallon	Weight per gallon	pounds of product per/ ac@ 15 gals/ac	28-0-0 product cost per ac
$370	$ 0.185	15	10.67 lbs	160.05	$ 29.60

- 2 bushels approximately lost per acre average (wheel tracks) @ $5 bu=$10/ac
- $8/acre cost for application (fuel + equipment or custom)
- Opportunity cost? (no $ cost assigned)

* ***Average total gain from top-dressing = $12.06/acre at 67 bu/ac average***

- 12 cents 1/5th protein discount from 14 to 13 pro =.18 cents/bushel gain (going from 13.2 to 13.5)
- .18 x 67 bu/ac =$12.06/ac
- +15 per 1/5th from 14.0 to 14.6
- +25 per 1/5th from 14.6 and up

* ***Total economic impact of activity, $47.60 - $12.06 = $35.54 per acre LOSS average.***

Treatment	Cost/Benefit Analysis by Site								Mean
	Fosston	Fosston[2]	Manvel	Oslo	Warren	Argyle	Stephen	Roseau	
Topdress Protein	12.5	14.3	15.5	12.0	11.7	15.9	11.7	14.5	13.5
No Topdress Protein	12.0	13.7	14.2	12.2	12.2	15.6	11.8	14.3	13.2
Protein Gain/Loss	0.5	0.6	1.3	-0.2	-0.5	0.3	-0.1	0.2	0.3
$ Protein Gain/bu	0.300	0.405	0.925	-0.120	-0.300	0.375	-0.060	0.300	0.180
Top dress Yield	95.4	57.1	53.1	57.5	67.8	42.8	79.2	78.8	66.5
Total $ Gain Top-dress for Protein	$28.62	$23.13	$49.12	($6.90)	($20.34)	$16.05	($4.75)	$23.64	$11.96
Application Costs (including wheel damage @ 2 bu/ac*$5bu.	$47.60	$47.60	$47.60	$47.60	$47.60	$47.60	$47.60	$47.60	$47.60
Financial Gain/Loss	($18.98)	($24.47)	1.52	($54.50)	($67.94)	($31.55)	($52.35)	($23.96)	($35.64)

The overall average economic impact loss per acre for topdressing in this study was a loss of $35.54 per acre. Of the sites, only one demonstrated a positive economic return of $1.52. The range of economic losses across the other seven sites spanned from a low of -$18.98 to a high of -$67.94.

Discussion

Does topdressing increase yields?

Yields did not increase in this study as a result of topdressing. Studies have found conflicting results regarding its efficacy; however replicated field based studies are few and outdated. Wheel track damage and excessive nitrogen leaching due to extreme rainfall are suspected to have had the greatest negative influence on yield outcomes.

In this study, crop damage was the primary culprit for yield loss at each of the locations to varying degrees because of substantial wheel ruts created applying the topdress. Tram tracks in future studies are recommended.

Furthermore, significant nitrogen losses were believed to have occurred before topdressing which may have contributed to yield loss because there was between 45-50lbs less nitrogen put on in the strips receiving the topdress treatments. Given the year, it is possible the total nitrogen needs planned for were insufficient. Furthermore, nitrogen losses also likely occurred after topdressing. For example, at the Warren location an additional 3.5 inches fell within two weeks after topdressing.

While numerous small plot studies exist exploring the relationship between yield and protein, the lack of field-based nitrogen use research for hard red spring wheat is concerning and should be expanded. Field based studies in Manitoba from the early 90's did find some small yield increases from topdressing, but those are now dated and need replication.[4]

Does topdressing increase protein?

Protein did significantly (statistically) increase as a result of topdressing which is in line with what other studies have found with post-anthesis application. This study also found that approximately 30% of the time, top dressing provided no discernable protein benefit.

Overall, protein increased in the topdress condition by 0.3 percent. This is slightly below what might be expected based on past studies that suggest 0.5 to 1.0 percent protein increases. However, upon closer examination we did find that in five study locations the average increase was 0.58 percent. It is the other three that provide more pause for reflection. Those sites had a negative, or non-effect. This was not surprising because: 1) past studies of post-anthesis nitrogen[2,8] have found 20-35% of the plots studied showed no significant protein increase and, 2) the timing for nitrogen application (5 leaf) was targeted more for yield than protein (typically post anthesis).

Is topdressing cost effective?

Topdressing nitrogen in this study lost $35/acre on the average (range of seven sites -18.98/ac to -$67.94/ac) and was only financially viable in one of the eight study locations (return of $1.52/ac).

These financial costs do not include opportunity costs (the time spent accomplishing topdressing when you could have been doing something else more productive).

An economic decision making tool for post anthesis nitrogen application that models the probability of financial returns based on current protein premium/discounts and the price of supplemental nitrogen can be accessed at: http://blog.lib.umn.edu/efans/cropnews/2014/07/late-season-applications-of-ni.html.

Future Direction

√ Future studies should explore breaking different cultivars into performance classes based on differing protein potentials (e.g. those above vs. those below 14 pro).[8] Given the range of nitrogen use efficiency estimated by several studies [3], to be between .46 to.93, it is quite possible that new higher yielding cultivars express reactions to nitrogen production and environmental stresses differently.

√ Explore topdressing with high yielding cultivars across a variety of environments and in future years.

o A finding that tends to be consistent across a number of small plot studies is that all varieties respond equally well to additional N. There is a dearth of field-based research that thoroughly examines this issue across a wide range of cultivars and conditions.

√ Explore variable rate applying nitrogen throughout a field as a way to improve nutrient use efficiency and reduce nutrient loss based on changes in soil type, organic matter content, and water and nutrient holding capacity.

√ Future studies should include soil tests throughout the production season.

o Identify initial and residual levels of soil nitrogen

√ Incorporate on the go protein monitoring to map field protein coupled with yield monitor data to illuminate locations within fields where high protein and yields exist.

√ Explore potential soil/microbial based effects or interactions with the applied fertilizer.

√ Attempts should be made to isolate circumstances where mineralization may be occurring.

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[i] The mission of the NWMN On-Farm Research collaborative is to address priority production concerns through field scale research. Activities are funded through support from the Minnesota wheat check-off and the Minnesota Department of Agriculture