Managing Nitrogen Rates for reduce-till Dryland Wheat

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Introduction: Fertilizer nitrogen (N) costs have increased nearly 70 % in the last 5 years in the Central Great Plains region (CGPR) and increased nearly 35% in the last 10 months. This increase in fertilizer cost, has coincided with a decrease in dryland crop yields due to drought. The question then becomes "should optimal N fertilizer rates be less in dry years with low yields" and if that is the case "how much less"? Another consideration is "how does optimum fertilizer N rate change with wheat price and N cost"? Wheat prices were exceptionally good this past year and the extra value for the commodity also, influences a farmer's choice with respect to optimal N rate. In this manuscript, we evaluate dryland winter wheat yield response to applied N over a four-year period and calculate optimal N rates with changing wheat price and N costs.

Methods: Wheat in a winter wheat-summer fallow, reduce–till system, was fertilized at 0, 30, 60 and 90 lbs of N per acre on a Weld silt loam soil. Fertilizer was applied in a preplant broadcast application as ammonium nitrate. Soil samples (top 2 feet) were collected from each plot at planting time before fertilization and after wheat harvest each year and analyzed for nitrate-N (NO_3-N) and ammonium-N (NH_4-N). Wheat yield was measured (Fig 1a), relative wheat yield was calculated by normalizing each year's wheat yield data on the maximum yield measured in a given year (Fig 1b) and a response function was fitted to that data to determine the economically optimum N rate (Eq [1]). This allowed us to use data that varied from year to year all in one equation (Fig 1b). We then inserted the economics of fertilizer costs at $0.38-0.64/lb of N and inserted prices of wheat at $3.72-$8.72/bushel. A production cost estimate of $59.7 for winter wheat-millet-fallow was then used as a production cost estimate to develop Eq [2]. Equation 2 was then optimized for different yield scenarios and costs of N to develop table 1, table 2 and table 3.

Eq [1] $\text{Relative wheat Yield} = 84.67875 + 0.46388N - 0.00356N^2$

Where N is lbs of N per acre and Relative wheat yield is a number between 0 and 100 (R^2=0.78).

Price of N is $ 0.38, 0.49-0.0.64 per lb actual (UAN at $240-405/ton and Urea at $342-576/ton). Wheat price set at $3.72, $4.72, $5.72, $6.72, $7.72 and $8.72 per bushel (10 year ave price for January wheat is ~$4.00). Assume production costs of $59.7 for WMF.

Eq [2] Net returns = (a +bN -cN2) * maxyd * Price -0.38N – 59.7

where,

Net returns:	is in $ per acre
a:	is the y intercept of the N response function (84.67875)
b:	is the linear slope of the response function (0.46388)
c:	is the quadratic slope of the response function (0.00356)
maxyield:	is the wheat grain yield range you are concerned with
Price:	is the grain price in $ per bushel ($3.72-8.72).
0.38 :	is the price of fertilizer N in $ per lb of N (0.38-0.64)
59.7:	is the production costs for wheat in WMF in $ per acre

The same analysis was generated from a fit of the data where the residual N in the top two feet of the profile was added to the N applied just prior to planting this produced the following equation (Eq [3]).

Eq [3]   Relative wheat Yield = 71.79430 +0.55854NapResN -0.00283NapResN^2

Where NapResN is the lbs of N applied per acre, plus the residual N found in the soil (top two feet) at planting and Relative wheat yield is a number between 0 and 100 (R^2=0.73). Residual nitrate-N plus ammonium-N in the top two feet of the soil profile for the N rate experiments presented here were 39, 18, 39 and 24 lbs of N per acre for the years 1995, 1996, 1997 and 1998 respectfully. The average N available for the 4 site-years the experiment was conducted is 30 lbs N in the top two feet of the soil profile prior to planting.

RESULTS: Wheat yield response varied from year to year and was correlated to rainfall and temperature during the growing season (Fig 1a). However, after calculating relative yield the response to N was observed to be similar irrespective of year (Fig 1b). Maximum yield was calculated at 65 lbs of N per acre. However, farmers are more interested in maximizing net returns than in maximizing yield. The data in table 1 provides calculated optimum N rates based on these data (Fig1a) where maximum net returns are expected for various yield ranges and wheat prices.

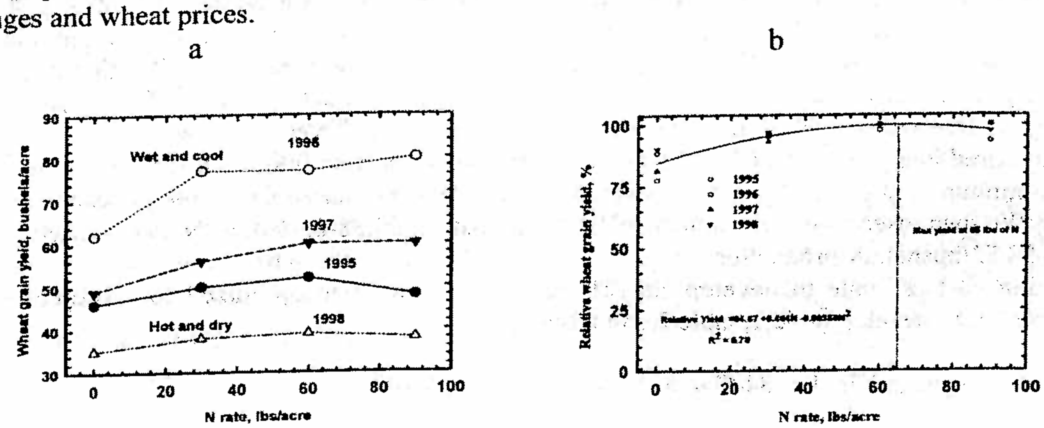

Fig 1. a) Wheat yield as a function of N rate, b) Relative wheat yield as a function of N rate.

For dryland wheat, in dry years the optimum fertilizer N rate is less than 20 lbs with our soils and residual N levels of 18-39 lbs (table 2). For average years, a reasonable N rate is about 20-35 lbs. However, with 45 bushel wheat at $8.72 per bushel, the economically optimum N rate increases to 48 lbs. In high yield years, the economically optimum N rate (the N rate where net returns are maximum) is still in the 40-50 lb range. It never reaches the "maximum relative yield range", which we calculated to be at 65lbs of applied N. Because it is difficult to know if a year is going to be dry/hot or wet/cool it might make sense to fertilize for the average conditions with 30-40 lbs of N most years (table 1). We also generated a table of optimum N rates where we assumed an additional 30% increase in fertilizer prices (table 2). In a Table 2 we see a decline in optimum N rate that is most dramatic in dry years.

We also generated a table using Eq.[3] where the residual N found in the top two feet of the soil profile is included in the regression fit (table 3). The difficulty in generating table 3 was in deciding what $ value to give to the 18-39 lbs of residual N found in these soils. In this analysis we assumed the same $ value of the applied N fertilizer. The N rate plus residual N required to reach maximum yield calculated from Eq.[3] is 99 lbs. Which approximates closely what we expect from adding 30 lbs to the 65 predicted by Eq.[2] (65+30=95). It is not surprising, how the optimum N rate increases if one considers the residual N already in the soil. The trends are similar as in table 1 and 2 in that as yields decline, the optimum N rate declines, and as wheat price increases so does optimum N rate.

Table 1. Economically optimum fertilizer N rate when residual N is 18-39 lbs in the top 2 feet of the soil profile at 6 different wheat prices of $3.72, through $8.72 ($/bushel). Here we assume fertilizer cost $0.49/lb N).

	yield range	$3.72	$4.72	$5.72	$6.72	$7.72	$8.72
Climate	bushels/acre		-------------- optimum N rate, lbs/acre * --------------				
Dry years	15	0	0	0	0	6	13
	20	0	0	5	14	21	26
	25	0	7	17	24	29	34
average years	30	3	17	25	31	35	39
	40	19	29	35	40	43	43
	45	24	33	38	42	45	48
wet years	50	28	36	41	45	47	49
	60	34	41	45	48	50	52
	70	39	44	48	51	52	54

* This table is based on the data analyzed at Akron and is not universal in its application. The array of optimum N rates decreases with a decrease in yield potential and at lower wheat prices. Optimum N rates calculated using Eq.[1].

Table 2. Economically optimum fertilizer N rate when residual N is 18-39 lbs in the top 2 feet of the soil profile at 6 wheat prices of $3.72, through $8.72 ($/bushel). Here we assume a 30% increase in fertilizer cost (N cost =$0.64/lb).

	yield range	$3.72	$4.72	$5.72	$6.72	$7.72	$8.72
Climate	bushels/acre		-------------- optimum N rate, lbs/acre * --------------				
Dry years	15	0	0	0	0	0	0
	20	0	0	0	0	7	14
	25	0	0	2	12	19	24
average years	30	0	2	13	21	26	31
	40	5	18	26	32	36	39
	45	11	23	30	35	39	42
wet years	50	17	27	34	38	42	45
	60	25	33	39	43	46	49
	70	31	38	43	46	49	50

* Optimum N rates calculated using Eq.[1].

Table 3. Economically optimum fertilizer N rate with residual N as part of equation (top 2 feet) at 6 wheat prices of $3.72, through $8.72 ($/bushel). (N cost =$0.49/lb).

	yield range	$3.72	$4.72	$5.72	$6.72	$7.72	$8.72
Climate	bushels/acre		------------- optimum N rate, lbs/acre * -------------				
Dry years	15	0	0	0	13	24	32
	20	0	7	23	34	43	49
	25	6	25	38	47	54	59
average years	30	21	38	48	56	61	66
	40	41	53	61	66	71	74
	45	47	58	65	70	74	77
wet years	50	52	62	68	73	76	79
	60	60	68	73	77	80	82
	70	65	72	77	80	83	84

*. Optimum N rates calculated using Eq.[3]. To use any of these tables a person really should have a good handle on residual N in the top 2 feet of the soil profile. It is interesting that if a person subtracts 30 lbs from the values in this table they will get a good approximation of the data generated in Table 1. The table is based on data analyzed at Akron. It is not universal in its application. The array of optimum N rates decreases with a decrease in yield potential and at lower wheat prices.

Concluding remarks: These optimum N rate tables are helpful in interpreting the general economic relationships with respect to wheat yield and N rate and residual N but are not a substitute for soil testing from a reputable soil test lab. The tables do represent a reasonable guess at N fertility needs for winter wheat planted in dryland-silt loam soils in the CGPR. The analysis indicates that the economically optimum N rate decreases (as might be expected) when yield potential is low, when wheat prices are low, and when N fertilizer costs are high (compare table 1 with table 2 for the same wheat price and yield level). The N rate that is needed to maximize net returns is always less than that needed for maximum yield. Even at the highest yield potential (70 bushel) the calculated optimum N rate in table 2 (which reflects current N prices) is at least 13 lbs less than the N rate required for maximum yield. This analysis is based on data collected from a wheat-fallow reduce-till rotation. We have other N rate response data that we intend to include in the analysis collected from other rotations. We are curious how much the optimal N rate relationships might change with wheat-legume-green fallow, wheat-corn-millet-fallow, and wheat-corn-sunflower-fallow.

This last table (table 4) is how it use to be, 2 years ago, when N prices were 30% lower than today. In those days we could add a little more N at the same yield potential and make it work. However even at that time the maximum N recommended did not exceed 55 lbs at a yield potential of 70 bushel and at a $7.72 wheat price.

Table 4. Economically optimum fertilizer N rate (the fertilizer rate at which maximum net returns are expected) for various yield ranges and wheat prices. Residual N is 20-40 lbs in the top 2 feet of the soil profile. Wheat prices used are $3.72, $4.72, $5.72, 6.72 and $7.72 per bushel. N cost at $ 0.38/lb actual.

	yield range		$3.72	$4.72	$5.72	$6.72	$7.72
Climate	bushels/acre		-------------- optimum N rate, lbs/acre --------------				
dry years	15		0	0	3	12	19
	20		0	9	18	25	31
	25		8	20	28	33	37
average years	30		17	27	34	39	42
	40		29	37	42	45	48
	45		33	40	44	48	50
wet years	50		36	43	46	49	51
	60		41	46	50	52	54
	70		45	49	52	54	55

* This table is based on the data analyzed at Akron and is not universal in its application. The array of optimum N rates decreases with a decrease in yield potential and at lower wheat prices.

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