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NITROGEN RATES FOR DRYLAND TRITICALE HAY

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ABSTRACT

Dryland farmers/ranchers in the CGPR have recently taken an interest in triticale as a hay crop. Triticale is well adapted and its forage is palatable and nutritionally competitive with other annual forages grown in the region. On deficient soils, triticale's forage-yield response to applied fertilizer-N is impressive. Our objective here was to quantify the response of dryland triticale to applied N and to residual inorganic N. Winter triticale (cultivar NE422T) was planted into either wheat or millet stubble over three site years at the USDA-ARS Central Great Plains Research Station. In two experiments (2007-2009) just prior to planting, the crop was top-dressed with 0, 25, 50, 75 or 100 lbs of fertilizer N as urea or ammonium nitrate in a typical replicated randomized complete block design field experiment. In an earlier (1995) experiment, using similar design and methods, winter triticale (NE422T) was fertilized at 0, 20, 40, 60, 80 and 120 lbs of fertilizer N per acre. Forage yield was harvested just as the awns were beginning to emerge from the boot. A quadratic N response equation was fitted to the measured yield response and EONR tables were generated using the fitted N response equations.

INTRODUCTION

Fertilizer costs have increased nearly 70% in the last 7 years. This increase in fertilizer cost has coincided with a decrease in dryland crop yields due to drought (Colorado Ag statistics 2002-2009). 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 commodity price and N cost"? Hay prices were exceptionally good during the drought years of 2001-2007, because there just wasn't much hay to go around. The value of the hay also, influences a farmer's choice with respect to N rate. Several methods have been used to estimate fertilizer N needs for forage and cereal grains (Mullen et al. 2003, Hernandez and Mulla 2008, Black and Bauer 1988. Dahnke et al.1988, Hergert et al. 2007). In general, most fertilizer recommendations start with a yield goal (YG) from which an N requirement is calculated. The logic is that a given unit of yield (grain or hay in this case) has an inherent "unit of N" needed/required to grow the plant and make the yield in the YG. In situations where soil sampling/testing is available a soil "test analysis" is then incorporated to evaluate N available at the time of sampling (usually NO_3-N). The soil test might include soil organic matter (SOM) measurement to estimate what will be made available through N mineralization of SOM (N_{min}). A fertilizer amount is then recommended to make up for the shortfall of inorganic N and the estimate from N_{min} to match the calculated N requirement (Cabrera et al 1994). Another simpler (although empirical and soil and site specific) approach is to fit an N response function to N rate by yield data for a regions soil. Typically the response function is fit either to a calculation of relative yield or to actual yield and then a quadratic equation or similar curve linear model is fit to the data using multiple-linear regression. The fitted grain yield N rate equation is then used to calculate economic optimum N rate (EONR) for a specific soil, climate and yield range. Because yield levels are lower in the CGPR then other areas of the country most of the fertilizer needed can be put on either at planting time or just prior to planting. What farmers in the CGPR need are simple estimates of what is a reasonable N rate for hay production? In this manuscript, we evaluate dryland winter triticale-hay yield response to applied N using 3 sites years of data and calculate optimal N rates with changing triticale-hay price and N costs.

MATERIALS AND METHODS

Winter triticale (cultivar NE422T) was no-till planted into wheat stubble in 2007 and millet stubble in 2009. In 2007 and 2009 the crop was fertilized at 0, 25, 50, 75 and 100 lbs of N per acre on a Weld silt loam soil. Fertilizer was applied in a preplant broadcast application as Urea. Soil samples (top 2 feet) were collected from each plot at planting time before fertilization and after harvest each year and analyzed for nitrate-N (NO_3-N) and ammonium-N (NH_4-N). In an earlier (1995) experiment, using similar design and methods, winter triticale (NE422T) was fertilized at 0, 20, 40, 60, 80 and 120 lbs of fertilizer N per acre. In all three site--years forage yield was harvested just as the awns were beginning to emerge from the boot. Triticale hay yield was measured (Fig 1a), relative triticale-hay yield was calculated by normalizing each year's hay 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). This idea follows "the wisdom of crowds' idea in that 3 years of data is probably a better approximation of the N response than any single site-year (Surowiecki J. 2004). We then inserted the economics of fertilizer costs at $0.50-0.75/lb of N and inserted prices of hay at $40-$100/ton. A production cost estimate of $100 for no-till winter triticale-hay 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] $$\text{Relative triticale - hay Yield} = 41.73374 + 1.04474N - 0.00519N^2$$

Where N is lbs of N per acre and Relative triticale-hay yield is a number between 0 and 100 (R^2=0.70).

Price of N is $ 0.50 and $ 0.75 per lb actual (Urea at $342-576/ton). Hay price set at $40, $60, $80 and $100 per ton (the 5 year average price for triticale hay is $65/ton). Assume production costs of $100 per acre for dryland fall planted winter triticale.

Eq. [2] $$\text{Net returns} = (a + bN - cN2) * \text{maxyd} * \text{Price} - \$0.50N - \$100$$

where,

Net returns:	is in $ per acre
a:	is the y intercept of the N response function (41.73374)
b:	is the linear slope of the response function (1.04474)
c:	is the quadratic slope of the response function (-0.00519)
maxyield:	is the triticale -hay yield range you are concerned with
Price:	is the Hay price in $ per ton ($40-$100).
0.50 :	is the price of fertilizer N in $ per lb of N ($0.50-0.75)
$100:	is the production costs for winter triticale hay 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 triticale - hay Yield = 20.88458 + 0.93720NapResN - 0.00303NapResN^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 ($R^2 = 0.65$). Residual nitrate-N plus ammonium-N in the top two feet of the soil profile for the N rate experiments presented here were 92, 9, and 47 lbs of N per acre for the years 1995, 2007 and 2009 respectfully. The average N available for the 3 site-years the experiment was conducted is 49 lbs N in the top two feet of the soil profile prior to planting.

RESULTS AND DISCUSSION

Triticale 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 100 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 (rounded to the nearest 5 lbs) based on these data (Fig. 1a) where maximum net returns are expected for various yield ranges and hay prices.

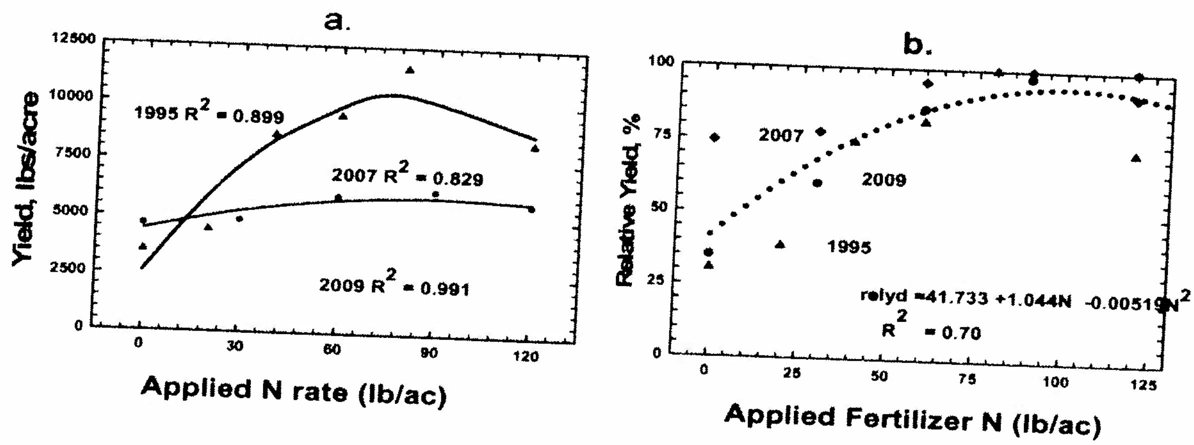

Figure 1. a) Triticale-hay yield (lbs/acre) as a function of N rate, b) Relative wheat yield as a function of N rate.

For dryland triticale, in dry years the optimum fertilizer N rate is between 0 and 80 lbs of N/acre with our soils and residual N levels of 10-92 lbs (Table 1). For average years, a reasonable N rate is between 60 and 80 lbs N/acre. However, with 4 ton per acre yields and hay at $100/ton, the economically optimum N rate increases to 89 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 100lbs 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 60-80 lbs of N most years (Table 1). We also generated a table of optimum N rates where we assumed an additional 50% increase in fertilizer prices (Table 2). In table 2 we see a decline in optimum N rate with increase in N cost.

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 10-92 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 154 lbs. Which approximates closely what we expect from adding 49 lbs to the 100 predicted by Eq.[2] (100 + 49 = 149). 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 49 lbs in the top 2 feet of the soil profile at 4 different triticale hay prices of $40/ton, through $100/ton. Here we assume fertilizer cost $0.50/lb N using Eq. [1].

Climate	yield range Tons/acre	$40/ton	$60/ton	$80/ton	$100/ton
		-----------------	optimum N rate, lbs/acre *	-----------------	
Dry years	1.0	0	20	40	50
	1.5	0	35	55	65
	2.0	40	60	70	75
Average years	3.0	60	75	80	85
	3.5	65	80	85	90
	4.0	70	80	85	90
Wet years	5.0	75	85	90	90
	5.5	80	85	90	90
	6.0	80	90	90	90

Table 2. Economically optimum fertilizer N rate where residual N averaged 49 lbs in the top 2 feet of the soil profile at 4 different triticale hay prices of $40/ton, through $100/ton. Here we assume a 50% increase in fertilizer cost (N cost =$0.75/lb). Optimum N rates calculated using Eq. [1].

Climate	yield range Tons/acre	$40/ton	$60/ton	$80/ton	$100/ton
		-----------------	optimum N rate, lbs/acre *	-----------------	
Dry years	1.0	0	0	10	30
	1.5	0	20	30	35
	2.0	10	30	55	65
Average years	3.0	40	60	70	70
	3.5	50	65	75	75
	4.0	50	70	80	80
Wet years	5.0	65	75	85	85
	5.5	70	80	85	90
	6.0	70	80	85	90

Table 3. Economically optimum fertilizer N rate with residual N as part of equation (top 2 feet) at 4 different triticale hay prices of $40/ton, through $100/ton. Here we assume fertilizer cost $0.50/lb N) using Eq. [3].

Climate	yield range Tons/acre	$40/ton	$60/ton	$80/ton	$100/ton
		optimum N rate, lbs/acre *			
Dry years	1.0	0	15	50	70
	1.5	0	50	55	90
	2.0	50	85	105	115
Average years	3.0	85	110	120	125
	3.5	95	115	125	130
	4.0	105	120	130	135
Wet years	5.0	115	125	135	140
	5.5	115	130	135	140
	6.0	120	130	137	140

These optimum N rate tables are helpful in interpreting the general economic relationships with respect to dryland triticale-hay yield and N rate/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 this crop 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 hay prices are low, and when N fertilizer costs are high (compare Table 1 with Table 2 for the same hay 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 (5-6 ton/acre) the calculated optimum N rate in Table 2 (which reflects current N prices) is at least 20 lbs less than the N rate required for maximum yield.

REFERENCES

Black, A.L. and A. Bauer. 1988. Setting winter wheat yield goals p.24-34. In J.L. Havlin (ed.) Proc Workshop Central Great Plains Profitable Wheat Management , Wichita, KS. 17-20 AUG. 1988. Potash and Phosphate Inst. Atlanta GA.

Cabrera M.L. M.F. Vigil and D.E. Kissel. 1994. Potential nitrogen mineralization: Laboratory and field evaluations. In Soil testing: Prospects for improving nutrient recommendations SSSA special publication 40. p15-29. Soil Science Society America. Madison WI.

Chang, J.M., D.E. Clay, C.G. Carlson, C.L. Reese, S.A. Clay, and M.M. Ellsbury. 2004. Defining yield goals and management zones to minimize yield and nitrogen and phosphorous fertilizer recommendation errors. Agron J. 96:825-831.

Colorado Agricultural Statistics 2002, 2003, 2004, 2005, 2006, 2007, 2008,2009. USDA NASS Colorado Field Office. Available at www.nass.usda.gov/co USDA-NASS, 645 Parfet Street. Lakewood Colorado.

Dahnke , W.C., L.J. Swenson, R.J. Goos, and A.G. Leholm. 1988. Choosing a crop yield Goal. SF-822 North Dakota State Ext. Serv. Fargo ND.

Dahnke , W.C., C. Fanning, and A. Cattanach. 1992. Fertilizing corn grain, popcorn, silage corn and sweet corn. SF-722 North Dakota State Ext. Serv. Fargo ND.

Girma Kefyalew, S.L., Holtz, D.B., Arnall. L.M., Fultz, T.L., Hanks, K.D., Lawles, C.J., Mack, K.W., Owen, S.D., Reed, J.Santillano, O. Walsh, M.J. White, and W.R. Ruan. 2007. Weather, fertilizer, previous year yield and fertilizer levels affect ensuing year fertilizer response of wheat. Agron. J. 99:1607-1614.

Mullen R.W., K.W. Freeman, W.R. Raun, G.V. Johnson, M.L. Stone, and J.B. Solie. 2003. Identifying an in–season response index and the potential to increase hweat yield with nitrogen. Agron. J. 95:347-351.

Johnson G.V., and W.R. Raun. 2003. Nitrogen response index as a guide to fertilizer management.. J. of plant nutrition. 26:2, 249-262.

Surowiecki J. 2004. The wisdom of crowds. Anchor books, New York.