Yield Variability Considerations for Spring Wheat Yield Goals

By Lyle Prunty and R. J. Goos

Efficient agriculture requires that management decisions be as site specific as possible. In this article, North Dakota researchers demonstrate that year-to-year variability in site or cropping system yield potential is an important factor for making nitrogen (N) rate decisions.

WHEAT YIELD in the Great Plains is typified by wide year-to-year variations, largely due to climatic factors. These yield variations make it difficult for farmers to evaluate needs for variable crop inputs. Variability in yield has received little attention, but needs to be considered when setting yield goals for N fertilization of spring wheat.

We recently developed a methodology for economic choice of N rate based on average yield, variability of yield, the cost for N, soil test N results, and the price of wheat. Our method is based on wheat response to N fertilizer being a linear-plateau function in any particular year. However, what that plateau will be in the coming season is unknown to the producer when the yield goal and N rate are set.

The N-Budget for Spring Wheat

The N-budget approach, in one form or another, is used by most laboratories to make N fertilizer recommendations for wheat, although the exact approach differs among laboratories. The producer establishes the yield goal and obtains an analysis of the soil for nitrate-N. The fertilizer needed is calculated as the product of yield goal and an N coefficient, less soil nitrate-N. The N coefficient has been determined experimentally from N rate experiments. For spring wheat in the northern Great Plains, the coefficient is about 2.5 lb of N per bushel of expected yield.

Profitability and Yield Goal

We feel that variability should be recognized as an important determinant of profitability, but in the commonly used decision-making schemes, it is not. Nevertheless, many producers take their experience with variability into account by fertilizing for the exceptionally good year. In the process, some set yield goals too high.

Clearly, there are environmental and economic consequences of the N fertilization rate decision. A method for including variability when establishing the yield goal is needed. Our objective was to adapt the linear-plateau production function for this purpose. It is the one most closely associated with the N-budget, yield-goal approach and has been widely used.

The Average Production Function for Spring Wheat

Our method of using the linear-plateau model involves averaging in the variability. As an example, consider three years in which the plateau yield is different (**Figure 1**). We can calculate the average response for these three years and see that we no longer have a simple linear-plateau graph, but rather a graph with three different response slopes, then the plateau (**Figure 1** - dashed line). If we were to produce a similar response graph from 20 or more years of data, it would be a nearly smooth curve.

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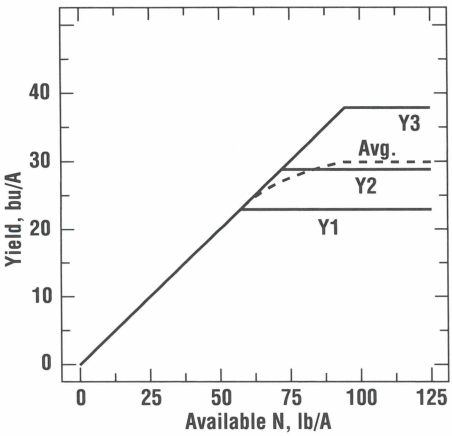


Figure 1. Linear-plateau response for three different years with plateau yields of 23, 29 and 38 bu/A, respectively. Average plateau yield is 30 bu/A. Average response for the three years together is shown by the dashed line.

We calculated the statistical smoothing effect of variability to find the most profitable N fertilization yield goal for spring wheat. To accomplish this, we: 1) used the linear-plateau function for single-year response of spring wheat to available N; 2) defined potential yield; 3) presumed random year-to-year variability in potential yield and calculated potential yield variability from North Dakota yield data; 4) developed the average expected N response function; and 5) found the slope of the N response function and employed it to find the most profitable yield goal.

Our definition of "potential yield" is the yield for a given land unit in a given year when all controllable production inputs (fertilizer, herbicides, etc.) are near "optimal" in terms of maximizing yield. Potential yield often has wide annual variations. This in turn leads to wide variations in the amount of N fertilizer actually needed by a wheat crop to achieve potential yield (**Figure 1**). Potential yield is random and cannot be predicted at the time the fertilization decision is made.

We examined spring wheat yield data from plots under advanced management (fertility, weed control, etc. not limiting) and two rotations at several Branch Experiment Stations in North Dakota (**Table 1**). These yields are in essence "potential yields". Spring wheat yields at the western most branch stations (Williston and Dickinson) show a very high variability in potential yield, especially when planted after cereals or sunflower (recrop). Yields from the stations further to the east (Minot and Carrington) were less variable.

We calculated by statistical techniques the influence of yield variability on most profitable yield for an average yield of 30 bu/A. Our calculations were performed over the range of coefficient of variation (CV) from 5 to 70 percent. (See box for explanation of CV.) The slopes of the response functions were then calculated for the same CVs. Representative curves of slope versus available N are shown in **Figure 2**. The slope tells us the additional wheat produced per added pound of available N.

Data from **Table 1** and slopes as in **Figure 2** were used to find the yield goal that would result in the greatest return for several cost/price situations **(Table 2)**. For other situations we developed a table of average yield multipliers **(Table 3)** that apply for various combinations of CV and cost/price ratio.

Table 1. North Dakota yields of hard red spring wheat in replicated variety or rotation trials.

Site	Rotation	'80	'81	'82	'83	'84	'85	'86	'87	'88	Mean, bu/A	CV, %
		Yield, bu/A										
Dickinson	Fallow	23	44	49	36	43	52	55	33	8	38	40
Dickinson	Recrop	0	14	25	39	27	21	31	9	0	18	74
Williston	Fallow	13	38	50	26	23	12	43	22	6	26	58
Williston	Recrop	1	29	41	26	10	15	31	21	3	20	69
Minot	Fallow	27	39	53	48	52	61	44	35	18	42	32
Minot	Recrop	8	33	48	49	40	54	38	10	8	32	58
Carrington	Fallow	40	38	56	43	55	47	47	44	24	44	22

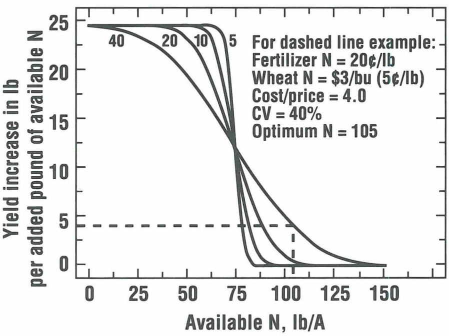


Figure 2. Slope of the expected response to N for several CVs when the average long-term potential yield is 30 bu/A.

Let's now consider specific values based on recent costs and prices. Suppose the applied cost for N fertilizer, including interest charges from purchase to harvest, is 20¢/lb and the price of wheat (expected) is $3.00/bu, or 5¢/lb. Under these conditions, addition of N fertilizer will be profitable as long as 4 lb of wheat or more are produced for each added pound of N. For a CV of 40, the break-even N rate is about 105 lb of available N (**Figure 2**).

At a cost/price ratio of 3.60 (**Table 3**), a simple rule-of-thumb works for finding the most profitable yield goal. It is very close to the average yield plus one standard deviation. **This implies that, as long as the cost/price of 3.60 prevails, a farmer's harvested yield should equal or exceed his fertilization yield goal about 15 years in 100, or about 1 in 6.**

Determining a most-profitable yield-goal by using the multipliers in **Table 3** is straightforward. First, verify that yield values used in the analysis are at the potential yield level. The average yields of **Table 1**, for instance, are from plots that received N fertilizer at a high enough level that it is virtually certain that N was not limiting. A good way for spring wheat farmers to check to see if past yields have been limited by N is to check the protein content records. If protein is greater than 14 percent, (12 percent for winter wheat) N was probably not limiting.

Table 3. Multipliers[1] for calculating most profitable yield goal when average potential yield is known.

CV, %	Cost per lb N / Price per lb wheat 2.4	3.6	4.8	18.0
5	1.07	1.06	1.04	0.97
10	1.13	1.11	1.09	0.93
20	1.26	1.21	1.17	0.87
40	1.51	1.42	1.34	0.73
60	1.77	1.62	1.50	0.60
80	2.03	1.83	1.68	0.46

[1]If cost/price equals 12.0, then the multiplier is 1.00 for all values of CV.

Second, determine the CV and cost/price values. The CV may be calculated or a reasonable estimate may be possible by referring to data from nearby research plots. Calculate the expected cost/price ratio as in the numerical example above. The cost of interest and application should be added to the fertilizer material cost. Third, find the multiplier from the table as determined by CV and cost/price. Finally, multiply the average yield by the multiplier. If the average yield is determined to be less than the potential yield according to the first step, then some rational upward adjustment of the average yield may be considered before applying the multiplier.

Table 2. Most profitable yield goal determined by the point where the cost per pound of additional N fertilizer equals the added income produced by that pound of N.

Location	Rotation	CV, %	Average yield; N not limiting	Cost per lb N/ price per lb wheat 2.4	3.6	4.8	18.0
			---------- Yield, bu/A				----------
Dickinson	Fallow	40	38	57	54	51	28
Dickinson	Recrop	74	18	35	32	29	9
Williston	Fallow	58	26	46	42	39	16
Williston	Recrop	69	20	38	35	32	11
Minot	Fallow	32	42	58	55	53	34
Minot	Recrop	58	32	57	52	48	19
Carrington	Fallow	22	44	55	53	52	38

Summary

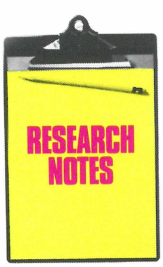
This methodology is practical because it has similarities to the existing yield-goal approach and because necessary data are available or can be estimated. It is crucial to know average potential yield and its variability. Although this paper addresses only the N input, the principles developed here can readily be extended to multiple inputs. For instance, the expected value of yield as a function of N and P could be found under the assumption that in the responsive region to each nutrient, the response slope is uniform each year, but the plateau yield level has a value that is randomly distributed through years with some mean and variance. Future improved predictability of climatic factors could also be included in the methodology. ■

Coefficient of variability (CV) is one way of expressing the variability of data. The CV increases as variability increases and is calculated by dividing the standard deviation by the average for the data set and expressing the result as a percent. Standard deviation (sd) can be determined automatically in most computer spreadsheets or can be calculated by hand as follows.

Example: yields=60, 20, 40, 30, 50 bu/A; 60+20+40+30+50=200; average=40;

$60^2+20^2+40^2+30^2+50^2=9{,}000$

$$\text{sd} = \sqrt{\frac{\text{sum of each squared yield} - \dfrac{(\text{yield sum})^2}{\text{no. of years}}}{\text{years} - 1}} = \sqrt{\frac{9{,}000 - \dfrac{200^2}{5}}{5-1}} = \sqrt{\frac{9{,}000 - 8{,}000}{4}} = \sqrt{250} = 15.8$$



New York

Growth, Yield and Quality of Forage Maize under Different Nitrogen Management Practices

STUDIES were conducted to evaluate three corn (maize) hybrids under different sidedress nitrogen (N) rates . . . 0, 50, 125 and 225 lb/A . . . applied at the V4 growth stage. The effect of timing of N fertilization was also evaluated . . . 62.5+62.5 lb/A N at the V4 and V8 growth stages and 67+67+67 lb/A at the V4, V8 and R1 stages.

Yield response to N was curvilinear to rate, with optimum economic yield occurring at rates of 125 to 140 lb/A. Split applications did not increase yields, improve forage quality or decrease residual soil nitrate-N levels compared to single rate applications. Higher N rates did increase residual soil levels in both years.

Researchers pointed out that when farmers apply higher rates of N to forage corn, they must balance potential benefits (higher yields and improved quality) with the potential risk associated with increased residual soil nitrate-N levels. ■

Source: Cox W.J., S. Kalonge, D.J.R. Cherney and W.S. Reid. 1993. Agron. J. 85:341-347.