**Predicting Yield Goals**

**Abstract**

Predicting the fertilizer nitrogen (N) rate required before planting a crop gave rise to the concept of establishing a pre-season yield goal and then fertilizing for that expected yield. The objective of this work was to evaluate the efficacy of predicting yield goals, made possible using data from two long-term experiments. Winter wheat (Triticum aestivum L.) grain yield data from Experiment 222 (Stillwater, OK, 1969-present) and Experiment 502 (Lahoma, OK, 1970-present) were used. Annual preplant N rates were applied for 45 and 44 years, respectively. Both trials employed randomized complete block experimental designs with four replications. This work applied the concept that the average yield of the last 3-5 years, plus 20%’ could be used to predict the ensuing years’ yield, or yield goal. In Experiment 222, treatments 1 and 4 (0-30-37 and 135-30-37) and in Experiment 502, treatments 2 and 7 (0-20-55 and 112-20-55, N-P-K) were used to test this concept. Pre-plant fertilizer sources for N, P, and K, were; urea (45-0-0); triple super phosphate (0-20-0); and potassium chloride (0-0-50). Past 3, 4, and/or 5-year wheat yield averages (yield goal) were not positively correlated with current season yields at either location for any of the treatments evaluated. Failure of the yield goal concept to predict current-year yield levels is largely due to the unpredictable influence of year to year environments that change dramatically.

***Rationale***

The yield goal concept has been used for cereal crops, but has not been examined using yield data from long-term experiments.

**Introduction**

Before 1957, N rate recommendations were based on soil criteria and crop management. Since 1970, the yield goal approach has been a popular method for maize in the Central Great Plains and that can convert the expected yield into an N rate recommendation using fixed factors (Fernandez et al., 2009). Work by Dahnke et al. (1988) defined yield goal as the 'yield per acre you hope to grow.' This was further clarified in noting that what you hope to grow and what you end up with are two different things. Yield goals can vary all the way from past average yield to potential yield. They defined potential yield as the highest possible yield obtainable with ideal management, soil, and weather. For this paper, what they define as potential yield would be ‘maximum yield,’ since 'potential' yield is bound to specific soil and weather conditions that can change. Rehm and Schmitt (1989) noted that with favorable soil moisture at planting it would be smart to aim for a 10 to 20% increase over the recent average when selecting a grain yield goal. They also indicated that if soil moisture is limiting, use of history and past maximums (used to generate averages) may not be the best method for setting a grain yield goal for the upcoming crop. Use of farm and/or county averages was not suggested for progressive farmers concerned with high farm profitability (Rehm and Schmitt, 1989).

A practical range for a yield goal should be between average to near maximum yield, observed by you or a neighbor under similar conditions (Dahnke et al., 1988). North Dakota State University had recommended that the yield goal could be the best achievable yield in the last four to five years and that is usually 30 to 33% higher than the average yield. Nonetheless, this has been updated to reflect that NDSU no longer employs yield goals in any of the crops for which they make N fertilizer recommendations (Dave Franzen, North Dakota State University, personal communication, February 2017).

Prior studies from Black and Bauer (1988) understood yield goals as needing to be based on how much water is available to the winter wheat crop from stored soil water to a depth of 1.5m in the spring plus the anticipated amount of growing season precipitation. Combining yield goal, soil test NO3-N and a simple estimate of nitrogen use efficiency can be used to estimate N fertilization requirements. Oklahoma State University generally recommends that farmers apply 33 kg N/ha for every 1 Mg of wheat (2 lb N/ac for every bushel of wheat) they hope to produce, minus the amount of NO3-N in the surface (0-15 cm) soil profile (Zhang and Raun, 2006). With a yield goal of 2690 kg ha-1 (40 bu/ac) and an average grain N content of 2.36%, estimated total N removed would equal 63.6 kg N ha-1. The N use (soil N + fertilizer N) efficiency would be 71% (63.6 kg N ha-1 removed /89.6 kg N ha-1, or 80 lb N/ac for a 40 bu/ac yield goal). This is obviously far greater than the 33% reported for cereal grain production by Olson and Swallow (1984), and Raun and Johnson (1999). Even though some of the N-fertilizer needs of the crop can be met by fall applied N, the best time to make final N adjustments is in the spring before the winter wheat surpasses the 3-leaf stage (Black and Bauer, 1988).

The use of realistic yield goals combined with soil testing have assisted farmers in estimating preplant and/or in-season fertilizer N needs. When yield goals are applied, it explicitly places the risk of predicting the environment (good or bad year) on the producer, but that commonly assures adequate N for above-average growing conditions. University extension (e.g., soil testing), fertilizer dealers and private consulting organizations have historically used yield goals, due to the lack of a better alternative.

A series of recent studies coming from Raun et al. (2001), Raun et al. (2002) and Raun et al. (2005) emulated the yield goal concept, but instead, used mid-season normalized difference vegetative index (NDVI) sensor readings to predict yield potential. Unlike the yield goal approach, they used NDVI-estimated-growth from planting to sensing (readings generally collected in late February to March) to reliably establish yield potential. This was then used to determine probable N removal and an ensuing mid-season fertilizer N rate. This mid-season fertilizer N rate was expected to deliver that desired level of yield. Implicit in this work was having a reliable estimate of the response index (RI) or an in-season estimate of N response, derived from an N Rich Strip (Mullen et al., 2003). Furthermore, fundamental to this work was the understanding that estimates of both yield potential and N responsiveness are needed and that they are independent of each other (Arnall et al., 2013 and Raun et al., 2011).

Maximum Return to Nitrogen (MRTN) is a procedure for estimating economically optimum N rates. It has been used in the Midwestern US states, and determines preplant N rates by estimating the yield increase to applied N using current grain and fertilizer prices (Sawyer et al., 2006). This approach provides generalized N rate recommendations over large areas and years. However, it fails to address the issue of year-to-year variability in temperature and rainfall (Shanahan, 2011; Van Es et al., 2006) and does not provide site-year recommendations.

Comprehensive work by Dhital and Raun, 2016, employing 213 site years of data showed that optimum N rates fluctuated from year to year at all locations. They further reported the need to adjust fertilizer N rates by year and location in regions where historically the same rates are being applied, year after year.

Although optimal N rates can vary substantially within and between fields, most US maize producers still apply the same rates to entire farms (Scharf et al., 2005). Limiting application rates is the most important factor in reducing environmental impacts; nonetheless, inappropriate methods and poor timing continues to pose the risk of N loss to the environment (Ribaudo et al., 2012). Additionally, the inability to accurately estimate optimum N rates results in over-fertilization for some years and fields and under-fertilization in others and a lower NUE (Shanahan, 2011). Consequently, there is an urgent need to improve N fertilizer management. As such, the accurate estimation of optimum N rates, year-to-year and field-to-field remains elusive (Van Es et al., 2006).

***Objective***

The objectives of this work were to test the validity of the yield goal concept using long-term experiments where wheat grain yield data had been collected for over 40 years.

**Materials and Methods**

Winter wheat (Triticum aestivum L.) grain yield data from Experiment 222 (Stillwater, OK, 1969-present) and Experiment 502 (Lahoma, OK, 1970-present) were used to test the hypothesis that yield goals could be used to predict yield for an ensuing year, and that would in turn be used to predict the preplant fertilizer N rate. For both field experiments, nitrogen (N), phosphorus (P) and potassium (K) were broadcast applied and incorporated before planting in all years. Pre-plant fertilizer sources were ammonium nitrate (34-0-0), triple superphosphate (0-20-0), and potassium chloride (0-0-50). Both trials employed a randomized complete block experimental design with four replications. In Experiment 222, treatments 1 and 4 (0-30-37 and 135-30-37) and in Experiment 502, treatments 2 and 7 (0-20-55 and 112-20-55, N-P-K) were used to test this concept. All fertilizers were broadcast applied and incorporated, before planting in the fall, each year. Weed control followed the Oklahoma Agricultural Experiment Station protocol and where different herbicides were used over this extended time period. The soil at Experiment 222 is a Kirkland silt loam, fine, mixed, thermic, Udertic Paleustoll and at Experiment 502, a Grant silt loam, fine-silty, mixed, superactive, thermic, Udic Argiustoll. These two long-term experiments are located in Stillwater (Experiment 222) and Lahoma (Experiment 502), OK.

Depending on the treatment and year sampled, soil pH in Experiment 222 and Experiment 502 have ranged between \_\_\_\_ and \_\_\_\_, respectively. Over the years included, average annual rainfall at these two sites have been \_\_\_\_\_\_, and \_\_\_\_\_, with a range of \_\_\_\_\_\_ and \_\_\_\_\_\_\_, respectively.

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For each trial, grain yields were averaged over the prior 3, 4, and 5 year periods, for the 4 treatments delineated, and a linear regression model developed versus the ensuing years’ yield. Fox example, treatment 4 in Experiment 222 (135-30-37), the yield was 2.59, 1.71, and 2.02 Mg ha-1 in 1969, 1970, and 1971, respectively. The average of these three values, + 20% would be the “yield goal” and that was 2.52 Mg ha-1. This would constitute the first X value in the regression equation and where the first Y value would be the yield that was observed in 1972 (just following 1969, 1970, and 1971), that was 1.59 Mg ha-1. Grain yields for each sequence of three years +20% were successively computed and added to the X,Y data base until years ran out. The last sequence of 3 years, was 2013, 2014, and 2015 (actual values for Treatment 4 were 0.78, 2.37, and 2.99 Mg ha-1, with an average of 2.46 Mg ha-1), and where the 2016 actual yield was 4.42 Mg ha-1. Using this approach, a total of 42 values for X and Y were included in the regression equation developed (average of the last 3 years + 20% versus the ensuing years’ yield value).

**Results**

For the methods described, it was assumed that there would be interdependence of regression since prior year yields’ were expected to have an influence on ensuing years. Interdependence of regression would not violate that particular assumption because the yield goal concept implies that there should indeed be a relationship. Thus the formula to “predict” what that yield will be, implicitly embraces that yield from the three, four, or five prior years’ would influence or impact the ensuing one year. In all cases, and over the time periods evaluated, the prior 3, 4, and/or 5-year yield average showed no relationship with the following years yield, at both sites, and for both treatments included at each site (Figures 1, 2, 3, 4).

For both treatments in Experiment 222 and Experiment 502, as the number of years used to estimate yield increased from 3, to 4, to 5, data on the x-axis or yield goal, compressed (Figures 1-4). This was expected, as the average value included more observations. Furthermore, as the number of years used to estimate yield increased, the coefficient of determination (r2) for the linear relationship between yield goal and the observed yield showed no definite increase and/or decrease (Table 1).

**Discussion**

Finding that yield goals cannot be predicted is of value considering the number of regions where this concept has been applied, over many years, and for a range of cereal crops. Some of the US states where yield goals have been used include Illinois (Olson, 2000), Iowa (Miller, 1986), Kansas (Black and Bauer, 1988), Minnesota (Rehm and Schmitt, 1989), Missouri (Scharf and Lory, 2006), Nebraska (Shapiro, 2008), North Dakota (Dahnke et al., 1988), and Oklahoma (Raun et al., 2001). This is by no means an endorsement, as many states like North Dakota, have publicly distanced themselves from the use of this concept (<https://www.ag.ndsu.edu/cpr/soils/nitrogen-rate-and-yield-between-fields-are-not-related-05-26-16>). The question being asked in this work was simply whether or not it was possible. These results from two comprehensive winter wheat experiments and that included a wide range of environments, suggest that yield goals would not be an appropriate strategy for determining pre-plant fertilizer N rates.

Furthermore, this work now highlights the importance of using better methods to predict yield potential (replacement for yield goals), using mid-season active sensor data.

Notwithstanding, work by Glick and Roberts (1984) noted that researchers assume complete independence of observations in statistical models applied to their data. Furthermore, they noted that the magnitude and direction of bias because of inconsistency of assumptions of interdependence.

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Figure 1. Linear relationship between the average treatment yield for the previous 3, 4, and 5 years (yield goal), versus grain yield for the ensuing 1 year, Treatment 1, 0-29-37, N-P-K, Experiment 222, Stillwater, OK, 1969-2016.

Figure 2. Linear relationship between the average treatment yield for the previous 3, 4, and 5 years (yield goal), versus grain yield for the ensuing 1 year, Treatment 4, 135-29-37, N-P-K, Experiment 222, Stillwater, OK, 1969-2016.

Figure 3. Linear relationship between the average treatment yield for the previous 3, 4, and 5 years (yield goal), versus grain yield for the ensuing 1 year, Treatment 2, 0-20-55, N-P-K, Experiment 502, Lahoma, OK, 1971-2016.

Figure 4. Linear relationship between the average treatment yield for the previous 3, 4, and 5 years (yield goal), versus grain yield for the ensuing 1 year, Treatment 7, 112-20-55, N-P-K, Experiment 502, Lahoma, OK, 1971-2016.

Table 1. Linear relationship between the average treatment yield for the previous 3, 4, and 5 years (yield goal), versus grain yield for the ensuing 1 year, Experiment 222, Stillwater, OK, 1969-2016, (Treatment 1, 0-29-37, N-P-K, and Treatment 4, 135-29-37), and Experiment 502, Lahoma, OK, 1970-2016, (Treatment 2, 0-22-55, N-P-K and Treatment 7, 112-20-55).

Location Treatment, N-P-K Linear Equation Years R2

Exp. 222 0-29-37 y=0.29x+0.82 3 0.05

Exp. 222 0-29-37 y=0.46x+0.58 4 0.09

Exp. 222 0-29-37 y=0.42x+1.73 5 0.04

Exp. 222 135-29-37 y=-0.02x+2.07 3 0.01

Exp. 222 135-29-37 y=-0.01x+2.05 4 0.01

Exp. 222 135-29-37 y=-0.09+2.19 5 0.01

Exp. 502 0-20-55 y=-0.14x+1.45 3 0.01

Exp. 502 0-22-55 y=0.26x+1.21 4 0.03

Exp. 502 0-20-55 y=0.29x+1.14 5 0.03

Exp. 502 112-20-55 y=0.10+3.42 3 0.01

Exp. 502 112-20-55 y=0.10x+2.72 4 0.01

Exp.502 112-20-55 y=0.36x+1.78 5 0.04