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Nitrogen Requirements and Yield Potential of Spring Wheat as Affected by Water

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Nitrogen (N) is the nutrient that most commonly limits yield of wheat and other crops in Montana. Deficiency symptoms are frequently characterized by general chlorosis (absence of chlorophyll, or yellowing of leaves), and reduction in plant growth rate. Deficiency symptoms in spring wheat, when present, frequently appear in the late spring or early summer depending on the level of severity. Once present, symptoms become more severe through the vegetative growth period. At maturity, N deficient plants are shorter, and contain fewer tillers and smaller heads than healthy plants. Ultimately, grain yield is reduced and the grain protein content is low.

Nitrogen typically represents a grower's largest fertilizer cost input. Current fertilizer N recommendations in Montana are based on an average relationship between available N requirements (NR) and estimated yield potential [NR (lbs/a) = Yield potential (bu/a) x 2.5-3.0]. The recommendation assumes 2.5-3.0 lbs N are needed to produce each bushel of grain. Since yield potential is most closely associated with available water (stored soil water + growing season rainfall + irrigation), we were interested in determining the effects of available water supply on available N requirements and spring wheat yield potential.

A 3-year (1996-1998) field study was conducted near Havre, Montana at the Northern Ag Research Center. Soil NO_3-N test levels were 8, 40, 41 lbs/a (0-24 inch depth), prior to fertilization, in 1996, 1997, and 1998, respectively. A solid-set irrigation system was used to create three distinct water environments (low, moderate, high). In the low water regime, wheat was grown under dryland conditions, except for a single application shortly after crop emergence (approximately 2.5 inches for stand establishment). In the moderate regime, wheat received a single application after crop emergence, plus two irrigation events during the vegetative growth period (late-tillering and heading). In the high water regime, wheat was irrigated as in the moderate regime, plus during grain-fill (2 events in 1996, 1 event in 1997 and 1998). Within each water regime, four spring wheat varieties (Amidon, Hi-line, McNeal, Rambo) were seeded in factorial combination with five N fertilizer levels (low regime 0, 25, 50, 100, and 150 lbs/a; moderate regime 0, 30, 60,120, and 180 lbs N/a; high regime 0, 35, 70, 140, and 210 lbs/a). Available N was defined as the sum of fertilizer N + soil NO_3-N (NO_3-N +NH_4-N in 1996) to a depth of 24 inches.

Spring wheat yields were responsive to N fertilization and water, reflecting the low indigenous soil N levels and dry environment. Visual differences in growth due to N deficiency and drought stress were typically apparent by jointing prior to flag leaf emergence. Grain yield versus available N relationships for 1996 were typical of responses observed across the three years of this study. As expected, available water increased wheat yield potential and the response to N. Under high water stress, the response to N was small and yield potential was low, producing a comparatively flat curve (Figure 1). As water conditions improved, the response to N increased, producing a steeper curve that reached a higher plateau. Yield potential at the plateau levels, or where N was no longer limiting yields, differed across the three growing seasons. Yield potentials under high moisture conditions were lower in 1997 (56 bu/a) than in 1996 (74 bu/a) or 1998 (70 bu/a). The lower yield potentials in 1997 were attributed to the high heat conditions experienced during grain-fill. These high heat conditions shorten the duration of the grain-fill period and lower yield by reducing kernel weight size. Spring wheat grain yield increased approximately linearly with available water over the three growing seasons (Figure 2). The relationship between yield and available water indicates that it takes approximately 4 inches of water to produce the first bushel of grain. Thereafter, yield potential increases approximately 5 bu/a with each inch of water. Small differences in this relationship were observed across the four cultivars. Overall, the yield potential of McNeal was greater than the other three cultivars across the range of water regimes created in this study.

Nitrogen requirements were defined as the point along the yield-available N curves (Figure 1) where increases in N no longer paid for themselves through higher yield, or where dollars returned from fertilizer N were maximized. Maximum economic yields were within 1 bu/a of the theoretical maximum; hence they are very near the yield potentials expressed in Figure 2. Generally, N requirements were not affected by cultivar selection. In other words, the fertilizer N required to maximize yield were similar for Amidon, Hiline, McNeal, and Rambo. Hence, the results can be averaged across the four cultivars. Available N requirements (soil N + fertilizer N) for maximum economic yield increased linearly with available water for both growing seasons (Figure 3). The relationship between NR and available water indicates that N requirements increased approximately 10 lbs N/a with each inch of additional water. For example, approximately 52 lbs N/a acre was needed to achieve maximum yield when growing season moisture was 9 inches, whereas N requirements increased to 102 lbs N/a at 14 inches of growing season moisture.

Fertilizer Facts:

! Spring wheat yield increases approximately 5 bu/a for each inch of water.

! Nitrogen requirements increased by 10 lbs N/a for each inch of additional growing season available water.

! Available water and N management practices are intimately tied together in production decisions.

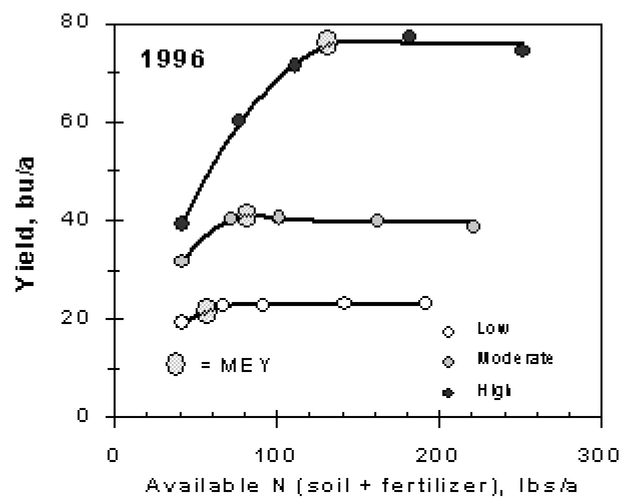

Figure 1. Grain yield and available N relationships for spring wheat grown under three water regimes. MEY = maximum economic yield or return from N assuming a 20:1 wheat price ($/bu) to N cost ($/lb) ratio. Low, moderate, and high water = 9.3, 13.5, and 18.6 inches of growing season available water, respectively.

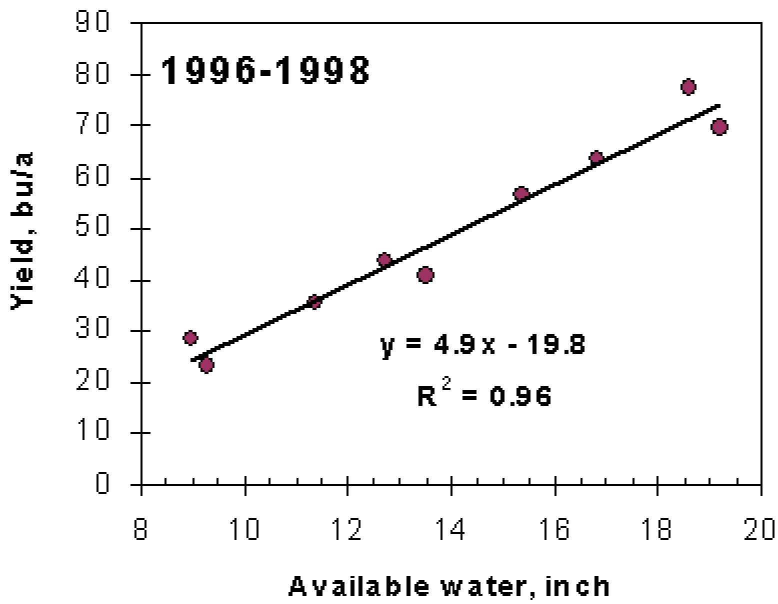

Figure 2. Spring wheat yield potential and available water averaged over four cultivars (Amidon, y = 4.6 x – 17.1; Hi-line, y = 4.5 x – 15.3; McNeal, y = 5.3 x – 22.3; Rambo, y = 5.2 x – 24.5; where y = yield, x = available water).

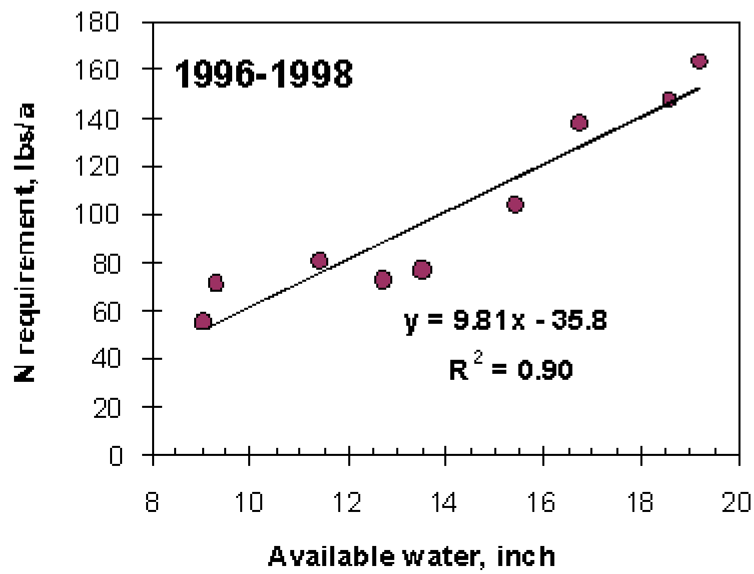

Figure 3. Spring wheat N requirements and available water.

Edited by Jeff Jacobsen, Extension Soil Scientist, and Clain Jones, Adjunct Assistant Professor