Field scale N fertilizer recommendations: Effect of variable soil N test and available water

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Introduction

Many fields have significant spatial variability of soil fertility(Bouma, and Finke, 1993). Fertilizing a farm field with a single rate of fertilizer when soil fertility levels vary with location in the field leads to overfertilization and underfertilization of large area (Mulla, 1993). This is the basis behind the development of technology to spatially vary the application rate of fertilizer within a field. A majority of fields, however, still have a single rate of fertilizer applied evenly across the field. Soil test calibration relationships (i.e. recommended fertilizer rate versus soil test values) are used to obtain the recommended fertilizer rate from a soil test on a composite soil sample from the field.

Relationships among yield response, applied fertilizer, and soil fertility levels (soil test) are highly non-linear. Quadratic equations and other non-linear yield response models are often used. Linear yield response equations up to a critical value of soil test followed by a flat line have also been used. This approach is also highly non-linear at the junction point between the responsive and flat portions. Unfortunately, there are significant problems with estimating spatial averages of non-linear relationships.

Kachanoski and Fairchild(1996) developed stochastic equations to describe the average yield gain on a field basis from the application of a single constant rate of fertilizer, in fields with variable soil fertility. The equations were solved numerically for the specific case of nitrogen fertilizer on corn in Ontario. These authors indicated the soil test calibrations obtained from low variability (for example small plots) will not hold for sites with higher variability. This research assumed the only limiting factor controlling crop response for N fertilizer was the soil test value. In Saskatchewan, crop response to fertilizer is controlled by two main factors, soil N test and available water. These two factors can vary significantly within a field and previous work suggests they are likely positively correlated in space. The influence of joint variability of N test and available water (and their correlation) on field average yield response to applied fertilizer N, has never been analyzed.

Objectives

(1). To examine the relationships between average yield response to fertilizer N and average soil N test, for fields with variable soil test and available water.

(2). To examine the spatial scaling problem for field scale fertilizer response using the crop response function of Campbell et al.(1993).

Methods

The crop response model for wheat yield increase from applied N fertilizer for a given soil test(x) and available water(W) given by Campbell et al.(1993) is

$$Y(N) = B \cdot N - C \cdot N^2 \quad (1)$$

where B =6.88-0.25.x $+0.035 \cdot W + 0.00083 \cdot x \cdot W$ and C=0.053.

For fields with variable soil test and available water, the average field yield response to applied fertilizer can be given by

$$\bar{Y}(N, \bar{x}, \bar{W}, \sigma_x, \sigma_W, r) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(\bar{x}, \bar{W}, \sigma_x, \sigma_W, r; x, W) \cdot Y(N, x, W) dx \ dW \quad (2)$$

where $\bar{x}$, W are the mean of soil N test and water use σ_x and σ_w are the standard deviation of soil test and water use. r is the correlation coefficient between soil N test and water use. f(), the joint probability density function of soil test and water use, can be written as

$$f(x, W) = \frac{1}{2 \cdot \pi \cdot \sigma_x \cdot \sigma_W \cdot x \cdot \sqrt{1 - r^2}} \cdot \exp\left[-\frac{1}{2} \left(\frac{(\ln(x) - u)^2}{\sigma_x^2} + 2 \cdot r \cdot \frac{(\ln(x) - u) \cdot (W - \bar{W})}{\sigma_x \cdot \sigma_W} \_ \frac{(W - W)^2}{\sigma_y^2} \right) \cdot \frac{1}{1 - r^2} \right.$$

where $u = \ln(\bar{x}) - 0.5 \cdot \sigma_x^2$.

Experiments showed that the correlation, r, between soil N test and available water can be positive, zero, or negative. Therefore, we consider cases where r=-1, 0, and 1, for evaluating the effect of correlation between soil N test and available water on field average yield and maximum economical rate of fertilizer N (MERN). Equation (2) was solved analytically for different scenarios of variations in soil test and available water and correlation between them.

Results

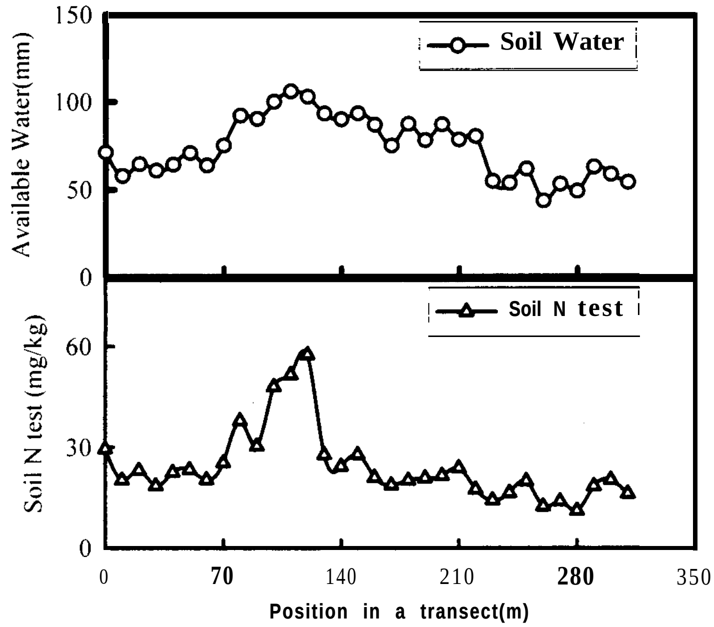

Figure 1. Example of spatial variability of soil test and available water(Purdue, site 1, Saskatchewan, 1997)

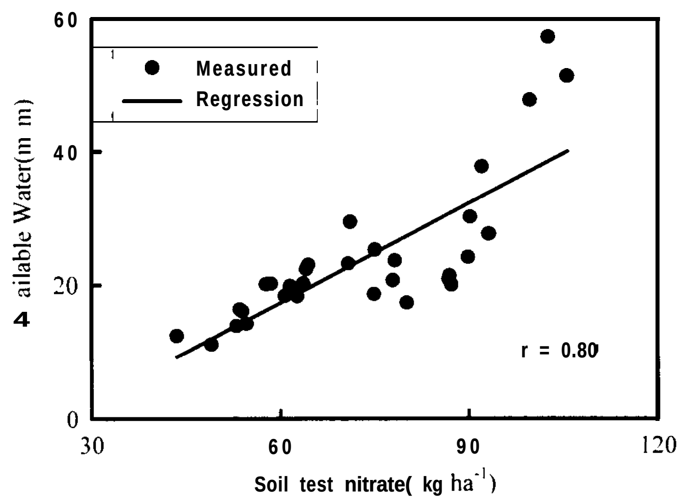

Figure 2. Example of the correlation r (within a field) between soil test and available water (Purdue, site 1, Saskatchewan, 1997).

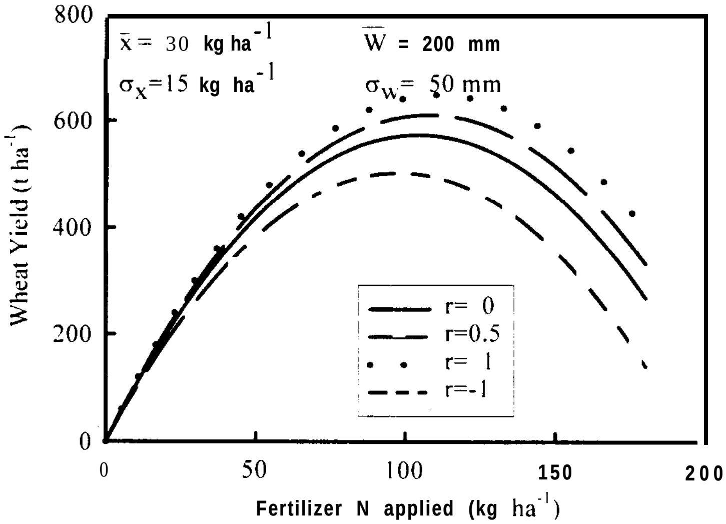

Figure 3. Example of average crop response to fertilizer in a variable field showing the influence of the correlation of soil test and available water.

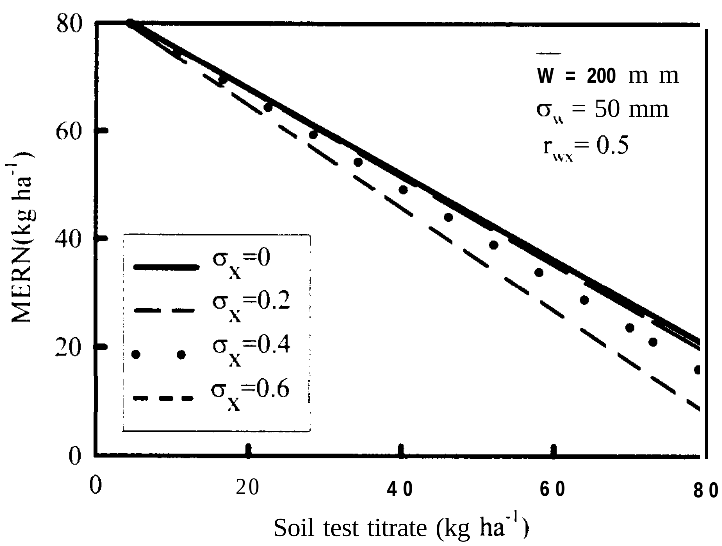

Figure 4. Effect of variation in soil test on recommended fertilizer rate.

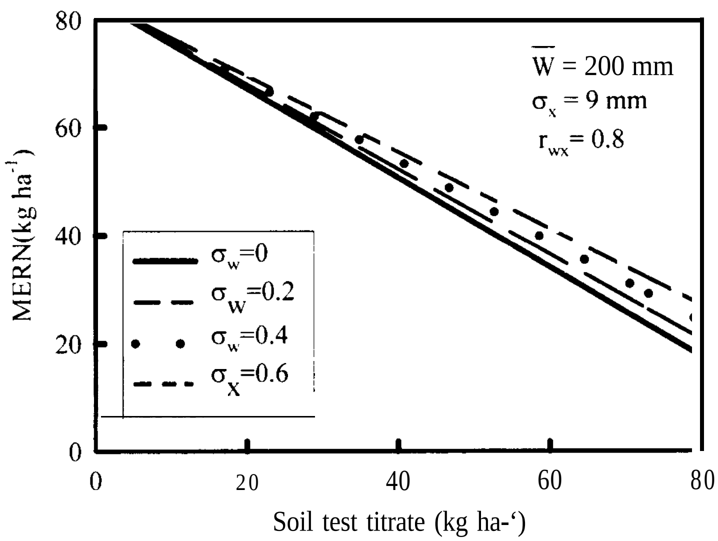

Figure 5. Effect of variation in available water on recommended fertilizer rate.

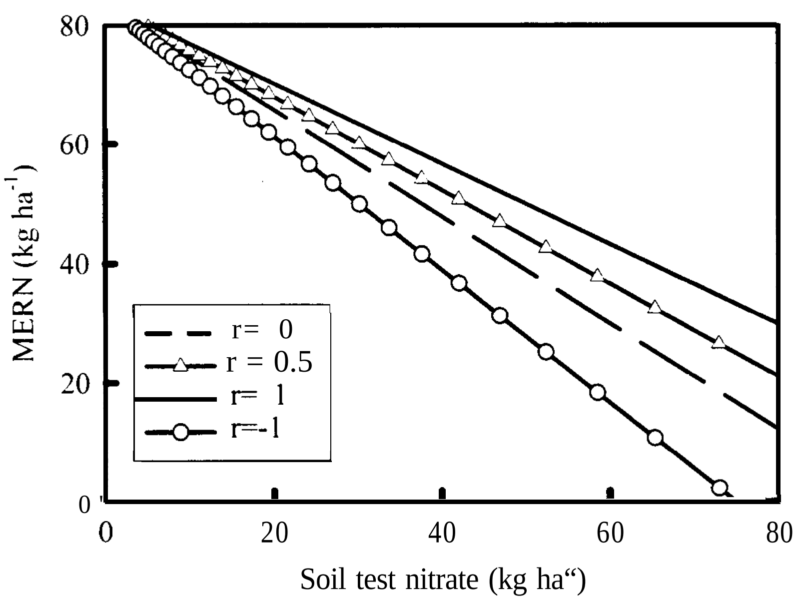

Figure 6. Effect of correlation between soil test and available water on recommended fertilizer rate.

Conclusions

(1). Spatial variation in soil N test and available water within many fields, influence the field average yield response to fertilizer.

(2). The maximum economic rate of fertilizer N (MERN) does not depend on only the average soil test and average available water in the field. The MERN also depends on (1) the amount of variability of soil test and water use in the field, and (2) the spatial correlation between soil test and available water.

(3). Soil N test variation decreased MERN for the same average soil N test, suggesting less fertlizer be applied.

(4). Correlation between soil N test and available water has a strong influence on MERN. Positive correlation increases MERN, while negative correlation decreases MERN.

References

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