SPRING WHEAT RESPONSE TO NITROGEN AND WATER.

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INTRODUCTION

The semiarid environment of southwestern Saskatchewan has resulted in cropping schemes with a high incidence of summerfallow. The two year fallow-wheat rotation is preferred because it increases spring soil water reserves and stabilizes farm income (Zentner et al. 1979); however, it is also associated with high soil degradation. Consequently, it is desirable to reduce the proportion of fallow in crop rotations. Recent technological developments such as reduced tillage practices, more efficient and affordable herbicides, higher yielding wheat cultivars and management practices such as snow trapping have made extended cropping systems less risky.

Successful stubble cropping requires, among other things, a better tuned fertilizer strategy. In a previous study (Selles et al. 1985) it was shown that regardless of fertility level, water is the main factor determining the yield of grain crops in the Brown soil zone of Saskatchewan. This fact has been recognized by the Provincial Soil Testing Laboratories of Saskatchewan and Alberta. However, the degree to which the recommended N fertilizer rates must be adjusted to reflect spring soil water and anticipated growing season rainfall have not been clearly defined.

The objective of this study was to develop production functions relating the yield of hard red spring wheat (HRWS) grown on stubble to available spring soil water, growing season precipitation, soil NO_3-N in the fall, and applied fertilizer N.

MATERIALS AND METHODS

Yield data from fertilizer trials carried with HRSW seeded on stubble at Swift Current from 1982 to 1986 were correlated to soil NO_3-N in the first 60 cm, available spring soil water in the 0-120 cm depth, and May-July precipitation. The experimental plots received fertilizer N as 34-0-0 mid-row banded at seeding time at rates ranging from 0 to 100 kg/ha; fertilizer P as 11-51-0 was also applied with the seed at a rate of 20 kg/ha of P_2O_5.

For the purposes of this study it was assumed that the crop could not distinguish between soil N and that supplied as fertilizer, nor between stored spring soil water and growing season precipitation. Thus, grain yields were regressed against total available N (soil plus fertilizer N) and and total available W (soil plus rainfall water) using a second degree polynomial of N and W.

RESULTS AND DISCUSSION

During the duration of the study, a wide range of environmental conditions was encountered (Table 1). Moisture conditions varied from the above normal precipitation during 1982 and 1986 to extreme drought during 1984 and 1985. Fall soil NO_3-N in the first 60 cm of soil varied from 13 to 46 kg/ha, and spring soil moisture ranged from -39 to 70 mm (soil water - PWP).

Table 1. Available spring soil water, May-July precipitation, and soil test N

YEAR	SPRING+ WATER (mm)	MAY-JULY RAINFALL (mm)	NO_3-N 0-60 cm (kg/ha)
1982	42	244	20
1983	70	187	25
1984	30	100	13
1985	-39	73	32
1986	11	205	46

+ Available water in 0-120 cm soil depth

The regression analysis, using the backward elimination procedure and no intercept indicated that the only significant terms were the interaction of the square of water with nitrogen and the square of water with the square of nitrogen. This produced the following highly significant production function ($P < 0.0001$):

$$\text{yield} = 0.000699*W^2*N - 0.00000313*W^2*N^2 \qquad R^2 = 0.935 \qquad [1]$$

The amount of total available N required for maximum yield (N_{max}) is obtained by solving the first derivative of this equation for N. In this case N_{max} was 112 kg/ha, and was independent of the level of available water. Examination of N_{max} values obtained from regression equations of the form $y = a + bN + cN^2$, calculated for each year, indicated that in 4 of the 5 years N_{max} varied between 92 and 131 kg/ha (Table 2). In the remaining year N_{max} was -16; but, here the regression was not significant.

Table 2. Values of N_{max} obtained for individual year regressions.

Year	N_{max} kg/ha	Y_{max} kg/ha	R^2
1982	115	3026	0.92
1983	110	2165	0.99
1984	-16	695	-.38
1985	92	573	0.13
1986	131	2091	0.94

The yield achievable when N is not limiting (Y_{max}) is obtained by:

$$Y_{max} = 0.039*W^2 \qquad [2]$$

The magnitude of the slope of W^2 is similar to that found by Staple and Lehane (1954) in their quadratic model relating grain yields with evapotranspiration.

We also developed a highly significant ($P < 0.0001$) relationship using a linear term for water:

$$Yield = 0.1812*W*N - 0.000848*W*N^2 \qquad R^2 = 0.956 \qquad [3]$$

Solving this equation for N_{max} gives 107 kg/ha and an expression for Y_{max} of:

$$Y_{max} = 9.68*W \qquad [4]$$

The slope of the Y_{max} for this second model is similar to that reported by Staple and Lehane (1954) for their linear model, and to that reported by Campbell et al. (1987) in a recent study of crop rotation at Swift Current. This indicates that in spite of the improvements in HRSW varieties, the yield increases per unit of additional water has remained largely unchanged from that of 40 years ago.

To select the most appropriate function, the predicted yields of each of the functions was regressed against the actual yields and an F test was applied to these regressions to determine whether the slope=1 and intercept=0. Results of this test (Table 3) indicate that equation (3) was better than equation (1); thus, the discussion on this paper is based on equation (3).

Table 3. F test for the slope and intercept of the actual v/s estimated yields obtained with the two models.

EQUATION	Regressor	F value	df	Probability[+]	R^2
$Y=A*W^2*N+B*W^2*N^2$	Intercept	12.26	1/30	0.0015	.881
	Slope	5.37	1/30	0.0274	
$Y=A*W*N+B*W*N^2$	Intercept	0.006	1/30	0.938	.832
	Slope	0.366	1/30	0.549	

+ Probability of having a value 0 for the intercept and 1 for the slope.

Although N_{max} is of interest from a research point of view, producers are interested in a rate of N that maximizes net returns (N_{econ}). This total available N level is obtained at the point on the production surface where the the value of the additional yield obtained is equal to the cost of the last increment of fertilizer. In other words:

$dY/dN \times Pw = Cn$ where Pw is the price of wheat   [5]
Cn is the cost of nitrogen

Although the theoretical maximum return is obtained by using equation (5), it is often desirable to include other factors such as risk. The Saskatchewan Soil Testing Laboratory, for example, bases their recommendations on the assumption that he last dollar spent on fertilizer produces 1.5 dollars of additional yield. In other words (using equation (3) and solving for N_{econ}):

$$N_{econ} = (0.1812 - (1.5 \times Cn)/(Pw \times W))/ 0.001696 \qquad [6]$$

Equation 6 indicates that N_{econ} is proportional to the nitrogen/wheat price ratio and to the amount of total available water (Fig. 1).

The usefulness of this model is that it explicitly recognizes the moisture by fertilizer interaction, and allows the user to assign probabilities (or chances) of being successful with stubble cropping. When this model is combined with a probability of rainfall (Fig. 2), it allows producers to obtain a better estimation of the N rates they should apply to their spring wheat crop providing the amount of plant available water in the spring and the NO_3-N content of the soil to 60 cm in the fall are known.

A small computer model has been built using equations (3) and (6). The model works by first asking the producer what level of risk he is able or willing to take, this is transformed into a probability which is used to calculate the precipitation level corresponding to his risk preference using a probability of rainfall distribution such as the one presented in Fig. 2. Next the depth of moist soil in spring is entered, which is transformed into soil available water; for example, the silty loam soil used in this study is capable of holding 172 mm of water in 120 cm depth. The soil available water and the probable rainfall are the components of total available water. Next, the soil test level of N (NO_3-N in the first 60 cm) is supplied to the program, together with the price of wheat and the cost of N. With this information, the program calculates N_{econ} using equation 6. The expected yield is calculated using equation (3) and the rate of fertilization is calculated by substracting the soil test N level from N_{econ}. The program gives also alternative rates of N fertilization with their respective expected yields and economic results.

With this type of fertility model the guess-work of selecting a rate of fertilization for a dry, a normal, or a wet year is avoided and since this is taken care of by the producer's capacity and preference to take risk.

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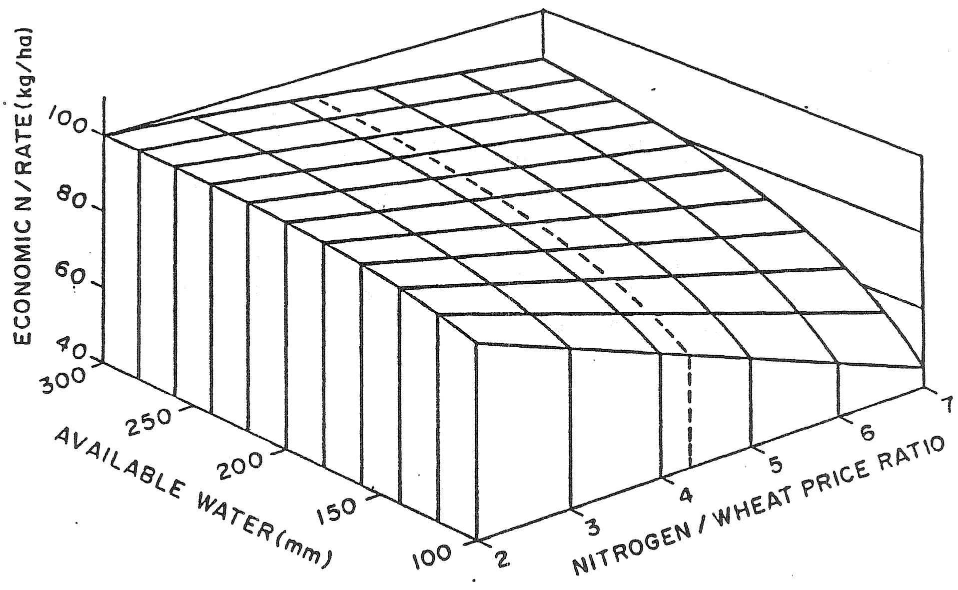

Figure 1. Economic N rates as a function of total available water and nitrogen/wheat price ratio predicted by equation 6.

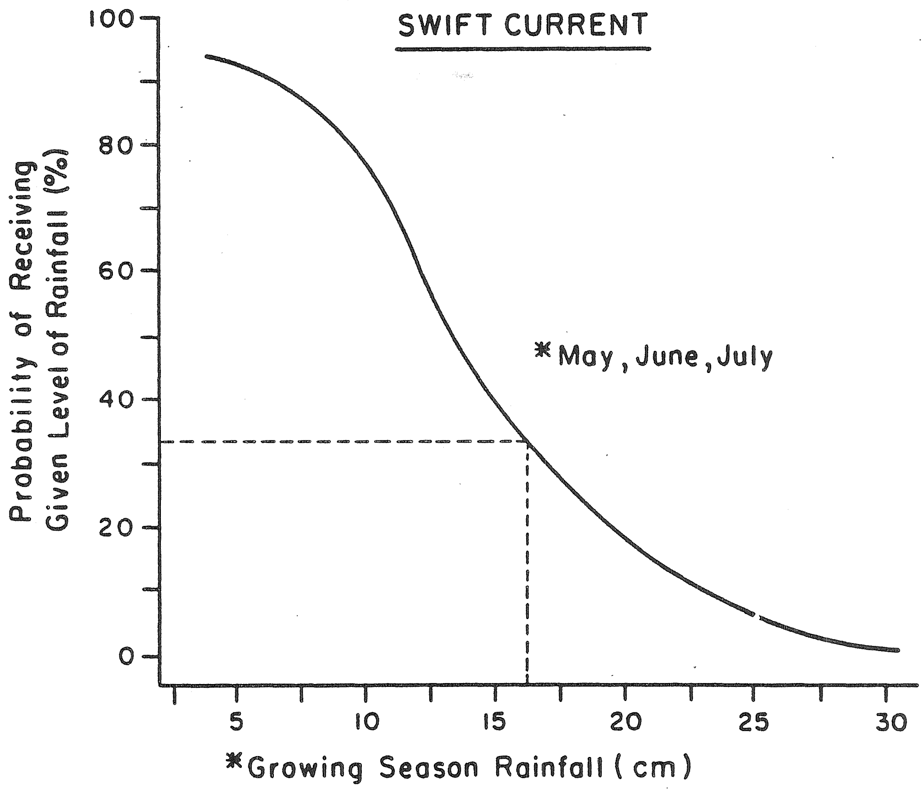

Figure 2. Probability distribution of rainfall at Swift Current.

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