SOIL FERTILITY RESEARCH - TEXAS HIGH PLAINS

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ABSTRACT

Multirate nitrogen and phosphorus field studies were conducted for several years with irrigated wheat, grain sorghum and corn on the major soil types of the Texas High Plains for the purpose of developing soil test correlations for nitrogen and phosphorus. Soil samples were taken prior to fertilizer application in increments of 0-6, 6-12, 12-24, and 24-36 inches. These samples were analyzed for nitrate-N and soil test phosphorus. Regression analyses and analysis of variance were used to test various mathematical models relating grain yields to soil test measurements and fertilizer rates.

Second order polynomial equations of the form $\hat{y} = C + aN_f + bN_r + cN_f^2 + dN_r^2 + eN_fN_r$ were found to be useful in relating grain yield ($\hat{y}$) to applied fertilizer (N_f) and residual soil nitrate-N (N_r) measured to some sampling depth. It was necessary to use N_f and N_r as separate independent variables because the marginal rate of substitution of N_r for N_f was variable and thus N_r and N_f were not additive in their effects on yield.

The Cate-Nelson ANOVM (Analysis of Variance Method) for partitioning soils for expected crop response to applied P fertilizer was found to be superior to four other models tested when a standard extraction procedure was used. However, when phosphorus dissolution rates constants (k_A) were determined using the two constant rate equation, a semilog relationship was found between crop response (Δy) to applied P and the dissolution rate constant.

OBJECTIVES

Use of fertilizers in a crop production system is an economic investment and should be done with the expectation of a reasonable return for that investment. Insufficient fertilizer applications are costly in lost yields and over application results in unwarrented production costs. One of the keys to efficient use of fertilizers is to apply the amount necessary to obtain the desired crop production levels. In order to apply correct amounts of fertilizers, it is necessary to know the expected crop response to applied fertilizers in relationship to the nutrient supplying power of the soil. On the Texas High Plains it is necessary to apply nitrogen fertilizer to most irrigated crops and frequently it is necessary to also apply phosphorus fertilizer in order to achieve the yield potential.

The objectives of the research reported here were to 1) develop laboratory tests suitable for assessing the nutrient supplying power of Texas High Plains soils and 2) develop quantitative relationships between expected crop response, soil test values, and rates of applied fertilizer.

MATERIALS AND METHODS

Multirate nitrogen and phosphorus fertilizer irrigated field trials were conducted at various locations on the Texas High Plains from 1966 to 1983. The trials were conducted on the major soil types and included grain sorghum, corn and wheat.

Table 1. Regression equations for six location years of data with coefficients of determination (R^2) and standard errors of estimate (SE) for grain sorghum and corn yields ($\hat{y}$) in lbs/A as influenced by residual nitrate-N (N_r) measured to several depths and fertilizer N (N_f) in lbs/A. Models used were: $\hat{y} = C + aN_f + bN_f^2$, $\hat{y} = C + aN + bN^2$ where $N = N_f + N_r$, $\hat{y} = C + aN_f + bN_f^2 + cN_r + dN_r^2 + eN_fN_r$.

Soil Sample depth, in.	Equation Number	Regression Equation	R^2	SE
		Sorghum		
	1	$\hat{y} = 4745 + 39.34N_f - 0.116N_f^2$	0.592	1074
0-6	2	$\hat{y} = 3697 + 53.77N - 0.167N^2$	0.708	908
0-12	3	$\hat{y} = 3022 + 58.73N - 0.172N^2$	0.762	820
0-24	4	$\hat{y} = 2170 + 59.00N - 0.147N^2$	0.821.	712
0-36	5	$\hat{y} = 1802 + 53.59N - 0.114N^2$	0.824	705
0-6	6	$\hat{y} = 2382 + 54.74N_f - 0.098N_f^2 + 164.71N_r - 0.818N_r^2 - 1.097N_aN_r$	0.808	793
0-12	7	$\hat{y} = 2093 + 56.45N_f - 0.103N_f^2 + 110.86N_r - 0.433N_r^2 - 0.671N_aN_r$	0.814	780
0-24	8	$\hat{y} = 3036 + 56.60N_f - 0.099N_f^2 + 13.70N_r + 0.328N_r^2 - 0.384N_aN_r$	0.803	745
0-36	9	$\hat{y} = 2042 + 55.74N_f - 0.117N_f^2 + 45.25N_r - 0.089N_r^2 - 0.225N_aN_r$	0.836	733
		Corn		
	1	$\hat{y} = 91.6 + 0.98N_f - 0.003N_f^2$	0.609	27.6
0-6	2	$\hat{y} = 39.7 + 1.44N - 0.004N^2$	0.877	15.5
0-12	3	$\hat{y} = 20.5 + 1.39N - 0.003N^2$	0.933	11.4
0-24	4	$\hat{y} = -6.9 + 1.35N - 0.002N^2$	0.933	11.4
0-36	5	$\hat{y} = -31.3 + 1.31N - 0.002N^2$	0.902	13.8
0-6	6	$\hat{y} = 51.6 + 1.45N_f - 0.002N_f^2 + 0.04N_r + 0.023N_r^2 - 0.014N_aN_r$	0.964	9.0
0-12	7	$\hat{y} = 47.2 + 1.41N_f - 0.002N_f^2 + 0.28N_r + 0.006N_r^2 - 0.008N_aN_r$	0.959	9.0
0-24	8	$\hat{y} = 47.4 + 1.47N_f - 0.002N_f^2 + 0.06N_r + 0.003N_r^2 - 0.005N_aN_r$	0.967	8.7
0-36	9	$\hat{y} = 49.3 + 1.55N_f - 0.002N_f^2 - 0.06N_r + 0.002N_r^2 - 0.004N_aN_r$	0.971	8.0

Table 2. Regression equations four location years data with coefficients of determination (R^2) for wheat grain yield ($\hat{y}$) in bu/A as influenced by residual nitrate-nitrogen (Nr) measured to several depths, and applied N (N_f) in lbs/A. Models used were: $\hat{y} = C + aN_f + bN_f^2$, $\hat{y} = C + aN + bN^2$ where $N = N_f + Nr$ and $\hat{y} = C + aN_f + bN_f^2 + cNr + dNr^2 + e\,N_fNr$.

Soil Sample depth, in.	Equation Number	Regression Equation	R^2
	1	$\hat{y} = 50.6 + 0.0246N_f - 0.0008N_f^2$	0.258
0-6	2	$\hat{y} = 40.2 + 0.369N - 0.0011N^2$	0.275
0-12	3	$\hat{y} = 28.5 + 0.490N - 0.0014N^2$	0.384
0-24	4	$\hat{y} = 11.6 + 0.558N - 0.0013N^2$	0.346
0-36	5	$\hat{y} = -1.2 + 0.580N - 0.0011N^2$	0.409
0-6	6	$\hat{y} = 6.5 + 0.440N_f + 2.611Nr - 0.0005N_f^2 - 0.0340Nr^2 - 0.0072N_fNr$	0.763
0-12	7	$\hat{y} = 17.2 + 0.447N_f + 1.023Nr - 0.0006N_f^2 - 0.0065Nr^2 - 0.0038N_fNr$	0.828
0-24	8	$\hat{y} = 42.5 + 0.528N_f + 0.129Nr - 0.0005N_f^2 - 0.0004Nr^2 - 0.003N_fNr$	0.841
0-36	9	$\hat{y} = 26.8 + 0.510N_f + 0.313Nr - 0.0005N_f^2 - 0.0009Nr^2 - 0.0022N_fNr$	0.839

Table 3. Amount of fertilizer nitrogen required to produce a given yield of sorghum grain at various levels of residual soil nitrate-N as determined by Equation 6, Table 1.

Yield lbs/A	Residual Nitrate-N (0-6") lbs/A						
	5	10	15	20	25	30	35
	lbs/A						
4000	17	1					
5000	40	25	9				
6000	66	53	39	21			
7000	96	87	75	62	44	21	
7500	113	107	99	90	76	56	26
8000	133	131	131	138			

Table 4. Cate-Nelson ANOV partitioning method for P extracted with 0.025M EDTA in 1.4M acetate buffer using Δy_{max} for 22 location years of grain sorghum data.

Test No.	Δy_{max} lbs/A	P ppm	Range in class SS for three classes
4	2357	3.1	
1	2492	3.6	4,232,731 - 15,629,762
2	3131	3.8	7,977,890 - 15,096,846
3	2973	4.0	11,324,274 - 18,550,886
8	566	6.2	8,170,845 - 16,027,863
6	1029	6.4	6,820,667 - 15,300,682
11	3110	6.7	10,870,092 - 16,213,951
10	1952	6.8	12,204,454 - 16,265,256
5	1600	7.0	12,718,683 - 15,945,949
7	1670	7.1	13,662,682 - 15,774,137
12	1020	8.1	12,862,855 - 14,208,250
13	1954	8.5	15,173,485 - 15,390,972
9	198	10.0	12,244,621 - 12,811,867
15	1080	13.9	12,241,842 - 12,485,231
17	6	14.0	9,351,937 - 9,914,721
19	557	14.0	8,235,863 - 8,401,541
14	1037	15.0	8,720,395 - 8,790,787
18	66	15.1	6,577,023 - 6,648,370
16	-263	16.6	3,831,185
21	160	20.4	
20	298	24.9	
23	531	26.7	
22	311	43.5	

Nitrogen rates ranged from 0 to 240 lbs N/A, generally applied in 40 lb./A increments. Phosphorus rates ranged from 0 to 40 lbs. P/A generally applied in 20 lb./A increments. Soil samples were taken prior to fertilizer application in 0-6, 6-12, 12-24, and 24-36 inches. Nitrates were extracted using a 0.05 M sodium sulfate solution and determined on a Technicon AutoAnalyzer. Phosphorus was extracted using 0.025 M EDTA in 1.4 M ammonium acetate and determined on a Technicon AutoAnalyzer (Onken et al., 1980). Phosphorus dissolution rate constants were obtained by determining phosphorus in an EDTA extract at time intervals ranging from 1.0 minute to 24 hours (Onken and Matheson, 1982). Various mathematical models were utilized in analyzing the data including second order polynomials, power functions, logarithmic functions, Mitscherlich curves, and the Cate-Nelson ANOVM (Cate and Nelson, 1971) and the two constant rate equation.

RESULTS AND DISCUSSION

Several models were fitted to the response data for grain sorghum, corn and wheat in an effort to describe the relationship between grain yield and applied fertilizer N and residual soil nitrate-N, Tables 1 and 2. The poorest relationship was obtained when residual nitrate-N was excluded and only applied fertilizer N was considered (Eq. 1 in Tables 1 and 2, R^2 values of 0.592, 0.609 and 0.258 for sorghum, corn, and wheat respectively). The relationships were greatly improved when residual nitrate-N was included (Eqs. 2, 3, 4, and 5 in Tables 1 and 2) as measured by R^2 and standard error of the estimate (SE). For these equations, applied fertilizer N and residual nitrate-N were summed to produce a single independent variable. A further improvement in the relationship occurred when applied fertilizer N and residual nitrate-N were treated as separate independent variables and the equations developed by multiple linear regression (Eqs. 6, 7, 8, and 9 in Tables 1 and 2); the most pronounced being with wheat, Table 2. In general, inclusion of residual nitrate-N measured to depths greater than 6 inches had only small effects on R^2 and SE values, which indicates that soil samples taken to 6 inches would most often be sufficient to assess the N supplying power of the soil.

Inability to predict substantially beyond experimental data limits is one of the problems associated with the use of empirical equations. This problem is shown in Table 3. Equation 6 from Table 1 was used to calculate the N fertilizer requirement for several sorghum grain yields at seven levels of residual soil nitrate-N. For the studies used in developing this equation, yields ranged from 1,500 to 9,000 lbs/A and residual nitrate-N levels from 5 to 35 lbs/A in the top six inches. It can be noted in Table 3 that the equation began predicting spurious results at a yield level of 8,000 lbs/A and residual nitrate-N levels above 10 lbs/A. It predicted the same fertilizer requirement at 15 lbs of residual nitrate-N/A and a greater fertilizer requirement at 20 lbs of residual nitrate-N/A than at 10 lbs of residual nitrate-N/A. Therefore, empirical equations need to be used with some caution and should be developed over the widest possible range of experimental conditions.

In addition to providing information relative to N fertilizer requirements, these equations can also provide other useful information as illustrated in Figure 1. The relationship between fertilizer use efficiency (FUE) and grain yield, applied fertilizer $N(N_f)$ and residual soil nitrate-N (N_r) measured to 6 inches is shown in Figure 1. Fertilizer use efficiency was calculated as follows:

$$FUE = (\text{yield a } N_f - \text{check yield})/N_f$$

As would be expected, due to the quadratic nature of the response equation, FUE decreased with increasing rates of fertilizer N and yield levels. The figure also shows that, pound for pound, residual soil nitrate in the six inch sampling increment had a greater depressing effect on FUE than applied fertilizer N. Thus, these types of response equations might also yield useful management information.

For developing P soil test correlations we have investigated two procedures. The Cate-Nelson Analysis of Variance Method for partitioning sample analyses was found to be useful in routine soil testing. It was found to yield higher R^2 values than the Mitscherlich, logarithmic or quadratic equations. Data from 22 location years are shown partitioned into three classes in Table 4. This partitioning was based upon actual yield changes (Δy max) due to the application of P fertilizer. The R^2 for this three class partitioning was 0.742.

Our second approach for relating extractable soil P to crop response involved dissolution kinetics. The solubility of soil P compounds and the reaction rates and products of applied P compounds are important to crop production. Thus, the dissolution of soil P compounds related to plant response would be useful in the study of P reactions in soil. Due to the many and varied P compounds in soils, the identification of each, determination of its dissolution in the presence of other soil components and its contribution to plant nutrition becomes a difficult task. However, if a combined P dissolution rate constant in a given solution could be related to plant response to applied P it could provide a measure of P reaction rates in soil and predict subsequent effects on plant growth. For this purpose we selected six soils on which grain sorghum response to applied P varied widely and extracted them with an EDTA solution. Dissolution rate constants were calculated using eight kinetic models. One that was found to be particularly useful was the two constant rate equation; $\ln C_A = \ln k_A + b\ln t$. We found that the P dissolution rate constants (k_A) were closely related to grain sorghum response to applied P, Figure 2. The availability of this measureable parameter to relate dissolution of soil P to crop response is seen as being very useful in agronomic research. Techniques may be developed for determination of reaction rates of fertilizer P, prediction of P availability over time, and evaluation of the effects of such factors on temperature, moisture, P sources, and organic and inorganic components of P reactions in soils.

LITERATURE CITED

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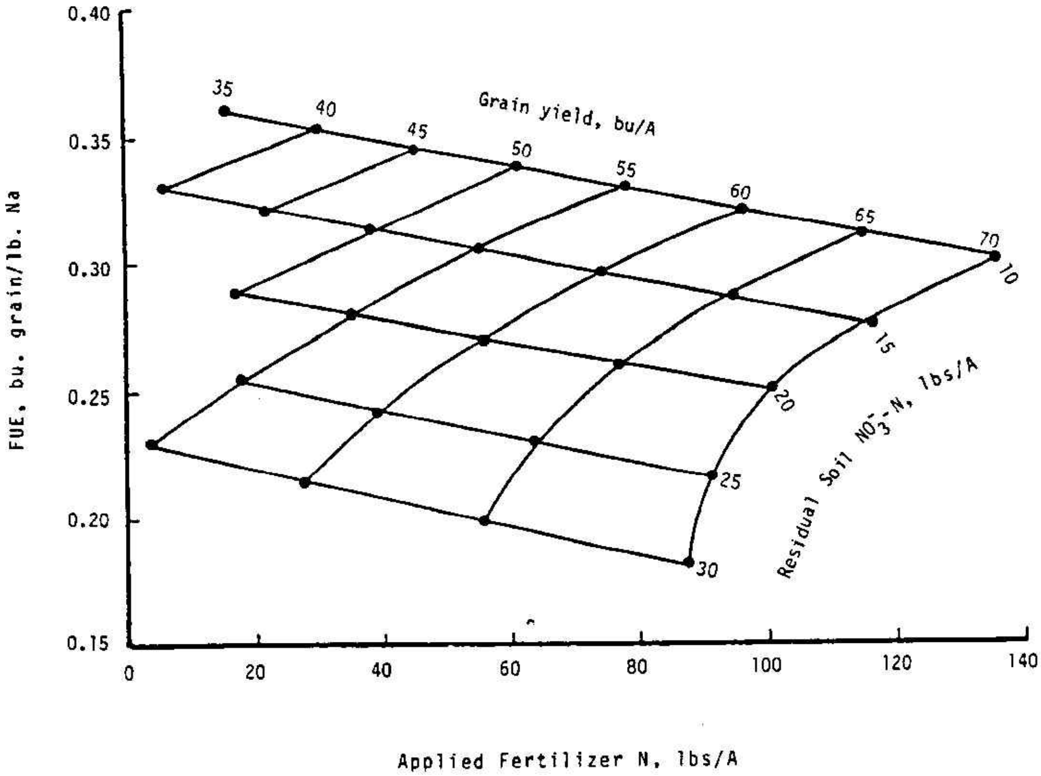

Figure 1. Relationship between fertilizer use efficiency and applied fertilizer nitrogen at several wheat grain yields and residual soil nitrate levels measured to 6.0 inches.

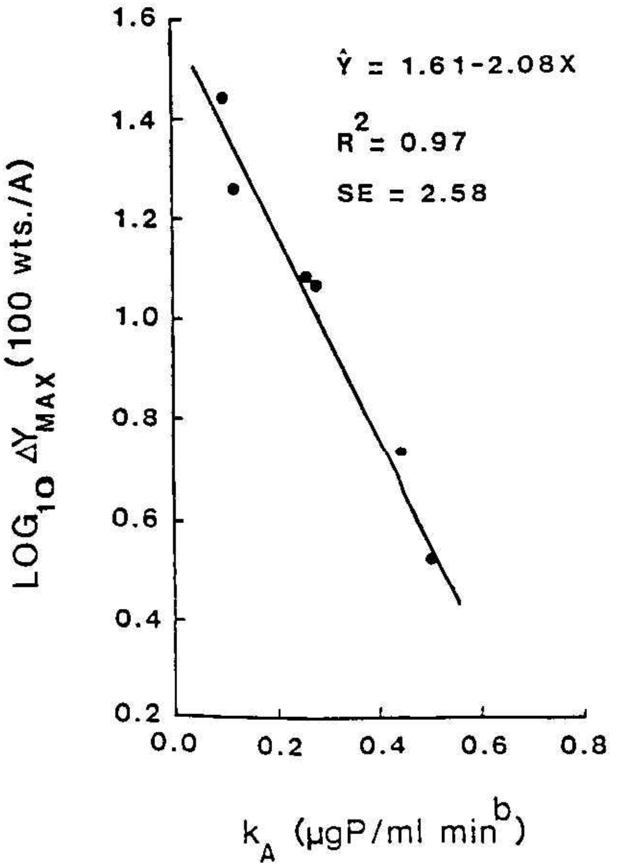

Figure 2. Relationship between grain sorghum yield response to applied P, Δy_{max}, and the rate constant, k_A, for the two-constant rate equation.