USING SUFFICIENCY AND RECOMMENDATION INFORMATION TO CALCULATE FERTILIZER RESPONSE CURVE AND PROFITABILITY ESTIMATES.

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The importance of sound fertility programs in efficient, profitable farming operations is well known - especially in times of low crop prices. Likewise, the importance of a sound soil testing program - and recommendation guidelines that relate these soil test values to credible, long-term research results - is recognized as the best way of obtaining maximum economic returns from fertilizer dollars. Unfortunatly, there are few tools available for evaluating the profitability of a specific fertility programs - even though there is an increasingly important need of emphasizing fertility economics.

While we can sometimes use specific research study results and/or long-term sufficiency percentages and response probabilities to demonstrate the economic advantages of sound fertility programs, dealers and farm advisors must often "fly by the seat of their pants" when answering specific questions about fertilizer economics. Many past attempts at evaluating the profitability of fertility programs have generally been with "all or nothing" examples - that is - comparisons between achieving the established yield goal with recommended rates vs. yield if no fertilizer is applied. Also, most of these evaluations are limited to only one nutrient. There are many other questions for which we have provided farmers and dealers little information on which to base a solid answer. For instance, how would you handle the following situations?

Example 1. With a soil P value of 10 lb/A (Bray P-1), Kansas State University would recommend 46 lbs P_2O_5/A for wheat production (irrigated). What do you tell a farmer who asks what would happen if he only applied 25 lbs P_2O_5/A?

Example 2. A farmer has a field testing 32 lbs nitrate N (24") and 12 lbs P/A. Kansas State University recommendations for 155 bu/A corn would be 177 lbs N/A and 55 lbs P_2O_5/A. With N costing \$.16/lb N and P at \$.21/lb P_2O_5, this amounts to a \$39.87/A fertilizer bill. How do you advise a farmer to best spend his money if he is limited to only \$30.00/A? What information can you provide to the lender who wants an estimate of this fertilizer expenditure reduction on the farmers ability to repay the loan?

Example 3. A grower is developing plans for three fields;

Intended Crop	Yield Goal	Acres	Exp. Crop Price	Nutrient Cost ($/lb) N	P_2O_5	K_2O	Soil Test (lbs/A) N	P	K	Recommendations N	P_2O_5	K_2O
Corn	165	132	$2.80	$.15	$.21	$.12	64	22	186	159	37	44
G. Sorghum	80	80	$2.20	$.15	$.25	$.14	40	14	195	64	42	37
Wheat	55	100	$3.00	$.20	$.25	$.14	25	8	248	77	50	6

Example 3 con't)

Recommendations from KSU result in a fertilizer bill of about $9760 for the three fields but the farmer insists he can only afford to spend a total of $6000. How do you best apportion these dollars to the various nutrients in each field in order to make optimum use of the limited money supply? What is your estimate of the amount of profit this farmer may forfeit due to not following these University recommendations?

While these are difficult questions to which there may be no easy answers, or even basic guidelines on which to base an answer, similar questions/decisions are confronted by farmers and dealers every day. While many of us are reluctant to provide estimates to questions such as these - due to concerns of not having enough data to give reliable, accurate answers - a method of developing a best estimate is needed. It is up to us to provide a sound, scientific approach to these types of fertilizer economics questions in order to properly advise farmers. This paper uses the previous three examples to breifly describe a proposed way of approaching this subject.

Before starting, however, several things to keep in mind about the approach to be presented.

1. While final yield estimates are made, understand that I don't beleive that this is a yield prediction model. This concept hopefully gives a best estimate of probable results based on long-term research results.

2. As are the state university recommendation guidelines on which it is based, this approach should be viewed as providing guidelines only. If there are valid reasons for refining these guidelines, they should be adjusted to reflect specific local situations.

3. The specific equations used to calculate recommended rates and sufficiency percentages are not important - this concept can be adapted to a variety of equation forms as well as "approaches" to making fertilizer recommendations.

4. Recommendation equations for nutrients such as P and K must represent the amount of a nutrient needed to optimize crop production for that crop year only. While build-up and maintenance recommendations may reflect the optimum long-term fertility program over several crop years in some regions, this concept only deals with short-term, current year economics.

Developing The Equations Used

Nitrogen. The basic method most often used to develop N recommendations (Nrec) consists of defining the total amount of N required for production at a given yield level, and then subtracting various N credits such as profile soil test N, manure credits, previous crop credits, organic matter contributions, etc. While states may use different factors in determining N recommendations (eg. NH_4-N and/or NO_3-N vs. organic matter), similar equations are used - or could be adapted.

These equations can be refined and rearanged to calculate either an adjusted recommended N rate (Nadj) for a given sufficiency level (Y) of the yield goal or the sufficiency of a given N rate as compared to the stated yield goal. The following wheat N recommendation example illustrates this.

<u>Wheat (SD)</u> $Nrec = (YG \times 2.4) - (NO_3\text{-}N) - (\text{Previous Crop}) - (\text{Manure})$

(Eq. 1) $Nadj = (YG \times Y \times 2.4) - (NO_3\text{-}N) - (\text{Credits})$

(Eq. 2) $$Y = \frac{Nadj + NO_3\text{-}N + Credits}{YG \times 2.4}$$

Similar relationships can be derived for other equation types and can be used to estimate the effect reduced N rates have on yield and profitability or to calculate an adjusted N recommendation for reduced yield potentials (Table 1).

<u>Phosphorus and Potassium.</u> While the the equations commonly used for N recommendations are straight forward and easily adapted to evaluating N fertility programs, the recommendation equations used for P and K are not as straight forward or easily manipulated. Also, due to differences in P and K soil chemistry as well as the meaning of P and K soil test values (as compared to N), a different approach is necessary. While the best approach would be to have P and K application rate response curves defined at all soil test levels for each crop, adequate information of this type has not been available.

The following discussion details a way in which estimated P and K response curves at various soil test levels can be calculated by using crop P and K recommendation equations and corresponding sufficiency equations. As was pointed out earlier, it is not the specific equations used or the specific values calculated that are important. State and/or regional information can be substituted into the concept. The following derivation and explaination uses Kansas State University P and K recommendations for irrigated wheat and a sufficiency equation I selected. In the following equations, "ln (x)" means the natural logarithm (base e) of '(x)', and "Exp (x)" is the number 'e' raised to the '(x)' power.

<u>Wheat (KS)</u> $Prec = Exp\ ((4.255 + (-.0426 \times Pst\ ))$

(Eq. 3) $$Pst = \frac{((\ln\ (Prec)) - 4.255)}{-.0426}$$

Refering to Example 1, at a soil P test (Pst) of 10 lb/A, KSU recommendations call for 46 lbs P_2O_5/A. What is the consequence of applying only 25 pounds? Since the farmer wants to apply 21 lbs P_2O_5/A less than recommendations call for (Prec - Papp), there is still a recommendation of 21 lbs P_2O_5/A. To begin to estimate the effect of this rate reduction, we might start by asking - "What is the equivalent P soil test value (Pest) for which a 21 lbs P_2O_5/A recommendation would be made?" Equation 3 can be refined to answer this question.

$$\text{(Eq. 4)} \qquad \text{Pest} = \frac{((\ln(\text{Prec} - \text{Papp})) - 4.255)}{-.0426}$$

For the example:

$$\text{Pest} = \frac{((\ln(46 - 25)) - 4.255)}{-.0426} = 28.4$$

At a P soil test value of 28.4, therefore, KSU would give a recommendation of 21 lbs P_2O_5/A. The next question would be "What is the % sufficiency for wheat at a soil P test level of 28.4?". By inserting the equivalent P soil test value into an equation describing the sufficiency of a given P soil test value for a particular crop, an estimate of the effect of reduced P application rates can be obtained. In the following equations, "Y" is the expected fraction of maximum yield obtained at a given soil test value (Y x 100 = % Sufficiency).

$$\text{(Eq. 5)} \qquad Y = 1 - (\text{Exp}(-.07 \times \text{Pst}))$$

$$\text{Pst of 10 lb P/A} \qquad Y = 1 - (\text{Exp}(-.07 \times 10)) = .503$$

$$\text{Pest of 28.4 lb P/A} \qquad Y = 1 - (\text{Exp}(-.07 \times 28.4)) = .863$$

For this example then, we would estimate that about 50.3% of maximum yield would be acheived if no fertilizer P was applied while an application of 25 lbs P_2O_5/A would give 86.3% of maximum yield. Assuming a yield potential of 60 bu/A, this translates into a potential 8.2 bu/A yield loss.

Equation 5 can also be rearranged to a form which allows the calculation of an equivalent soil P test value at a given Y value (Eq.6). Since both equations provide an equivalent Pst value, the right hand portion of Eq. 6 can be substituted into the left hand portion of Equation 4. The resulting equation (Eq.7) can be rearranged providing a method of solving for Y at a given P rate in one step (Eq. 8).

$$\text{(Eq. 6)} \qquad \text{Pest} = \frac{(\ln(1 - Y)}{-.07}$$

Combining Equations 4 and 6 gives:

$$\text{(Eq. 7)} \qquad \frac{(\ln(1-Y))}{-.07} = \frac{((\ln(\text{Prec} - \text{Papp})) - 4.255)}{-.0426}$$

Rearranging Equation 7 allows us to solve directly for Y :

$$\text{(Eq. 8)} \qquad Y = 1 - (\text{Exp}((\frac{((\ln(\text{Prec} - \text{Papp})) - 4.255)}{-.0426}) \times -.07))$$

Using the previous example we can now solve for Y in one step :

$$Y = 1 - (\text{Exp}((\frac{((\ln(46 - 25)) - 4.255)}{-.0426}) \times -.07)) = .863$$

Figure 1 shows the calculated P response curves generated with Equation 8 at several soil P test levels. Equations for K can be derived in a similar manner, and the following equations are an example using KSU's recommendations for irrigated wheat and a sufficiency equation I supplied. The steps involved are similar to those previously discussed for phosphorus.

$$Krec = 80 + (-.3 \times Kst) \qquad Y = (1 - (Exp\ ((\frac{Kst}{(9.6 - (.02 \times Kst))}) \times -.07)))$$

$$Kest = \frac{(Krec - Kapp - 80)}{-.3} \qquad Kest = \frac{(480 \times (\ln (1-Y)))}{((\ln (1-Y)) - 3.5)}$$

$$\text{(Eq. 9)} \qquad Y = (1 - (Exp\ (\frac{((\frac{(Krec - Kapp - 80)}{-.3}) \times 3.5)}{((\frac{(Krec - Kapp - 80)}{-.3}) - 480)})))$$

Handling More Complex Questions

The questions posed earlier in examples 2 and 3 are not as easily answered by using the previously developed equations. However, if these equations are rearranged to solve for the adjusted N, P and/or K rate (eg. Padj) required to achieve a given sufficiency level, answers to these questions can be estimated. The following are the KSU recommendation equations for corn.

$$Nrec = (1.35 \times YG) - NO_3\text{-}N \qquad Prec = (Exp\ (4.45375 + (-.0378 \times Pst))) \qquad Krec = (100 - (Kst \times -.3))$$

Using the same P and K sufficiency equations as were used in the previous wheat example, the following equations can be obtained by using or rearranging equations 1, 8 and 9.

$$Nadj = (YG \times Y \times 1.35) - NO_3\text{-}N \qquad Padj = (Prec - (Exp\ (4.45375 + (-.0426 \times (\frac{(\ln (1-Y))}{-.07})))))$$

$$Kadj = Krec - 80 - ((\frac{(480 \times (\ln (1-Y)))}{((\ln (1-Y)) - 3.5)}) \times -.3)$$

Table 1 presents examples of how this procedure can be used to produce similar equations for several other states and crops - even though the recommendation and sufficiency equations vary widely.

By providing the initial P and K recommendation for a given soil test value - the adjusted N, P and K recommendation recommendations needed to attain the specified sufficiency level can be calculated. By incorporating these and other crop budget data into a computer spreadsheet program, information vital to ag lenders, farmers and farm advisors is generated.

For instance, in Example 2 the farmer was limited to \$30.00/A for his fertility program while the University recommendations presented to him amounted to about \$40.00/A. By using the above equations, we might estimate that a best alternative fertility program would consist of 157 lbs N/A, 28 lbs P_2O_5 and no potash. Based on $2.80/bu. corn (includes government payments), it would also be estimated that he should expect to net $41.22 less per acre on the estimated 137 bu/A crop than might have been the case if he had followed the University recommendations and acheived his potential of 155 bu/A. These results were obtained by adjusting the desired sufficiency level until the adjusted fertilizer recommendations required to obtain the specified sufficiency level amounted to $30.00/Acre.

Example 3 involves the best use of a limited money supply and is complicated by the fact that three different crops would be grown on three fields of varying fertility status. Also, recommended fertility management programs call for the use of different N, P and K sources purchased during different times of the year - resulting in varying nutrient costs.

Using another spreadsheet program based on these same types of equations, it is possible to provide the grower with an alternative fertility program which would hopefully result in maximum returns on his limited money supply. At the same time, it also allows the farmer and/or ag lender the opportunity to have an estimate of the financial consequences of not following a sound fertility program.

By increasing the sufficiency level for the three crops and fields in small increments, and selectively retaining only the incremental increases giving the greatest marginal return to fertilizer, estimates to questions similar to Example 3 can be developed. For Example 3, the predicted 3.3%, 7.5% and 33.3% yield reductions for wheat, corn and sorghum, respectively, could cost the farmer about $4,645 in potential profit across the 312 acres - as compared to following University recommendation guidelines. The adjusted fertility program and other results are summarized below, while more complete sample crop planning estimates are shown in Table 2.

					University Rec's		Adjusted Recommendations				
							Recommendations				
Crop	Yield Goal	% Of Y. Goal	Est. Yield	Acres	Fertilizer Cost	Marginal Return	N	P	K	Fertilizer Cost	Marginal Return
					- - - $/A - - -		- - lb/A - -			- - - $/A - - -	
Corn	165	96.7	159.6	132	$36.97	$292.28	151	24	15	$29.58	$284.58
G. Sorghum	80	91.5	74.0	80	$25.12	$83.19	56	19	0	$13.25	$81.79
Wheat	55	66.7	37.2	100	$28.71	$67.54	34	15	0	$10.53	$32.37

While we all know that the estimates provided for these three examples are not absolutely correct, they are certainly better than pulling some numbers from "thin air". There are probably some farmers and farm advisors capable of developing these types of alternative fertility programs, but, there are many more who are not. The same is true for estimating the effects of specific fertility programs on crop yields and profitability. While we all say that profits and yields are likely to decline as fertilizer rates are reduced below University recommendations, we havn't been willing and/or able to say how much. I beleive the time has come to give our best estimate.

SUMMARY

The need for applying economics to fertility programs is greater than ever before. While many of us are uneasy about estimating the effects of a specific fertility program on crop yield and profitability, these questions are raised by farmers, dealers and ag lenders everyday. Because of current agricultural marketplace conditions, it is important that we use previously generated research data to: 1) Provide information showing the probable financial effects of following sound fertility programs, 2) Estimate the financial effect of fertility programs using less than recommended nutrient rates and 3) If there is still no alternative to reducing nutrient application rates, develop an alternative fertility program within the growers budget that allows for maximum economic returns.

While the information generated by this approach can be viewed as a rough estimate only, farmers and dealers are only asking us for an estimate. They understand that there are many factors affecting crop growth and development and that we can't predict yield - just as we can't predict the exact amount of fertilizer required to produce optimum yields.

There are several points about this and other approaches to handling fertilizer economics that may be raised and discussed.

1) Sufficiency equations are based on 100% of maximum yield while recommendations are generally designed to obtain less than 100% of maximum yield. I have worked out ways of dealing with this, but still think there is a simpler, more logical way of doing it.

2) Is it valid to base one year economic estimates on long term research information? Every time we make a fertilizer recommendation we are influencing current year economics. If we have enough confidence to use our long term research data to make recommendations, I feel confident about basing economic estimates on this same data.

3) The results of this approach are strongly influenced by expected crop prices, yield goal, specific soil test results, etc. What if this information is found to be incorrect? Farmers are forced to make many decisions on this same information every year. Farmers and dealers are not asking for an absolute prediction, they only want a best estimate using the best information available to them.

4) It is possible that by combining sufficiency data with data used to generate fertilizer recommendations in this manner, a better understanding of the recommendations might result.

Hopefully, this proposed method of dealing with fertilizer economics, or some other method, will be further developed in order to provide farmers, dealers and other farm advisors some guidelines for answering increasingly difficult fertilizer economics questions.

Table 1. Examples Of Adapting Several States Recommendation And Sufficiency Information.

South Dakota - Wheat

$$Prec = 1.99 + (.95 \times YG) + (.68 \times Pst) + (-.02 \times YG \times Pst) + (-.02 \times Pst^2)$$

$$Y = e^{(-.0852 \times Pst)} \longrightarrow Pest = \frac{(\ln (1 - Y))}{-.0852}$$

$$Papp = (Prec - (1.99 + (.94 \times YG) + (.68 \times Pest) + (-.02 \times YG \times Pest) + (-.02 \times Pest^2)$$

Missouri - Wheat (D = desired Pst = 45 lb/A

$$Prec = \frac{(110 \times (D^{.5} - Pest^{.5})}{8} + ((YG \times .6) \times (1 - \frac{(Pst^2)}{(D^2)}))$$

$$\text{Fertility Index} = \%\ \text{Sufficiency} = \frac{200 \times Pst}{D} - \frac{100 \times Pst^2}{D^2}$$

$$Y = \frac{2 \times Pst}{D} - \frac{Pst^2}{D^2}$$

$$0 = Pst^2 - (2Pst \times D) + YD^2$$

Note: Because of build-up/maintenance recommendations, Missouri P and K recommendation equation altered to reflect crop response in year of application after discussion with Missouri

Using Quadratic Equation: $Pest = \frac{2D - (4D^2 - 4D^2 Y)^{.5}}{2}$

$$Papp = (Prec - (13.75 \times (D^{.5} - Pest^{.5})) - ((YG * .6) \times (1 - (\frac{Pest^2}{D^2})))$$

$$Nrec = (YG \times 1.26) + 18 - O.M.\ Credit$$

$$Nadj = (YG \times Y \times 1.26) + 18 - O.M.\ Credit$$

$$Y = \frac{Nadj - 18 + O.M.\ Credit}{YG \times 1.26}$$

Nebraska - Grain Sorghum & Corn

Sorghum

$$Nrec = (1.1 \times YG) - ((\%OM - 1) \times 20) + 50 - Nst$$

$$Nadj = (1.1 \times YG \times Y) - ((\%OM - 1) \times 20) + 50 - Nst$$

$$Y = \frac{Nadj + ((\%OM - 1) \times 20) - 50 + Nst}{YG \times 1.1}$$

Corn

$$Nrec = (\frac{(.9 \times YG)}{(1- (.0008 \times YG))}) + 50 - Nst$$

$$Nadj = (\frac{(.9 \times Y \times YG)}{(1- (.0008 \times YG))}) + 50 - Nst$$

$$Y = \frac{(Nadj - 50 + Nst)}{(.9 \times YG) + (Nadj \times .0008 \times YG) - (50 \times .0008 \times YG) + (Nst \times .0008 \times YG)}$$

Table 2. Fertilizer Crop Planning Estimates (Example 3).

Dale F. Leikam	Field 1	Field 2	Field 3
Crop	Corn	Sorghum	Wheat
Yield Goal	165	80	55
Acres In Field	132	80	100
Total Fertilizer $ Available		$6,000.00	
NO3 N - 0-24" (lb/A)	64	40	25
Soil P Test (lb/A)	22	14	8
Soil K Test (lb/A)	186	195	248
% Of Yield Goal w/o Fertilizer	28.7%	38.5%	41.7%
Crop Price ($/bu)	$2.80	$2.20	$3.00
N Cost ($/lb N)	$0.15	$0.15	$0.20
P Cost ($/lb P2O5)	$0.21	$0.25	$0.25
K Cost ($/lb K2O)	$0.12	$0.14	$0.14
N Rec @ Yield Goal (lb/A)	159	64	77
P Rec @ Yield Goal (lb/A)	37	42	50
K Rec @ Yield Goal (lb/A)	44	37	6
Fertilizer $/A @ Yield Goal	$36.97	$25.12	$28.71
Fertilizer $/Field @ Yield Goal	$4,880.60	$2,009.80	$2,871.12
Total $ For Fields @ Yield Goals		$9,761.53	
% Of Yield Goal @ Adj. Recs	96.7%	92.5%	67.7%
Expected Yield (units/A)	159.6	74.0	37.2
Adjusted N Rec (lb N/A)	151	56	34
Adjusted P Rec (lb P2O5/A)	24	19	15
Adjusted K Rec (lb K2O/A)	15	0	0
Fert. $/A @ Expected Yield	$29.58	$13.25	$10.53
Fert $/Field @ Expected Yield	$3,904.28	$1,059.61	$1,053.09
Total $ For Fields @ Adj. Rec's		$6,016.97	

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Marginal $ Return/A @ Yield Goal	$292.28	$83.19	$67.54
Marginal $ Return/A @ Adj Recs	$284.58	$81.79	$32.37
$/A Loss From Reduced Recs	$7.70	$1.39	$35.17
larginal Return/Field @ Y. Goal	$38,581.62	$6,654.82	$6,753.88
arginal Return/Field @ Adj Recs	$37,564.84	$6,543.59	$3,236.91
;/Field Loss From Reduced Recs	$1,016.78	$111.22	$3,516.97

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mbined $ Loss From All Fields	$4,644.96
: Increment $Return/$Invested	$3.83

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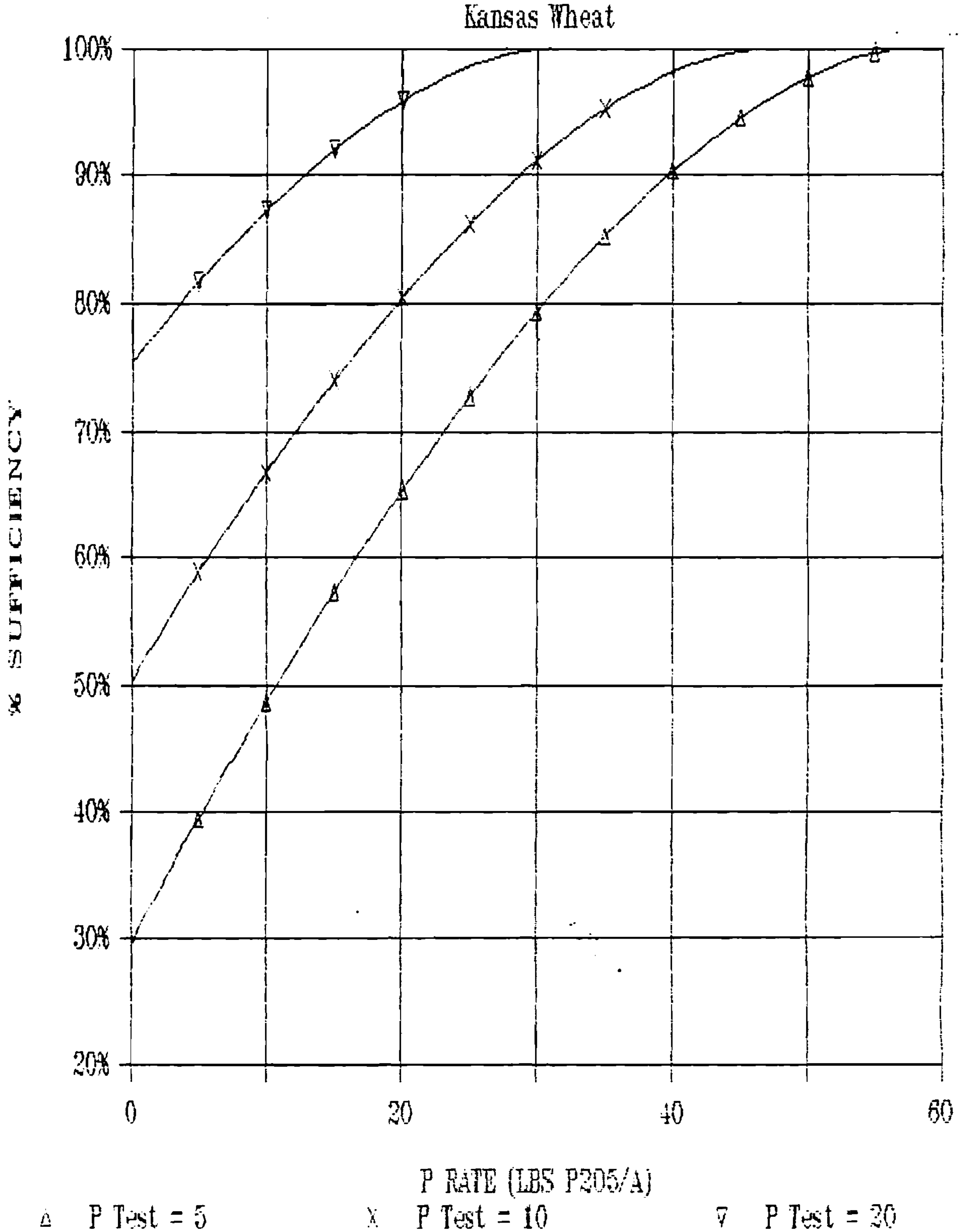
Fig. 1. Calculated P Response Curves



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